FINAL REPORT

DAIRY FARM STRAY VOLTAGE

SUMMARY

ASSEMBLED BY

THE ELECTROMAGNETICS RESEARCH FOUNDATION, INC

ROUTE 2

UNDERWOOD, MINNESOTA 56586

FOR

MINNESOTA DEPARTMENT OF PUBLIC SERVICES

ST. PAUL, MINNESOTA

PREFACE

This report is the result of the charge of the Minnesota State Legislature to assemble information concerning stray voltage with a special emphasis on ground currents and their perceived effects on dairy cows and humans. The information was also intended to present the perspective of dairy farmers.

The organization of this report is presented in the Project Design and is intended to provide information helpful in recommending research activities to correlate cause and effect. At this time the variability in farm measurements invalidates any attempt to correlate effects with measurements of electromagnetic parameters. The chosen method to validate the hypothesis that electricity affects animals and humans on the dairy farms is to search for correlations between changes in electrical exposure and changes in the behavior, health and production of dairy cows. In that process a number of factors arise. The factors that correlate are different for different farms. The most common correlation relates to the location and quantity of electricity entering and/or leaving the earth. Factors such as type of dairy operation and for that matter, management do not play a dominant role. When the electrical conditions are favorable the dairy operation is profitable and prospers. Stray voltage management procedures which are learned through the process of working in stray voltage barns have helped some farmers survive financially. There seems to be no region of the country that does not experience the stray voltage problem including those farms that use no electricity.

The final set of information provided is the presentation of the raw data from a few dairy farms. These data are intended to provide information for showing correlations between effects in the dairy operation and changing electrical conditions. As mentioned previously different farms show different correlations than other farms. These data tend to show short term or long term changes in milk production, water consumption, somatic cell count, mastitis correlating with changes in the electrical system on and near the farms. One set of data is especially intriguing. Joe Kenning has been talking about the errors in scale measurement on his farm which he feels have a connection with his dairy operation. Obviously there is no direct connection but is there a cause that could affect both the reading of the scale and the dairy animals? Joe had recorded data on both and these data are presented for your thoughts.

The information assembled has required the cooperation and assistance of hundreds of people. The Electromagnetics Research Foundation is especially appreciative of the efforts of all people involved.

Duane A. Dahlberg

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THE ELECTROMAGNETICS RESEARCH FOUNDATION (TERF), INC.

THE ELECTROMAGNETICS RESEARCH FOUNDATION, INC. (TERF) is a non profit corporation dedicated to understanding the role of electromagnetics in living systems. The corporation was conceived at the "grass roots" level in the State of Minnesota, is incorporated in the State of Minnesota and has expanded to include an active chapter in Wisconsin as well as all who have an interest in electromagnetics as it relates to living systems. The major functions are research and information management. Information management includes collection and dissemination of electromagnetics information as it relates to life and research emphasizes field investigations and problem solving.

In the mid 1980's dairy farmers in Minnesota chose to organize a non-profit corporation for the purpose of resolving the stray voltage problem. The original name of the corporation was Resolve the Stray Voltage Problem, Inc (RSVP). A number of seminars were presented for dairy farmers in Minnesota at which as many as 200 people attended.

A survey was prepared by a member of the corporation and sent to dairy farmers responding to a report in the a dairy magazine. The survey provided information from dairy farmers in 20 states revealing a common problem that was not being resolved.

Through all of these efforts and its involvement in a legislative project administered by the Minnesota Department of Agriculture, the members of the corporation became convinced that the problem on the dairy farm was far more complex than simply the shock experienced by the cows when they would touch a conducting member of the barn. A decision was made by the corporation to change its name and broaden its purpose so as to include whatever electromagnetic (EM) energy might affect the cows. In addition the connection of stray voltage to human health effects for dairy operators and their families required that the corporation in its new form also study human health effects.

Especially in 1986 and 1987 the corporation and members of the corporation encouraged the Minnesota Legislature to fund a research project analyzing electromagnetic effects on dairy cows. The corporation actively monitored this research project. Funds were far too limited to accomplish a total analysis of the data assembled. Even so valuable information was obtained. The report is available through the Minnesota Department of Agriculture.

In February 1989 a seminar, STRAY VOLTAGE, "Beyond the Shock", was sponsored in Minnesota by TERF. The purpose of the seminar was informational providing experiences of dairy operators and hog producers who are dealing with the problems of stray voltage and reports on current research and corrective efforts. Presenters at the seminar included dairy operators and other professionals involved in stray voltage monitoring and research. The primary emphasis was an analysis of effects not attributable either directly or indirectly to intermittent shocks from AC voltages between two cow contact points. Approximately 70 people attended. A survey completed by 30 of those attending provided information for 25 dairy operations. 23 of those dairy operators indicated a stray voltage problem, 19 had isolation devices and on all 23 farms there were also human health problems.

The conference, Electric Blankets, Microwaves, Power Lines: A Hidden Health Cost?, at Concordia College, Moorhead, MN on March 11, 1989 was co-sponsored by TERF and Tri-College Center for Environmental Studies. The keynote speaker was Dr. David O. Carpenter, the Executive Secretary and the Spokesperson for the New York Powerline Project.

In addition a seminar was conducted at the University of Wisconsin, River Falls in April 1989 with TERF as one of the sponsors.

TERF served as an intervener for stray voltage issues before the Public Service Commission of Wisconsin. The Wisconsin chapter has been active in both the PSC's 106 and 108 dockets. The 106 docket involved the shock effect and the setting of safe cow contact voltage level. Docket 108 dealt with other potential electrical causes. Establishing a measurement protocol for all electromagnetic fields and electric currents which could be in the dairy cow's environment and potentially cause affect. The PSC chose to maintain a separation between the study of animal health and human health. After many meetings and considerable debate an instrument evaluation project was undertaken on August 27-29, 1991 at the University of Wisconsin farm near Arlington. Representatives from TERF, the electric utilities, telephone company, PSC, and representative of engineering and testing groups were present and participated. A number of important results were demonstrated and only a few will be mentioned. Using a small portable electric generator for injecting current into the ground between two sets of ground rods, it was shown that once electricity is in the ground it travels in all directions and extensively beyond the limits of the space between the two sets of ground rods. Voltages were found on other sets of ground rods a few hundred meters away. The magnetic fields produced by current in the ground from the generator as well as the ambient AC in the ground were measured by milligauss meters above the ground surface. Milligauss meters can detect ground currents. No attempt was made to calibrate these measurements. The contribution of the generator current was distinguishable from other currents because of having a slightly different frequency than the utility power. This difference produced a beat frequency that was observable on recordings. Demonstrated also was significant changes in both DC voltages and currents on and in components in the dairy barn when AC was injected by the generator into the ground at some distance from the barn. Hindsight tells us that it would have been valuable to have had the livestock health evaluated while the tests were being conducted on the University Farm especially in light of the fact that some calves died during the test days. This project on the Arlington farm provided sufficient information to take the next step of testing the measurement protocol on two operating dairy farms. The process to provide funding for TERF and research organizations to prepare and perform these tests had begun. As a result of conflicts between TERF, the PSC staff and the electric utility personnel, however, all further tests and research were canceled.

Questionnaires have been prepared, administered and analyzed providing valuable information relevant to animal and human health effects perceived to be caused by electromagnetic energy. TERF provides information to interested individuals, conducts field investigations and provides speakers on request.

As a response to requests of TERF and the actions of legislators in Minnesota governor requested the state agencies to investigate the stray voltage problem. The report produced from public hearings were brought before the Minnesota Environmental Quality Board (MNEQB) for their approval. The conflicts surrounding the content of this report precipitated the establishing of a steering committee to study and develop solutions to the stray voltage problem. The steering committee was officially established by the EQB to guide State Agencies and Departments in their stray voltage activities. The committee included two members of TERF (Dave Lusty, dairy farmer and president of MNTERF and Duane Dahlberg, Concordia College), two electrical utilities representatives and staff persons from five State Agencies and Departments. In addition the Minnesota Department of Public Services set up and carried out one farm demonstration especially for the members of the EQB and two educational seminars. All three were well organized and successfully accomplished their purposes. EQB board members and their staffs, dairy operators, electric utility representatives, and others were involved.

An addition outcome of the actions of the MNEQB was a decision by the Minnesota Public Utilities Commission to begin a stray voltage rule making process. The rule making process is long and tedious and the end is no where in sight at this time.

TERF has also been active in the legislative process. In the 1994 session of the Minnesota Legislature they did respond to the continued calls from the dairy farmers. The consequences of this legislation is the reason for the appointing of the team of scientists and for the preparation by TERF of the farmers information relative to the stray voltage problem.

Future projects include development of an information management system, continued surveying of areas perceived as being affected by electromagnetic fields and currents, monitoring of farm experiments and research and developing research proposals.

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DAIRY FARM STRAY VOLTAGE

SUMMARY

PROJECT DESIGN

INTRODUCTION

This research is motivated by dairy farmers' concerns about stray voltage effects on their dairy operations. Even though stray voltage and various aspects of related electrical effects have been researched world wide, much additional research is needed to delineate specific relationships between stray voltage and dairies. The specific purpose of this survey is to summarize current findings and portray strategies in dealing with perceived stray voltage problems.

INFORMATIONAL BASE

This survey report is accompanied by additional information summarizing stray voltage related information in four forms. .

1. An extensive bibliography of publications from around the world includes specific studies, from a variety of research situations, investigating the relation of electricity to plants, animals and humans. See Appendix A.

2. Specific papers prepared by the authors, including those presented at academic conferences, summarize their research on specific projects. See Appendix B.

3. A history of the stray voltage problem as portrayed by news articles from newspapers and farm magazines. See Appendix C.

4. Descriptions of 100 individual stray voltage cases. See Appendix D

THE STRAY VOLTAGE PROBLEM

Dairy farmers' perceptions that stray voltage might be a factor in their dairy operations has been gradual as have strategies for dealing with these perceived perceptions. Generally, dairy problems are assigned to stray voltage only as a last resort because it is not well understood either by electricity specialists or dairy operators, and if admitted is difficult to deal with. Research pinpointing specific cause and effect relations is difficult because of ambiguities in these relationships and difficulties in controlling for important variables appearing to affect these relationships. Chapter IV, "Perceptions of the Effects of Electromagnetic Fields", and chapter I, "The Emergence of EM Associated Problems" discuss the process of growing awareness.

Researchers have drawn on a broad theoretical base to deal with the diverse variables perceived to affect dairy operations. This includes laboratory and field research. First, in order to understand effects of EM energies, it is necessary to understand their sources, and these are many and increasing with the industrializing process [See chapter II, "EM Energy and Living Organisms". Second, the electrical nature of living organisms is not well understood even though some relation between electrical energies and living organisms has been assumed for centuries [See chapter II, "EM Energy and Living Organisms". Third, a major body of literature discusses the relationship of EM energies to living organisms [See chapter II, "EM Energies and Living Organisms".

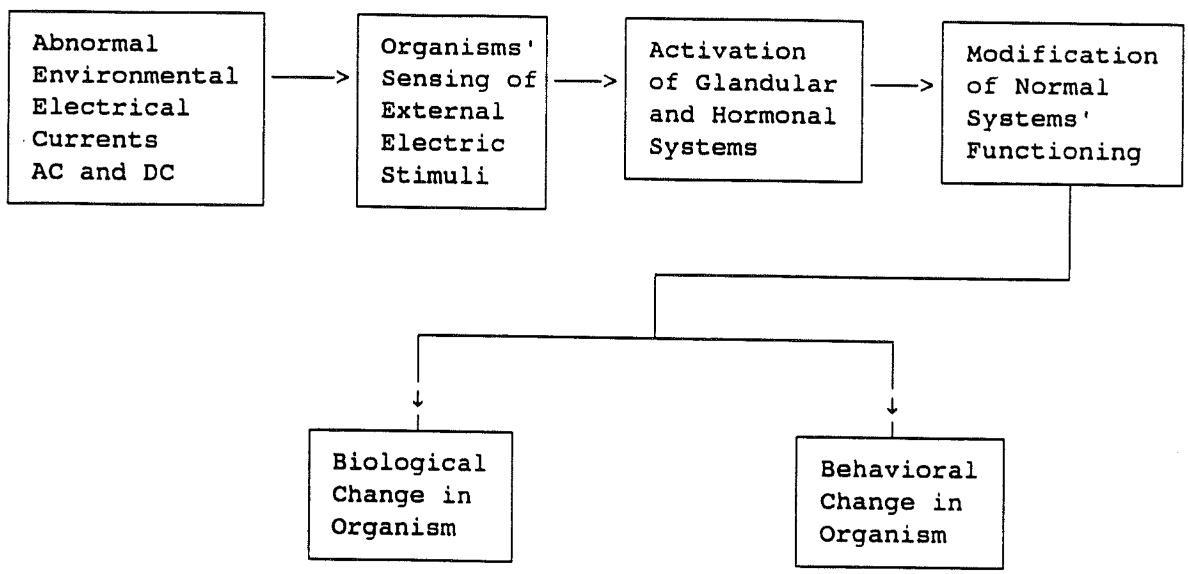
Suggested effects of EM energies on living organisms include altering metabolism, and cardiovascular, endocrine, immune and reproductive processes. Of particular interest to this research is the notion of chronic stress syndrome that can occur when the biocycle is chronically abnormal. This is important if low EM energies affect living organisms, and if living organisms, such as cattle, are exposed to these energies for prolonged periods.

No suitable model exists in research literature to account for the observed and perceived effects found in field investigations. Various models might be presented to guide research and foster understanding of EM energies' relation to living organisms. Two models are most often used in the United States. One is based on shock current assuming that smaller currents have little or no effect on living organisms. Cattle are affected when exposed to higher currents carried through power sources associated with the dairy activities. The second assumes that effects are produced only if the energy absorbed causes a sufficient internal temperature increase. However, other research suggests that EM energy interacts directly with the electrical system of the living organism. The electrical system of living organisms is only gradually becoming understood even through practical applications of low level electrical energies are variously used such as in the control of heart rhythms. However an understanding of the interaction between electrical signaling and hormonal processes is gradually emerging. These models are discussed in chapter XIII, "Summary".

Included also in this summary are chapters on measurements, chapter VI, quantitative results, chapter VII, and a specific case study, chapter VIII. A special analysis of approximately 100 dairy farms with severe stray voltage problems is the focus of chapter IX , "Multi-case Studey"of this report. In response to requests from the Department of Public Services and members of TERF additional chapters have been prepared involving transformer loading, chapter X; a typical stray voltage farm, chapter XI; mitigation methods, chapter XII; and a projected research project, chapter XIV.

A general relational model (Figure 1) provides a tentative framework for examining information related to problems perceived to be related to electricity on dairy farms. It is as follows:

Figure 1: EM Energies' Relation to Living Organisms



INTRODUCTION

Stories abound about unusual and sometimes unbelievable health problems among humans and animals where causes are unclear or unknown. These problems occur in homes, office buildings, businesses and sometimes in whole towns and regions. Health specialists often have difficulty in pinpointing specific causes when investigating these unusual problems. When no clear cause is found, those who are affected are resigned to coping with the effects and working on recovery rather than continuing to search for causes. General labels are attached to these occurrences, such as sick buildings, indoor air pollutants, tight buildings and environmental illnesses. These conditions do not lend themselves easily to scientific investigations, and so health consequences are assigned to unknown but nfortunate circumstances or even personal instabilities.

With no easy research methods available to determine cause and effect, the scientific and medical communities are left with limited tools to scientifically analyze the perceived problems. Consequently, in order to maintain a reputation of objectivity it is prudent for scientists not to become involved in ambiguous situations where unknown dimensions cannot be observed and controlled. However, the scientific and medical communities' curiosity grows as health problems with ambiguous origins increase. That curiosity is encouraging development of new methods for scientifically investigating specific cases.

Investigating complex environmental problems requires important and innovative changes in researching. Scientists traditionally feel more comfortable doing research in their special disciplines and neat research packages rather than experimenting with unknown technologies involving other scientists. When there is no model to test, samples are small, and the number of variables to examine large, scientific approaches and statistical analyses are quite limited. This is often the case in environmental research.

In general, environmental factors affect living organisms in non-specific ways because of individual variations among organisms. An organism's environment contains many toxins, energies and pathogens that can affect the organism individually or synergistically. A team of researchers with appropriate specialized knowledge along with complex problem solving bilities is required to solve health problems stemming from environmental origins. The methodology used will not only require a plan for developing an understanding of the problem, but also a plan for how to use information.

In addition, these researchers need skills in interpersonal relationships to successfully bridge each other's esoteric languages. Those doing the research will want to learn how to communicate with one another so as to be able to draw conclusions and develop consensus. Those who have worked in the area of scientific problem solving, for example, know how difficult it is for specialists from various disciplines to set aside their ideological differences and develop an appreciation for the information each discipline can provide for the others.

We emphasize at the outset that one important goal is to demonstrate process and content in environmental problem solving. To this end, we concentrate on one environmental factor that can contribute to health problems. Discussing only one environmental factor is nonetheless complicated in that health effects described here can be caused by a number of different factors and most often by more than one. Further, they can affect the problem either independently or synergistically. The environmental factor in this discussion is electromagnetic (EM) energy and its possible effect on living organisms.

An impetus to involvement in environmental problem solving is the perception that a number of health effect cases appear to connect more with location and external factors than with internal disposition and genetic make-up. Consequently, an investigation of a cause or causes of a specific perceived problem should include both internal and external factors. Among the external factors are physical factors such as energies and chemicals (especially those that are foreign to living organisms) and pathogens. Most often consideration of health problems centers on pathogens and chemicals because their influences are better understood. However, the external physical factors can also affect living organisms. An analysis of energies used in the functioning of living organisms draws our attention to EM energies. Of all the parameters that could influence the appropriate functioning of living organism, EMs ought to be considered primary. Living organisms are as dependent on EM energies as they are on chemicals for maintaining good health. In considering external factors which can cause health effects it is prudent to consider the EM environment. The complexity of EM exposure in turn complicates investigations of EM interaction with living organisms. Therefore, a better understanding of the physical nature of EM energies along with the electrical and magnetic nature of living organisms is fundamental to understanding how external EM energy relates to health problems. In order to legitimize this approach for studying the potential impact of EM's on health, perhaps this field of study should be named. We suggest **Electromagnetics Ecology.**

The study of EM energy effects needs an interdisciplinary team of knowledgeable researchers. The problem of EM effects on living organisms requires study within the framework of multiple electric and magnetic energies and electric currents to which living organisms are exposed since consideration must be given to the many interactions between organisms and their EM context. The number of effects are potentially numerous. This kind of research requires more ingenious and creative preparation than is normally needed in more traditional and less comprehensive research. It is much easier to design studies where a single cause, such as the 60 Hz magnetic field, is correlated with a single consequence, such as one kind of cancer. However this procedure, as compared to using a multiple variable approach, is far too time consuming to meet present informational needs about the effects of EM energies.

Appropriate research methods can be established for determining EM energy effects even though unique research problems exist. The NASA organization used a method called "systems analysis" in their development of the space program. This method enabled NASA to complete its ambitious goal of landing people on the surface of the moon and returning them safely to earth. The systems approach is based on an interdisciplinary process of discovery, synthesis, and consensus. Basic tenets are that all information is valuable, no information is to be discarded, and every member of the interdisciplinary team is heard. Information is classified as being either qualitative or quantitative, and information in either of these categories is considered valuable. This approach usually assures that no potentially pertinent information is ignored.

Modern scientifically oriented societies generally perceive that quantitative information is of greater value than qualitative. For some purposes quantitative information is more valuable, but not invariably so. Regardless of data type, people set up equipment, make measurements, decide what to measure and interpret the results. In working with environmental problem solving and research, it is especially important not to lose sight of the value of qualitative information. If one analyzed the methods by which humans gathered their information for survival throughout time, one would discover that most of it is qualitatively based. After all, humans continue to analyze and digest their information through their usual sensory system.

As with much other research, the systems approach to problem solving begins with a period of information gathering by a suitable interdisciplinary group of researchers. For the area of EM energy and its interactions this comprises a broad data base. Information is obtained from qualitative descriptions provided by people experiencing what they perceive to be effects of EM energies, observations of events, numerical measurements by technical people, and a study of the research literature from throughout the world. This discussion centers on EM energies as they impact the dairy industry since there is a significant body of both qualitative and quantitative information available to the authors gathered through their decade long involvement with this subject.

This work includes background information on electromagnetics, a historical summary of developing concerns and responses, qualitative information, reports on practical experiments, and other quantitative findings.

CHAPTER I

THE EMERGENCE OF EM ASSOCIATED PROBLEMS

OVERVIEW

A very extensive body of literature has emerged during the last one hundred years linking various forms of electromagnetic (EM) energies to biological changes and health effects in living organisms (Barnothy 1969; Presman 1970). Since publication of the New York State Power Line Project report (Ahlbom et al. 1987), an increasing quantity of information has appeared in academic journals, magazines, and books relating various health effects to EM energies (McAauliffe 1985; Edwards 1987; Brodeur 1990). During the last five to ten years nearly all major news magazines, numerous scientific journals, newspapers, and radio and television stations have presented information raising concerns about how EM energies are associated with human and animal health.

Consequently, these writings fostered political activities. On October 6, 1987, The U.S. House Subcommittee on Water and Power Resources held a hearing titled "Health Effects of Transmission Lines." On March 8th, 1990, a hearing before the U.S. House of Representatives, Interior and Insular Affairs Subcommittee on General Oversight and Investigations, considered implications of recent research on health effects of electric power lines and associated EM fields.

EM research is not limited by political boundaries. Though segmented, a variety of EM research has been done in various nations. The scientific community in the United States and Canada has concentrated their research to a narrowly defined area for potential health effects from electromagnetic (EM) energy. The major research effort has centered on the question of whether or not 60 Hz magnetic fields produced by transmission/distribution lines, VDT's and home wiring and appliances can cause or promote cancer. A number of these research projects are accepted as providing valid information and methodologies for relating and evaluating associations between EM's and health in organisms. The works of Werthheimer and Leeper (1979, 1982 & 1987), Savitz (1988) and Matanoski (1991) from the U. S. and Tominius (1982) and Ahlbom (1987,1992) from Sweden are a few examples. As various task forces assess present scientific knowledge about EM impacts on health, the word most commonly used to summarize the results is 'inconclusive.'

A number of scientists, other professionals and non-professionals perceive a broad range of health effects associated with a number of electromagnetic (EM) exposures. Within a sector of the scientific community, especially in eastern and western Europe, the perception is that microwave exposure enhances the stress syndrome. Effects could include health problems associated with the cardiovascular, central nervous, and immune systems.Subjective complaints abound among persons working and living in electromagnetic environments. Some of these complaints are headaches, eyestrain, fatigue derived from over-all weakness, and dizziness. People indicate other experiences such as frequent and easy irritation, extending to unsociability, and sometimes manifesting hypochondriasis. Mental depression combined with short term memory loss are also associated with exposure to EM energies.

Dairy operators throughout United States and Canada, as well as in other parts of the world, have known for approximately 50 years that some aspect or aspects of electromagnetic energies on dairy farms affect the behavior, production, and health of cows. Traditionally electrical shock has been known to affect livestock at levels below those that apparently affect humans. The term used to characterize this problem is stray voltage. To deal with this problem, special care was taken to avoid faults or shorts that might cause electric currents to access livestock and especially the dairy cow. In spite of these measures, the stray voltage problem continued to be an albatross around the necks of dairy farmers.

Today stray voltage problems still plague the dairy farmers, and they attest to dramatic outcomes assumed to derive from electrical causes. They have observed such extreme behavior such as seeing cows fall over dead while in the dairy barn and have witnessed highly productive cows deteriorate in health and production either dying or requiring shipment by year's end. In addition, dairy farmers inexplicably experience deterioration in their own health and the health of their children. Consequently they perceive a tie between cattle and human health. Nor do they perceive these associations between EM's and human health as limited to dairy operations. Nationally persons who live and work in EM environments, such as near power lines, substations, etc., are asking questions about EM's relation to their health problems. It is becoming clear that a major environmental problem is emerging, with dramatic potential, as more and more information develops relating health problems to living near transmission lines, distribution lines, transformers, substations, and the earth grounding systems.

THE STRAY VOLTAGE PROBLEM

Theories attempting to explain the consequences of stray voltage have gradually emerged. Persons dealing with this problem based their actions on the model of a shock current. This assumes an electric potential (voltage) difference between two different points that the cows might touch such as the barn floor with their feet and the water cup with their mouths. The electrical potential between two contact points on the animal causes current to flow through the animal's body. Most often this kind of exposure to alternating current was of short duration causing a shock. The shock appeared to be associated with certain behavioral problems such as reluctance to enter parlor or stall; cattle continuously moving their legs while in stalls; cattle kicking off milkers; unusual and adverse behavior while in the barn, sometimes being impossible to control; uneven, incomplete, and/or slow milkout; and poor water consumption. The assumption was that when the shock was sufficiently intense the additional stress would result in health and production problems in the dairy animals. Such effects were multiple and recurring mastitis (not responding to treatment); high somatic cell count; breeding problems and reduced milk production; cow production peaking early and not holding; and swollen legs and joints.

No direct causal link was established between cows receiving shocks and their health and productivity. As a consequence the observed behavioral problems were often used as an indirect assessment of the extent of the stray voltage problem on a farm. Stray voltage is a general term used to describe effects attributable to electricity, but this phenomenon is also known by other voltage names such as neutral-to-earth (NE), neutral-to-ground, tingle, extraneous, transient, and metal structures-to-earth.

Persons in dairy and electrical industries have long recognized that dairy farmers need to maintain a safe electrical environment for ensuring the health and production of dairy cows, but farmers rarely realized how electricity might be affecting their cows. It was usually assumed that a management error was the cause if health and production problems occurred. In fact it has been common for dairy farmers to search for nutritional causes, equipment failures, errors in milking procedure, water quality problems, or anything else other than electricity that could produce the observed effects. They would also consult with specialists from related industries, university extension people and veterinarians to help find answers. It seemed as if dairy people would consider an electrical cause only as a last resort disbelieving that electricity could cause the kinds of problems described by the dairy operators.

As electrical use increased on farms and generally throughout society, more dairy farmers experienced behavioral, health and production problems in their dairy herds that seemed to have no obvious attributable cause. Consequently during the 1970's, specialists in the dairy and electrical industries began to suspect the implication of electricity. Potential electrical problems were investigated especially if dairy farmers experi-enced electrical shocks in their barns. Initially investigations centered on problems in the farm's electrical system that could cause a shock current to reach the cow. As previously indicated, a shock current is produced by a voltage difference between cow contact points and is considered a shock current if it produces a perceived response from the cow. Electrical measurements assessing this problem revealed that if electricity entered the earth from faulty wiring, poor ground connections and faulty electrical equipment, that could lead to a ground fault or excessive electricity traveling through the earth. Cows could be exposed to these shock currents. Experience, supported by experimentation, showed that reducing those sources of electricity did produce significant improvements in behavior, health and production of the cows. Unfortunately, the reduction in the cow's exposure to shock voltages did not always produce or maintain an improvement in the behavior, health and production of the dairy cows.

Logically one could postulate that at certain levels of electrical shock the health and production of dairy cattle could be adversely affected. Demonstrations and research clearly indicate that shocking livestock with alternating currents in the range of one or more milliamps can cause behavioral responses (Albright et al. 1991). The empirical evidence gathered in field investigations of affected dairy herds correlated many of the health and production effects with the behavioral responses (Appleman 1978; Fairbank 1977; Lillemars 1980).

University researchers and extension personnel became much more involved in the stray voltage problem in the late 1970's and early 1980's. Being legitimately concerned with problems in agriculture, they were diligently searching for causes and solutions to the stray voltage problem (Lefcourt 1991). The involved specialists made the operational assumption that stray voltage was merely the "shock" current to which an animal is unintentionally exposed as a result of certain electrical conditions (Gustafson 1984). These persons held that the results of the shock effect included the cluster of herd problems such as poor and uneven milkout, extreme nervousness while in the parlor or stall, reluctance to enter the parlor or stall, reduced feed intake in the parlor, reluctance to drink water, increased manure deposition in the parlor, recurring mastitis that is resistant to treatment and lowered milk production (Gustafson 1982). These notions were based mostly on qualitative information, and without access to specific experiments and theory clarifying the parameters of the problem of stray voltage.

Consequently, assessing the reality of stray voltage required standardization of measurement. Within the framework of the shock model, the choice was to measure the neutral-to-earth (N-E) voltage as the indicator of a potential problem. This measurement was made by first installing a reference ground rod at some distance from any possible source of electricity in the ground and then measuring the alternating current (AC) voltage between the reference rod and the electric neutral wire. The assumption was that the reference rod represented the true zero ground to which all measurements could be referenced. Of course, since the cow did not extend from the neutral to the reference ground, cow contact voltages were also measured. This measurement was again the AC voltage between the floor of the barn and the stall dividers or the water cups. In order to reduce the possibility of the cows being exposed to different voltages from one point to another in the barn, all conducting parts were usually connected together and connected to the farm neutral. As a consequence measurements were often simplified by measuring between the farm neutral and the floor of the barn to get cow contact voltages. This procedure also assumed that since a certain resistance existed between the reference rod and the barn floor, the N-E voltage would always be larger than the cow contact voltages. Thus, measurements to determine the potential for stray voltage problems were initially based most often on N-E AC voltages. The cow contact voltages which could potentially shock the animal were assumed to be less than the derived N-E AC voltages. Surprisingly this assumption was not always supported. In some barns, and at times in most barns, the cow contact voltages were higher than the N-E voltages.

Electricity reaches the neutral and grounded conductors in the barn from many different sources. As mentioned previously, the initial source was considered to be the farm's electrical system. A high N-E voltage was an indicator of an electrical problem on the farm. As the on-farm sources were eliminated, however, high N-E voltages often remained. Another source of N-E AC voltages on the farm is the voltage on the primary neutral. This occurs since the electrical distribution lines also have the neutral connected to the earth, and the electric utility neutral and the farm neutral are connected together. The current going through the earth on the primary side of the electrical system can significantly increase the N-E voltage measured on the farm. Cows could also receive a shock from the current reaching the barn from the primary system. On the farm the electrical problems can be solved and the loads appropriately balanced so as to be able to independently reduce the N-E and cow contact voltage to a very low value which is unable to cause the animals to be shocked electrically. On the primary side, attempts are made to maintain a balanced load on the three phase lines in order to reduce the voltage on the primary neutral. Balance is rarely achieved because of variations in electrical use both in time and location. Consequently there is always N-E voltage on the electric utility system. Since the primary and secondary neutral are connected on the farm, the voltage on the primary neutral will be on the secondary or farm neutral.

The University of Minnesota and a number of other universities have developed models of the primary and secondary electric systems, how they interact and why N-E voltages develop. The preferred solution for controlling the contribution of N-E voltage from the primary system was to use a device that separated the primary and secondary neutrals. The process was called isolation and accomplished by such things ranging from an air gap in the neutral line to isolation transformers.

A significant research effort began in the universities during the late 1970's and the early 1980's funded mainly by the electric utility industry. The models developed by these researchers were tested in the dairy barns of universities. The assumption that the cows were intermittently shocked when touching various conducting members in the barn set the experimental agenda. The question for which the experts wanted answers was, "At what level of shock current and also shock voltage did the cattle show some visible response and at what level was there a negative effect on health and production" (Stray Voltage 1984). As a result of the research of the early 1980's some answers were forthcoming. These findings indicate "Problems of animal health and production attributable to voltages between the grounded-neutral system and true earth have risen sharply in rural areas. Animal production problems, particularly with dairy cows, have been observed at voltage levels of 0.75 to 1.0 VAC" (Gustafson 1981). A variety of cow responses to strayvoltages have been reported from farm case studies. Commonly cited cattle responses include:

1)intermittent periods of poor production; 2) unexplained poor production; 3) increased incidence of mastitis; 4) elevated somatic cell counts; 5) increased milking times; 6) incomplete milk letdown; 7) extreme nervousness while in the milking parlor; 8) reluctance to enter the milking parlor; 9) rapid exit from the parlor; 10) reluctance to use water bowls or metallic feeders; and 11) altered consummatory behavior (lapping of water from the watering device) (Bodman 1981; Craine 1975; Fairbank 1977; Rodenburg 1984).

Additional conclusions were drawn from research carried out by a number of universities during the late 1970's and early 1980's. This research investigated whether shocking cattle with 60 Hz electric currents can cause the effects known to the dairy operators. The conclusions indicate that shocking the cows can cause behavioral but not health and production effects. Specifically:

> current levels used (in the research) resulted in voltage ranges of 1-5 volts. These voltages have not produced inhibition of the milk ejection reflex nor increased incidence of mastitis or other diseases of cows in our studies. It is doubtful that 1-5 volts of extraneous current can be a direct cause of lost milk production on properly managed farms....1. Cows exhibit behavioral response between 2 and 4 ma of current application. 2. Cows appear to adapt rapidly during short periods and to subsequent periods of current applications. 3. Current applications up to 8 ma applied prior to and during milking do not cause significant reductions in milk production or adversely affect milk composition. 4. Current applications up to 4 ma applied every 4 hours for a period of 96 hrs do not adversely affect milk production, milk composition, or the feed and water intake...from a practical standpoint, the cows in this study exhibited no evidence of a "stress" response to electrical shock. However, the severe behavioral responses to shock would almost assuredly result in management problems (Stray Voltage 1984).

In 1988 the general conclusion stated "The findings of recent studies, however, surprised researchers and may surprise you. These studies indicate stray voltage doesn't directly decrease milk production. But the way a dairyman manages the problem can cause a decline" (Stray Voltage Study 1988). Throughout the 1980's, however, there was strong disparate evidence that electricity in the cow's environment was having effects, and a growing number of dairy farmers were experiencing an onset of behavioral, health and production problems which had traditionally been associated with stray voltage. Nevertheless, electrical utilities continued to install equipment and encourage methods to mitigate the shock voltage. Grounding was increased on the dairy farms, all conducting parts of the barn were continually electrically bonded, isolation devices were installed, electrical systems were installed on farms separating the neutral and ground connections, equipotential planes were constructed, and electronic grounding systems were tried.

All of these changes provided some relief from stray voltage effects; however, no one of these mitigation devices consistently aided the dairy farmer. All of these changes have resulted in a better grounded farm which can cause an increase in the current going to and from the farm through the earth. Especially the electrical bonding of all conducting parts of the barn and the use of an equipotential plane can, therefore, cause greater electrical currents to be in the cow's environment. Dairy farmers across the nation continued to struggle with the effects of stray voltage even though the cows were in an environment where they could not experience a shock voltage.

The most recent general findings resulting from the extensive university research of the 1980's provides the following conclusions:

1. "Older recommendations for tolerable levels of cow contact voltages (0.5 V (1980) and 0.7 V (1987)) were based on the lowest values for perceived currents and low values for body, contact, path, and source impedances. These past voltage recommendations need to be reviewed in light of recent research" (Lefcourt 1991, pp.3-22).

2. The consensus of most of animal scientists involved in research in the United States and Canada is that, "In general, 1- to 2-mA currents are required to elicit a behavioral response in a dairy cow. These currents correspond to about 0.5 to 2 V. Currents up to 4.0 mA do not appear to inhibit the milk ejection reflex, depress milk production significantly, or increase the incidence of mastitis or other diseases of the cow. Cows must be exposed to at least 4 V on their water bowls before approximately 7 percent of the cows will continue after 2 days, to drink less water. Most cows (more than 90 percent) adapt within 2 days to constant voltages as high as 6 V on the water bowl" (Lefcourt 1991, pp.3-22).

3. Some additional conclusions are, "Mastitis is a fact of life in the dairy industry, and it is caused by infection of the udder and not electricity. It should be emphasized that factors such as mistreatment of cows, milking machine problems, disease, poor sanitation, and nutritional disorders may cause cows to manifest any of the symptoms that are associated with stray voltage/current problems" (Lefcourt 1991, pp.3-23).

REVIEW OF THE PRESENT STATUS OF STRAY VOLTAGE

As mentioned previously, the stray voltage problem has been an albatross around the necks of dairy farmers for many years and continues to plague them today. Every year additional dairy farmers experience the encroachment of stray voltage into their operations. Current stories of stray voltage effects among the dairy farmers reflect a continuation of and consistency with past problems. For some the onset of problems correlates with electrical changes but among others there is no clear association.

A disheartening outcome of this problem, as perceived by the dairy farmers, is the number of dairy farmers forced out of business because of stray voltage. Either the stray voltage problem has not been resolved on the farm or the causes were not recognized prior to the farm becoming insolvent. Consequently, the general response to these problems has been a sense of helplessness and discouragement. This mood may be enhanced among individual farmers in that there may be no solution to the stray voltage problem even after attempting to correct every possible electrical problem on the farm. Also, the farmer may bear additional costs for further mitigating activities such as being required to pay for the isolating device. The purpose of this device is really to correct a problem on the electrical utility system rather than on the farm's system per se. The implication of this practice is that the problem is the fault of the farmer even though the farmer has no control over the cause. In cases where the isolation does not solve the problem, the problem's source is still likely derived from an off-farm source, and the farmer is left to attempt another solution.

Farmers continue to ask the electric utilities, university specialists and state agency personnel to help them solve a problem which is affecting the health and production of their diary herds and perhaps their and their family's health as well. Similar concerns are expressed by other livestock confinement operators and the general public, especially those living near transmission and distribution lines, transformers, substations, and the earth grounding systems. Particularly in the States of Minnesota and Wisconsin, the state departments and agencies, electric utilities, and dairy farmers through The Electromagnetics Research Foundation, Inc. (TERF), are meeting and developing strategies to resolve dairy animal problems associated with EM energy. Committees in Minnesota and Wisconsin, though organized somewhat differently, are functioning similarly to deal with this problem. The directive of each committee is to give higher priority to understanding the relation of dairy animals to their EM environments and to develop a plan to solve associated problems. Although only dairy animals are to be considered, the human health issue is frequently discussed because the dairy farmers recognize effects on both humans and animals. These perceptions are well documented and, in some cases, supported by medical doctors. Unfortunately for those affected by stray voltage, this ameliorative process is very slow since vested interests play a significant role in solving problems in controversial areas such as this.

Non-profit corporations, dairy farmers, and interested specialists have been independently investigating the stray voltage problem for a decade or more. Mostly a systems type of methodology was used in these investigations. Accompanying this research a body of relevant information has emerged dealing with perceived associations between EM energies and the health of animals and humans in field settings. The research attempted to quantify the major variables in the subjects' EM environment. Available instruments facilitated obtaining as much information as possible about electric and magnetic fields and electric currents. Important, and sometimes serendipitous, discoveries were made through these measurements. Observations of the actions and responses of cows in the dairy barns revealed that cows sensed some adverse stimulus seeming to be continually present in the barn. Frequently the cows would also respond to a random event that appeared to be present only for a relatively short period of time and then would disappear.

The effects were observed in stalls where the only cow contacts were the hooves of the cows as they stood on the floor of the barn. In barns where stray voltage is an important factor, 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. In some barns where the AC potential on the conducting parts of the barn are especially high, however, the cows stay away from all conducting parts. Noted especially is the appearance of effects from a continuous exposure which can impact the animal chronically. The overall well being of the animals tends to degenerate in direct relationship to time spent in the barn. DC and AC electric currents were both present in the floor and in all conducting members in the barn.

Small electric and magnetic fields were also present throughout the cows' environment. Even on farms that had an isolation device installed these electric fields and currents were nonetheless present though changed in magnitude. Cutting off the electric power to the farm did not have consistent effects. On some farms the magnitudes would decrease and on others they would increase. This implies that electricity was reaching the barn from sources independent of the farms' electrical system, and the pathway was through the earth. Thus the cows' electrical environment was affected by both AC and DC electricity 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 is inadvertently transmitted into 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 aggregate impact of this amount of current continually flowing in the earth. However, it is known that dairy cows experience a set of behavioral, health and production effects when an electrical problem exists proximate to dairy farms where electricity is short circuited into the earth. Farmers, dairy equipment suppliers, power suppliers, agricultural extension specialists, veterinarians, feed suppliers, and electricians will attest to this. Consequently, dairy farmers are directed toward considering how electricity reaches humans and animals through the earth as well as how this electricity affects them. An important empirical discovery has shown an association between the effects in dairy herds and the grounding of the electric utility neutral on the farm. Measurements show that significant alternating and direct currents are entering and leaving the earth by means of the primary and secondary grounding systems.

Recommendations for mitigating stray voltage consisted of methods that reduce current between the floor of the barn and conducting parts in the barn that were connected to the neutral of the electrical system. The theory rests on the assumption that a cow will be effected when receiving a current of a mA or more when contacting conducting elements in the barn. From this assumption, isolating the farm neutral, the equipotential plane, and electrical bonding were logical mitigating methods. The method, or combination of methods, was used that provided an environment such that a cow was unable to experience a mA of current. The problem was assumed solved when the voltage measured between the floor and any conducting part of the barn which the cow could touch was less than 0.5 volts. When using high input impedance digital meters, higher voltages were acceptable as long as they were less than the 0.5 volts when using a 300 ohm shunt.

A theoretical shortcoming is that this approach is based on the shock requirement (intermitant exposure) but does not take into account possible effects from continuous exposure of cattle to lower levels of currents and possible currents from electric, magnetic and EM fields in the barn. The mitigation procedures did reduce the potential for electrical shock in the barn but did not necessarily reduce the amount of electricity or EM energy in the barn. Under certain conditions isolation of the farm neutral could reduce the amount of EM energy reaching the barn but in others could even increase the EM energy reaching it.

Electrical bonding and the equipotential plane likely increase the amount of EM energy in the cow's environment increasing the likelihood of EM effects. This is suggested in that, in an important proportion of the cases using mitigation, cow behavior would improve for a short time only to regress again later on into pre-mitigation behavior and sometimes lowered milk production. In cases, for example, in which the electronic grounding system was installed, the behavior, health, and production of the cows would change. At times one dominant production effect would be replaced by another which might cause an increase in the overall productivity of the herd but not necessarily cause the herd to be healthier. The general expression of the dairy farmers is that the mitigation methods can reduce the measured voltage causing the shocking of the cows. From the stand point of effects on the cows, however, there is, at best, improvement in productivity to an acceptable level, but other effects are still present. In the cases where isolating the farm has significant beneficial effects, the beneficial changes for some will be immediate while for others the improvements in the herd will occur gradually over a period of 6 months to a year.

Based on studying the mitigation methodologies on a few hundred farms, The Electromagnetics Research Foundation, Inc. (TERF) concludes that none of the present mitigation methods solves 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 responses. 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 dairy operators. On approximately 30% of the farms, the change has been beneficial and continued to be beneficial. However, for the other approximately 70%, the changes have been beneficial for a short period of time, have had no real beneficial impact, or have caused more serious problems for the cows and operators. Isolation has been the most beneficial of all the applied mitigations procedures. However, isolating devices can be only temporary since they redirect the current that goes into or is in the earth (Aneshansley & Gorewit 1992; Appleman 1987).

A number of surveys were conducted attempting to assess dairy operators' perception of the stray voltage problem. Results indicate that somewhere between 20 and 40 % of the nation's dairy farms experience effects on dairy cows from some form or forms of electromagnetic energies (Dahlberg and Falk 1993); (Gustafson 1981); and (Appleman and Gustafson 1985). Of those experiencing stray voltage problems, operators estimate a yearly loss per farm of between $20,000 and $30,000.

These estimates are not likely to be overestimates given how dairy problems are defined as stray voltage problems. The information published by the electrical utility industry defines stray voltage in terms of the magnitude of the neutral-to-earth voltage measurement and cow contact voltages in the dairy barn. Survey results indicate that, in general, dairy farmers assume that a certain voltage level decides the presence of stray voltage. Consequently many dairy farmers who experience the classic symptoms of stray voltage in their dairy herds automatically assume that the cause cannot be electricity. The dilemma for the dairy farmer is that according to the measurements used to identify stray voltage the problem is easily eliminated, but the effects on the behavior, health, and production of the cows cannot be eliminated. Surveys and farm investigations identified several hundred farms where the classic stray voltage effects persist with continuous cow contact voltages less than 0.5 volts AC. In the traditional sense, the shocking of cows cannot occur on these farms.

Determining the presence of stray voltage based on effects includes confusing and unclear choices. On the one hand, using effects as the criteria can be flawed because many of the effects can have different causes. On the other hand, correlating effects to possible stray voltage causes can be helpful provided one recognizes that there might be other causes. It is also important to consider that farmers often consult with various specialists when determining if their problem has electrically based causes since other ways of dealing with the problem are usually simpler. Thus a stray voltage explanation becomes a kind of "court of last resort."

There are other reasons why dairy farmers do not readily concede that they have a stray voltage problem. Admitting to a stray voltage problem is economically destructive. Loans are much more difficult to obtain and the value of the farm as a viable dairy operation is drastically reduced. And there is the consideration of personal health. Some of the surveying dealt with the perceived association between effects in the dairy herd and human physical health effects. These surveys included responses from about 200 dairy operators who are experiencing a stray voltage problem. There was a highly significant correlation between the level of health and production of the dairy herds and physical health symptoms reported by those working in the dairy operation especially while they were in the barn.

Other studies attempt to assess the effects of stray voltage. One study was completed in 1993 based on a survey of 369 dairy farms in the State of Minnesota. Other studies gathered information from more than 100 dairy farms from other states, as well as from homes, elementary schools and businesses both in rural and urban areas. These studies indicate that there is a correlation between levels of behavioral and health symptoms in dairy herds, health symptoms among humans and problems with electrical equipment. If there is a stray voltage problem on the dairy farm causing problems for cattle, there are commensurate health problems for the dairy operators and unusual effects in electrical equipment used on the farm. Significant correlations were found between human and animal symptoms and proximity to transmission lines. However there was a weak correlation between human and animal symptoms and proximity to a natural gas or oil pipeline. Stray voltage problems also exist at long distances from either electrical transmission or pipe lines. It seems appropriate to assume that transmission lines and pipe lines are sources of stray voltage but certainly are not the only sources of electricity associated with the assessed symptoms.

From these surveys, one can conclude that the mitigation methods developed as solutions to the problem have on the average only served as band-aids with short term benefits. The mitigation procedures help some dairy operations, while for others the problems are made worse. These studies suggest that underlying assumptions about stray voltage problems need revision. Careful consideration must be given to the use of the earth as a significant part of our electrical system (Dahlberg and Falk, 1993).

CHAPTER II

EM ENERGY AND LIVING ORGANISMS

INTRODUCTION

Research into how EM energy interacts with living organisms has been ongoing for many years throughout the world (Barnothy 1969; Becker 1982; Nordenstrom 1983; Marino 1985; and Sugarman 1992). Here we discuss theories about the electrical nature of living organisms as well as theories about how EM fields external to the living organism have both positive and negative effects on the organism.

A paper, Biological Effects of Power Frequency Electric and Magnetic Fields, prepared for the US Congress, Office of Technology Assessment, draws the following conclusions:

> there is now a very large volume of scientific findings based on experiments at the cellular level and from studies with animals and people which clearly establish that low frequency magnetic fields can interact with, and produce changes in, biological systems. While most of this work is of very high quality, the results are complex. Current scientific understanding does not yet allow us to interpret the evidence in a single coherent framework. Even more frustrating, it does not yet allow us to draw definite conclusions about questions of possible risks or to offer clear, science-based advice on strategies to minimize or avoid potential risks.
>
> Of the effects discussed, the central nervous system effects including circadian rhythm changes in animals and the possibility of cancer promotion appear most worthy of concern with respect to public health consequences (Nair, et al. 1989 p. 67).

The final report of the New York State Power Lines Project states:.

> In conclusion, results of the New York funded projects document biologic effects of electric and magnetic fields in several systems. The variety of effects of magnetic fields have not been previously appreciated. Several areas of potential concern for public health have been identified, but more research must be done before final conclusions can be drawn. Of particular concern is the demonstration of a possible association of residential magnetic fields with incidence of certain childhood cancers. Further study of this possible association and mechanisms to explain it are important. The variety of behavioral and nervous system effects may not constitute a major hazard because most appear to be reversible, but they may impact temporarily on human function. Further research should also be done in this area" (Ahlbom, et al. 1987 p. 10).

In this section we consider some basic information on the nature of EM energy, the sources of these energies and their effects on living organisms.

BASIC ELECTROMAGNETICS

An electrical charge is one of the fundamental forces of nature having properties associated with the electron and proton. Electrons and protons are the basic building blocks of atoms and molecules. Consequently, all matter is an aggregate of these particles, and so, any piece of material can have a charge. Probably the most confusing aspect of electric charges is that there are these two kinds, electrons and protons. The charge on an electron is identical to the charge on a proton except that by bringing an electron and a proton close together, as in an hydrogen atom, the charge on the electron and proton neutralize each other. The hydrogen atom, therefore, displays nearly a zero charge even though it is made up of an electron and a proton each with a charge.

The nature and effects of a charge are normally not seen in a simple way, as for example, in gravitational force. If one were to rub a comb on a piece of wool, the comb can pull electrons free from the wool and end up with a surplus of electrons. Of course the wool will then be deficient in electrons. The comb is said to be negatively charged and the wool positively charged. Now each object can produce a force on all other objects which may or may not be visible. If balloons were rubbed together, the balloons would repel each other but probably would stick to a painted wall. In general the existence of this kind of electrical force is described as an electric field. Any time an object has a surplus of either charge it will produce a force field, or electric field, around it.

Electric fields can cause charged particles to move in all materials. The better the conducting ability of the material, such as copper, the faster charges will move. The force of the electric field is designated as electric potential, more commonly called voltage, and the movement of the charged particles is called electric current. Two interactions of EM's with matter have now been identified. An electric field can apply a force on the charged particles in the object causing them to move as electric current.

Most persons have been enamored by magnets at some time in their lives. A magnet also produces a force on objects, and this ability is described with reference to its magnetic field. One notes that any magnet affects other magnets as well as certain elements, such as iron and nickel, with its magnetic field. In order not to complicate these associations any more than necessary, the magnet will be assumed to have an intrinsic property able to produce a magnetic force. The complication is that the movement of charged particles can also produce a magnetic force such as by an electric current in a wire. Thus a magnetic field will exist in the region of any electric current with its moving charges. This magnetic field will produce the same force on materials as does the familiar magnet. An interesting aspect of the magnetic field is that if it is changing in magnitude, an electric current will be induced in objects that happen to experience changes in the magnetic field. In sum, a magnetic field can produce a force on objects and can also create electric currents in objects.

There is still one more force to be considered in EM's. In its simplest form, if charged particles oscillate like a person on a swing though more rapidly, an EM field is produced. The radio waves that travel at the speed of light from the tall transmitting towers, to be intercepted by the radio antenna, is a form of EM wave. It has energy and can apply a force on all objects. The major interaction for radio waves and microwaves is to cause charged particles in objects to oscillate. Of course there are other EM waves such as x-rays and gamma rays. However, they appear to interact most often with objects somewhat differently from those alluded to this far. In this discussion all EM waves with frequencies greater than light will be set aside.

ENVIRONMENTAL EM ENERGIES

Natural Sources:

Some EM exposures derive from electric fields and currents occurring naturally in the environment. It is possible that for millions of years the earth and atmosphere contained DC electric and magnetic fields and

EM emissions as well as extra low frequency (ELF) currents. It is also likely that these have significant biological effects (Becker and Selden 1985).

A natural electric field exists between the earth and the ionosphere produced by a dynamo effect apparently connected to thunderstorms. Because of the field and an atmosphere with a finite resistance there is also electric current present in the atmosphere. The surface of the earth is normally negative relative to the ionosphere, and the electric field is in the range of 100 V/m. The values of the field vary with atmospheric conditions. Dust storms in desert areas can cause an increase and reversal of the polarity of the field. During thunderstorms, and even in advance of thunderstorms, the fields will often increase, change rapidly and also reverse polarity. Small positive and negative ions are present throughout the atmosphere because of naturally occurring electric discharges and ionizing radiation. Again under hot, dry, and windy conditions, positive ions are produced by the shearing forces of the atmosphere. Therefore, in dry air there is an increase in positive ion concentration. The increase in positive ions under these atmospheric conditions may be associated with changes in atmospheric electric fields which also occur during these same atmospheric conditions. Changes in air ion concentrations are always ahead of weather changes. The changes in small ion concentrations are usually significantly less than in large ion concentrations. Air flow from industrial areas shows an increase in large air ion levels and a decrease in small air ion levels. Research indicates that small air ion levels depend upon the ionization process. A drop in air pressure is associated with an increase in positive and negative ion levels (Niziol 1987). AC fields are naturally present only at very low magnitudes. At 60 Hz, the natural level is in the range of 0.001 V/m. Pulsed radio frequency fields are another phenomenon associated with thunderstorms.

In addition to the atmospheric fields are the electric currents and electric and magnetic fields of the earth. The strongest field is the DC magnetic field which is normally in the range of 400 to 800 mg. Other fields are quite small, but even though small, they cannot be ignored when considering effects. The currents in the earth are mainly DC and normally small. Although currents are present throughout the earth, major currents appear to exist in the earth's outer core. These currents are postulated to be responsible for the DC magnetic field. Other currents in the earth are associated with electromagnetic activities in the upper atmosphere, the atmospheric electric field and the rotation of the earth. In fact the earth and its atmosphere can be pictured as a large EM dynamo operating in dynamic equilibrium. The system is dynamic because the electric and magnetic fields and currents are continuously changing. And there is also an equilibrium, a balance, and a certain degree of predictable pattern dictated by the nature of the system.

Technological Sources:

Industrialization introduced significant quantities of EM energy into the environment. These EM energies benefit humans by providing valuable human comforts, but they can also be detrimental by exposing humans to a complex array of EM energies with possible harmful effects. These exposures include the 60 Hz electric and magnetic fields emanating from transmission and distribution lines; direct current (DC) electric and magnetic fields associated with DC transmission lines, ion fields, batteries, welders, electronic systems, etc.; 60 Hz and DC currents in the earth resulting from utilizing the earth as the ultimate ground and sink for electricity; 60 Hz electric and magnetic fields surrounding all electrical devices and electric wiring in homes and the work place; Rf and microwave fields from sources such as microwave relays, military communications, commercial satellites, direct broadcast TV satellites, microwave ovens, medical diathermy, weather satellites, AM and FM radios (commercial and ham), military satellites, CB's, electrical power lines, VDT's (video display terminals), and radar systems.

Industrialized nations depend heavily on the use of electricity. As an example, the United States generates, distributes and uses nearly 300 billion watts of 60 Hz power. The EM fields and currents associated with this electrical use of power are in the extensive electrical transmission and distribution systems as well as in the earth and atmosphere. Radiation from electrical power lines leaks into the magnetosphere and stimulates strong very-low-frequency wave activity out to many earth radii. Observations in Antarctica show that wave activity induced by power lines tends to occur during the daytime when power consumption is high in the source region in eastern Canada. The wave frequency ranges from 1 to 8 Kilohertz. This man-made wave activity may have significant effects on energetic electrons trapped in the earth's radiation belts (Park and Helliwell 1978).

The transmission/distribution grid carries mainly 60 Hz AC with a few lines carrying DC. The transmission lines and the major distribution lines that carry 60 Hz AC are, in general, three phase delta or wye systems. Substations are established for switching the electricity carried on transmission lines to other transmission lines and finally to distribution lines. Usually the electrical potential of the distribution lines is 7200 volts. The three phase lines coming from the substations are usually separated into three single phase lines, each of which provides electrical energy to a group of users.

Safety emerged as a key issue as the 60 Hz power system developed to provide electrical energy to residences and industries. An extensive grounding network developed in an attempt to avoid lethal or annoying shocks from electrical equipment. Grounding of 60 Hz electrical systems emerged as a requirement throughout the electrical power system. The outcome of the very complex electrical system is the continual use of the earth as a current carrier. Investigations reveal that in the existing national electric transmission/distribution system, a large fraction of the current on the neutral side of the system inadvertently ends 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. The neutral wire is in the system to carry the return current but actually carries only a small percentage of it.

There are many reasons for the current being in the earth rather than in the intended carrying lines. The earth has inadvertently become a more critical component of the system as the transmission/distribution system evolved. This is so because the earth is being used as the reference ground for an electrical system that is laterally interconnected over the entire continent. It is not surprising, then, that the earth, being the reference and a conductor, carries current that may be vital for the practical functioning of this interconnected system. As a result of emphasizing safety from shock and electrocution, codes were established that require low resistance grounding. One side of the distribution system, referred to as the neutral, is interconnected with the grounding system and consequently is connected to the earth through the ground rods. At least one ground rod is connected to the neutral at the location of each user.

As late as the early 1960's the normal residential user of electricity did not have a separate ground wire with the high voltage and neutral wires. The ground wire was added to the electric wiring system to assure that the parts of electrically operated equipment touched by people would be directly connected to the earth, thus avoiding shock. Before the introduction of the ground wire the neutral was connected to the earth by means of a grounding wire and ground rod. Afterwards the ground wire was connected to the earth through the grounding wire and then the ground rod. The benefits of having a separate ground could have been significant except that the ground and neutral wires are connected together. Therefore, no real change occurred in the electrical system except for adding an additional wire that provides a greater assurance that the neutral side of the electrical system is connected to those parts of electrically operated equipment exposed to human touch. The special ground wire and more sensitive electronic equipment, however, have encouraged and resulted in additional earth connections. These additional earth connections have provided a lower resistance path for the electric current in the neutral wire.

Multiple connections of the neutral to the earth occurs at all homes, businesses, factories, substations, electric generation facilities, and along distribution lines. Usually a number of ground rods are used at each user site, and in addition the neutral may be connected to other conductors in the earth such as wells and water pipes. Because of these multiple connections, the earth becomes the path of least resistance for the current on the neutral side of the distribution system. Beside the deliberate grounding system, electricity is induced into the earth by the AC magnetic field associated with all alternating currents through inductive coupling and conducted into the earth by electric fields through capacitive coupling and by means of all resistive paths such as towers, poles, vegetation, etc.

The amount of electricity entering the earth is not constant. One reason for this variation likely derives from some major generators of electricity maintaining a constant output of electrical energy regardless of demand. Consequently, during times of lower use it is possible that surplus electricity creates a condition requiring the surplus electrical energy to be dissipated in the earth.

Magnetic fields are produced in the environment of living organisms as a result of electric current imbalances in underground feeder lines. These imbalances are caused by looping the feeder lines and tying the feeder neutrals together; leaving an open circuit on the feeder neutral; and connecting grounds to telephone lines, water pipes, natural gas pipe lines, and other conductors in the earth. Interconnections in overhead electric lines also create imbalances. These imbalances not only increase the magnetic fields emanating from the overhead lines but also increase exposure of living organisms to the electric currents in water pipes and other conductors connected to the grounding system. An organism's exposure to these currents can be by direct contact as a resistive path through the organism or by induction from the magnetic fields produced by the currents.

Electrical currents in the earth are affected by their interaction with natural earth materials and objects embedded by humans such as gas and oil pipelines. Through our general knowledge of the earth's composition and the nature of electricity, one would expect non-linear materials, differences in conductivity and polarizability, and rectifying systems to affect how electricity moves and changes its physical make up. AC of any frequency, in the earth, has the potential of being altered. Problem solving research, conducted on dairy farms and in the laboratory, provides some preliminary information. One kind of observed change is the rectification of a portion of the 60 Hz and other alternating and direct currents. Materials in the earth, such as water and combinations of conductors and semi-conductors, can partially rectify AC. DC cells, associated with chemicals and metallic pipelines in the earth as well as the presence of AC on the pipelines, require cathodic protection to avoid pipeline corrosion. This protection is specifically supplied to the pipeline by means of an electronic DC supply.

How does this process occur? Experimental data suggest a process similar to the charging of a battery. Cells appear to develop which are driven by, or at least connected to, the presence of AC in the earth. Ion migration, and/or chemical reactions, are probably the charging mechanisms.

It is possible that the natural chemical cells can be driven or enhanced by the electrical current in the earth. If DC is present from sources such as buried natural gas or oil pipelines, DC transmission line return or cathodic protection rectifiers on the pipelines, the cells are probably driven more vigorously. Both the AC and DC in the earth will also use the neutral wire and other conductors in the earth. In addition to DC, the harmonics of the 60 Hz AC, such as 120, 180, 240 Hz, etc., can be generated in both components of the transmission/distribution system and also in earth materials.

There are also short duration and sometimes high voltage pulses of EM energy that can be either on the distribution line or in the earth. Transients in the currents of the neutral-grounding system occur when there are changes in electrical usage such as motors being started or stopped, lights turned off or on, etc.

Currents in the neutral and, consequently, in the earth, are complex and rarely retain the simple 60 Hz sine shape. Currents in the earth can also change the electrical character of materials in contact with the earth such as floors and walls of buildings. The model of the electric cell suggests that the electrical charge of the floors and/or earth can differ in polarity and intensity according to the location of the electrodes of the cell. Also since direct currents can be present in the earth and in other conducting materials in contact with the earth, the cracking of concrete floors and walls of buildings in regions of significant earth currents could indicate affects of these currents.

In summation, in the highly electrified environment of our industrialized era, there are many sources of atmospheric ions beside the natural ones. Additional contributions come from electric transmission and distribution lines, substations and from the additional ionizing materials introduced into the environment from the nuclear industry. This includes radioactive krypton that is discharged into the atmosphere from the nuclear power industry and is having a recognizable effect on ion production.

ELECTRICAL NATURE OF LIVING ORGANISMS

Thus far, the description of EM's focused on physical interactions with matter. Possible interactions of EM's with living organisms are important if one is to understand the variety of impacts of EM energy. The living organism may be considered as a system or a conglomerate of systems, and by implication, will have its own EM energies. In addition to understanding the basic physical interactions of EM energy, it is also necessary to know something about the electric circuits and the EM nature of living organisms.

Literature is now more likely to include information describing the electrical nature of the human body as well as that of animals and plants. In the last ten years a number of books describe electric currents and their values within the human body and in many other living organisms (Becker 1985; Nordenstrom 1983). The cardiovascular system, for example, contains many electrical circuits through which electric currents flow. In fact Bjorn Nordenstrom argues that if appropriate direct currents are not in these circuits the body is not healthy (Nordenstrom 1983). The central nervous system appears to require the presence of direct currents in its circuits in order to be able to process information and send messages (Becker 1985). Direct currents are probably due to electron flow along the nerve fibers. In connection with these currents it is found that the sensory nerve fibers have a positive potential at the peripheral end and motor fibers have a negative potential. Magnetic fields are present in various areas of the body from the heart muscles to the brain. These magnetic fields have only recently been measured because their magnitudes are so small (Cohen year?). If functionalist theory has any validity, these magnetic fields exist to serve an appropriate function in the body. As their purpose is understood so also the impact of magnetic fields in the environment on these internal fields can be more easily understood and evaluated.

The electrical processes are made complex in an organism not only by its various electrical circuits but also by the different types of materials contained in the organism. These materials are conductors, non-conductors, and semiconductors. The materials can be liquids, gases, or solids which can be inhomogeneous, non-isotropic, and subject to compositional change. Research has shown that ions and molecules carried across cell membranes change the actions of the cells and, therefore, organs. For example, it is well known that a biasing electric current on a pacemaker cell will affect the pumping rate of the heart (Polk and Postow 1986). Rectification of AC to DC occurs in organisms because of these complexities especially from the combinations of semiconductors. Electrical fields will produce forces on ionic materials as well as on polarized or polarizable neutral molecules.

Through conduction the effects of radio frequency (Rf) can be observed at points away from the place of absorption. Cells appear to have the properties of semiconductors. Therefore, an Rf field causes cathodic excitation of a neuromuscular preparation to be increased and the anodic excitation to be decreased resulting in a change in charge on the surface of a cell. Rf fields can produce electric negativity of a nerve. A change in the charge of a nerve cell has significant consequences for the functioning of the entire organism since such a physiological change produces a change in its controlling functions. As a consequence an organism, or its parts, could function as an Rf detector. The cerebral cortex and inter-brain structures, especially the hypothalamus, may be the most sensitive to EM fields since it is the primary sensor to the outside world. The effects are broad banned in terms of their electrical inclusiveness. It is possible that the effects are caused by DC resulting from the rectification action occurring in the living organism. The rectification occurring in the body is probably quite independent of frequency and may be quite independent of intensity as well.

The effects of an Rf field on the nervous system will also depend on the state of the nervous system. Rf fields can produce a greater or lesser effect depending on the chemical stimulation of the nervous system (Jaski 1961). For example, if an animal is under the influence of a narcotic, a greater Rf field is required to cause damage to the animal. Psychotone in rats causes the opposite reaction with a lesser Rf field required to cause damage. It appears as if these chemicals shift the ability to transmit signals in the organism. Such connection certainly emphasize the interrelationships among the various chemicals and energies to which organisms are exposed (Marha, et al.1971). According to Marha, chemicals that have carcinogenic effects have pi electrons in their molecules which are closely related to semiconductor properties. This raises the question as to whether the semiconducting nature of the chemicals plays an important role in their carcinogenic effect, and whether this effect is changed by the presence of an EM field.

The nonlinear and semiconducting nature of nerve cells is connected to the ability of persons, including the deaf, to be able to hear the radiation from a pulse-modulated transmitter (Frey 1961, 1962). The sound source seems to be in the area of the occiput. Low frequency EM fields can also cause sounds. It is thought that weak currents are produced by the fields that excite the auditory cells or auditory nerves (Frey 1962a, Wieske 1963)."Electrical signals are clearly important in the control of biological processes and in carrying information from one part of the body to another. Nerve cells propagate electrical signals from sensors of pressure, temperature, light, sound, etc., to the brain and return control signals to muscles, the heart, etc., yet if we choose to stimulate these processes with external electrical inputs, we have a relatively limited understanding of how a given electrical input will affect various biological organs, what the safe limits of exposure are (particularly over extended periods of time), and how electrical signals are carried across cell membranes or propagated along nerves" (Polk and Postow 1986, p.100).

A book published in 1983, Biological Closed Electric Circuits: Clinical, Experimental, and Theoretical Evidence for an Additional Circulatory System, by Dr. Bjorn Nordenstrom, will undoubtedly importantly impact theories about biomedicine. Dr. Nordenstrom's book draws together his and others' research substantiating his theory that all living systems contain numerous functioning electrical circuits. Electric fields produced within the body provide the force and energy which maintains these currents for whatever purpose is required. These circuits, he maintains, exist in all bodily functions, and these DC currents determine the organism's well being. He discusses circuits that are switched on by an injury, an infection, or a tumor, or even by the normal activity of the body's organs. His measurements indicate that electric currents are present in arteries and veins and at times in small electrical conducting holes in capillary walls. These currents set up the fields which draw white blood cells and metabolic compounds into and out of surrounding tissues. These currents are maintained in the body by electromagnetic fields for whatever purpose is required. This electrical system, says Nordenstrom, works to balance the activity of internal organs and, in the case of injuries, represents the very foundation of the healing process. The term biological closed electric circuits (BCEC) is used to identify these natural circuits of living organisms.

Nordenstrom's theories about the body's electrical circuitry describes a complex process. Theories are made even more complex if one takes into account an organism's diverse composition of different types of materials. These materials are conductors, non-conductors and semiconductors. Further, the materials can be liquids, gases, or solids which can be inhomogeneous, non-isotropic and subject to compositional change. Research has shown that ions and molecules carried across cell membranes change the actions of the cells and, therefore, organs. Nonlinearities of membrane resistance and capacitance characteristic of semiconductors can rectify AC currents in the organism as well as change the electrical charging of cell surfaces. As in the case of electronic components, the appropriate combination of semiconducting materials can cause rectification as well as amplification. Direct currents may be of special significance because of its association with ion generation and movement. It is well known that a biasing electric current on a pacemaker cell will affect the pumping rate of the heart (Polk and Postow 1986). "These nonlinearities also provide a vehicle for phase locking of pacemaker cells and a partial explanation for the increased sensitivity of biological systems to electric fields at frequencies near their natural firing rates" (Polk and Postow 1986, p.136). Electrical fields will produce forces on ionic materials as well as on polarized or polarizable neutral molecules.

Normally the interior of cells in an organism are negative with respect to the surrounding fluid by 50 to 150 mV. The resistivities of cell membranes are about 100 million times the resistivity of the fluid inside and outside the cell. The electric fields in the body of the organism are necessary for the normal functioning of the membranes. Externally applied fields, as part of the organism's electrical environment, would be expected to affect the membranes, as well. For some fish, electric fields in the range of 10 nV/cm can be sensed. The highest sensitivity to electric fields known in the Animal Kingdom is 5 nV/cm for elasmobranch fishes (Kalmijn 1992). The membranes that provide for this sensitivity appear to be amplifiers. Their ability to amplify appears to be related to their having properties similar to a conventional electronic amplifier. Membranes also act like diodes transmitting electric current and directing it in one or another direction. Metal ions, such as calcium, sodium and potassium ions, are common current carriers in the various circuits of the body.

Different tissue in the organism can each carry specific charges in accordance with its electrical impedance, ionic concentrations and polarizability. These charges can be changed artificially by introducing outside currents into the circuits. Short circuiting in the organism can level potential differences. Tissue can have galvanic cells which will function as batteries in the organic system because of the differences in materials in the body. These galvanic cells may be charging or discharging at different rates depending on the ionic concentrations and electrical circuit impedances. Artificially or naturally changing chemical composition within the tissue could, therefore, affect the current output of the galvanic cells. Changes in the electrical output of the galvanic cells could likewise change the chemical composition of the tissue. Pharmacological compounds provided to the body can affect the electrical output of the galvanic cells and the currents in the BCEC systems.

Other research attempts to integrate the electrical and chemical composition of organisms. Dr. Robert Becker measured different potentials at various points on the human body. He states that all living organisms carry a complex electric field. The more complex the organism the more complex the field. He has also shown that the human body is equally an electrical system and a chemical system. For example injuries of the body will develop one electric polarity immediately after injury and at some point later the polarity will be reversed. The implication is that the body generates a current that moves in the circuits of the body to produce the electric polarity required for healing an injury.

Relative values of electric potentials exist between points on the body's surface as a normal characteristic. This means that certain surface areas are more positive and others are more negative. The surface of the body is most often positive in regions of large concentrations of neurons, such as on the head and the spinal chords, and negative at the points of nerve sensor concentrations, such as hands and feet. Acupuncture points, in general, are positive relative to the surrounding area.

Dr. Becker discovered that direct currents are required in the functioning of the central nervous system. When a human subject is told to make a certain muscular movement after being given a signal, there is an increase in negative DC after the signal. The increase in DC, however, turns on almost a half-second before the muscular action is performed. This condition is known as the readiness potential and seems to imply that the DC system commands the nerve-impulse system. Dr. Benjamin Libet, University of California, also finds that the readiness potential preceded the decision. The brain seems to have a "mind" of its own. Perhaps the DC potential system in the brain provides a specific electronic context for making decisions. The DC system seems to reside in the perineural system and carries the signals for healing, and the nerves, themselves are not connected with the healing (Becker 1990).

Degree of an organism's alertness seems tied to electric potential. On the one hand, the more negative the brain's electrical system is, the more alert is the person. On the other hand, a positive potential causes the brain to be anesthetized. These discoveries suggest that currents in the nervous system are associated with the electric potentials and literally control all the functions of the nervous system including decisions, inter-pretations, commands and feelings. Polk and Postow discuss the function of electrical signals in biological functioning in stating:

> Electrical signals are clearly important in the control of biological processes and in carrying information from one part of the body to another. Nerve cells propagate electrical signals from sensors of pressure, temperature, light, sound, etc. to the brain and return control signals to muscles, the heart, etc., yet if we choose to stimulate these processes with external electrical inputs, we have a relatively limited understanding of how a given electrical input will affect various biological organs, what the safe limits of exposure are (particularly over extended periods of time), and how electrical signals are carried across cell membranes or propagated along nerves (Polk and Postow 1986, p. 100).

It is likely also that the nonlinear and semiconducting natures of nerve cells is connected with the ability of persons, including the deaf, to hear the radiation from a pulse-modulated transmitter (Frey 1961,1962).

Research indicates that magnetic fields are present in living organisms both from the earth's natural magnetic field and from localized direct currents either external to or within the living organism. In addition, living organisms have minute particles of magnetic materials at various locations. David Cohen, a pioneer in the development of equipment for measuring magnetic fields produced within the human body, measured magnetic fields which are from a million to a billion times smaller than the earth's magnetic field. They are present in various areas of the body from the heart muscles to the brain (Cohen year?). In the posterior wall of the ethoid sinus (located high up at the back of the nasal passage, just in front of the pituitary gland) are minute crystals of magnetite, and the ethoid sinus is closely connected to the central nervous system.

Other organismic substances are subject to magnetic fields. Water is a major component of living organisms and appears to have the ability to be affected by magnetic fields. Physiochemical properties of water are changed upon exposure to magnetic fields. Water becomes less hard as it flows in a glass tube a few millimeters in diameter between the poles of a magnet at speeds from 0.3 to 0.5 m/s. Other properties of water are also affected by magnetic fields (Minenko et al. 1962). Surface tension and viscosity increase with the strength of magnetic field exposure peaking in value about 8000 gauss for surface tension and 1500 gauss for viscosity. Electrical resistance varies with magnetic field intensity in an oscillatory manner. Investigations revealed that optimal reduction in hardness occurred at field strengths between 1500 to 4500 gauss and the amount of scale was lowest at speeds ranging from 0.4 to 0.5 m/s. Suspended solids in magnetically treated water tend to be rhombohedral and other shapes. In untreated water crystals tend to be needle shaped. In addition, magnetically treated water can produce behavioral and biological changes in living organisms (Kogan & Tikhonova 1965, Glebov et al. 1965).

Natural and artificially produced EM energies affect not only water but plants as well. The effects on the plants and water can alter the biochemical processes of the organism that consumes the plants and water though this does not explain all changes in the consuming organism. Therefore, it is likely Em energies directly affect macrosystems of the body as well. Energy input of any form, even at low levels, into water containing oxygen causes the formation of hydrogen peroxide (Gmelin 1963). These energies could be light, sound, electric or magnetic fields, or ionizing radiation. When one considers the nature of living tissue, added EM energy could lead to an increase in the presence of hydrogen peroxide. Some research has indicated that changes of hydrogen peroxide levels of ingested water can have effects in such areas of circadian rhythms, and these effects are equivalent to those correlated with exposures to weak 10 Hz electric fields (Wever 1985b). A suggested mechanism for the effects of electrical energy on living organisms is the formation of hydrogen peroxide by the electrical energy either in the body or in water before it is ingested into the organism.

EFFECTS OF EM ENERGY ON LIVING ORGANISMS

General:

From one perspective, living organisms might be thought of as homeostatic systems subject to various other systems. From this perspective Michaelson and Lu indicate (1992):

> To maintain homeostasis, mammals possess precise coordinating control systems that react to changes in the internal and external environments. Among these controllers are the interacting neural and endocrine systems, which are among the prime physiological regulators of the body. Perturbations caused by environmental factors such as electric, magnetic, or electromagnetic fields can be manifested by functional changes in these regulatory systems of the body. Acting alone or in concert, the various components of the neuroendocrine system play a central role in the integrative activities that are required for homeostasis.

The literature dealing with EM energies and living organisms is quite diverse and deals with a broad range of physiological effects. About 200 studies are reflected in Marino's (1985) summarizing statements that follow:

1. EMFs can alter the metabolism of all body systems, including the nervous, endocrine, cardiovascular, hematological, immune response, and reproductive.

2. The effects on each tissue or system are largely independent of EMF frequency.

3. An organism's response to an EMF is determined in part by its physiological history and genetic predisposition; individual animals, even in an apparently homogeneous population, may exhibit changes in opposite directions in a dependent biological parameter.

4. EMF-induced biological effects are best characterized as adaptive or compensatory; they present the organism with environmental factors to which it must accommodate.

Other researchers draw similar conclusions. For instance, Presman (1970) indicates that repeated exposures to low intensities of EM fields can produce the same morphological changes as a single high intensity exposure. Morphological changes in tissues and organs are produced by EM energies at levels below that which can cause a thermal effect. These changes appear to be connected to the deterioration of the functioning of the regulation and metabolic processes of the body. Most frequently the changes are observed in the "tissues of the peripheral and central nervous system and impair its regulatory functions by disruption of the corresponding links or by alteration of the structure of the nerve cells, themselves" (Presman 1970, p.97). Often the effects on specific areas of the central nervous system is nearly independent of frequency, and there appears to be greater effects at low intensities than at high.

Multiple exposures are cumulative in their consequences. Strong fields usually lead to adaptation whereas exposure to weak fields appears to be cumulative leading to greater changes in the organism (Presman 1970). For low intensities or short exposures the effects in the organism are the reverse of the effects produced by long exposures or high intensities. Effects from direct interaction with the nervous system appear to be independent of field intensity and frequency. In addition, very wide ranges of both frequency and intensity affect the electrical activity of the cerebral cortex and subcortical structures (Presman 1970).

Presman (1970) goes on to say:

> A comparison of the effects of EMFs at the molecular level in vitro and in the entire organism show that they differ significantly. The nature and magnitude of changes at the molecular level in the organism are almost independent of the frequency, whereas in experiments in vitro such effects are frequency-dependent and are often of a resonance nature. The effect of EMFs on the biochemical activity of macromolecules in vitro may even be the opposite of that observed in the entire organism (p.179).

At the molecular level ,research shows that cells appear to whisper to each other using electrical messages. The whispering may link cancer to electromagnetic exposure. It is believed that cells send messages to each other across a thin membrane that has an electrical gradient referred to as the membrane potential. The membrane potential acts as a barrier against the inward and outward flow of signals. However, within certain powerline and microwave fields, these electric gradients may be changed. This altered signal may result in out-of-control cell growth characteristic of cancer (Adey 1988).

The pineal gland is considered the master gland of the body. Theoretically it is the remnant of the third eye and especially noted for its production of numerous body chemicals. These chemicals are connected to and interact with other glands of the body, as well, including the pituitary. Neurohormones, released by the pineal gland, are important in regulating the brain's operational level. The pineal gland also regulates the body's clock. It is sensitive to the daily cyclic pattern of the earth's magnetic field. Changes in the magnetic field of the earth are quite small, and the melatonin secretion in humans changes as the natural magnetic field changes. Consequently, inadvertent or advertent changes in the DC magnetic fields experienced by living organisms can change the melatonin output. Part of the retina output is diverted to the pineal gland which affects the melatonin output according to light levels. The abnormal secretion of the neurohormones by the pineal gland, by this reasoning, could be linked to behavior abnormalities.

Chronic stress syndrome can occur when the biocycle is chronically abnormal. One of the effects often associated with stress is a decline in competency of the immune system. As an example, the effectiveness of cancer chemotherapeutic drugs seems to correlate with the point of the patient's biocycle when the drug is administered (Becker. 1990).

These chemical processes are tied to electrical ones. Rf effects can be observed at points away from the place of absorption. That is because of current conduction. As discussed earlier, cells appear to have the properties of semiconductors. Therefore, an Rf field causes cathodic excitation of a neuromuscular preparation to increase and the anodic excitation to decrease resulting in a change in charge on the surface of a cell. Rf fields produce the electric negativity of a nerve. A change in the charge of a nerve cell has significant consequences for the functioning of the entire organism since such a physiological change produces a change in its controlling functions. As a consequence, an organism or its parts could function as an Rf detector.

The effects of an Rf field on the nervous system will also depend on the state of the nervous system. Rf fields can produce a greater or lesser effect depending on the chemical stimulation of the nervous system (Jaski 1961). For example, if an animal is under the influence of a narcotic, a greater Rf field is required to cause damage to the animal. However, psychotone in rats requires a lower Rf field to cause damage. It appears as if this chemical shifts the organisms's ability to transmit signals.

Such connections certainly emphasize the interrelationships between various chemicals and an organism's exposure to electric energies (Marha, et al. 1971). According to Marha, chemicals that have carcinogenic effects have pi electrons in their molecules which is closely related to its semiconductor properties. The substantive question raised by this is whether the semiconducting nature of the chemicals plays an important role in their carcinogenic effect, and whether this effect is changed by the presence of an EM field.

An understanding of the electrical circuits in living organisms may help to explain the interrelationships of the chemical and physical processes in the body. White blood cells carry a negative charge on their surface and, therefore, will be attracted to positively charged areas of the body. If an electric current is produced in the veins and/ or arteries from an external source, the white blood cells will be attracted to the positive electrode. Blood clots are seen to form as a result of these applied currents. There is also the possibility that when these electric currents and fields are disturbed either by external sources or by internal changes, adverse effects can result. In turn, these adverse effects could impact the immune system.

Dr. Nordenstrom discusses the possible role of biological closed electric circuits (BCEC) in biogenesis, including carcinogenesis. He states:

> Strong currents will destroy cells and tissue. Weak currents, on the other hand, will more gently create new internal and external environments for cells. The currents will also directly interfere with cellular metabolism and modify structural elements of cells...A large number of chemicals, physical and biological factors are capable of inducing cancer. They all seem to have the capability, direct or indirect, of polarizing tissue. A unidirectional activation of BCEC system by weak currents over a long time will change the internal and external environment of cells. Surviving, modified cells still capable of multiplying may then possibly produce neoplastic tissue. It is suggested that activated BCEC systems, under certain circumstances, represent a common factor in carcinogenesis (Nordenstrom 1983 p.10).

Both weak and low energy electric currents can modify tissue structure when acting over long time periods (Nordenstrom 1983). From constant magnetic fields to microwave fields, EM energies affect the electrical activity of various parts of the brain. The cerebral cortex and the inter brain structures, particularly the hypothalamus, are very sensitive to EM fields.

> The hypothalamus is responsible for humoral regulation of the blood sugar; it regulates the activity of the endocrine organs—the hypophysis, the adrenal cortex, and so on. Direct electric stimulation of the hypothalamus causes changes in the number of eosinophils and lymphocytes, in the secretion of the adrenocorticotrophic hormone by the hypophysis, the ascorbic acid content of the adrenals, and so on (Presman 1970 p. 132).

Exposure to high frequency fields have been shown to increase the sugar content of the urine and the blood with sugar curves characteristic of pre-diabetic conditions.

EM fields can also affect the cells, the protein, and mineral composition of the blood. The effects observed can very with species and even strain of animal emphasizing difficulties in replicating experimental results. Calcium levels in the blood increase with EM exposure which affects the specialized aspects of animal's appetites. Animals also desire to consume more calcium when exposed to EM fields. Microwave fields, electric and magnetic fields all negatively affect the reproductive processes. Magnetic and microwave fields also adversely affect metabolic processes and cell multiplication and differentiation in embryonic development (Presman 1970).

Dr. Nordenstrom writes:

> Simple electrotechnical analogies imply that a local decrease or increase of transported current may give rise to undesired as well as useful effects. A local change in density of current anywhere in a biologically closed circuit might lead to anesthesia, or produce pain or other undesired effects far away from the site of the driving force for the closed circuit transports. Clinical consideration which can not simply be understood by the known and accepted mechanism of referred pain might be explained in this way. For example, degenerative alterations in the cervical spine may not only give

rise to pain in the distribution of an affected nerve but also to symptoms of local peripheral injury associated the pain, e.g., tenderness to local palpation or active contraction of a muscle or muscles (Nordenstrom 1983 p.331).

Effects from Technological Sources of EM energies:

The precise consequences of EM energies on living organisms is complex and presently involves research from various segments of the international community. Governments are making assumptions based on the consequent pool of information as for example Sweden. "On September 30, 1992 officials from the National Board for Industrial and Technical Development of Sweden formally announced that they would be acting 'on the assumption that there is a connection between exposure to power frequency magnetic fields and cancer, in particular childhood cancer'" (Brodeur 1992 p.114). One of the studies on which this decision was based discovered that children living in dwellings where they were exposed to average 60 Hz magnetic fields of more than one milligauss experienced twice the risk of developing leukemia as those exposed to less than one milligauss. Children exposed to average 60 Hz magnetic fields of more than two milligauss had nearly three times the occurrence. For adults exposed to average 60 Hz magnetic fields of more than 2 milligauss had a 70% increased risk to both acute and chronic myeloid leukemia.

Another study examined workers in industries where there was exposure to the 60 Hz magnetic fields and found that those exposed to average fields of 2.9 milligauss were three times as likely to develop lymphocytic leukemia as workers exposed to average fields of less than 1.6 milligauss. Those exposed to average fields of more than 4.1 milligauss experienced an increased risk four times greater. A study in Helsinki found that women exposed to 60 Hz magnetic fields from VDT's at average levels of three milligauss suffered miscarriages at a rate nearly three and one-half times greater than those exposed to average fields of one milligauss. A recent study at the University of Adelaide found that women working with computer monitors developed primary brain tumors at nearly 5 times the normal rate (Brodeur 1992)

EM fields may affect human susceptibility to breast cancer by increasing the amount of estrogen in the body (SN:7/3/93, p. 10). There might also be a connection between breast cancer and melatonin levels. Magnetic and electric fields appear to affect the functioning of the pineal gland and depress or time shift melatonin secretion in animals (Reiter et al. 1993). A connection exists between the eyes and the pineal gland. Light also affects the melatonin production either as part of the functioning of the eye or in the pineal gland as a result of information from the eyes. Light suppresses the production of melatonin which implies that more melatonin is produced at night than during the day. "The reduction in the circadian melatonin rhythm resulting from electric and/or magnetic field exposure is not trivial because the melatonin rhythm is generally considered to be relatively unperturbable, and its alteration typically is associated with some malady. Thus, the magnitude of the change induced by ELF fields must be considered to be physiologically significant" (Reiter et al. 1992, p. 23). Detrimental effects have been associated with the nocturnal depression of melatonin production. The effects from a weak melatonin cycle are similar to the effects that are being associated with EM exposure. These include the suppression of the immune system, changes in reproductive and endocrine physiology, and psychological depression (Reiter 1993).

Abberations in the manner in which the pineal gland functions and probably melatonin production have been related to the occurrence of a number of different types of cancer including breast cancer, ovarian cancer, prostate cancer and melanoma (Cohen et al. 1978, Leone et al. 1988, Narita and Kudo. 1985, and Philo & Berowitz 1988). Another melatonin connection is recognized from results of cellular level studies of the exposure of estrogen-dependent breast cancer cells to 60 Hz magnetic fields (Liburdy et al. 1993a, b). 60 Hz magnetic fields between 2 and 12 mG separately appear to have no affect on MCF-7 breast cancer cells. In the lower range of these magnetic fields the growth of these cells in the presence of melatonin is partially inhibited. Melatonin has been known to inhibit the growth of these cancer cells, and at certain levels of exposure to 60 Hz magnetic fields, the ability of melatonin to inhibit the growth is blocked. Research involving whole animal exposure finds magnetic fields able to affect melatonin production, and cellular level studies find 60 Hz magnetic fields affecting the normal action of melatonin.

Both 60 Hz and DC magnetic fields affect melatonin and its functions either directly or indirectly. Since changing magnetic fields induce electric currents in conducting regions of living organisms, the noted effects may also be influenced by electric charge.

Magnetic fields, estrogen related cancer cell growth and melatonin appear to be connected among female laboratory animals. It is likely, therefore, that the male reproductive system could also be affected. One effect might be alteration in the fetal development of males. Mcgivern studied pregnant rats exposed to low level pulsed magnetic fields during the time the fetal brain is undergoing sexual differentiation. The results revealed that the exposures demasculinized the scent-marking behavior when male rats matured and also led to 'really huge' testes and prostate glands in the adult animal. In 1972 a group of researchers at the University of Manitoba did similar experiments. Their results showed that if rats were exposed prenatally, they developed heavier testicles. If exposed as adults, the testicle size decreased. This is especially important for humans because the rat reproductive system is far more difficult to affect than humans' reproductive system (SN. 1994. Vol 145. p. 26).

Concern over increasing rates of mental illness in industrialized societies has led to a realization that environmental factors may be implicated in this rise. One of these environmental factors is EM energies (Wilson, et al. 1992). Psychological depression and phase shifting of the melatonin cycle may be linked. One such possible link recognizes behavioral change associated with atmospheric electrical changes. Similar links may associate mental illness with exposure to EM energy of human origin.

A study in Sweden involved persons, with acute environmental sensitivity, who were exposed to 50 Hz, 20-40 V/m and 20 kHz, 5-10 V/m electric fields. The subjects were exposed to 20 mg magnetic fields of the same frequencies,as well. Most of the subjects noticed such symptoms as "burning sensation or feeling of heat as if exposed to sun radiation in the face (mainly on the cheeks), vertigo, nausea, pain or deep sensations of discomfort in head, neck shoulders, arms or legs, tiredness or concentration difficulties" (Wennberg, et al. 1990. Experiments were repeated a year later with the same subjects though with no more than random effects. It is unclear why this change in response occurred, but it emphasizes the difficulty of obtaining consistent results in EM research. Recent work at Lund Technical University in Sweden has also found the same effects of the earlier study to be associated with AC electric fields. They call it electrical hypersensitivity (Floberg 1993).

Nonetheless, a growing body of research confirms that both AC and DC fields have biological effects on living organisms. A number of experiments find effects of ELF fields occurring below the perception level of the organism being examined. In particular, behavioral modification has been detected, as well as calcium efflux changes in vitro brain slice preparation, in mammals exposed to field levels below perception level. In addition, human circadian rhythms are shown to be affected by 10 Hz electric fields of 2.5 V/m (Polk and Postow 1986). Goodman and Henderson (1991) have modified RNA transcription—the process of making molecules of messenger RNA from the DNA template—and protein synthesis through exposure to 60 Hz EM fields.

Other researchers, in both eastern and western nations, focus on the effects of radio and microwaves. For example, Gordon and Sadchikova, of the USSR Institute of Labor Hygiene and Occupational Diseases, summarize information presented at a conference in Warsaw in 1971. They identified a comprehensive set of symptoms which they called microwave sickness. Its first signs are low blood pressure and slow pulse. The later and most common effects are chronic excitation of the sympathetic nervous system (stress syndrome) and high blood pressure. This phase also often includes headaches, dizziness, eye pain, sleeplessness, irritability, anxiety, stomach pain, nervous tension, inability to concentrate, hair loss, plus an increased incidence of appendicitis, cataracts, reproductive problems, and cancer. The chronic symptoms are eventually succeeded by crises of adrenal exhaustion and ischemic heart disease (blockage of coronary arteries and heart attack).

One of the models for effects from Rf is that the absorbed EM energy increases the internal temperature of the body and, therefore, causes physical and health effects. In general, effects resulting from temperature increases are termed thermal. Thermal effects are noted at high intensities. From 40 to 100 mw/cm will cause serious injury and hemorrhaging to blood vessels in the internal organs (Deichmann, et al. 1959). It is also possible for some organs to be seriously injured without the entire organism being overheated. This phenomenon is called "dimensional resonance" in which some part of the object irradiated is comparable with multiples of one-half the wavelength. Standing waves can be produced in the organ. Implanted metal may also cause a concentration of energy.

Another source of information derives from complaints by persons working in Rf fields:

> Workers complain of headaches and eyestrain, together with a flow of tears, of fatigue derived from over-all weakness, and dizziness after prolonged standing. At night their sleep is disturbed and superficial and they are sleepy in daytime. Such persons are moody, frequently irritated, even unsociable. They manifest hypochondriac reactions and a feeling of fear. Sometimes they perceive nervous tension or, on the contrary, mental depression combined with deterioration of intellectual functions (notably memory impairment). Over a longer period, definite sluggishness and inability to make decisions result. Those affected complain of a pulling sensation in the scalp and on the brow, loss of hair, pain in the muscles and in the heart region (together with a pounding of the heart)., and breathing difficulties. Not infrequently they complain of difficulties in their sex life. It is moreover possible to observe slight trembling of the eyelids, the tongue, and the fingers, increased perspiration of the extremities, dermographism (writing on the skin: hypersensitivity to mechanical stimulation), and brittleness of fingernails (Marha, et al. p.30).

A Russian study also reports a decrease in lactation among nursing mothers occurs when they are exposed to 10 cm Rf fields.

Although the list of complaints is often subjective, there is research that supports the reality of these effects under Rf exposure particularly those on the nervous system such as induced agitation, excitement and increased motor activities. In some experiments tranquil animals can be turned into aggressive ones. In fact, the entire nervous system can react to Rf fields. All of the various sensing systems, such as seeing, hearing and feeling, are changed by exposure to the fields. One interesting effect appears to be a decrease in the sex ratio at birth, i.e., an increase in the proportion of females born. Also fields may disrupt women's menstrual cycle, and pregnant humans and animals show an increase in the percentage of miscarriages under Rf field exposure. Some research also shows fetal retardation, congenital defects, and an increase in infant mortality. The effects on the cardiovascular system indicated in research include changes in blood flow, blood pressure levels, and rate of heart beat; and hemorrhaging and bleeding can occur in organs under Rf exposure.

Insects seem to be affected by Rf field exposures as well. Marha et al. indicate "Irradiation of various kinds of insects by the Rf field produces an over-all reaction similar to that observed in experiments with mammals. The first symptom is unrest, attempts to escape, then disturbance of motor coordination, stiffening and immobility, and, after a certain interval, death" (p.38). At low field intensities there appears to be an increase in the growth of wood in trees whereas at higher intensities growth is inhibited. The international consensus concludes that pulsed fields are more interactive with organisms than are cw fields.

Direct electrical currents are shown to be connected with plant growth. In fact, direct currents are present in many parts of the plant such as in the roots and stems. These current densities are in the range of 0.02 and 0.08 A/m. Various studies suggest that the growth of both nerves and bones can be influenced by electric fields and can also produce detrimental effects. The understanding of body mechanisms are not sufficiently understood to specifically predict levels at which either adverse or beneficial effects will occur (Polk and Postow 1986). Some studies do consider the effects of electric fields on bone loss due to disuse. As an example, plaster casts containing field producing plates were placed on the legs of 48 male lab rats. Various fields were applied over a period of 28 days. The results were compared to a control group of rats having casts but no electric fields. It was found that bone weight loss and size loss were reduced by the electric field treatments. However, bone tumors were found on eight of the rats treated with fields while no tumors were found in the control group. The 30 Hertz fields had the greatest effects, and the DC fields had the least. These results are preliminary and need more study (Bullard et al. 1967).

Electric fields are able both to inhibit and stimulate growth of tissue and healing. Most often the DC electric field is associated with these effects. Around an electrode that is negatively charged, both healing and infection are suppressed. A positively charged electrode, however, will stimulate growth (Polk and Postow 1986). When normal blood is exposed to direct currents, a morphological change occurs in which red blood cells are turned into monstrous cells and cell complexes. Deposition of calcium is observed in tissue after an injury. A weak current can also prevent bacterial growth (Nordenstrom 1983).

Researchers have shown particular interest in DC magnetic field effects on organisms because of their continuous exposure deriving from the earth's magnetic field. Long term exposure to large DC magnetic fields apparently disturbs the normal functioning of organisms. A 'magnetic' syndrome is identified as resulting in decreased tissue respiration, drop in body temperature, retarded growth and disappearance of the estral cycle in females. Most interesting are effects associated with reducing the DC magnetic field levels to near zero. The scotopic flicker-fusion limit decreases to one-half its normal value after ten days of field reduction. Flicker fusion is a very sensitive test of the central nervous system reaction. It is likely that natural EM fields are required for organismic vitality, and when changes in the natural field persist for a sufficiently long time, the organism can no longer adapt (Biescher).

Flora show effects from both DC and AC magnetic fields. Some plants respond to the geomagnetic field of the earth while growing and to pre-germination magnetic treatment of the seeds. Potatoes irradiated with ELF magnetic fields were found to have a shorter germination period and an increase in the quality and yield of the crop. Potatoes also have a receptive mechanism that adjusts to very weak geomagnetic field changes which may affect the plant's metabolism (Pittman 1972). Wheat seedlings exposed to a magnetic field consumed less oxygen than seedlings that were not exposed. The wheat seedlings in general had longer stalks and roots and grew faster than the untreated wheat. This suggests an increased metabolic efficiency in treated seedlings (Pittman and Ormrod 1970). Other studies reveal that exposing seeds retards sprouting by from 8 to 12 hours compared to control seeds, increases the percentage germination of unchilled apple and apricot seeds, and increases the yields of snap beans.

Magnetic fields are believed to affect the migration of various animals, particularly birds. It is generally known that migrating animals, such as waterfowl, travel in part according to the magnetic field of the earth. One theory suggests that the wing motion in flight, interacting with the earth's magnetic field, induces an electric current in the conducting areas of the wings. Therefore, as the bird flies in different directions different magnitudes and directions of current will be induced. Learning to sense the magnitude and direction of the induced current can provide directional information for the bird. A bird's sense of direction is affected by stormy weather which may be related to changes in the electromagnetic environment occurring during stormy conditions (Barnothy). Woodmice are known to possess a unique method for using magnetic fields to sense direction. In some ways they sample the magnetic field around them, and based on this information, the field mice chart their routes (Mather and Baker 1981). Bacteria, planarians, mollusks, insects, fish, and salamanders all have some magnetic sense of direction.

It is realistic to conclude that magnetic fields can strongly influence blood platelets, blood coagulation and fibrinolytic processes in animals. These conditions increase with time and sometimes vary directly with the intensity of the static magnetic field. Magnetic fields, no larger than 50 gauss, can significantly effect organisms. Short term exposure to very large magnetic fields often show little effect on animals. Long exposures to either large or small fields can often have greater effects. As an example, the growth of young mice is stunted after weeks of exposure. Exposure times of from 5 to 9 days extends the healing time of wounds. This may be caused by a strong magnetic field inhibiting the production of large protein molecules. As exposure time increases, the effects are compounded. When exposure ends, the symptoms are usually reversible, and the organism can return to normal existence (Gorczynska and Weigrzynowicz 1983).

Effects Associated with Natural EM Energies:

The discipline of biometeorology attempts to document the association of health factors in living organisms to meteorological conditions, a discussion that has been going on for many years. This internationally based research attempts to investigate connections between the natural EM energies of the atmosphere and biological and health factors. Parameters being investigated include EM radiation from the atmosphere (spheric), electric fields, ion concentrations and magnetic fields (Landsberg 1969).

Living organisms, including humans, tend to display unique behaviors prior to thunderstorms, the Fohn winds of Central Europe, the Chinook winds in the United States and sometimes to ordinary weather changes. Many studies and reports are available relating a number of health factors and behavioral responses to such weather conditions or changes (Landsberg 1969). For example, Fohn and sirocco winds in Europe are historically associated with headaches, hemicrania, epileptic fits, asthma, thromboembolism and joint pain (Konig, et al. 1981). The changes in weather which produce variations in the electromagnetic fields of the earth-atmosphere system can produce changes in the currents in the channels of the BCEC system of living organisms. If these additional currents exceed the organism's physiological tolerance, by being too large or too small, they could cause a response.

The sun emits radio waves of all frequencies, and at times these wave intensities can be in a range able to produce biological effects. The sun also emits bursts of Rf radiation which can produce pulses of Rf energy in a range from 10 to 50 kHz (Dull 1939). In addition, large air movements involving fronts with unstable moist boundaries can also become Rf field sources in the same frequency range. Research also ties these emissions to human vital statistics such as the mortality rate (Dull 1941), birth rate, traffic mishaps, and industrial accidents (Assman 1955).

Medical Applications:

Attempts to use electrical charges to improve health come from antiquity. In AD 46 Scribonious Largus recommended using electrical stimulation derived from a particular species of fish for healing. By 1830 Carol Matteucci demonstrated that electrical current was generated in injured tissue setting the stage for modern applications. Since then applications were attempted in endocrinology, immunology, neurology, cardiology and other areas (Bauer, 1983).

Now there is an emerging understanding of how membrane and electricity interact. When DC is passed through tissue between platinum electrodes, fibrous membranes are produced in the tissue. An example is the production of fibrous tissue around a cardiac pacemaker and its electrode. Fibrous tissue is electrically insulating and therefore can interrupt or stop the flow of electricity. Fibrous membrane can be explained as the deposition of material in the electrical circuits of the body. Consequently, electric currents can produce fibrous membranes in the body which will be controlled by the insulating quality of the membrane produced. Under certain conditions of current reversal, calcium is deposited in the fibrous structure. It is possible that this process is responsible for the success in the healing of bone fractures with electric currents. Consequently, the normal healing of fractures may result from currents in the BCEC's (Biological Closed Electric Circuits) of the body. Both direct currents and alternating currents will produce fibrous material, but there is a difference in its structure from the two currents. The direct currents, which can reverse direction at appropriate times, appear to offer the best possibility for therapeutic purposes. The currents artificially activate the BCEC systems to bring about the healing.

An extensive body of research provides evidence that DC electric fields and/or currents can stimulate bone growth in both humans and animals. In fact, electric currents are being used clinically for treating nonunion of bones and pseudorathrosis. Even though clear models are not established for defining cellular activity in the bone healing process, the evidence is sufficiently firm to encourage the search for an adequate model.

Richard Lubin, a biochemist, feels that the parathyroid hormone signals or acts to stimulate the breakdown of bone and inhibit bone growth. He thinks that it is the induced electric field that changes the electric charge on the membrane. Research surrounding this discovery provides some interesting information concerning electrical characteristics of bones and magnitudes of currents capable of producing bone growth. Bones are shown to produce both piezoelectricity and streaming potentials. In the dry section of the bones, a stress will cause an electrical current to flow (the piezoelectric effect). In the micro canals of bones, liquid in bone is caused to flow when the bone is under stress (streaming potentials). The flow carries ions which produces a current and establishes the potential. The inverse of these two processes also occurs in bones.

The electric fields surrounding the organism and currents which pass through bones will produce a physical stress on the bones. In addition, the collagen-hydozypatite interface in the bone has potential for rectifying properties. One method of implementing the healing process is to place two electrodes in the bone with the negative in the region where growth is desired. Bone growth will occur around the negative electrode (cathode) when small direct currents (1-10 microamps) are allowed to flow between the two electrodes. The greatest growth appears to be nearest the electrode. At the same time, in some of the experiments, bone necrosis occurred around the positive electrode (anode), becoming serious at currents above 20 microamps. In all of these experiments, because of the complex conductivity of the body, actual values of currents in bones are difficult to evaluate. Other bone union research also indicates that the direction of the current is not only important but also that the continued beneficial effects require the periodic reversal of the direction on the current. AC induction fields also are known to aid in bone healing.

Tadpoles have the ability to regenerate limbs that are lost before their metamorphosis into adult frogs. The regenerated limbs are not always as large or as developed as the original, but they are functional. General information on the effects of electric currents on limb regeneration in adult frogs suggests that both magnitude and direction of current are important in the regeneration process. As an example, if approximately 0.2 microamps of current are introduced into the stump after amputation, a negative current initiated partial regeneration, a positive current caused extensive destruction of the limb, and limbs receiving no current just showed a healing response (Becker and Marino 1982).

One study reported using pulsing EM fields to heal leg fractures that had failed to heal after operations, other treatments, or because of infections. The leg was placed between two coils producing a pulsing EM field instead of attaching electrodes directly to the bone. The field produced a weak electric current in the bone leading to bone healing. The study reported a success rate of nearly eighty percent with no adverse side effects (Basset).

A good deal of worldwide research has gone on relating electromagnetic fields to health care and healing facilitation. China's experimentation with the effects of low electrical energy charges understandably is associated with acupuncture. Researchers in other countries, such as Pullman et al. (1983) in Australia, experimented with the use of electricity in diminishing pain. In Poland, Gorezynska and Wergrzynowics (1983) studied blood coagulation. Yasuda (1977) in Japan and Chang et al. (1984) in Taiwan also examined bone regeneration.

The former eastern block of nations carried out extensive research on microelectricity and its effects on a variety of subjects including human health. This is evidenced by a number of international conferences held in Russia and Poland in past years. For instance, in 1978 a conference in Izhevsk, Russia on magnetotherapy involved 62 reports by physicists, chemists, biologists and physicians. In 1984 the 7th symposium on electromagnetic fields was held at the Technical University of Wroclaw in Poland. Reports at these conferences included such topics as the relation of microelectricity to the nervous system (Gorbach 1982 and Toroptsev and Soldatova 1981), lung disease (Pyntkin and Semenov 1982), antibody reproduction in the spleen (Mel'nikov et al. 1982), cell division (Mamontov and Ivanova 1971), the liver (Dumanskiy and Rudichenko 1976), metabolism (Dumanskiy and Tomashevaskaya 1978), testicular tissues (Uditsev & Khlynin 1978), and catecholamines of the brain (Grin' 1978).

This international interest in the fields of bioelectrics and biomagnetics continues. As an example, electroanesthesia is and has been used internationally for various surgical procedures. In other procedures, electrical currents are found useful in reducing pain in various areas of the body and assisting in tendon and cartilage healing. Research also continues in the area of nerve and spinal cord regeneration with electric currents and fields. At present injuries of this kind are seen as irreparable (Borgens et al. 1993).

Electromagnetic fields have proven to be a valuable tool for treating a variety of medical problems. But there is another side to electromagnetism. Today individuals, scientific and medical groups, public officials and the legal system are questioning the safety of extensive exposure to EM energy in both the indoor and outdoor environment.

CHAPTER III

APPROACHES IN RESEARCHING PERCEIVED EFFECTS OF ELECTROMAGNETIC FIELDS

The unique characteristics of electromagnetic currents and their effects pose unique problems in doing research. The diversity of information, the array of interested specialists, the problem context and variety of social and political systems involved all complicate the search for appropriate research methodologies in dealing with, for example, the stray voltage problems on dairy farms. Building on existing information is useful but difficult. By design information from accepted stray voltage research is limited to affects on the milking cows and the cause being the shock from an AC voltage between the floor and a metal contact. At the same time numerous specialized research projects searching for effects from many other aspects of EM energy can provide important information. In this context, we suggest some approaches that are or could be used in investigating the effects of EM currents.

SPECIAL PROBLEMS

Before discussing specific methodologies, perhaps there is some merit in reviewing problems related to examining possible EM current effects on dairy cattle.

1. Much is not known about the connections of EM currents and living organisms. This means that research often begins with limited theory and a lack of clear understanding about the relationship of EM currents and the dairy.

2. That is not to say there are no relevant theories and models. Various theories and models connect low level EM currents to a variety of subjects, humans and other animals. However, research tends to focus rather narrowly in the search for a particular effect from a particular level or kind of EM current. The dairy barn is a much more complex EM environment than that. Understanding possible synergistic effects, in itself, poses a particular problem.

3. As discussed elsewhere, the cultural context of existing research is quite varied in that EM research is world wide. Culture colors research approaches and findings both in their interpretation and application. Language and cultural barriers frustrate the use of relevant information in continuing research.

4. Researchers in the same culture, but representing different specialized fields, have language difficulties as well. In fact, one might make the case that understanding research in other disciplines in the same culture may be more difficult than understanding research done in another culture but in the same discipline. This is important since EM research requires input from a variety of disciplines.

5. Research takes place within the context of skepticism and a denial by some that there is a connection between EM currents and dairy problems. Meanwhile impacted dairy farmers are clamoring for remedies to what they perceive as importantly negative connections. Hence pressures to quickly provide information for suffering dairyists conflicts with time taken in convincing others of the need to do the research.

6. Measurement and instrumentation present problems. EM cur rents assessed here are of low magnitude, and are both AC and DC. In addition, tracing underground electric movement in its vagaries and variations presents additional problems. Combining these assessments with an assessment of possible effects on cattle and humans complicates the process further. Appropriate instruments are required for deriving descriptions of cow and human behavior as observed by the dairy operators.

7. Data analysis is important if one is to assess the magnitude of possible associations between EM currents and cow behavior. This usually means utilizing mathematical and statistical analysis. It is necessary to use methods that appropriately assess diverse variables that meet the requirements for particular kinds of scales such as ordinal, interval or ratio. Therefore, the kind of calibration on an electrical instrument must meet the same statistical standards as a scale assessing cow behavior.

8. Once data are generated, they must be interpreted. One makes judgments about the magnitude of correlations, levels of significance, and their meaning. Do large correlations mean what they appear to mean? Are nearly significant correlations important, or may they be overlooked? Interpretation about levels of significance take on much greater meaning when they have implications for a particular dairy enterprise.

9. The goal of this research is to assist in diminishing EM related problems in the dairy barn. Findings are usually not so clear cut as to suggest one easily made change. Rather, they are likely to suggest several options, and the option taken is subject to the pragmatic constraints of time and cost.

10. In research parlance, this kind of research is usually referred to as applied research. Researchers who make clear distinctions between applied research and some other kind of "pure" research are not likely to want to enter this arena since it is very much need oriented. Here, applicable knowledge, whether derived from research unsullied by pragmatism or from specific dairy operational needs, is nonetheless applicable if it helps to explain EM currents and their effects.

This list is not intended to frighten potential researchers from entering this fascinating world of discovery. Rather it is simply to suggest aspects of this research that pose particular problems for the researcher. We also recognize that these problems are not necessarily limited to EM research as it applies to the dairy barn. In fact it is hoped that the following suggested approaches have much wider applicability than to this research problem alone. We turn now to discussing approaches that are or might be helpful in doing EM related and other research.

SYSTEMS ANALYSIS

It has been helpful, in researching EM currents and their effects, to view the interaction process as systems. Systems analysis is not new, and some persons view it as antiquated. However, when viewing living organisms in relation to their environment, it proves useful to view the involved elements as systems.

Systems analysis is used within and across research disciplines, and linkages may occur within and among these disciplines. For instance in the social sciences, Loomis describes a systematic linkage.

Von Bertalanffy discusses the goals of The Society for General Systems Research, organized in 1954, as investigating and developing concepts that overlap various fields (isomorphy), minimizing duplication, and promoting unity among the sciences (p. 15). Certainly these goals are commensurate with the goals of EM research. Particularly this approach is needed to overcome some of the segmentation of knowledge associated with examining EM currents and their effects.

In the context of increasing scientific specialization, it is imperative to implement dialogue across disciplinary lines in order to better understand systems of various phenomena. Klein (1986) sees this process as "part of the general evolution of knowledge (p. 409). She adds that the process of convergence, among other things, "functions as a means of solving 'practical' problems within society" (p. 409). In fact, Chubin et al., (1986) in their work, compile examples and suggestions of how interdisciplinary research might be carried out including its organization and administration. The research we discuss builds on the notion that systems models combined with interdisciplinary research is fundamental to examining the relationship between living organisms and EM currents.

A number of observations and conclusions from this research experience are perhaps warranted. First, this research requires a cross-disciplinary team of researchers. The primary researchers in these investigations were a sociologist and a physicist. However even this limited research required information from biology, psychology, ecology, soils, etc., and firsthand experience reporting from an array of persons describing their experiences.

Second, researchers need first hand experience with the nature of the problem acquired through meetings with dairy people, representatives of electric utilities, relevant political figures, representatives of governmental agencies, and other interested persons. This includes an understanding of political systems, particularly if researchers are to have access to facilitating agencies.

Third, the complexity of this problem requires a number of different approaches that combine knowledge acquired through controlled laboratory experimentation and on-site assessment. Each method has its advantages and disadvantages in helping to understanding EM currents. Laboratories provide better circumstances for controlling and experimenting with major variables than does the cow barn. However the cow barn may contain important variables not known or easily replicated in the laboratory.

Fourth, because this problem is multifaceted, one research project does not produce clear and conclusive findings. This means that team members need to make prolonged commitments and adapt research interests to fit the research problem. Long-range commitment is necessary to provide findings that will ameliorate the perceived problem, and team size may shrink and expand depending on the particular facet under investigation.

Fifth, Information must be efficiently shared. Perceived EM problems are immediate, and researchers need to communicate efficiently in sharing findings even though they may at times seem mediocre. Given present knowledge about EM currents, the importance of particular bits of information cannot always be known at the time of its discovery (Falk and Dahlberg, 1993).

CHAPTER IV

PERCEPTIONS OF THE EFFECTS OF ELECTROMAGNETIC FIELDS

So far the discussion centers around the need to develop a model that purveys the complex interaction between electrical circuitry in living organisms and in the organism's environment. By what process do persons come to believe that there is such an interaction? At various points in the preceding pages, references indicate how dairy farmers came to believe in this interaction based on their own direct experiences. These perceptions were disseminated as anecdotal information, the beginnings of theory building, and eventually involving discussion among important segments of the scientific community. Is there a model that describes this process of information sharing? The answer is "yes," and is drawn from the social sciences.

From antiquity, persons associated low level electric charges with human functioning and healing as discussed earlier. Cultures around the world formulated theories about electricity and organisms through trial and error, historical accident, and systematic research and filtered these ideas through their social values and cultural heritage. By whatever process, problems associated with EM currents now center among dairyists, though the precise connection between dairy animal and dairyist emerges somewhat belatedly.

Theorists and model builders among the social scientists, particularly collective behavior and social movement analysts, have long been interested in the process of collective definition through emergent leadership (LaPiere, 1938:281-293), their legitimation (Lang & Lang, 1961:236-253), and the process of developing value credibility (Turner & Killian, 1957:331-359). We turn now to these disciplines to help describe the emergent process by which dairyists and others came to believe that EM currents were at least partly responsible for their problems.

Various theoretical models of collective behavior might be appropriate for describing and analyzing assumed EM current problems which include: 1) social contagion, 2) emergent norm, 3) value-added 4) social behavioral, and 5) resource mobilization (Miller 1985). Though these theories overlap somewhat, there is merit in using primarily one theory to focus and describe this social process. Here we use Smelser's (1963) value-added theory.

Smelser's value-added theory assumes that positive collective action (in this case the ameliorative activities in reducing EMF effects) emerge from negative beliefs about social structural conduciveness and strain. Precipitating factors occur amidst these beliefs to mobilize positive collective outcomes. Various social controls and constraints (short-circuiting beliefs) limit and control the belief process as it moves toward ameliorative action (pp. 12-21) (The short-circuiting language seems somehow appropriate). The primary focus ...is not so much to evaluate Smelser's theory of collective behavior as it is to utilize the theory in describing the role of specialists in creating 'generalized beliefs' (Smelser, 1963:79-13) about EMFs or in short-circuiting the belief forming process (Dahlberg and Falk).

Smelser (1963:69) indicates that collective resolutions move not only on a horizontal line from problem recognition to amelioration but on a vertical general-specific line as well. As an example, he suggests that when scientific knowledge is found wanting in a specific instance, the problem seeks resolution by requiring more general levels of information before re-applying the knowledge to the specific problem. It is suggested here that specific EMF dairy problems require more generalized inputs in order to ameliorate these perceived problems (Dahlberg and Falk). And these generalized inputs may extend to the global scientific community.

Smelser specifically identifies stages, along the horizontal axis, through which an idea must move (he believes) to induce social change. Adapted to this analysis are: structural conduciveness, structural strain, belief that EM currents pose health and economic problems, precipitating action, mobilization of resources, and ameliorative action (See Figure 1).

According to Smelser, the first step in dealing with a problem rests in the possibility of making changes. Structural conduciveness means only that society is sufficiently flexible to permit various corrective actions for dealing with factors perceived to threaten health or livelihood as in the dairy enterprise. Modern societies usually provide a fairly flexible context for persons using collective action to deal with some cause or issue, and some of these actions have been in the agricultural sector. Certainly many of the dairy people with problems believe that change is possible, even though it may be difficult to attain.

Structural strain, in the social sense, assumes that society is not in full equilibrium. Strains are not difficult to find in the dairy industry even without EM problems. In the economic arena, the overriding strain is the balance between maintenance and operational costs versus payment for milk products. In the past, government has regulated this balance in attempting to guarantee a sufficient milk supply for the public. As discussed earlier, any factor that interferes with this balance can cause failure of the dairy enterprise. Stray voltage problems induce additional strain by introducing elements whose consequences are not easily understood or corrected.

The belief that stray voltage poses economic and health problems emerged slowly because of existing ambiguities in the cause and effect relation between EM currents and animal health. To persons unaware of a possible connection between EM's and cow health, consequences appeared to be random and were sometimes assigned to poor dairy management. Only as careful managers realized they were not at fault did an important core of dairy operators come to believe that EM currents were detrimental to their dairy operations. This belief emerged as operators informally shared their experiences and suspicions with neighbors or formally communicated through articles published in trade magazines.

A dedicated core of convinced dairy farmers proceeded to convince, not only their unconvinced colleagues, but other relevant groups, such as agriculture extension agencies, politicians at various levels of government, electrical specialists, veterinarians, and particularly the utility personnel, that the world needed a new approach for dealing with electrically related dairy problems. This precipitating action included the development of new organizations including research groups, voicing concerns at various public meetings and special hearings, corresponding with relevant agencies, and pressuring perceived influentials to seek ameliorative action.

Certainly dairyists realized, early on, that various resources were needed to deal with this ill defined association between stray voltage and their dairy operations. To mobilize these resources sympathetic specialists, from inside and outside the academy, were invited to examine dairy operations and make suggestions. Some experimented on their own sometimes with at least limited success. As in the case discussed in detail, operators sometimes violated safety codes in attempts to ameliorate the problem. As problem awareness spread, public and private agencies began to make more resources available sometimes by direct pressuring from dairy persons and sometimes facilitated by persons outside the dairy organizations.

One important resource is lacking, that is a clear model or set of theories that relate stray voltage to cow health. This shortage of basic information importantly hampers ameliorative action since without this, electric utilities, dairy farmers and others have only limited direction in their attempts to rectify these delineated problems. Various action has been initiated, but large investments for dealing with the problem are not likely without clear indications that initiated changes will be successful.

Smelser's theory suggests that problem amelioration moves not only along a horizontal axis, as just described, but also along a vertical axis. Vertical movement toward greater knowledge inclusiveness occurs in part because information is not sufficient locally to deal with the dairy barn problem. In this case, seeking ways to rectify this problem eventually leads to drawing on relevant information from throughout the world. So in the first stages of Smelser's model, involvement becomes ever more expansive. As relevant knowledge accumulates, specific components of this body of knowledge are extracted in attempting to make them relevant for dairy barn solutions. Assuming that specific and applicable information is forthcoming, this information becomes narrowly focused in moving down the vertical axis toward ameliorative action.

One other of Smelser's notions, short circuiting, seems particularly appropriate to this discussion both in image and theory. In its simplest imagery, the notion brings to mind two bare wires that touch, causing an arc or short, thereby preventing the electricity from completing its circuit to generate light or power a motor. In its social parallel, Smelser uses this imagery to describe how the social process, instead of moving through its stages to problem amelioration, gets side-tracked or shorted out.

Without thinking too much about it, quite a few short-circuiting factors come to mind. It is not our intent here to list all or even most of the involved short-circuiting factors. Rather some factors are indicated at each of Smelser's stages that suggest why progress toward problem amelioration is hampered or short-circuited. The discussion elsewhere covers quite a few of these factors as well.

1. Conduciveness Social. Even though democratic societies generally provide fair latitude to persons speaking about and taking action on relevant problems, there are various restraints that limit behavior. The notion that low level electricity emerging from the ground might cause problems in a dairy barn is itself sufficiently bazaar to some so as to inhibit a broad discussion. Scientists are themselves hedged round by numerous norms and priorities that limit doing research in this area. Utilities would not be expected to rush into relevant research since problem rectification could entail a large economic investment. As discussed elsewhere, dairyists themselves may not go down this path believing that the problem is essentially due to bad management.

2. Social Strain. Strains in the dairy industry are coun tered by other societal strains. Most veterinarians have limited time for animal experimentation that would lead to dealing with unexplained illness in cattle. In the academy, pressures to do research and publish usually do not include projects with limited or no financial support. Until very recently, financial support in dealing with EM currents has been limited or non-existant. Electric utilities attempt to provide services at lowest cost, and provision for research or experimentation is thereby limited. Dairyists themselves are kept busy with routine operations permitting little time or money for either political action or experimentation.

3. Generalized Belief. It is difficult to convince others that EM currents are a problem without some supporting body of information. Relevant information has been very segmented by culture, area of specialization, and application. This segmentation inhibits a pooling of information that would establish a belief that EM currents are relevant to problems in the dairy barn.

4. Belief in Negative Effects. Electricity is a key compon ent of modern societies, and human societies would be vastly different without it. Hence, electricity is viewed more in positive than negative terms. Particularly, persons generally have not perceived low levels of EM current as causing problems. Given the array of persons with vested interests in electricity, it should surprise no one that viewing low levels of electricity as negative meets with resistance.

5. Researching EM Currents. Funding restrains are focal even when persons perceive associations between EM currents and dairy problems. Research occurs when funding agencies are convinced that a problem is of sufficient magnitude to warrant research investment. Research necessarily must overcome important obstacles given the nature of the research required, the state of available and relevant information, and the segmentation of this information and the research community. Specific problems in research methodology are discussed at another point.

6. Research Not Applied. Research is of little value for ameliorating dairy problems unless the derived information is dispensed to persons who can apply it. As in previous steps, information needs sharing. The research community and the market place often are not well acquainted. The esoteric language of the scientific community requires translating into the language of other specialties in the form of understandable models, informational booklets, workshops, public forums, etc. Smelser's theory suggests that without the completion of each step, including this one, EM problems in the dairy barn will go unsolved.

CHAPTER V

INFORMATION BASE

These concepts described in the previous section have been applied and tested as the authors have researched the stray voltage problem over a ten- year period. Following is a discussion of the information developed in conjunction with dairy farmers. Much of the information describing the process of obtaining the public acceptance of the problem enabling action to begin a mitigation of the problem will not be included.

INTRODUCTION

Concern about the relation of EM energies to the dairy industry has generated both qualitative and quantitative information. The quality of the information is such that it can be especially helpful in analyzing the potential EM interactions with living organisms. At this time there is insufficient research to tie EM energies precisely to specific observable effects on dairy cattle. However, the logic of science suggests that available information can be most helpful in developing and guiding research on this subject. Particularly, the compilation of information provides a beginning point for understanding electrical problems faced by dairy farmers. Current investigation includes information from at least 1000 dairy farms nation wide. This data base includes information from other than dairy farms including turkey, chicken, hog, beef, and horse farms. In addition, individuals provide information delineating human and pet health problems in homes, shops, and businesses, some of which are near substations, transmission and distribution lines, natural gas and oil pipe lines, and radio, television, and cellular phone towers.

Traditionally a distinction is made between qualitative and quantitative research, and both have their approaches to dealing with their investigative phenomena. Even though these two approaches have dedicated advocates, sometimes arguing that only one or the other capably reveals truth, current researchers often need to deal with an array of interactive phenomena. Hence they find it useful to use both quantitative and qualitative data even integrating them into a unified approach. At one level, these approaches are both descriptive in that they are attempting to understand and explain the workings of the natural and social orders of the world. Hence one may describe relationships among variables by attaching values to them and showing correlations and associations through the use of mathematical models and formulae. On the other hand, one may describe the perceived phenomena with more subjective and colorful language attempting to show nuances not readily noticed in mathematical language.

The various academic disciplines have tended to emphasize one or other of the approaches to knowledge acquisition. Distinguished from the development of laws in the physical sciences, the development of laws in life sciences is based almost completely on non-replicable events if by that is meant controlling for the complex array of variables present amongst living organisms. In the physical sciences, laws are developed for inanimate objects. Although objects and systems may also be complex, it is far easier to reproduce the state of an inanimate object than an animate one. Even so, most laws in the physical sciences are based on specific ideal conditions and specifically measured parameters. As a consequence, the acceptance of a physical law is in part based on its acceptance by the interested community which in turn is influenced by the world view of the time.

Unfortunately, no law in the physical sciences alone describes reality, only the view of reality encompassed in the development of the law. Laws are models displaying concepts of reality that meet present needs. Given present human populations and their survival needs, it is imperative that these laws be understood and utilized in order to provide a thoughtful and informed life style.

Establishing physical laws provides an orderly approach to engineering the world. The laws upon which present technological development is based have, therefore, enabled the world to reach the state it is in today. The application of this technology, for the most part, has been very beneficial. However, in the minds of many people, there is general concern about the ability of present technology to provide for the needs of the world into the next century. There is a kind of idea inertia or parsimony in change that appeals to many who, pointing to the success of the present world view, wish to continue thinking about physical laws as absolute reality. Perhaps the time is right to re-examine these laws. If one were to consider the process for systematically examining the laws, interdisciplinary teams of topical specialists is one way to examine more systematically the state of our world understanding. Historically, progress in understanding is not based solely on traditional research organizations and methodologies. It is also based on human perception which results from the collection of qualitative information.

What is qualitative research?

> Qualitative research wants to know what kinds of things people are doing, what kinds of processes are at work, what kinds of meanings are being constructed, what kinds of purposes and goals inform the participants' acts, what kinds of problems, constraints and contingencies they see in the worlds they occupy" (Guy et al. 1987, 256).

The qualitative approach is especially significant in applying physical laws to living organisms. Rather than competing with the quantitative approach, the qualitative approach places flesh on the skeletal structure of physical law. It broadens the research context allowing for alternative explanations of phenomena. This is particularly important when considering the relation of EM energies to living organisms since there is far less than consensus in this investigative area. In this section there will be general observations, descriptions of specific qualitative associations, and experimental results associated with exposure to EM energies.

QUALITATIVE INFORMATION

To this point, a number of observations and conclusions are drawn from the collected information. One generalization is that human health problems are similar across the specific settings. Animal behavior, health, and production effects also show similar patterns in the various settings examined. In fact, the core group of effects for humans is not only similar for various types of electrical exposure, but also are similar to the effects attributable to other toxins. This portrayal is consistent with information provided by persons suffering from multiple chemical sensitivity and organizations working with the chemically poisoned. Individuals who have been exposed to excessive quantities of chemicals often develop a condition of chemical sensitivity and are unable to tolerate additional exposure to chemicals. These persons who are chemically sensitive are also very sensitive to exposures of EM energy. The effects for both types of exposure are quite similar. There are no groups organized that work primarily with electrically sensitive people, and there is no information indicating whether or not electrically sensitive people are also chemically sensitive.

It appears that EM energy effects are not tied solely to living organisms. Numerous and unusual electrical problems have been reported. A few of the reported problems include incandescent lamp failures, unusually high rate of battery failure, radio and TV set failure (unrelated to lightening), unusually large number of motor burnouts, occasional shocks from water lines or faucets, noisy telephones requiring frequent service calls or having false rings, accelerated corrosion of well casings or other buried pipes, and unexplained fluctuations in electric bills.

Among livestock a number of these symptoms and characteristics can be directly caused by toxins and other factors. Some people claim that the health and production problems in the dairy industry also can be caused indirectly by improper management of the livestock's behavioral and health problems ("Stray Voltage Study" 1988). However this particular research finds that basic health and production problems originate from factors independent of management. Dairy management style does not correlate either positively or negatively with the health and production of dairy cows, though one would not want to say that good management is unimportant in dairy operations. In the absence of electrically based problems, management style certainly is associated with profitability on dairy farms. However, electrical conditions or changes in the electrical system on dairy farms are associated with their profitability. A staggering number of dairy farms with unquestionable operational records show changes in the health and production of dairy herds coinciding with both advertent and inadvertent electrical changes. Numerous dairy farms have had isolation devices installed, equipotential planes constructed, grounding changes, electrical upgrading, and electronic grounding systems on the farm with sometimes immediate and sometimes delayed effects on the health and production of the cows. At this time with present understanding of the stray voltage problem, there can be no denial that electricity is affecting dairy cows especially while in the barn but not only while in the barn.

Dairy operators and other professionals engaged in the dairy industry have detailed a litany of effects which they perceive to be associated with stray voltage. Dairy operators can provide valuable information because of their proximity to cattle and are able to describe conditions and events on their farms they perceive to affect their animals' behavior, health, and production. When this information is shared with animal and electrical professionals, it may alert other dairyists to changes occurring among dairy herds. At the present time these professionals perceive a wide range of factors related to the exposure of cows to electricity. The list of factors presented here is as inclusive as possible though not intended to be excessive. Since the information for developing this list has come from professionals in the dairy industry, as well as published literature, and since all information is valuable, it was considered important to be more inclusive rather than less.

Various kinds of cow behaviors are alluded to above as they appear in selected research findings. A compiled list includes restlessness when in stalls or parlor; unwillingness to enter barn, parlor, or stall; leaping into the stall and crashing to the floor; refusal to eat or drink while in the stall; lapping in the water cup; pressing their noses against stalls (especially while being milked); distended eyes (appearing as if being under stress); dancing in stalls or parlor; kicking at farmer when being washed; kicking off milkers; difficulty walking and getting up; uneven milkout and letdown (some quarters will release milk well while others will not); long milking time; peaking in production in the first weeks of the lactation cycle; inability to maintain weight; inflamed sphincter valve even among unmilked heifers; stress rings on hoofs as well as excessive hoof growth; tough hides resulting in bent and broken injection needles; poor production; sudden onset of mastitis (which resists treatment with antibiotics); leg sores which will not heal nor respond to accepted treatment methods; breedback difficulties; breeding problems (silent heats, absorptions, and spontaneous abortions); calves having poor survival rates and unable to grow at normal rates; calves with symptoms such as abscesses, sore gums, burnt knees, unable to suck, and diarrhea; immune system failures resulting in chlamydia, pneumonia, bovine viral diarrhea, leukemia, and anemia, as well as an unusually large number of a variety of health problems which resulted in high veterinarian bills.

Cow behavior inside and outside the barn is sometimes very different. Cows that are completely content outside the barn and could be milked with a portable milking machine without being tied can become very unruly in the barn. This behavior includes the cows not standing still in their stalls; kicking the handler when being washed or kicking off the milkers numerous times during the milking process. On entering the stall, the cow changes from being very calm and quiet to being nervous and tense. A common sight on these cows are large lumps and sores on their joints and legs. These lumps and sores persist for long periods and no medical treatment to date seems to correct this condition. Often the cows, on which these lumps and sores persist, become lame and are usually slaughtered. On some farms, heifers brought into the barn when freshening, have, within a month, virtually deteriorated to a skeleton with hide covering it. Veterinarians are unable to determine the cause or successfully treat this condition. Because of the large number of slaughter animals, it is impossible to cull the herd appropriately and profitably. In dairy operations where these conditions occur, it is difficult to make adequate replacements since sufficiently productive cows are not available to keep the operation going.

There is little information relating horse behavior to EM energy since horses are much less important in the economy of industrialized nations. However, horses in barns also display unusual behavioral problems that may be attributable to stray voltage. These behavioral problems are described as stereotypic stress-related behaviors and include stall-walking and weaving, kicking at walls and digging in the floor. Dairy farmers with stray voltage problems, who have horses, experience similar problems with both horses and cattle.

EM energy is associated with some behavioral factors among swine. These include reduced rate of weight gain and nervousness. In some cases mastitis and breeding problems are attributed to stray voltage (Wright et al. 1986). It might also be true that milder forms of cannibalism, such as tail biting, is also a consequence of stray voltage.

Dog kennel operators have also reported problems similar to those attributed to stray voltage effects among other animals. Some of these are inability of dogs to drink from water buckets, change in disposition, change in physical appearance, inability to reproduce, birth defects, and pups dying for no reason. Kennels with these kinds of problems are characterized by the absence of some other kinds of life. In some of these kennels there are no mice or mice droppings, no flies, no rats, and no cats. Around some of the kennels there are no frogs in ponds, no fish in streams and no mosquitoes in the air. This suggests that living organisms with some choice stay clear of the area.

In Courtenay, B.C., rabbit breeders noted particular behavioral characteristics of domestic rabbits housed under a 414,000 volt transmission line. Noted were birth defects, such as crippled and oddly twisted feet, and curved spines. Many breeders also experienced unusual numbers of stillbirths. Concurrent with these rabbit problems were many reports of human health problems. Research has shown that both the central nervous and digestive systems of rabbits are adversely affected by moderate 50 Hz electric fields (Hansson 1981).

Pets seem also to be affected adversely on farms where the stray voltage effects are experienced among livestock. Pets are sickly, cease to bear litters, give birth to small, unhealthy litters, leave the farm, and are found dead with no apparent cause of death.

As previously indicated, dairy farmers and others are associating human health problems to stray voltage. That is, when farmers associate problems between livestock and other animals on the farm, it is logical to look for associations between these animals and their own health. Possible effects perceived to be associated with EM energies include health factors that are part of the stress syndrome relating to the central nervous, cardiovascular and immune systems. Although such a comprehensive connection is not immediately obvious, it is important to realize that all bodily functions occur not only through chemical processes but also through the influence of electric and magnetic energies. Some associated human health effects include: tingling, numbness and/or pains in arms and legs, chronic fatigue, aching and swollen knees, dizziness, frequent headaches, frequent flu-like symptoms, vision problems, pressure behind the eyes, disorientation, short term memory loss, frequent irritability, often feeling under stress, swollen abdomen, unexplained nausea, open sores not healing, allergies, problems with menstrual cycle for females, rheumatoid arthritis, high incidence of non-malignant body tumors, neurological illness such as multiple sclerosis, heart related ailments, high incidences of cancers (especially leukemia and brain), and having illness that medical professionals cannot diagnose.

Others beside dairy operators have noted similar health problems associated with exposure to EM energy (Rea, et al. 1991, Marha, et al.). In Maple Shade, N.J., persons complained about health problems arising from living proximate to the U.S. Navy's Aegis command installation. The complaints included pressure building up throughout the body, muscle spasms, burning and tingling sensations, severe headaches, extreme eye pains, and ringing in the ears. As in most other cases of health problems associated with electrical sources, the medical profession could diagnose specific causes of health problems for the people involved. Similar complaints in the vicinity of Taos, New Mexico spawned an investigative team formed by Sandia and included experts from Sandia, Los Alamos National Laboratories, Air Force's Phillips Laboratory, and the University of New Mexico. The team's informal report indicated that they were unable to determine the cause or causes of the effects, and that the project would continue until the causes could be determined. One of the areas investigated was EM exposure. In measuring for EM fields they discovered high levels of magnetic fields from currents of the harmonics of 60 Hz at some rural locations. They also discovered that the hum heard by the affected people was not an audible sound and was not affected by ear plugs. In addition, the perception of those affected was that EM energy was the cause (Mullins, et al. 1993). Similar cases have been reported at U.S. House hearings on EM effects.

London researchers reported that workers in a London hospital described patients as being affected by EM energy generated from video systems, computers, and other electronic devices and electrical appliances. In addition, they observed that small changes in frequency produced dramatic mood changes in the patients. Also allergy specialists observed that people suffering from food or chemical allergies may be generating their own EM fields thereby disrupting electronic devices (Brain Mind Bulletin 1987).

In Western Europe as early as the 1920's, investigations were assessing the health effects of electric currents in the earth. A brief summary of the findings are included because the associations between EM fields and living organisms, discovered 65 years ago, are quite similar to the information from modern livestock confinement operations today. According to those involved in the investigations, it was believed that negative electric currents (probably the movement of electrons) produced cancer and other health problems. In some cases the regions of exposure could be narrowed to the location of the bed in the room. That is apparently the reason the term "radiation" was used to describe the cause. That is, the dowser was the only person and dowsing was the only method capable of detecting the regions of negative current. This concept is reminiscent of the searching for lay lines which, again, are determined by dowsing methods. The theory was that certain regions in the earth have a higher probability of carrying electrical currents. The methodology compared these regions of high negative electrical currents in the earth with the region's cancer mortality rate.

In 1928-29 an experiment in a small town in Bavaria tested this relationship. Lines of ground currents were located using the dowsing method since this was an acceptable scientific method in Europe at that time. No known instruments at the time could measure what the dowser could measure. This method apparently assumed that the human body was a sensor of electrical energy and that underground waterways had some connection with these underground currents as well. Results showed that all the cancer deaths occurred along the strong underground lines of current. Depth of the underground currents varied between 35 and 125 meters.

The Bavarian study drew various associations between currents and health. It concluded that cancer deaths were related to speed of water flow and that earthquakes change the location of underground currents. Other health effects for humans included itching, fatigue, nervousness, hysteria, abdominal pain, swollen feet, palpitation while lying down, weight loss, suffered breathlessness, annoying cough, feeling faint, weakness of eyes, headaches, dizziness, numbness, rheumatism, heart spasms, gallbladder problems, phlebitis, thrombosis, epilepsy, mental deficiency, mental illness, suicide, and thyroid problems. Effects were also noted on plants correlating the dying of plants and regions earth currents.

The regions of currents were also associated with effects on animals. Pigs appeared to be more sensitive to earth currents than horses or cows. The observed effects included decreases in growth rate, dysentery, blackish rash, death, weak offspring, stomach problems and an inability to eat, failure of the reproductive system, lameness, and stiffness. The milk supply of cows and goats dropped of more rapidly than normal.

The study included other observations and recommendations. It suggests that living quarters should not be built with concrete and iron girders in their cellars or in their ceilings between floors in multiple story buildings, because iron girders "reflect" earth currents. It was noted that dowsing rods respond to every iron beam and heating pipe. Sitting above heating pipes and iron girders was agonizing (Van Pohl 1983).

Without assuming the validity or non-validity of dowsing as a method for detecting underground currents, other interesting studies about dowsing are worth discussing. One experiment correlated responses to magnetic field gradients. Measurements indicated that a gradient of 0.3 to 0.5 mOe/m (mOe/m is equivalent to mg/m) was detectable and at 2 to 3 mOe/m detection was more accurate than lower levels. There also appears to be a saturation point in the range of from 20 to 50 mOe. The human body appears to adjust to the higher fields. In order to detect the gradient under saturation conditions it is necessary for the dowser to walk faster. Because there are many causes of magnetic field gradients, a dowser can fail, for example, to locate water. Water can provide a magnetic field gradient if there is an electric charge moving through the water, but a metal pipe or ore deposits can produce a gradient which is not distinguishable (Recard 1964). In another experiment, strain gauges were attached to the dowser's arms and rod. The strain gauges measured a contraction of the arm muscle a half second before the rod dips. This is reminiscent of the "readiness potential" observed in the nervous system. In still another experiment the dowser was wrapped with material that shielded the body from magnetic fields. Only small sections of the body were left unshielded in each experiment. The results revealed two regions of the dowser's body that, when not shielded, made it possible for the dowser to detect a magnetic gradient. These results suggest that the suparenal, the pineal or possibly the pituitary gland are the magnetic sensors (Wolkomir 1985).

Recent national legislation requires the National Institutes of Health to investigate alternative medical procedures. One of these is energy medicine in which external energies are administered to the body in amounts similar to those that the body itself uses in its energetic control system. These energies are believed to activate pre-existing energetic control systems. It may be that a healer uses his or her own electrical control systems to produce external electromagnetic energy fields that interact with those of the patient. The interaction could restore balance in the internal forces or reinforce the electrical systems so that the body returns toward a normal condition. A licensed healer from Poland, Mietek Wirkus, feels that electromagnetic energy is involved in the healing process. He does not touch patients, so any energy must be of a type transmissible across space. Electromagnetic energy is coupled between source and receiver inductively, capacitively, resistively or by means of EM waves. For the healer, energy can be transferred by electric fields, magnetic fields or electromagnetic waves. Given these wide possibilities, investigators in this field should consider each and all of these as possible interaction mechanisms (Becker 1990).

It is likely that the human ability to adapt to effects of EM energies has surpassed the realization of the changes that have occurred. Humans can adapt by consuming chemical supplements or using medications. This ability to adapt has, of course, its consequences.

CHAPTER VI

MEASURED ASSOCIATIONS BETWEEN EM CURRENTS AND LIVING ORGANISMS

As previously discussed, dairy farmers have documented various dairy herd characteristics with events and conditions directly or indirectly associated with electrical systems and electrical use. Farm records and other information reveal that the onset of these effects coincide with the energizing of transmission lines proximate to the farm, energizing of active cathodic protection systems on oil and natural gas pipelines, installing underground telephone cable networks, additions of substations in a distribution system, re-routing of electrical loads, changes in routing of distribution lines, additions to the number of electrical connections on a distribution line, installing ungrounded delta electrical service, adding isolators on distribution lines, changing the distribution and on-farm grounding systems such as decreasing the resistance of the grounding on the farm and on the distribution line. Additional activities such as disconnecting and connecting grounds, ground faults (shorts to ground on electrical wires or equipment) on the farm or on a nearby farm, and changing the farm's electrical system (rewiring or increasing the size of the electrical service into the farm) are also associated with changes in behavior, health, and production of the animals. In short, most electrical changes have their coinciding change among animals.

Some other associations are more difficult to quantify but are important nonetheless. Changes in the magnitude of effects can also correlate with weather changes. Humid weather and the onset of precipitation often increase the effects. Other factors compounding these effects include ground moisture, location of dairy barn, proximity of animals to operating electrical equipment, and location of animals in the barn. Dairy farmers have noted changes in level of effect with fluctuations in electrical use caused by such factors as the time of significant corn drying in the fall and higher use during extended weekends in summer especially in lake areas with vacation homes. Farmers within five to ten miles of the UPA/CPA DC transmission line commonly observe that cows are adversely affected when the wind is blowing from the transmission line to the farm. Judging from the number of isolators installed, the perception is that the current on the primary neutral is associated with the stray voltage problem. Of special concern to the dairy farmers is that the steady state cow contact voltages (between the floor and metal components such as the water cup or stall divider) do not correlate with the level of effects for the cows. The presence of stray voltage as usually determined by the electric utility industry is a cow contact voltage greater than 0.5 VAC. Many farms with the most serious effects for the cows have cow contact voltages less than 0.1 VAC. At the same time farms with low contact voltages can have large electric currents in the conducting components of the barn.

Observations which puzzle dairy farmers include dairy cows' changed behavior and disposition in the barn compared with outside, changes in the survival rate of calves housed in the dairy barn, and rapid deterioration of freshened heifers when brought into the barn. For some reason, cows that are gentle and look for attention when outside the barn become ugly and destructive in the barn to the point of injuring the person working with the animals. Dairy farmers attempt to control calf mortality by placing them individually in hutches outside the barn. On many farms the survival of calves depends on the use of hutches, but for others survival rates are equally high whether housed inside or outside the barn. Dairy farmers observe that both calves and cows on straw packs are healthier than those in clean pens where animals are directly on concrete. On farms where survival rates for calves are especially low, farmers have housed calves in trailers electrically isolated from the ground. In all cases, survival rates increased to nearly 100% for calves in trailers. When dairy cows were housed in a similar trailer, their milk production increased significantly, they became disease free and stress tests revealed lower stress levels than cows housed in the traditional facilities on the farm. A number of farmers as well as electrical engineers have discovered that connecting a 12 V battery between the water well and a ground rod on the farm correlates with a significant improvement in the behavior, health and production of the dairy cows. Unfortunately the apparent benefits may not last.

Dairy operators experiencing stray voltage problems have learned how to cope with these problems because solutions are not easily obtainable. Coping has meant seeking advice from an array of persons and experimenting on their own. They learned that if a cow is unable to get up or develops an especially adverse behavior in the barn, the only means of reversing the behavior is to remove the cow from the barn. Frequently dairy operators have taken their affected cows to another farm where there is no known stray voltage problem. When this is done, the cows are effectively changed and produce significantly more milk. The negative effects re-emerge if the cows are returned to the original farm. Dairy operators discovered that cows are healthier and have higher milk production the longer they are kept out of the barn. This is true in summer and winter unless temperatures are very low.

Anyone and all of these adverse behavioral characteristics require a considerable amount of patience. For dairy operators to survive financially, they must devote much more time to the dairy operation and especially the care of the animals. They must be far more cautious just to be able to milk the cows and much more observant to catch changes in the animals and developing health problems. Obviously much more time will be required to manage the routine operations which adds to the dairy operator's work load. Through experimentation, dairy operators have discovered changes in nutrition and supplements that can help the cows survive longer and slow problem health effects. Some of the findings suggest management methods which are diametrically opposed to standard and accepted practices. Since these divergent practices work for stray voltage conditions, the dairy operators use them to survive until the problem can be corrected. Professionals have been working with the dairy operators who are experiencing stray voltage problems. In general there has been a great deal of frustration among these people. Many nutritional experts, veterinarians, and electricians have chosen not to go to stray voltage farms because they are unable to correct the problem and so feel helpless. Electricians have helped with the installation of isolation devices, corrected faults, and balanced loads on the farms without being able to eliminate the behavioral, health, and production problems of the cows. Veterinarians have often been unable to improve the health of the cows on stray voltage dairy farms. Neither can they identify a specific cause for the severe health problems. Nutritional experts and dairy equipment suppliers are unable to determine any deficiency in their products or in the farmers' management.

One needs to recognize that the dairy problems described here are not all necessarily totally attributable to stray voltage. Certainly there can be other causes. Specialists in animal physiology have detailed these in various published reports (Lefcourt 1991). Stray voltage may be only one of many stressors affecting the well being of the dairy cows. An important observation is that on a specific farm or for a specific cow any one or any set of the effects described previously can be caused by, promoted by, and perhaps even improved by the presence of stray voltage. Stray voltage appears to have the capability of participating in all of the effects described and possibly even more. It is not limited to causing directly only behavioral problems or any small set of specific health effects. Other stressors likewise can also participate in the effects described. The state of behavior, health, and production of dairy cows will be related to many different factors at any one time. When one specific factor such as the electrical environment or the changes in the electrical environments appear highly correlated with the behavior, health, and production of the dairy herd, it is important, however, to place a high priority on addressing the question of how that factor can be responsible. Some effects are difficult to associate with causes other than electrical. As expressed previously, the majority of dairy farmers would much prefer to work with any other cause than stray voltage. That is because these effects are so destructive to the dairy operation, and ameliorating the problems requires spending significant amounts of money to engage appropriate specialists to examine management procedures and search for solutions. Relegating the cause of problems to stray voltage comes when every other cause has been eliminated. There is no doubt that many dairy farmers consider stray voltage to be a curse because they have little or no control over its presence or its elimination. An example of the problem's extensity is indicated in that even Amish communities using no electricity are not necessarily immune from the presence and effects of stray voltage.

Any and all of these adverse behavioral characteristics found in dairies require considerable patience in their amelioration. Farmers are required to take much more time and be far more cautious just in performing the milking routines. Obviously managing the other routines adds even more time to the dairy operator's work load. Professionals are working with the dairy operators who are experiencing stray voltage problems but not without a great deal of frustration. Many specialists choose not to go to farms with stray voltage problems because they are unable to make corrections. For instance, electricians have helped with installing isolation devices, corrected faults and balanced loads on the farms but often without eliminating the behavioral, health, and production problems of the cows. Veterinarians often are unable to improve the health of the cows on stray voltage dairy farms since they cannot identify a clear cause for these problems. Nutritional specialists and dairy equipment suppliers are unable to determine any deficiency in their products or in the farmers management that might be causing the problems.

In face of these causal ambiguities it seems almost trite to say that problem amelioration requires a good deal more and precise information to identify specific correlations between conditions and consequences. For this purpose it is necessary to analyze the past electrical changes, including any EM measurements that might have been made, in order to establish a data base for ascertaining any cause and effect associations.AC and DC currents are not equally analyzable.

AC is the simplest to measure and is consistently reproducible. The AC potentials vary over a fairly wide range, and sometimes correlates with the level of effects observed in the dairy herd. Isolating devices often change the voltage levels and cause daily variabilities. Cow contact voltages vary over a fairly large range. If the farm has some mitigating device, cow contact voltages are invariably under 0.5 VAC and often significantly lower.

DC potentials are measured between various points in the barn to determine maximum potentials that might exist between two points on a cow. These measurements are extremely difficult to make because of chemical reaction, the presence of natural galvanic cells, and structural differences in barns. It is determined, after considerable effort in establishing circuits in the barn, that there appear to be sources of DC energy not associated with any definable galvanic cell. The origin of this DC energy cannot be absolutely identified except that it is in the earth or floor of the barn. The DC potentials vary with ground moisture, to some extent with the time of day and as to whether cattle are in or out of the barn. The DC potential between the barn ground and the power supplier's neutral affect the DC within the barn. DC voltages at cow contact points usually vary from 0.1 to about 0.7 VDC. DC voltages that are measured in the barn would be expected to result from a combination of EMF's and resistive potentials.

There are electric circuits in the barn through which DC is continuously flowing. All materials in the barn appear to be components in the circuit including the cows. Recordings of DC in barns reveal changes in currents in components when the cows leave the barn and also when they return. Even though recordings of AC in barn components have not been made, it is logical to conclude that the same conditions exist for AC. The same circuits are available for AC as for DC. During milking there is often an increase in DC components. The increase might be due to adding an additional circuit by putting the milkers on the cows or adding AC to the earth on the farm.

As an example of measurement in the barn, a multimeter is connected between a steel plate on which a cow stands and the milker claw. Between these two points DC voltage between 0.2 to 0.45V would produce a current through the multimeter of between 20 to 60 microamps. The current levels inducing behavioral responses varied from one cow to the next. The behavioral responses occurred only during the times the meter was measuring current. With the multimeter on a current scale, the resistance of the meter is small with respect to the whole circuit through the milk and cow and is providing an additional electric current path accessing the cow. Electrical contact was also made on cows after milking in order to measure currents that might cause a behavioral response. Again a multimeter was used and placed between the cow and the stall divider in the barn. The direct current values were in the range of 20 microamps or less and caused a behavioral response from the cow. AC voltages at the cow contact points were significantly lower than the DC. Therefore, the assumption is made that the AC was affecting at a lower level than the DC.

The DC potential between the stall floor and the gutter chain were also measured. Values in the range of 0.2 V were quite common. This DC potential would be responsible for a current flow in the cow during urination. The cows demonstrated a change in urination habits while in the barn and under these electrical conditions. One would also anticipate a similar response for AC voltages between the gutter and the stall floor.

DC is in the conducting materials in the barn as a measurable current and the cows are a part of the conducting path for the DC when the cow is in the barn and more so when the milker is on the cow. Measurements of DC and AC in the barn indicate that the earth, the components in the barn and the cattle are a complex and dynamic electrical system. These results suggest that DC can be a factor in the effects experienced in dairy barns. In barns where AC could be easily injected into the ground or floor of the barn, DC measurements were made between cow contact points in the barn. In all cases the DC changes in response to the injected AC. Between certain specific points, that change is an increase, and the DC increase remains even after the injection current is turned off. After a time, the DC returns to an equilibrium level which is usually near the original value.

The magnetic field of the earth is normally about 600 mg and is present both inside and outside of buildings. Measured values of DC magnetic field in barns ranged between 400 and 800 mg. The differences usually related to locations in the barn especially in areas with more iron. Iron is used for a number of purposes in the barn and is a magnetic material which becomes a magnet as it is exposed to the magnetic field of the earth. Consequently the measured DC magnetic field in the barn will be the sum of the earth's actual magnetic field and the magnetic field induced in the iron. In addition iron in the earth will likewise affect the DC magnetic fields. DC magnetic fields are also produced by direct currents. Direct currents in conjunction with the iron contribute to DC magnetic field anomalies in the barn. The magnetometer is the instrument used for measuring DC magnetic fields. Further investigations of magnetic fields in the dairy barns can be useful in fully understanding the stray voltage problem.

60 Hz alternating currents also produce magnetic fields. Different from the DC magnetic field the AC magnetic field is only produced by an alternating electric current and can induce alternating currents in materials. The AC magnetic fields are measured with a milligauss meter. Since there are 60 Hz electric currents present in barns, there will also be 60 Hz magnetic fields. AC magnetic fields are associated with operating electrical equipment, water lines, and electrical wiring. Whenever there is an AC electric current there will be an associated AC magnetic field. Magnetic fields are produced by all equipment using AC power and will create AC electric fields in materials including animals and humans. These electric fields in turn will produce alternating currents. Because of the AC magnetic fields produced by electrical equipment, it is not surprising that some problems among cows are associated with their proximity to operating AC equipment.

The effects of AC magnetic fields from electrical equipment are undoubtedly also associated with the stray voltage problem. The milligauss meter also provides an indirect method for identifying electric currents. A consequence of measurements with the milligauss meter is the determination of currents present in the ground. Other measurements have shown that even when the farm neutral is electrically isolated from the utility neutral, and the electrical power on the farm is disconnected, alternating currents are still present in the barn. When the electricity to the farm is turned off, the AC magnetic fields derive from currents on distribution and transmission lines off the farm and from electrical current in the earth. All sources are connected to the fields that are measured. It is not uncommon, however, to find locations where the AC magnetic field has its highest values near the surface of the earth. The implication of such a finding is that the alternating currents contributing most to the meter measurements are in the earth. An important reason exists for measuring both the DC and AC magnetic fields. A set of research literature describes a possible synergistic effect resulting from the exposure of living organisms to a specific combination of the two magnetic fields. The physical concept is magnetic resonance.

Higher frequencies, including harmonics and radio frequencies, were recorded in measurements between two earth points indicating an apparent presence in the earth. 60 Hz transformations in the earth including rectification and combination of various phases from many different sources are certainly factors in this complex wave form. Of course the manner in which the distribution system functions also affects the distortion of the normal 60 Hz AC. The radio frequencies in the range of one MHz, which are also recorded, most probably result from communications systems. Further investigation of the higher frequency EM energy is important in determining the origin, travel route, association with the 60 Hz, and its effects on dairy cows.

The research included additional on site measurements such as ion levels in the barn and soil conductivity. Riley Hendrickson, who conducted the ion measurements, concluded that the numbers of ions and the ratio of positive to negative ions were approximately equivalent to ambient levels in the atmosphere. James Richardson measured soil conductivity and found high conductivities in and under the barn as well as in other areas around farms that are noted for their livestock problems. Conductivity is an indicator of the ease with which electric currents can travel through the earth and the level of electromagnetic dynamics in and around the barn. Conductivity can also indicate ion mobility which determines charge separation equilibriums and consequent DC electric fields.

Measuring possible DC electric potentials and fields in the barn is a formidable task. Many methods were used in this measurement including high impedance instruments such as electrometers. The only system that could be demonstrated to be reproducible was the electric field mill. Electric field mills have been used for many years to measure atmospheric electric fields. More recently, these same field mills were used by a number of people to measure ion concentrations and electric fields in the vicinity of the two DC transmission lines in Minnesota. The specific field mill used in this work was designed and constructed by Professor Donald Olson, a now deceased professor from the University of Minnesota—Duluth.

For these measurements, the field mill was modified to operate in an inverted state so as to facilitate measuring the electric field very near the ground or floor of the barn. The first research task was to determine the direction of the field near the floor's surface. Using the normal calibration procedure, the field mill consistently measured a positive electric field in the barn. The floor, then, is more positively charged than points above the barn floor. True values of the field were not possible since very little information is available for utilizing the field mill within a structure. Crude estimates indicated the electric field to be on the order of ten V/m. As a comparison, the normal fair weather atmospheric field ranges between 100 and 200 V/m and is negative. Measurements of the DC electric field tend to indicate an association between a positive DC field and the cows behavior, production, and health.

Too few field measurements were made on farms where the problems were minimal to verify a clear connection between the positive field and the effects. Field mill measurements indicated that, in general, the largest positive fields exist over concrete whether inside or outside the barn. The smallest positive fields exist over soil which is very dry. Inside the barn, the magnitude of the positive field commonly decreased rapidly with height. The field went through zero as one moved upward to a slightly negative value (5 to 10 V/m) one foot above the floor. In the region directly over the gutter, the electric field is either very nearly zero or a few V/m negative which is consistent with DC potential measurements between the gutter and the barn floor.

When measuring fields of such small magnitude, the field mill itself can influence the magnitude of the field being measured. Such factors are difficult to quantify. In fact, at one foot from the floor and above, the DC electric fields are too complex to accurately measure or assess with the field mill. Other structural elements in the barn, as well as the cattle and other factors, influence the field at larger distances from the floor. The DC voltages on the neutral wires also impacted DC measurements. Additional work on instrumentation will be necessary to assess more accurately the value of this measurement.

The locations of the cows in the barn often correlated with other observations. Something associated with the floor of the barn appears to interfere with the well being of cows. Particularly this research discovered two associations between cow location and effects. Cows in end stalls or with vacant stalls on one or both sides had a greater probability of demonstrating behavioral, health, and production effects. Also, cattle nearest operating electrical equipment show the greatest adverse effects.

These findings again indicate the great need to discover the cause of the negative condition in the dairy barn. The EM factors which may be implicated are the DC potentials associated with the currents in all conducting media in the barn and the electric currents in the earth, the AC reaching the barn's grounding system directly through the earth and other conductors connected to the barn, and higher frequencies associated with radio and microwave sources and transients.

Preliminary experiments were performed to discover whether simulating an electric fault would produce predictable consequences. One experiment simulated a variable magnitude AC electric fault to ground. The barn chosen for the experiments was equipped with an equipotential plane. The cows were standing on that equipotential plane, and all conductors that cows could contact were welded to that plane. The cows demonstrated behavioral changes each time this experiment was performed. At times and for some cows the behavioral changes were extreme to the point of being potentially life threatening had not the experiment been ended. An interesting observation was that the cows responded minutes after the fault was simulated. In addition, measurements of DC fields and potentials during experiments with the simulated fault revealed that the equipotential plane was more positive with respect to the neutral system. The DC potentials between various points in the barn also changed.

DC experiments were performed utilizing either a 12v auto battery, a 12v battery charger or a 0-13v regulated DC supply to change the cows' exposures to DC. These experiments were systematically repeated under different conditions. The basic experimental method applied a DC potential to the equipotential plane with respect to the neutral or grounding system of the farm or a ceiling conductor in the barn. The DC electric field mill indicated a charging of the equipotential plane either positively or negatively determined by the polarity of the DC supply. As in the case of the fault simulation, the cows showed behavioral changes. In one case of DC being introduced into the equipotential plane, every cow in the barn turned at an angle of about 45 degrees to their normal direction and leaned against the steel stall dividers that are welded to the equipotential plane. The equipotential plane was connected to the positive terminal of the DC power supply. Attempts to reverse negative effects of stray voltage with direct currents has also provided valuable information. One experiment involved the adjusting of the DC voltage between the equipotential plane and an earth ground. Increasing the negative or decreasing the positive charge on the equipotential plane, cows that previously milked out unevenly in the four quarters could be caused to completely let down their milk evenly and completely in all four quarters. Not only did they milk out evenly but their behavior improved. In this experiment the voltage level required for each cow to milk out evenly and completely was different and the required levels changed with time. A frustrating result of this experiment that a continuous flow of direct current into the equipotential plane eventually made the stray voltage effects worse than conditions before the experiment began. Even though frustrating, this result is consistent with the concept that, without regard for source, DC in the ground has the effect of separating electric charges as would occur in the charging of a battery. Measurements of DC and AC potentials during this set of experiments revealed a charging effect in the ground that slowly dissipated requiring days to return to normal levels. AC potentials in and around the barn appeared to be affected by changes in applied DC potential. The effects were mutual in that changes in AC levels affected DC potentials, and changes in DC levels affected AC potentials.

A note is added about researcher participation. In each of these experiments of injecting current into the ground, those assisting in the work complained about not feeling well. Complaints included dizziness, headaches, nausea, aching legs, and coordination and concentration problems. The duration of the experiments were limited so as not to cause those assisting in the experiment any additional adverse effects.

Electrical experimentation and manipulation has developed in the care of other animals as well. One such group so treated is race horses because of a problem called stereotypic stress related behavior. The assumption is that a horse requires the normal electric field of the atmosphere for good health. Without exposure to this field, horses will be under a greater stress. Whenever a horse is in a barn, the barn shields it from the atmospheric field. An artificial field is established by placing a wire grid suspended about 8 foot from the barn's floor. A DC potential is applied between the grid and the floor with the grid positive with respect to the floor. The field which is developed in the region of the horse is somewhat higher than the natural clear weather field. The clear weather field is between 100 and 200 volts/meter (V/m), and the field for the horse in the barn is up to 2500 V/m. The success is believed to be approximately 80% in which the stereotypic behaviors are moderated, and the horses demonstrate lower stress levels.

Results of this contrived field treatment are based on appropriately functioning equipment used in the treatment. It is believed that low level radio frequency fields associated with some equipment will have a negative effect on the horses and negate the positive effect of the DC electric field. The justification for believing that the Rf fields are creating a problem in some equipment is based on the common knowledge that horses respond to earthquake activity. More so in recent years, measurements are made identifying the Rf emissions in rock movement during earthquakes. In addition, rock crushing experiments have measured Rf radiation (Smith 1984).

CHAPTER VII

QUANTITATIVE RESULTS

GENERAL SURVEYS

Surveys are commonly used for gathering and providing information in searching for associations among relevant factors. They can provide data from a much larger informational base with less expense than on-site case research requires. Information derived from surveys permits some assessment of the extensity of particular problems, in this case problems dairy people are having with perceived stray voltage effects. To this end, a number of surveys were completed, and their results are summarized so as to provide a broader context for the associated discussions (Falk 1993).

State of Minnesota Survey:

Complaints from dairy people concerned with electromagnetic fields prompted the Minnesota Department of Agriculture to sample dairy farmers' perceived problems. Approximately 37.5 percent of the 20,000 dairy farm operators in Minnesota received a questionnaire left by state dairy inspectors at the time of their regular dairy inspection. Fourteen percent of the questionnaires were returned representing just over 5 percent of all dairy farms. Eventually Dahlberg and Falk were given the raw data and analyzed the 1075 completed questionnaires. Survey information is limited in terms of the proportion of questionnaires returned and lack of some basic control variables such as dairy herd size, characteristics of the respondent, years in the dairy industry, etc. However, the returns provided some original information about farmers' perceptions of this problem. Also the survey established important parameters for future research. Findings are discussed keeping in mind sample quality and limitations in doing a secondary data analysis.

Only 45 percent of the returned questionnaires indicate that milk production is as high as it should be given the operational style used. Forty percent indicate that cows milk out unevenly, and 38 percent that cattle with health problems are not adequately responding to treatment. About one-fifth of the respondents report problems with overall milk production, cattle being uneasy while milking, having swollen joints, and pressing their noses against metal objects. Unfortunately, there was no direct question determining whether respondents perceived these problems to be a consequence of stray voltage. However, the covering letter clearly indicated this as the purpose of the survey.

One way of assessing a tie between EM currents and other factors is to correlate items most clearly identifying presence of EM currents with the other items. Two items seem to suggest EM current presence; uneasiness of cattle while being milked and cattle pressing their noses against metal objects. All other items in the questionnaire correlate significantly with the statement about uneasiness while milking except one on seasonal variation. Items, such as milking out slowly, uneven milking, and fluctuation in levels of production, correlate positively with uneasiness while milking. Items such as production being as high as it should be and the stock improving by generation are inversely related to milking uneasiness.

As with uneasiness while milking, most other items correlate significantly and positively with the item on cattle pressing noses to metal and inversely to production as high as it should be and stock improving by generation. Though not necessarily consciously recognized, the dairyists' responses suggest that EM currents are tied to various other herd problems and behavior. Dairy farmers have most often mentioned the sudden onset of mastitis as the most apparent indicator of stray voltage. In the survey responses, health effects included mastitis, and this correlated significantly with the other items in the survey.

The survey asked dairy farmers to indicate their somatic cell count levels and their average rolling herd pounds of milk production. Even though quite a number of persons did not respond to these two questions, a sufficiently high proportion of persons did respond so as to permit an analysis of these estimates in relation to the reported cattle health symptoms (there were about 560 usable responses).

It seems reasonable to assume that there is an inverse relationship between somatic cell counts and average pounds of milk production. These values were placed into two scales of eight categories each and correlated. Even though the correlation coefficient was not large ($r = -.219$), it was significant ($p < .000$) and inverse. Since these two factors are related, PROBIT (a program that permits estimating correlations between scaled items and a dichotomy) is used to determine if cell count and milk production are together related to the reported presence of a specific cattle health symptom.

Ten of the twelve health characteristics are significantly related to somatic cell counts and pounds of milk production. The two items having no significant association are cattle pressing noses against metal objects and the next generation of heifers having difficulty adjusting to the milking routine. It is noted that relatively few persons responded to these two items. The health symptoms, such as slow and uneven milking, cattle uneasy while being milked, reluctance to enter stalls, swollen legs, milk level fluctuation, and fighting health problems, tend to be positively correlated with cell counts and inversely related to milk production. The opposite is true for responses to whether production is as high as it ought to be and whether each generation of heifers is improving in that these items are positively correlated with milk production and inversely to somatic cell counts.

These findings provide some confirmation, then, that certain reported dairy cattle characteristics have a statistically significant association with cell counts and milk production. These items are used as a nucleus of items in estimating health characteristics in future surveys.

Dairy Herd Management Survey:

A second source of information specifically ties stray voltage to dairy problems. A Minnesota dairy couple published a letter in the April, 1987 issue of "Dairy Herd Management" magazine inviting comments on EM current problems. An instrument with open-ended questions was mailed to interested persons. In 67 responses from twelve states, problems emerged not covered in the Minnesota survey such as cattle having mastitis and poor reproduction. Ties between EM currents and dairy production problems were clearly delineated since the instrument asked about EM current detection, ameliorative action, cost of action and success of action. One respondent even suggested that the problem ought to be titled "electrical pollution."

Only fifty-one percent of this group were willing to affirm that ameliorative action was successful in reducing EM current effects. According to the dairy operators who completed the questionnaire, the source of the stray voltage problem was the electric utility in 46% of the cases and unknown for 20%. The other 34% were identified in one way or another. It is interesting to note that when dairy operators were asked what should be done, 70% responded by asking for greater cooperation by electric utilities, state agencies and experts, and 20% wanted more research. Corrective outcomes varied among the farms. In general, no ultimate solutions were forthcoming.

Purposive Sample Survey:

In another survey, by Dahlberg and Falk, questionnaires were mailed to a purposive sample of dairy farmers. This was done in an attempt to determine if and what EM factors might be related to the health of dairy herds and the health of dairy operators and their family members. An original mailing of 750 questionnaires yielded a usable return of 369 (49.2%). The questionnaire included 27 symptoms of cow health problems that might possibly be a consequence of EM related factors as previously discussed.

A composite score of items checked as being present among the dairy cattle constituted a score for each dairy operation. It is not surprising, when comparing score differences between those persons indicating they had stray voltage problems and those who did not, that persons perceiving that they had problems also had significantly higher composite cattle health problem scores ($p < .000$). Using the same analytical technique, persons who reported being near an electric transmission line ($p = .001$) or a pipe line ($p = .043$) also reported having significantly higher health problems among their cattle.

One section of the questionnaire asked respondents to check items related to electrical equipment and machinery such as unusually high rates of battery failure, increasing motor burnouts, unexplained fluctuations in electric bills, etc. A composite score of these items was calculated and correlated with the composite score of cattle health problems. This yielded a correlation coefficient of .664 ($p = .001$). This suggests some association between cattle health problems and problems with electrical equipment.

Since the composite health score is statistically related to presence or absence of a transmission line or pipeline, item by item estimates were made through use of chi-square to determine what items might appear more predominantly related. When related to presence of transmission lines, only four items are found not to be significant. These are items related to cattle pressing their noses against conducting material, inflamed sphincter valve, finding excessive teeth in troughs, and calf symptoms (p .05).

The same process is repeated to estimate the relationship of individual cow symptoms and nearness to a pipeline. Not many individual symptoms are found to be significantly related in that only three items are found to be significant. These items are breedback difficulties, cows having trouble getting up, and breeding problems.

Equipment problem items are also individually related to presence of electric transmission lines or pipe lines. Five of the eight items are related to presence of an electric transmission line and three of the eight to the proximity of a pipe line. Characteristics related to proximity of an electric transmission line include lamp failures, high rate of battery failure, occasional shocks from faucets, and accelerated corrosion of well casings and pipes. The three items related to presence of pipelines are lamp failures, radio and TV failure, and accelerated corrosion of well casings and pipes. It is important to keep in mind that, even though the effects on the dairy farms are greater near transmission lines, serious and significant problems also exist in areas far removed from transmission lines and pipelines. The transmission lines appear to be one of the contributors to stray voltage and natural gas and oil pipelines appear to be other contributors.

One area of interest is the dairy operator's perception of the magnitude of an EM current problem. In this survey 151 of the 369 cases had more than 10 of 27 cattle symptoms checked and 232 had more than 5 symptoms checked. There were 18 cases in which fewer than 6 cattle symptoms were checked, and the dairy operator was experiencing what he perceived to be a stray voltage problem. In 28 cases in which an isolating device was in operation, fewer than 6 symptoms were checked.

An important purpose of this survey was to discover the correlations of reported symptoms with mitigation methods. Farmers were asked whether the farm had an isolating system in operation. The answer was simply 'yes' or 'no'. T-tests determined if the mean differences of the number of cattle symptoms checked and the number of machine effects checked varied by whether or not the farm has an isolation system. The results are as follows: For the farms with an isolation system the average number of cow symptoms checked was 12.2, and for farms without an isolation system the average number checked was 6.6. Among machine questions, the average number checked was 1.9 with isolation and 1.0 without isolation ($p < .000$ in both cases).

Earlier, discussion dealt with the theoretical relationship between isolation systems and dairy cattle problems. This study finds the relationship between perceived health problems and isolation systems to be reversed from intended outcomes in that isolated farms had, on the average, more problems than the non-isolated. Statistically the inverse correlation is significant beyond any possibility of a "chance" event. Individual cattle symptoms were related to presence or absence of an isolating device. All items were significant ($p < .050$). Certainly one conclusion is that isolating farms is not resolving the "stray voltage" problem. However, this finding cannot explain why isolation is not resolving the problem.

As with cattle health problems, a series of items possibly symptomatic of EM current influence on human health were included in the questionnaire. Listed were such symptoms as numbness in arms and legs, frequent flu-like symptoms, excessive fatigue, allergies, ears ringing, etc. Two additional items elicited specific responses from women relative to their menstrual cycle. As with cattle symptoms, a composite score of selected health symptoms was calculated for each case. These scores were correlated with age to determine if age factors might be influencing the sample. The correlation coefficient relating age to the composite human health score was .072, and was not significant. This suggests that age is not related to extent of health effects.

Next, human health symptoms composite scores were correlated with cow health symptom scores to determine if there might be an association. This calculation yielded a correlation coefficient of .645 ($p < .000$) suggesting a fairly strong association between these symptoms. The same calculation was repeated separately for men and women since the two items related specifically to women were omitted from the prior calculation. The correlation between women's health symptoms and cattle's symptoms is .603 (for $N = 37$, $p < .000$) and for men is .654 (for $N = 319$, $p < .000$). Thus, gender appears to differentiate little in terms of these associations.

The questionnaire allowed the respondents to check symptoms for an additional person within their household. The composite health symptoms score was correlated with cattle symptoms also for this group ($N = 139$). The correlation coefficient for the second group was lower (.375) but significant ($p < .000$) suggesting that symptoms of the second person tend to correspond with cattle health symptoms as well.

As with the cattle symptoms, the composite human health symptoms score was correlated with the composite score of machinery problems. The correlation coefficient was .630 ($p < .000$) suggesting that as with cattle symptoms, human symptoms are also associated with machinery problems. These data permit the conclusion that health symptoms in cattle and humans and select machinery problems are somehow related.

The average composite human health symptoms score for persons near and not near an electric transmission line and near and not near a pipe line were compared to determine if significant differences exist between these scores. A t-test estimate indicates that there is a significant difference according to proximity to an electric transmission line ($p < .000$) but not according to proximity to a pipe line ($p = .084$).

Human health items were individually related to the presence or absence of electric transmission lines and pipelines for both the primary (those filling out the questionnaire) and secondary groups of respondents. Seventeen of the twenty-three items are significant for the first group when determining if responses vary with presence of an electric transmission line. For the first group, items not related include problems with breathing, neurological illness, malignant body tumors, and occurrence of heart related ailments.

The relation of individual human health items to pipelines is much less distinct. None of the individual items yields a significant Chi-square ($p > .05$), when calculated for the primary group of respondents though one item for the primary group, heart related ailments, nearly reaches significance level ($p = .053$).

In an earlier study, Falk (1988) used a collective behavior model to assess growing awareness of suspected stray voltage problems on dairy farms. In this survey, persons were asked specifically to indicate whether symptoms of their household health problems tended to occur when they observed health problems among their cattle. About thirty-one (30.9) percent indicated they noticed such an association.

Additional statistical assessments were made to determine the association of reported cattle symptoms, human symptoms, and machinery problems with responses to this item. First, a t-test determined if composite scores of cattle symptoms, human symptoms, and machinery problems differed significantly between those indicating they did or did not observe an association between human and cattle problems. In all cases the t-test was significant ($p < .000$) with higher average scores for the group perceiving this association.

To determine which specific items might be associated with the perception that cattle and human health problems tend to occur at the same time, Chi-square assessments were made for each item of the cattle and human health measures and machinery problems. Among the cattle health problems and machinery problems all items are found to be significant. Among the person's health symptoms, 17 of 23 are significant. The four not significant are neurological illness, high incidence of body tumors and heart related ailments. Given the high number of significant associations between all other items (collectively and individually), it appears that persons have a justified awareness that these symptoms are somehow related.

Following the checklist of human health symptoms, persons were asked to indicate whether any members of their household were regularly treated for any of the listed symptoms. About twenty-nine (28.9) percent answered affirmatively. As with the previous item, a t-test determined if composite scores of cattle symptoms, human symptoms and machinery problems differed significantly between those indicating they did or did not receive treatment for any of these symptoms. Also as with the previous item, in all cases the t-tests were significant ($p < .000$) with average higher scores for the group reporting treatment.

To determine which specific items might be associated with reported treatment for human health problems, Chi-square assessments were made for each item of the cattle and human health measures and machinery problems. Among the cattle health problems all but two are significant. High somatic cell count and excessive teeth in feed bunks were not significant. Three of the eight machinery problems were not significant: radio and T.V. failure, motor burnouts, and occasional shocks. Among the human health symptoms five were not significant. These include a high rate of malignant and non-malignant body tumors and heart related ailments. One reason these items are not significant is the low percent of persons reporting these symptoms (five percent or less). All other items are significant.

To summarize, there is a high level of statistically significant association among the cattle and human health measures and machinery problems with responses to human health treatment and a perception that human ailments tend to occur along with cattle ailments. Eighty-five percent of the statistical assessments related to these two items are statistically significant suggesting some tie among these three assessed symptom categories.

Earlier, we discussed the relationship between presence or absence of an isolation device and cattle health symptoms. The statistical tests were also applied to the relationship of reported isolation devices with human health and machinery problems. As was true with cow health problems, the average number of human health problems was, in all cases, higher (5.7) on farms with an isolation system than among farms with no isolation (3.6). When items were individually related to presence or absence of an isolation device, 12 of the 23 human health items and five of the eight machinery items were significant.

CHAPTER VIII

A CASE STUDY

As discussed in preceding chapters, dairy farmers observed that changes in the grounding of the secondary and primary neutral lines affect dairy cow behavior, health, and production. One change made to correct these problems 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 using the isolator is ineffective, however, and additional changes were examined. Empirical evidence convinced many dairy farmers that disconnecting the primary grounding at the transformer pole and at adjacent electric utility poles affects the well being of their dairy cows and provides immediate improvements. They report water consumption increases (necessary to good milk production), cows relax more and are less agitated providing better milk output, and there is marked reduction in tail switching and moving about in the stall. Ironically, the cows' condition degenerates again when the ground wires are reconnected in compliance with national electric codes. On one farm where the owner finally resorted to disconnecting the primary grounding wires, the results were especially beneficial for his dairy cows. The longer the grounding wires were disconnected the greater was the improvement in the herd. The electric utility, to comply with national codes, informed the operator of their plans to reconnect the ground. On learning this, the dairy operator decided to schedule a testing procedure to assess consequences of this re-grounding.

A veterinarian conducted three tests involving a body scoring procedure and blood analysis. One test was conducted on April 2, 1992 while the ground wire was still disconnected. On April 14, 1992, the utility company reconnected the wires, and the system was grounded according to the power company's 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 both repeated on May 1, 1992, 17 days after the ground wire on the transformer was re-connected. 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 nearly one month. During the entire test period, management practices remained the same as prior to the re-connecting. 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 an isolator was in operation at the transformer which disconnects the utility neutral from the farm neutral. Therefore, the only path available for the electric current on the utility neutral to reach the farm grounding system and/or the barn was through the earth.

A second test was conducted one year later on the same farm. The Minnesota Environmental Quality Board (MEQB) determined the importance of carefully examining the suggested connection between ground currents and stray voltage effects in dairy herds. More specifically, this study assessed whether changes in grounding of the electrical utility's primary neutral affected the behavior, health, and production of dairy cows.

A measurement protocol was developed for measuring as many electric and magnetic parameters as possible as well as monitoring the behavior, health, and production of the dairy cows (Dahlberg, Mairs and Hendrickson 1993). The decision to develop a protocol resulted from the inability to consistently or permanently eliminate the health and production problems by reducing cow contact voltages. A variety of measurement instrumentation was used in the process of determining the electromagnetic energies in and around the barn. Different types of potential and current measuring instruments were used in attempting to arrive at the best understanding of the various AC and DC potentials, fields and currents to which the animals were subjected. A veterinarian was contracted to monitor the behavior, health, and production of the dairy animals which included a series of blood tests. In addition Dave and Sue Lusty, the dairy operators, were to maintain their own records during the test period.

Developing a protocol for this second test became a political struggle between the electric utilities and The Electromagnetics Research Foundation (TERF). The test involved the connecting and disconnecting of the utility neutral grounding wire at the transformer pole and one additional pole on the feeder line. The test was to determine possible effects of the current going into the earth on the grounding wires and reaching the barn so as be able to affect the dairy cows. The test period was determined by financial constraints to be one month. TERF requested the month be divided into two two-week segments with the grounding wires connected for one two-week segment and disconnected for the other two week segment. Using the results of the first study, the two weeks of disconnection was necessary to allow time for many of the changes to occur especially in the blood parameters. The electric utility representatives refused to allow the study to be done unless the test month were divided into four segments each one week long with the grounding wires disconnected for intervals no greater than one week. In spite of the veterinarians opinion that one week would be too short for effects to be measurable in the blood parameter, the electric utilities position prevailed. In addition, obtaining a significant instantaneous change in electrical parameters on the farm at the times of connection and disconnection was not too likely because the connections and disconnections were made during low use time and the currents going into the ground on the primary neutral were unusually low averaging about 20 mA.

The measured current going into the earth on the primary neutral averaged about 20 to 30 mA with the exception of high use time when the current could reach 50 mA as it did two times. One was a 15 hour period extending over two days and the other occurred while using a grain dryer on the farm. During the 15 hour period the magnitude of the current going into the earth on the primary neutral was between 100 and 200 mA which is the normal range for this farm. During this period, the secondary parameters changed significantly in response to the additional current going into the earth. Currents going into the ground on the primary neutral have been measured on the Lusty farm for a number of years. The only time 20 to 30 mA has been measured was for a period before the test began and during the test period. The normal current going into the earth on the primary neutral has been and is about 150 mA. On a rare occasion the current may go as low as 40 to 60 mA but has never remained at those low levels outside the periods indicated. A number of times the current has been over 200 mA and even when the entire three phase line serving the farm was down, the current in the utility neutral grounding wire was 120mA. A cause other than the electrical conditions on the farm had to have brought about the low current levels on the primary grounding wire during the test period

Every day of the test period the OTP Parkers Prairie substation three phase line was perfectly balanced. Not only were three phases perfectly balanced at 22-23 A, but also those currents were maintained 24 hours of each day for every day of the test period. At the same time the current on the neutral wire which is normally sensitive to the imbalance varied during each day and from day to day. In the Minnesota Public Utility's hearings, information was provided indicating that perfectly balanced three phase lines is not a possibility.

All of these procedures and anomalous measurements certainly affected the results of the test making any possible changes in behavior, health, and production, and especially the blood parameters, far more difficult to detect. Even under the best experimental conditions it is difficult to establish causes of health problems among living organisms in the presence of environmental toxins. Progress in systematic research is impeded when a level playing field is not available. However, in spite of all the problems, the project provided some valuable findings particularly since this information adds to results from the first study which was conducted under cleaner experimental conditions, and with only one change being made.

Results 1992

Some of the resultant changes found in the 1992 assessment are summarized as follows: Of the ten cows for which blood testing was done, two could not be used because either the data were not available or the blood samples were not of sufficient quality for reliable testing. The information on the other eight cows revealed that the fibrinogen dropped among five of the cows with two dropping significantly after ground re-connection; for three there was an increase in fibrinogen with two being significant; for five cows there was a decrease in white blood cells (WBC) with three being significant; and for three of the cows the WBC increased with none being significant. In addition, seven cows decreased 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.

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 exposed to more electricity and, consequently, placed under greater stress commensurate with the increase. Acute stress or infection are, however, expected to cause significant increases in segmented neutrophils and decreases in lymphocytes which is opposite to these findings. The fact that blood samples were taken 17 days after the connection of the ground wire and at the beginning of greater exposure to ground currents suggests that by then the blood should not show a profile 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 suggest that electricity can also produce other changes in cattle. These changes in blood parameters could point to the beginning of an immune system breakdown and/or a dangerous pre-cancerous condition. This possibility is significant because veterinarians, who work with the stray voltage problem, are increasingly concerned that electricity appears to be breaking down the cow's immune system.

The veterinarian observed that the cows became more restless and were having more difficulty getting up and lying comfortably after the grounds were re-connected. Results of the body scoring showed that even after only a week following ground re-connection, 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 usually causes an increase in fibrinogen and in monocyte counts. In the blood tests, however, the opposite occurred. Fibrinogen tended to decrease and monocytes for six of the eight cows tested significantly decreased. More research is required to understand these bewildering findings.

Experienced clinicians recognize that blood parameter values fluctuate in all living animals. On any specific day the values depend on the animal's response to its accumulated insults. A single blood test, as performed in this study, is not sufficient to assess the animals accumulated insults particularly since they include EM energies. Perhaps what is assessed here is analogous to the "lag" phase following a vaccination. The immune system is showing a change, and from a clinical point of view, the change is to a worsening condition.

The milk processor's records indicated that the somatic cell count (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. Water consumption dropped 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 important because 16.3 gallons intake is already relatively 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 the cows showed signs of stiffness and developed sore and swollen legs within a few days after the reconnection.

Other direct and informal assessments were made. Electric levels were monitored to determine effects from turning on and off the 240 VAC motors in the barn. A significant increase in electric spikes (sudden peaks) were measured after reconnecting the neutral. More informal observations indicate that during the year following the reconnection, herd production decreased while herd health problems increased. Furthermore, when the cows spend the majority of time, night and day, away from the barn, they are healthier and produce more. Also important is the dairy operators' belief that they are experiencing more health problems personally and associate this with time spent in the dairy barn.

All voltages measured in the barn, over many years of testing, reveal that, except for transients, the cows cannot receive a shock voltage of over 0.25 VAC, which is much less than the shock voltages used in university research. At the same time, electricity from the utility system is reaching the barn, probably through the earth. Many measurements indicate that current is 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, the dairy operator made 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 farm was out. During this outage, there was from 110 to 120 mA AC in the primary neutral ground wire and from 100 to 110 mA after the outage. 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, AC was in the barn. Obviously, the currents measured when the power was off had to come from sources other than the farm but also beyond the region served by this three phase line. The fact that the current decreased when the power returned was 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.

In summary it is evident that these cows' behavior, health and production characteristics are affected by electrical exposures that go beyond the traditional shock voltages characterized by neutral to earth voltage measurements. The only change made in this before and after study was the connection of two ground wires to the ground rods on the electric utility system. Nevertheless, these cows displayed very definite changes in their measured characteristics following the grounding procedure. There were significant changes in some of the blood parameters, and most of the production and behavioral changes were negative.

Results 1993

The 1993 study provided valuable electrical measurements which revealed some relationships among the electrical parameters. A connection was noted between the amount of AC going into the earth and DC levels in the barn. DC levels sometimes respond immediately to change and other times respond very slowly. There were large fluctuations in the DC levels measured between points connected and not connected to the neutral of the electric systems. If DC potentials and currents were solely from the natural chemical interactions with soil and metal, the rapidity of the changes should not occur. At least two possibilities exist for the AC in the earth to be connected to these changes. One is the rectifying of the AC by the naturally occurring rectifying materials in the earth. A second is the possibility that the AC electric energy is driving the natural chemical cells in the earth. Because it is expected that high ionic chemical levels will be present around barns and in water, additional electrical energy could affect the functioning of chemical cells.

When considering the correlations between the farm electrical measurements, it is important to keep in mind that the measurements are made by connecting to different parts of the farm ground circuits. These, therefore would be expected to show a greater degree of correlation. The fact that the correlations were not especially good would imply that other sources of electrical current not connected to the farm electrical system were reaching the farm. The measurements of electric currents that can reach the dairy cows indicate sources are associated with both electrical use on the farm and electrical use elsewhere in the electrical distribution system. In all, the data are recordings of ever present electric potentials and currents which are not associated with either the primary grounding on the farm or electrical use on the farm. Significant changes occurred very suddenly in some secondary measurements but were not associated with normal electric use on the farm. Connecting and disconnecting the grounds on the primary neutral do not significantly affect the existence of this AC electric energy. The existence of over 100 mA on the grounding wire at the time when the entire three phase line was without power certainly emphasizes the extent to which the earth conducts current. AC potentials and currents were present throughout the barn, and all other buildings on the farm, even when the electricity to the farm is turned off. On this farm the secondary neutral is electrically isolated from the primary neutral. Again the pathways for this electrical energy reaching the farm must be through the earth from other distribution systems, from other substations and perhaps from any part of the transmission/distribution system anywhere in the country. The term ground currents has been used to describe this source of electrical energy in the dairy barn. These aspects of the electrical system have been demonstrated numerous times on the Lusty farm. Electricity to the farm is turned off and measurements made between points on the farm and in the barn. When current measurements are made, the values not only remain the same but actually have increased when the power on the farm is turned off. AC involves phase factors and different sources can have different phases. At times the different sources can tend to cancel and lower values recorded by the meters.

Cow contact voltages as measured between the water line and the location of the rear hoof were, in general, below 10 mVAC and between -300 and -450 mVDC and between the locations of the rear and front hooves (RH—FH) were in the 1mV range for AC and less for DC. In addition to cow contact voltages, the electric and magnetic fields present in the barn can also add to the electric current and fields in the cows.

The measurements reveal that the barn is a complex electromagnetic environment which is continually changing. The wave forms of currents that are in the earth and grounding system are rarely a pure 60 Hz sine wave. Most often the wave form indicates a mixture of frequencies with the fundamental 60 Hz. It is important that the measuring equipment sees only the sum of the electricity at the points of measurement. This complexity implies both the possibility of effects on the electricity by the earth materials and outputs of electronic circuitry going into the earth through the grounding system. Consequently, determining specific associations between the measured electric parameters and the increase or decrease in effects on the dairy herd is difficult.

During two periods of the test when the grounds were connected, the AC going into the ground at the primary transformer ground rod was considerably higher than during the rest of the test period. These periods were a 15 hours for which there is no determined cause, and two days when drying fans were used. The unexplained excursion occurred on the primary neutral system on March 18 and 19 affecting nearly all parameters in and around the barn. No change was made in electrical use on the farm which could have caused the current going into the ground on the primary neutral to increase from an average of about 30 to an average of over 100 mA. Something occurred on the primary causing these changes, and these changes require explanation.

The only change in the measured electric parameters which consistently occurred was an increase in the noise associated with the measurements with connection and a decrease in noise with disconnection of the neutrals. The behavior, health and production of the cows did change over the period of the test. Some of these changes were associated with the connection and disconnection of the grounding wires and some with other changes. Some of these observations follow:

One way to consider water consumption data is to determine the average daily water intake for each of the four measured periods. The results are 17.0 gallons per cow during connection period 3-16 through 3-24; 19.3 gallons per cow for the disconnection period 3-25 through 3-31; 19.4 gallons per cow for the connection period 4-1 through 4-8; and 21.6 gallons per day for the disconnection period 4-9 through 4-14. There was an increase in water consumption during the month of testing with the greatest increases during the periods of disconnection. Daily water consumption shows that increases occurred after disconnection and decreases after connection.

Milk production per cow had a similar upward trend during the test period. The daily average milk production for the first period of connection was 47.6 pounds per cow, for the first period of disconnection was 49.5 pounds per cow, for the second period of connection was 49.5 pounds per cow and for the second period of disconnection was 53.4 pounds per cow. Similar to water consumption, milk production had its largest gains during the periods of disconnection of the neutral grounding wire and a leveling of production during the second connection period. Because all cows are different, it is also valuable to consider the milk production for individual cows. Records of daily production were available for some cows covering the entire month of testing. This is important since the herd average does not take into account cow differences in their lactation cycle. Individual cow averages reveals a somewhat different picture. For over 50 % of the cows, for which daily production measurements were available, the production was lower during both periods of connection when compared with periods of disconnection. Except for one case, the production for the other cows increased throughout the month and had a leveling of milk production during the second period of connection. There were two periods in which the current into the ground was measured to be considerable higher. These periods were March 18 - 19 and April 4. For nearly all of the cows for which daily measurements were made, production was down on those specific days and/or sometimes for a day or two following.

Studies relating EM energy to humans, as discussed previously, suggests that the duration of time for consequences to occur varies individually. The same is likely true for dairy animals. The time required for the change in the blood parameter for each cow may be different and the direction of change can depend on both the individual animal and the time of the test. The small changes in current going into the ground at the times of connecting and disconnecting could likely not provide very conclusive information. In addition, the short period, six days, for which the grounds were disconnected and the two periods of measured significant increases of current entering the earth would confound the blood parameter results. The change that occurred during the March 18 and 19 excursion was far more significant in changing the electrical environment of the cows than the connecting and disconnecting of the grounds.

Blood tests can provide information about a number of health patterns including immune response and stress. According to veterinarians, the blood patterns can be quite different for different cow conditions. For example a stress leukogram, showing animal stress, consists of a reduction in the lymphocyte level resulting in a reversal of the normal lymphocyte neutrophil ratio. During this test period a number of cows at different times had blood results indicative of stress. Some of these were explained as being associated with illness. If the lymphocyte count goes up and the neutrophils go down the cause can be the beginning of a total immune system breakdown and/or indicative of a dangerous precancerous condition. Opposite changes in blood parameters reveal quite different causes, and each cause is detrimental to the well being of the animal. In addition the effects of electricity on this farm were present before, during and after the test period. Given these complications, it seems most important to consider the blood parameters that were abnormal during the test period and spend less time searching for correlations between blood parameter levels and connection or disconnection of the primary grounding wires.

Elevation in CPK implies muscle trauma or damage. Observations by Dave Lusty and veterinarians suggested an ongoing leg and hock problem among the cows during the test period. The CPK levels for all cows throughout the test period were significantly above the normal values. Tests on other dairy cows under stray voltage conditions have shown the same high CPK levels. Dairy operators who have required medical attention have also experienced CPK levels which are significantly above normal. In addition it is well known that people experiencing electrocution will show a significantly elevated CPK level. This information should encourage researching the connection between stray voltage and high CPK levels.

Such a study should be important whether or not the high CPK levels directly affect the production of the dairy cows.

Total protein, another blood parameter measured, on average was high for 62 % of the dairy cows during the test period. High values of total protein are associated with dehydration and/or with inflammation caused by illness or disease. Fibrinogen is a specific protein which connects to long duration of disease. Although the number of cows with high Fibrinogen was not large, a few cows maintained a high fibrinogen level for the entire test period. The Lusty farm is known as having significant stray voltage problems which are especially serious when the primary grounding wires are connected. The high protein levels may provide a clue to long term effects of stray voltage.

The white blood cell count is probably the most complex to analyze. The information provided in the report by Dr. Ryder is very helpful. The graphing of the leukocyte count provides a portrayal of the stress levels for each of the cows during the test period. As was mentioned previously, the opposite of a stress leukogram, a decrease in neutrophils and increase in lymphocytes, points to the possibility of immune system effects. Does exposure to electricity more likely produce a stress or immune system effect? Research from Eastern Europe indicates that both are possible. The duration of exposure or type of electricity may influence which is more likely. On the average 25 % of the herd had high white blood cell counts during the test period. This percentage implies that stress and/or immune system problems are important factors to consider in the health of dairy cattle during the test period.

Summary

The excursions on March 18 and 19 as well as the other electrical events which produced random short term changes complicated the establishing of a meaningful statistical analysis. In addition, the periods of connection and disconnection of the grounds were respectively 8 days and 6 days. This is too limited a time for many possible effects to appear in the dairy herd.

A comprehensive examination of the blood parameters suggests, at a minimum, that a health problem exists in this herd. Even though the test conditions were less than ideal, there was individual variation among the cows, and the blood parameters were complex, the blood tests do provide valuable information concerning the overall health of individual cows.

A number of inconsistencies exist in the recorded data which need both discussion and explanation. In some cases the effect of the inconsistencies can jeopardize the very purpose of the study. A description of the method by which currents can be maintained between 20 and 30 mA should certainly be a priority both for knowing how to reduce the current reaching farms and to clarify the reason for these changes at this particular time. Obviously going from 150 mA to zero mA of current entering the ground is very different than going from 30 mA to zero mA when disconnecting the primary neutral grounds. This can significantly impact research results. It is unfortunate that the typical conditions for this dairy farm did not exist for this research project. It is important to note that the greatest number of acute effects occurred in the dairy herd after the March 18 and 19 excursion. Why did this abberation specifically occur during this research period?

Researchers must consider the methods used in measuring for stray voltage. Variability in the ratio of the primary neutral to remote ground AC voltage and current entering the earth on the primary neutral at the transformer pole points out the unreliability of the neutral to earth voltage as a predictor of the amount of current reaching the barn from the primary neutral grounding. In addition, the measurement of both AC and DC currents in the earth and conducted through the barns and homes must be a priority since current directly and indirectly determines EM exposure of cows and people.

CHAPTER IX

MULTI-CASE STUDY

RESEARCH METHODOLOGY

As discussed previously, for various reasons adequate methodology for researching the perceived relationship between EM energies and dairy problems was wanting. Consequently field procedures, modes of electrical assessment, measurement of perceived effects, and modes of analysis needed developing for this research.

It has been helpful, in researching EM currents and their effects, to view the interaction process as systems. Systems analysis is used within and across research disciplines, and linkages may occur within and among these disciplines as is required when dealing with diverse variables related to stray voltage and dairies. It permits the researchers, who must invariably represent different disciplines, to view variables that seem important, interactive and mutually influential. It allows for input from factors that otherwise might be excluded because they are poorly understood by individual researchers. Systems analysis is the research method guiding this research.

A two part questionnaire elicited information from dairy farmers. Part one of the questionnaire received a good deal of testing prior to its administration in this survey. It consisted of items about health experiences of cattle, pets, persons and equipment. Originally, the twenty-seven items on cow health were gleaned from prior research reflecting problems perceived by dairy operators. Items include such behavior as restlessness of cattle while in milking stalls, refusal to eat or drink, lapping at the water cup, pressing noses against stalls while milking, distended eyes, kicking the operator, kicking off milkers, difficulty in getting up or walking, uneven milking and letdown, sudden onset of mastitis, and reproductive problems. Standard statistical measures assessed the inter-association of these individual items.

Twenty-three items assessed health characteristics of dairy operators. These are mostly derived from research suggesting a tie between EM energies and human health. It is noted that the majority of these systems also typify characteristics of the human stress syndrome, a hypothetical and not well understood health phenomenon. Eight additional items assess problems with equipment around the dairy farm and home that could be tied to EM energies as correlated in previous studies. Prior research indicates a high correlation among cow and human health characteristics and equipment problems.

The second part of the questionnaire was more open-ended asking about specific electrical measurements along with experiences in dealing with electrical problems on the farm. In part it expanded on items responded to in the first part of the questionnaire and provided opportunity for respondents to elaborate on their experiences. It also included more questions about mitigative experiences and whether they worked. A copy of the questionnaire is in the appendix E.

RESEARCH SAMPLE

The criteria for the selections of the farms to be included in the case studies were the quality of information, the ability to identify the dairy operator and the location of the farm, and special characteristics which would be especially useful for this study. The sample was purposive in that persons were included who were known to have some problems with what they perceived to be a consequence of or related to stray voltage. The questionnaire was distributed by a designated information manager through a network of interested dairy farmers. As is not unusual, delays occurred in getting returns due to seasonal farming responsibilities. However, 75 of the cases contained sufficient information to include in the analysis. General information about respondents age, gender and duration living in present home is included.

DATA ANALYSIS

Much of the information from part one of the questionnaire was pre-coded for input into a standard data analysis package. Other open-ended items, particularly in part two of the questionnaire, were categorized and also coded for input. Data were then entered onto computer disks for analysis. Various methods are employed to ascertain the data implications. Each case is presented separately in appendix D, and summary data is presented in tabular form.

DATA SUMMARY

Interpretation of these data necessarily is considered in the context of persons who believe they have stray voltage problems and have so indicated as participants in this study. This discussion of findings is based on seventy-five cases with sufficient data to include in the compiled case analyses. A summary of this information along with the item codes are in Table 1.

Twenty-seven items in the questionnaire assess problems with dairy cattle and are subdivided, in this analysis, into production, behavior and health. These items were used in earlier surveys and are based on item correlational analysis. Four items assess observed cow behavior, and all four are reported to occur on more than 75 % of the seventy-five dairy farms with "cattle pressing their noses against stall pipes, water cups or cement curbs," "cattle kicking off milkers," and cattle dancing back and forth in stalls reported on 84 or more percent of the farms (See figure 1).

Thirteen items assess cow health (See figure 2). Recurring mastitis and trouble with cattle getting up are reported on nearly 90 % of the farms. All but four of the thirteen health problems occur on more than half of the farms including cattle with swollen legs, high veterinarian bills, cattle maintaining weight in cold weather, stress rings on hoofs, tough hides and immune system failures. Also occurring are leukemia/anemia (27 cases), inflamed sphincter valve (33 cases), tanish discharge about face (34 cases) and excessive teeth found in feedbunks (23 cases).

Production is the third category assessed with seven items, and all production symptoms are reported on 47 or more of the 75 dairy operations (See figure 3). Uneven or slow milkout and breeding problems are reported on 92 percent of the farms. The least frequently reported, poor water consumption, is reported on 63 % of the farms. Poor milk production, breedback difficulties, production peaking early and high somatic cell counts are reported for 84 % or more of the farms.

Three items specifically identified problems with calves. All three are reported in 38 (50 %) or more cases (See figure 4). These include problems with poor survival, retarded growth, and variety of symptoms including abscesses, sore gums, burnt knees and diarrhea.

In summary, these dairy farmers report high occurrences of cattle behavioral, health and production problems as assessed by the 27 questionnaire items. It is reasonable to determine if the three categories of behavioral, health and production problems occur independently of each other or together. Correlational analysis assessing these associations indicates that to a large degree they do occur together. Table two shows these associations to be significant ($p < .001$).

Earlier research indicates that health problems among cattle often has its counterpart among other animals living on the farm. Since many farms have pet cats, three items assess cat health and behavior (See figure 5). Over 43 of the 75 farms report that cats appear to be sickly, have no, small or unhealthy litters, die or leave the farm. This indicates that problems with cattle often accompanies problems with cats as well.

Previous research also indicates that problems with equipment may also occur on farms with animal health problems. In this study, equipment problems are correlated with cattle symptoms as a single category and also with each of the three sub-categories of cow production, behavior and health. All correlations are significant (See table two) as is consistent with previous findings. Equipment problems are not reported as often as animal problems, among these cases, though they are frequently reported (See figure 6). Incandescent lamp failures are reported in 42 of the 75 cases. Least frequently reported are increasing motor burnouts and radio and TV failure (27 cases). Other occurrences are high battery failure (34 cases), occasional shocks from pipes and furnace (39 cases), noisy telephones (42 cases), and accelerated pipe corrosion (33 cases).

Dairy farmers are not only concerned about the health of their livestock and pets, but their own health as well. Twenty-three items assess the health of persons living on the farm. The questionnaire provides opportunity for the respondent to report on his/her health and the health of up to two additional persons. Two of the items specifically assess women's health problems. The age distribution of the respondents is shown in figure 7, indicating that the modal age is in the 40's. Fourteen of the 75 respondents are female.

Health problems are presented, first, with only the respondent's reported characteristics, second, with characteristics of the 2nd and/or 3rd person, and third, the two additional characteristics for the female respondents. Health characteristics of respondents are presented in figure 8. Frequency of reported characteristics range from two (neurological illness and malignant body tumors) to 64 (excessive fatigue). Also reported in more than 50 cases are tingling and numbness, excessive fatigue, frequent irritability, often feeling under stress, and weakness and pain in legs, and forgetfulness. Frequent headaches, vision problems, ears ringing and generally not feeling well are reported in 40 or more cases. Flu-like symptoms are reported in about half of the cases.

The pattern of reported human health problems does not change appreciably when symptoms of additional persons are included (See figure 9). Excessive fatigue is the most frequently reported and malignant body tumors is least frequently reported. Beside fatigue, tingling and numbness, often feeling under stress, and weakness and pain in legs are reported 100 or more times.

Eight of the fourteen female respondents report feeling bloated and retaining body fluids and an equal number report problems with menstrual cycles. Since 61 of the respondents are male, the characteristics of the 2nd persons are likely to be female, and the total frequency for these items increases to 35 and 23 cases respectively (See figure 10). In summary, 11 (13 if the two female items are included) of the health problems reported by these respondents occur in half or more of the cases.

Since previous studies find that respondent's health problems are correlated with cow symptoms, this association is re-assessed in this sample and found to be significant. Correlations with cow symptoms are significant whether related to cow symptoms as a single category or subdivided into cow production, behavior and health ($p < .001$). And as with cow symptoms, respondent's health correlates significantly with equipment problems as well ($p < .001$)(See table 2).

The literature, discussed elsewhere, identifies stress syndrome characteristics, and items in this survey tend to correspond with those characteristics. However, stress symptoms may not be sufficiently great to induce persons to seek medical treatment. Nonetheless, 27 of the 75 respondents indicate that they sought treatment for one or more of the listed symptoms. Also 40 of the 75 respondents indicate that human health problems tend to occur at the time animals are experiencing health problems. The total number of cow symptoms differs little between persons having received health treatment and those not having received treatment (See figure 11). However when the t-test is used to assess differences between those having and not having been treated by cow production, behavior and health problems, the treated category has the higher means (See table 3). And this is true with equipment problems as well. Of course, persons receiving treatment would be expected to report a greater number of health symptoms, and this is found to be true as well.

Respondents vary considerably in the length of time living on their farm ranging from one to sixty years (See figure 12). As a check, respondent's number of reported health symptoms were correlated by length of time living on their present farm, and this was found not to be significant (Spearman's rho = -.051, $p > .05$). This is not surprising since levels of exposure, prior experiences before moving to present farm, exposure at other sites, differential levels of exposure and various other factors complicate this relationship.

Respondents indicate whether they are near an electric or pipe line. Frequency of cow and human symptoms are reported relative to their saying they are near these lines. Symptom frequency varies some according to persons saying they are near an electric or pipe line. The lowest frequencies for both cattle and humans is where no line is near (See figure 13). Table 3 summarizes t-test assessments for presence of an electric or pipe line for cow, human and equipment symptoms (See table 3). For those near an electric line, higher frequencies are reported for cow production and behavior problems, and cow and respondent's health symptoms. However presence or absence of an electric line does not affect frequency of reported equipment problems. Mean differences do not occur among these symptoms for presence of a pipeline, though the relatively small number of respondents living by pipelines affects this assessment.

These dairy operators have taken various actions in dealing with their perceived stray voltage problems, and some more than one. Fifty-one respondents indicate using an isolation device, and eight an equipotential plane or electric grounding system. Eighty-eight percent using a grounding system or equipotential plane report no improvement in their problems, and fifty-five percent found none with an isolation device (See figure 14). Reported symptoms, for cattle and respondents, reflects this pattern in that mean cattle symptoms are highest with use of a grounding system and lowest with use of an isolation device. Among respondents, isolation device is lowest with equipotential plane being highest, though the mean number of symptoms reported does not vary much among the three mitigation procedures (See figure 15). The number of symptoms, particularly for cattle, remains relatively high. It is an understatement to say these data suggest a need for continuing experimentation with alternative mitigation systems.

TABLE 1 : SUMMARY OF CASES

CASE #	# COW SYMPTOMS	# CAT SYMPTOMS	OTHER PETS	PERSON A SYMPS	PERSON B SYMPS	PERSON C SYMPS	CORRELATION	TREATMENT	MACHINE PROBS	YEARS LIVING	PROBLEMS	TRANSLINE	PIPELINE	ISOLATION	WIRECHANGE	NEW LINE	NEW PIPE	STOCK BEHAVIOR	HUMAN CHANGE	ELECTRIC CHANGE	MITIGATION TYPE	MITIGATION CHANGE
102	27	3	N	11	6	0	Y	Y	5	40	Y	Y	Y	Y	3	N	N				1	I
104	23	2	-	14	10	0	-	Y	6	24	Y	Y	N	Y	2	Y	N	Y	Y	Y	1	I
105	21	2	-	8	6	0	Y	N	4	52	Y	Y	Y	Y	3	N	N				1	N
108	20	2	-	10	4	0	Y	Y	4	2	Y	Y	N	Y	1,5	N	N				1,2	N
101	27	3	Y	14	15	16	Y	N	7	3	Y	Y	Y	Y	4	N	N				3	N
109	27	3	Y	15	15	7	-	-	5	-	Y	Y	N	Y	4	Y	N	Y	Y	N	2	N
110	22	2	N	8	8	11	Y	Y	3	27	Y	Y	N	Y	-	N	N				1	I
113	18	0	Y	12	0	0	Y	N	4	19	Y	N	N	Y	1,2,3,4	Y	N	Y	Y	N	1,2,3	N
115	12	3	N	14	0	0	Y	N	2	58	Y	N	Y	N	-	Y	N	Y	N	N	4	N
116	26	3	Y	17	14	12	Y	Y	8	37	Y	N	N	Y	1,2,4	N	N				4	I
117	19	3	Y	8	13	14	Y	N	4	43	Y	N	N	Y	3	N	N				1	N
122	21	3	Y	11	15	13	Y	Y	5	9	Y	N	N	Y	3	N	N				1	N
123	21	3	Y	15	4	0	Y	N	6	15	Y	N	Y	N	3	N	N				1,2	N
124	25	1	-	4	7	0	Y	N	5	29	Y	Y	Y	Y	4	N	N				1	I
125	24	3	Y	13	14	1	N	N	1	30	Y	Y	Y	Y	1,2,3,4	N	Y	N	Y	N	1	N
111	26	3	N	15	4	0	Y	N	3	56	Y	Y	N	Y	3	Y	N	Y	N	N	1	N
128	27	3	Y	15	13	0	Y	Y	7	26	Y	N	N	Y	1,2,3,4	N	N				1,2,3	N
149	21	3	N	16	21	21	Y	Y	6	-	Y	Y	N	Y	3,4	N	N				1	N
150	16	3	Y	11	9	9	Y	N	3	35	Y	Y	N	Y	3	N	N				1	N
153	16	2	N	8	7	4	Y	Y	7	19	Y	Y	N	Y	3,4	N	N				1,3	N
154	21	3	N	8	6	0	Y	N	8	30	Y	Y	N	Y	1,3	Y	N	Y	N	N	1	N
156	25	2	N	13	10	0	Y	Y	4	40	Y	N	Y	N	1	N	N				1	N
159	18	2	N	10	10	0	Y	N	4	3	Y	N	N	Y	1	N	N				1	I
166	11	0	N	5	13	0	-	Y	3	50	Y	N	N	Y	3	N	N				1	I

SUMMARY OF CASES

CASE #	# COW SYMPTOMS	# CAT SYMPTOMS	OTHER PETS	PERSON A SYMPS	PERSON B SYMPS	PERSON C SYMPS	CORRELATION	TREATMENT	MACHINE PROBS	YEARS LIVING	PROBLEMS	TRANSLINE	PIPELINE	ISOLATION	WIRECHANGE	NEW LINE	NEW PIPE	STOCK BEHAVIOR	HUMAN CHANGE	ELECTRIC CHANGE	MITIGATION TYPE	MITIGATION CHANGE
172	13	0	N	6	0	0	—	N	1	17	y	N	N	N	1	N	N				4	N
173	26	3	N	15	2	0	—	N	2	16	y	y	N	—	—	N	N				—	—
174	24	2	N	8	0	0	y	N	4	18	y	N	N	y	3	N	N				1	I
175	23	3	y	12	5	0	y	N	4	25	y	y	y	y	2	y	N	y	N	N	1	I
176	26	1	N	8	7	3	N	N	6	—	y	y	y	y	—	y	N	y	N	N	—	—
180	15	2	N	8	1	0	—	N	3	15	y	—	—	N	—	N	N				—	—
129	15	0	N	8	9	0	y	y	1	52	y	y	y	N	—	y	N	y	y	N	—	—
181	20	3	N	11	0	0	—	N	5	47	y	y	N	N	—	N	N				—	—
169	19	0	N	11	6	0	—	N	4	7	y	y	N	y	3	N	N				1	N
182	23	3	N	8	10	9	—	y	3	60	y	y	N	—	4	N	N				—	—
183	13	2	N	9	3	0	y	y	1	30	y	N	y	N	—	N	N				—	—
184	15	0	—	10	0	0	N	N	2	17	y	y	y	N	—	N	N				—	—
185	21	1	N	14	9	7	y	y	5	28	y	y	N	y	3	N	N				1	I
186	20	3	y	9	4	3	y	y	6	50	y	N	y	y	3	N	N				1	I
187	23	0	—	16	16	4	y	y	3	58	y	y	y	N	—	N	N				—	—
189	20	2	N	8	5	0	—	N	1	22	y	N	N	y	3	N	N				1	N
190	13	1	N	6	0	0	—	N	2	41	y	y	N	y	3	N	N				1	N
135	27	3	y	14	12	0	—	y	7	24	y	y	N	y	1, 2	y	N	N	y	N	3	N
158	20	3	N	9	10	8	y	y	1	20	y	y	N	y	2,4	N	N				1, 2	I
120	27	1	N	18	17	0	—	y	5	8	y	y	N	y	3	N	N				1	N
157	20	0	N	10	0	0	y	N	4	36	y	y	N	y	3	N	N				1	N
119	27	3	y	15	15	16	—	N	0	38	y	y	N	y	3	N	N				1	I
118	27	3	y	13	6	0	y	N	7	1	y	N	N	y	3	N	N				1	I
193	15	2	N	9	0	0	—	N	5	40	y	N	y	N	—	N	N				—	—

SUMMARY OF CASES

CASE #	# COW SYMPTOMS	# CAT SYMPTOMS	OTHER PETS	PERSON A SYMPS	PERSON B SYMPS	PERSON C SYMPS	CORRELATION	TREATMENT	MACHINE PROBS	YEARS LIVING	PROBLEMS	TRANSLINE	PIPELINE	ISOLATION	WIRECHANGE	NEW LINE	NEW PIPE	STOCK BEHAVIOR	HUMAN CHANGE	ELECTRIC CHANGE	MITIGATION TYPE	MITIGATION CHANGE
192	22	3	y	14	1	0	y	y	2	30	y	N	y	y	3	N	N				1	I
177	18	2	N	10	1	0	y	y	0	60	y	y	N	y	3	N	N				1	I
256	25	3	—	15	0	0	—	y	7	7	y	y	N	y	3	N	N				1	I
126	14	2	—	9	0	0	—	N	1	38	y	y	y	y	3	N	y	y	y	N	1	I
273	21	3	y	12	11	14	y	N	5	34	y	N	N	—	—	N	N				—	—
188	18	1	—	12	2	0	y	N	4	54	y	y	N	—	1	N	N				—	—
141	19	2	y	12	8	10	y	N	6	6	y	y	N	N	2	y	N	N	N	N	2	N
136	19	3	y	9	9	1	N	N	1	14	y	N	N	y	3	N	N				1	N
194	19	1	N	0	0	0	—	—	1	55	y	y	N	y	2,4	N	N				1	N
140	18	3	N	2	0	0	—	—	3	29	N	N	N	—	1,4	N	N				—	—
133	7	3	N	11	0	0	N	N	1	15	y	—	—	—	—	N	N				—	—
200	19	0	N	16	13	10	y	—	2	48	y	y	N	y	1,2	N	N				1	N
142	14	3	N	5	2	0	N	y	2	24	y	—	N	N	1	N	N				—	—
197	14	3	y	4	7	1	—	—	6	25	y	N	y	y	2,4	N	N				1, 3	N
198	13	0	—	0	0	0	—	—	5	25	y	N	y	y	2	y	N	N	N	N	1	I
179	7	1	—	1	0	0	—	—	1	30	—	y	N	y	3	N	N				1	N
258	24	3	y	11	8	0	y	y	6	13	y	N	N	y	4	N	N				1, 3	I
145	12	1	—	5	0	0	N	N	3	40	N	N	y	y	2,3	N	N				1	N
144	17	0	—	5	1	0	—	—	0	21	y	N	y	N	3,4	N	N				—	—
143	5	1	—	1	0	0	—	—	0	20	y	N	N	y	—	N	N				1, 2	N
137	14	0	—	4	3	0	—	—	0	32	y	—	N	y	4	N	N				1	I
275	20	2	N	19	17	0	y	y	6	43	y	N	N	N	—	N	N				—	—
147	18	1	N	7	1	0	y	N	4	44	y	N	N	N	4	N	N				1, 3	N
148	10	3	N	1	1	0	y	—	2	35	y	N	N	y	2	N	N				1	—

SUMMARY OF CASES

CASE #	276	277	278
# COW SYMPTOMS	15	15	7
# CAT SYMPTOMS	2	0	0
OTHER PETS	y	N	N
PERSON A SYMPS	10	6	0
PERSON B SYMPS	13	3	0
PERSON C SYMPS	0	0	0
CORRELATION	1	1	N
TREATMENT	y	N	N
MACHINE PROBS	4	3	3
YEARS LIVING	30	21	10
PROBLEMS	y	y	N
TRANSLINE	N	N	N
PIPELINE	N	N	N
ISOLATION	y	y	y
WIRECHANGE	1	2,3	1
NEW LINE	1	N	y
NEW PIPE	1	N	N
STOCK BEHAVIOR			y
HUMAN CHANGE			N
ELECTRIC CHANGE			N
MITIGATION TYPE	1	1	1
MITIGATION CHANGE	1	I	N

VARIABLE CODES

CASE # = Case number
COW SYMPTOMS = Total number of cattle symptoms checked
CAT SYMPTOMS = Total number of cat symptoms checked
OTHER PETS = Health problems in other pets; Y=yes, N=no
PERSON A SYMPS = Total number of symptoms checked for person one
PERSON B SYMPS = Total number of symptoms checked for person two
PERSON C SYMPS = Total number of symptoms checked for person three
CORRELATION = Health problems occurring with animal problems; Y=yes, N=no
TREATMENT = Household members regularly treated; Y=yes, N=no
MACHINE PROBS = Total number of machine problems checked
YEARS LIVING = Number of years having lived in present location
PROBLEMS = Feel there is a stray voltage problem; Y=yes, N=no
TRANSLINE = Transmission line near living/work area; Y=yes, N=no
PIPELINE = Pipeline near living/work area; Y=yes, N=no
ISOLATION = Electrical isolating device near; Y=yes, N=no
WIRECHANGE = Changes in electrical wiring
NEW LINE = Recent addition of electrical line; Y=yes, N=no
NEW PIPE = Recent addition of pipe line; Y=yes, N=no
STOCK BEHAVIOR = Changes in livestock behavior; Y=yes, N=no
HUMAN CHANGE = Changes in human health; Y=yes, N=no
ELECTRIC CHANGE = Changes in electrical equipment; Y=yes, N=no
MITIGATION TYPE = Types of mitigation changes; 1=neutral isolation, 2=equipotential plane, 3=Electric grounding system, 4=other
MITIGATION CHANGE = changes in animal, human health or in equipment, I=improvement, N=no improvement, S=short term improvement D=disimprovement, P=improvement in production only

Table 2: Spearman's Rho Correlations for Relationships Among Cow, Human and Equipment Symptoms

	Cow Production	Cow Behavior	Cow Health	Human Health	Equipment Problems
Cow Production	1.000				
Cow Behavior	.632***	1.000			
Cow Health	.635***	.501***	1.000		
Respondent's Health	.468***	.409***	.565***	1.000	
Equipment Problems	.368**	.392***	.492***	.375***	1.000

N = 75, * = $p < .05$, ** = $p < .01$, *** = $p < .001$

	Total Cow Symptoms	Respondent's Health	Equipment Problems
Total Cow Symptoms	1.000		
Respondent's Health	.522***	1.000	
Equipment Problems	.446***	.375***	1.000

N = 75, * = $p < .05$, ** = $p < .01$, *** = $p < .001$

Table 3: Comparison of Cow and Human Effects by Respondent's Health Treatment, and Presence of Electric and Pipe Lines

Respondent Having Had Medical Treatment

	Means			
	Yes	No	t-value	Significance*
Cow Production	5.48	4.96	1.973	.025
Cow Behavior	4.56	4.13	1.755	.040
Cow Health Problems	5.07	4.23	2.079	.019
Respondents' Health	12.04	8.69	3.324	.001
Equipment Problems	4.37	3.35	2.100	.018

Presence of Electric Line

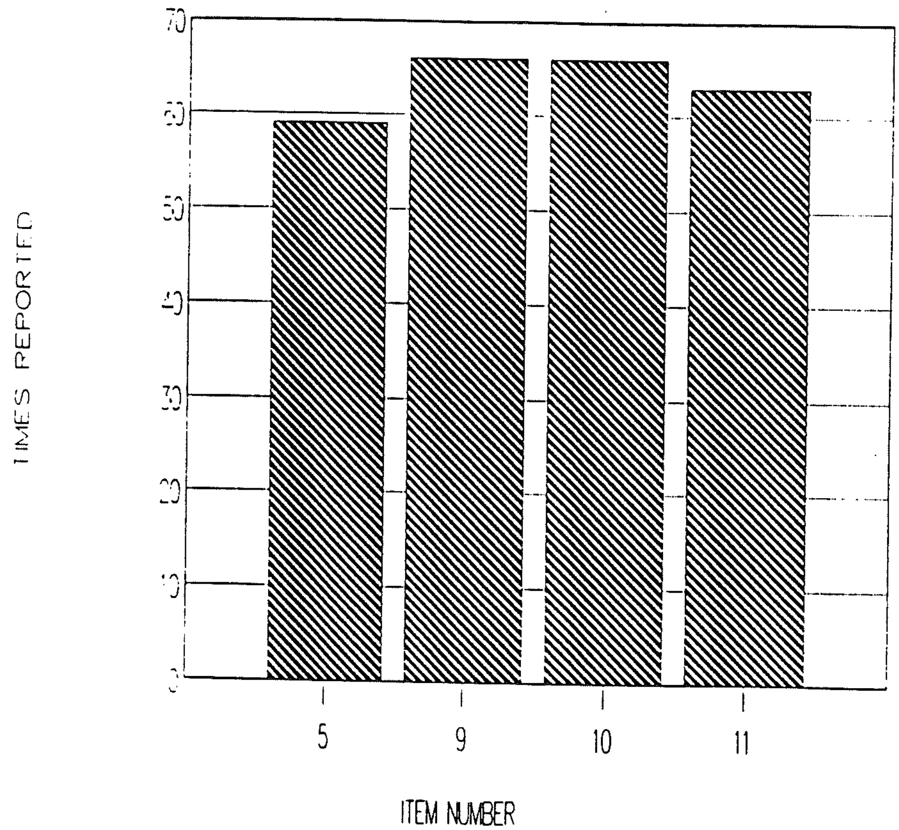
	Means			
	Yes	No	t-value	Significance*
Cow Production	5.42	4.86	2.198	.015
Cow Behavior	4.55	4.00	2.386	.009
Cow Health Problems	4.95	4.11	2.156	.016
Respondents' Health	10.95	8.81	2.120	.018
Equipment Problems	3.82	3.62	0.406	ns

Presence of Pipe Line

	Means			
	Yes	No	t-value	Significance*
Cow Production	5.32	5.08	0.850	ns
Cow Behavior	4.14	4.34	0.773	ns
Cow Health Problems	4.41	4.58	0.347	ns
Respondents' Health	9.59	10.02	0.355	ns
Equipment Problems	3.46	3.75	0.409	ns

*Based on one-tailed t-test for independent samples

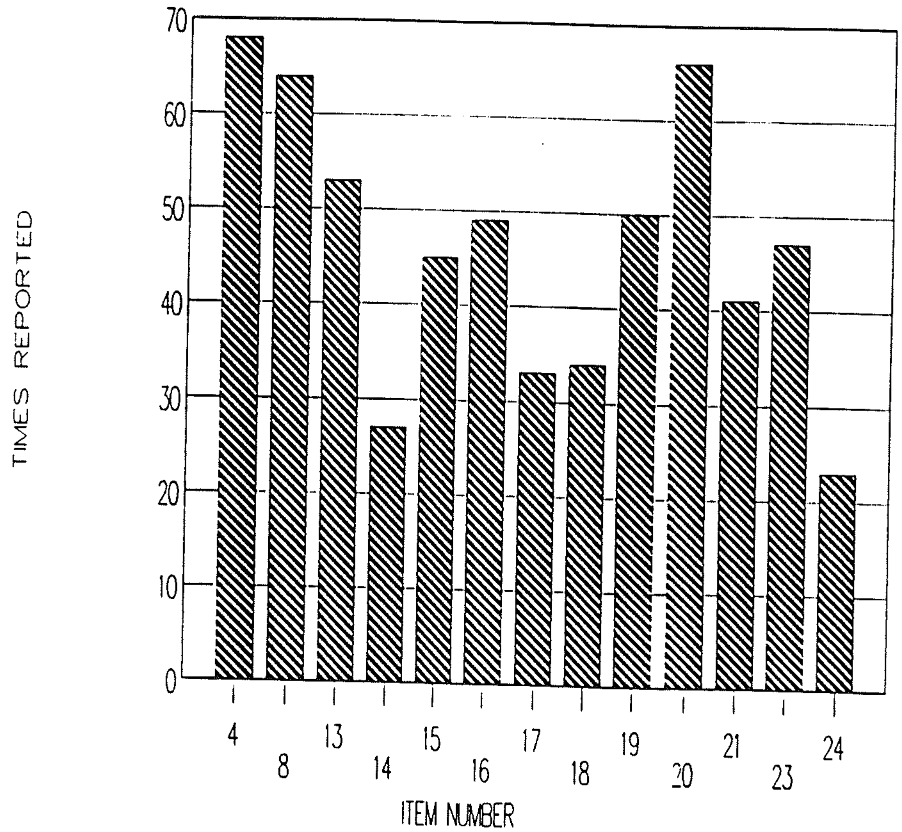
FIGURE 1: TIMES PROBLEM INDICATED BY KIND OF COW BEHAVIOR PROBLEM



Total number of cases = 75

5. cows reluctant to enter barn and/or stalls
9. cattle dancing back and forth in stalls
10. cattle kicking off milkers
11. cattle pressing their noses against stall pipes, water cups or cement curbs

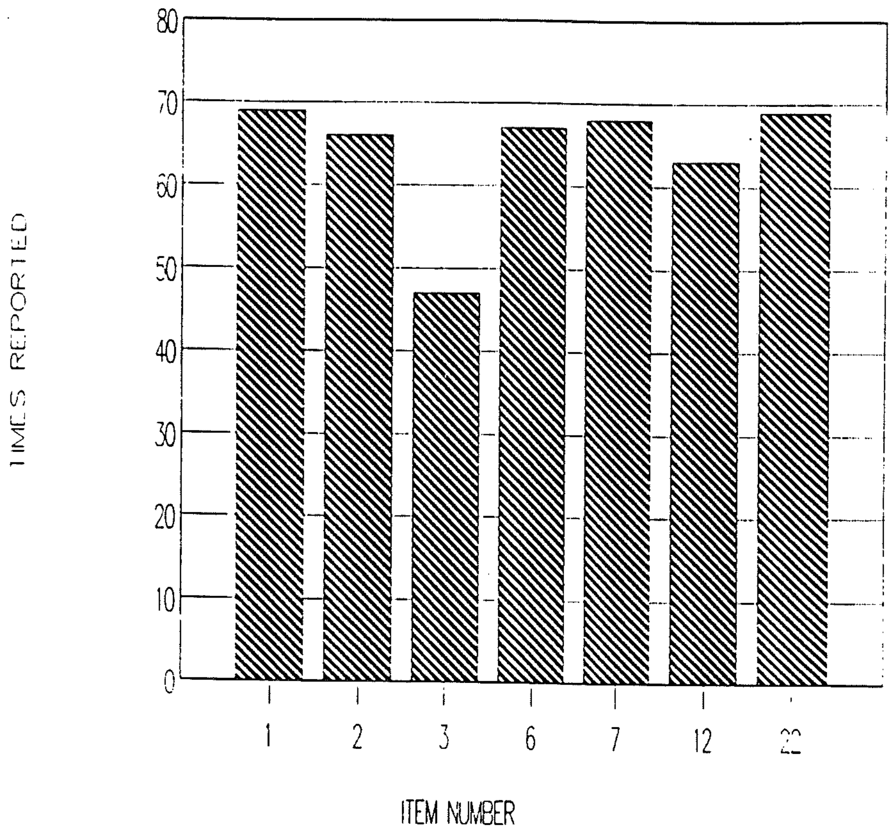
FIGURE 2: TIMES PROBLEM INDICATED BY KIND OF COW HEALTH PROBLEM



Total N = 75

4. multiple or recurring mastitis (not responding to treatment)
8. swollen legs and joints
13. high veterinarian bills
14. leukemia/anemia
15. inability to maintain weight in cold weather
16. poor hair coat, constant lice problems
17. inflamed sphincter valve (even among unmilked heifers)
18. tanish discharge under eyes, nostrils, and ears
19. stress rings on the hoofs (excessive growth)
20. heifers and cows have trouble getting up (legs seem numb)
21. tough hides which result in bent and broken injection needles
23. immune system failures resulting in Chlamydia, pneumonia, and Bovine Viral Diarrhea
24. excessive teeth found in feeders and feedbunk

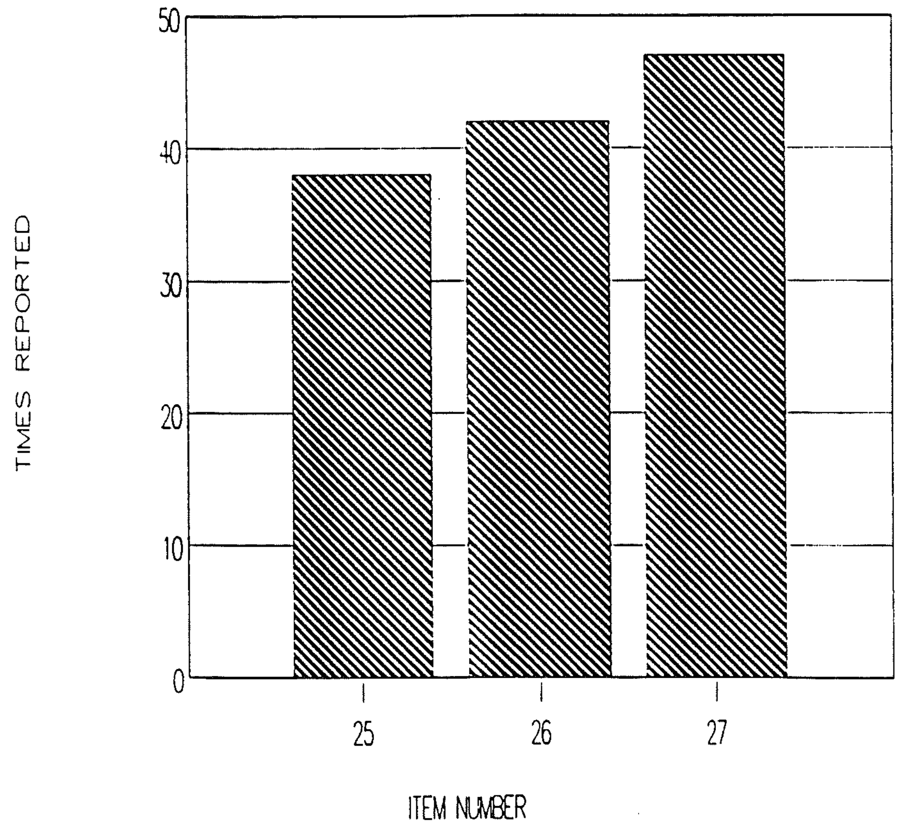
FIGURE 3: TIMES PROBLEM INDICATED BY KIND OF COW PRODUCTION PROBLEM



Total number = 75

1. uneven, incomplete and/or slow milkout
2. poor milk production
3. poor water consumption
6. breedback difficulties
7. cow production peaking early and not holding
12. high somatic cell counts
22. breeding problems, such as: silent heats, absorptions, and spontaneous abortions

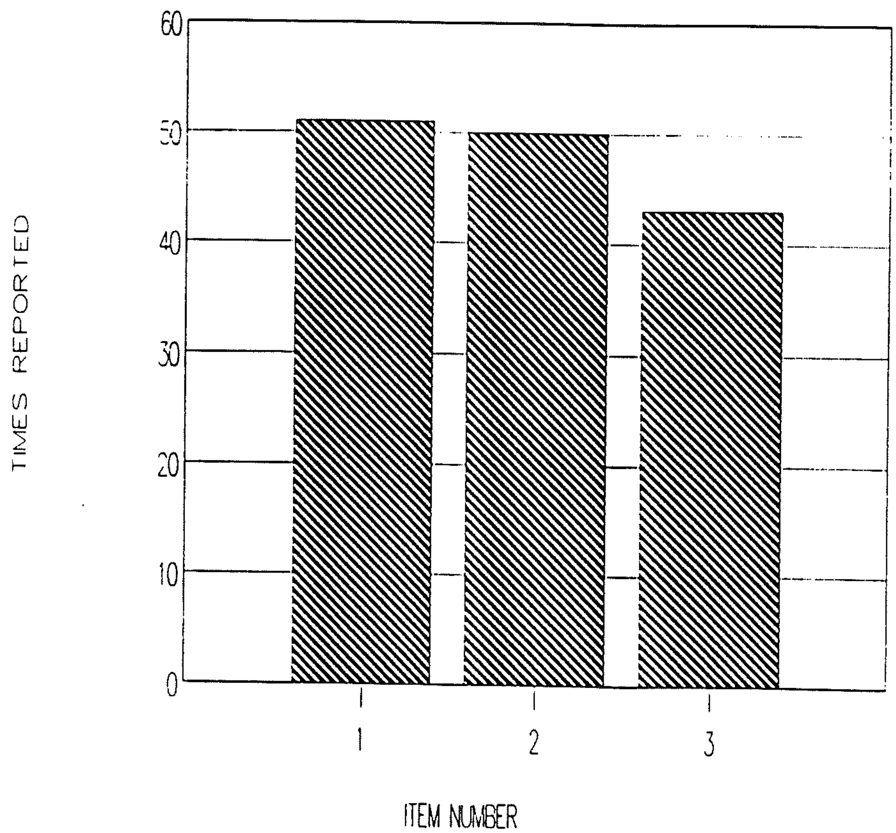
FIGURE 4: TIMES PROBLEM INDICATED BY KIND OF CALF PROBLEM



Total number of cases = 75

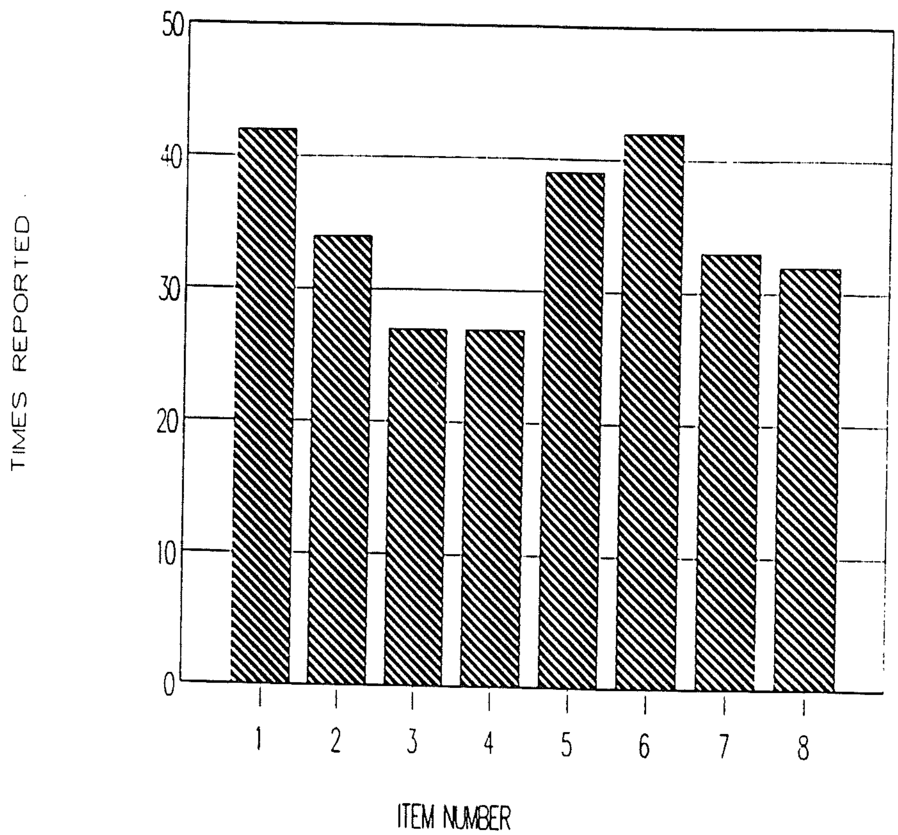
25. calves having poor survival rate
26. calves unable to grow at normal rate
27. calves with symptoms such as abscesses, sore gums, burnt knees, unable to suck, rolls, tongue, diarrhea, and/or loose hair

FIGURE 5: TIMES PROBLEM INDICATED BY KIND OF CAT PROBLEM



1. cats sickly with rough, dull and shaggy coats
2. cats cease to bear litters or give birth to small, unhealthy litters
3. cats leave farm or die

FIGURE 6: TIMES PROBLEM INDICATED BY KIND OF EQUIPMENT PROBLEM



Total number of cases = 75

1. incandescent lamp failures (sometimes in groups, explosions)
2. unusually high rate of battery failure
3. radio and TV set failure (non-lightening related)
4. increasing motor burnouts
5. occasional shocks from water lines or furnaces
6. noisy telephone requiring frequent service calls or having false rings
7. accelerated corrosion of well casings or other buried pipes
8. unexplained fluctuations in electric bills

FIGURE 7: AGE DISTRIBUTION OF 75 RESPONDENTS

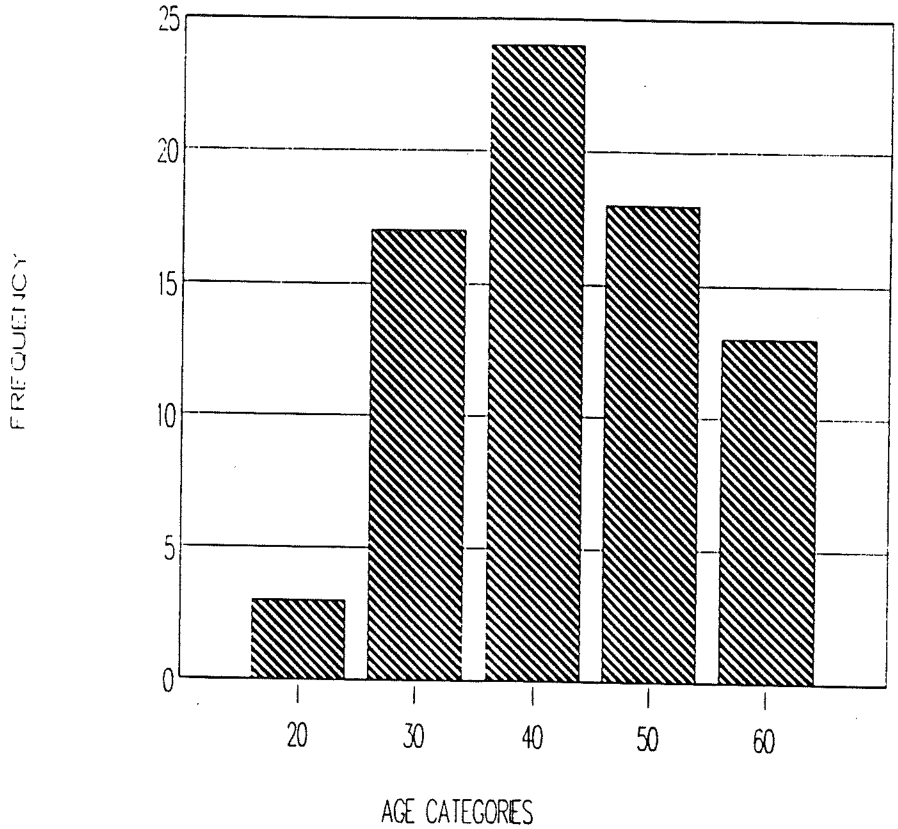
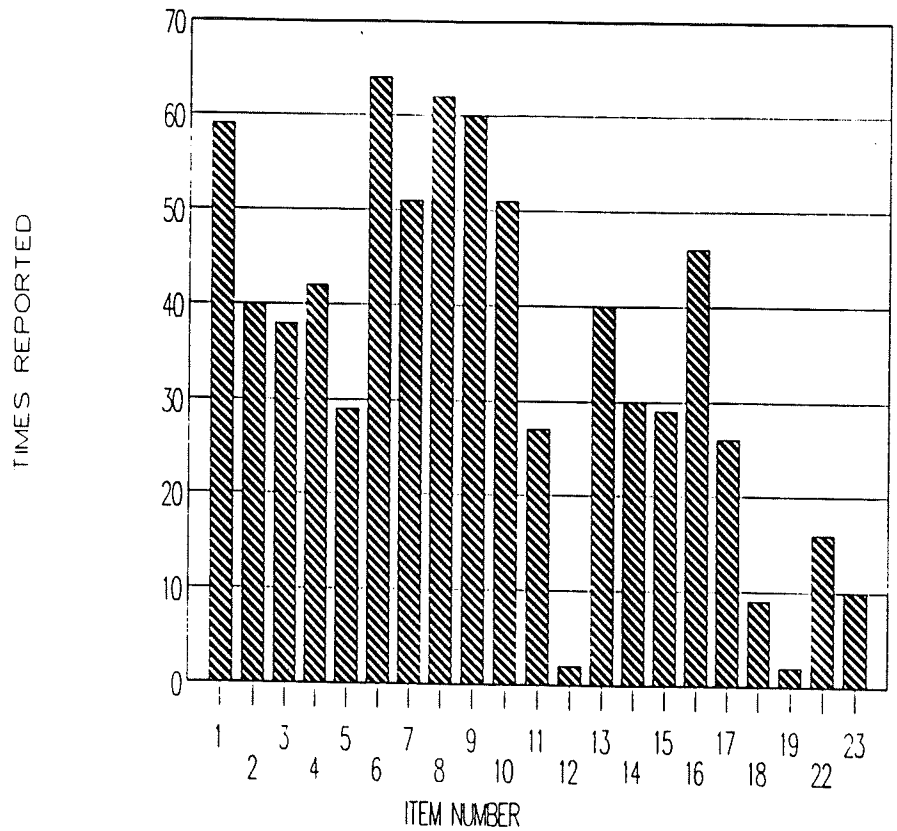


FIGURE 8: TIMES PROBLEM INDICATED

RESPONDENT INDICATING OWN PROBLEM



ITEMS ON HUMAN HEALTH PROBLEMS

1. tingling or numbness in arms or legs
2. frequent headaches
3. frequent flu-like or cold symptoms
4. vision problems (e.g., blurred or heavy eyelids)
5. problems with breathing
6. excessive fatigue
7. frequent irritability
8. often feeling under stress
9. weakness & pain in legs
10. forgetfulness
11. allergies
12. neurological illness
13. ears ringing
14. pressure behind eyes
15. unexplained nausea
16. unexplained general feeling of not being well
17. reheumatoid arthritis
18. high incidence of non-malignant body tumors
19. occurrence of malignant body tumors
22. having an illness that medical professionals cannot diagnose
23. occurrence of heart related ailments

FIGURE 9: TIMES PROBLEM INDICATED

PROBLEMS INDICATED FOR ALL PERSONS

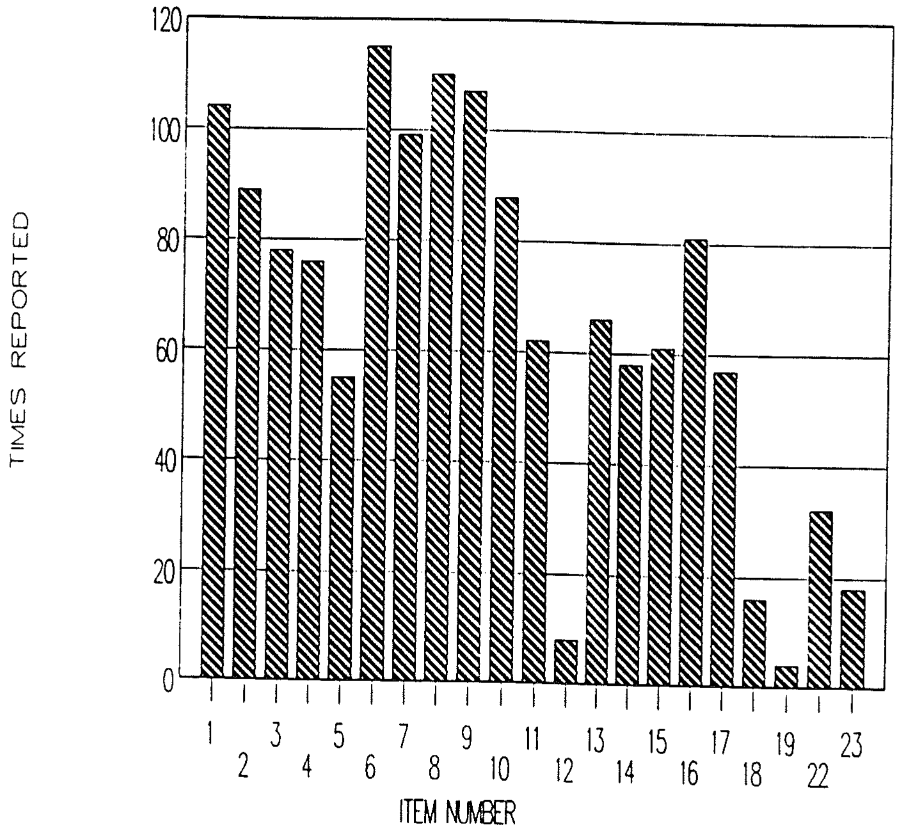
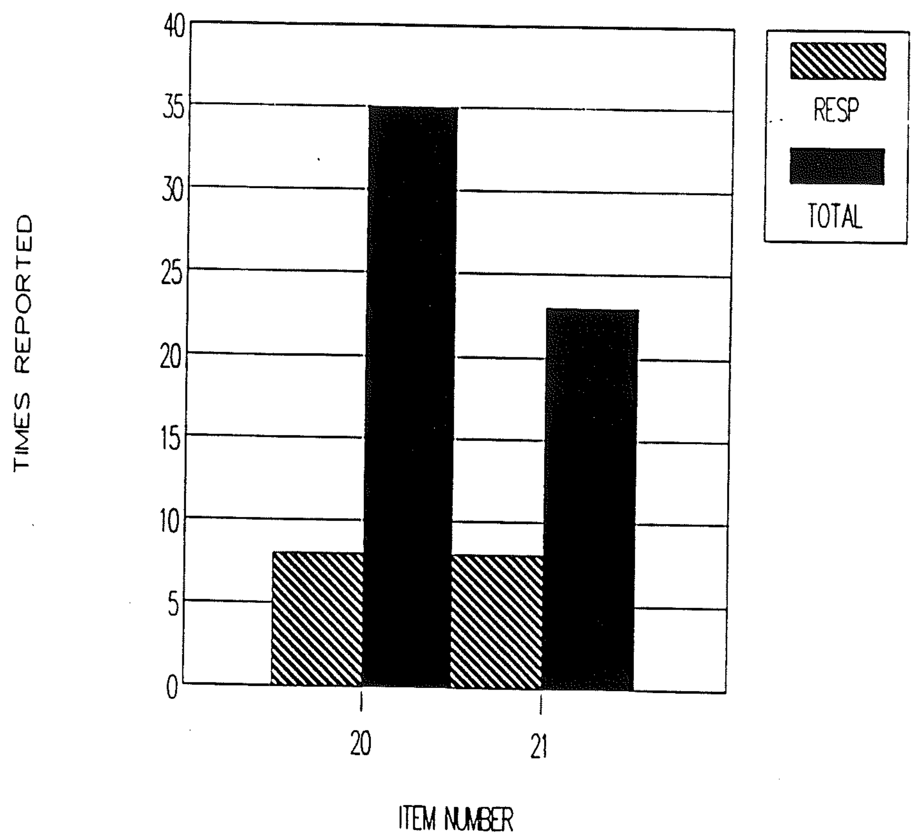


FIGURE 10: TIMES PROBLEM INDICATED FOR FEMALE RESPONDENTS AND TOTAL



Female respondents = 14

21. (females) feeling bloated/retaining body fluids
22. (females) problems with menstrual cycle

FIGURE 11: MEAN COW SYMPTOMS BY PRESENCE OF HEALTH TREATMENT

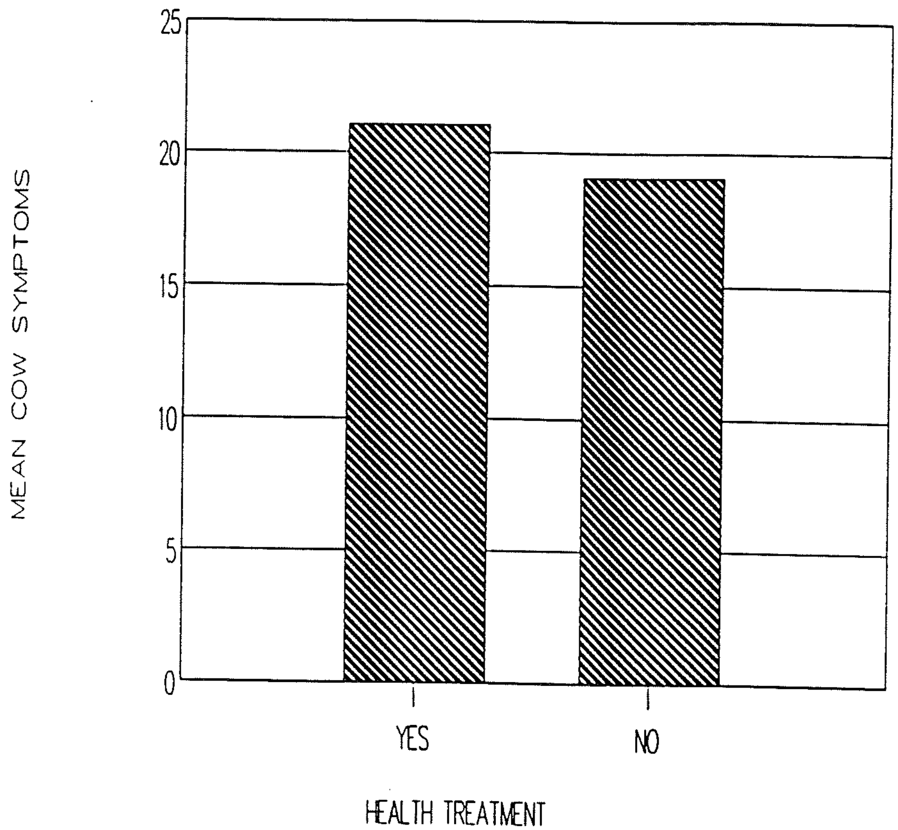


FIGURE 12: NUMBER YEARS LIVING ON PRESENT FARM

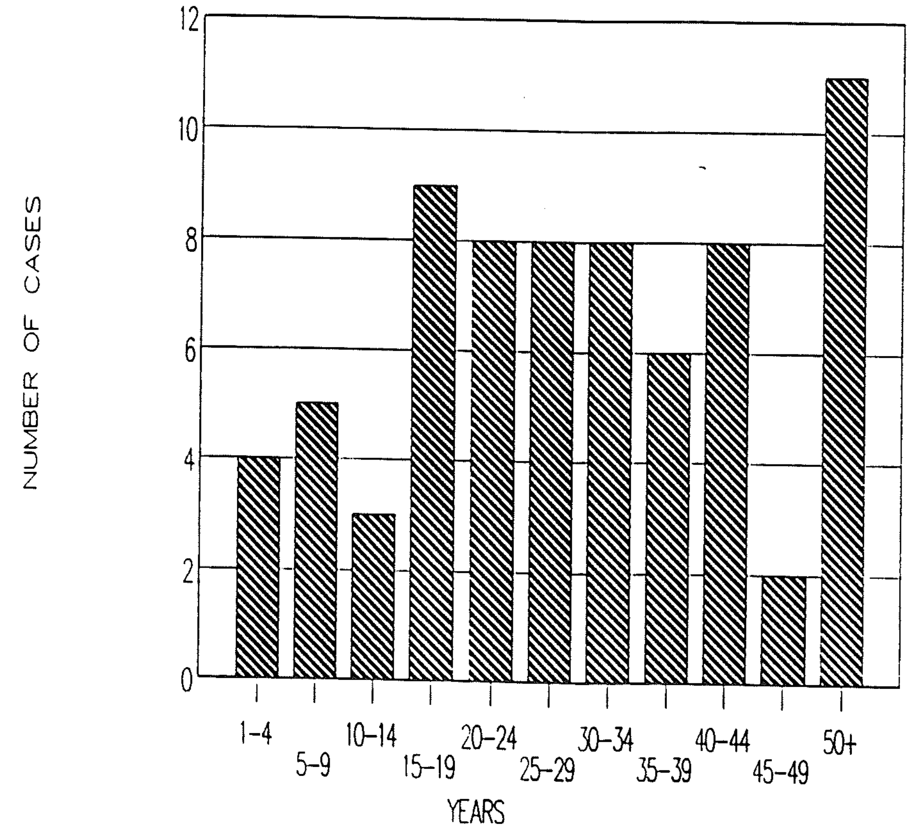


FIGURE 13: MEAN HEALTH SYMPTOMS BY PRESENCE OF LINE

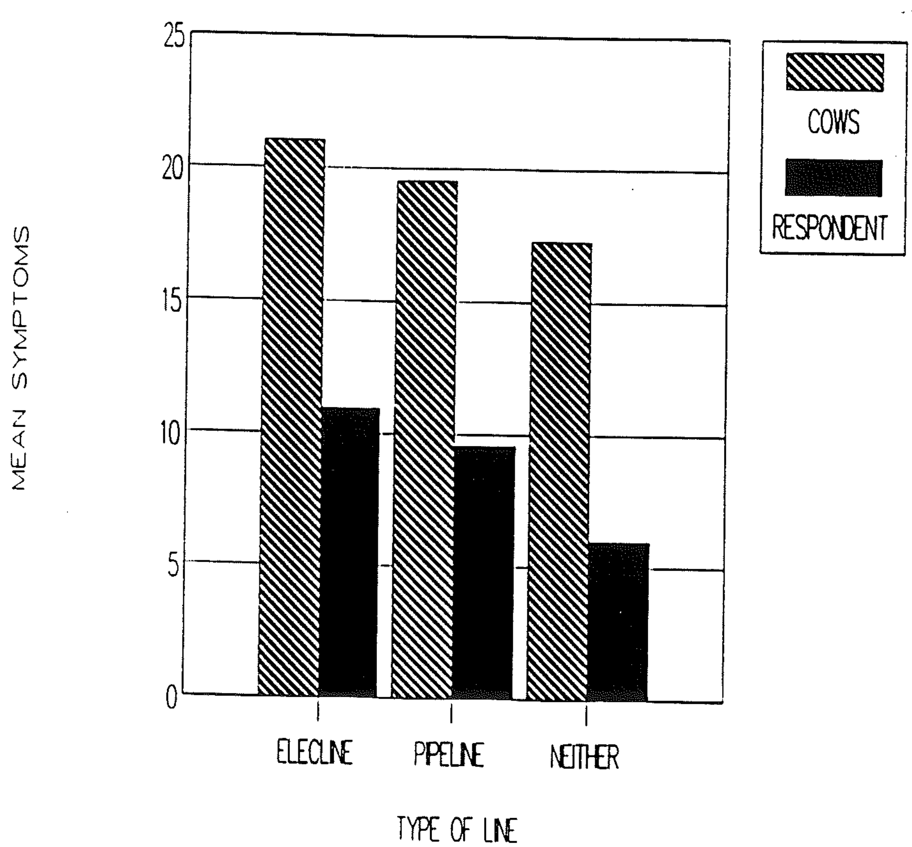
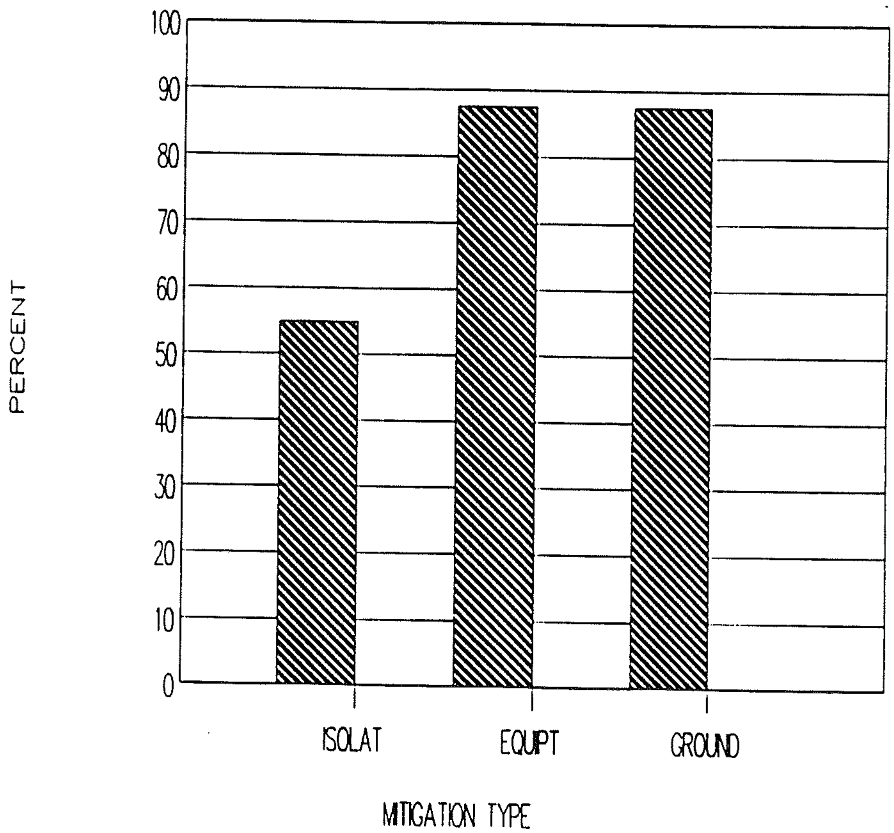
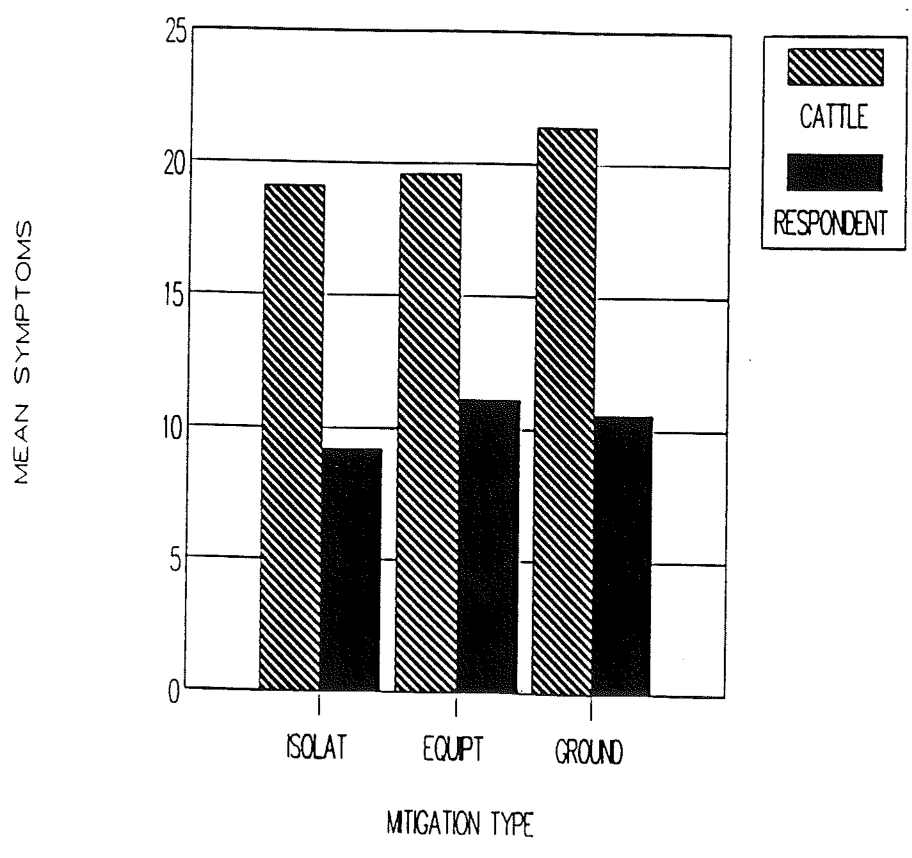


FIGURE 14: MITIGATION TYPE BY PERCENT NOT IMPROVING PROBLEMS



Based on fifty-eight respondents indicating one or more types of mitigation.

FIGURE 15: MEAN HEALTH SYMPTOMS BY MITIGATION TYPE



Based on fifty-eight respondents indicating one or more types of mitigation.

CHAPTER X

ELECTRIC CURRENT MEASUREMENTS AND TRANSFORMER LOADING

Farms were chosen that had primary and secondary neutrals separated. The farms were disconnected from the transformer at the disconnect box, the farm was on a four wire connection and the load was put on the system between the disconnect box and electric meter.

The following conditions existed with no load on the farm and the primary grounding connected:

0.01 -0.02 mg 60 Hz vertical field throughout the barn and farm yard area.

Ground to stall Fluke 87 measurements were 2.50 mA and 88 mV DC; 3.1 mV and 0.08mA AC.

Using a 240 V load with fault produced the following changes:

82 mV DC; 0.36mA and 8.5 mV AC

With three wire system, Swain clamp-on meter on secondary grounding wire at the barn:

0.2 to 0.3 mA when the transformer is loaded with farm off. Turning on the load with a fault the current on the grounding wire went up to 16 mA AC. Other tests indicated that the only connection was the current from the case of the load into the ground and into the farm grounding system. The load was in a conducting case on the ground at the meter pole. Electrically isolating the load from the earth reduced the current to 0.3 mA.

For the second farm, the conditions are described as follows:

With the farm off:

1.4mV and 0.04mA AC; 200 mV and 3.3 mA DC between the steel wall and the stall divider.

0.2 mA AC on wire connecting the water line connected to ground grid as measured with the Swain meter.

Farm off, transformer load on:

6.8 mV and 0.15 mA AC and 203 mV and 3.15 mA DC

1.6 mA on wire as measured with the Swain meter.

Farm off, 1hp load added to the transformer:

With transformer ground connected 2mA AC on the wire and 0.18 mA between stall and metal wall.

With ground rod disconnected there was 1.5 mA AC on the wire and 0.05 mA between the two contact points.

Adding the 240 V fault load the current in the wire decreased from 1.6 to 1.2 mA

Whenever 240 V loads were added to the system under four wire conditions, the currents increased in all wires connected to ground rods or grounding grids.

A third farm was also analyzed because of its quite different system.

Farm is not isolated and has an EGS system operating.

With the farm electricity on and the EGS system off AC currents were present in all grounding wires and steel stall dividers at levels between 25 and 150 mA AC. These same values were present with the farm electricity turned off. Some changes occurred from one place of measurement to another. With the farm electricity on and the EGS system on, current measurements on grounds and stall dividers in the barn were reduced to values ranging around 1 mA AC. Under these same conditions 1400 mA AC were entering the EGS grounding grid. As loads were added on the farm the current going to the EGS grid increased to over 2000 mA AC. With the EGS off, 260 mA AC entered the barn neutral from the primary neutral. Turning the barn electricity off, the current was 220 mA entering the barn neutral and therefore going into the earth. Disconnecting the electricity to the entire farm did not change the results. On the primary grounding wire there was 25 mA with the EGS on and 44 mA with the EGS off.

CONCLUSIONS

The measurements were all made at low use time to more easily observe the changes.

Electricity does reach the barn directly through the earth as demonstrated by the changes when loading the transformer.

Disconnecting the primary grounding wire significantly decreasing the current in the ground in the barn and around the farm.

Isolation decreases dramatically the quantity of primary neutral current going through the farm grounding system. The current going directly from the primary to secondary neutral goes into the entire grounding system and everything connected to that system and finally into the earth to return to the substation.

Through phase control the EGS puts large quantities of current into the earth on its grounding grid which neutralizes or counters the electricity coming into the barn from the primary neutral. The overall consequence of this technology is to increase the current discharged to the earth.

CHAPTER XI

THE TYPICAL STRAY VOLTAGE FARM

While every stray voltage story is different, the information gathered from many dairy farmers and their consultants shows striking similarities among affected farms. This information forms the basis for the following description of a "typical" stray voltage farm.

The typical owner battling stay voltage on the dairy farm is first of all a good farmer, with a history of successful experience in the dairy business. While the farmer may have recently purchased the farm, or recently have made significant modifications in equipment or buildings, there may be no apparent reason for the appearance in the dairy herd of effects that are serious enough to require some type of immediate response. The cows develop new and undesirable behaviors, such as not eating and drinking in appropriate quantities, dancing back and forth in their stalls, and kicking off milkers. They refuse to enter the parlor or stalls, and they show signs of stress in the bulging of their eyes. At about the same time the cows develop multiple or recurring mastitis that does not respond to treatment. There is uneven, incomplete and/or slow milkout and the somatic cell count begins to rise.

As the problems persist, milk production begins to decrease, as cow production peaks early and does not hold. The farmer encounters breedback difficulties and breeding problems such as silent heats, absorptions, and spontaneous abortions. Heifers and cows have trouble getting up, and their legs seem to be numb. Many cows have swollen legs and joints.

At the same time a variety of health problems develop in the herd, resulting in high veterinary bills. The cows experience immune system failures resulting in chlamydia, pneumonia, and bovine viral diarrhea (BVD). They are susceptible to leukemia/anemia, are unable to maintain weight in cold weather, and they experience inflamed sphincter valve (even among unmilked heifers).

As the farmer continues to observe the cattle closely, stress rings on the hooves are seen. Also noticed, are the cows pressing their noses against stall pipes, water cups or cement curbs.

As these effects are observed in the cows, an alarming set of effects may also be taking place among the calves. They may have a poor survival rate, and those who live seem unable to grow at a normal rate. Symptoms such as abscesses, sore gums, burnt knees, and loose hair are common. The calves are often unable to suck normally, and they may experience debilitating diarrhea.

Even pets on the farm are affected. Cats seem to be more commonly affected than other pets. They often become sickly, with rough, dull and shaggy coats. They often can no longer bear litters, or they give birth to small, unhealthy litters. Some cats leave the farm and die. The dogs may develop stiff joints and become skittish at certain places on the farm property. Dogs, too, may have trouble bearing litters, and they seem to have an increased susceptibility to cancer.

Electrical problems may also begin to occur more frequently. Incandescent bulbs blow out, radios and TVs fail, there is an increase in electric motor burnouts, people occasionally receive a shock from water lines or faucets, and there is unexplained fluctuation in electric bills. Under certain conditions, especially near DC transmission lines or pipelines, the farmer may experience an accelerated corrosion of well casings or buried pipes, and an unusually high rate of battery failure.

Most alarming to the farmer are the effects that are observed among the family members. These effects are most numerous and most severe among the members of the family who are the most involved in milking and work in the barn for extended periods of time. Family members, including, on some farms, those members of the family not often associated with the milking, experience excessive fatigue. It has become common for them to feel generally unwell, with no specific apparent cause. They often feel under stress and are frequently irritable and forgetful. Some have tingling or numbness in their arms and legs, and sometimes weakness and pain in their legs. They have frequent headaches, and some vision problems such as blurred vision or heavy eyelids; sometimes they feel pressure behind their eyes. Some family members have problems with breathing and with ringing in the ears . They have frequent cold and flu symptoms, unexplained nausea, and an increased problem with allergies. One or more of the members of the family may have developed rheumatoid arthritis. The women of the family complain that they feel bloated, and they appear to be retaining body fluid. Most disturbing is the fact that one or more of the family members may have developed an illness that health professionals have not been able to diagnose.

As each of the effects in the dairy herd is noted, the farmer treats it in the accepted manner. As is usually the case with problems in a dairy herd, the farmer suspects that improved management can resolve the problems. Like all good dairy farmers, there is a lifetime of experience to draw from in analyzing management causes. Soon the farmer exhausts all options for management solutions, but conditions continue to deteriorate. In growing frustration, the farmer calls in a series of farm consultants and experts. These individuals are asked to analyze the feed, check for any unusual disease, test the milking equipment and look for any management deficiency. The focus of attention is always on the dairy herd, since it is the dairy herd that provides the income for the farm operation. The consultants make suggestions ranging from procedural changes to buying their equipment or special services. The farmer acts on the information immediately, spending a considerable amount of money having new equipment installed, introducing a more expensive feeding system, and beginning an extensive vaccination program.

Most often none of these approaches resolves the problems, and the conditions continue to deteriorate. After spending a considerable amount of money making changes, the farmer continues to lose cattle and production. The consultants have no more suggestions, and so now the subject of stray voltage arises. The farmer brings in the electric utility, electricians and other experts to determine if a stray voltage problem exists. If a possible stray voltage problem is identified, based on cow contact voltage of greater than 0.5 VAC with a 500 ohm shunt on the meter, the electric utility installs an isolation system. At the same time additional grounding is often added to the farm to reduce the cow contact voltage. The farmer is also advised to add mitigation systems such as the equipotential plane.

The farmer may experience a number of results from these installations. There may be noticeable beneficial changes in cattle production, behavior and health. These changes may continue to be beneficial for a long period of time, or they may be temporarily beneficial for a week, a month or a year or more. Then, with no change in operation of the mitigation systems and with cow contact voltages below 0.5 VAC, the effects appear again, as serious as before any electrical mitigation was carried out.

When additional electrical measurements are made on the dairy farm, it is observed that certain electrical conditions tend to prevail. Even if electrical power is turned off on the farm, both alternating and direct currents are measured in conducting parts of the barn. Also AC electric potentials are present between two independent ground rods in the region around the barn. Both alternating and direct currents in conducting parts of the barn change as either 120 or 240 VAC loads are turned on. In barns where the problems are especially bad, alternating current in the range of 10-20 mA will appear in conducting parts of the barn when either 120 or 240 VAC loads are turned on. These conductors are not connected to either the secondary or the primary neutral.

Approximately 65% of the of the dairy farmers using an isolation system or other mitigation method experience no change or only a temporary change in the stray voltage effects. The changes resulting from mitigation efforts can also be detrimental. Adding grounding or installing an equipotential plane, for example, are options that are unlikely to cause any improvement in the problem; in fact, they more often aggravate the seriousness of the effects. Even though the problem has not been solved by any of these mitigation methods, however, the experience of the dairy farmer clearly demonstrates that there is an association between the effects on the farm and changes in the electrical system.

As the farm family continues to observe and analyze the effects on livestock, they learn to expect conditions to be worse when the cattle spend more time in the barn. The effects usually become more severe when ground moisture increases, when electric use in the region around the farm increases, and when there is an increase in underground installation of pipes or cables. The effects decrease when cattle spend less time in the barn and when there is a decrease in electrical usage near the farm Conditions usually improve significantly when primary grounding wires are disconnected.

Although the farm family has been preoccupied with the stray voltage effects on the livestock, eventually they take notice of the human health problems that are being experienced by the family members. Even though the family members recognize a connection between their health problems and the problems on the farm, their expert consultants continue to insist that it is impossible for stray voltage to have any effect on human health.

The operators of this typical stray voltage farm have not only experienced considerable financial losses, but have also spent thousands of dollars attempting to get the problem solved. They realize that when a farm is labeled as a stray voltage farm, it will no longer have value as a dairy operation. The family faces the prospect of losing their farm and their future.

CHAPTER XII

STRAY VOLTAGE MITIGATION

ISOLATION

Isolation is the most common choice for mitigating stray voltage. The electric utility decides the need for isolation on the basis of the magnitude of the cow contact voltages resulting from electric currents reaching the dairy barn by ways of the primary neutral. The magnitude of the cow contact voltage which determines the need for isolation is dependent on the specific utility. Many have selected 0.5 VAC as the minimum voltage for installing an isolation device. If cow contact voltages are less than 0.5 VAC, the farmer is informed that there is no stray voltage problem on the farm. Consequently a number of farms are not isolated eventhough they have documented the stray voltage effects and have not been able to find any other source of the problem. Many of these farms are forced to quit their dairy operation. In the preparation of this report approximately ten such cases were identified.

In addition ,126 cases with isolation devices were identified. The impact on the dairy operation after isolation is as follows: On 4 of the farms the problems became more severe, on 82 of the farms the isolator had either a temporary or no overall beneficial effect and on 40 of the farms there was a small to significant improvement.

In studying the individual cases it became clear that more than one electrical factor was involved. Especially for farms near natural gas and oil pipelines, DC transmission lines and sometimes AC transmission lines, the isolation devices were less likely to be effective. Most often if the farm is more isolated from other users or sources of electricity, the isolator is likely to be more effective. Unfortunately even these observations are not conclusive and exceptions occur. The presence of open neutral underground distribution lines complicate the picture.

EQUIPOTENTIAL PLANE

Only 11 farms using equipotential planes were identified. Farmers have in general received no help from the equipotential plane. Because farmers share information, there has been a reluctance to spend money on this mitigation method. The information for the 11 supports this contention. For 3 the problems became worse, for 7 there was no change and for 1 there seemed to be an improvement but a number of other changes had been made at the same time of adding the equipotential plane. In nearly every case a short term improvement was experienced but this condition did not persist. In order to continue milking cows on the equipotential plane, farmers discovered that it was necessary to disconnect all contacts between the equipotential plane and the primary or secondary neutrals.

ELECTRONIC GROUNDING SYSTEM

20 farms were identified that owned or had owned the EGS. The results experienced by the dairy farmers was mixed. For 3 farms the problems became worse requiring the removal of the system, for 9 there was either a temporary improvement no change in the problems experienced and for 8 farms there was some or a significant improvement for the dairy cows.

DISCONNECTING PRIMARY GROUNDING WIRES

Over the past number of years, farmers, in desperation, have disconnected the primary grounding on their farms and sometimes even off their farms. The information is limited for these cases because the farmers fear retribution for this action. In most cases the farmers have documented the changes associated with the disconnection of the grounds. In additional measurements have been made on these farms which demonstrates that electricity entering the earth at the primary grounding is reaching the barn. These measurements have demonstrated that not only the primary grounding on the farm but the primary grounding off the farm also contributes to the electricity in the ground.

Information has been obtained for 12 dairy farms where this action is known to have been taken.

CASE 1

Disconnecting the grounds were associated with an immediate increase in water and feed consumption, a longer term and steady increase in milk production, a decrease in the SCC and general overall improvement in health. In addition those working on the farm experienced an improvement in health. Upon reconnection all of the positive aspects of the disconnection returned. The adverse effects returned very quickly. Even with the grounds disconnected the problems were still not totally eliminated.

CASE 2

On this farm disconnecting the grounds improved the production and health of the cows but only continued for a short period of time.

CASE 3

The results of disconnecting the grounds on this farm were remarkable. When the grounds were connected cows were actually dying in their stalls, water and feed consumption were very low and all of the stray voltage problems were especially serious. When the grounds were disconnected the water and feed consumption went up immediately as well as the behavior of the cows improving. Milk production increased and SCC decreased, there was a general improvement in the health of the cows. For the people living on the farm there was also a clear and significant improvement in health. If the grounds were connected again all the effects reverted to the original severe state. When the grounds are connected, there are times when the farm family is forced to live elsewhere for a day or a few days until conditions improve.

CASE 4

On this farm the disconnecting of the grounds has an immediate and beneficial effect on behavior, milk production, SCC, water and feed consumption and general health of the animals. Within approximately one week after the grounds are disconnected. the benefits are no longer observed. This process can be repeated after the grounds are again connected for a period of time.

CASE 5

For this farmer the disconnection of the grounds was dramatic for both humans and animals. The water and feed consumption would increase immediately, the improvement in the behavior of the cows was significant and immediate and those working in the barn noticed an immediate improvement in their sense of well being. The production would increase and the SCC would decrease. The grounds were never allowed to be disconnected for a long period of time but it appeared as if the beneficial effects of the disconnection of the grounds would probably not continue indefinitely. Upon connection of the grounds the problems returned to the same level as before they were disconnected.

CASE 6

At the time of disconnection of the grounds, an immediate change occurred for both the animals and the people on the farm. Milk production increased and SCC decreased steadily until reaching a level never known on this farm during the time of dealing with stray voltage. The health of both animals and humans has improved significantly since the disconnection of these grounds.

CASE 7

This farmer experienced improvements from the disconnection of the grounds but not sufficient nor sufficiently long to save his dairy operation.

CASE 8

On this farm the beneficial impact was most noticeable when grounds associated with a nearby transmission line were disconnected. As for previous cases the benefits were associated with all aspects of the well being of both the cattle and people on the farm.

CASE 9

When all other electrical changes had been made and still no help for the animals or people, the farm disconnected the grounds. The beneficial effect in behavior of the cows and sense of well being of the people was immediate. The grounds were reconnected by the utility within a few days of disconnection so no long term effect could have been observed.

CASE 10

The problems became extremely serious on this farm for both animals and humans. The farmer disconnected the grounds and experienced immediate beneficial changes. The behavior, health and production as well as human health improved. This farm did not have a long period for recording the benefits because the electric utility disconnected his power.

CASE 11

On this farm survival for humans and animals required the disconnection of the grounds. Even some secondary grounding could not be connected. This farm had an unusual and unbelievable set of problems for both animals and humans which were unmanageable even with the grounds cut but incomprehensible if the grounds were connected.

CASE 12

This farm also has problems which can only be associated with electricity and electrical changes which are beyond comprehension. The farm family has lived and does on occasion live off the farm for periods of time as a means of survival. The disconnection of grounds is necessary on this farm simply to continue operation. The disconnection, however, does not solve the problem but does provide some relief.

NEUTRALIZING DIRECT CURRENTS

On five farms 12 VDC batteries have been used to mitigate the behavior, production and health effects. In all cases short term positive changes were accomplished. In only one case was the improvement significant over a longer period of time. The connections were made differently on each farm. Only by trial and error were the most appropriate points for connecting the batteries determined. Each farm is different.

ELECTRICAL ISOLATION FROM THE EARTH

Farmers discovered that raising animals off the floor with electrically resistive material separating the animals from the floor had beneficial effects. Two specific methods were used. One was simply allowing the buildup of a straw pack for dry cows and calves and a second was deliberately placing the cows in a trailer which was electrically isolated from the earth and some distance (1-2 m) above the surface. Both of these method were quite successful in reducing the loss of calves and improving the health of dray cows. The straw pack method was used for calves at the old University of Minnesota dairy barn in St. Paul. One dairy farmer had recorded success in significantly increasing milk production and improving cow health by using a trailer electrically isolated from the ground. Other dairy farmers had used this method for improving calf survival and growth. Eventhough the positive impact of this mitigation procedure is sufficient to encourage its use, the cost both in dollars and time is too great to make it realistic on a commercial scale.

This particular method of mitigation did not eliminate the exposure of the cows to all electromagnetic fields. The 60 Hz magnetic fields, for example, could reach the animals.

TRAP

The trap was developed by Vulcan Engineering for the purpose of controlling ground currents on dairy farms. The determination of trap location is based on the measurements between a set of five copper clad steel grids which are buried in the ground. The currents measured between the grids provides the information the major directions of current in the flow. When the direction of major current flows in the earth is determined, a wire grid is dug into the earth between the current flow and the farm. The grid is a series of wires which appear to be able to create a resonant effect for 60Hz and its harmonics. When functioning as designed, the grid absorbs the electrical currents in the resonant circuit and actually become hot. Again when functioning as designed grass does not grow above it (this may be partially caused by the salt used) and cattle will not cross the grid.

Of the five farms known to have a trap, three experienced an unusual improvement for both animals and people. The length of time that these improvements persisted ranged from a few months to approximately one year. As additional traps on different sides of the farm have been added for two farms, there were renewed improvements. Again these improvements did not persist for more than a few months.

The fact that this approach has had some success suggests that the current traveling through the earth is accessing the farms. It is important to point out that the traps are not connected to the neutral of any electrical system. The trap is a free standing unit not connected to any energy source or anything else.

CHAPTER XIII

SUMMARY

THE SHOCK

In considering the general nature of the stray voltage problem, it is important to begin with a fundamental principle. A well known incident that occasionally occurs in any electrical system is a ground fault by which a bare 120 VAC wire touches the earth. The electrical result of a fault is current traveling between the bare wire touching the earth and the neutral/ground.. In the dairy operation this current can and does reach the barn and the cow environment when the fault occurs on the farm or even at a nearby location. Ground faults are the classic and historic source of ground currents and also the classic and historic cause of stray voltage effects on dairy cows. The ground fault is responsible for ground currents and these ground currents enter the cow environment. Whether the electric currents from the ground fault primarily cause the animals to be shocked or cause them to be affected in other ways has never been experimentally determined.

From historic records, the ground fault is probably the fundamental reason for the origin of the stray voltage problem. The effects on dairy cows which have been associated with ground faults are the same as those identified today as occurring on stray voltage dairy farms. This correlation has been known and experienced in the dairy industry for nearly 50 years. When a farmer requests assistance for identifying a stray voltage problem, the fault is usually the first cause considered.

The decision process connecting the fault and effects determines the approaches for understanding how electricity might interact with the cows. The basic model of interaction was connected to the electrical shock. Except for some Eastern European research, very little information was available relating other models for interaction at the time of first encountering stray voltage. The dairy industry and the research institutions chose to use the shock model to explain the effects of stray voltage. Consequently up to the present the shock model has prevailed and has been the basic model for all investigations, mitigation and research. Although research institutions may have considered other models, none has been forthcoming in the dairy industry.

The ground fault can introduce sufficient currents into the cows environment to cause the cows to be shocked but the basic impact of ground faults is to cause currents to flow in the earth and produce ground currents. These ground currents can, of course, increase the cow contact voltages and the neutral to earth voltages which can provide opportunity for the cows to be shocked in the barn.

For at least ten years, dairy operators have been able to eliminate the potential for cows to be shocked in the dairy barn but have not been able to eliminate the effects of stray voltage. A number of observations made by dairy farmers can be used to evaluate the feasibility of using shock model to explain the stray voltage effects. The possibility for shock is associated with contact between the floor and a conducting member in the barn. These conducting members are usually stall dividers and water cups. With the exception of the water cup, the cow rarely needs to touch any conducting member in the barn and its only contact in the barn is the floor. If water consumption were decreased because of receiving a shock, there could be health and production problems. One would not anticipate that the cows would dance in their stalls, for example, if their water intake were low. Surprising is the fact that cows will frequently press their noses tightly against water cups, stall dividers, and curbing. While the cows are engaged in such an action they will stop dancing in the stalls. Again when removing their noses from the metal, they will begin dancing. Electrical changes in the cows environment have been associated with this action. If the shock is what the cow is avoiding, this action is not logical.

The type of barn should be able to predict the impact of the shock model because the parlor is quite different from the stall and for wooden stanchions. Stray voltage effects are common in all types of facilities from the old barns constructed from wood to the most modern parlor facility. There has been no documented differences in severity in stray voltage effects related to barn type.

There is sufficient information available today to suggest the need to expand the modeling of stray voltage problem. One of the purposes of this report is to suggest other models. Following some general summary statements models will be discussed.

GENERAL

There are at least two basically different effects that EM energies can have on living organisms. One effect is to regulate the spatial orientation and the rhythm of physiological processes. A second effect is changing behavior and vital processes. Both natural and technologically produced EM energies can produce effects. For example, natural earth and atmospheric EM fields may be basic forces synchronizing the rhythms of biological processes. The regulatory system of living organisms seems to respond to variations in these apparent major controlling natural EM fields. One may expect technologically produced fields to interfere with an organism's regulation system because these EM energies are of entirely different frequencies and intensities from the natural ones. Therefore, introduction of these foreign EM noises into the organism's environment have potential for producing harmful effects.

EM energy interact with living organisms in a number of possible ways. Photon absorption is especially important at higher frequencies. Induction currents, mainly from magnetic fields, capacitive currents from electric fields and contact (resistive) currents are important for lower frequencies and direct currents (DC). Magnetic and electric fields may also interact directly with or independent of induced currents. For example, electric fields cause currents in conductors. The biological systems have conducting regions, and within these regions there are currents and current densities to consider when they are exposed to either an electric or a magnetic field. When exposed to a higher frequency EM field, the electric field component generates an electric current of the same frequency, and that current is concentrated nearer the surface of the conducting region. For these higher frequencies, the effect of the magnetic component is considered less important because, alone, it produces a much smaller current in the same conducting region. It is possible, as well, for the magnetic field to produce intrinsic effects apart from the effects of the current induced into the conducting materials.

The earth carries about 65% of the return current in the 60 Hz transmission/distribution system. As a consequence, electric current is in the earth as well as in water pipes, sewer lines, ground wires or any other conducting materials in the earth. Everything touching the earth, including all structures such as buildings or parts of buildings, carry 60 Hz AC currents because the uncontained current is free to seek the easiest path to its destination. The presence of currents in all materials has become normative, but it certainly is not appropriate. This condition is essentially true for all EM sources. Whether the source is micro or radio wave transmission, 60 Hz AC or DC, each uses the earth as a reference in its ground connection. Therefore, the earth is connected to all sources of EM energy, and currents associated with each of these sources is in the earth. EM fields and currents in the earth, whether of natural or human origin, will access most living organisms because these organisms touch the earth or some solid material connected to the earth. As currents and fields in the earth change through natural fluctuations or human activity, so also will change the currents and fields experienced by living organisms in contact with them. There are EM energies in the earth and atmosphere which are naturally present and originate from a number of sources. EM energies from technological activities add to or subtract from the natural fields and currents and increase the complexity of EM fields and currents. These changes have significantly affected the level of EM exposure for living organisms.

Since the EM profile of both the atmosphere and earth have changed, living organisms who live at the boundary of the atmosphere and earth are experiencing new and greater currents and fields interacting with their bodies. For example, the floor of a building can be that boundary so that changes in either the EM energy in the floor or the region above the floor can affect the currents in living organisms in contact with the floor. It is also possible for an interaction to occur even when the organism does not make contact with the floor. The EM fields caused by charges and currents in the floor can induce currents in living organisms. So additional currents and fields in the earth can appear as additional currents and fields in living organisms. Just as currents exist and ions migrate in the earth, so can currents exist and ions migrate in living organisms in contact with the earth. It is now nearly impossible to locate a region in the world with only the natural EM fields because of the proliferated use of EM energy. As a consequence, it is more difficult to research the possible effects of EM energy because of the problem of identifying an unaffected or natural control space.

The human body is a complex array of materials with various electrical and magnetic characteristics. Materials range from good conductors, such as liquids, to good nonconductors, such as the fibrous materials. Other materials include semiconductors and combinations of semiconductors which can act as diodes. Bones have piezoelectric characteristics. In the bending of bones electrical potentials and currents are generated. The reverse effect also occurs, in that bones bend as electrical currents pass through them. The heart, of course, functions by electrical impulse. The entire nervous system transmits information through pulses of electrical energy. Sensory perception, such as vision, is the conversion of one form of EM energy to DC that is transmitted and read in the central nervous system.

When metal from implants is dissolved in tissue through corrosion, it can be carried off and encapsulated in fibrous tissue. Such ions as sodium, calcium and potassium are positively charged, and as they move through the body they create an electric current. These ions can be carried through the body by moving fluids, or they can be transported as if they were part of an operating battery creating an electric current. Electrical polarization of tissue produces electric fields, the only known force capable of producing long distance structural effects through an existing tissue matrix. The resistivity of the various areas of the body determines the electric current densities. In the regions of the body with low resistivity larger currents will be present in regions of high resistivity smaller currents will exist. Tissue and fluid resistivities depend upon frequency. Cells are dielectrics which have increasing resistivity with lower frequencies. For example, in some body materials resistivity is different in different directions, suggesting that it is non-isotropic material. Resistivity seems to be quite variable, but the appearance of variability could be an artifact of the measurement process.

Physiological effects on living organisms have been correlated with small direct currents, extra-low frequency (ELF) fields at volts/meter, low power radio frequency and microwaves, and combinations of these. Radio frequency fields modulated at ELF's, for example, demonstrate significant effects because the radio frequency fields appear to be the best carrier for most effectively exposing cells to the ELF fields. There is no clearly defined lower limit at which EM energy affects organisms. However, the levels at which effects are observed continues to go down. Research shows that different results occur under cellular or segmental exposure as compared to whole body exposure. Sometimes effects are frequency dependent and sometimes frequency independent. Pulsed EM energies seem to produce greater effects than steady state energies. Higher frequency EM energies can affect molecular states which may cause a biological or health effect. Lower frequencies likely interact more as separate magnetic and electric fields. Each can produce electric currents in the conducting areas of the organism. These currents can produce effects either by polarizing charge at cell boundaries or by transporting ions through the electric circuits in the body. DC can cause negative effects under some conditions and positive effects under others. In some cases magnitude windows characterize the effects in such a way that greater effects can occur at low intensity levels and not at higher.

If biological processes depend on electrical signals for appropriate functioning, the magnitudes of 60 Hz fields, as well as higher frequencies produced in human technologies, can overwhelm the natural signals. Natural electric fields at frequencies above 50 Hz are very small, on the order of 0.001 V/m. Because of modern technology, the AC electric fields in the environment of living organisms are much higher than they were prior to the industrial age. At some level these fields may produce environments that exceed the coping capabilities of living organisms.

There is very little research to guide theory and model construction for some types of EM exposure. Among these exposures are the effects of direct current electric fields, the effects of transients, and the effects of continuous currents at levels similar to those that are naturally present in the body. Living organisms rarely experience only one external source of EM energy, and for now research results do not help in analyzing the effects experienced from combinations of these parameters—synergistic effects. Models based on physical principles, used successfully with non living systems, are not adequate to explain physical changes in biological systems. Living organisms apparently involve interaction mechanisms that are both nonlinear and interactive (Szent-Gyorgyi 1960). Among biological systems, a small gradient over a long period of time may produce significant effects even when the potential for change seems small.

We have suggested the term electromagnetics ecology for the study of the overall interaction of environmental EM energies with living organisms. The development of electromagnetics ecology as a viable area of study will require addressing a number of issues.

One issue is the importance of considering the multiple sources of EM energies. The design of our electric transmission/distribution system is especially important. Over the North American continent the earth is used as a major current carrying conductor in the system. Because dairy farms are so well grounded, electricity can and does reach these farms as it travels in the earth. For population centers electric current in the earth is found concentrated in water pipes and other conductors in contact with the earth. These electric currents are not limited to wires and are free to interact with humans and animals whether in schools, homes, offices and factories or on dairy farms.

The tendency to separate stray voltage effects on the dairy farms from effects associated with transmission lines, electric blankets, and transformers cannot be supported. In reality it is the same electricity interacting with humans and animals, whether it derives from cellular phones, police radar or any other electrical usage. There certainly can be some differences in the effects from each source, but there seems to be a general effect that we can best refer to as "stress like."

Research methodologies which can deal with multiple effects from multiple sources will be important in the investigations. In addition the possible effects of continuous currents at levels similar to those that are naturally present in the body requires careful study. Exposures of greater magnitudes may not necessarily produce the greatest effects. Living organisms rarely experience only one external source of EM energy, and at present research results do not help in analyzing the effects experienced from synergisms.

No suitable theories and models emerge from extant literature to guide ameliorative action in dealing with undesirable EM effects. The gap between theory and application continues to allow an informational void that is in many respects costly for living organisms. There may be a common set of health effects that can occur because of the interaction of any form or combination of forms of externally produced EM energies with the natural fields and currents in the body. This certainly does not exclude some of the known specific health and biological effects, but in addition there may be a mechanism which fits with more recent understanding of the functions of EM currents and fields in the bodies of living organisms.

It is possible that research results will only be reproducible when more of the individual inadvertent EM exposures in each research laboratory is taken into account. Two research laboratories could not be expected to have the same ambient EM environment. That ambient state is where the control group lives. In laboratory research using animals, it is also important to determine the EM environment under which the animals were raised. The accumulative differences between individuals do affect their sensitivities to such factors as EM energies. Survival of experimental animals may be determined more by the EM environment in which they were raised than by their inherent sensitivity to EM energy.

There is a political side to these knowledge shortfalls. The establishing of correlations between health and EM energies has far reaching impacts. The electrical industry, whether associated with delivery or emission of EM energy or with the construction or marketing of electrical equipment, is likely to be required to undergo significant changes. In many cases organizations with the highest vested interest control the acquisition and dispensing of information related to the effects of EM energy. The public often feels threatened by any possible loss of electrical service or any other perceived retribution. In addition, individuals may face choices of relocating their residence, changing employment and revising lifestyles in order to reduce exposure to EM energy. Each can represent economic costs which may be beyond available resources. Consequently, there may be a public reluctance to discuss perceptions of effects of EM energies on health and/or the health of livestock. Many adversely affected persons also feel that neither the electrical industry nor governmental agencies are willing to support a serious program to discover cause and effect relations suitable for developing solutions.

INTERACTION MODELS

Models exist for objects as large as quasars and as small as atoms. Models have also been proposed which portray energy forms. The interaction model attempts to describe the processes occurring as energy and objects interact. Two interactions which have special significance in this research involve EM energy in the earth and EM energy in living organisms.

THE EARTH AND ELECTROMAGNETICS

The earth is made up of diverse materials which differ in electric and magnetic properties. These differences influence the electrical and magnetic dynamics of the earth. The magnitude of electric currents in specific regions of the earth, for example, is greatly affected by the electrical conductivity profile of the earth materials. The sources of natural EM energy in the earth result from electrical activity the atmosphere, the ion currents brought about by the rotation of the earth and induction currents from magnetic field variations produced by solar charged particles. The distributions of these EM energies create the basic natural EM dynamics of the earth.

Dowsing—a Tool for Detecting EM Distributions:

There is evidence to suggest that dowsing can be used to detect EM energy in the earth. Throughout history there has been research demonstrating that the human body senses a changing magnetic field as it moves through a magnetic field anomaly. In the case of dowsing for water the natural electric currents in the aquifers produce a variation in the earth's magnetic field around the aquifer. Those individuals who are especially sensitive to the changes in magnetic field will respond in some way as they walk through the magnetic field anomaly associated with electric currents in the water. Obviously these changes in magnetic field are very small resulting in an unconscious internal effect that is apparently visualized by using a prop of some type. Historically the prop has been a tree branch or a pair of conductors bent into the shape of the letter L. Electronic instruments do not appear to be sufficiently selective in their response to the specific change in magnetic field to measure what is sensed by humans.

Dowsers have recognized, while searching for water, that materials other than water carried electric currents, and that magnetic materials in the earth also could produce magnetic field anomalies. These factors have influenced the success of the dowser but also have encouraged different applications of dowsing. The concept is applied by employees of city and state water departments for locating buried water lines and by employees of electric utilities for locating underground electrical cables. The magnetic field anomalies resulting from electric currents in the pipes and cables can be detected by the dowsing methodology, and no expensive equipment is required.

Another application of the dowsing technique is for the purpose of identifying the ley lines in the earth. The state of the earth before the additions of industrial EM energy has been described as a network of lines of EM energy within the earth (Leviton 1989). Historically a segment of society, usually associated with the artistic community, has had an interest in the ley lines of the earth because of the sense that they are associated with human well being. Ley lines are detected by dowsing methods and are considered to be regions of electromagnetic energy in the earth. Public interest seems to acknowledge the value of knowing the locations of the ley lines in the earth when the Seattle Arts Commission funded a project to locate the ley lines throughout the city of Seattle (Leviton 1989). There may be other applications of the dowser methodologies, but this diverse group certainly encourages a study of the significance of information obtained through dowsing.

Natural Conducting Paths:

Certainly the fact that the earth is a diverse conductor suggests the possibility of a well developed system of electric current paths within the earth. These current paths would be the primary carriers of electric current in the earth. They are primary because they most likely represent regions of normally highest electric conductivity. Within the context of the ley line model, these conducting paths would be the ley lines. Knowledge of earth materials predicts that underground water bodies would play an important role in electrical conduction. Because the earth is continually evolving, one expects some variation in the location and the intensity of the earth's ley lines. Within this model the ley lines may also have a connection with electric currents in the atmosphere. As mentioned previously, the atmospheric electric field drives an electric current between the atmosphere and the earth. Under fair weather conditions the current flows to the earth whereas under stormy conditions the electrical currents can either go into the earth or out of the earth depending on the electrical charge at the base of the clouds. Surface conductivity determines the locations of greatest interchange of electric current between the atmosphere and the earth. These points may well be the beginnings or ends of the ley lines.

The Effects of Technological Growth on the Conducting Paths:

Electrical conductivities within the earth have changed in the era of industrialization. Conducting materials such as natural gas and oil pipelines and electric cables have been buried in the earth. Railroad tracks have been laid on the earth. Mining operations and drilling for oil, natural gas, and water have also affected conductivities. Consequently in many regions of the earth the natural currents have had to adjust to those changes in conductivity. The adjustments include changes in the locations and intensities of the ley lines. Changes also occur in the electrical conductivity on or above the earth's surface, such as in steel buildings or structures with steel embedded concrete.

Imagine for a moment the additional electrical currents which have been added to the circuits in the earth as a result of industrialization. Any calculation of these currents in the earth is complicated by an inability to know how the earth materials affect the characteristics of this EM energy. The relative phases of the currents in the earth will be especially important in determining electric current levels at specific points in the earth. The largest addition is the 60 Hz electric current which results from the use of the earth by electric utilities as a current carrying conductor. Radio transmitters also use the earth as part of the antenna which connects the circuits in the earth to Rf EM energies. In addition, over the years concern over military defense of the country has led to the utilization of the earth for transmitting low frequency signals to submarines and other military equipment. The perceived need to connect all electrical equipment to the earth for safety reasons has added many sources of EM energy to the circuits of the earth. If the ley lines are the regions of greatest electrical conductivity, one would expect that much of the technologically produced electrical energy would travel in the ley lines rather than in other areas of the earth. The magnitude of the technologically produced currents dwarfs that of the natural currents at most times, except at specific locations during thunderstorms. Overloading the circuits in the earth can lead to changes in these circuits such as enlarging those in existence and/or adding more circuits. Overloading the circuits will cause the currents to spread more extensively so that currents will be present in all regions of the earth. The detection of the natural ley lines in the earth has now been complicated by the effects of the additional currents in the earth. Dowsing methods may not be able to distinguish between natural and technologically produced currents. Thus ley lines may become indistinguishable from other current carrying paths in the earth.

Measurement of Earth Current Flow:

Historically currents in the earth have been measured by placing three specially designed rods in the ground which would simultaneously provide a measure of the electric currents in the North-South and East-West directions. These electric currents are DC with low frequency oscillations caused primarily by the ion fluctuations in the upper atmosphere. Measuring these same currents today has become a formidable task. The 60 Hz currents in the earth overwhelm the natural currents making it difficult to recognize the natural currents. Because natural 60 Hz currents are nearly nonexistent, all 60 Hz currents that are measured can be assumed to be from technological sources.

Although the existence of ley lines has been already established by the dowser, the scientist requires reproducible measurements such as those provided by electronic meters to validate the existence of ley lines and to use them as a basis for further understanding. Using the observation of two crossing rods cannot give numbers which are required for computer modeling and mathematical equation. In principle the changes in magnetic fields experienced by the dowser could be assessed by measuring the electric current induced in an appropriate conductor or by measuring the force on charged particles moving through the magnetic field. Instruments can be built to measure extremely small magnetic fields and changes in magnetic fields for either of these techniques. The problem encountered with electronic devices is to separate changes in a magnetic field that one would like to measure from all the other changes in a magnetic field that are encountered in the measurement environment. At a specific location the earth's natural magnetic field is nearly constant and DC in character. Direct currents in the conducting areas of the earth such as aquifers produce small DC magnetic fields which add to or subtract from the natural magnetic field of the earth. These additions or subtractions are the anomalies which apparently create the response of the dowser and the rods. Electronically distinguishing the anomaly from the natural field is a significant limiting factor for measuring the magnetic field produced separately by direct currents in the conducting areas of the earth.

Although indirect, one possible means for electronically locating the ley lines is to measure the 60 Hz magnetic field. If the EM model of earth can be characterized as having an electronic circuitry with preferred regions for current flow, called ley lines, the 60 Hz currents are also concentrated in the regions of the ley lines. These 60 Hz currents produce 60 Hz magnetic fields, and these magnetic fields can be measured by electronic instruments. The 60 Hz magnetic field produced by the 60 Hz electric currents are unique to technological production and can easily be distinguished from magnetic fields naturally occurring in the earth.

Galvanic Cells in the Earth:

Another important characterization of the earth's EM energy involves the interaction of the EM energy with earth materials. In the earth are natural galvanic cells that can be produced by differences in chemical composition at different points in the earth and by migration of ions through water. A galvanic cell is similar to a flashlight battery. These galvanic cells can be sources of low level DC in the earth. Galvanic cell production is enhanced both by adding solid conductors to the earth and increasing the ionic content. The necessary components for the galvanic cell are two different metals with a suitable ionic path between them. Steel posts, steel pipelines, copper electric cables, copper ground rods, etc., are buried in the earth as part of the industrialization of the world. All of these materials, as well as many chemicals added to the environment, create a new set of conditions for the galvanic cells. One consequence of these changes is the corrosion of buried metallic materials. Part of the process in the galvanic cells is the migration of the metal ions from the solid pipe or cable (commonly called corrosion). The technological solution has been the addition of anode fields around the buried conductors. The anodes are sacrificed rather than the buried cable or pipe. This is called passive cathodic protection and essentially sets up galvanic cells or DC in the earth opposing the pipe corrosion process.

AC in the earth certainly is interacting with the earth materials. One observed interaction is the rectification of a portion of the 60 Hz and other AC to direct currents. Materials in the earth, such as water and combinations of conductors and semi-conductors, can partially rectify the AC. Another observed interaction involves the AC on the metal conductors buried in the earth. Any oxidation of the metal conductors or coatings on the conductors creates a rectifier. The rectification of the AC on the conductors, unfortunately, not only produces an additional DC but increases the corrosion of the conductors. In addition to the DC cells, associated with chemicals and metallic conductors in the earth, the presence of AC increases the requirement for cathodic protection to avoid the corrosion of the conductors. This additional current decreases the effectiveness of the sacrificial anodes. To overcome this difficulty, electronic DC power supplies are used that basically add a direct current to the conductor. This procedure is called active cathodic protection. The negative side effect of cathodic protection is to add another source of electricity to the earth to overcome the AC which is already in the earth. The DC is quite free to travel great distances in the earth. This may solve the problem of conductor corrosion, but it creates another problem by adding DC to the earth.

Effects of Galvanic Cells in the Earth:

AC in the earth can be rectified to DC by earth materials. By means of rectification or other processes in the earth it is possible that the natural chemical cells can be driven or enhanced. The cells are likely driven more vigorously if DC is present from sources such as buried natural gas or oil pipelines, DC transmission line return or cathodic protection rectifiers on the pipelines. Driving of the cells or DC resulting from all of the known sources will undoubtedly affect the electric charge state in various regions of the earth. The process may be compared to the charging of a battery. One area of the cell will become positively charged and another negatively. Ion migration, and/or chemical reactions, are the most likely charging mechanisms. One could speculate as to how these direct currents might affect the mineral content of the soil, for example, the migration of metal ions from the soil to aquifers or water bodies.

Currents in the earth can also change the electrical character of materials in contact with the earth such as floors and walls of buildings. The model of the electric cell suggests that the electrical charge of the floors and/or earth can differ in polarity and intensity according to the location of the electrodes of the cell. It is a simple step to expect also that direct currents in the earth are affecting concrete floors and walls of buildings as the electric charge of the concrete is changed as a result of the forced migration of ions away from or into the concrete. Of course, the neutral of the distribution system will be a part of earth circuits since it is connected to the earth through ground rods at so many locations.

LIVING ORGANISMS AND ELECTROMAGNETICS

State of Model Development:

A number of models have been used over the years to suggest how EM energies affect living organisms. As discussed previously, two models were most often used in the United States to assess EM effects. One is based on the shock current. If a living organism experiences a short duration current through its body of sufficient magnitude to cause a shock, which is a perceived response, an effect can occur. Smaller currents are assumed to cause organisms no negative effects. A second model is associated with the effect of temperature increase in an organism as a result of exposure to EM energy that is absorbed by molecules. The assumption is that effects are produced only if the energy absorbed causes an internal temperature increase sufficient to affect the organism.

Eastern European research proposes a general model suggesting that EM energy interacts directly with the electrical system of the living organism. The effects of radio and micro wave frequencies are referred to as the microwave syndrome which is much like the stress syndrome. A model developed in Sweden associates effects with appropriate direct currents in the electrical circuits of the organism. Various additional and more specific models are associated with synergistic effects from two or more EM energies and their effects on specific organs such as the pineal gland.

No suitable model exists in research literature to account for the observed and perceived effects found in field investigations. In most investigations, the magnitudes of the EM parameters in the space occupied by humans and animals are small compared with those predicted by accepted models to be able to cause the observed health effects. More recent research involving EM energies and health effects, however, is pointing toward effects at levels below those considered harmful by earlier models. More recent research also reveals a broadening of models relating cause and effect so as to include non-traditional mechanisms. At present, however, there is no scientific consensus concerning health effects from EM energies. In general, research investigates a single form of EM energy, such as the 60 Hz magnetic field, as it may affect living organisms through a very specific mechanism with a specific health effect, for example, cancer. Most certainly the fewer the variables in a study, the more easily statistical significance can be established. However, as the exposure to environmental factors increases, evidence is mounting that points to a set of causes and a set of effects which may be quite difficult to separate. For example the causes might be a collection of chemicals along with a physical factor such as EM's and noise. The effects might be all of or any one of the health problems connected with stress.

Suggested Model:

Measurements made investigating problem areas, surveys of affected people and industries and a study of relevant literature have led to the development of the following interaction model. This model is macroscopic and general. A physical analogue is used to illustrate how this interaction model works.

Physical Analogue

:The body of a living organism can be compared to a complex electronic circuit which is dependent upon specific electric currents, potentials and fields, as well as magnetic fields, in order to function as designed. An external energy source, with the appropriate format, is provided for the circuit so it can perform its purpose. The circuit, including its energy source, becomes a viable operating system that functions as long it has energy and the parts function as designed. Information is, in general, provided to the circuit by a variety of means, and the circuit will perform a task and possibly produce other information. In diagnosing problems in a physical circuit, some measuring instrument is used to determine the electric currents, potentials, resistances and waveforms. If the system is functioning as designed, these measured parameters must lie within prescribed boundaries, and if they differ from the allowed tolerances, a repair or correction of the system is required. It is possible for some correcting to be performed by the circuit itself, by using appropriate feedback mechanisms. In general, if the circuit is not performing as designed some repair is required. Depending upon the sensitivity of the circuit to outside EM influences, certain shielding is required. This protection or shielding has become a more important requirement. Greater complexity and sensitivity to EM radiation and noise requires more physical shielding. Greater amounts of EM energy reaching the electronic circuits through the grounding paths requires electronic shielding. Electronic circuits, for the most part, can be understood, and the external interferences can, in principle, be controlled.

The Living Organism:

The electric and magnetic nature of living organisms such as is exemplified in EKG and EEG monitoring has been recognized for years, and specific EM characteristics are used to determine a person's state of health. In a much more complex way, a living organism has EM characteristics similar to an electronic system, and in fact, has components that perform functions similar to components in electronic circuits. Many of the electrical circuits and components are still to be identified and understood, but they are known to exist. Enough is known to at least speculate that what happens electrically in living organisms may be modeled by comparing these systems with electronic systems.

An important difference in the circuits of living organisms is their ability to create their own electrical energy. In healthy living organisms a feedback mechanism automatically repairs a problem in a system. Of course, external assistance is provided when a system or component is not able to repair itself. Most often in Western cultures the repair is accomplished through providing chemicals or performing surgery. Whether the electrical systems or something else has malfunctioned, the treatment puts the system back on track. A living organism receives energy mainly from chemicals in the form of a food which the system processes. As the food is processed both the chemical and electrical systems can receive energy. The chemical and the electrical characteristics are closely interconnected. Chemical changes produce electrical changes, and electrical changes can produce changes in the chemistry. For example, chemicals in processed food provide the appropriate energy that charges batteries in order that the electrical circuits can function. It seems natural that supplemental chemicals could affect the chemical balance of the body and also affect the functioning of the electrical circuits. As a consequence, appropriate mineral supplements provided in the diet could actually be the necessary ingredients for improving the electric current flow in the circuits of the body or the electrical potentials at the surfaces of cells.

Interaction between Living organisms and EM Energy:

It is probable that circuits of the living organisms interact with the natural EM energies in their environments, either receiving information or energy from them or attempting to exclude their influences through appropriate shielding. Faraday shields are often provided for sensitive electronic circuitry. Living organisms most often rely on their own natural components to provide shielding. Even so, changes in the natural EM fields do have their influences on living organisms. Because living organisms are internally electrically driven, mechanisms exist for external EM energy to interact with the organism's circuits. A number of mechanisms have already been suggested. EM energy interacts with the pineal gland and affects the manner in which it functions. Laboratory research has demonstrated a resonance effect connecting ELF EM energy and the DC magnetic field exposure with calcium efflux from cells. EM exposure can affect the electric potentials on cell surfaces. Electric currents can increase or decrease bone growth. An electric current is used as an anesthesia in dental practice. Indeed, a sufficient number of research findings suggest that living organisms are influenced by their EM environment. Electric fields can influence the surface potentials of organisms which in turn can affect the currents in the circuits connected to the surface potentials. Magnetic fields can induce currents directly into the electrical circuits of the organism. Contact with electrical sources, including the earth, can create current flow through the organism.

CHAPTER XIV

RECOMMENDED RESEARCH PROJECT

The purpose of this research is to develop protocol for measuring electromagnetic parameters, identify health parameters, utilize the mobile barn for comparing electromagnetic (EM)parameters of an elevated space to that of a conventional barn and to compare and correlate health and production data of a selected group of dairy cows in the two spaces.

The proposed project will be divided into two sections. The first is to design and construct the Mobile Experimental Barn (MEB) and develop equipment and protocol for measuring the EM parameters. The second phase is a continuous monitoring of EM parameters and the behavior, health and production effects among the dairy cows. The EM parameters and the health, production and behavior records of the cows will be analyzed comparing the two sets of cows and searching for correlations.

Developing the MEB as a major research tool for studying the stray voltage problem results from pragmatic experimentation and consequential information provided by dairy farmers. Dairy farmers have experimented with housing animals in trailers isolated from the ground. Their findings indicate a dramatic improvement in the health and production of dairy cows and the survival and health of calves and hogs when housed in the elevated trailer. In addition, farmers have determined that the electricity in the earth associated with the overall distribution and transmission grounding system can have a significant influence on the health and production in the dairy operation. Specifically, the MEB would be constructed to test the effect of housing and milking a set of eight cows in a more or less earth EM field-isolated facility.

The MEB would be a conventional wood structure, 14' x 40', and would be built upon a reinforced mobile home frame. It would contain eight tie stalls to house eight milk cows, and the equipment would be comparable to that of a conventional barn. The barn would meet the requirements of a Grade A facility so the milk from the test cows could be sold.

There would be minor changes for test purposes. For example, individual drinking cups would be equipped with water meters to monitor water intake. The floor would be steel with divisions in it to aid in experimentation. The MEB would also have a metal ceiling (totally electrically insulated from the rest of the structure) to assist in the creation of EM fields.

Present knowledge suggests the following parameters be measured: a) Alternating current (AC) magnetic fields and static magnetic fields; b) AC and direct current (DC) electric fields; c) Electric currents accessing the cows; d) Air ions; e) radio and microwave radiation fields. As an additional body of information, the meteorological parameters should be monitored at the research site.

An entire data gathering system has been developed and tested with the exception of sensors for measuring DC electric fields. In addition, TERF and its consultants have had experience preparing appropriate measurement protocol and would prepare one for this research project.

Sixteen dairy cows will be selected for the research. They will be chosen in pairs, each pair having very similar health and production histories. One set of eight will be housed in the MEB and the other eight in the conventional barn for a full lactation cycle. The cows in each facility will be managed in a comparable manner. They will be tested for diseases and problems known to have an impact on health and production. Equipment used in the dairy operation will be carefully checked, compared and maintained throughout the research project.

An example of a stray voltage effect is uneven milk let-down of the dairy cow. Although a biological reason may exist for this effect among dairy cows, the more likely cause is a physical parameter. Behavioral changes, because they can have a physical cause, are also to be carefully analyzed and compared. Production, health and management records are to be maintained for each individual animal in order to be able to compare other parameters in the event that any one correlates with EM parameters.

A carefully screened "problem" farm will be selected as the location of the research. A concerted effort will be made to find a farm which has a barn where reliable and reproducible measurements are possible and which is physically comparable to the MEB. The entire operation (i.e.: nutrition, exercise, etc.) will duplicate the conventional, except for its electrical isolation from the earth. The MEB will be set up on the selected farm in close proximity to the conventional dairy barn. It will, however, be established, as much as possible, as a free standing unit. The barn will be raised off from the ground and electrically insulated from EM fields and electric currents which either originate with the electrical power system itself or are present in the earth as a result of the complex transmission-distribution system.

The research project is projected to span a period of two years and will be divided into two phases as discussed previously. The first six months will be the set-up phase. First, the barn will be designed and built and equipment assembled. Second, the barn, monitoring equipment, and data collection system will be installed and tested.

The second phase will span 18 months extending beyond an entire lactation cycle of the cows. During this phase there will be a continuous monitoring of EM and health, production and behavioral parameters which are to be correlated with each other and with the records on health, production, and behavior of the cows. The data collected will be statistically analyzed to determine the degree of correlation between EM parameters and health, production and behavioral effects. Later in this phase, EM parameters in the MEB will be systematically changed in order to examine possible causal relationships to physiological and behavioral effects.

The investigative team is to consist of qualified persons experienced in multidisciplinary research. The team is also required to be familiar with some aspect of the stray voltage problem. For problem solving research involving both biological and physical systems, and in order to establish a model relating physical and chemical effects on biological systems, a multidisciplinary approach is mandatory. In addition, professional people from a cross section of disciplines offers a check and balance, and provides for greater objectivity. The primary team will include: a) Dairy farmer; b) Electrical/Electronic engineer; c) animal physiologist; d) Physicist (EM fields); e) Veterinarian. Other specialists will be invited to participate as needed.

The research team will establish the research protocol, monitor research progress, and analyze, interpret, and report the results. In order to most effectively accomplish the proposed objectives, the team and its associated consultants will be required to meet regularly as a group and discus specific research problems with the consultants. The research needs will determine the frequency and time of meetings with the basic research group and with consultants.

CHAPTER XV

FINAL THOUGHTS

The solution to the problem is, of course, the desire of the farmers and everyone else in the dairy industry. To suggest a solution at this time is inappropriate. For the stray voltage problem the first requirement is to determine cause and effect relationships. Research to provide such information requires time. The dairy farmers do not have much time, however. A plan, based on present knowledge and which will improve conditions for the dairy farmers should and can be initiated. Experience with other environmental changes encourages us to act when there is the appearance of ill effects. Certainly we can have an electrical transmission/distribution system which is not required to use the earth as one of the conductors. With present knowledge the process of decreasing the electric current in the earth must be a serious goal of the electric suppliers

It is of general concern then to understand how external sources of EM energy induce changes in current flow in living organism and to consider how these changes might affect the information and functioning of the systems. Energy would be required to counter the change in order for an organism's system to regain normality. A correction toward normalcy might require a sufficiently large amount of energy so as to place additional stress on the organism, especially if the external source continued to feed extraneous currents into the organism's circuits. Such added stress can result in many responses. Hostile EM energy environments may be creating additional stress for living organisms thereby increasing the potential for unwanted physiological consequences.

A number of mechanisms may exist for modeling the interaction of environmental EM energy with living organisms. One hypothesis that needs testing is the concept of additional currents in the body's electrical circuits capable of producing a stress on the organism. Research is urgently needed to clarify understanding of electrical circuits in living organisms, to study the EM environment of living organisms and to develop on-site research methods where perceived problems exist. An international survey of research into all areas of EM effects would be especially helpful in providing an informational base for guiding all future research.

The discovery of knowledge is a shared enterprise, and this especially applies to EM research. It is argued here that EM energies have the potential for affecting living organisms, both animal and human, in important and as yet poorly understood ways. If that is the case, it is important to recognize the global importance of these effects. By implication, then, this research requires involvement and input from many diverse cultures, many areas of expertise and many human occupations, with all available skills united for understanding this complex phenomenon. You are invited to participate in this endeavor.

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EFFECTS ON DAIRY HERD HEALTH AND PRODUCTION RESULTING FROM PRIMARY NEUTRAL GROUNDING PRACTICES

Interpretations of the Measurements on the Lusty Farm

by
The Electromagnetics Research Foundation, Inc

The issue to be investigated in this study is the suggested connection between the ground currents in the electric utility transmission/distribution system and stray voltage effects in dairy herds. More specifically the study was to determine whether or not the behavior, health and production of the dairy cows were affected by changes in grounding of the primary neutral on the farm owned and operated by Dave and Sue Lusty. This report will be divided into interpretations of electrical measurement data, interpretations of animal and human issues and general conclusions.

ELECTRICAL MEASUREMENT DATA

1. In a general way, the variations in the AC magnetic field follow the primary current. There are some shifts in the magnitude of the AC magnetic fields which correlate with changes in the water line to gutter chain currents.

2. The AC magnetic field appeared to be slightly correlated with on farm variations in electrical use. The major component seemed quite independent of on farm electrical use. This is, of course, also true of the primary current going into the ground. The sources of currents on the primary neutral and the sources of currents producing the AC magnetic fields in the barn were a mixture of on farm use of electricity as well as off farm uses.

3. There were a number of abrupt changes in measurement values. These will be listed and evaluated later.

a) at 6:00, 3.17. the WL--FH ACV increased, the RH--FH ACV decreased, the SN to RG ACV decreased, the PN ACV and ACA rose and the AC magnetic field increased.

b) The same changes occurred on 3.18 except the WL--FH ACV decreased. Some of these changes occurred on other days but the changes were smaller.

c) A shift in nearly all measured parameters occurring between approximately 18:45, 3.18 and 10:50, 3.19. The PN--RG ACV went from 1.5 V to 0.2 V to 1.5 V, the PN ACA from 20 mA to

175 mA to 10 mA (both of these are averages because of large variability), the SN--RG ACV from 20 mV to 120 mV to 10 mV, the WL--RH ACV up by factor of 4; the RH--FH ACV up by a factor of 4, the WL--GC ACA increased for about 125 minutes then dropped to a very low value for the remainder of the period, the RH--FH DCV up and erratic, the WL--RH DCV went from -300mA to -420 mA to -380 mA (held at the more negative value), the PN--RG DCV remained virtually unchanged, the PN DCA significantly increased negatively and erratic.

d) At 8:40 3:22. the AC magnetic field doubled, became less variable and remained fairly constant until 3:31, the WL--GC ACA increased and held fairly constant in the 25 mA range until 3:31 and the RH--FH ACV went up and remained fairly constant.

e) At 14:49, 3.24, all secondary parameters became less noisy except for AC magnetic field.

f) The RH--FH DCA slowly decreased between 3-24 and 3-31.

g) At 12:17, 3-31. WL--RH ACV became noisier and higher, the SN--RG ACV became noisier, the WL--GC ACA went from 17mA to nearly zero, the RH--FH DCV became noisier and increased at about 16:10, 3-31, the RH--FH ACV increased and became noisier.

h) On 4-3 and 4-4, the operation of a 10 hp motor correlated with a significant increase in both PN--RG ACV and ACA, and a small increase in secondary parameters except for the AC magnetic field which decreased.

i) For 4-4, 4-5, 4-13 and 4-15, there were large excursions of the PN--RG DCV and PN DCA. The only association on secondary parameters was a more rapid fluctuations of the WL--GC ACA.

j) Between 9:25--15:40, 4-7, AC magnetic field doubled, the WL--RH ACV, SN--RG ACV, WL--GC ACA all decreased slightly and changes occurred for both the primary and secondary DCV,

k) At 12:10, 4-8, the PN--RG DCV changed pattern, all of the AC parameters showed a slight increase but the increase was delayed by as much as one hour, the AC magnetic field decreased and the WL--RH DCV appeared to slowly become more negative.

l) At 15:00, 4-14, the PN--RG DCV increased negatively and became noisier, the PN DCA increased negatively, the WL--RH ACV and SN--RG ACV went up slightly and became noisier, the AC magnetic field went down slightly, the WL--RH DCV became more negative and noisier. At 11:30 something occurred causing an increase in the WL--RH ACV, SN--RG ACV and RH--FH ACV and DCV and a decrease in the same quantities at 21:10.

4. Except for high use times, the PN--RG ACV averaged about

1.0 V or less and PN ACA averaged about 30 mA or less. The 3-18--3-19 excursion increased the PN average current to about 175 mA and the PN--RG ACV decreased the voltage to an average of about 0.2 V.

5. The average value of the PN--RG DCV was in the range of from -500 to -600 mV.

6. The WL--RH DCV began on 3-16 at -250 mV and ranged between -300 and -450 mV for most of the study period. In general,values were less negative when the grounds were connected than when disconnected. On 3-18 the DCV went from about -300 to -400 mV when the PN--RG ACA suddenly increased. The value went back to about -300 mV on 3-19 when the PN--RG ACA decreased again. The DCV values also varied much more before 3-24 than after and again during the second connection of the grounds.

7. The RH--FH ACV ranged between 5 and 10 mV on 3-16 and 3-19 and between 2 and 5 mV on 3-17 and 3-18. After the excursion on 3-18 and 3-19 the RH--FH ACV was hardly above 1 mV throughout the test. Something occurred which caused a significant increase in RH--FH ACV at about 5:50, 3-16 which did not appear to be connected with power use on the farm or change in the PN parameters.

8. The RH--FH DCV increased in variability as well as magnitude during ACV increase on 3-16. The DCV did not decrease as the ACV decreased. The same occurred during the excursion of 3-18 and 3-19. Consequently the DCV reached its maximum value on 3-19 and decreased throughout the test period.

9. The three phase and neutral current graphs for the OTP Parkers Prairie Substation show nearly constant currents between 22-23 A for the entire period and for each day. No increases and decreases which followed daily and seasonal energy use appeared with the exception of the first three days of the test and except for the neutral. The neutral current graphs showed some of the typical variations for the entire test period. Since the current on the neutral should partially reflect the differences of the currents on the phase wires, one can only speculate that these variations represent currents picked up from other distribution lines. In comparing these data with electric current data from other lines in the area, one notes significant differences and there is no way to determine actual load variations during the test period.

10. The number of impulses on the phase wires on the farm were quite regular until 4-5 after which the number was nearly zero. Interesting is the fact that the largest number of impulses occurred near the midnight hour. Equipment for users of electricity should more likely be operating during the normal time of farm activity.

11. The primary neutral to remote ground AC voltage has been accepted as the true voltage of the primary neutral. The

primary neutral voltage of the primary neutral is considered to be a measure of the current that would go into the secondary grounding system and affect the EM exposure on the farm. In this analysis the remote ground is accepted as the zero point for referencing the primary voltage.

In the study, measurements are recorded simultaneously for both the current going into the ground on the primary neutral at the transformer pole and the voltage on the primary neutral relative to the earth. In principle, the ratio of the voltage to the current will be a measure of the resistance to the flow of current into the earth. If currents did not exist in the earth from distant sources, either at the transformer pole ground or the remote ground, the ratio would be a constant, varying only with variations in soil characteristics in the region of the ground rods.

Calculating these ratios for the days the grounds were connected revealed variations for each day of from 20 to 30% with wild excursions at times. The largest excursion was the 15 hour period on March 18 and 19, where the ratio decreased by a factor of approximately 20.

The variability of the ratio of the primary neutral to remote ground AC voltage and the current going into the earth on the primary neutral can not be assumed to be the true voltage of the primary neutral. The fact of the variability suggests that current in the earth from many different sources are affecting the measurements. In addition, the measure of the primary neutral to remote ground AC voltage may be only a rough indicator of the potential for effects from the current going into the earth on the primary neutral. These results make it very clear that the true measurement is the current that goes into the earth with isolation or the current going onto the farm ground with no isolation. The electric current directly and indirectly produces the affects on the animals and people.

ANIMAL AND HUMAN ISSUES

1, On 3-19 Dr. Beehler noted unusually strange behavior in the dairy herd which he thought could be attributable to stray voltage. On 3-24 behavior was more normal but there was beginning to be a greater incidence of swollen hocks and redness erythema. The swollen hock problem was often discussed throughout the study period. The restlessness decreased after 3-24 and increased again 4-8 and 4-13. Milk production was lowest at the beginning of the study period with the most milk being dumped between 3-17 and 3-22 and on 3-31. The increases in milk production began on 3-25 and continued through 3-15. Water consumption also increased through the test period with low points on 3-19, 4-2, 4-5 and 4-7 and a drop on 4-14. Plateaus in the increase coincided with the ground connections and the 3-18 and 3-19 excursion. The largest fraction of the cows being treated occurred between 3-19 and 3-23 which is immediately after the excursion while the grounds were connected. On 3-26 and 3-27 a smaller maxima occurred. Overall treatment became less through the test period. Blood tests revealed high CPK levels throughout the test period. The total protein was high throughout the test period for 80% of those tested and the white blood count was elevated for the entire test period for 5 cows and periodically elevated for others. Other blood parameters increased and decreased during the study period but no clear pattern developed.

2. Dave and Sue Lusty maintained records of dairy herd for the entire test period as well as additional information of conditions before the test period began. This information is helpful in analyzing the possible associations. The red feet problem began to be noticed for many cows on 3-21 and were noted to be less red on 3-22. During the morning milking on 3-25 cows were not as cranky but much tail switching. On the morning of 3-26 the majority of cows were up in milk. On 3-28 it was noted that the feet for all of the cows in the tie stalls were very red as well as for some in the stanchions. The cows' behavior had been average to calm between the evening of 3-26 and the evening of 3-31. On the morning of 3-30 the cows' behavior had been the best of the entire winter. Conditions changed especially at the evening milking on 3-31. More problems for the cows and calves 4-5 which might have been associated with the grain drying. Behavior of cows was average to cranky until evening of 4-8. Behavior average or better for the duration of th test period until the evening of 4-14. During the test period one cow was noted to fall to the floor and after getting up demonstrating the behavioral resposes associated with stray voltage. Anything other than electricity causing such an event is unlikely.

In general the comments seem to lean in the direction of more problems when the grounds were connected than when not connected. The highest level of effects appeared to be during and shortly after the excursion of 3-18 and 3-19.

On the final page of the report by Sue and Dave Lusty are General Comments by Dave Lusty which are quoted:

"Behavior of this herd got much more calm for milking and not near as much kicking by February 1. This change occurred during the last half of January. Three heifers that freshened last fall and early winter all foundered within hours after having to live in the dairy barn (stiff legs and hard to walk). This severe foundering was confirmed by vets. Not a single heifer that freshened just before and during test time had symptoms of severe foundering.

As usual the herd health problems were more severe during the Spring thaws. Swollen legs were the worst during the first two weekends of the test and some rainy days. Suggest the cathodic protection practices on telephone lines be investigated because the dc voltage from WL-RH was sometimes higher when this occurred.

My observations of cows was very limited timewise. I'm sure if time permitted many more behavior problems would be detected. One full-time person with the proper knowledge of dairy cows and working with the farmer to gather information is very necessary for any future testing such as this."

From the farm measurements milk production was at the lowest level between 3-15 and 3-20. An increase in milk production occurred after that and declining again to 4-3. After 4-4 there was a steady increase in milk production. Throughout the period milk production rose from about 23 to 28 (units uncertain). Water consumption increased from about 15 gallons per cow per day on 3-8 to 24 on 4-13. A sudden increase in water consumption occurred on 3-25. Between 3-25 and 4-6 water consumption remained fairly constant. On 4-7 water consumption reached a low point and increased rapidly to its highest point on 4-13 and dropped on 4-14. SCC was above 300,000 on 3-23, 3-29, 3-31, 4-6 and 4-8 and below 100,000 on 3-9, 3-15, 3-25 and 4-14.

3. As the stray voltage effects on dairy herds are being increasingly recognized, so also the effects on the dairy operators who work with the cattle. During this study, Sue and Dave Lusty recorded some of their health experiences. On the morning of 3-19 Sue's legs ached while in the milk house. Sue had been in the barn much of day on 3-26 and her foot was in such pain that she could hardly stand. Dave experienced severe aching in shoulders and hips during milking on the evening of 3-31 and morning of 4-1. Dave became very sick with cold and flue on 4-1. No recording of events was made for 4-2 and 4-3. Sue's legs ached very badly again during the morning of 4-7

GENERAL CONCLUSIONS

1. This study is certainly a first in the quality of the data collected by the manager of the project and the diversity of parameters included. Because of these two factors a large amount of information is available which helps in the understanding of the electric energies in and around the dairy barn. Some of the observations are:

a) Numerous connections exist between primary and secondary electrical parameters. Most of these have been pointed out. Important is a connection between the amount of AC going into the earth and DC levels in the barn. DC levels sometimes respond immediately to the change and other times very slowly.

b) The AC measurements on the secondary system indicate many sources of the electrical energy. Some of the sources are on the farm and many others are off farm. In all the data there are ever present electric potentials and currents which are not associated with either the primary grounding on the farm or electrical use on the farm. Connecting and disconnecting the grounds on the primary neutral do not significantly affect the existence of this AC electric energy. Measurements have been made on the Lusty farm at the time of an outage of the entire three phase line. AC potentials and currents were present throughout the barn and all other buildings on the farm. On this farm the secondary neutral is electrically isolated from the primary neutral. The electrical energy is also reaching the farm by other conducting paths in the earth from other distribution systems, from other substations and perhaps from any part of the transmission/distribution system anywhere in the country. The term ground currents has been used to describe this source of electrical energy in the dairy barn.

c) There are large fluctuations in the DC levels measured between points connected and not connected to the neutral of the electric systems. If DC potentials and currents were solely from the natural chemical interactions with soil and metal, the rapidity of the changes should not occur. It is likely that the AC in the earth is connected to these changes. At least two possibilities exist. One is the rectifying of the AC by the naturally occurring rectifying materials in the earth. A second is the possibility that the AC electric energy is driving the natural chemical cells in the earth. Because it is expected that high ionic chemical levels will be present around barns and in water, additional electrical energy could affect the functioning of chemical cells.

d) Cow contact voltages as measured from WL--RH were, in general, below 10 mVAC and between -300 and -450 mVDC and from RH--FH were in the 1mV range for AC and less for DC. In addition to cow contact voltages, the electric and magnetic fields present in the barn can also add to the electric current and fields in the cows. The only change in the measured electric parameters which consistently occurred at connection and disconnection of the neutrals was an increase in the noise associated with the measurements when connected and the decrease in noise when disconnected.

e) The measurement data reveal that the barn is a complex electromagnetic environment which is continually changing. Consequently, the determining of specific associations between the measured electric parameters and the increase or decrease in effects for the dairy herd is difficult. The excursions on 3-18 and 3-19 as well as the other electrical events which produced random short term changes complicate the establishing if a meaningful statistical analysis. In addition, the periods of connection and disconnection of the grounds were respectively 8 days and 6 days which is to short for many effects to appear in the dairy herd.

f) The high CPK and TP provide important information concerning the cause or causes of health problems in the dairy herd. Since at no time during the test were the cows free from the effects of stray voltage, the pattern for each cow should be separately considered. In studies of effects of EM energy on humans, it has discovered that time is an important parameter and is, in general, different for each person. The beginning of effects and the specific effects occur at different times for each individual, after the beginning of the exposure. The same is probably true for the dairy animals. As a consequence the time required for the change in the blood parameter for each cow may be different and the direction of change can be dependent on both the individual animal and the time of the test. For example increases and decreases for lymphocytes and neutrophils can indicate different health problems and, therefore, can change quite differently for different cows. The small changes in current going into the ground at the times of connecting and disconnecting could likely not provide very conclusive information. In addition the short duration of each test was probably not sufficient to provide definitive results. Especially significant is that the grounds were disconnected for a maximum of 6 days as opposed the long time of connection of grounds before the test and 8 days during the test. In addition to the farmers the veterinarians expressed the concern that one week was not sufficient to observer measurable changes in blood parameters, health and production. It was unfortunate that agreement wasn't possible for the test period to be divided into a period of two weeks on and a period of two weeks off. The change that occurred during the 3-18 and 3-19 excursion was far more significant in changing the electrical environment of the cows than the connecting and disconnecting of the grounds. A study was done on the Lusty farm in 1992 in which blood tests were done before and after connecting the grounds. Blood tests were done before the grounds were connected and 17 days after. The changes in blood parameters are quite significant in this study and the report from this study will be included.

2. Consideration must be given to the methods used for measuring for stray voltage. The variability of the ratio of the primary neutral to remote ground AC voltage and the current going into the earth on the primary neutral at the transformer pole points out the unreliability of the neutral to earth voltage as a predictor of the amount of current reaching the barn from the primary neutral grounding. In addition, since the current directly and indirectly determines the EM exposure of the cows and people, measurements of currents, both AC and DC, in the earth and conducted through the barns and homes <u>must be a priority</u>.

3. A number of inconsistencies exist in the recorded data which need both discussion and explanation. In some cases the effect of the inconsistencies can jeopardize the very purpose of the study. Since the issue of ground currents and their potential effects was thought sufficiently valid by the Minnesota Environmental Quality Board and Public Utility Commission to warrant funding, every effort should have been made to test the concept that the change in current going into the earth on the primary neutral affects the behavior, health and production of dairy cows. The following are some observations:

a) Every day of the test period the OTP Parkers Prairie substation three phase line was perfectly balanced. Not only were three phases perfectly balanced at 22-23 A but also those currents were maintained 24 hours of each day for every day of the test period. At the same time the current on the neutral wire which is normally sensitive to the imbalance varied during each day and from day to day. In the Minnesota Public Utility's hearings information was provided that indicated that perfectly balanced three phase lines was not a possibility. An explanation is needed to show how and why the constant currents were maintained on the Parkers Prairie line and why the neutral current did not correlate with phase currents.

b) An unexplained excursion occurred on the primary neutral system on 3-18 and 3-19 which affected nearly all parameters in and around the barn. No change was made in electrical use on the farm which could have caused the current going into the ground on the PN to triple and the PN--RG ACV to decrease by a factor of five. Something occurred on the primary system which had a very specific lifetime. The cause of this event must be known.

c) Changes occurred very suddenly in some secondary measurements which were significant but correlated with no change in normal electric use on the farm. Because these changes did not appear to be associated with changes in the recorded data for the primary system, other sources of electricity must reach the farm through other conducting paths. These sources need to be investigated.

d) The measured current going into the earth on the primary neutral averaged about 20 to 30 mA with the exception of high use time when the current could reach 50 mA and the excursion. During the excursion on 3-18 and 3-19 the current going into the earth on the primary neutral was between 100 and 200 mA. Measurements of the current going into the ground on the primary neutral have been measured on the Lusty farm over a period of a number of years. The only time 20 to 30 mA has been measured was for a period before the test began and during the test period. The normal current going into the earth on the primary neutral has been and is about 150mA. On a rare occasion the current may go as low as 40 to 60 mA but has never remained at those low levels. A number of times the current has been over 200 mA and even when the entire three phase line serving the farm was down, the current in the PN was 130mA. Electrical use on the farm does not and can not produce these changes. A description of the method by which currents can be maintained between 20 and 30 mA should certainly be a priority both for knowing how to reduce the current reaching farms and to clarify the reason for these changes at this time.

4. This research project was developed and conducted to test a possible association between the disconnection of the primary grounding on and near the farm and stray voltage effects in the dairy herd on the farm. Obviously going from 150 mA to zero mA of current entering the ground when disconnecting the primary neutral grounds is very different than going from 30 mA to zero mA and can significantly impact the discoveries. It is unfortunate that the typical conditions for this dairy farm did

not exist for this research project.

For a period of approximately 15 hours an electric excursion occurred during which time the magnitude of the current going into the earth on the primary neutral was in the normal range for this farm. During this period, the secondary parameters changed significantly in response to the additional current going into the earth. Also the greatest number of acute effects occurred in the dairy herd during and for a period of a few days after the excursion. Considering the amount of money provided by the State and all of the extra work required of the Lustys and the team that set up the test, these apparent discrepancies require investigation and explanation. Even under the best experimental conditions establishing causes of health problems for living organisms in the presence of environmental toxins is very difficult. When a level playing field isn't even available, progress is that much slower. For the many tragic cases such as the dairy operations of Dave Lusty, Lonnie Nelson, Darrell Franze, Art Borgerding, Harold Johnson, Joe Kenning and Roblee Johnson delays in dealing with the cause of the problems mean, most probably,an end to their dairy operations.

ADDITIONAL INFORMATION ON LUSTY FARM TEST

Obtaining a significant instantaneous change in electrical parameters on the farm at the times of connection and disconnection is not too likely because the connections and disconnections were made during low use time and the currents going into the ground on the primary neutral were unusually low during the entire test period. All one hour averaging of the data has a tendency to destroy potential correlations because multiple sources make up the levels of AC and DC measured in the barn. These sources can change from one second to the next. Any connection between one source and measured parameters in the barn would best be determined when the one source was dominant. During two periods of the test for which the grounds were connected the AC going into the ground at the primary transformer ground rod was considerably higher than the rest of the test period. These periods were the excursion on 3-18 and 3-19 and the use of the drying fans on 4-4 and 4-5. When considering the correlations between the secondary parameters, it is important to keep in mind that the measurements are made by connecting to different parts of the farm ground circuits. These, therefore would be expected to show a greater degree of correlation. The fact that the correlations are not especially good would also imply a complexity of sources. Some of the sources are associated with the secondary neutral currents on the farm and some from currents of other sources that are not associated directly with the secondary electrical system. This characteristic of the electrical system has been demonstrated numerous times on the Lusty farm. Electricity to the farm is turned off and measurements made between points on the farm and in the barn. When current measurements are made, the values not only remain significant but actually have increased when the power on the farm is turned off. AC involves phase factors and different sources can have different phases. At times the different sources can tend to cancel and lower values will be recorded by the meters.

The wave forms of currents that are in the earth and grounding system are rarely a pure 60 Hz sine wave. Most often the wave form indicates a mixture of frequencies with the fundamental 60 Hz. Again the measuring equipment sees only the sum of the electricity at the points of measurement. The fact that it is very complex implies both the possibility of effects on the electricity by the earth materials and outputs of electronic circuitry going into the earth through the grounding system. One of the possible effects by the earth is the rectification of AC to DC. During this test there were sufficient correlations between changes in AC and DC to indicate that they are not totally independent. They problem is that not only is rectification in the earth possible but the AC energy could affect the chemical interactions occurring in the earth.

One way to consider the water consumption data is to determine the average daily water consumption for each of the four periods. The results are 17.0 gallons per cow during connection period 3-16--3-24; 19.3 gallons per cow for the disconnection period 3-25--3-31; 19.4 gallons per cow for the connection period 4-1--4-8; and 21.6 gallons per day for the disconnection period 4-9--4-14. There was an increase in water consumption during the month of testing with the greatest increases during the periods of disconnection. When looking at the daily water consumption, increases occurred after disconnection and decreases after connection.

Milk production per cow had a similar upward trend during the test period. Averaging over each period separately, the daily milk production for the first period of connection was 47.6 pounds per cow, for the first period of disconnection was 49.5 pounds per cow, for the second period of connection was 49.5 pounds per cow and for the second period of disconnection was 53.4 pounds per cow. Similar to water consumption, milk production had its largest gains during the periods of disconnection of the neutral grounding wire and a leveling of production during the second connection period. Because all cows are different it is also valuable to consider the milk production for individual cows. A record was made of the daily production of some of the cows which covered the entire month of testing. Averaging over the entire herd does not take into account the fact that the cows are at different points in their lactation cycle. Averaging over each of the periods for each cow individual revealed a somewhat different picture. For over 50 % of the cows for which daily production measurements were made, the production was lower for both periods of connection compared with the periods of disconnection. Except for one case the production for the other cows increased throughout the month and had a leveling of milk production during the second period of connection. There were two time periods in which the current into the ground was measured to be considerable higher. These times were 3-18 and 3-19 and 4-4.

For nearly all of the cows for which daily measurements were made, production was down on those specific days and/or sometimes for a day or two after these times.

The short period, six days, for which the grounds were disconnected and the two periods of measured significant increases of current going into the earth would confound the blood parameter results. Blood tests can provide information about a number of health patterns including immune response and stress. According to veterinarians, the blood patterns can be quite different for different cow conditions. For example a stress leukogram, showing animal stress consists of a reduction in the lymphocyte level resulting in a reversal of the normal lymphocyte neutrophil ratio. During this test period a number of cows at different times had blood results indicative of stress. Some of these were explained as being associated with illness. If the lymphocyte count goes up and the neutrophils go down the cause can be the beginning of a total immune system breakdown and/or indicative of a dangerous precancerous condition. Opposite changes in blood parameters reveal quite different causes and each cause detrimental to the well being of the animal. In addition the effects of electricity on this farm were present before, during and after the test period. Understanding these complications, it is probably most important to consider the blood parameters that were abnormal during the test period and spend less time searching for correlations between blood parameter levels and connection or disconnection of the primary grounding wires.

Elevation in CPK implies muscle trauma or damage. Observations by Dave Lusty and veterinarians suggested an ongoing leg and hock problem among the cows during the period of the test. The CPK levels for all cows throughout the test period were significantly above the normal values. Tests on other dairy cows under stray voltage conditions have shown the same high CPK levels. Dairy operators who have required medical attention have also experienced CPK levels which are significantly above normal. In addition it is well known that people experiencing electrocution will show a significantly elevated CPK level. This information should encourage some studies to discover the connection, if any, between stray voltage and high CPK levels. Such a study should be important whether or not the high CPK levels directly affect the production of the dairy cows.

Total protein, another blood parameter measured, was high on the average for 62 % of the dairy cows for the test period. High values of total protein are associated with dehydration and/or with inflammation caused by illness or disease. Fibrinogen is a specific protein which connects to long duration disease. Although the number of cows with high Fibrinogen was not large, a few cows maintained a high fibrinogen level for the entire test period. The Lusty farm is known as having significant stray voltage problems which are especially serious when the primary grounding wires are connected. The high protein levels may provide a clue to the effects of stray voltage.

The white blood cell count is probably the most complex to analyze. The information provided in the report by Dr. Ryder is very helpful. The graphing of the leukocyte count provides a picture of the stress levels for each of the cows for the test period. As was mentioned previously, the opposite of a stress leukogram, a decrease in neutrophils and increase in lymphocytes, points to the possibility of immune system effects. Does exposure to electricity more likely produce a stress or immune system effect? Research from Eastern Europe indicates that both are possible. It is possible that duration of exposure or type of electricity may influence which is more likely. On the average 25 % of the herd had high white blood cell counts during the test period. That percentage implies that stress and/or immune system problems was a significant factor in the health of the dairy during the test period.

A comprehensive examination of the blood parameters suggests, at a minimum, that a health problem exists in this herd. Even though the test procedure was less than desirable, the individual cows are different, and the blood parameters are complex, the blood tests provide valuable information concerning the overall health of the individual cows.

Electromagnetic Fields and Currents- An Emerging Environmental Issue

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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 on living organisms. Since the publication of the results of the New York State Power Line Project, an increasing quantity of information has been presented in various journals, magazines and books relating various health effects to EM energies. One of the most recent is "Currents of Death" by Paul Brodeur published in 1989. On October 6, 1987, The U.S. House Subcommittee on Water and Power Resources held a hearing, "Health Effects of Transmission Lines." On March the 8, 1990 a hearing before the U.S. House of Representatives, Interior and Insular Affairs Subcommittee on General Oversight and Investigations considered implications of recent research into health effects of electric power lines and associated EM fields. For many reasons, specific cause and effects links have been difficult to establish. One reason is the complexity of EM energies to which living organisms are exposed and the rapid increase in machines emitting EM energies with which people work and play. Another reason is that we have tried to separate the health effects of the various electromagnetic fields (EMF) and currents, expecting drastically different mechanisms. In reality there may be only a relatively few mechanisms, and synergistic health effects between the fields and currents may be very significant. Also, complex forms of the EM energy may be more closely correlated to health effects than simple forms.

The effects include all those aspects of health which are part of the stress syndrome - effects on the central nervous, cardiovascular and immune systems. We should not be surprised by these associations because it is known that all of the functions of the bodies and minds of humans and animals work as a result of electrical, magnetic, and chemical energies.

In all regions of the earth, electricity and magnetism exist. They hold things together and push things apart. They make candles burn and cause the photosynthetic process in the leaves of plants. They are part of our weather process. They light our day and heat our planet. All living organisms are engulfed in various EM energies. It is a primary and fundamental force of nature. We use the term electric current when we refer to charged particles streaming from one point to another. We use the terms electric, magnetic and EM fields to specify those areas where charged objects will experience forces. We also at times interchange these terms even though we should always be exact. From our experiences we would expect to find no region of space in which only one electric or magnetic force were present. Examples are the electric field of the atmosphere, the magnetic field of the earth and the EM radiation from the sun.

Living organisms, being a part of the natural world, are dependent upon the various natural forces and certainly including the EM. EM radiation heats our bodies, stimulates our eyes to see, regulates cyclic processes and probably enhances our total well being. In the plant world, EM radiation is the key to growth and therefore the key to feeding the world.

The earth and the atmosphere can be pictured as a large EM dynamo. There exists a dynamic equilibrium -- dynamic because the electric and magnetic fields and currents are continuously changing; equilibrium because there is a pattern dictated by the nature of the system. Living organisms, again, are on the earth or in the atmosphere so must share in that EM dynamic equilibrium. We walk along on a carpet, especially of synthetic materials, and, if the air is dry, we have a shocking experience. How does the electricity get into our bodies? Why does it only happen when the humidity is low? What does that tell us about our general interaction with the earth-atmosphere EM system?

In our industrialization we are introducing large amounts of EM energy into our world. We have done this because of the great benefits in human comforts. We surround ourselves today with multiple EMF's: the 60 Hz electric and magnetic fields emanating from transmission and distribution lines; direct current (DC) electric and magnetic fields associated with DC transmission lines, ion fields, batteries, welders, electronic systems, etc.; 60 Hz and DC currents in the earth resulting from our utilization of the earth as a sink for electricity and the ultimate ground; 60 Hz electric and magnetic fields present around all electrical devices and electric wiring in homes and the work place; radio frequency (RF) and microwave fields from sources such as microwave relays, military communications, commercial satellites, direct broadcast TV satellites, microwave ovens, medical diathermy, weather satellites, AM and FM radio, military satellites, ham radios, CB's, electrical power lines, VDT's, and radar systems.

In the US alone we generate nearly 300 billion watts of 60 Hz power which is moving through the extensive electrical transmission and distribution system and the earth.

The major portion of electricity is generated at coal fired, oil fired, hydro and nuclear facilities. The electricity is transported by a complex system of transmission/distribution lines in the form of either DC or 60 Hz AC. On the transmission lines 60 Hz AC is usually in a three phase format. Substations are established for switching the electricity on the transmission lines to other transmission lines and finally to distribution lines. Usually the potential of 7200 volts beginning as three phase system. Distribution lines are usually separated into three single phase lines, each of which provides electrical energy to a group of users. As we humans have developed our 60

Hz power system for providing the energy in our homes and industries, we have learned that certain care is required. Standing in a filled bathtub holding onto a bare wire coming from an outlet will probably be lethal. Sometimes we have experience touching a toaster which has not been properly grounded and feel as though we are going to light up. We take these experiences seriously and therefore in the development of our electrical power system have recognized a mandatory grounding requirement. A good but very complex system has evolved which uses the earth as a necessary current carrying conductor.

Electrical engineers expert in electrical transmission/distribution systems claim that the earth carries between 60 and 75 % of the return flow. The neutral wire is in the system to carry the return current but actually carries only a minor percentage of it. There are many reasons for the current being in the earth rather than on the lines. As the transmission/distribution system has evolved, the earth has inadvertently become a more critical component. The earth is being used as the reference ground for the entire transmission/distribution system which is laterally interconnected over the entire continent. It is not surprising, therefore, that the earth, being the reference and a conductor, carries current. Over a concern for protecting against shock and electrocution, codes have been established which require ground rods in the earth to have a certain low resistance. One side of the distribution system, referred to as the neutral, is interconnected with the grounding system and consequently connected to the earth through the ground rods. At the location of each user, at least one ground rod is connected to the neutral. Usually a number of ground rods are used as well the neutral being connected to other conductors in the earth such as wells and water pipes. Multiple connections of the neutral to the earth occurs at all homes, businesses, factories, substations, electric generation facilities and along distribution lines. The earth can then become the path of least resistance for the current on the neutral side of the distribution system. Electricity is induced in the earth by the AC magnetic field associated with all alternating currents through inductive coupling and conducted into the earth by electric fields through capacitive coupling and by means of all resistive paths such as towers, poles, vegetation, etc. The major generators of electricity maintain a constant output of electrical energy irrespective of demand. Consequently, during times of lower use it is possible that more electricity is generating than is needed. Although every attempt is made to avoid such events, they do occur which requires the surplus electrical energy to be dissipated and the earth can be used for that purpose.

The electrical currents in the earth are affected by their interaction with earth materials and objects embedded in the earth such as natural gas and oil pipelines. Through general knowledge of earth material and the nature of electricity, one would expect non linear materials, differences in conductivity and polarizability, and rectifying systems to affect the manner in which electricity moves in the earth and also to affect the physical make up. AC in the earth, of any frequency, has the potential of being altered. Problem solving research conducted on dairy farms and in the laboratory provides preliminary information. An observed change is the rectification of a portion of the 60 Hz and other AC to DC. Materials in the earth such as water and combinations of conductors and semi-conductors can partially rectify AC. DC cells associated with chemicals and metallic pipelines in the earth as well as the presence of AC on the pipelines requires cathodic protection to avoid corrosion of the pipeline. Specifically DC is supplied to the pipeline by means of an electronic DC supply.

Experimental data suggest the model of the charging of a battery. Cells appear to develop which are driven by the presence of AC in th earth. Ion migration and/or chemical reactions are probably the charging mechanisms. The possibility exists that the natural chemical cells can be driven or enhanced by the electrical current in the earth; obviously if DC is present from sources such as natural gas or oil pipelines in the earth, DC transmission line return or cathodic protection rectifiers on the pipeline in the earth, the cells are probably driven more vigorously. Both the AC and DC in the earth will also use the neutral wire and other conductors in the earth. In addition to DC the harmonics of the 60Hz AC, such as 120, 180, 240 Hz, etc. can be generated in both components of the transmission/distribution system and also in earth materials. Transients in the currents of the neutral-grounding system occur in the process of changes in electrical usage such as motors being started or stopped, etc. these transients likewise can and do travel in the earth. Currents in the neutral-ground and, consequently, in the earth, therefore, are, in general complex and rarely retain the simple 60 Hz sine shape.

The currents of the earth can also change the electrical character of the materials in contact with the earth such as floors and walls of buildings. The model of the electric cell would suggest the electrical charge of the floors and/or earth can differ in polarity and intensity according to the location of the electrodes of the cell. The model also suggests that direct currents can be present in the earth and other conducting materials in contact with the earth.

Since most living organisms are in contact with the earth or some solid material connected to the earth, the EM fields and currents present in the earth, whether natural or of human origin. will access them. As currents and fields in the earth are changed through human activity, so will the currents and fields experienced by living organisms be changed. There are EMF's of the earth and in the atmosphere which are naturally present and complex. Additional EM energies change the natural fields and currents increasing the complexities. Those complexities can include changing the electrical character of the floors of buildings. Again, since most living organisms are attached to the earth, additional currents and fields in the earth can appear, then, as additional currents and fields in the living organisms.

As currents exist and ions migrate in the earth, so can currents exist and ions migrate in living organisms that are in contact with the earth. All of these EMF's surround the living organisms and the very difficult question, for which we would like an answer, concerns possible biological and/or health effects caused by these additional fields. Since present research considers very specific and well defined fields, cause and effect in laboratory work is probably quite different from cause and effect in the real world.

In the space occupied by people and other living systems there exists today a significant diversity of EMF fields (EMF) which are produced because of human activity. Research results which connect relatively small EMFs and electrical currents to a number of human and animal physiological effects are more frequently appearing in the published literature. In many cases the effects may be caused synergistically by more than one EMF or in connection with toxic chemicals or other energy forms. In addition, a large quantity of experimental work and anecdotal information is being reported which links uncontrolled EMFs and change in electromagnetic parameters with a set of physiological problems in animals and humans. These effects are connected with both direct radiation from sources and also with EM energy present in the earth.

Professionals have known for years that ground faults--a bare electrical wire in contact with the earth--on dairy farms can cause a set of production, health and behavioral effects in the dairy herd. They are also familiar with similar cases for horses, hogs, turkeys and beef cattle. Today many are experiencing and/or have experienced the association of this set of effects with electrical distribution problems on the farm and off the farm. Professionals do not question these facts.

Some of the effects on dairy cows which have been observed and reported are: restlessness when in stalls or parlor, unwillingness to enter barn parlor or stall, leaping into the stall and crashing to the floor, refusal to eat or drink while in the stall, lapping in the water cup, pressing their noses against stalls, especially while being milked, dancing in stalls or parlor, kicking at farmer when being washed, kicking off milkers, difficulty walking and getting up, distended eyes (appeared to be under stress), uneven milkout and letdown (some quarters will release milk well while others will not), long milking time, peaking in production in the first weeks of the lactation cycle, poor production, sudden onset of mastitis (which often appears unaffected by antibiotics), unusually large number of a variety of health problems which resulted in high veterinarian bills, leukemia, spontaneous abortions, breeding problems, and leg sores which do not heal nor respond to accepted treatment methods.

A partial list of associated human health effects include: tingling, numbness and/or pains in arms and legs, chronic fatigue, aching and swollen knees, dizziness, frequent headaches, vision problems, disorientation, memory loss, irritability under stress, swollen abdomen, nausea, open sores unable to heal, allergies for females--problems with menstrual cycle, other effects more difficult to assess are high incidences of cancers (especially leukemia and brain), neurological disabilities, and cardiovascular problems.

Correlations are being reported which connect effects in both animals and humans with electrical changes. Farm records and other information provided case histories correlating changes in the level of health effects to: additions of substations, re-routing of electrical loads, changes in routing of distribution lines, changes in the grounding systems on and off the farm, changes in the farm protection equipment electrical system, addition of transmission lines, active cathodic for oil and NG pipelines, buried telephone cable, isolating transformers, spark gaps, saturable coils, etc.

Other information suggests additional EM connections. Changes in level of effects correlates with the following parameters: weather changes (humid weather often caused greater effects), ground moisture, location of barn, long weekend especially in areas of lakes with vacation homes, summer weekend often associated with lakes areas, proximity of animals to operating electrical equipment, location of animals in the barn.

We could expect that all dairy farm problems do not have a single cause. A number of surveys have been conducted, however, to attempt to assess the perception of the dairy operator. The results indicate that somewhere between 20 and 40 % of the dairy farms in the States of Minnesota and Wisconsin experience effects on dairy cows from some form or forms of electromagnetic energies. The dairy operators estimate the yearly loss from each farm experiencing "stray voltage" problems is between $20,000 and $30,000. Imagine the economic loss to the States of Minnesota and Wisconsin alone. Some of the surveying dealt with the perceived association between effects in the dairy herd and human physical health effects. These surveys included responses from 125 dairy operators. The correlation was overwhelming--nearly 100%. Where effects were experienced in the dairy herds, physical health effects were experienced by those working in the barn especially while in the barn.

Throughout the country, accounts are being given of homes, office buildings, businesses, whole regions and villages where unusual and sometimes unbelievable health problems for both humans and animals exist. In some cases experts have investigated and in most cases the conclusions concerning cause are inconclusive. No cause can be linked to the observed health effects, General labels have been attached such as sick buildings, indoor air pollution, tight buildings and environmental illness. Scientifically the cause or causes for these conditions are in the category of speculation. The associations appear to involve location as opposed to genetic make-up. In searching for the cause or causes, logic would encourage the examination of all physical, chemical and biological parameters which are characteristic of location. All of these parameters require investigation because living organisms are sensitive to and can be affected by any one or all. Most often an investigation centers on pathogens and chemicals because their influences are better understood whereas the physical parameters are largely ignored because the effects are not well understood. An analysis of energies used in the functioning to living organisms, draws our attention to EMs. Of all the parameters that could influence the appropriate functioning of living organism, EMs should be near the top. For that reason, logic again would suggest that the EM environment of living organisms would be crucial for well being.

Investigations by The Electromagnetics Research Foundation (TERF) and Concordia College faculty are in process at locations perceived by residents to have unusual health problems. In some cases chemical and biological causes have already been investigated. In this work the assumption is that EM energy is at least one of the parameters capable of causing the perceived effects. Consequently a special effort is made to identify and measure the various EM parameters as well as conduct a health survey.

Some of the preliminary results are now available. Where significant health problems exist, one or more of the following physical characteristics also exist: 1) electric transmission line in the general area; 2) distribution lines close by; 3) substation close to area affected; 4) area directly between two substations; 5) buried cables; 6) buried NG or oil pipeline near by; 7) high ground water table; 8) certain soil conditions and electrical transmission and distribution system grounding. The seriousness of the problems is connected to the number of characteristics that allow a specific presence of EM energy in the space occupied by the living organism. Specific implies some combination of DC and AC. 60 Hz magnetic fields external to buildings will persist in the range from 0.2 to 1.0 mg and inside the buildings the range is usually somewhat higher. The sources of the EM energy can be either by direct radiation, by conduction through the earth or a combination of the two. 60 Hz electric currents from human sources are measured between any two points in the earth. The magnitudes of these currents vary from one place to the next. Incorporated in the 60 Hz in the earth are a number of harmonics as well as radio frequencies. In addition spikes of transient currents are observed to be present in the earth even when measurements are made which are independent of the neutral of the power system. DC in the earth varies in an oscillatory manner and the magnitude of the oscillations appears to be correlated to the magnitude of AC in the ground. In essence, AC and DC in the earth are somehow connected and affect the observed nature of each other.

Health information provided reveals that a number of serious human illnesses are possible, including neurological disabilities, various types of cancer and cardiovascular problems. Chronic fatigue becomes a serious problem for all people, young and old, in these areas. Most often, observed health problems are not age dependent.

In most areas investigated, the magnitudes of the 60 Hz magnetic and electric fields in the space where people live and work are small compared with those predicted by research to potentially be able to cause the investigated health effects. The expected response is to assume the cause or causes, therefore, cannot be EM. Such a conclusion, however, may be irresponsible. Since nearly all living organisms spend the majority of their time connected to the earth or solid objects on or in the earth, careful consideration must be given to the level of exposure to EM energy from direct and indirect contact with the earth. In addition, further studies delving into "window" and synergistic effects are necessary. The observed correlations appear to be more closely associated to the state of EM energy in the earth than to energy which is radiated. Experimental evidence which supports this correlation for cattle has been generated on a number of dairy farms. Dairy operators have experimented with housing dairy cows and calves about 5 feet off the ground and electrically isolated from the earth. Consistently both the cows and the calves are much healthier when housed off the ground as compared with on the ground. In addition the cows increased in milk production by nearly 50% when housed off the ground. One dairy operator had approximately a 30% death rate for calves when housed on the ground and less than a 5% death rate when housed on a trailer which was electrically isolated from the earth.

As previously described the dairy industry does not question the recorded fact that ground faults in the electrical system produces the set of health effects associated with "stray voltage". Only anecdotal information is available relating ground faults, caused by a high potential electrical wire driving AC into the earth, and human health effects. The number of documented cases showing a connection between ground faults and health effects in humans is growing, however. When the number of documented cases becomes sufficiently large a statistical analysis will be made to assess the significance of the information.

Evidence is surfacing in all areas of society implicating EM energy in human and animal health. As one reads the research literature relating EM's and health, no clear model has evolved. There is, in fact, a sense of something missing. In general the research has dealt with the investigation of a single form of EM energy, such as the 60 Hz magnetic field, as it may affect living organisms through a very specific mechanism and cause a specific health effect, for example, cancer. Most certainly the fewer variables in a study, the more easily statistical significance can be established. As complex environmental problems are being exposed, evidence is mounting which is pointing to a set of causes and a set of effects. For example the causes might be a collection of chemicals as well as physical parameter as EM's and noise. The effects might be all of or any one of the health problems connected with stress. Perhaps the methodology for investigating environmental problems requires a fresh approach. Consider the possibility of treating an environmental problem within the context of a systems, problem solving study. Very briefly, an interdisciplinary team would be established to investigate case studies and anecdotal information for the purpose of identifying the problem. After the problem has been determined, the team would prepare a research protocol for determining its association with specific EM energies, if it exists. Better models can then be proposed and tested and research recommend that hopefully can determine cause and effect. Since it is the interaction of the living organism with the foreign environment that has the potential of causing effects, field studies will be required to more quickly establish the most productive approach to research. For the case of the perceived connection between various EM configurations and human and animal health, a significant quantity of anecdotal information is available relating specific geographic areas as having the perceived connection. In order to legitimize this approach for studying the potential impact of EM's on health, perhaps a name should be established for this field of study, such as "Electromagnetics Ecology".

In the background paper, "Biological Effects of Power Frequency Electric and Magnetic Fields," prepared for the US Congress, Office of Technology Assessment, the following conclusions were presented: ...", there is now a very large volume of scientific findings based on experiments at the cellular level and from studies with animals and people which clearly establish that low frequency magnetic fields can interact with, and produce changes in, biological systems. While most of this work is of very high quality, the results are complex. Current scientific understanding does not yet allow us to interpret the evidence in a single coherent framework. Even more frustrating, it does not yet allow us to draw definite conclusions about questions of possible risks or to offer clear, science-based advice on strategies to minimize or avoid potential risks.

Of the effects discussed, the central nervous system effects including circadian rhythm changes in animals and the possibility of cancer promotion appear most worthy of concern with respect to public health consequences. From the final report, "Biological Effects of Power Line Fields," of the New York State Power Lines Project: "In conclusion, results of the New York funded projects document biologic effects of electric and magnetic fields in several systems. The variety of effects of magnetic fields have not been previously appreciated. Several areas of potential concern for public health have been identified, but more research must be done before final conclusions can be drawn. Of particular concern is the demonstration of a possible association of residential magnetic fields with incidence of certain childhood cancers. Further study of this possible association and mechanisms to explain it are important. The variety of behavioral and nervous system effects may not constitute a major hazard because most appear to be reversible, but they may impact temporarily on human function. Further research should also be done in this area."

These are examples of the concerns expressed by many scientists and panels asked to assess the health risks of electromagnetic fields.

Recognizing the health issues associated with EMFs on dairy farms, a group of people organized The Electromagnetics Research Foundation Inc. The Electromagnetics Research Foundation (TERF) is a non-profit corporation dedicated to understanding the role of EMs in living systems. The corporation was conceived at the "grass roots" level in the State of Minnesota, is incorporated in the State of Minnesota has expanded to include an active chapter in Wisconsin and Missouri as well as all who have an interest in EMs as it relates to living systems. The major functions are research and information management. Information management includes collection and dissemination of EMs information as it relates to life, and research emphasizes field investigations and problem solving.

At the present time there is no scientific consensus relative to EMF effects. The newer research in all EMF's, however, is pointing toward effects at much lower levels than even considered in the early research in this country. The more recent research also reveals a broadening of the models relating cause and effect so as to include non-traditional mechanisms. Small direct currents, extra-low frequency (ELF) fields at volts/meter, low power radio frequency and microwaves, and combinations of these, have been correlated with physiological effects on living systems. Radio frequency fields modulated at ELF's, for example, have demonstrated significant effects because the radio frequency fields appear to be the best carrier for most effectively exposing cells to the ELF fields. Although there is no clearly defined lower level for effects from any EMF, the levels at which effects are observed continues to go down. One of the most disconcerting aspects of research in EMF effects, is the problem of reproducibility. This is especially noted in the utilization of EMFs in health assist activities. Traditional statistical methods are difficult to apply when individual differences in specific effects in living organisms are so great. In spite of the uncertainties, electric field and currents are used for bone unions, anesthesia and pain relief.

The human body is a complex array of materials of various electrical and magnetic characteristics. Materials range from good conductors such as liquids to good nonconductors such as walls of the blood vessels. Other materials include semiconductors and combinations of semiconductors which can act as diodes. Bones have piezoelectric characteristics, that is bending of bones can produce electrical potentials and currents as well as the opposite--electrical currents causing bones to bend. Such ions as sodium, calcium and potassium represent positive charges that can move throughout the body. We know that the heart functions by electrical impulse. The entire nervous system transmits information at least by pulses of electrical energy. Sensory perception such as the vision of the eyes is the conversion of one form of EM energy to DC which is transmitted and read through the CNS. These are known facts that are not disputed.

David Cohen of MIT has been a pioneer in the development of equipment for measuring magnetic fields produced within the human body. The sizes of these magnetic fields which he measures are from a million to a billion times smaller than the earth's magnetic field. They are present in various areas of the body from the heart muscles to the brain.

Robert Becker, a medical researcher formerly from the New York State University system has measured different potentials at different points on the human body. He says that all living organisms carry a complex electric field. The more complex the organism the more complex the field. His book The Body Electric, published in 1985 presents his research and models.

Ross Adey, Medical physiologist from the Jerry L. Pettis Memorial Veterans Hospital, Loma Linda, CA, says that cell membranes contain protein strands that are activated by packets of EM energy perhaps generated by another cell or at the membrane by a chemical reaction. The weak signal embodied in the EM energy rapidly spreads across the cell surface, is amplified and passes across the membrane to the cell's interior. ...A thorough understanding of how EM "whispering" among cells is amplified into louder "talking" will shake up assumptions about all sorts of cell processes, says Adey, including those involving memory.

A book published in 1983, Biological Closed Electric Circuits: Clinical, Experimental, and Theoretical Evidence for an Additional Circulatory System by Dr. Bjorn Nordenstrom will undoubtedly have a significant impact on biomedicine. Dr. Nordenstrom's book draws together his and others' research which substantiates his theories that all living systems contain numerous functioning electrical circuits. Electric fields produced within the body provide the force and energy which maintains these currents for whatever purpose is required. These circuits, he maintains, exist in all bodily functions and the DC currents present determine the well being of the body. He speaks of circuits that are switched on by an injury, an infection, or a tumor, or even by the normal activity of the body's organs. His measurements indicate that electric currents course through arteries and veins and across capillary walls, drawing white blood cells and metabolic compounds into and out of surrounding tissues. These currents are maintained in the body by electromagnetic fields for whatever purpose is required. This electrical system, says Nordenstrom, works to balance the activity of internal organs and, in the case of injuries, represents the very foundation of the healing process.

Dr. Nordenstrom writes, "Simple electrotechnical analogues imply that a local decrease or increase of transported current may give rise to undesired as well as useful effects. A local change in density of current anywhere in a biologically closed circuit might lead to anesthesia, or produce pain or other undesired effects far away from the site of the driving force for the closed circuit transports. Clinical consideration which can not simply be understood by the known and accepted mechanism of referred pain might be explained in this way. For example, degenerative alterations in the cervical spine may not only give rise to pain in the distribution of an affected nerve but also to symptoms of local peripheral injury associated with pain, e.g., tenderness to local palpation or active contraction of a muscle or muscles."

Dr. Nordenstrom discusses the possible role of biological closed electric circuits (BCEC) in biogenesis, including carcinogenesis. "Strong currents will destroy cells and tissue. Weak currents, on the other hand, will more gently create new internal and external environments for cells. The currents will also directly interfere with cellular metabolism and modify structural elements of cells." A large variety of chemical, physical and biological factors can induce cancer. The capability is not surprising. Many chemicals should have the capability to activate BCEC systems with different magnitudes of energies, either primarily by their own electro-(physico-)chemical potentials or secondarily over a chronic injury polarization. It is therefore possible to understand that BCEC systems under certain circumstances may function as a common mechanism in carcinogenesis."

The specific physiological effects from ELF fields are critically summarized by Andrew A. Marino researcher, at the Louisiana State University Medical Center, in his contribution to the <u>Assessments and Viewpoints on the Biological and Human Health Effects of Extremely low Frequency Electromagnetic fields (a compilation of commissioned papers for ELF literature review project)</u> under the direction of the American Institute of Biological Sciences. The summary of the nearly 200 research reports which Dr. Marino reviewed is:

"1. EMFs can alter the metabolism of all body systems, including the nervous, endocrine, cardiovascular, hematological, immune response, and reproductive.

2. The effects on each tissue or system are largely independent of EMF frequency.

3. An organism's response to an EMF is determined in part by its physiological history and genetic predisposition; individual animals, even in an apparently homogeneous population, may exhibit changes in opposite directions in a dependent biological parameter.

4. EMF-induced biological effects are best characterized as adaptive or compensatory; they present the organism with environmental factors to which it must accommodate."

Even though this study did not completely exclude effects from higher frequencies there is another body of research concentrating on radio and microwaves. Both western and eastern nations have contributed to this research but let me highlight information provided at a conference in Warsaw in 1971 by Zinaida V. Gordon and Maria N. Sadchikova of the USSR Institute of Labor Hygiene and Occupational Diseases. They identified a comprehensive set of symptoms which they called microwave sickness. Its first signs are low blood pressure and slow pulse. The later and most common effects are chronic excitation of the sympathetic nervous system(stress syndrome) and high blood pressure. This phase also often includes headaches, dizziness, eye pain, sleeplessness, irritability, anxiety, stomach pain, nervous tension, inability to concentrate, hair loss, plus an increased incidence of appendicitis, cataracts, reproductive problems, and cancer. The chronic symptoms are eventually succeeded by crises of adrenal exhaustion and ischemic heart disease (blockage of coronary arteries and heart attack).

EM energies can cause adverse effects in the central nervous system, cardiovascular system, and immune system. The levels which induce these effects is debated; the exact mechanism is uncertain; and the specific effect on an individual species does vary. The real impact from EM energy can only be assessed through an open acknowledgment of a number of interaction mechanisms which have potential for causing biological and health effects.

The conclusion always expressed is the need for more and independent research. Today only the Electric Power Research Institute, the research arm of the Electric Utilities, the Department of Energy and the Navy provide funding for research on electromagnetics and health. The Environmental Protection Agency eliminated its EMs division about seven years ago.

Drawing from all available information, we must conclude that EMFs at low levels affect human and animal health. The scientific proof requires: 1) that research money be made available to independent teams; 2) that better models for the interaction of electromagnetic fields on living organisms be used; 3) that consideration be given to electricity reaching living organisms through direct contact with the ground, floors of buildings and other solid objects carrying electricity and; 4) that the totality of EM exposure be recognized in determining health correlations and in locating appropriate control regions.

We need to reconsider our rationale for not seriously utilizing mechanisms of interaction other than thermal or shock in determining potential biological and health effects.

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AN EXPLORATION OF THE RELATION OF SELF-REPORTED HEALTH CHARACTERISTICS TO ELECTRO-MAGNETIC FIELDS IN AN URBAN SETTING

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tissues (Udintsev & Khylnin, 1978), and catecholamines of the brain (Grin', 1978).

Most of these studies were initiated to discover positive EMF applications in health and healing. However other studies focus on the possible negative effects of EMFs particularly in stimulating cancer (Vagero and Olin, 1983; Lester and Moore, 1982; and Wertheimer and Leeper, 1979, 1982 and 1987). Other studies examine EMFs in relation to cardiac disease (Rea, 1978), human reaction time (Hamer, 1968 and Persinger, et al., 1975), sensitivity to the electrical environment (Marino, et al., 1980), and suicide rates (Park and Helliwell, 1978; and Perry, et al., 1982).

Various health benefits and dangers of electrical current continue to be discussed both inside the academic community and in the public press. A report on DOE activities, given at the American Public Power Association National Conference (Gyuk, 1988), suggests that even though no proven health hazards have emerged, there are biological effects. The stance suggested in this report is concern but not alarm and a need for further scientific research.

Perhaps the most ambitious research project to date is the New York Powerlines Project. It suggests that thresholds for biologic effects of EMFs be examined, that field effects on learning ability be examined and that the association between EMFs and cancer, particularly leukemia, be investigated (Ahlbom, et al., 1987). Morgan, et al. (1987) suggest that regulatory dilemmas will likely orbit around such issues as how calcium ions attached to neural tissue are released after EMF exposure, how EMFs affect the rate of DNA synthesis, specific effects on endocrine hormonal processes and the proteinkinase activity in cells following field exposure.

Most research is carried out in laboratories. However, since persons live in other than controlled laboratory settings, it is important to assess EMF effects on humans in the context of daily activities. A significant diversity of EMF's are produced today, and humans may live amidst a variety of EMF outside the area. The research attempts to establish an exploratory association between EMF levels and self-reported health complaints. It is anticipated that health complaints, or a specific complaint, will occur more frequently in those locations, or side of street, where 60 Hz EMF frequencies occur in greater magnitude, i.e., nearest the power line. However, it is noted that only the width of a two-lane street distinguishes differences in housing distance from the power line since the line runs in front rather than behind the houses on the even numbered side of the street. In so far as possible, locational parameters are established to determine if EMFs might be a logical explanation for self-reported health problems.

RESEARCH METHOD

As a result of these concerns, a research project was initiated in October, 1988 and continues to the present. Research exploring EMF health effects entails a variety of problems both in establishing EMF frequencies and magnitudes and tying these to specific health problems. Basic research conditions vary greatly in the natural setting as compared to laboratory research because of difficulties in controlling for possible intervening variables. For example, there are important distinctions in measuring surface as compared to ground EMF's. Furthermore, measuring DC currents is more difficult than measuring AC currents, and portable specialized equipment for use outside the laboratory is expensive and difficult to acquire. Also, EMF magnitudes are variable and are likely subject to time, weather, soil and other conditions.

Establishing a tie to specific health conditions is also difficult, though earlier studies suggest a link between EMF levels and some health problems, such as cancer (Wertheimer and Leeper, 1979, 1982 & 1987). In these cases, ties may be made more precisely since there is a larger data base about the particular forms of cancer being studied. This study could not be so focused since it originates from general health complaints seeming to arise in a with such levels are controllable in the laboratory but must be found to exist in the external environment before long term health consequences can be assessed in living areas.

Even with these important limitations, health concerns stemming from EMFs and a growing accumulation of general, and some specific, information seemed to warrant exploratory research. A questionnaire was devised to assess health factors that includes a list of such symptoms as frequent headaches, feeling stressed, feeling as if one had the flu, numbness, memory loss, visual problems, fatigue, irritability, and among women, fluid retention and painful menstruation. Beside gender, control factors included age, length of residence, time of day and season when feeling best and worst, and whether other persons in the home also displayed any of the symptoms indicated.

EMF assessment focused on 60 Hz magnetic fields. The first was taken at earth surface level on the sidewalk directly in front of the home (M1). A second measure consists of a summed directional location of electric currents producing the 60 Hz field (D1). Third and fourth assessments repeated the first two measures but at two meters above the ground (M2 & D2). A fifth assessment taken at ground level estimates the 60Hz electric field at the earth's surface which perhaps indicates the quantity of current in the ground (E1). A few homes were selected for additional measurements.

The sample site includes approximately fourteen blocks adjacent to a 65 kilovolt AC electric power line in the city of Moorhead. Each household in the selected area was contacted for personal interviewing by a student research team. In some cases, more than one person per household was interviewed, though information about other household members was also assessed via the primary respondent in each household. Research teams of students also completed the EMF measurements. Assessments were completed in 1989. The total number of completed questionnaires from primary respondents is 77.

In spite of some inherent problems in linear analysis, various statistical methods are used in assessing and interpreting the data. PROBIT (predicting a

The strategy for estimating EMF relations to health symptoms is to determine if symptoms and EMF measures predict side of street.

Model: (EMF——> Side of Street <——Health Symptoms).

The five EMF measures were discussed above. All five EMF measures taken together do predict side of street ($P < .001$). However directional measures (D1 & D2) tended to be highest on the side of the street where magnetic measures were lowest (M1, M2 & E1). When magnetic measures were separated from the directional ones, they continued to predict side of street ($P < .001$). This supports the notion that EMFs do differ by side of street with magnitudes being greatest nearest the lines.

Next we determined if symptoms also predicted side of street. The following symptoms for the whole group were used in this determination: pain in limbs, headaches, flu-like symptoms, fatigue, irritability, anxiety, stress, feeling weak and having allergies. First, all items were individually analyzed to determine if their frequency of reporting differed by side of street. Only one item is found to be significant. Allergies are more likely to be reported on the side of street nearest the line ($P = .049$)

Since those health symptoms possibly related to EMFs are likely not consistent among individuals, two composite variables were created by assigning symptoms to the side of street where they were the more likely to be reported and summing them (indexing). The two variables are then used to predict side of street. For the whole sample these symptoms do predict side of street ($P = .049$). Those symptoms more likely reported nearest the power line are pains in limbs, headaches, irritability, stress and allergies.

Separating men and women and predicting side of street from symptoms improved slightly the level of significance for men to $P = .042$ but not for women ($P = .148$) and is not significant. For women, the index included fluid retention and menstruation problems. Men living nearest the lines were more likely to report having pains in limbs, headaches, being irritable, anxiety, weakness, and allergies.

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STRAYVOLTAGE IN THE DAIRY BARN:

DISCOVERY AND RESPONSE

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STRAYVOLTAGE AND THE DAIRY INDUSTRY

INTRODUCTION

Human activities have significantly diversified the earth's already existing electromagnetic fields (EMFs). Various researchers and technicians in a variety of disciplines (here referred to as the literati) are currently examining the effects of EMFs in numerous settings around the world. Persons in the dairy industry are voicing concerns reflective of various beliefs and assumptions that electrical transmission lines and other sources are creating fields of stray voltage that effect output in their dairy operations. This is leading dairyists to seek verification of their beliefs and develop strategies to cope with these perceived problems.

Collective behavior and social movement analysts have long been interested in the process of emergent leadership (LaPiere, 1938:281-293), their legitimation (Lang & Lang, 1961:236-253), and the process of developing value credibility within social movements (Turner & Killian, 1957:331-359). The technical nature of EMFs is forcing dairyists to seek out specialists, the literati, to help clarify, explain and legitimate beliefs about the problem of stray voltage in the dairy industry in order to diminish supposed EMF consequences. These EMF literati include scientific researchers, agricultural extensionists, agricultural product technicians, and others. Since the literati are neither belief nor value homogeneous about EMFs, it seems worthwhile to analyze the role of the literati vis-a-vis dairyists as dairyists attempt to formulate a constructive knowledge system for ameliorating EMF problems.

reconstitution of a component of action." Therefore, beliefs about structural strain are central to establishing the basis for collective outcome.

The resource mobilization theory of collective behavior suggests that social strain is not always necessary for collective action to occur (Miller, 1985,315). However, there are numerous general conditions perceived as inducing strain in the dairy industry such as over-production of dairy products, deflation of land values, increased automation and labor costs, dependence on governmental price supports, energy cost fluctuation, and competition in an international market. More specific inducements to perceived strain include increased sanitation requirements in production, and complex record keeping of herd acquisition, their maintenance and production. Dairyists tend to perceive a lessened personal control over a widening sphere of external influences. This occurs parallel to notions that the "family farm" and its commensurate personal support system is giving way to less personal external control systems.

Smelser (1963:51) suggests that ambiguity is a basic component of strain. Collective action might be expected in a situation where decreasing personal control, accompanied by erosion of the personal support system, accompanies economic strain. Ambiguity occurs when existing remedies are perceived as inadequate and alternatives are not apparent. This is precisely the condition for dairyists perceiving that EMF factors decrease their dairy herd production. There is ambiguity both in defining the problem and in seeking ameliorative action. Thus general strains in agriculture provide a broad context within which specific EMF factors produce additional strains. This idea is now discussed more specifically.

Belief that EMFs Are Part of the Economic Problem:

Agriculturalists have a history of resisting condemnation of their land for such uses as water control, wildlife mitigation, road-building, urban acquisition, etc., and this includes electric power line construction. Even though electric lines are important in the modernization of rural life, transmission lines are perceived as inconveniences to farm operations. They chop up fields, pose hazards in the movement of equipment and present barriers to field cultivation. Therefore it is not a great leap for dairypeople to associate their problems with perceived power line residues (EMFs).

Dairy operators attribute a variety of problems to stray voltage. These include such cattle behavior as unwillingness to enter the barn or stalls, refusal to eat and drink, unable to clean feed off the cement floor, dancing in the stalls and kicking the handler while being washed. More serious problems attributed to stray voltage are breeding problems, spontaneous abortion, longer milking time and general reduction in milk production (Dahlberg, 1987).

Complaints from dairy people concerned with electromagnetic fields prompted the Minnesota Department of Agriculture to sample dairy farmers' problems. The author was able to obtain the raw data and analyze 1075 returned questionnaires. Approximately 37.5 percent of the 20,000 dairy farms in Minnesota received the questionnaire left by inspectors at the time of their regular dairy inspection. Fourteen percent of the questionnaires were returned representing just over 5 percent of all dairy farms. Basic controls such as dairy herd size, gender of the respondent, years in the diary industry, etc. were not part of the questionnaire. Findings are discussed keeping in mind problems of sample quality and secondary data analysis.

tends to be short-circuited leaving the perceived problem in a state of ambiguity.

Diary people only gradually associate EMFs with dairy problems. This situation differs somewhat from the earlier quarrel between agriculturalists and electric power companies when media kept the public informed. Data from the Minnesota and purposive study suggest that the suspected tie between cattle behavior and dairy problems is disseminated primarily through personal networks and secondarily through concerned persons using available media. Only 7 percent of the respondents in the purposive sample think that the general public is aware of the problems with stray voltage. At present, brief statements about EMFs are beginning to appear in newspapers.

Mobilization of Resources:

Smelser's value-added theory rests of the premise that positive steps toward problem amelioration occur when there is generalized recognition and acceptance of a particular problem. As discussed above, many dairy people and the general public do not perceive a tie of EMFs to dairy problems. Concerned dairyists and some literati are in the process of mobilizing resources to generalize the belief that EMFs and dairy problems are related. Ellig indicates that resource mobilization is a necessary component in maintaining farm protest (1985). In this context mobilization seems less oriented toward protest than it is toward direct amelioration of perceived EMF consequences. McCarthy and Zald (1977) suggest, among other things, that resource mobilization includes transforming the mass and elites into sympathizers. Dealing with EMF effects specifically requires mobilizing resources, both human and economic, in and outside the dairy industry. Buttel and Flinn (1976) show that particularly in

environmental issues, support is diffuse and tends to cut across more traditional coalition lines. This would seem to be the case here particularly as it involves the literati as defined earlier.

Credible causal evidence must be transmitted amongst a broad social network in order to mobilize action. The chain of influence includes other dairyists, other agriculturalists, political figures local and national, the electrical power industry, electricians and electrical engineers, persons servicing dairy equipment, other users of electricity, and the scientific community. As indicated in discussing the purposive sample, a trade journal was used to elicit support and share information about EMFs, and the importance of such strategies has long been recognized (Schettler, 1960:251-267). To date this represents a limited beginning in the process of creating a generalized belief.

ROLE OF THE LITERATI

Because of the technical nature of EMFs, it is expedient that actionists utilize specialists to demonstrate causal relationships between EMFs and dairy problems and to provide public testimony. In the past, the literati have figured in the process of power legitimization (Roberts and Kloss (1979:219-226). Dairyists recognize the need to mobilize literati if they are to deal successfully with the electrical power industry. Use of literati also entails raising the necessary research funding. Without industry wide consensus, funding must come through the initiatives of interested persons and smaller groups rather than from the primary dairy organizations or government agencies. Knowledgeable researchers are necessary to lend technical credence to the funding proposals.

topics such as shielding effectiveness of concrete (Bruhin, 1984), establishing models for grounding (Kikuchi, 1984), compatibility in telecommunication networks (Lorke, 1984), development of green algae (Yankyavichyus et al., 1978), effects on the nervous system (Gorbach, 1982 and Toroptsev & Soldatova, 1981), lung disease (Pyntkin & Semenov, 1982), antibody reproduction in the spleen (Mel'nikov, et al., 1982), cell division (Mamontov & Ivanova, 1971), the liver (Dumanskiy & Rudichenko, 1976), metabolism (Dumanskiy & Tomashevskaya, 1978), testicular tissues (Udintsev & Khlynin, 1978), and catecholamines of the brain (Grin', 1978).

Emergence of International Dialogue:

Perhaps this sample of topics demonstrates that intensive investigations in EMFs continue on both sides of the iron curtain. Judging from published materials, it appears that research in Russia has been more broadly health oriented while research in the west is more diffuse. It is also apparent that research is being shared across political boundaries, and that there is an emerging convergence and assimilation of findings. An example of this is an article wherein Ivanhoe (1982) (Dept. of Pharmacology, U. of Calif. San Francisco), on the basis of 169 references, speculates that the emergence of human brain size paralleled geomagnetic intensity. Perhaps, the fund of information accruing about electromagnetic fields is beginning to move the public view from that of mystery and suspicion to a recognized, though highly technical, body of knowledge.

Much research focuses on the positive uses of electricity in health and healing, and they establish rather exact parameters of electromagnetic intensities for maximum effect in treatment while recognizing that incorrect

levels might produce ill effects. Some studies specifically examine negative EMF effects. Marino, et al. (1980) studied sensitivity to change in the electrical environment and Hamer (1968) and Persinger, et al. (1975) its effect on human reaction time. Vagero and Olin (1983) utilized the Swedish Census Environment Registry to study cancer in the electronics industry. Lester and Moore (1982) also examined cancer incidence and electromagnetic radiation. Power line effects are specifically studied by Park and Helliwell (1978), and Perry, et al. (1981) correlated exposure to power lines with suicide rates (United Kingdom). Important studies by Wertheimer and Leeper, (1979, 1982 & 1987) established a correlation between electrical home wiring and cancer. Rea (1978) examined another EMF problem, that of environmentally triggered cardiac disease.

Other studies investigate low voltage effects on animals. Delgado, et al. (1982) in Spain examined the effects on chicken eggs, Jaffe and Stern (1979) the path of electric flow in chick embryos (U.S.), and Krueger, et al. (1975) effects on chicken fecundity. Fischer, et al. (1976 & 1978) (German) examined effects on neural systems of rats and Marino, et al., (1976) (U.S.). the generational effects on mice.

As in positive effects, EMF researchers are not consensual on negative effects. This was apparent when the dialogue among researchers made public the differences over the Seafarer Project (Boffey, 1976 and Larkin, 1977). This project was a proposed large communication system that fueled the controversy over whether electricity flowing through the ground was quite different in its consequences from line transmission. Political sides were taken, and scientists for and against the project entered the controversy, a controversy directly relevant to stray voltage in dairy barns.

political process. Morgan, et al., (1987) discuss problems in regulating power companies when such informational ambiguity exists.

3. In traditional academic research: The literati and the market-place are not always well acquainted. Often laboratory research is viewed as "hard" science and applied science as "soft" science or even pseudo-science. Such views tend to inhibit amelioration of assumed EMF problems when they are not easily studied in traditional laboratory confines. The literati are divided, then, not only on what is consensual information but also on the valid locus of research and its commensurate methodology. Nonetheless there is growing awareness that there are effects (Ahlbom, et al., 1987).

LITERATI AND THE SHORT-CIRCUITING PROCESS:

Using Smelser's concepts, we can say that there are a number of ways in which the literati serve to short-circuit ameliorative processes. That is, the scientific and academic community perceives EMFs relative to their own specific situations thereby removing their scientific relevance from the more generalized body of knowledge suitable for application in the dairy barn (movement up and down the vertical axis). Figure 1 diagrams this process through Smelser's several stages.

1. Conduciveness. Persons are limited in action by their perceptions of normative restraints. Literati may feel that institutional, national and other identities limit their involvement in collective processes and events particularly if events are controversial.

2. Strain. Literati operate in their own system of structural strain. Strains in academic and other research institutions may limit interest and concern for strains in other systems such as in the dairy industry.

3. Generalized Belief. Since research on EMFs is highly segmented and specialized, individual knowledge may not be perceived as relevant to the dairy barn much less it being a problem there.

4. Belief in Negative Effects. There is a lack of consensus on negative effects of EMFs specific to dairy cattle. Amidst ambiguous and sometimes inconsistent findings, the literati are unable or unwilling to advise dairyists on ameliorative action.

5. Researching EMF Affects. Funding constraints, alternative research interests, and methodological problems inhibit doing relative research specific to the dairy barn. Funding for adequate research is subject to the values of persons controlling the purse strings, and these persons may feel sufficiently threatened by possible EMF effects to withhold or frustrate research support. Persons and groups most profiting from ameliorative action do not have sufficient funds for research (even when recognizing the need for it) or are not sufficiently organized to obtain funding from external sources. In the midst of scarce resources, literati have been known to engage in strategies of boundary maintenance that tend to inhibit sharing information and cooperating in applicable research.

6. Research Not Applied. Research is carried out but it is not applied to the ameliorative process or communicated effectively to persons seeking use of relevant information. Scientific journals tend to appear esoteric to persons outside the discipline and to most dairyists. On the whole, the literati have not been sufficiently communicative with dairyists to translate research needs into adequate ameliorative action.

FIGURE 1: AMELIORATION PROCESS OF ELECTROMAGNETIC EFFECTS IN THE DAIRY BARN

ROLE OF THE LITERATI

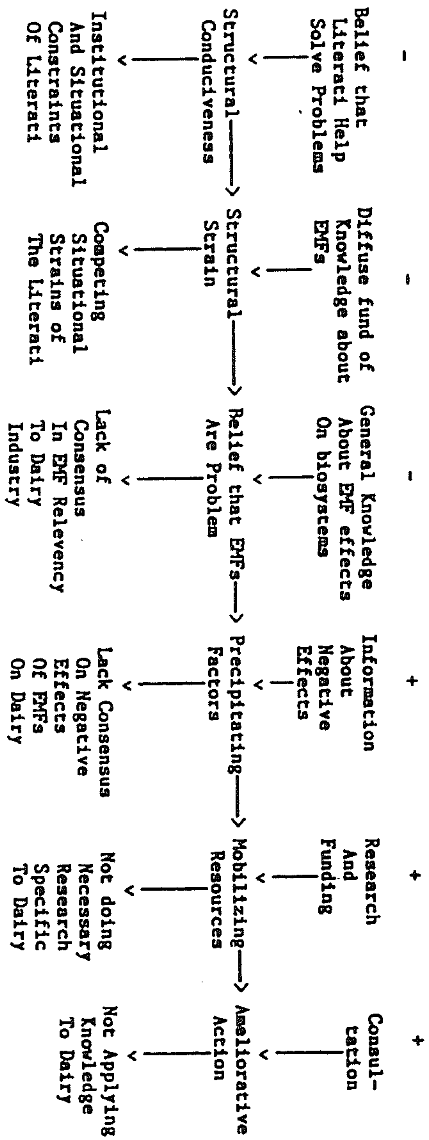

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TABLE 1: PHI AND CONTINGENCY COEFFICIENTS OF CORRELATION FOR SURVEY ITEMS ON STRAY VOLTAGE

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	#16	#17
#1 Slow																	
#2 Uneven	.527***																
#3 Lt Down	.440***	.418***															
#4 Uneasy	.419***	.446***	.476***														
#5 Reluct	.276***	.308***	.379***	.469***													
#6 Joints	.288***	.269***	.231***	.309***	.244***												
#7 Fluct	.330***	.387***	.328***	.412***	.326***	.292***											
#8 Health	.374***	.449***	.345***	.383***	.324***	.277***	.367***										
#9 Prass	.294***	.315***	.304***	.309***	.306***	.239***	.279***	.275***									
#10 Higher	-.218***	-.305***	-.239***	-.298***	-.225***	-.195***	-.304***	-.305***	.201***								
#11 Inprv	-.196***	-.275***	-.201***	-.187***	-.123***	-.181***	-.213***	.253***	.182***	.290***							
#12 Adjust	.221***	.214***	.332***	.337***	.312***	.195***	.245***	.203***	.228***	-.157***	-.169***						
#13 Barnsa	-.206***	-.184***	-.121*	-.126**	-.115*	-.051ns	-.198***	-.199***	-.118*	.137**	.155***	-.077					
#14 Season	-.170***	-.146**	-.073ns	-.092ns	-.091ns	-.107ns	-.201***	-.144**	-.101ns	.109*	.160***	-.071	.770***				
#15 Vary	.229***	.270***	.228***	.218***	.172***	.102**	.298***	.342***	.212***	-.202***	-.150***	.162***	.127**	-.062ns			
#16 Averg	.101ns	.174***	.153**	.079ns	.076ns	.058ns	.188***	.103ns	.113ns	-.243***	-.204***	.119ns	-.180ns	-.188ns	.192		
#17 OHIA	.017ns	-.074*	-.042ns	.006ns	.000ns	.006ns	.005ns	.063*	.001ns	.013***	.006ns	.006ns	.070ns	-.095ns	.012ns	-.196***	

Source; Survey by Minnesota Department of Agriculture, 1986.

N = 1075

Phi is used for all 2 x 2 table computations
The contingency coefficient is used for all tables > 2 x 2; probability is calculated by chi-square.
Items 13, 14, and 17 assessed by contingency coefficients with maximum value < 1.0

* = P < .05 ** = P < .01 *** = P < .001

RESEARCH PROBLEMS IN RELATING PERCEIVED EFFECTS OF ELECTROMAGNETIC FIELDS ON ANIMALS AND HUMANS: AN EMERGING FIELD IN ENVIRONMENTAL STUDIES

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RESEARCH PROBLEMS IN RELATING PERCEIVED EFFECTS OF ELECTROMAGNETIC FIELDS ON ANIMALS AND HUMANS: AN EMERGING FIELD IN ENVIRONMENTAL STUDIES

Introduction

This paper reviews the emergent perceptive process that stray voltage affects animal and human health. Three cross-disciplinary research projects are reviewed to indicate specific kinds of problems associated with attempts to link stray voltage and human health. This discussion is couched in the context of Smelser's value-added theory to locate current research in its broader social context. Briefly discussed are continuing needs for cross-disciplinary research and suggestions for overcoming "short-circuiting" processes in problem amelioration.

Problems in the Dairy Barns

There is growing awareness in this and other countries that "stray voltage" may be causing animal and human health problems. Particularly this awareness is growing among dairyists and is now extending to human communities as well. Stray voltage is a term used, particularly by dairy farmers, to describe a particular kind of low level electricity. It is electricity lost as current flows through wires or any other source of resistance, including ground rods (Paul 1988). One technical term for stray voltage is "neutral-to-earth voltage," but this is not a sufficiently inclusive term in light of more recent research efforts and investigations. The main sources are power lines and current carried in the earth. It is a common phenomenon in most of the nation's utility systems to use the Earth as a conductor in returning electrical power to its source. Instead of the electricity going back to the source in wires it becomes lost or stray. As a consequence of the stray electricity living organisms can be exposed to various electric currents and magnetic fields. Living organisms can also be exposed to electromagnetic reported effects include stress-related behaviors such as stall walking and weaving, inability to gain weight, dull coats, dull eyes, loose manure and sinus problems (Smith 1984).

Collective behavior and social change models are useful in analyzing perceptions of environmental problems (e.g., Buttel and Flinn 1976; Ellig 1985; Kroll-Smith and Couch 1989; and Ungar 1992). Dahlberg and Falk (1991b; Falk 1987, 1988, and 1990; and Falk and Dahlberg 1991) have traced the growing awareness of perceived problems associated with stray voltage through application of Smelser's Value-added collective behavior model. Since space does not permit an in-depth discussion of the Smelser model here, the dimensions are summarized as follows:

1. Structural conduciveness: Sufficient latitude exists in the American society to permit persons to take a variety of actions when they perceive factors threatening their livelihood, in this case the health of dairy animals.

2. Structural strain: strain exists at various points in the dairy industry even without EMF effects. These include maintenance costs, increments in equipment costs to meet production regulations, animal health treatment costs, decreasing profit margins, etc.

3. Belief that EMFs pose economic and health problems. An important core of dairy operators believe that EMF effects are detrimental to their dairy operations as exemplified in public and privately organized surveys, andarticles in trade publications.

4. Precipitating action: Dairyists have organized, attend public hearings, correspond with relevant agencies, and pressure perceived influentials to seek ameliorative action.

5. Mobilizing resources: Some of these activities have stimulated more research and funding of research and systematic sharing of knowledge that may

Delgado et al. 1982; Gorbach 1982; Grin 1978; Nordenstrom 1983; Perry et al. 1981; Pool 1990; Rea 1978; Toroptsev and Soldatova 1981; Vagero and Olin 1983; and Wertheimer and Leeper 1979, 1982, and 1987). A partial list of perceived human health effects include: tingling, numbness and/or pains in arms and legs, chronic fatigue, aching and swollen knees, dizziness, frequent headaches, vision problems, disorientation, memory loss, irritability under stress, swollen abdomen, nausea, open sores not healing, allergies, and among females, problems with the menstrual cycle. Other effects more difficult to assess are a high incidence of cancers (especially leukemia and brain), neurological disabilities and cardiovascular problems (Dahlberg & Falk 1990).

If the Smelser model is used, one might suggest that understanding the relation of human health to EMFs lags the perception of the relation of dairy cow health to EMFs. There seems to be an emergent belief that EMFs do affect human health as this discussion is entering the public arena. For example, a recent article in the The Wall Street Journal suggests a link between the use of electric razors and cancer (Rundle 1992).

The role played by research specialists in this problem have not been stellar. A variety of academy characteristics serve to delay amelioration of these perceived problems, a process which Smelser (1963) calls "short-circuiting." Here the assumption is that understanding EMF effects and facilitating ameliorative action requires a diminution of short-circuiting processes in the academy. It is suggested that these activities include less academic boundary maintenance, lowered susceptibility to political pressures in project funding and findings, and increased cross-disciplinary research as, e.g., discussed by Campbell (1986). In this connection three low-cost, interdisciplinary research projects are reviewed. The primary researchers are a physicist and a sociologist.

frequencies, e.g., at 60 Hz., and not at other frequencies. Experiments with such levels are controllable in the laboratory but must be found to exist in the external environment before long term health consequences can be assessed in living areas.

A questionnaire assesses health factors that includes a list of such symptoms as frequent headaches, feeling stressed, feeling as if one had the flu, numbness, memory loss, visual problems, fatigue, irritability, and among women, fluid retention and painful menstruation. Items derive from prior studies and case histories of persons thought to be affected by EMF presence. Beside gender, control factors include age, length of residence, time of day and season when feeling best and worst, and whether other persons in the home also displayed any of the symptoms indicated.

EMF assessment focused on 60 Hz magnetic fields. The first was taken at earth surface level on the sidewalk directly in front of the home. A second measure consists of a summed directional location of electric currents producing the 60 Hz field. Third and fourth assessments repeated the first two measures but at two meters above the ground. A fifth assessment taken at ground level estimates the 60 Hz electric field at the earth's surface which perhaps indicates the quantity of current in the ground. Each household in the selected area was contacted for personal interviewing by a student research team. In some cases, more than one person per household was interviewed, though information about other household members was also assessed via the primary respondent in each household. Research teams of students also completed the EMF measurement. The total number of completed questionnaires from primary respondents is 77.

The strategy for estimating EMF relations to health symptoms is to determine if symptoms and EMF measures predict side of street. The primary statistical method for this assessment was PROBIT (predicting a dichotomy form questions raised about EMF effects on humans, a laboratory experiment was undertaken to estimate short term effects on select aspects of human behavior. The object of the study was to examine and quantify the effects of short duration exposure to electromagnetic fields in terms of short term recall, reading comprehension, and reaction time. In addition, two surveys were given to the subjects (N = 35), one to determine conscious sensitivity to EMF's, and the other to gauge long-term conditions that could be linked to excessive exposure to EMF's. Subjects were not informed about the nature of the study until the last figures were gathered.

A summary of the research procedure follows:

Time I--------------------->	Time II----------------	Time III
Mercury Vapor Lamp Off	Mercury Vapor Lamp On	Exit Questionnaire
Memory Test I	Memory Test I	
Memory Test II	Memory Test II	
Comprehension Test (6 items)	Comprehension Test (6 items)	
Reaction Tests (5 tests)	Reaction Tests (5 tests)	
Post Test (15 items)	Post Test (15 items)	

A small room (psychology laboratory) with a mercury vapor light in an adjoining room was mapped to find the point of greatest field intensity of EMFS. The field was found to be not uniform in its variation throughout the room. The experiment was set up in two parts so that the same variables could be assessed with the light off and the light on. The subjects were individually administered the tests while seated at the point of greatest field intensity [6 milligauss (mg) and head level and 2.2 mg at foot level]. At this placement, the field measured .43 mg at head level and .63 mg at foot identical to the one given with the light off. Finally, the subject was given an exit questionnaire designed to elicit any long term conditions or circumstances that might be related to excessive exposure to EMF's.

Data derived from this research project are analyzed using standard statistical techniques. As in much research, probability of .05 is considered the acceptable error level. Differences in reaction times between light off and light on conditions. They are significantly faster in the second (p = .018) and fifth tests (p = .009). When all reaction times are summed the difference is also significant (p = .034).

General learning theory would suggest that persons would perform second experiments more quickly. Therefore one cannot simply account for changes in response to the presence of the lights. It is possible that equal or more learning could take place without lights producing an equal or even lower reaction time at Time II. Future experiments will need to take this into account. There were no significant differences between Time I and Time II tests on either of the two memory tests or the comprehension test using correlated t-test estimations. However on the 15 item post test, persons responded affirmatively more often to ten of 15 physical symptom items in the light on or Time II condition. This finding is significant when differences are estimated with the sign test (p = .006) (Dahlberg & Falk 1991).

Project 3. An assessment of electromagnetic ecology in a California elementary school (Dahlberg and Falk 1991a): Complaints by persons working in an elementary school led to inviting a physicist to make an EMF assessment to determine if adjacent utility lines might be the cause of health symptoms associated with EMFs. The school consists of five pods, four in each corner of a rectangle and a central office and work area. This pod arrangement facilitated research in that each pod could be treated as a separate analytical unit. EMF assessments were made in each of the five pods and also

Discussion and Conclusions

This paper assumes that environmental research requires input from diverse fields of knowledge and academic disciplines. Experience in researching health effects of electromagnetic fields certainly confirms this assumption. The primary researchers in these investigations were a sociologist and a physicist. However even this low budget research required information from biology, psychology, ecology, soils, etc., and firsthand experience reporting from an array of persons attempting to explain their health symptoms. First then, this research requires a cross-disciplinary team of researchers. That entails dealing with such things as acquiring a minimal understanding of one another's technical language, the kinds of scales used in measurement, and statistics appropriate for assessing these measurements. It also requires reaching a consensus on a satisfactory theoretical base and research methodology.

Second, it is necessary that researchers have some first hand experience with the nature of the problem (in this case with perceived EMF effects on health) acquired through meetings with concerned persons discussing their experiences, representatives of electric utilities, relevant political figures, representatives of governmental agencies, and other interested persons. In this instance, it requires some understanding of political structure and organization, particularly if researchers are to have access to facilitating agencies both in information acquisition and ameliorative action.

Third, the complexity of this problem requires a number of different approaches that combine knowledge acquired through controlled laboratory experimentation and on-site assessment. As previously indicated, each method has its advantages and disadvantages. Variables may be much more carefully controlled in a laboratory setting lending a precision not possible on site. However the laboratory does not reflect the array of synergistic effects that

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SUMMARY OF EXPERIENCES, LITERATURE SEARCHES, COMMENTS AND DISCUSSION OF STRAY VOLTAGE

PREPARED FOR PRESENTATION ON
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TO
THE PUBLIC SERVICE COMMISSION OF WISCONSIN
DOCKET NO. 05-EI-108
INVESTIGATION ON THE COMMISSION'S OWN MOTION INTO THE PRACTICES, POLICIES, AND PROCEDURES OF PROVIDING ELECTRIC UTILITY SERVICE AS IT RELATES TO THE POTENTIAL ADVERSE EFFECTS ON DAIRY LIVESTOCK FROM ELECTROMAGNETIC FIELDS, GROUND CURRENTS, AND DIRECT CURRENTS ASSOCIATED WITH THAT SERVICE

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INTRODUCTION

Several years ago, the firm of A. B. Brogden Ltd. was retained to provide expertise in a stray voltage investigation. During that investigation and several that followed, it became apparent that existing literature on stray voltage was inadequate to explain many of the observations being made in the dairy industry. Starting about November 1987, articles from various disciplines were collected and reviewed.

The conclusions reached is that pulsed waveforms and transients are the most likely cause of biological effects.

This presentation is a summary of experience and literature searches that lead to that conclusion.

CASE HISTORY #1

Mr. Lee Montgomery, a dairyman and purebred Holstein breeder near Chatham, Ontario, with a tie stall operation, milking 20 to 25 cattle experienced a progressive increase in many symptoms from the early 1970's until the first week of March 1988.

Cattle Symptoms included; Low production, slow milkout, uneven milkout, poor conception rate, high abortion rate, mastitis, swelling in legs and joints, rough coats, high somatic cell count, sudden jumpiness, kicking off the milk machine, two unusual cattle deaths, broken neck straps, mangers not cleaned out, and numerous signs of stress. Stress included; flaring nostrils, bugged eyes, tense muscles, twitching or flinching, bellowing and swishing tails.

There was virtually no measurable voltage. The utility had separated the transformer neutral in 1980 and the barn had been supplied by an isolating transformer since 1982. Mr. Montgomery had tried both total bonding of metal stantion, waterbowls, vacuum line, etc. and total unbonding. In every attempt, unbonding resulted in better herd performance.

Other coincidental occurrences included; short incandescent lamp life (lamps were generally 130 Volt while the maximum measured voltage rarely exceeded 125), telephone interference, television interference, and farm cats that became sterile. Several neighbors reported frequent incandescent lamp failure and one neighbor about two miles away experienced two electric furnace failures, three TV set failures and one light fixture within seven years. Line crews indicated there was a high number of pole fires in the area for several years prior to 1988.

Investigation by technicians, engineers and others spanned several years. Pen recorders and oscilloscopes were tried but nothing definitive could be found. In late 1987 an ordinary radio speaker was connected between primary neutral and a remote ground. Clicks and sharp bursts of buzzing sounds soon made us aware that there was much more than 60 hertz on the neutral of this rural distribution. This simple device was really a very cheap transient monitor which proved to very effective within its frequency range.

Simultaneous monitoring with an oscilloscope worked even better. Watching and listening revealed there were many transients so short that the speaker was unable to respond. In an attempt to get a better picture of what was happening a BMI 4800 power monitor was set up in early March of 1988. Our intention was to familiarize ourselves for a few days with the instrument and then launch into a organized investigation. During the familiarization step, the BMI recorded transients between grounded objects. Values exceeding 200 volts were recorded twice. See appendix 1. In several cases the transient occurred exactly when there was a change in the low level background 60 Hz. These transients lasted only 1 to 3 microseconds.

Meanwhile the Utility began to make repairs to insulators, loose neutral and grounding connections on the rural distribution system in response to complaints of TV interference. Repairs were not local to the farm but occurred two to ten miles distant. Several subsequent observations were made; the ground transients ceased, light bulbs at Mr. Montgomery's and his neighbors lasted longer despite the RMS level remaining constant, milkout time decreased from 1 hr. 20 min. to 55 min. over the next month, milkout became even in all quarters, production increased by 25 %, the conception rate climbed back toward normal, and <u>no</u> abortions occurred in the year following. Television interference subsided as did noise on the telephone system. No change was made in feed, equipment, personnel, farm wiring, for months <u>before or after</u> March of 1988.

One question to be answered was, "Could short duration pulses of 3 to 4 microseconds have affected the cattle?". Posing it to several people in the veterinarian and medical fields did not yield an answer. To check whether the transients might be responsible, a simple pulse generator was constructed to do field tests of short pulse effects on cattle. Results are in appendix 2, but briefly, single 4 to 6 microsecond pulses of 30 volts are definitely sensed by cattle when applied between front and rear hoofs. The most significant observations were <u>milk letdown</u> and <u>disrupted breathing and/or abdominal activity</u>.

A second question was, "Could incandescent lamp life be affected by power system transients?" The service departments of several lamp manufacturers were contacted from whom we learned of a lamp failure mode called " filament arcing" caused by overvoltage in varying degrees. Specifically, a very short spike does not have enough RMS power to cause overheating of the filament and its failure. But if the spike is high enough, the hot, nearly ionized gas near the filament may ionize and break into conduction. At this point a large current may flow through the hot gas causing an arc. If the arcing current is large enough, a fuse built into the base of the lamp usually blows. The current flowing through the gas finds the path of least resistance which turns out to be along a path from one end of the filament to the other through the ionized gas. If the arcing is strong enough, it will sever the filament right at the point where the filament is attached to the support at one end and very often at both ends. Where this type of failure occurs, sometimes the entire filament lies in the glass envelope in one piece leaving only its weld beads on the support. We were unable to obtain values at which this happens. A larger pulse generator capable of 1900 V pulses which could be placed across a 120 V AC circuit was constructed. A typical pulse decays to 0 volts in about 5 microseconds. Filament arcing failure has been found to occur with spikes of 1200 volts and higher. Lower overvoltages can cause similar failure if the pulse is sufficiently long in duration. 220 V 60Hz can cause this failure within a few cycles of 60 Hz, but not have enough detail is available to make any conclusive statement.

With this knowledge, several lamps which failed prior to March 1988 were re-examined, in particular, two lamps which had failed under unusual circumstances. In February 1988, a family member returned home from an evening shift at a retail store and was watching a late night movie. In the TV room, the ceiling fixture contained three incandescent lamps. At about 2:30 AM, all three lamp failed simultaneously with a POP! One was replaced immediately, but the other two were recovered for examination. Both of these lamps had totally severed filaments and blown fuses. In all probability a strong power system transient was responsible.

This stray voltage case appeared to be the result of transients, a power quality problem caused by one or more defects in the utility's distribution system.

CASE HISTORY #2

We were not involved with this case, but it has been documented and is presented here as it presents an interesting aspect of stray voltage.

Mr. Amos Martin, a dairy farmer near Cambridge, Ontario, experienced low production, high abortion rate, feeding problems, drinking problems and other stray voltage symptoms in his herd. Mr. Eric Johnson working for the Ontario Milk Marketing Board and Mr. Bob white of Alfa-Laval in 1981, diagnosed his problem as stray voltage. There was only one serious problem with this diagnosis in the classical sense of stray voltage. That was, Mr. Martin is a Mennonite and had no electrical service to his farm at all. A voltage gradient could be measured across the barnyard. Mr. White designed a ground grid for the barn. The herd recovered soon after the installation of the grid.

This case strongly suggests ground currents were responsible.

Case history #3

We were not involved with this case either but it is noted here because of its particular conclusion. A report, written by the foreman in charge of the utility's service crew, is unavailable, probably due to its age. The few details were related to us by the crew foreman from memory.

In the late 1960's a rural distribution system near Strathroy, Ontario was found to have a high harmonic content. The correction of the harmonic situation corrected a stray voltage problem in a nearby dairy herd. The crew satisfied themselves that the harmonics on the distribution sysem had affected the herd adversely.

We do not know if the utility's investigation was prompted by a stray voltage complaint.

Harmonic are also well known in power quality problems.

Case history #4

The name of this farmer and his location is withheld per his wishes. His case is nearing a critical point in negotiating a settlement.

The farmer maintained a dairy herd and harness race horse stable. He was successful in both endeavors for many years. The dairy herd was 25 to 35 head. Horses were bred, raised, trained and raced. In about 1980 a 230 kv tower line was constructed across his property about 500 to 700 ft from his house, barn and stables. The line consists of two parallel runs of 230 kV feeders on a single row of towers. It crossed directly over the south end of the training track. Minor problems developed at first, but these grew worse during the next few years while, coincidently, the audible corona discharge grew perceptibly louder until it could be heard quite clearly at the house. In 1986, stray voltage was suspected and tingle voltage filters were installed in the barn and in the stable.

At the peak of the problems, cattle symptoms included; Low, irregular production, slow milkout, uneven milkout, low conception rate, high abortion rate, birth deformities, mastitis, swelling in legs and joints, rough coats, high somatic cell count, mangers not cleaned out, sudden kicking at milking attendants, lapping at water in water bowls, sudden kicking off of the milk machine, several unusual cattle death, and undiagnosed neurological problems.

Horse problems included; abortion, birth deformities, stillbirths, low blood hemoglobin, aggressiveness in the stable but not in the field and sudden uncontrolable bolting off the south end of the training track taking driver and sulky over fences or whatever obstacles lay in its path.

Other problems encountered were; short incandescent lamp life, breakdown of electrical wiring and failure of motors and appliances. Several specific items and events were documented or witnessed by several people.

Two silo unloaders with motors that were controlled through magnetic starters and momentary contact push buttons would start spontaneously.

At the well, which was about 200 feet from the barn and fed with an under ground cable, several people experienced shocks, even if the power to the well was shut off at the barn. There was no separate ground rod at the well.

Daily, lamps would flicker during the noon hour and again from 5:00 PM to 8:30 PM. The flicker occurred as single blinks spaced anywhere from a few seconds to a few minutes apart. The cattle could not be handled during these times so evening chores had to be completed before 5:30 PM.

Neighbors who occupied a house practically under the power line reported three failures at their electrical panel, one of which resulted in a fire.

In August 1987 a combine parked overnight adjacent to the 230 kV line caught fire and burned. Apparently, this was caused by electrical breakdown of the alternator.

In July 1988 two tractors and an electronic control on a baler experienced electrical problems while parked near the power line.

In July of 1988 the cattle suffered from so much neurological damage that the herd had to be destroyed.

In the events listed above, the combine fire, the tractor electrical failures and house panel failure bear a resemblance to electrical failures experienced in EHV substations and swichyards.[1,2,3] Basically, high voltage combined with high short circuit current capabilities can create extremely large transient currents during capacitor switching, flashover of protective gaps and restrikes during airbreak switch operation, which couple electromagnetically to equipment in proximity. Here was a possible explanation for events that occurred near the power line, since this farm was only about two miles from a switchyard/transformer station at one end of 230 kV line, .

The rural feeder (a grounded Y system probably 13.8/8 kV) ran under the 230 kV almost at right angles. The branch service to this farm is almost parallel to the 230 kV line, about 600 ft away and 500 ft in length terminating at a pole mounted transformer. The Farm 240/120 V service extends in three directions from this point with the barn run extending another 200 ft., nearly parallel to the 230 kV. The neutrals are connected at the transformer. To examine the effect of transients from the 230 kV on this 700 ft. parallel run, calculations developed for inductive coordination-ordination (the practice of calculating and reducing induced voltages on communication systems from power systems) were used. Magnetic coupling was the easiest to calculate and is usually responsible for induced voltages at the distance involved (500 ft.). We made several assumptions; the high frequency impedance of the 230 kV line was 500 ohms, the highest transient voltage of the line was its zero to peak voltage (162 kV) and ground resistivity was 100 meters-ohms. Calculations were done assuming a 5,000 Hz ringing transient and a 50,000 Hz ringing transient. (Inductive Coordination is usually used up to 5000 Hz., so extrapolation to 50,000 Hz entails some risk.) The results were that the open circuit voltage induced end to end along the 700 ft. branch neutral from the rural distribution to the barn was 300 volts at 5,000 Hz and 3,000 volts at 50,000 Hz. Although this is a very rough estimate, it told us what we needed to know. Even if only 1% of a 50,000 Hz transient of 1/2 cycle (a pulse of 30 volts for 10 microseconds) actually got to the cow in the barn it would reach values we knew would produce observable effects.

The blinking lights coincide to periods of the day when changing loads cause step regulators to be most active.

It appears the normal operations (perhaps combined with equipment problems) at the switchyard could have been a major source of severe transients.

MEDICAL INFORMATION

The transient or impulse test performed on two cows in case #1 lead to a search of literature on the subject of biological effects of pulses and other waveshapes.

The effects of very large magnitude single pulses was collected by Charles Dalziel when he related the hazard of short duration pulses to their energy content.[4] He presented a history of human accidents and many of the effects suffered by the victims including; sudden pain, temperature abnormality, prolonged headaches, dizziness, semiconsciousness, strong muscle reaction, partial loss of sight (temporary and permanent), temporary paralyses and of course death.

Neurology and Electrotherapy tells us that nerves transmit information by pulses of electro-chemical action along the membrane of the nerve axon. A nerve is more easily triggered by a changing stimulus than steady one.[5] After each impulse the cell must recover its electro-chemical potential. There is a period of about 1 millisecond during which the cell cannot be made to send another impulse called the absolute refractory period. The cell goes through a relative refractory period as its sensitivity to stimulus returns to normal and is often followed by a brief period of supernormal sensitivity.[6] These factors can help explain the frequency response of nerves. At DC the only change occurs at the application and removal of voltage. Otherwise DC current must be high enougn to stimulate the nerve by its magnitude only. At low frequencies, 20 to 1000 Hz, the alternating current presents one change of stimulus after another with enough time for all nerve cells to recover sensitivity between stimuli. As the frequency is increased, the cells only have time to partially recover sensitivity (relative refractory period) and magnitudes of the current must be increased to continue stimulation.

Another factor in electrical stimulation is the <u>duration</u> over which the stimulus must be applied in order to stimulate a cell. Pulse durations of 500 microseconds or longer stimulate nerve cells equally well but shorter pulses require higher levels of current. At about 50 microseconds the current necessary to stimulate the nerve will be about double that at 500 microseconds. At shorter durations the current requirement rises rapidly, at 10 to 20 microseconds the current will have to be 4 to 5 times the current of 500 microseconds.[7] (In the cow impulse test of case #1 muscle reactions were observed with pulses not exceeding 6 microseconds at the 30 volt level. If cattle nervous system responses are similar to those of humans, the cattle should be much more sensitive to longer duration pulses. It is likely that at 10 or 50 microseconds cattle may sense pulses as little as 5 to 10 volts. These voltages are below the minimum threshold setting of a BMI or Dranetz power monitor and at too short a duration to be recorded on a Waverider. In short, cows are likely sensitive to transient voltages which cannot be measured by equipment in common use during stray voltage investigations.)

Another factor of nerve sensitivity is <u>accommodation</u>, the ability of a nerve cell to adapt to a slowly rising potential so as to require a higher stimulus. Roughly, a rise time of 50 milliseconds or less will avoid accommodation. A nerve may double it threshold if allowed to accommodate,

In electrotherapy, the contraction of a muscle through stimulation of its motor nerve is often sought in treatment. When all of the factors in the above paragraph are considered it helps account for observations like "The ideal current for stimulating normal muscle, then, is one whose individual impulses are relatively short, whose frequency is between 50 and 200 per second,... A stimulus that reaches its maximum intensity abruptly and then dies away less rapidly (exponentially), is probably ideal."[8] and "The sine wave form of the ordinary alternating house current is not as well tolerated. So much uncomfortable sensory stimulation is produced by this current that the muscular contraction tolerated is not effective."[9]

Another response of the nervous system is <u>habituation</u> (appendix 3). When a repetitive wave pattern is used for long periods, it becomes less effective.[10]

Another response of nerve cells is called <u>temporal summation</u>. When a very brief subthreshold stimulus is applied to a neuron the potential along its membrane is affected though the cell does not transmit a pulse. The potential then returns to normal very quickly. If before the membrane potential returns to normal a second subthreshold stimulus is applied, the second stimulus value is added to the remainder of the first, possibly exceeding the threshold.[11] In this way short bursts of small electrical pulses at high frequency may be able to stimulate a nerve just as well as a long duration single pulse.

Electrical stimulation to nerves may not only cause muscle contractions and sensations. For instance, "The autonomic nervous system controls the internal activities of the body such as circulation and digestion."[12] and "it is a fact that your nerves control the diameter of your blood vessels; therefore, if you have something wrong with a nerve, the size of the blood vessels may be altered and the flow of blood will be affected."[13] Both vasoconstriction and vasodilation have been observed as effects of electrical stimulation in medical research.[14]

Whenever the nerves to a muscle are stimulated, the muscle undergoes a contraction but the mechanical processes continue very briefly after stimulation ceases. If very brief stimuli are repeated rapidly enough, the muscle will, in effect, have a continuous <u>tetanic contraction</u>.[15] This relates to the levels of 60 Hz sine wave current commonly referred to as "no-let-go" which occurs at 6-9 ma.

MEDICAL APPLICATION OF ELECTRICITY

"The application of electrical stimulation to relieve pain dates back to 46 A.D. when Scribonius Largus described the use of the torpedo fish and electric eel to control pain."[16] This statement catches most people by surprise. Electricity in medicine is supposedly something new.

Applications of DC current are electrolysis, iontophoresis, cataphoresis and electro-osmosis. Electrolysis is the separation of ions in solution and is most commonly known for removal of hair. "The result of migration of charged particles produces specific physiochemical reactions... The increased alkalinity of the cathode produces liquification of protein and the softening of tissues... At the anode,... increased acidity brings about a coagulation of protein and a hardening of tissue."[17] Iontophoresis is the introduction of various ions into tissues through the skin by electricity."[18] Iontophoresis is not a common technique, but there is a fair bit of research on the subject. Drug which have been introduced through the skin include vasodilators, local anesthetics, astringents and enzymes. Cataphoresis is the movement of "... nondissociated colloid molecules, such as droplets of fat, albumin, particles of starch, blood cells, bacteria, and other single cells, all of which have an electrical charge due to the adsorption of ions, under the influence of a direct current toward the negative pole. Electro-osmosis is the shifting of the water content of the tissues through membrane structures with an electrical charge."[19]

Promotion of bone repair using constant DC, pulsed DC and induced currents from pulsed electromagnetic fields has been demonstrated but the mechanisms for such promotion is not known.[20] Similarly, repair of soft tissues has been demonstrated with DC current.[21]

Pain relieve can be accomplished through transcutaneous electrical nerve stimulation (TENS). A wide variety of TENS stimulators are available with a wide variety of outputs. Pulse magnitudes ranging from 30 to 160 ma, pulse widths from 9 to 400 microseconds and repetition rates from 1 to 200 pulses/second are available from a wide selection of TENS units. Some stimulators offer rapid bursts of pulses repeated at a slow rate. There are several theories about how TENS accomplishes analgesia. One is that these train of pulses causes a blockage of the nerve signal that transmit pain. A second is that the pulses activate the bodies natural mechanism for suppressing pain such as the release of hormones called endorphins.[22] Other work indicates that electroacupuncture, the replacement of manipulation of needles in standard acupuncture with stimulation by low frequency high-intensity electrical pulses, stimulates the anterior lobe of the pituitary gland to release adrenocorticotropic hormone (ACTH) which acts on the adrenal glands to release cortisol (appendix 3). It is important here to realize that the pituitary gland is particularly important in the endocrine system.[23] (This brings up the possibility that other endocrine activities may be stimulated by electrical pulses. Oxytocin, the hormone responsible for milk letdown, is released from the posterior lobe of the pituitary. Recall one observation in the cow impulse test of case #1 was milk letdown.) Other observations that have been made is that patients using TENS experience an increase in peripheral skin temperature and that temperatures distal to the stimulation site increased.[24] (This may be related to changes in blood flow caused by stimulation of the nerves controlling vessel diameter.) In TENS supervised, controlled medical application limits the effects to selected sites on the body, whereas stray currents may travel through much of a cows body, from mouth to feet thereby stimulating many nerves and possibly producing many undesirable effects. Contraindications for TENS include pregnancy.[25]

Electro convulsive therapy (shock treatment) is the highest profile electrical treatment. Years ago sine wave voltage was used but this have given way to pulse waveforms.

Magnetotherapy is a not very well known form of therapy which uses alternating magnetic fields to induce current within a patient's body.[26] At least one manufacturer of magnetotherapy equipment uses near square wave current to induce short pulsed currents. The beneficial medical effects may be exaggerated but it appears certain physiological effects are produced (appendix 4).

OTHER PULSE APPLICATION

A recent development in electronics is the "stun gun or electric gun". These devices are claimed to disable a person for several minutes after a brief application of supposedly non-hazardous electric current. These devices generate a series of high frequency, damped sinusoidal waves (pulsed) from about 70 kilohertz to 250 kilohertz depending on the design. The output of these devices is in the thousands of volts and the pulses are applied from 13 to 50 times per second depending on the design. One pulse of the stun gun has a similar description to the transient created by capacitor switching.

POWER QUALITY

Stray voltage is beginning to be treated as a Power Quality problem.[26] Whenever current disturbances occur on the line side of a system, a corresponding disturbance will occur on the neutral or ground side. Delta systems in distribution are not immune from causing ground disturbances. Every insulator, lightning arrestor, switch, transformer and capacitor has a ground connection. It is well known that a single fault to ground on large delta distribution systems carries amperes not milliamperes due to capacitance and leakage to ground. In fact delta distribution systems have experienced extreme transient voltage, especially with arcing faults.[27]

Transients are caused by switching of; motors, solenoids, lights, transformers, capacitor banks and distribution lines, and by; lightning, insulator flashover, incipient faults, and induced disturbances from larger nearby system. Another source, rarely if ever mentioned, is intermittent neutral connections on a multigrounded system. Transmission and distribution systems use many connectors and splices. If a loose connection occurs on the hot side, the added resistance will heat the connection eventually to the point of failure. Customers will notice power quality problems. Infrared scanning can be used to find these bad connections. But what happens when a neutral connection becomes loose. So often the neutral current has alternate paths; common neutral with alternate feeds and earth return especially at end-of-line services. Because the current can take alternate paths, the hot connection will not occur to the same extent if it occurs at all. But at the moment of switchover of neutral current from the neutral wire to an alternate path, another mechanism takes place. Self inductance and the interruption of current on the neutral causes transients, moreover mutual inductance with the line conductors, will also cause a transient in these conductors as well. The parallel conductors of a distribution systems simply represents a huge air core transformer. di/dt on the neutral creates a voltage lengthwise along the line and neutral conductors. If the loose neutral remains open, standard neutral to earth voltage readings can be used to locate the open, but momentary opens will be more difficult to locate. We suspect that the transients in case #1 may have been caused by this mechanism as well as insulator flashover.

Pulsed waveforms occur when non-linear loads or elements are used in the power system. For example, a DC power supply, powered from 120 volt 60 Hz., using a full wave rectifier and capacitor filter, draws current in a short burst every 1/120th of a second. Other items which contribute to pulsed currents are electronic incandescent light dimmers, fluorescent lights, high intensity discharge lights and saturated iron cores of transformers subjected to overvoltage. Pulsed waveforms are most commonly analysed using Fourier series. The Fourier series represents the distortion by a series of harmonics. Weighing these harmonic frequencies against the equivalent 60 Hz (usually 1:1 for frequencies below 1000 Hz) it is usually determined that the harmonics are less significant than the fundamental. Understanding that Fourier analysis is a mathematical representation by constant magnitudes of a fundamental frequency and constant magnitudes of its harmonics is important in understanding any effects harmonics may have. Fourier analysis is a very useful mathematical tool but the harmonics, in reality, are modulated by the fundamental frequency. This phenomena has long been known to occur in high frequency work when frequency multipliers are used. Harmonics obtained from a non-linear device are modulated at the frequency of the fundamental. In the case of current into a DC power supply, the harmonics are "pulsed". Harmonic analysis may be misleading if only the amplitude is considered. In electrotherapy waveforms are not described in terms of harmonics, but in terms of; duration of pulse, peak value, rise time and pulse frequency. Case #3, where harmonics on a distribution system were blamed for stray voltage symptoms, may be easier to understand if we knew the nature of the waveforms.

The example of a DC power supply reveals another point worth noting. The current waveform is far more pulsed (distorted) than the voltage. Generally, this is true in distribution systems as well (We strive for constant voltage and leave the current variable). This being the case, we would expect the magnetic field to contain more distortion than the electric field and if it is these distortions that are responsible for biological effective, we would expect epidemiolgic studies to relate health effects more closely with magnetic fields than with electric fields. Wertheimer and Leeper produced some of the most famous studies showing a connection to human health from magnetic fields.

For the electrical utilities, an important source of pulsed waveforms is overvoltage on a distribution system with the associated saturation of iron core transformers. Since most distribution systems have transformers as 100% of their load, this can become a significant power quality problem.

Appendix 5, 24 dead starlings on a power line was blamed on many things from poison to collision with the line. Electrocution has been ruled out. The most outstanding thing is that the birds have gripped onto the line as if they experienced a tetanic contraction.

EARTH CURRENTS

Most people in the electrical industry have heard the statement that current entering the earth through rods dissipates rapidly. When that statement relates to step and touch potentials, it is absolutely true. Close to large sources of earth currents such as ground rods, the resistivity of the earth is the main factor governing current distribution. But at a distance other forces come into play; skin effects and proximity effects.

Skin effect is the self coupling of a current in a conductor which forces the current to crowd itself to the outer surfaces. It applies to all conductors, <u>including the earth</u>. It is <u>frequency dependant</u> and providing earth resistivity is constant for a great depth, 60 Hz currents will occupy a great depth. As frequency increases, the corresponding depth is shallower. Skin depth is that distance below the surface of a conductor where the current density has diminished to 1/e of its value at the surface. Frequencies over 10 MHz are considered to have practically no depth. Any steep wavefront transient in earth current will have its a high frequency component crowded close to the Earth's surface.

Proximity effect is the magnetic coupling of two parallel currents which forces them together if they are in opposite directions and apart if in the same direction. The return earth currents of transmission lines are always opposite to the line current so that the earth current is crowded toward the transmission line. The equivalent return current depth which must be calculated in inductive coordination studies is given by

$$De = 2160\,[p/f]^{1/2}\ \text{ft.}$$ [28]

where p = ground resistivity in meter-ohms
and f = frequency in Hz

for uniform conductivity earth (which never happens). The formula gives the depth of the return current as if it was on a conductor buried at that depth. In reality, the current is spread out, with highest density at the surface and lesser density as depth increases.

Both skin effect and proximity effect cause the earth currents to be concentrated near the surface of the earth, along pipelines, fences, railway tracks, etc. Although this has been known for many years, it seems only recently that any possible relationship to health effects has been recognized.29 AC ground currents with high frequency components will have these components concentrated at the earth surface even more than the fundamental making the currents near the surface richer in high frequency than the source. The sharp spikes of voltage visible in appendix 1 may be the high frequency component of a very rapid change in earth current concentrated near the Earth's surface by these effects.

The possibility of EMF from ground currents and potentials must be considered. Sharp wavefronts currents have stronger inductive powers than power frequencies and since they are crowded to the earth surface, they will have an influence on the electromagnetic environment along that surface.

"It can be concluded that the return current (not if it exists but where it exists) is the most crucial influence on the magnitude of the magnetic field of the power system in areas where human exposure is most likely."30

Earth resistivity plays an important role in determining earth current location. Appendix 6 indicates a measurement method that may be useful for plotting resistivity around farm sites, power lines, water courses, etc.

ELECTROMAGNETIC FIELDS

During the investigation in case #1 some observations were made which led to the undertaking of some simple EMF tests. In January 1988, the vacuum lines in the barn which were supposed to be totally isolated from ground, were found to be inadvertently grounded at one side of the barn near an underground steel waterline connecting the house and barn. The inadvertent connection was removed and unexpectedly a slight improvement in herd performance was observed. Since there was a small voltage imposed on the vacuum line from this ground connection, the question arose whether the small voltage could have enough electric field to affect the cattle. The logical answer was "no" as the electric field created by this voltage would be far less than those found from ordinary wiring and appliances. But just in case, it was decided to try a field test. This barn was laid out in three rows of; 4 stantions + 3 box pens, 12 stantions, and 12 stantions respectively. The pulsator electrics from the vacuum line over the third row was disconnected. They would be reconnected only at milking time. To this third row vacuum line, now isolated not only from ground but from the vacuum lines over the other rows except for about 1 hr. per day, 0.7 volts was applied through stepdown transformers. The transformer assembly was powered from 120 volt and the ground side of the 0.7 volts was at a remote rod about 100 feet from the barn. The test started Sunday afternoon. As expected, there was no change on Monday. On Tuesday, Mr. Montgomery was away for the day. The hired hand noticed the third row milked out slightly slower in the morning and noticeably slower in the evening. On Wednesday morning, the third row was in such a mess Mr. Montgomery phone our office in desperation. Four out of ten lactating cows in the third row had let their milk out on the floor. The other six were drastically down in production. The other two rows of cattle were not affected. Of course the test was dismantled. The cows took about three days to recover.

It did not seem reasonable that these effects could be caused by 0.7 volts AC sine wave and the effects were too dramatic and too localized to have been coincidence. Line voltage transients coupled through the transformer or ground gradient transients between the remote rod and the barn floor were suspected. The early March BMI recordings (appendix 1) confirming transients existed in the earth current, and the fact that sharp microsecond power transients could cause incandescent lamp failure, leaves both possibilities open.

In June 1988 another field test was performed. After morning milking, one cow was left in her stantion in the second row. About four hours later the vacuum line was isolated and using the pulse generator designed for lamp failure tests, individual pulses in 50 volt increments were applied to the vacuum line. At 500 volts, the cow exhibited several sign of stress. The voltage never exceeded 1500. At the end of the test (about 20 minutes) the cow had had a full milk letdown. It was not certain wether the electric field caused the effects or if some stray leakage was allowing current to reach the cow. In July, using the same cow in the same stantion we performed a similar test using a short, well insulated pipe instead of the longer vacuum line. The pipe was about three feet long and was placed parallel to the vacuum line and slightly behind the vacuum line. No significant effects were observed. Later the test was repeated with the pipe placed at a right angle to the vacuum line directly over the cow's back but once again no significant effects were observed. No conclusions were reached because so many possibilities exist.

PULSED EMF

Finding information about pulsed EMF was easier than finding information about pulsed stray voltage.

Pafkova states "Independently it was found and published in the USSR, USA and in Czechoslovakia that pulsed fields are significantly biologically more effective than non-pulsed fields." Pafkova found significant changes in fetal development of mice when the pregnant female was exposed to pulsed fields of 285 V/cm, 10 microsecond width and 300 pulses/sec. for four hours/day from the first to the 17th day of pregnancy. (Appendix 7)

Baum, Ekstrom, Skidmore, Wyant and Atkinson found no effects when rats were exposed pulsed fields of 447 kV/m, 5 nsec. rise time, 550 nsec. 1/e fall time and 5 pulses/sec. for 23 to 24 hour/day for 94 weeks (2.5 X 10^8 pulses) beginning 4 months after birth. They also found no effect on fertility or neonatal abnormalities of progeny of rats exposed in pairs to 3.4 X 10^7 pulses from 4 Months of age.[31]

> These two studies seem to have found contradictory results from pulsed electrostatic fields. Albeit, there are differences in methods and intensity, the exposure time per day may have significance and the habituation response noted in MEDICAL INFORMATION may offer a clue. Could the almost continuous exposure in the Baum, Ekstrom, Skidmore, Wyant and Atkinson study have elicited a habituation response in the rats which prevented development of observable effects while the shorter 4 hr./day exposure of Pavkova's did not?

Wever found effects on human circadian rhythms using 10 Hz., 2.5 V/m square wave electric fields.[32] Further study by Sulzman and Murrish found effects in monkeys using 60 Hz., 26 and 39 kV/m sine wave electric fields accompanied by 60 Hz., 100 microtesla sine wave magnetic fields. The differences in methods between the studies make comparisons very difficult, but can these differences account for the ratio of <u>10,000:1</u> of electric fields? Even if each study were in error by one order of magnitude, the ratio is still 100:1. Could low value pulsed waveforms be many times more effective than the sine wave? In retrospect, it might be advisable to investigate whether normal power contains components similar in biological effect to those of the square wave.

Recent work strongly indicates that the often reported ill health effects of exposure to fluorescent lights may be due to the pulsation of light caused by the zero crossing of current and subsequent re-strike or the arc (appendix 8).

From DC to microwave to light, is it pulses or pulse trains that trigger biological responses?

MISCELLANEOUS BIOLOGICAL ITEMS

It has been noted several times that a very few humans have the ability to "hear" certain types of electromagnetic radiation (appendices 9 and 10). Birds have long been known to be sensitive to microwaves (appendix 10) and many animal species are known to have electromagnetic senses (appendix 12).

EFFECTS ON CATTLE

The effects of the usually referred to stray voltage (60 Hz) was very well summed up by Appleman and Gustafson in 1985.[33] But the conclusion that "stray voltage effects are behavioral and not endocrine or physiological might better be restated to say "low magnitude, 60 Hz voltage effects are behavioral. Future research should include distorted waveshapes and transients known to be part of the current, voltage, electric fields and magnetic fields .

INVESTIGATION PRACTICES

When a stray voltage situation cannot be remedied by the dairyman, his vet, his electrician or the power company a thorough investigation should be undertaken. A complete history from the herdsman is essential. Nothing is above suspicion. In one recent investigation a monitor detected bursts of 200 kHz. signal over 20 volts in magnitude, in the milk parlor. There are several possible source of such a signal, but the one source that electrical utilities should be concerned with is their own power line carrier transmission.

RESEARCH DIRECTION

Suppose that a particular population has been found to have a significantly higher incidence of some illnesses than the average population. And suppose that epidemiologic studies found the only common factor was their water supply from a particular river. A research program might be set up to study the possibility of ill health effects caused by the water. If the research team uses water from their local domestic water supply, which happens to have no connection to the suspected source, the study would obviously be faulty and would probably find no effect. And certainly it would find no effects if the water were distilled and charcoaled filtered. The study would be criticized as being unscientific.

Yet... this is exactly what is happening in stray voltage and in health effects of EMF research today. Our power lines are rivers of electrical energy, and each one has its own characteristics. Each one has its own particular pollution or level and type of Power Quality. When an epidemiologic study implicates the magnetic fields of a power line, research is so often done in labs with fields generated by equipment plugged into their local domestic electrical supply, which happens to have no connection to the suspected source. And as far as filtering, you are hard pressed to find even a footnote in most research papers about whether there are filters, power conditioners, etc to eliminate disturbances of various kinds. But it may be these disturbances which are biologically significant.

Electrical/EMF health issues are environmental concerns just like chemical pollution. The major difference is that unlike chemical pollution which can be detected after the event (sometimes decades later), electrical/EMF pollution can be turned off instantly by the flick of a switch leaving only forensic evidence of its previous presence.

Stray voltage and health effects are related. And both are related to power quality, electrotherapy, neurology and environmental concerns. Research must include all disciplines that relate and the field observations of the agricultural community.

CONCLUSIONS

Pulsed waveforms are biologically more significant than sine wave. Exposure to pulsed voltages and EMF occur in association with power systems, earth currents and wide ranges of radio/radar transmission. The exposure limits based on steady state sinusoidal waveforms are probably inappropriate and may be several times higher than is safe.

TEST OF COW REACTION TO IMPULSE VOLTAGE

INTRODUCTION

During the investigation of stray voltage at Lee Montgomery's farm, voltage impulses were recorded from 20 volts to over 40 volts, lasting from one microsecond to several microseconds. The recordings were made on a BMI 4800 power monitor. To answer the question "Are cows affected by, or feel, such impulses, when applied to contact points?" tests were carried out on April 9 and 12, 1988, in the barn at Lee Montgomery's Dairy Farm.

CONCLUSIONS

Cows do feel impulse voltages as low as 30 volts and durations of 4 to 5 microseconds.

SET UP

The circuit to apply impulse voltages is shown in figure 1. A small capacitor is charged to a controlled voltage by a DC voltage source. A double throw switch in the circuit is used to remove the charging source, and apply the charged capacitor across cow contact points. The peak of the voltage impulse is controlled by the voltage on the DC source, while the duration of the impulse is a function of the capacitors size and the resistance through which it discharges. In this case the DC source was 9 volt batteries connected in series to give between 9 and 63 volts in 9 volt steps. The resistance through which the capacitor discharged was either a test resister of 560 ohms or the cow front hooves to rear hooves pathway.

Two mats of 1/4" soldered mesh were placed in front of the manger in the large box pen in Lee Montgomery's barn. Wire leads were run from the two mesh mats to the impulse generating circuit. The cow was fed grain in the manger to attract it into position with its front feet on one mat and its rear feet on the other. On April 9, 1988 the test of the Mary cow was observed by Lee Montgomery and Alex Furo. On April 12, 1988 the test of the Nina cow was observed by Lee Montgomery, Vern Osborne, Art Groenewegen and Alex Furo.

The impulse generator was tested across the wetted fingers of the observers. Two could feel the impulses, two could not. Page 7 and 8 of appendix 1 shows the voltage pattern when applied across wetted fingers. These patterns differ markedly from the pattern generated across a 560 ohm resister or through contact with a cow.

MARY COW - OBSERVATIONS

The Mary cow is an older, quiet dispositioned animal.

1. Flinching occasionally close to the application of impulse.

2. Stopped eating at times.

3. Became suspicious and uneasy.

4. At the end of the test Mr. Montgomery's inspection of the cow revealed that she had had a milk let down.

5. At no time during the test did the Mary cow try to pull herself out of the standtion.

6. Upon release from the standtion the Mary cow immediately moved to the far corner of the box pen, and became extremely relucted to be moved from that position. When she was finally encouraged to leave the box pen she smelled the floor towards the manger before venturing through the box pen gate.

NINA COW - OBSERVATIONS

On April 12, 1988 the test was repeated with Vern Osborne and Art Groenewegen from the Ridgetown College of Agricultural Science as witnesses. It was the intent to use the Mary cow again, but Mr. Montgomery reported that the Mary cow exhibited such reluctance to go near the box pen manger that he felt it better, for the benefit of the cow and the test, that a new subject be used.

The Nina cow is a younger more high strung animal, more prone to milk let down. She was placed in the box stall a few hours before the test to allow her to accommodate herself to the new surroundings. A safety resister had been added to the charging circuit, but this caused a second set of impulses on the closing of the switch. (the exact cause of the second set of impulses was not determined, but from the timing of these impulses it appears to be related to contact bounce on the reclosing action.) The results of this is that the Nina cow was subjected to somewhat more impulses than the Mary cow. Part way through the test, the leads would be disconnected before the switch was reclosed, and later the resistor was simply by passed.

1. Reactions of the Nena cow was similar to those of the Mary cow, but less severe.

2. Upon release from the stantion after the test, the Nena cow did not rush to the far corner of the box cow, but moved through the box pen more or less normally.

3. After a few minutes she was given more grain mix at the manger and here it was observed that she did have reluctance to re-enter the stantion. She did enter after some hesitation and took the feed in such a manner that after ever mouthfull she held her head up in a position of awareness or anticipation while she chewed.

4. It is well known that short impulses do not register on either analogue or digital meters and out of curiosity a Data Precision model 935 digital volt meter on the two volt AC scale was connected in parallel with the BMI 4800. The digital meter measured a peak voltage of .003 volts during an impulse of over 30 volts.

Mr. Osborne and Mr. Groenewegen are issuing separate observations.

DISCUSSION

Since the voltage wave forms with the 560 ohms test resistor and with the cow are similar in magnitude, shape and duration it is valid to conclude that a front hoof to rear hoof pathway is basically resistive and approximately equal to that of the test resister. This value is in agreement with those reported by Appleman and Gustafson in the Journal of Dairy Sciences, Volume 68, #6 1985, page 1557. We can deduce from this, that the pathway was indeed through the cow, and not over the skin as is sometime noted with high frequency electrical currents.

Of particular importance to Dairymen and Electrical Contractors is that the instruments, recommended by most publications of Ontario Hydro, Ministry of Agriculture and concerned Organizations, do not indicate with any accuracy whatever the presents of impulses.

In almost all laboratory tests, cattle response to stray voltage is evaluated by applying a regulated voltage or current with very little chance of impulses being included. This differs greatly from field conditions were voltages on cow contact points are caused by load imbalance, leakage current, motor switching, etc., all of which have impulses associated with them. For instance a running motor that causes 1/2 volt to appear at a cow contact by unbalancing the neutral would cause approximately 2 1/2 volts surge during start up and significally higher impulses at the closing and opening of its starting switch. This may explain why research on voltage sensitivity often indicates 1 volt 60 Hz as satisfactory but experience with "dirty or noisey" field conditions dictates that anything over 0.35 can cause a problem. When we realize that every farm is different, with different wiring arrangements, different grounding, different equipment, etc. it is not surprising that different levels of maximum stray voltage may be tollerable, depending on how clean or dirty the farm electrical system is.

Research into cattle response both behavioural and endocrine, as summarized by Applemen and Gustafson in their above mentioned article, indicates that cattle response is totally behavioural and endocrine response is practically non existent. We can safely say that cattle will have behavioural response to impulse voltages as well. Since we know of no study made using impulse voltages to test for endocrine response we cannot comment on this. (It has been suggested to us though, by people in the biomedical field, that a condition know as "nerve block" initiated by electrical stimulation be investigated as this could lead to endocrine response, internal disorders, and other effects.)

A review of the existing literature on stray voltage reveals cases were impulses or surges have affected dairy herds. This is reported again by Applemen and Goustoffman in their above mentioned report under "Induced voltages on electrically isolated conductive equipment" and in the publication 155 by the Ontario Ministry of Agricultural and Food, titled "Stray Voltage Problem with Dairy Cows" (1982?) on page 10, under the heading "Stray Voltages not Related to N-E Voltages." The stray voltage in these cases appear to be caused by a condition where an isolated metal system became charged with a voltage, and it scapacitance to ground was sufficient to store a signifigant charge. Cattle touching this metal would experience the sudden discharge through their body to ground <u>identical</u> to the method used in this test to generate impulses.

The traces of the discharge through wetted finger of observers (appendix pg 7, 8) are markedly different, owing to the fact that the resistance through human skin is so much higher than through the hoof to hoof pathway of cows. As a comparison of the traces clearly demonstrates, the discharge through the observers fingers is much longer in time, therefore lower in current.

Peak current value occurred through the Nina Cow, Appendix Page 25

I = 65V ÷ 560 ohms
  = 116 mA.

Time of impulse to decay to near 0 = 6 microseconds.

IMPULSE TEST SET-UP

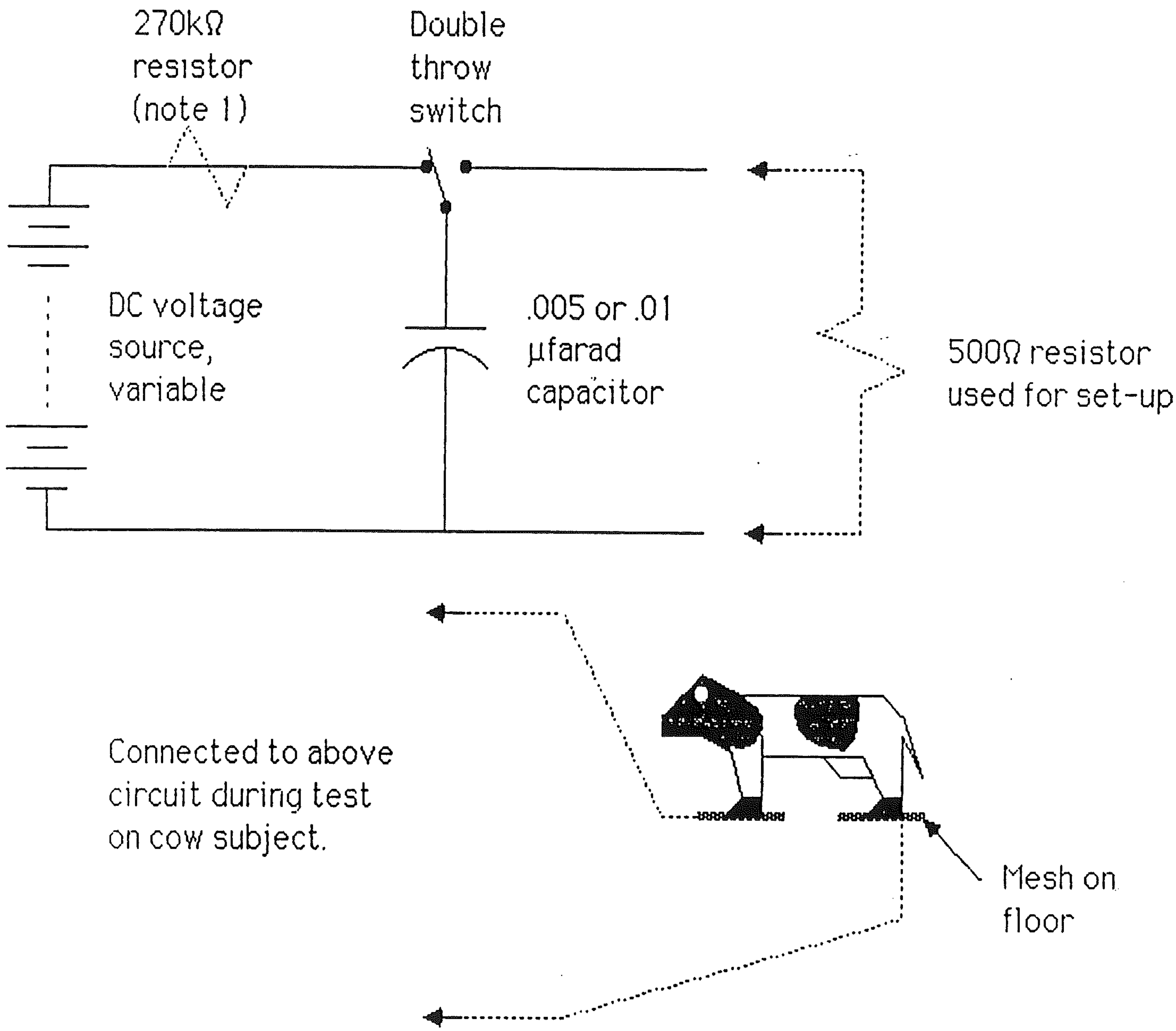


Figure #1

Note 1 Resistor added, for Nina test, as a precaution to limit current in case accidental contact was made across the poles of the switch, was found to cause impulses on the return action and was removed toward the end of the test

Date: May 13, 1988

To: Whom It May Concern

From: Vernon R. Osborne and Arthur R. Groenewegen

Re: Animal Response to Electrical Shock

On Tuesday, April 12th, 1988, we were asked to observe a demonstration test (conducted by Alex Furo), designed to simulate the stray voltage conditions on the farm of L. Montgomery in Dover Township. A lactating Holstein dairy cow was subjected to short duration electrical pulses ranging in voltage levels.

Behavioral responses are usually the quickest and most easily noticed changes when an animal is in an adverse situation. Considering this, we concentrated on looking for any unusual behavioral signs from the cow as a consequence of anxiety. We observed the following behavioral and/or physiological responses of the animal on test:

- flaring nostrils;
- front leg twitching;
- slight arching through the shoulder;
- ears pointed;
- disrupted breathing and/or abdominal activity;
- milk let down.

If you have any questions on what we witnessed at this demonstration please do not hesitate to contact us.

Yours sincerely,

V. R. Osborne   A. R. Groenewegen

DRAFT REPORT

INVESTIGATION INTO PROBLEMS AT THE FARM OF

S. BARRY MOORE - LINDSAY, ONTARIO

SUMMARY

History of events and electrical problems as related to us, along with existing knowledge of power system transients, lead us to conclude that large power system transients from a 230,000 volt line across Mr. Moore's property are the likely cause of damage to his dairy cattle, horses and electrical equipment.

STRAY VOLTAGE

The principles of stray voltage as outlined by the Ontario Ministry of Agricultural and Food, Ontario Hydro and others is well documented and will not be repeated here. It will be sufficient to say that stray voltage is usually thought of as that voltage created by return current on a multi grounded neutral conductor. It can be applied to cattle whenever they make contact between objects bonded to the neutral and ground.

The usual understanding of stray voltage though is only part of the story. Return currents along the neutral conductor take many forms. Although some stray voltage information includes voltages of short duration, See Appendixes A1 and A2 ,few include the very short duration pulses of currents caused by switching of motors, solenoids, lights, transformers, capacitor banks and distribution lines. These short durations pulses (transients) are well known in the electronics/computer industry as being responsible for a wide range of data losses and equipment failures. Appendix B1 and B2 are copies of manufacturers literature which has a good layman's description of transients. Many of these transients show up between the neutral conductor and ground with magnitudes into the hundreds of volts. These transients take many forms, including pulses of various time durations, rates of rise, rates of decay and oscillations or ringing.

Quality voltmeters and recorders, commonly used by investigators of stray voltage, do not respond quickly enough to indicate transients. Instruments with response time of even one quarter second cannot properly respond to transients of such short duration. Appendix C is an article from Otter Tail Power Company. Otter Tail is the only utility known to us that routinely investigates for transients in stray voltage.

EFFECTS ON CATTLE

The effects of the usually referred to stray voltage is very well summed up in Appendixes D1 and D2. These articles summarize the research on stray voltage. The conclusion is that "stray voltage effects are "behavioural" and not endocrine or physiological." A close examination of the tests procedures show that no consideration is given to the complete spectrum of conditions that exists on neutral to earth voltages as discussed above.

The only research found on the effects of short duration exposure to voltage is shown in Appendix D3. The time duration of 0.0167 seconds is a far cry from transients that can exist for 0.000001 seconds. The conclusions of these research papers should be restated to say "the effects of low magnitude, steady, 60 Hz current on cattle are behavioural". Because of the differences between controlled application of 60 Hz currents in the lab and the uncontrolled application of neutral voltage containing a whole spectrum of transients, these studies cannot conclude that the effect of stray voltage is only behavioural. Conducted tests did not simulate field conditions.

Interestly enough, an indication of biological response to short duration currents is available through human experience. In medical science, electrotheraputics is the application of electricity to create physiological effects. Very small currents or pulses are used to assist the healing of nonunited bone fractures. Pain relieve is accomplished through transcutaneous nerve stimulation which creates a condition called 'nerve block'. The pulses for this pain relief are about 100 millionths of a second long, are 20 milliamp to 50 milliamp maximum in magnitude and have a repetition rate of 4 to 185 times a second. The different reactions of nerves and muscles to various wave forms and pulses is routinely used in diagnosis of nerves and muscles damage.

Electro convulsive therapy (shock treatment) is the most commonly known but much concern about side effects has reduced the use of this treatment.

Appendix E gives us some insight into the effects of larger pulses. These effect's are obviously more than behavioral. Reference materials citing both vasoconstriction and vasodilation as effects of electrical stimulation demonstrate the possibility of contradictory observations. Contradictory observations by dairy workers does not invalidate their observations. Contradictory observations are consistent with similar observations in research. The concluding statement of Appendix E "The physiological mechanisms involved in the circulatory changes observed in this study remain unclear" clearly demonstrates the lack of present day knowledge. If nothing else, this study should make clear the effect of short high level pulses are different from the effects of continuous low level application of voltage or current.

Some direct human experience of very large magnitude single pulses was collected by Charles F. Dalziel when he related the hazard of short duration pulses to their energy content. Appendix F, starting on page 1036 lists a history of human accidents and many of the effects suffered by the victims including; sudden pain, temperature abnormality, prolonged headaches, dizziness, semi consciousness, strong muscle reaction, partial lost of sight (temporary and permanent), temporary paralyses and of course death.

A recent development in electronics is the "stun gun or electric gun". These devices are claimed to disable a person for several minutes after a brief application of supposedly non-hazardous electric current. These devices generate a series of high frequency, damped sinusoidal waves from about 70 kilohertz to 250 kilohertz depending on the design. The output of these devices is in the thousands of volts and the pulses are applied from 13 to 50 times per second depending on the design. One pulse of the stun gun has a similar description to the transient created by capacitor switching.

The above listed appendicies certainly suggest many more effects of electricity then just behavioural. In fact field observation from dairymen and many investigators list "low consception rates and high abortion rates" as symptoms of stray voltage. Note page 7 of Appendix D2. These symptoms are sometimes attributed to the stress caused by the stray voltage but it should be obvious that much more research is needed.

HISTORICAL DATA AT THE BARRY MOORE FARM

The events as related to us are as follows:

A. In 1979 and 1980 Ontario Hydro erected a 230 kV tower line through the property of Mr. Moore. See Farm layout sketch Appendix G.

B. Mr. Moore soon noted afterwards the following conditions in his herd;
- Milk let down problems
- Asinemia
- Some cows collapsed in their stalls
- Increase in calf abortions
- Lower conception rates
- Increase in mastitis
- Increase in the somatic cell count to approximately 300,000.
- Intermittant feed problems, cattle did not clean up the manger.

These conditions were more or less continuous until approximately May 1986.

C. During the same time interval as B electrical problems were experienced with the pump for the well.

D. During the same time interval as B there was an increase in incandescent lamp failure.

E. From 1982 on, the horses experienced the following problems;
   - Lower conception rates.
   - Would not work out well on the track.
   - Blood hemoglobin down from 13 to 9.

F. Heifers in pastures did not experience problems until after they were in the barn for the winter.

G. About May 19 or 24, 1986 during a storm, lighting struck the chimney of the house. The motor of the swimming pool circulating pump and the compressor motor of the milk cooler in the barn failed.

H. The next day (after Item G) a calf was aborted at eight months.

I. The rate of aborted calves increased dramaticly in the months following Item G.

J. Several people received shocks from the cover of the disconnect switch at the well, even when power had been shut off at the barn. (There is no ground rod at the well.)

K. Sometimes a cow would kick unexpectedly and violently, occasionally injuring a milking attendant.

L. Cows would collapse and die within five days, no temperature to indicate fever or infection.

M. Calves and foals would be born deformed, many were born breach. Long period of no live births in 1987.

N. Many symptoms increased in frequency and severity in 1986. This coincided with growing industrial development around Lindsay.

O. Milk productivity was noticeably down and irregular.

P. Somatic cell counts went up to 400,000.

Q. The incident of lamp failures increased.

R. Lamps would flicker, especially during the noon hour and then again in the evening from 5:00 pm until 8:30 pm. During these periods the cattle were difficult to handle. Mr. Moore reported that if he was not able to finish his dairy chores by 5:30 pm he might not be able to finish them at all that evening due to the severe reaction on the cattle.

S. The Silo unloader in the barn (using a magnetic starter with a hold in contact or a latching circuit) would start on its own. No electrician could find the cause.

T. Horses being trained on the track would suddenly become uncontrollable as they rounded the end under the 230 kV line.

U. On August 7, 1987 a combine parked adjacent to the tower line for the night caught fire and burned, apparently due to an electrical failure involving the alternator.

V. At one point the utility increased the grounding along the neutral of the rural distribution line in an attempt to reduce the problems on the farm. But instead the problems become worse in the barn and the house, which had been relatively free of effects, began to experience electrical problems.

W. In April 1988, a light fixture in the dining area of the house burned the electrical cord from which it hung and crashed to the floor.

X. Two tractors and an electronic control on a baler experienced electrical problems while parked near the tower line on July 1, 1988.
On the same day the milk machine experienced an electrical failure.

Y. The utility had replaced the pole transformer. Mr. Moore had the overhead service lines replaced along with new panels and new wiring in the stable.

Z. Mr. Moore indicated that the tower ground rod was driven into the underground water stream that fed his well. He felt that electricity from the tower had traveled through the underground water stream and reached the barn through the submersible pump and wires from the well.

AA. In October 1986 Dr. Cody of the University of Guelph determined the problem experienced by the cattle was electrical and recommended the installation of tingle voltage filters. This was done in the barn and the stable.

AB. Neighbours who occupy a house close to the power line have reported three failures at the electrical panel, one of which resulted in a fire.

AC. Other neighbours along the power line have reported no incidences.

AD. After item 'X' on July 1, 1988 the cattle deteriorated. By the end of July disposal of the herd was necessary.

INVESTIGATION

On the evening of May 19, 1988 a preliminary visit was paid to Mr. Moore's farm. The following observations were made;

1. Standing just outside the south patio doors at the house approximately 500 ft. from the tower line the audible high voltage discharge could be heard clearly. The weather was humid with intermittant showers early that evening.

2. At about 8:10 pm the most westerly horse stable was being examined. At this time the entire row of lights in the stable was engaged in periodical flickering. Standing outside the stable it could be seen that lights at the house were <u>not</u> flickering. The flickering appeared as a sequence of slight blinks spaced anywhere from about 10 seconds to a few minutes apart. There was seven lights (approximately) of 60 to 100 watts each. The radio in the stable was on as well and at each blink of the light there was a single distint click from the radio. A bad connection was suspected but no sound of arcing light sockets, switches, fuses or wires could be heard. A bad connection is usually indicated by crackle over the radio, not single clicks. The light switch was operated a few times to determine whether dirty or worn contacts on the light switch might be causing the problem. There was no change as a result of this operation.

3. The second stable was visited where only one light was blinking. (This was later found to be a worn socket which was detected by its audible arcing while standing underneath the light).

4. At about 8:25 the barn was visited, but no similar phenomena occurred.

5. Shortly after 8:30 the first stable was revisited. The phenomena observed in item 2 did <u>not</u> repeat. (This is partial substantiation of historical data item R.) Chores had been completed hours before so the flickering could <u>not</u> be caused by gutter gleaner, silo unloaded (which had been disconnected), vacuum pump or milk cooler.

Five samples of failed lamps were sent to us. One is characteristic of failure by over voltage, ie. the filament is severed at the supports and the internal fuse was blown. It cannot yet be concluded from the lamp whether the over voltage was small over a long period or very high (thousands of volts) over a very short period (microseconds).

On October 25 and 26 1988 a second visit was paid to the farm with a BMI 4800 power scope to analyses the power system. The following observation were made.

1. The high voltage discharge was <u>no longer</u> audible at the house. The noise level was decreased so that one had to stand approximately 100 to 200 ft. away from the line in order to hear the sound at approximately the same intensity as in May. The weather was humid with intermittent showers.

2. No lights flickered or blinked anywhere on the farm. The radio in the stable never repeated the clicking heard in May.

3. Recording of effects of various barn loads are in Appendix H1.

4. Characteristics of the well pump disturbances on the electrical system were recorded, See Appendix H2. As a result of these observations thresholds for the BMI Monitor were set for the recordings made later.

5. Twelve hours of recording during the morning hours of October 26 are in Appendix H3.

<u>DISCUSSION</u>

In the historical data, as related to us, there are many items of interest. Item U, the combine fire and Item X and AB, electrical failures on equipment near the high voltage line bear a remarkable resemblance to failures of low voltage equipment in high voltage substation. Appendix's I-1, I-2 and I-3 refer to low voltage electrical equipment failure due to transients induced by high voltage systems. Appendix I-1 refers to substation of 345 kV and above but it must be pointed out that systems of lower voltage can have the same phenomena occurring but porportionally less. These studies and tests were done within the substation property, but it must be pointed out that once a transient has been produced on a transmission line it will travel as a wave for some distance before it eventually dissapates it's energy.

Unshielded wiring is especially susceptible to inductive effects. Farm equipment wiring is not shielded wiring. In the case of the combine, a standard alternator has semiconductor diodes as part of their power circuitry. The reverse voltage rating of the diodes is usually 50 volts to 100 volts. Appendix I-2 page 1081 makes reference to the susceptibility of diodes to reverse over voltage. It is therefore quite possibile that an induced voltage in the combine wiring was applied to the alternator diodes to cause them to fail. Failure of the diodes could result in a short circuit which would allow the battery to discharge through the wiring and the alternator.

Item AB: The failures and fires reported at a neighbour's service panel may also be related to induced transients.

Appendix J is a draft document by Ontario Hydro, which makes no mention of the possibility of damage by high frequency or steep wavefront transients from high voltage transmission lines. The date of Ontario Hydro's demonstration is five to six years after the studies of Appendices I-2 and I-3.

Could transients be responsible for other historical phenomena. Looking at the sketch of the farm, Appendix G, we see that the service line to the farm and overhead triplex to the barn form 500 ft. of parallel conductor approximately 500 ft. away from the 230 kV line. If an induced transient occurred on the overhead farm service, the line itself would become the voltage source. In effect, the 230 kV line forms the primary winding and Mr. Moore's overhead service forms the secondary winding of a large air core transformer. Appendix K1 is an attempt to show how the voltage might be distributed along the overhead conductor. Since the neutral is grounded at many points, one end of the overhead conductor would experience a positive change in voltage while the other end would experience a negative change in voltage. A point somewhere inbetween would have a zero potentional. The actual voltage distribution depends mainly on the impedances to ground of each grounding point. If one of the impedances to ground is changed, the voltage pattern along the overhead conductor with respect to ground will be altered accordingly. For example in Appendix K2 the grounding at the road is increased thereby reducing the impedance to ground at the road end of the overhead conductor.

This in effect ties that end closer to the ground potential and forces the barn end of the line higher in potential. The extra grounding at the road allows more current to flow in the overhead conductor as a result of the induced transient. More current on this overhead conductor means larger voltage drops across the impedances to ground at the house, stable and barn. This agrees well with Item V of the historical data, the house was relatively free of effects until the utility installed extra grounding along the road. It can also be seen that the wiring at the well would experience the induce voltage and would explain the historical item J, shocks received at the well even though power was turned off.

Historical data Item R, the time of day when disturbances were noticed is <u>especially</u> important. At noon and at late afternoon to early evening there is usually an increase in demand for power. There is a high rate of change of demand (ie. shifts from industrial to commercial or residential can raise or lower the demand very quickly.) During these times of changing demand automatic voltage regulation is most active. Regulation usual consist of on line tap changing, line switching and capacitor switching, all of which cause transients. It is known that improperly sized (undersized) switching equipment can lead to <u>very</u> severe transients.

Transients are different from the normal 3 phase current on a transmission line. Normal 60 cycle currents will nearly balance, so that at a distance from the transmission lines, there is effectively no 60 Hz magnetic field. Transients have significant ground currents through substation components or stray capacitance. This is usually refered to as zero sequence or residual components. In addition, transients caused by 3 phase switching may not only not balance but there may be a possibility of mutual reinforcement due to minute differences in the separation time of contacts on the switches.

Consider a ringing transient. The highest frequency which would be expected to produce this effect would have a quarter wave length equal to 500 ft. This is be approximately 1.9 megahertz, a high frequency but <u>not impossible</u> as pointed out in Appendix's I-1, I-2, and I-3.

The highest transient voltage that could be expected under normal operation would be the zero to peak voltage of the 230 kV. This is 162 thousand volts.

The current produced by this voltage at this frequency will depend on the high frequency impedance of the line. Without actual numbers to use we will use 500 ohms. (500 is often used) This gives us a transient peak current of 324 amps . Page 44 of Appendix I-4 shows a calculated current of 830 amps peak and a frequency of 1.3 megahertz in a loop around a high voltage substation. We can therefore conclude that our calculations are reasonable.

In order to calculate the voltage induced by magnetic coupling on the overhead conductors of Mr. Moore's property, we will use the principles of inductive coordination. Appendix 'L' is a section north to south across Mr. Moore's farm. The depth of the return current is given by;

$$De=2160[p/f]^{1/2} \text{ ft.}$$

where p=ground resistivity in meter-ohms, (ranging from 10 to 1000, 100 is used where the actual value is not known.)
and f=frequency in Hz.

Because the highest frequency considered by the inductive coordination calculations is 5000 Hz, we will use this figure initially.

$$De=2160[100/5000]^{1/2} \text{ ft}$$
$$=305 \text{ ft.}$$

The induced voltage is given by;

$$V=Ia(f/60)[0.0954+j0.2794xlog(Dex/Dax)] \text{ volts per mile}$$

where Ia=current in the 230 kV line

& Dex and Dax are the distances shown in Appendix 'L'

$$V=324(5000/60)[0.0954+j0.2794xlog(Dex/Dax)]$$
$$=3180+j635$$
$$=3242 \text{ volts/mile}$$

Or 307 volts along the length of the overhead conductor.

As pointed out many transients contain components of much higher frequencies. Although using inductive coordination beyond 5000 Hz entails some risk, the values at 50000 Hz are presented until more exact methods are found.

De=97 ft

V=31800+j720
=31808 volt/mile

Or 3012 volts along the length of the overhead conductor.

Both of the above calculated voltages would be severely reduced because of circuit loading through ground impedances and wire impedances, but even if this voltage were reduced to 10% of the calculated value it is obvious that the transients are significant.

Similar calculations for even higher frequencies would result in distances to the return ground current less than tower height, so calculations would seem to be invalid.

Many factors would affect the actual voltage;

Factors which would reduce the voltage are,

- Parallel conductors which also experience induced currents and in effect reduce the magnetic field or provide shielding. The tower ground conductor and the other phase conductors may be considered.
- Transients on other phases cancelling the effect.
- Stray capacitance to ground which could effectively reduce high frequency transient voltages.

Factors which may increase the voltage are;

- Higher frequency transients or transient waves with very steep wavefronts than considered in the calculations.
- Transients on other phases actually reinforcing the effect.
- Resonance effects of the 500 ft. length of overhead, the rural distribution, or of the 230 kV line itself.

- The Lindsay end of the 230 kV transmission line acting as a reflecting point and thereby providing the possibility of two steep wave fronts reinforcing each other at a point over the Moore Farm.
- Switches which allow restrikes during opening. This phenomena can effectively multiply the initial voltage considered. Appendix I-1 indicates most of the severe transients are caused by switching. Switching is controlled by the utilities.
- Ground waves which arrive out of phase with induced waves from the electrical distribution system. Waves propagate along transmission lines at a velocity of 984 feet/microsecond and waves on buried counterpoise (wire, pipe or other conductor) propagate at 408 feet/microsecond. A ringing transient having both power lines and ground components could be alternately in phase and out of phase (with respect to distance along the power line from the source of the transient). This could give the impression that the transient skips along, affecting some locations signifigantly while areas inbetween are less affected. See historical items F and AC.

The survey conducted October 25, 26, 1988 did not record any such phenomena. But must be pointed out that operational changes may have been made in the 230kV line as the amount of audible discharge had been greatly reduced. Also our observation of the blinking lights, which verifies the owner's historical data to us, did not occur during the October investigation.

Considering the historical data, known effects at substations and possible effects as shown in the discussion, all further investigation should include:

1. Complete equipment details of the 230 kV line as it was constructed in 1979 or 1980.

2. Equipment changes made over the years and the date of change.

3. Operating records, or logs, from the first day of operation to date.

4. Independent evaluation of the above data by experts familiar with power system transients.

5. Mechanics reports, Insurance Investigators reports, etc. on the combine fire and other farm equipment failure.

6. Insurance Investigators reports on the neighbour's panel failures.

7. Coordination study between buried pipelines or other metalic runs in the vicinity of the 230 kV line and ground connections back to the 230 kV equipment.

8. Interviews with high voltage operators.

Appendix M is a graph which shortens some of the standard noise frequency inductive coordination calculations. Using it to 'ballpark' the inductive effects of the power line to the overhead conductors, we see that at 500 ft. separation the inductive coupling factor is about 15 microhenrys per 1000 ft. so that we have 7-1/2 microhenrys of mutual coupling . We also see that at 50 ft. the coupling factor is almost 10 times as great, 130 microhenrys per 1000 ft. Therefore a 50 ft. conductor 50 ft. away and parallel to the transmission line has 6-1/2 microhenrys of mutual coupling. The implication here is; 50 ft. conductors placed 50 ft. from the transmission line will experience nearly the same magnitude of transients as 500 ft. conductors placed 500 ft. from the transmission line. Therefore if we conclude that exposed wiring within 50 ft. of the transmission line (such as the combine wiring) can be affected we must therefore logically conclude that the longer more distant overhead conductor will likewise be affected.

It is interesting to compare again Appendixes I-1, 2, 3 and 4 to Appendix J. An attitude of the power utilities becomes apparent;

> When damage occurs to utilities systems, costly long term investigations are undertaken to solve the problem and find solutions.

When damage occurs to other than utilities systems, there is nothing on their systems which could cause such damage.

The locations of many observed events happened in close proximity to the 230 kV line; item T, horses becoming uncontrolable on the track; items U and X, electrical failure on farm equipment; and item AB, the panel failures of a neighbours house. These items are in contrast to; items F, heifers in the back pasture having no symptoms and item AC, other neighbours not reporting problems. Interestingly, items F and AC occur on opposite sides of the items T, U, X and AB. This strongly suggests impulses reinforcing each other at some locations and cancelling each other elsewhere, such as might occur with a ringing transient.

Item 'S', the silo unloader starting spontaneously has two possibilities. Appendix 'N' is a representation of the arrangement of the controls. Where control wires are very long to a remote station, capacitance between conductors has allowed enough current flow to prevent the circuit from being shut off from the remote stop button. This raises the possibility that a severe transient may find enough capacitance to energize the starter in the first place. In this type of control the starter needs only be activated momentarily and it will 'hold' itself in causing the motor to run. Secondly, a severe transient might cause flashover between conductors of the circuit and energized the starter. As soon as the starter energizes, the hold in contacts effectively 'shorts out' the flashover (Contrast to item W, the ceiling fixture which burned its electrical cord. In this case a flashover between conductors through insulation can have destructive follow through current.) The contacts of the barn push-button station showed no sign of arcing and were designed with wide, double contact gaps. The 100 ft. or so of flexible cable <u>may</u> have experienced flashover through deteriorated insulation.

In appendix H1 the effects of various barn loads were recorded on the cow contact point. although some equipment, such as the milk cooler and exhaust fan caused some disturbance on the line to neutral (L N BARN) and Neutral to ground (N G BARN) no effects could be seen on the Water Bowl to Gutter cleaner chain (WB GTR C).

In Appendix H2 the impulses caused by the well pump shutting on and off were recorded. These did not cause disturbances on the water bowl to gutter cleaner chain.

From Appendix H2 a threshold value above those disturbances was chosen for a 12 hour monitoring period. Appendix H3 contains charts and graphs from the monitoring. Comparing summary charts of line to neutral impulses (L N IMPULSE) to neutral to remote ground impulses (BN RG IMPULSE) we can see that neutral to ground disturbances are <u>not</u> related to the line to neutral disturbances. Looking at the Neutral RMS voltage (BN BG Rms) we <u>can</u> see that the neutral to remote ground RMS and Impulses <u>are</u> related.

The line to neutral impulses are very regular suggesting a regular cycling load. A refrigerator or freezer would be suspected.

On the other hand the neutral impulses are closely tied to the neutral RMS. Since the farm was <u>not</u> opertional during the monitoring, ie. the load <u>did not</u> change,the neutral RMS & impulses must be related to the Utility distribution system!

It can also be seen by comparing the summary of the Water Bowl-Gutter Cleaner (WB GTF RMS) to the summary of neutral RMS (BN RG RMS) that there <u>is</u> a relationship. The Water Bowl-Gutter Cleaner RMS has a barely perceptible rise from 7:15 AM on, the same time that the neutral RMS rose signifigantly. We can conclude neutral RMS voltage shows up across these metal points in the barn. Whether this is due to leakage through the Tingle Voltage Filter, ground currents or other causes has yet to be determined. Logically, there is also the possibility that transient voltages on the neutral system also show up across the Water Bowl-Gutter Cleaner. The BMI 4800 has a minimum threshold setting for impulse voltages of <u>20</u> so impulses below this value <u>would not</u> be recorded.

REVIEW OF ONTARIO HYDRO REPORT

In November of 1988, the report of Messeurs: Baljet and Lat was received and reviewed with the following comments:

Ontario Hydro's Investigation concerned itself with three areas; live stock problems, incandescent lamp failure, and well pump switch failures. They neglected such basic items as: when the problem started, the daily pattern noticed by Mr. Moore, the problems with his horses in the stable, the uncontrolability of horses on the track, the combine fire, the two tractors and baler electrical failure, panel failures at a neighbouring house, pump motor failures, compressor motor failures, lamp fixture failures, spontaneous starting of the silo unloader, the worstening effects after extra grounding was installed on the rural feeder, and similarities to other failures recorded across the continent.

Considering the length of time Ontario Hydro spent at this study it is surprising that they did not come up with a better history. When researching any phenomena it is imperative to interview witnessses at length. Investigations into unusual events usually involves a combination of intuition, analysis, and adherence to certain common sense rules but first you must detail the events. In contrast, Appendix 'C' by Otter Tail Power the most experienced utility in stray voltage investigations stresses listening to the Farmer.

On page 7, Ontario Hydro described narrow spikes with relatively large voltages, lasting up to several millionths of a second, as being harmless. This is absolutely incorrect. We have demonstrated to representatives of the Ontario Ministry of Agricultural and Food that short duration spikes in the range from 30 to 60 volts which decayed exponentially to 0 volts in 5 to 6 microseconds causes stress and behavioural response in cattle. The representatives even notice disturbances in rumen movement and breathing patterns. These last observations may offer some explanation for long term observations by many Dairymen.

It is not surprising that Ontario Hydro did not measure more severe transients. This type of observation has been made before. It is well know that candid monitoring can change the results. A common example of this is the "speed of highway traffic changes depending on whether or not police radar traps are in place."

Ontario Hydro's investigation should have co-ordinated switching on the rural distribution and 230 kV systems exactly as was done in Appendices I2 and I3. Representative for Mr. Moore should review the procedure and attended the tests.

CORRECTIVE ACTIONS

The following suggestions are offered to reduce the possibility of induced transient voltages from the 230 kV line at Mr. Moore's Farm;

1. Redesign of 230 kV transmission system to reduce severe transients.

2. Relocate 230 kV transmission line away from Mr. Moore's property.

3. Replace 230 kV tower line with shielded cable in the vicinity of Mr. Moore's farm.

4. Resupply Mr. Moore's farm with an underground primary feeder, padmount transformer and underground secondary feeders to the house, shed and barn.

   This would not eliminate problems with horses on the race track, equipment in the field or problems at neighbouring properties. The problem with horses on the track could be solved by relocating the track to another part of the property.

APPENDIXES

A1 Britten, A. M., Insulate your cows from stray voltage, Dairy Herd Management, January 1980.

A2 Cloud, H. A., Appleman R. D., Gustafson R. J., Stray voltage problems with dairy cows, pg. 23, Rev. 1987.

B1 Innovative Technology, Descriptive literature.

B2 SSAC, Transients, pg. A16, A17.

C Folger, K., Otter Tail Power Company, Testing for Neutral-to-Earth Voltages, ~~IEEE~~ Winter meeting, Feb. 2,1988.

D1 Appleman R. D., Gustafson R. J., Sources of Stray Voltage and Effect on Cow Health and Performance, Journal of Dairy Science, Vol. 68, No. 6, June 1985, pg. 1554-1567.

D2 Gorewit, R. C., Zhao, X., Aneshansley, D. J., Ludington, D. C., Pellerin, R. A., Effects of Neutral-to-Earth Voltage on Animal Health and Reproduction in Cattle, Paper No. 87-3035, American Society of Agricultural Engineers.

D3 Currence, H., Steevens, B. J., Winter, D. F., Dick, W. K., Krause, G. F., Dairy Cow and Human Sensitivity to 60 Hertz Currents, Paper No. 87-3036, American Society of Agricultural Engineers.

E Mohr, T., Akers, T. K., Wessman, H. C., Effect of High Voltage Stimulation on Blood Flow in the Rat Hind Limb, Physical Therapy, Vol. 67, No. 4, April 1987.

F Dalziel, C. F., A Study of the Hazards of Impulse Currents, IEEE, Oct. 1953.

G Moore Farm Building Layout.

H1 Moore Barn Load Tests.

H2 Moore well pump motor tests.

H3 Moore Barn test, Oct 26, 1988.

I1 Standard Handbook for Electrical Engineers, Eleventh Edition, Chapter 17, Section 37.

I2 Sutton, H. J., Transients Induced in Control Cables Located in EHV Substations, IEEE Transactions on PowerApparatus and Systems, Vol PAS-89, No. 6, August 1970.

I3 Dietrich, R. E., Ramberg, H. C., Barber, J. C., BPA Experience with EMI Measurement and Shielding in EHV Substations, Proceedings of the American Power Conference, 1970, Vol. 32.

I4 Kotheimer, W. C., Control Circuit Transients, Power Engineering, January and February 1969.

J Demonstrations to Public of EHV Transmission Line Effects Ontario Hydro 'Draft' Document.

K1 Moore Farm, section along overhead conductors.

K2 Moore Farm, section along overhead conductors.

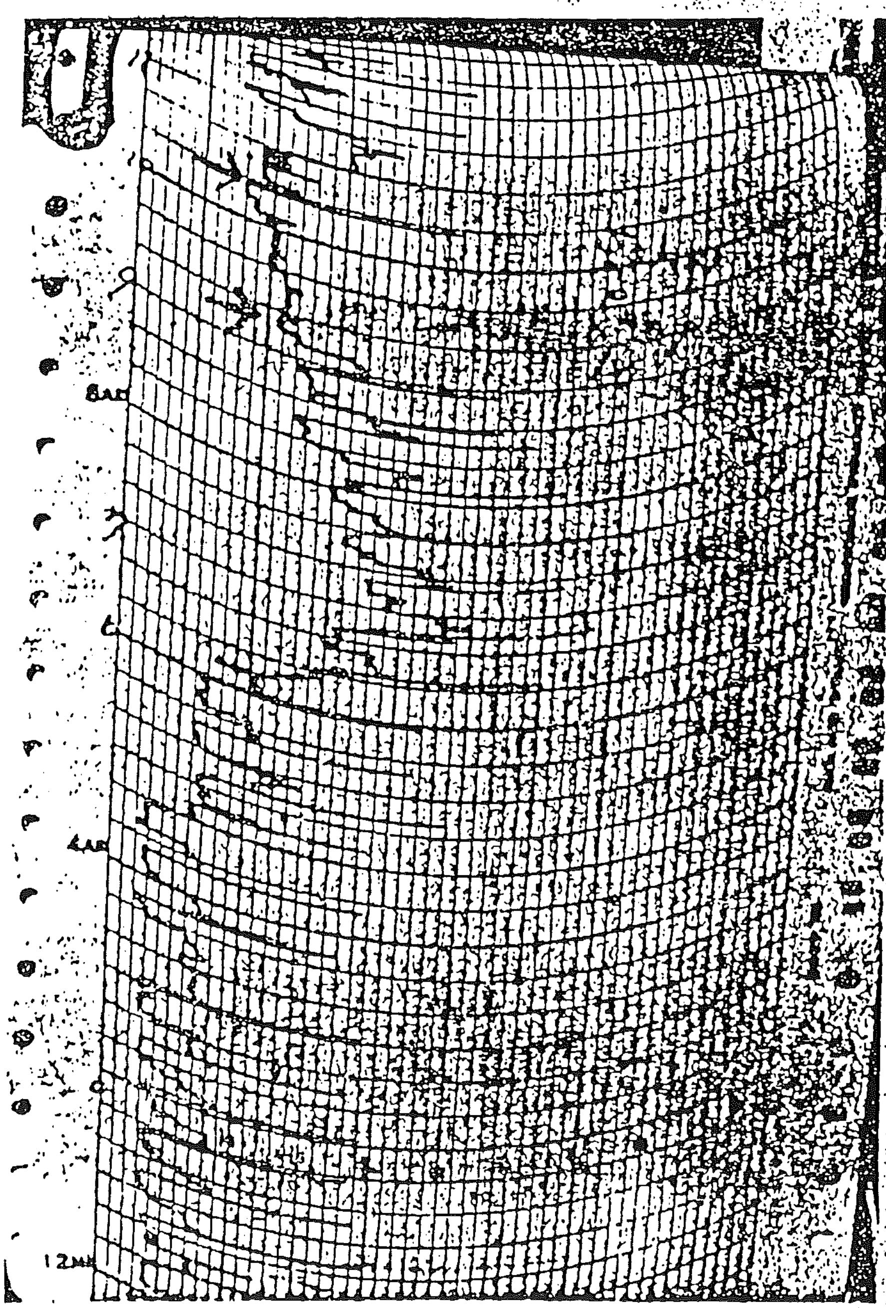
L Moore Farm, section through to 230 kV line.

M Coupling Factors for Longitudinal Induction, Special Publication C22.3, No. 3.1-1974, Inductive Coordination Handbook, pg 40.

N Silo Unloader circuit.

DAIRY HERD MANAGEMENT JANUARY 1980

Insulate your cows from stray voltage



A continuous reading from a voltage chart recorder on John Peel's farm shows transient voltage spikes appearing approximately every 20 minutes. The problem was traced to a refrigerator in the house.

By Dr. Allan M. Britten
Ferndale, Wash.

Many dairymen are experiencing poor cow performance or health problems at milking time due to small currents of electricity passing through the cow's body. This problem has been referred to by various names: neutral to ground voltage, neutral to ground potentials, stray voltage, transient voltage or "juice."

Mastitis flare-ups, high leucocyte counts, nervousness, kicking units, poor letdown, slow milking, reluctance to enter the parlor or stall and lowered production are all possible results of stray voltage.

The amount of voltage likely to cause a problem can be very small. It is generally agreed by most researchers in this area that 1 volt AC or more can cause a problem. There is some question as to the significance of voltages in the 0.5 to 1.0 volt range. Some workers feel that even .25 or .3 volts may be cause for concern. This is one of the dilemmas of the stray voltage problem — we can't be sure what the significant levels are.

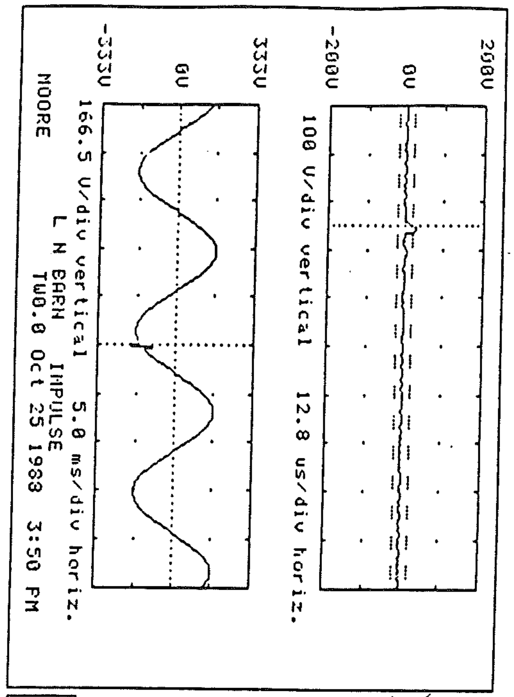
Most people can't feel potentials in this low range. Cows are more sensitive to these low voltages because they have four bare feet, usually stand on wet concrete, have a lower body resistance and often are connected to currents through sensitive, moist membranes (saliva in the mouth or milk in the teat).

It is helpful to try to get a better idea of what the cows may be feeling. Many people have had the experience of touching a metal spoon to a new dental filling in their mouth and getting a "tingle." In this case it is an extremely small DC current

MOORE TW0.0 Oct 25 1988

L N BARN IMPULSE 3:50:25.59PM

38 V peak
312° phase position
3.5 usec rise time
est. 75 uJoules (50 ohms)



BMI

at 3:52:38 milk m/c on

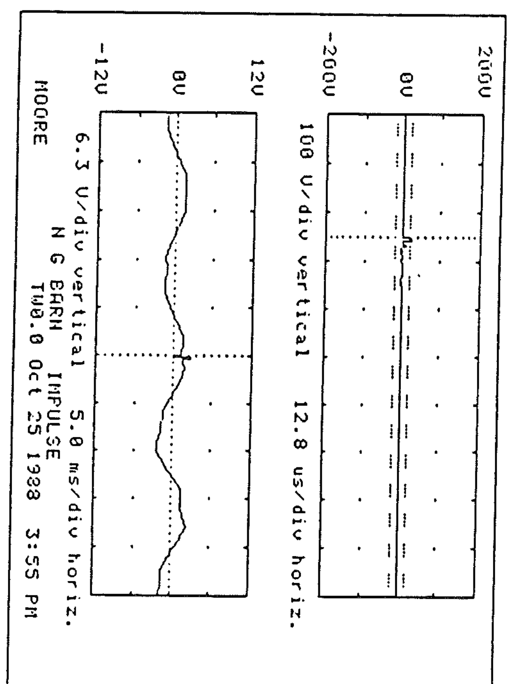
at 3:53:05 milk m/c off

MOORE TW0.0 Oct 25 1988

N G BARN IMPULSE 3:55:43.40PM

32 V peak
100° phase position
2.0 usec rise time
est. 21 uJoules (50 ohms)

at 3:55:43 gutter cleaner on

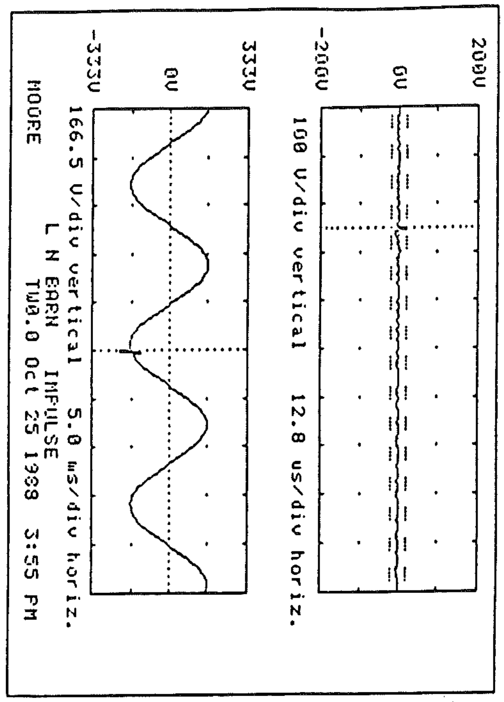


BMI

MOORE TWO.0 Oct 25 1988

L N BARN IMPULSE (3:55:43.41PM)

29 V peak
291° phase position
1.5 usec rise time
est. 34 uJoules (50 ohms)



BMI

at 3:55:54 gutter cleaner off

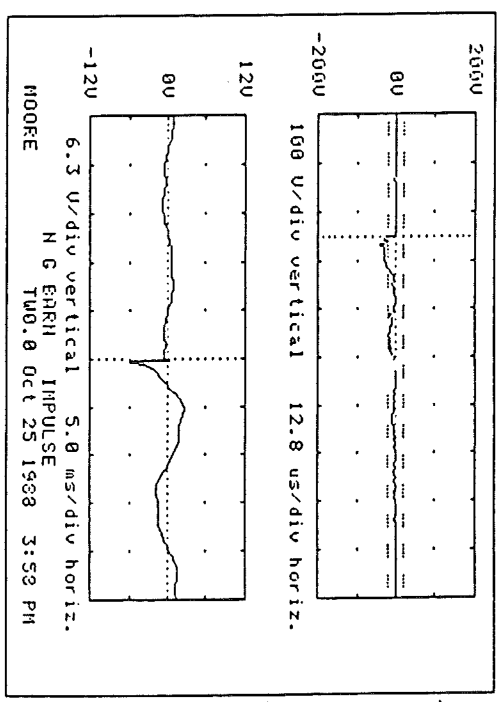
at 3:57:59 barn lights off

at 3:58:08 barn lights on

MOORE TWO.0 Oct 25 1988

N G BARN IMPULSE 3:58:08.23PM)

44 V peak
295° phase position
2.0 usec rise time
est. 240 uJoules (50 ohms)



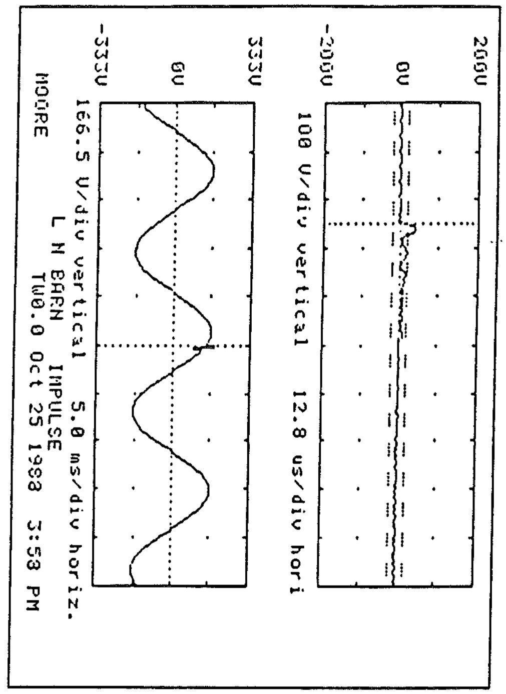
(1 impulse during recovery.)

BMI

MOORE TWO.0 Oct 25 1988

L N BARN IMPULSE 3:58:08.22PM

48 V peak
126° phase position
4.5 usec rise time
est. 220 uJoules (50 ohms)



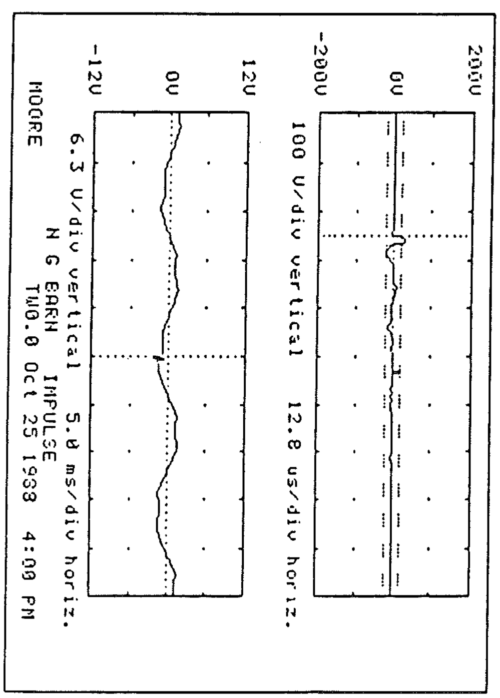
(1 impulse during recovery.)

BMI

MOORE TWO.0 Oct 25 1988

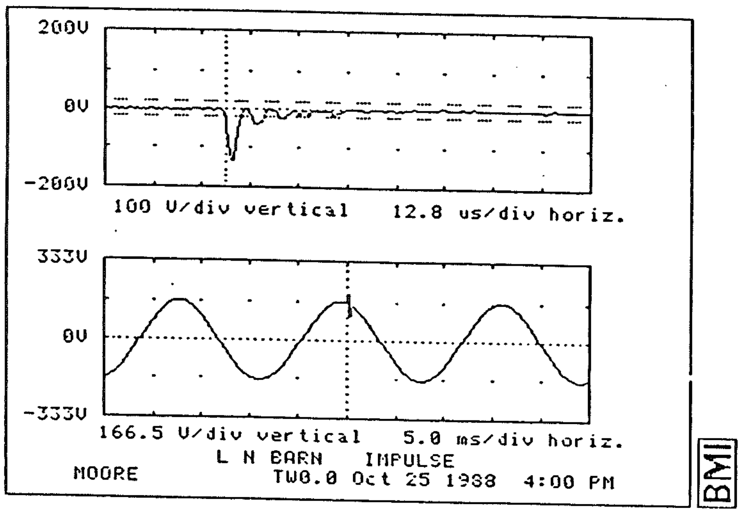
N G BARN IMPULSE 4:00:59.17PM

32 V peak
282° phase position
2.0 usec rise time
est. 93 uJoules (50 ohms)

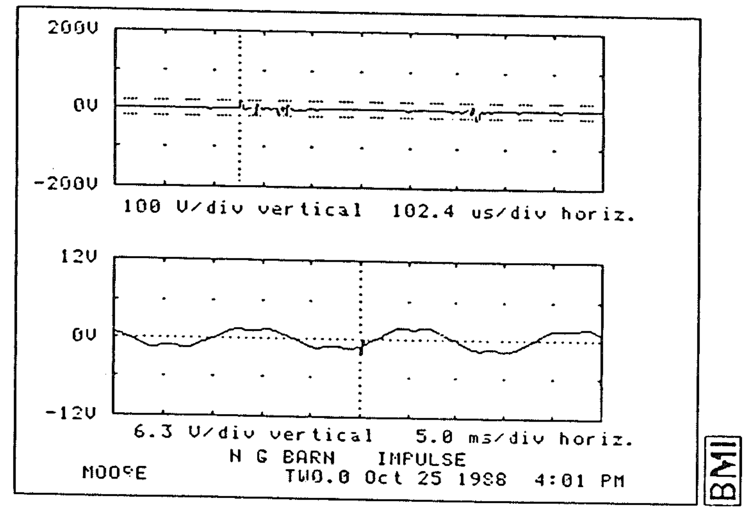


BMI

MOORE TWO.0 Oct 25 1988 4:00:59.17PM
L N BARN IMPULSE
140 V peak
113° phase position
4.0 usec rise time
est. 880 uJoules (50 ohms)



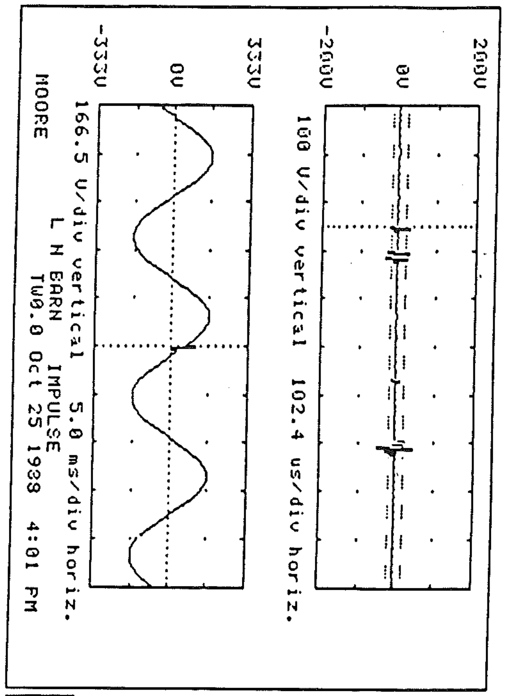
MOORE TWO.0 Oct 25 1988 4:01:15.27PM
N G BARN IMPULSE
25 V peak
338° phase position
8.0 usec rise time
est. 470 uJoules (50 ohms)



MOORE TWO.0 Oct 25 1988

L N BARN IMPULSE 4:01:15.25PM

51 V peak
165° phase position
16.0 usec rise time
est. 2.0 mJoules (50 ohms)

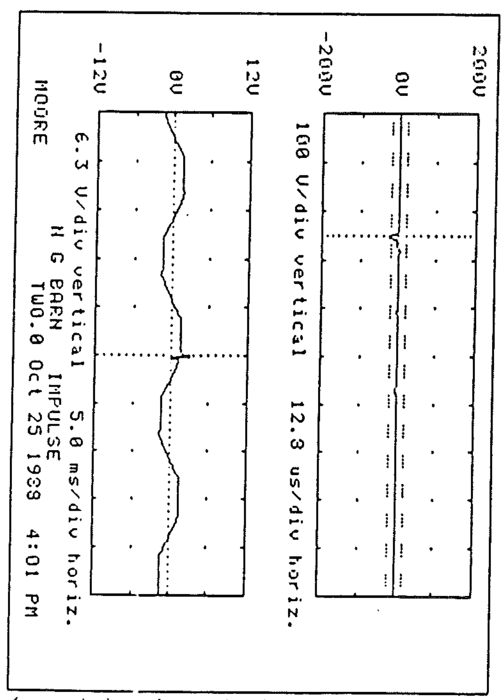


BMI

MOORE TWO.0 Oct 25 1988

N G BARN IMPULSE 4:01:35.00PM

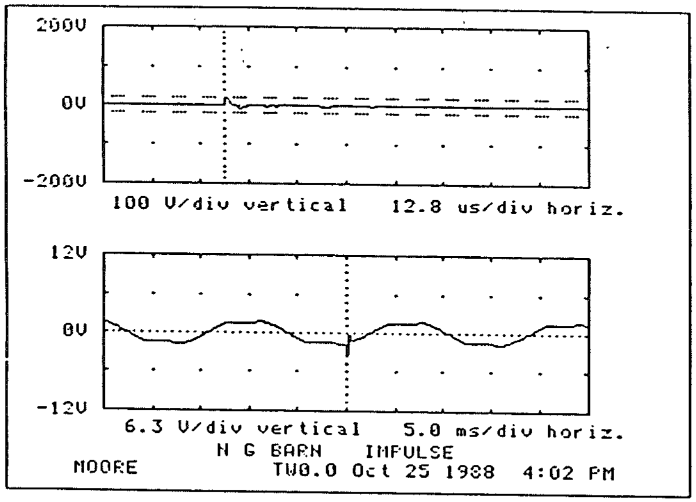
25 V peak
130° phase position
1.0 usec rise time
est. 18 uJoules (50 ohms)



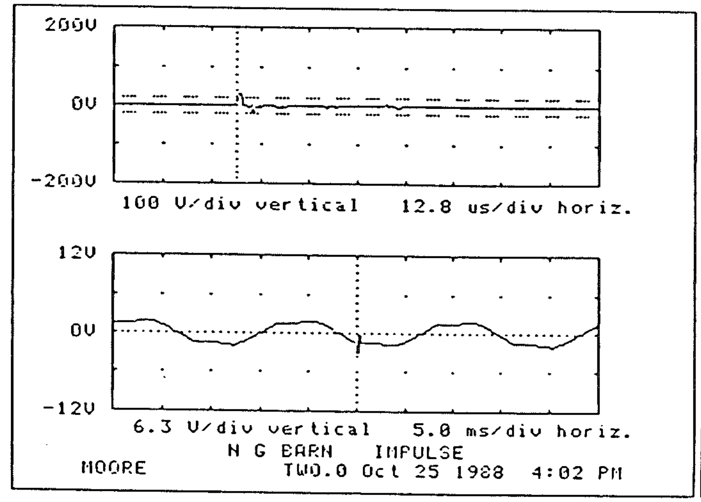
(4 impulses during recovery.)

BMI

MOORE TWO.0 Oct 25 1988
N G BARN IMPULSE 4:02:21.35PM
22 V peak
321° phase position
1.0 usec rise time
est. 21 uJoules (50 ohms)



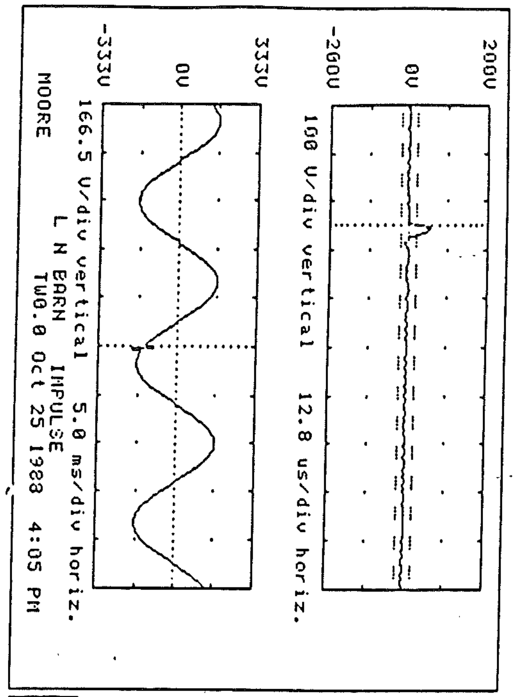
MOORE TWO.0 Oct 25 1988
N G BARN IMPULSE 4:02:34.19PM
38 V peak
230° phase position
2.5 usec rise time
est. 45 uJoules (50 ohms)



MOORE TW0.0 Oct 25 1988

L N BARN IMPULSE 4:05:18.13PM

64 V peak
243° phase position
2.5 usec rise time
est. 170 uJoules (50 ohms)



BMI

4:05:47 well power on

MOORE TW0.0 Oct 25 1988

STRIP CHART REPORT 4:06 PM
From 3:00 PM To 6:00 PM

L N BARN (Channel 1)

Rms:	116.6 Vrms	min,	123.8 Vrms	max
Noise:	0.1 Vpk	min,	1.2 Vpk	max
Freq:	60.0 Hz	min,	60.0 Hz	max
Imp:	38 counted,		140 Vpk	max

N G BARN (Channel 2)

Rms:	0.7 Vrms	min,	2.3 Vrms	max
Noise:	0.1 Vpk	min,	0.4 Vpk	max
Imp:	20 counted,		102 Vpk	max

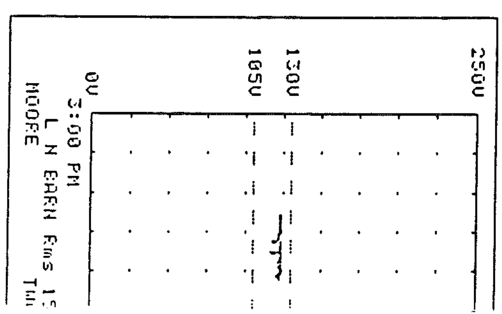
WB GTR C (Channel 3)

Rms:	0.0 Vrms	min,	0.1 Vrms	max
Noise:	0.1 Vpk	min,	0.2 Vpk	max
Imp:	0 counted			

MOORE TW0.0 Oct 25 1988

L N BARN Rms 4:06:59 PM

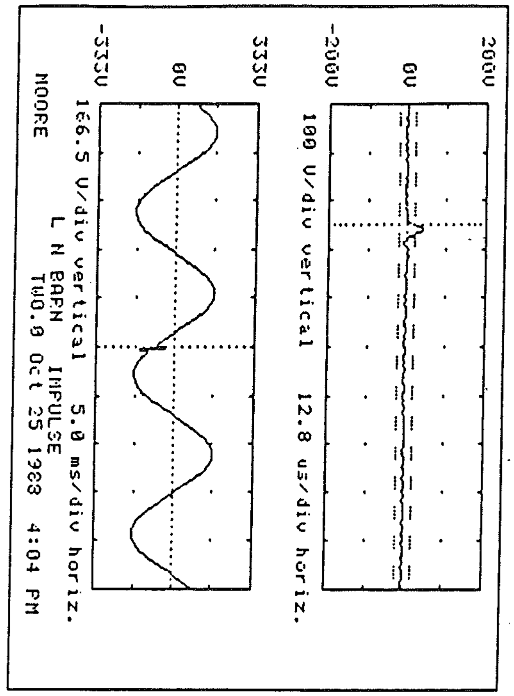
Rms: 116.6 Vrms min, 123.8 Vrms max



MOORE TWO.0 Oct 25 1988

L N BARN IMPULSE 4:04:46.64PM

48 V peak
217° phase position
3.0 usec rise time
est. 110 uJoules (50 ohms)

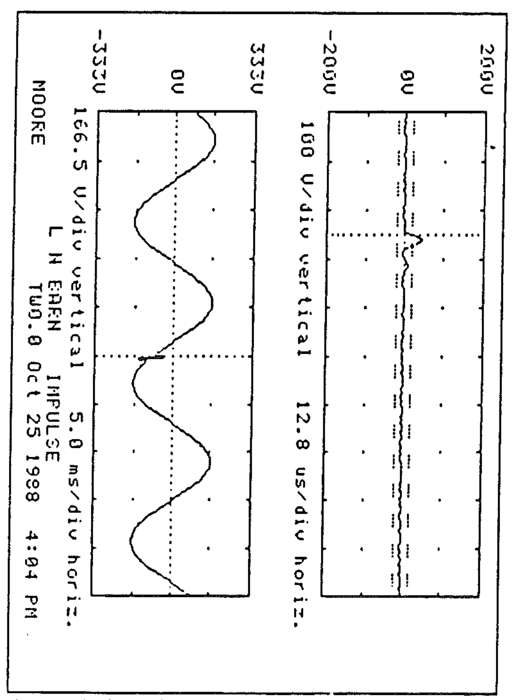


BMI

MOORE TWO.0 Oct 25 1988

L N BARN IMPULSE 4:04:47.58PM

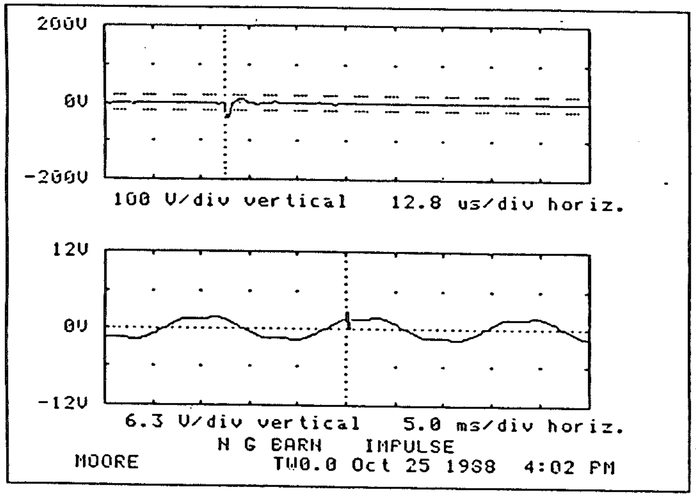
51 V peak
217° phase position
3.5 usec rise time
est. 130 uJoules (50 ohms)



(4 impulses during recovery.)

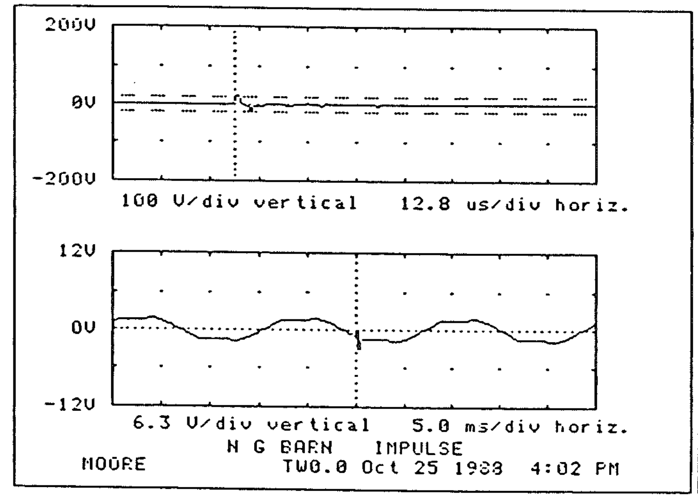
BMI

MOORE TW0.0 Oct 25 1988
N G BARN IMPULSE 4:02:41.85PM
44 V peak
56° phase position
2.5 usec rise time
est. 58 uJoules (50 ohms)



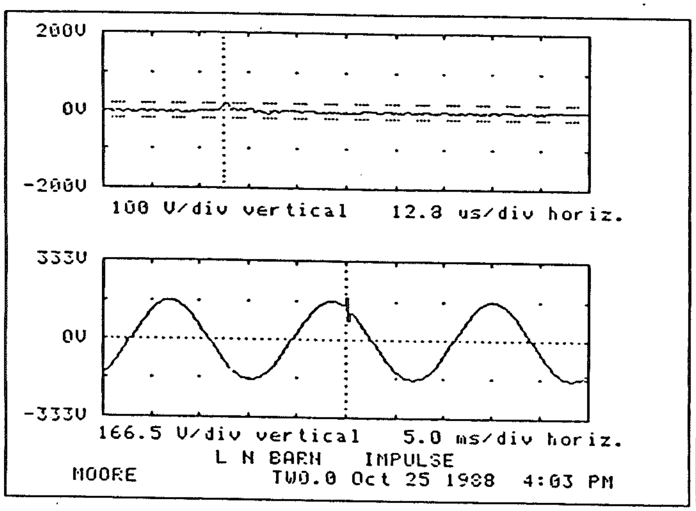
BMI

MOORE TW0.0 Oct 25 1988
N G BARN IMPULSE 4:02:43.28PM
32 V peak
217° phase position
2.5 usec rise time
est. 38 uJoules (50 ohms)



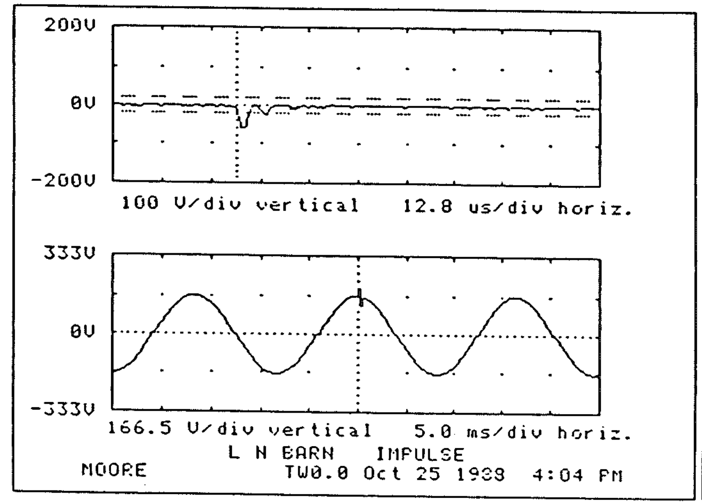
BMI

MOORE
L N BARN IMPULSE 4:03:05.21PM
25 V peak
130° phase position
1.0 usec rise time
est. 59 uJoules (50 ohms)



4:03:23 well power off

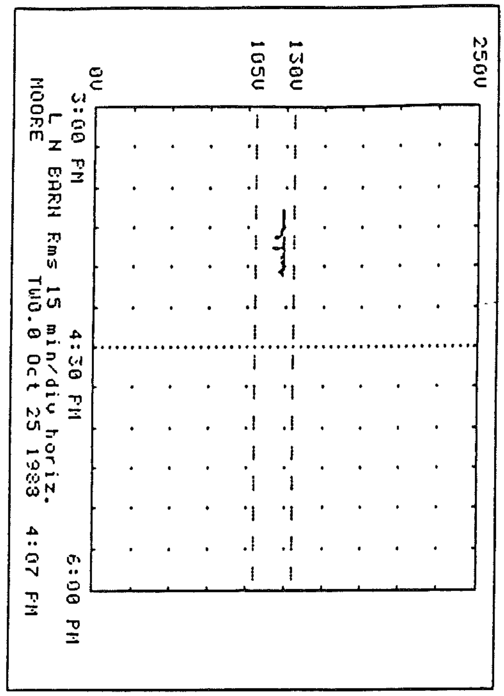
MOORE TW0.0 Oct 25 1988
L N BARN IMPULSE 4:04:38.23PM
64 V peak
100° phase position
3.0 usec rise time
est. 190 uJoules (50 ohms)



MOORE TW0.0 Oct 25 1988

L N BARN Rms 4:06:59 PM

Rms: 116.6 Vrms min, 123.8 Vrms max

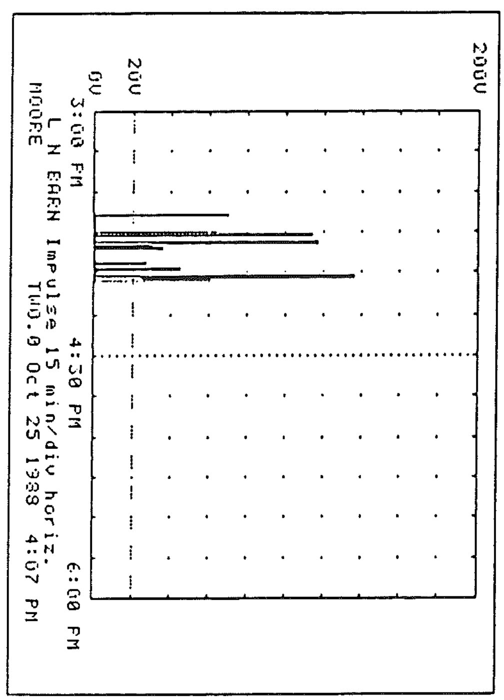


BMI

MOORE TW0.0 Oct 25 1988

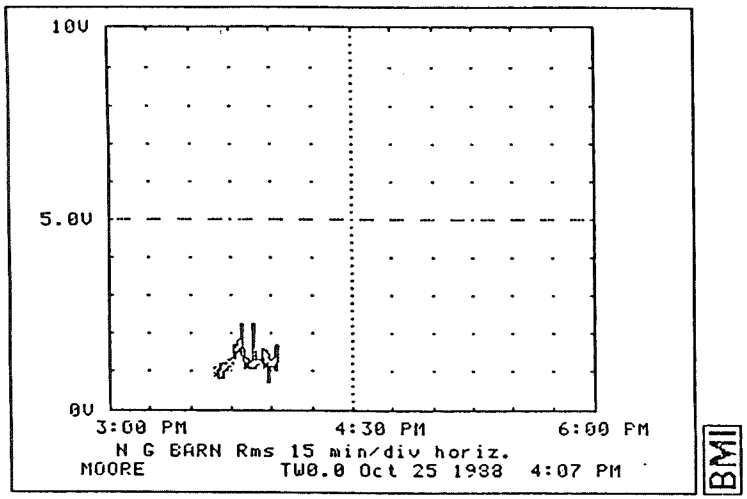
L N BARN Impulse 4:07:07 PM

Imp: 38 counted, 140 Vpk max

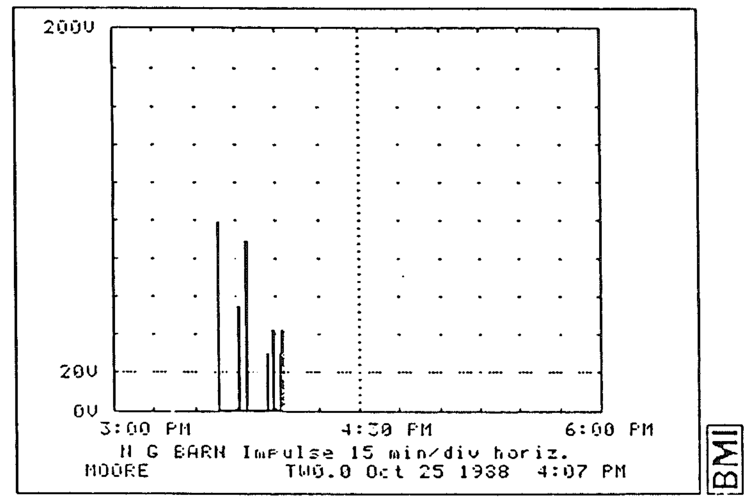


BMI

MOORE TW0.0 Oct 25 1988
N G BARN Rms 4:07:29 PM
Rms: 0.7 Vrms min, 2.3 Vrms max



MOORE TW0.0 Oct 25 1988
N G BARN Impulse 4:07:51 PM
Imp: 20 counted, 102 Vpk max



MOORE TW0.0 Oct 25 1988

Appendix H2

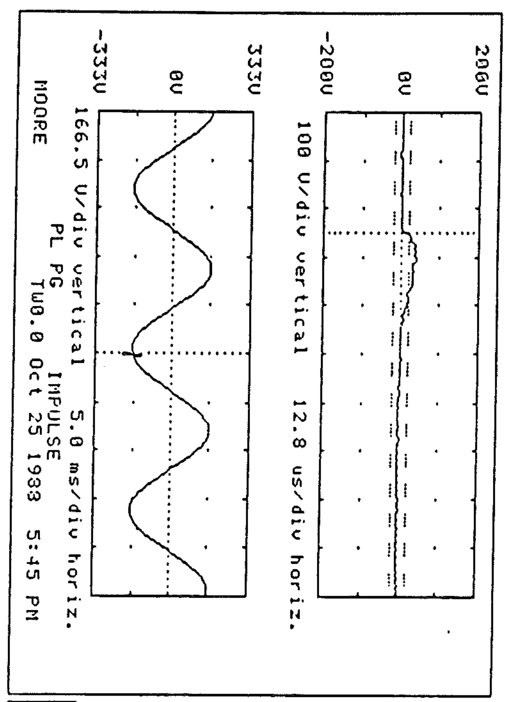
Taken at pump contactor

No corresponding disturbance from pump ground wire To remote ground

MOORE TW0.0 Oct 25 1988

PL PG IMPULSE 5:45:42.27PM

41_V peak
286° phase position
3.5 usec rise time
est. 470 uJoules (50 ohms)



BMI

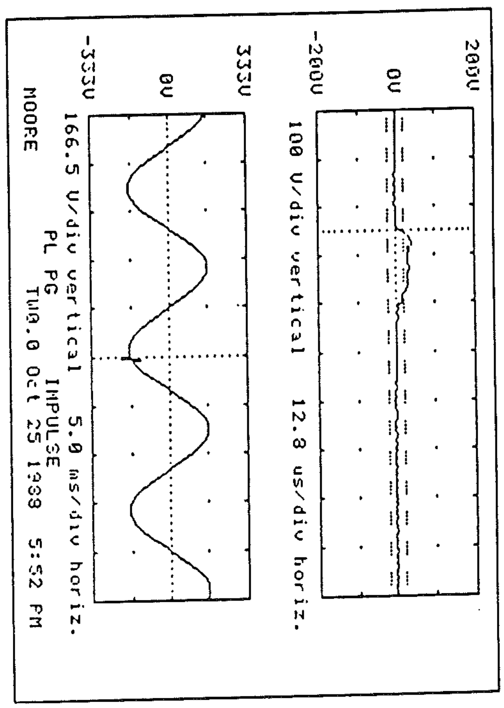
Taken at pump contactor

No corresponding disturbance from pump ground wire to remote ground

MOORE TW0.0 Oct 25 1988

PL PG IMPULSE 5:52:05.05PM

(44 V peak)
299° phase position
4.5 usec rise time
est. 470 uJoules (50 ohms)



BMI

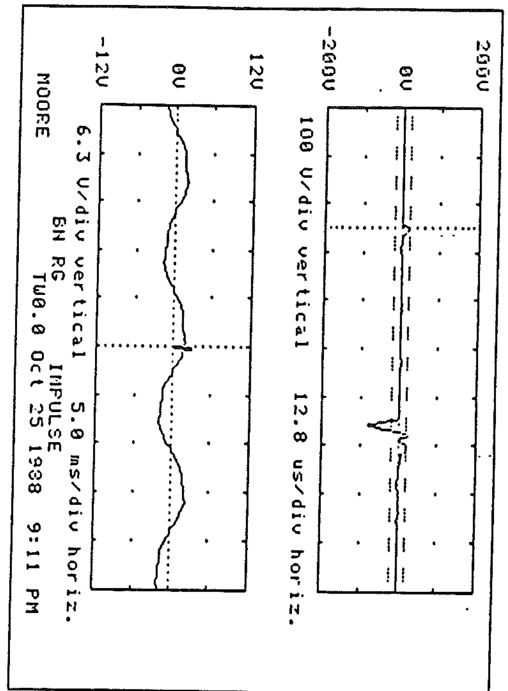
Appendix H

MOORE TW0.0 Oct 25 1988

BN RG IMPULSE (9:11:20.22PM)

pump shut off

83 V peak
134° phase position
1.0 usec rise time
est. 250 uJoules (50 ohms)



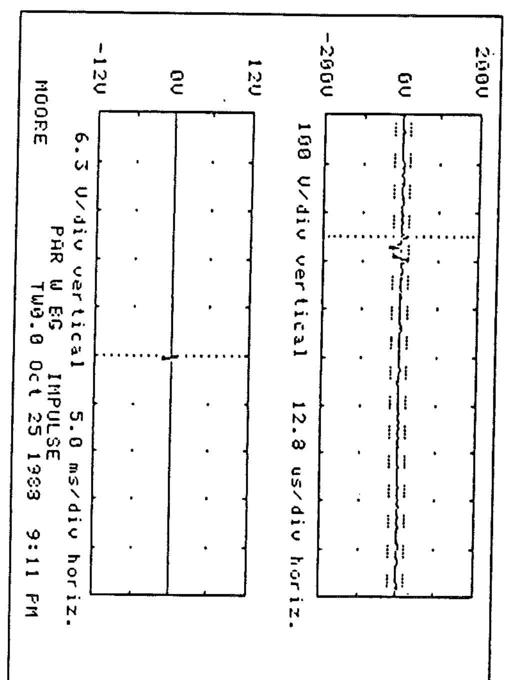
BMI

MOORE TW0.0 Oct 25 1988

PAR W BG IMPULSE 9:11:20.20PM

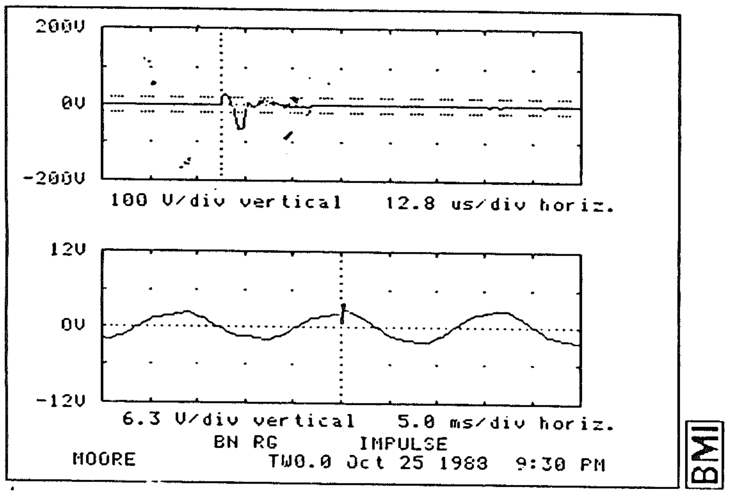
induced by pump shuting off

35 V peak
265° phase position
1.0 usec rise time
est. 110 uJoules (50 ohms)

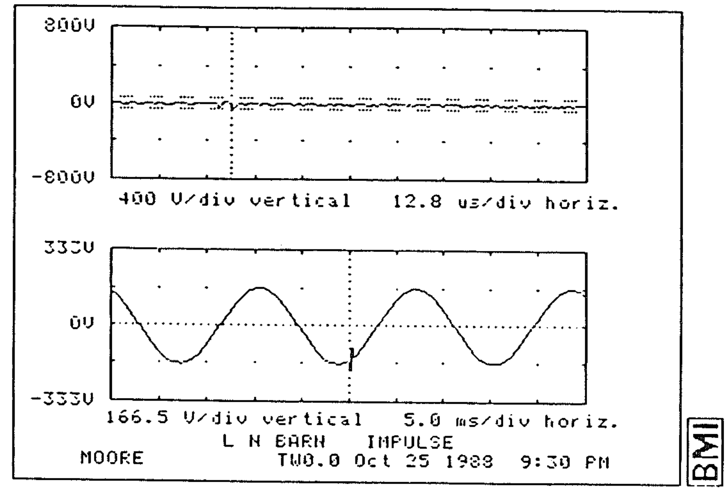


BMI

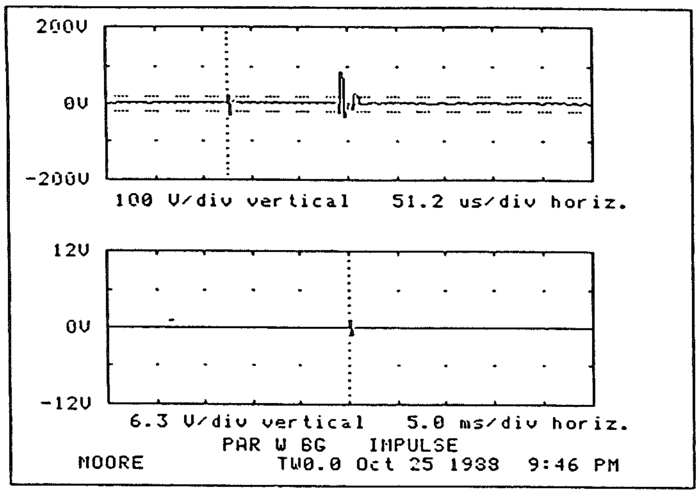
MOORE
BN RG
TW0.0
IMPULSE
Oct 25 1988
9:30:27.94PM
70 V peak
108° phase position
2.5 usec rise time
est. 240 uJoules (50 ohms)



MOORE
L N BARN
TW0.0
IMPULSE
Oct 25 1988
9:30:27.93PM
76 V peak
308° phase position
1.0 usec rise time
est. 540 uJoules (50 ohms)

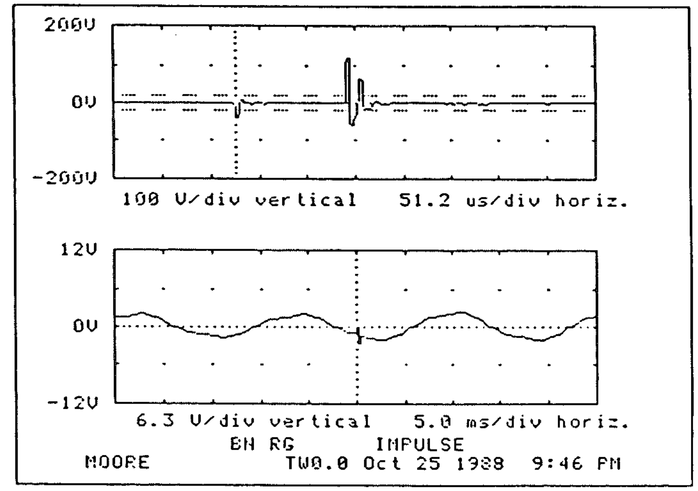


MOORE TW0.0 Oct 25 1988
PAR W BG IMPULSE 9:46:24.22PM
(92 V peak
No phase position
4.0 usec rise time
est. 1.5 mJoules (50 ohms)



BMI

MOORE TW0.0 Oct 25 1988
BN RG IMPULSE 9:46:24.23PM
127 V peak'
243° phase position
4.0 usec rise time
est. 2.1 mJoules (50 ohms)



BMI

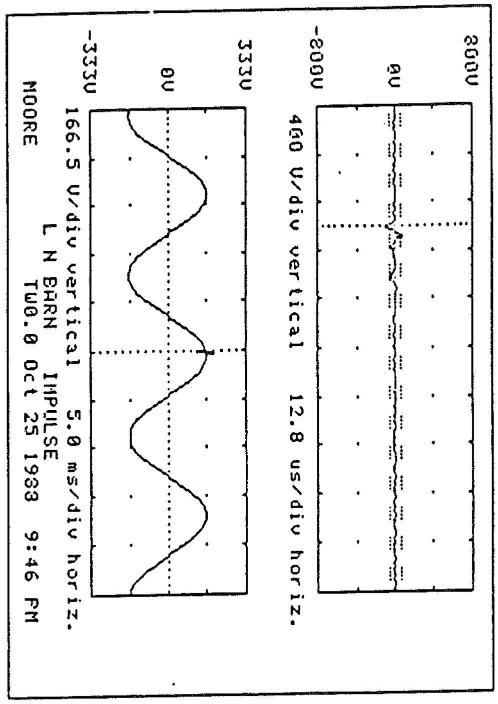
pump start

MOORE TW0.0 Oct 25 1988

L N BARN IMPULSE 9:46:24.29PM

Pump Start

(114 V peak)
82° phase position
1.0 usec rise time
est. 940 uJoules (50 ohms)

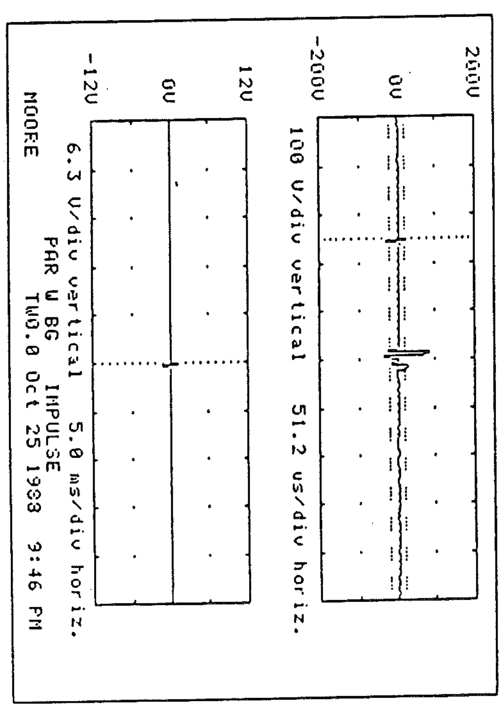


BMI

MOORE TW0.0 Oct 25 1988

PAR W BG IMPULSE 9:46:24.22PM

92 V peak
No phase position
4.0 usec rise time
est. 1.5 mJoules (50 ohms)

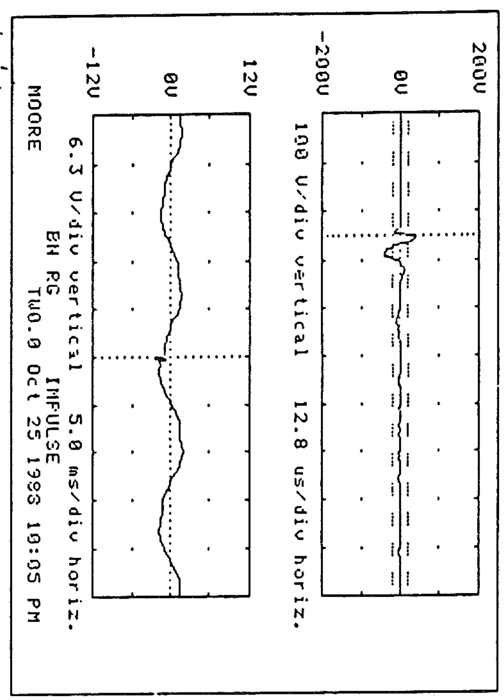


nothing in barn caused this

MOORE TWO.0 Oct 25 1988

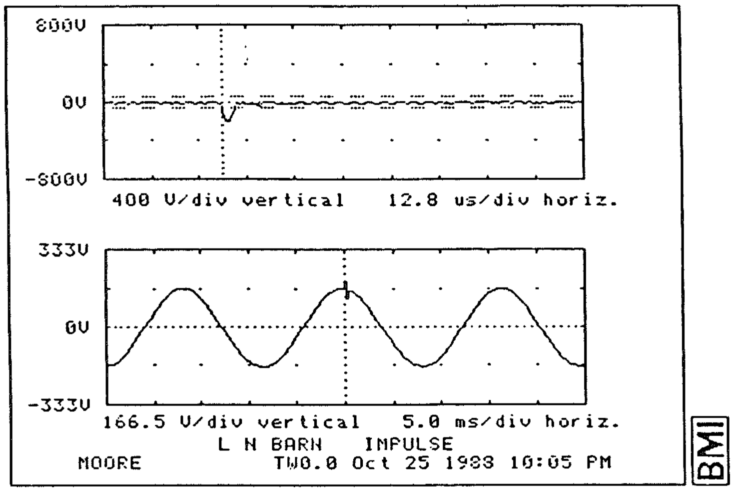
BN RG IMPULSE Not in barn 10:05:17.07PM

44 V peak
265° phase position
2.0 usec rise time
est. 170 uJoules (50 ohms)

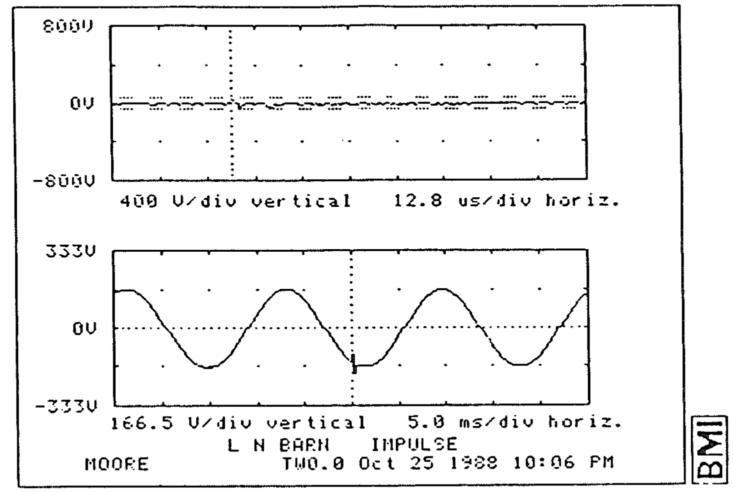


BMI

MOORE TW0.0 Oct 25 1988
L N BARN IMPULSE 10:05:17.01PM
216 V peak
104° phase position
3.0 usec rise time
est. 2.2 mJoules (50 ohms)



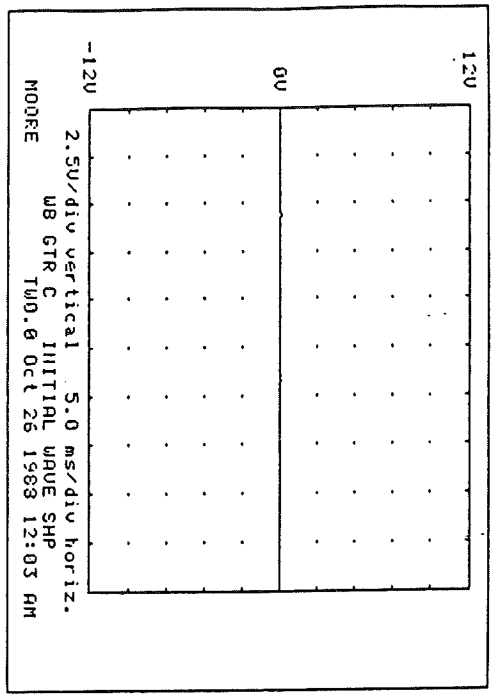
MOORE TW0.0 Oct 25 1988
L N BARN IMPULSE 10:06:40.00PM
64 V peak
252° phase position
1.0 usec rise time
est. 520 uJoules (50 ohms)



nothing in barn caused this

MOORE TWO.0 Oct 26 1988

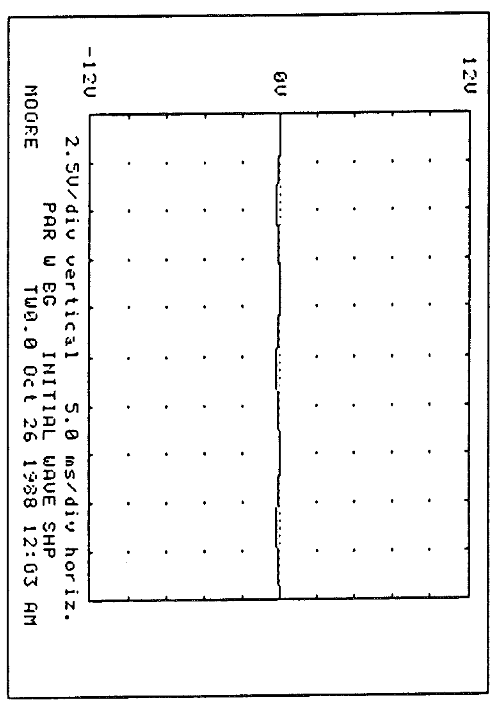
WB GTR C INITIAL WAVE SHP 12:03:03 AM



BMI

MOORE TWO.0 Oct 26 1988

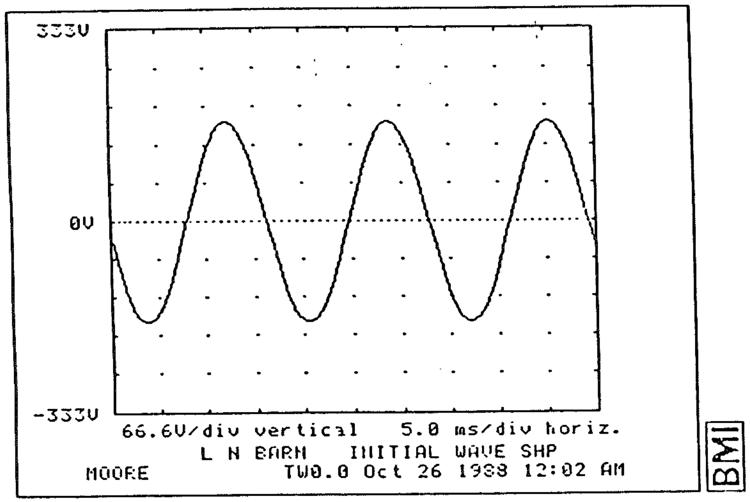
PAR W BG INITIAL WAVE SHP 12:03:11 AM



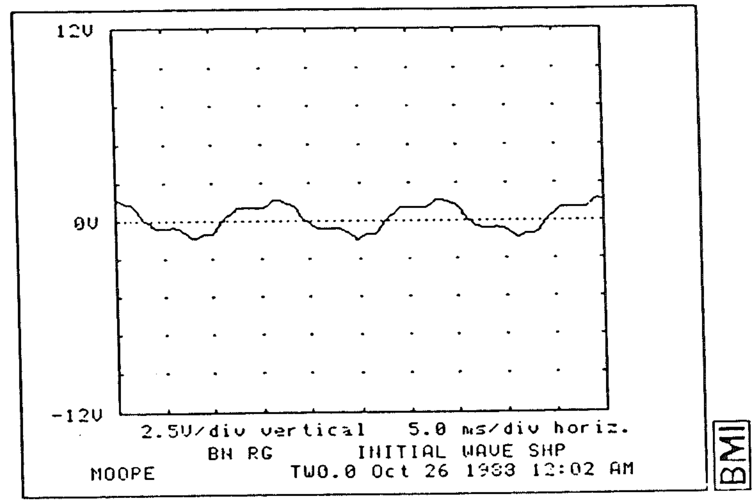
BMI

MOORE TWO.0 Oct 26 1988

MOORE TWO.0 Oct 26 1988
L N BARN INITIAL WAVE SHP 12:02:45 AM



MOORE TWO.0 Oct 26 1988
BN RG INITIAL WAVE SHP 12:02:54 AM

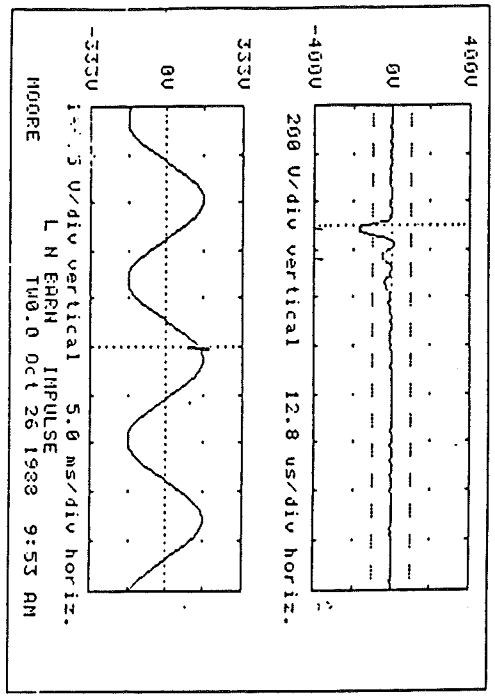


MOORE TWO.0 Oct 26 1988

MOORE TWO.0 Oct 26 1988

L N BARN IMPULSE 9:53:29.29AM

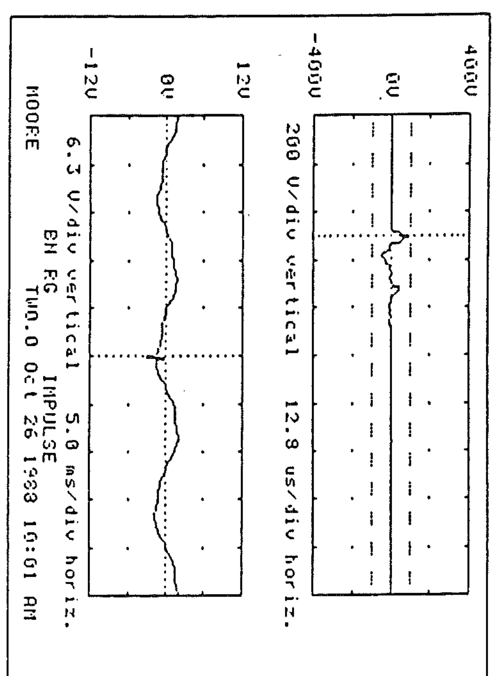
178 V peak
65° phase position
3.5 usec rise time
est. 1.7 mJoules (50 ohms)



MOORE TWO.0 Oct 26 1988

BN RG IMPULSE 10:01:16.82AM

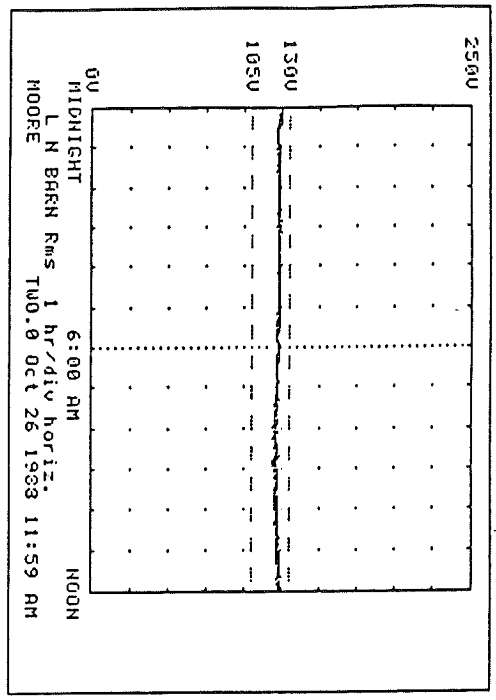
108 V peak
299° phase position
1.0 usec rise time
est. 520 uJoules (50 ohms)



MOORE TW0.0 Oct 26 1988

L N BARN Rms 11:59:38 AM

Rms: 118.6 Vrms min, 125.4 Vrms max

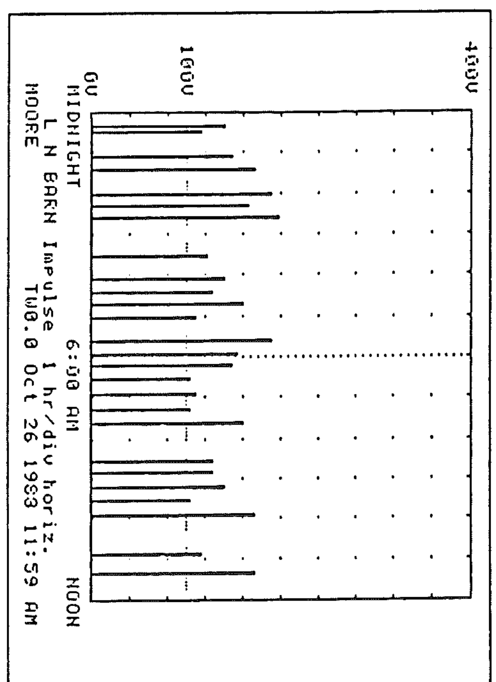


BMI

MOORE TW0.0 Oct 26 1988

L N BARN Impulse 11:59:44 AM

Imp: 25 counted, 203 Vpk max



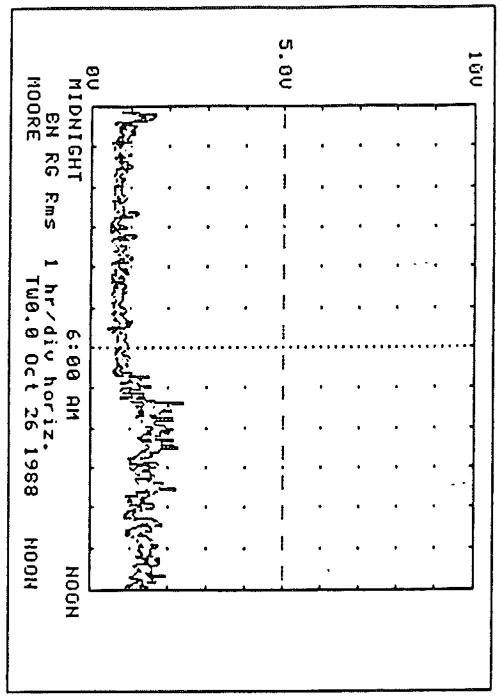
BMI

MOORE TW0.0 Oct 26 1988

MOORE TW0.0 Oct 26 1988

BN RG Rms 12:00:09 PM

Rms: 0.4 Vrms min, 2.4 Vrms max

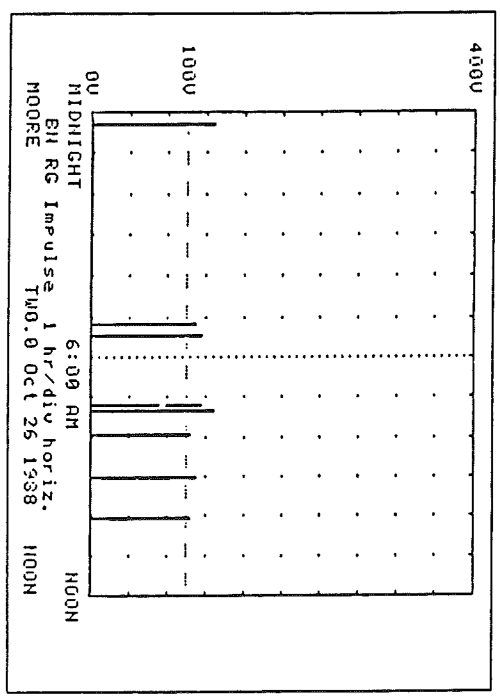


BMI

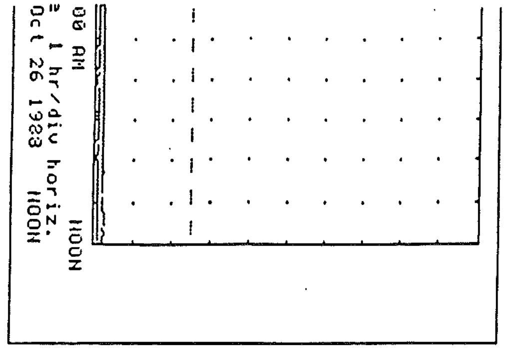
MOORE TW0.0 Oct 26 1988

BN RG Impulse 12:00:31 PM

Imp: 8 counted, 133 Vpk max



BMI

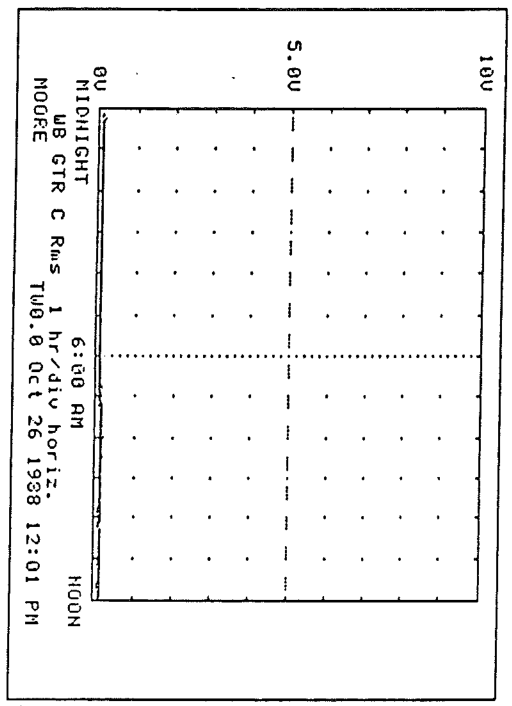


BMI

MOORE TW0.0 Oct 26 1988

WB GTR C Rms 12:01:16 PM

Rms: 0.0 Vrms min, 0.2 Vrms max

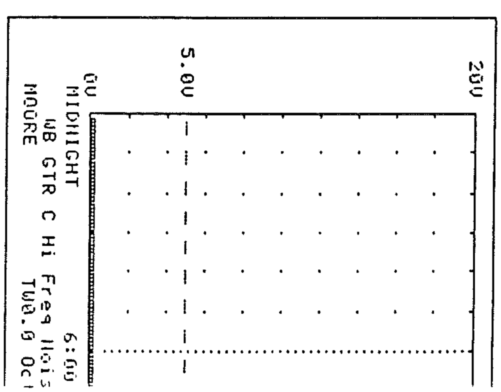


BMI

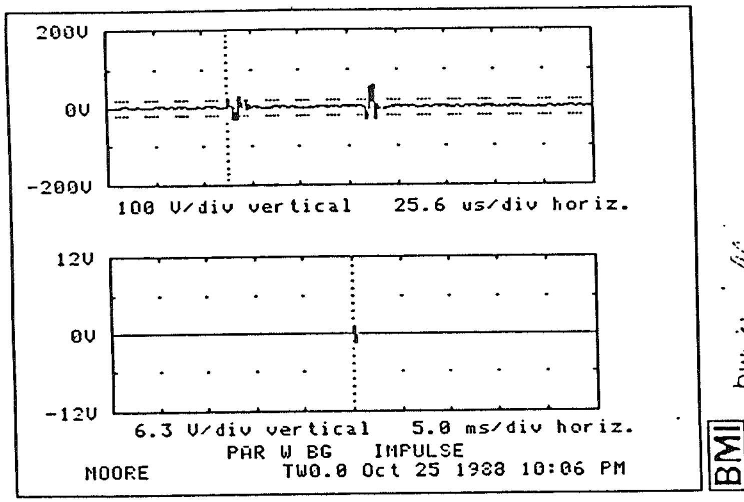
MOORE TW0.0 Oct 26 1988

WB GTR C Hi Freq Noise 12:01:39 PM

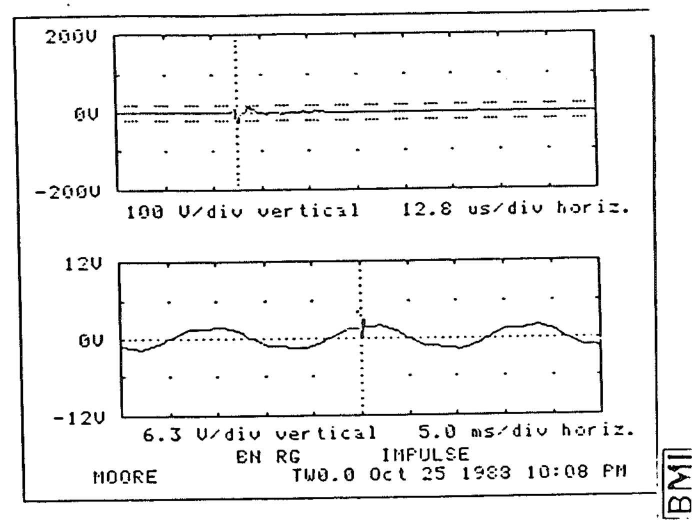
Noise: 0.1 Vpk min, 0.3 Vpk max



PAR W BG IMPULSE 10:06:39.99PM
70 V peak
178° phase position
4.0 usec rise time
est. 0.6 mJoules (50 ohms)



MOORE TW0.0 Oct 25 1988
BN RG IMPULSE 10:08:48.38PM
29 V peak
78° phase position
1.0 usec rise time
est. 33 uJoules (50 ohms)



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MOORE            TWO.0        Oct 26 1988

THRESHOLD REPORT                 12:02 AM

Type:       Ind. channels

L N BARN THRESHOLDS (Channel 1)
      Mode:                 AC
      Surge voltage:   130.0 Vrms
      Sag voltage:     105.0 Vrms
      Impulse:           100 Vpk
      High freq noise:   5.0 Vpk
      High frequency:   61.2 Hz
      Low  frequency:   58.8 Hz
      Wave shape:        20% variation
      Minimum duration: 0.1 cycles
      Line impedance:     50 ohms
      Hysteresis:       1.0%

BN RG THRESHOLDS (Channel 2)
      Mode:             NEUT-GND
      Surge voltage:     5.0 Vrms
      Impulse:           100 Vpk
      High freq noise:   5.0 Vpk
      Line impedance:     50 ohms
      Hysteresis:       1.0%

WB GTR C THRESHOLDS (Channel 3)
      Mode:             NEUT-GND
      Surge voltage:     5.0 Vrms
      Impulse:            20 Vpk
      High freq noise:   5.0 Vpk
      Line impedance:     50 ohms
      Hysteresis:       1.0%

PAR W BG THRESHOLDS (Channel 4)
      Mode:             NEUT-GND
      Surge voltage:     5.0 Vrms
      Impulse:            90 Vpk
      High freq noise:   5.0 Vpk
      Line impedance:     50 ohms
      Hysteresis:       1.0%

SUMMARY REPORT INTERVAL: 12Hr

12 HOUR STRIP CHARTS
      L N BARN Rms Voltage
      L N BARN Impulse
      L N BARN Hi Freq Noise
      BN RG Rms Voltage
      BN RG Impulse
      BN RG Hi Freq Noise
      WB GTR C Rms Voltage
      WB GTR C Impulse
      WB GTR C Hi Freq Noise
      PAR W BG Rms Voltage
      PAR W BG Impulse
      PAR W BG Hi Freq Noise

INACTIVE DISTURBANCES
      L N BARN Hi Freq Noise
      L N BARN Frequency
      BN RG Rms Voltage
      BN RG Hi Freq Noise
      WB GTR C Rms Voltage
      WB GTR C Hi Freq Noise
      PAR W BG Rms Voltage
      PAR W BG Hi Freq Noise

Internal UPS time:    5 minutes.


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MOORE            TWO.0        Oct 26 1988

L N BARN  INITIAL WAVE SHP 12:02:45 AM
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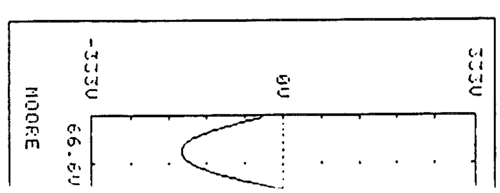

THE EFFECTS OF GROUND CURRENTS ON DAIRY COWS: A CASE STUDY

Daniel Hartsell, D.V.M., Duane Dahlberg, Ph.D., David Lusty, and Robert Scott, D.V.M.

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) an 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 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 focussed 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 non isolation 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 noting immediate improvements in the 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, assisting 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 diary cows owned and managed by Lustys on their farm. This farm offered an especially valuable opportunity to test the hypothesis because Lustys 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 neutral 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 Lusty's 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 con-

necting of the electric utility ground wires. Of significance is that Lusty's 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 (%) **0 - 1**
Basophils carry enzymes 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 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 scrapped 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 monocytes 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 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 Lustys' 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 mA AC 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 OF RESULTS

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 expressing 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 on 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 change 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.

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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	23.6	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

Draft

Veterinary and Human Toxicology, in press

Stray Voltage and Developmental, Reproductive and Other Toxicology Problems in Dogs, Cats and Cows: A Discussion

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ABSTRACT

Ten years ago, after 3 y of investigations under trying field conditions, attempts to determine the cause(s) of reproductive and developmental problems, at a dog kennel in Allegan County, Michigan, were suspended. This kennel had lost more than 120 litters of Shetland Sheepdogs (Shelties) over the preceding 12 y; many of the puppies that died were deformed as were several that survived. Similar effects occurred in Persian cats, although on a much smaller scale, and later in German Shepherds and Golden Retrievers. Such problems began after drilling a deeper water well and the building of a new kennel of concrete and metal fencing in 1969. Prior to that the kennel owner had successfully bred and raised at least 15 litters/y of mostly shelties in an old wooden chicken coop. Health problems in the kennel owner prevented her from breeding dogs in the late 1980's. She gradually resumed a more regular breeding schedule in 1989, initially with some success. However, in 1992 reproductive problems returned. Female dogs ceased cycling or had abnormal "unbreedable" seasons. Sperm checks revealed a lack of sperm in four males. Concurrently, neither the Persian nor mongrel female cats in the kennel showed signs of cycling. Two dairy farmers in Allegan County, who reportedly had similar health, reproductive and management concerns in cows, were contacted. Tests performed at the two dairy farms had revealed the presence of what has commonly been termed stray voltage. Equipment brought by the farmers to the kennel revealed the presence of AC and DC currents on the premises, which were later confirmed by a Staff Engineer expert of the Michigan Public Service Commission (PSC). Such current was detected even when

the electrical power to the premises was shut off. For example, 2.45 volts AC and -0.150 volts DC were detected at the well head, with variable amounts detected at various locations in the kennel. The current was not constant with transients (spikes) frequently detected. Similar problems were evident in Van Buren County, at a recently constructed kennel, about 15 miles south of the kennel in Allegan County. Shortly after moving to the property, health problems, not previously experienced by the breeder, began cropping up in the dogs. Experts from the power company, the PSC, and two independent consultants have taken a variety of measurements on the property. The numerous tests have confirmed the presence of stray voltage (AC and DC), with periodic voltage spikes, as well as electromagnetic fields and electric fields. None of the extensive tests have proven the property owner to be at fault. To date no litters have been produced in any of the dogs kept on the property. Bone and muscle problems continue to arise, particularly in young dogs. Occasionally interdigital cysts appear and then heal spontaneously. Deaths appearing to be due to electrocution still occur. The dearth of references on stray voltage in the toxicology literature led to this review. The relationship of such currents to the problems found on dairy farms, as well as the two dog kennels, is discussed.

One does not need to be a toxicologist to recognize that there is much concern in the world today about environmental pollutants. The media regularly informs us of the risks and the resultant reaction of special interest groups, governmental regulatory agencies and concerned citizens. We presume and trust that, in our best interests, appropriate action will be taken in such matters in a timely fashion. Although it is unlikely that serious problems will be ignored altogether, often, to our dismay, corrective measures take time. Thus, to us, it is surprising that a major pollutant, **stray voltage,** known to be present for decades now, has been ignored by, not only the appropriate authoritative agencies, but toxicologists in general. As a result, in spite of the fact that public health and safety appear major concerns in our society, one would be hard pressed to find a local or federal agency willing to accept responsibility in the area involving the methods used in the distribution of electricity.

Because of the lack of effective action in this area, in face of solid evidence that stray voltage continues to cause harmful effects in several species of domestic animals, or animals used for agricultural purposes and possibly humans as well, the authors have joined in an effort to bring this subject to the attention of the toxicology community. We do so fully aware of the reluctance of governmental agencies, utilities and academic institutions to admit stray voltage exists to any great extent and to investigate and resolve the problem. Much of such reluctance may come from the lack of cross-expertise and diversity in disciplines such as physics, physiology and electrical engineering. Thus, it took the combined efforts of a biochemical pharmacologist, a veterinary pathologist and an electrical engineer to put this position paper together. We learned a lot in the process, some of which came as a surprise. We have made every effort to describe the problems associated with stray voltage and to review the area in some detail. However, we feel we are not in a position to study this issue. Such an effort will require the interaction of individuals and agencies with appropriate backgrounds and resources if we hope to ever come to a better understanding of the role of electrical energy on and in mammalian homeostasis.

BACKGROUND ON THE ALLEGAN DOG KENNEL

Ten years ago, after 3 y of investigations under trying field conditions, attempts to determine the cause(s) of reproductive and developmental problems at a dog kennel in Allegan County, Michigan, were suspended. This kennel had lost more than 120 litters of Shetland Sheepdogs (Shelties) over the preceding 12 y; many of the puppies that died were deformed as were several that survived. Similar effects occurred in Persian cats, although on a much smaller scale, and later in German Shepherds and Golden Retrievers. Such problems began after drilling a deeper water well and the building of a new kennel of concrete and metal fencing in 1969. Prior to that the kennel owner had successfully bred and raised at least 15 litters/y of mostly shelties in an old wooden chicken coop. In contrast to the new kennel, which has an oil burning furnace, a kitchen area, indoor plumbing, a hot water heater, overhead fluorescent lights and a water evaporating air conditioner, the old kennel had minimal lighting, an oil fueled space heater and no indoor plumbing. Reproductive and developmental problems were virtually absent between 1953 and 1969.

In an effort to address the problems occurring in the Allegan kennel, several interested and concerned citizens (including several scientists) formed the Allegan Study Group. As the result, several investigations were carried out in the early 1980's. For example, in a carefully controlled two-year reproduction study, 24 Shetland Sheepdogs (4 males and 20 females, all of which had good reproductive histories) were brought into the kennel from many sources throughout the northeast. Within six months the reproductive performances of these dogs were comparable to those of the dogs kept regularly at this kennel, regardless of what dog food they ate or the source of the water they drank [1]. Fluoride was included as a variable in this study, as dog food containing rock phosphate contaminated with sodium fluoride had caused exostoses and mottled teeth in some of the dogs in the kennel [2]. However, it did not matter whether or not the dogs received fluoride in their diets. Attempts to duplicate the reproductive problems in rats, housed in metal cages and racks (with rubber wheels) in this kennel, were unsuccessful even though 100% of the rats receiving fluoride in the dog food they were fed experienced teeth problems as compared to a complete lack of such effects in the rats that were not given fluoride in their chow [3].

In the early 1980's, reproductive performance at this kennel came to a virtual standstill as the females (cats, as well as dogs) either stopped cycling or experienced difficulties resulting in disruptions in their cycles that precluded conception. Sperm counts in the males also fell dramatically. During this period contacts were made with experts in academia, government and industry in an effort to obtain insight as to what was going on at this kennel. Such consultations did lead us to check out various possibilities, but all attempts to further elucidate what was going on were unsuccessful. It was concluded that no toxic substance known could be introduced into that kennel and result in a virtual cessation in reproduction without causing marked signs of toxicity in the animals. Although health problems and unusual behavior in the dogs were observed in this kennel, consistent clinical signs were not evident. The fact that bitches could be shipped to other locations and with time produce viable litters indicated that we were dealing with a localized environmental problem. Even so, the effect did not appear to be seasonal and it didn't seem to matter whether the dogs were kept in the kennel or house, or whether or not they were ever allowed to exercise in the fenced in yard (dirt, vegetation) or only in their outside dog runs (cement). Since three breeds of dogs, as well as Persian cats, were affected, genetic factors were unlikely. The only apparent variable we knew of at the time that we couldn't control was the air. However, we didn't have the expertise or equipment to monitor the air. Having run out of ideas, along with time restraints (the members were all volunteers, for the most part participating in this project in their spare time), the Allegan Study Group suspended formal study at this kennel in 1984.

Health problems in the kennel owner prevented her from breeding dogs in the late 1980's. She gradually resumed a more regular breeding schedule in 1989, initially with some success. However, in 1992 reproductive problems returned. Female dogs ceased cycling or had abnormal "unbreedable" seasons. Sperm checks revealed a lack of sperm in four males (two Shelties and a Golden Retriever; all proven studs, 2½, 6 and 10 years old, respectively, as well as a 10½ month old German Shepherd). Concurrently, neither the Persian nor mongrel female cats in the kennel showed signs of cycling. Other clinical signs, recently observed in the dogs in this kennel, included virtually complete loss of hair in three dogs, with another three dogs having lost the hair on their tails in the last few months. Four dogs, including two (a greyhound and a Springer Spaniel) that were temporarily boarded at the kennel, died or were sacrificed in extremis with bloat; another, a female German Shepherd, with bloat was saved after extensive surgery (one foot of intestine was removed, along with the spleen). The dogs experienced gastric torsion (similar problems have been reported in cows exposed to stray voltage); the twisted stomach would not allow food or resultant gases to pass into the intestine. In a related area, several litters were lost in the 1980's as the pyloric valves of the puppies appeared to be paralyzed and milk would not pass into the intestine. The puppies screamed and died in apparent pain, in spite of heroic efforts to keep them alive. Very often bitches did not have milk and/or would not nurse (similar effects are common in cows who often will not "drop their milk"). More recently, nasal deformities in adult dogs (4 Shelties and a Golden Retriever) have occurred. The nose curves upward (concave) and the teeth become loose and fall out. Histopathological examination of one of these dogs revealed that a fibrosarcoma had replaced much of the bone in the nose. The heads of two other dogs, both less than two years old, tip sideways as the dogs can not hold them up. Several other dogs in this kennel have developed cancer, at an age far younger than those who have gotten cancer in past years. In addition, several apparently healthy dogs, including two in the past year, have been found dead after being seen shortly beforehand to be in apparent good health.

In the spring of 1992, the kennel owner contacted the Study Director of the

Allegan Study Group (T.A. Marks), the team that had investigated her problems ten years previously. Still at a loss as to what caused the problems at this kennel, but willing to track down any possible lead, the decision was made to contact two dairy farmers in Allegan County who reportedly had similar health, reproductive and management concerns, along with other problems in cows.

Tests performed at the two dairy farms had revealed the presence of what has commonly been termed stray voltage, but also has been called neutral to earth voltage (NEV), tingle voltage, extraneous voltage, transient voltage and metal structure-to-earth voltage [4]. The two farmers agreed to bring equipment, capable of measuring alternating current (AC), direct current (DC) and EMF's (electromagnetic fields), to the kennel. Such tests revealed the presence of AC and DC currents on the premises, which were later confirmed by a Staff Engineer expert (W.O. English) of the Michigan Public Service Commission [5]. Such current was detected even when the electrical power to the premises was shut off. For example, 2.45 volts AC and -0.150 volts DC were detected at the well head with variable amounts detected at various locations in the kennel. The current was not constant with transients (spikes) frequently detected.

BACKGROUND ON GOBLES DOG KENNEL

At this time, similar problems were evident in Van Buren County, at a recently constructed kennel, about 15 miles south of the kennel in Allegan County. This kennel was built on the property of C.C. Ratke, a veterinary pathologist and dog breeder with a 18 year history of successfully breeding dogs at other locations.

Shortly after moving to the property, health problems, not previously experienced by the breeder, began cropping up in the dogs [6]. Included in these problems were foot problems - interdigital cysts, which would not heal despite treatment. Anecdotal reports from dairy farmers experiencing problems with stray voltage indicated similar foot problems in their cattle. There was a high incidence of urinary tract infections. This was thought to be a consequence of decreased water consumption. The dogs probably were reluctant to drink if they experienced shocks when they attempted to drink from their metal water buckets which were attached to the chain link kennel fencing. Behavioral problems were noted in the dogs. They were reluctant to enter the kennel building. The dogs would also stand over their full food dishes appearing hungry, but they seemed unwilling to touch their food. All these strange behaviors might have also been caused by shocks. The dogs could have experienced shocks when they entered or left the kennel as well as when they attempted to eat from their metal food dishes. Puppies and young dogs raised on the property have had a high incidence of bone problems and other lameness with no apparent underlying cause. Muscle pain resembling cramping has occurred in several adult dogs without any preceding injury or activity that might explain the soreness. Reproductive problems have been extensive and include irregular cycles in the females, failure to conceive, and abortion. These problems have occurred in dogs that, at their previous location, had normal cycles and had produced litters. The only litter produced since the move to the current location was from a female who was sent off the property for most of her gestation. To add to these other problems, at least 5 unrelated dogs have died suddenly from what appeared to be electrocution.

Experts from the power company, the Michigan Public Service Commission, as well as two independent consultants have taken a variety of measurements on the property. The numerous tests have confirmed the presence of stray voltage (AC and DC), with periodic voltage spikes, as well as electromagnetic fields and electric fields [7]. None of the extensive tests have proven the property owner to be at fault. A 4 volt reading on the house was discovered to be due in part to faulty connections and grounding by the cable TV and telephone companies. The lines from these sources were bringing electrical currents from their common grounds back to the house.

Much time, money, and energy was spent on the part of the kennel owner in an effort to protect the animals at the site, according to the recommendations of both the power company and the Public Service Commission Staff, but little was done on the part of any of the utility companies to correct the underlying problem. The telephone company reluctantly changed their grounding at the house, but it still is not in accordance with the Public Service Commission's Staff recommendation. The power company isolated the transformer. Shortly after that the interdigital cysts, without further medical treatment, cleared up spontaneously in several dogs who had been suffering chronically from them; however, at least one dog who was a champion show dog has been left with unsightly permanent scars. The high incidence of urinary tract infections and the described behavioral abnormalities ceased after the owner "ultra" grounded the kennel according to the Public Service Commission Staff expert and power company recommendations. This involved interconnecting all the metal fence panels of the kennel both inside and out, then further connecting these to 4 ground rods at each of the four corners of the kennel and then ultimately to a common ground rod approximately 150 feet away from the kennel. This measure protects, only to a limited extent, the dogs while they are in the kennel, and does nothing for them outside of these confines on the property.

It is obvious that the problem is still there, based upon the electrical evaluations performed after the corrective measures were employed. There are indications that problems associated with stray voltage still exist in the dogs. To date no litters have been produced in any of the dogs kept on the property. This represents nearly 5 years of lost breeding potential. Bone and muscle problems continue to arise, particularly in young dogs being raised on the property. Occasionally interdigital cysts appear and then heal spontaneously. Deaths appearing to be due to electrocution still occur. With much of her finances tied up in the property, which now is essentially worthless due to the electrical "pollution", even leaving the site is no simple task. This leaves the owner feeling helpless, extremely frustrated and in a constant state of worry over the health and safety of her animals together with the thought that if the animals are being so affected, what about the potential dangers for humans on the property?

BACKGROUND ON STRAY VOLTAGE

The dearth of references on stray voltage in toxicology literature is surprising considering the extensive information in agricultural journals going back more than 40 years. For example, current from electrical equipment in the milking area was implicated in 1948 by an Australian researcher as the cause of problems in cows [8]. Similar conclusions were reached in New Zealand in 1962 [9] while Craine et al [10, 11] first reported stray voltage in the USA (Washington) in

1969 with similar reports coming out of Canada in 1975 [12]. Since then, stray voltage problems have continuously been reported in the United States and Canada with estimates as early as 1980 that 20% of all milking parlor operations were so affected [13, 14]. It has been concluded that 80% of Ontario, Canada dairy farms had voltages on the electrical neutral sufficiently high to be a potential problem with 29%-36% of these farms having a voltage drop between cow contact surfaces sufficient to be of concern [4]. Although the electrical makeup on the farms is responsible for some of the stray voltage problems, it has been estimated that off-farm sources may be involved in approximately two-thirds of all problem farms, and one communication reported that the principal sources of stray voltage in the Ontario farms surveyed were attributable to the neutral resistance of the distribution system and only 5% to on-farm sources [4].

INDICATIONS OF STRAY VOLTAGE ON DAIRY FARMS

Although signs of stray voltage problems in cows may vary from farm to farm, the following list includes most of the problems cited [4]:

1) intermittent periods of poor production,
2) unexplained poor production,
3) increased incidence of mastitis,
4) elevated somatic cell counts,
5) increased milking times,
6) incomplete milk letdown,
7) extreme nervousness while in the milking parlor,
8) reluctance to enter the milking parlor,
9) rapid exit from the parlor,

10) reluctance to use water bowls or metallic feeders,

11) altered consummatory behavior ("lapping" of water from the watering device."

12) breeding problems

13) inflamed feet at the hoof line

14) unexplained tumors

15) ineffectual medical treatment

16) apparent reduction in the immune response [15]

Efforts toward solving stray voltage problems in dairy cattle have led to several symposia and a rather extensive series of publications. Unfortunately most of the citations have been published in sources that are not routinely monitored by toxicologists [e.g., 16-19], although more easily attainable articles have been published [e.g., 20-24]. Thus, there is ample evidence that stray voltage is a problem on dairy farms, especially in the major dairy farm states (e.g., Minnesota, Wisconsin, Indiana, Ohio and Michigan). Several of these states have high water tables and numerous inland lakes, as well as the Great Lakes. However, the problems are not limited to dairy farms as farms that raise pigs and/or horses have had similar problems. Any situation where liquids are present on the floor or ground, in the proximity of electrical service, is a candidate for stray voltage problems.

APPLICABLE BACKGROUND ON ELECTRICITY

To better understand the problems associated with stray voltage, it is important that certain facts about the distribution of electricity be addressed, some of which may come as a surprise to biological scientists. It is common knowledge that for electrical current to flow, power lines are necessary. It is also generally understood that these lines must be unbroken in order for the electricity to be utilized. However, it is now realized that much of the electrical current that leaves the power plant does not return via an electrical line (i.e. the neutral line), but rather secondary conduits [25]. Estimates of how much current returns via secondary circuits have been stated as at least one-third [26] to 65% or more [27, 28]. Thus, the most significant common denominator to stray voltage is using the earth as a secondary conduit or neutral [5].

Most electrical circuits throughout the world are repeatedly grounded. For example, homes are routinely grounded to the cold water pipe, which means that returned ground current has direct access to drinking water sources. Thus, the neutral wire and the earth, with all the conductive objects buried therein, work in conjunction as an earth grounded network for return current. However, the earth cannot be viewed as a bottomless pit wherein energy can be dumped with the thought that such energy will simply disappear or be absorbed like liquid into a sponge. Energy is either converted to work, stored in an exchange loop between reactive components, radiated or emitted into the atmosphere or environment, or returned to its point of origin. Much of the world's electric current is continuously flowing either deeper in the earth or near the surface, taking paths of least resistance back to electrical distribution centers and power plants. Readily available paths of least resistance paralleling the neutral return conductor include metallic pipelines [26], underground and above ground water sources, fences, railroad tracks, etc. [5]. In fact, electrical companies have purposely used rivers as secondary neutrals in order to easily disseminate not only lighting but man made ground currents. It is these grounded currents, regardless of the source, that most likely are responsible for the problems found on dairy farms outlined above. When such currents enter a barn or kennel, through for example the well water, and then pass into cement floors reinforced with metal rods, etc., a potentially dangerous situation exists. In such a setting, should some animal or human come in contact with a conductor charged with sufficient current, then simultaneously touch a second conductor of lower potential, that living being then becomes the path of least resistance between these two conductors. Several things can happen, depending on the sustainable current (voltage) and the resistance inherent in that animal and its contact resistance. The lower the resistance, the higher the current (Ohms law).

BEHAVIORAL PROBLEMS IN DOGS

One of the features common to the two dairy farms in Allegan County and the two kennels described here, is the sudden demise of apparently young, healthy animals. Without any outward appearance of ill health, animals have been found dead within an hour of being observed as normal. Peculiar behavior, which made little sense before we became aware of stray voltage, often was observed in kennel animals over the years. For example, some dogs would refuse to come back into the kennel from their run, even when food was placed inside in a dish. Often they would approach the opening to the building in a cautious manner and sort of test the small opening, apparently for some inconspicuous danger. One dog (Golden Retriever), recently brought to the Allegan kennel, had had a good appetite and was overweight. However, soon after its arrival, this dog refused to eat out of a metal dish, although it would gulp down treats. When this dog was switched to a plastic dish, his appetite returned, after an initial apprehensiveness about eating out of this dish. Similarly, in some runs, the dogs refused to drink water out of metal pails and apparently survived by drinking out of puddles. We have measured alternating and direct currents on dog dishes, and on the metal fences along the runs. On at least one occasion several dogs suddenly refused to cross through a puddle of water between the outside yard and the house where formerly they eagerly travelled at feeding time.

ALLEGAN DOG KENNEL ENVIRONMENT

The Allegan kennel is located in a rural setting, adjacent to the Allegan State Forest and Lake Allegan (part of the Kalamazoo River). There is a hydroelectric plant less than three miles due west of the kennel and an electrical power substation, one mile east. The Palisades nuclear power station is located on Lake Michigan less than 25 miles southeast. There are some things at the dog kennels that seem more peculiar by their absence. For example, in spite of dog food being stockpiled in the Allegan kennel, evidence of vermin are rarely seen. Not only are animals such as mice and rats not seen, rodent droppings were not found, even with a thorough search, e.g., under pallets (where bags of dog food were stacked) that hadn't been moved in years, as well as other locations in the kennel. Mosquitoes are not a problem in spite of the presence of marshes on the property. The Gobles, Michigan dog kennel owner also does not have a mosquito problem, although a pond is located within 50 yards of the house and kennel. In addition, at the Allegan dog kennel, frogs no longer dwell there although years ago the kennel owner remembers guests being kept awake during summer nights by the noise generated by the spring peepers. As has been reported to us by dairy farmers plagued by stray voltage, the kennel, house and nearby property have frequently been hit by lightning strikes. Such strikes have burned out multiple electrical items including telephones and over the years three electric water heaters (two in the kennel). Interference on the phone is also a persistent problem.

The most common element associating all of the experiences above is the bonding of the primary neutral to secondary service neutrals, water lines, telephone cables, gas lines and TV cables. Power companies and communication companies have been encouraged (by codes) to common bond their equipment to reduce electric shock by allowing more paths for the dispersing of electric currents into the earth. Codes have also dictated that equipment should be grounded back to the electric neutral, preferably by a fourth ground wire. This has created the situation where a lightning strike or fault to the ground on the electric utility primary follows that ground back through the connection to the secondary service neutral, then on to customers equipment destroying it. It also allows for any disturbance on the electric primary neutral system, for any reason, to be experienced by the customer in the vicinity of the disturbance. Any deep earth currents can thus flow through wells and use the electric neutral for a return path. The whole situation is linked to using the earth as part of the electric circuit and interconnecting the primary and secondary neutrals.

PROBLEMS IN HUMANS ASSOCIATED WITH STRAY VOLTAGE

We scientists generally dismiss undocumented information as anecdotal; somehow anything that isn't obtained in a laboratory setting, under carefully controlled conditions, is not worthy of being taken very seriously. However, after years of checking out such input, there is no question in our minds that something is present at these locations that has detrimentally affected the habitats, making normal living difficult. Other educated people have visited these kennels and dairy farms and come away highly concerned about the health of the inhabitants. Farmers with stray voltage problems have reported to us that they and members of their families have experienced severe physical trauma on their farms including the near electrocution of one son while taking a bath, with another son of the same farmer suffering severe contractions while moving a wire lead around the farm during a "pie signature test" using the well as the center point. The creatine kinase (CK or CPK) levels of residents at this dairy farm have been measured in the thousands (norm is less than 200 units/L); CK is an indication of muscle damage and a prognostic indicator of electrical injury [29, 30].

ESTABLISHED EFFECTS OF ELECTRICITY ON HUMANS

One of the biggest problems to overcome in dealing with stray voltage is the lack of knowledge about the physiological effects of electricity among biological scientists including physicians and other health care providers. Although humans are very sensitive to very small currents because of their highly developed nervous systems [31], it is often difficult to prove whether a human or animal has been electrocuted. Death from electrocution can occur with no marks on the body [32]. Death at nominal voltages, such as the 120 to 240 volts often used for secondary service systems, can be attributed to one of three causes: (1) ventricular fibrillation (most common), (2) respiratory arrest, (3) asphyxia. Ventricular fibrillation leaves no characteristic evidence for the pathologist after death [32].

Also, the victim may have time after being electrocuted to move away from the source of current, or the current may no longer be present, or the dangerous circumstances may have occurred only temporarily and thus no longer exist at that site. Another complicating factor, making it difficult to determine that electrocution is the cause of death, is the fact that ventricular fibrillation is often the terminal condition in death from natural or other accidental causes. Someone found dead may have died of electrocution, but heart failure will most likely be the cause of death listed, unless burns are present or other evidence makes electrocution the obvious cause.

Currents too feeble to be perceived on the sensitive fingers may produce electrocution if they flow in the immediate vicinity of the human heart [33]. Admittedly this circumstance may be unlikely outside a hospital, but in more common surroundings, a current of approximately 150 mA for one second can cause ventricular fibrillation [32]. Ventricular fibrillation is life threatening since the only real relief requires the use of a defibrillator. It has long been recognized that deaths can occur from casual contact involving electric currents deemed to be safe for less susceptible individuals. Thus, "for such susceptible persons it is possible that contact with any electric circuit, which permits currents in excess of the threshold of sensation, might result in a fatality" [31].

STRAY VOLTAGE AS AN ENVIRONMENTAL POLLUTANT

It is incomprehensible that a society that is so concerned about parts per billion concentrations of chemicals, most of which have never been proven to cause fatal effects in humans [34], can simultaneously ignore the overwhelming evidence that stray voltage is having a major impact on animal health, and potentially could be a major human health hazard. Dairy, pig and horse farms, and dog kennels may be just the tip of the iceberg. The time is long overdue to view stray voltage as an environmental pollutant with far greater potential for affecting human health and the quality of life than any chemical contaminant known. The major difference is that unlike chemicals, which can be detected after the event (sometimes decades later), electrical/EMF pollution can be turned off instantly by the flick of a switch leaving only forensic evidence of its previous presence [35]. The fact that neutral currents have been shown to flow through gas pipelines at levels sufficient to explode methane, should volatile air:methane concentrations occur [26], is also reason for concern. Since underground currents are known to corrode gas pipelines and since gas is often under pressure in such pipelines, the potential for an explosion is very real.

TYPES OF ENERGY THAT CONTRIBUTE TO STRAY VOLTAGE

In any scientific investigation it is important that variables be kept to a minimum. However, studies involving environmental exposure to stray voltage are very difficult because of the inconsistencies, and the vastness of the systems involved. Stray voltages are far from constant (steady state) with transients and variations occurring randomly. Levels vary within a location as the electric system loads vary with the current following paths of least resistance. Higher currents occur near entry paths, such as wells, overhead and underground lines (including telephone and cable TV lines), metal pipes (gas as well as water lines), etc. To further complicate matters, DC currents and electromagnetic fields are involved in the overall effect [36]. On site, as well as off site sources, contribute to the effects.

On site sources include, or are the result of, unbalanced use of the service, bad wiring, faulty and/or deteriorated equipment, long inadequately sized wire runs, bad connections, improper use of the neutral, and using the earth as a path for return currents [5]. Ironically, off site sources develop for the same reasons. However, on site sources are easily located and remedied by the process of elimination involving finite possibilities. Off site remedial measures involve much more complex solutions because of the nearly unlimited possibilities and the involvement of numerous personalities and the expanse of the utility systems involved. Many times when a problem appears to be resolved changing factors can introduce more complex and confounding situations that cause the problem to reappear. Making the problem even more complex is the fact that little is known about how stray voltage and animal physiology interact under all circumstances. No subtle or long term effects have been studied as to how electric currents interact with living cells, outside of the short-term shock hazard situations reported by Dalziel [31, 33].

Stray voltage manifests itself as alternating and/or direct currents, by inductive or capacitive coupling, and/or conduction. Inductive coupling is accomplished by transferring energy using electromagnetic waves or fields that couple energy on to and/or through a conductive body. Capacitive coupling is the transfer of energy by varying the electric field and electric charge relative to two conductive bodies separated by a dielectric substance. Conduction is accomplished by using the molecular lattice of free electrons in a body or material as a path in which currents travel either directly, indirectly, passively or actively as an electric charge displacement. Where stray voltage exists, conduction is of primary concern with induction and capacitive coupling usually having a lesser role. Mediums of conduction include earth grounds, electric cable, telephone cable, TV cable, gas pipe, sewer pipe, building materials (e.g., reinforcement rods, metal support frames, concrete, metal siding, metal roofing, foil back insulation, metal conduits), metal equipment grounded or touching earth (e.g. vehicles, harvesters, plows, fences), live tree and shrubbery, wet wood products and products saturated with conductive solutes, solutions containing electrolytes, capacitive bodies, animal tissue, bodies of water, chemicals, gases, etc.

When AC and DC voltages appear simultaneously on the network, the response of the common network to their presence is governed by the superposition principle. This means that the effects are additive, not independent [37]. Situations involving different metals and electrolytes in the earth can cause AC to be rectified to DC with some of the AC riding through as ripple. The earth conducts DC voltages, both man-made and natural in origin. Some of the natural origins are electrokinetic processes, static charge migration, piezoelectric and quasi DC phenomena [5]. Man-made DC voltages originate from the transfer of energy by DC power lines, telephone and cable TV systems, DC operated equipment such as railroad signaling, cathodic protection of buried metals or submerged equipment, AC power line control equipment, and processes of manufacturing.

No one can verify the path of all neutral currents. The common ground arrangement is, to that extent, uncontrollable. The paths of conductivity are left to nature to determine. It is assumed and intended that the currents will follow the path expected (i.e., the neutral return conductor) but, there is no guarantee that things will happen the way expected. For example, in the Allegan kennel the well appears to be the source for ground currents that are dispersed through the complex before being able to return onto the neutral conductor [5]. The neutral may be the attracting medium for the earth currents, which then might travel up the well to the utility primary neutral network. This could explain the surges of over 3 volts measured on the well and the surges on the cages, when no power was being used on the site. Some devises, used by some utilities to separate the primary and secondary neutrals on a grounded "Y" network, do not provide absolute separation and thus are capable of passing currents under certain conditions.

ELECTROMAGNETIC FIELDS

No attempt has been made here to separate EMF's from other aspects of stray voltage since it is believed such fields play a role in the overall effects of these forces on living animals making sorting very difficult. Unfortunately the literature tends to concentrate on EMF effects on health while ignoring ground currents. We feel this is a major error, which could, at least partially, explain the inconsistent results obtained thus far, especially in cancer studies that studied the role of EMF's in cancer incidences. Rather than attempt to review the extensive literature on EMF's here, interested readers are referred to recent reviews on this subject [36, 38-42]. The complex nature of studying the effects of EMF's on human health are evident and involve an exposure pattern of intensities, durations, wave shapes and frequencies that have yet to be elucidated [36]. Adding the other aspects of stray voltage into a study can only raise the level of complexity even more. Clearly such studies will be costly. However, the appearance of clearly identifiable and quantitative effects on dairy farms could greatly simplify the problem.

There are additional confounders to studies on EMF's and cancer, which have not been mentioned in any of the literature, that relate to the variations in duplicate studies and even in the base study. Nothing has been mentioned about the orientation of the resultant magnetic field to the residences involved or the subjects as they are oriented during sleep. Usually the fields rotate about the wire as they travel along it. Nothing is mentioned in published studies on the rotational aspect of the fields. There also is no mention on how the distribution lines are oriented to the domicile or how other current conductive mediums, such as buried cable, water lines, sewer lines and gas lines, which are not as obvious as the overhead lines, are oriented to the homes or how much current they carry. Another common oversight is the orientation of the electric meter, fastened on the side of the house, to bed headboards and places of frequent use. In addition, no mention is made of the type of distribution service, whether looped, secondary/single feed primary, looped secondary/looped primary, looped primary/radial secondary or radial primary-radial secondary. The type of service can make a difference on the amount of current on the common neutral verses the amount of current traveling on the water pipes and other conductors going through homes. There appears no mention of how much static electricity each residence has and how that may be confounding the study outcome. The studies published thus far do not appear refined enough to come to a conclusion other than something is happening. The subtle variables must be addressed - some of which create stray voltage.

DAIRY FARMS AS PROGNOSTAGATORS

Milk production and somatic cell counts (indication of mastitis) are routinely monitored by dairy farmers and companies that purchase their milk. Since milk production falls and somatic cell counts frequently rise in the presence of stray voltage on dairy farms [4], residents of dairy farms with stray voltage problems can readily be identified and compared with residents of dairy farms without such problems. The role of stray voltage in milk production has been thoroughly documented. Even the electrical companies accept the association, although they tend to dismiss it as being the primary result of on site misuse of electricity. There is ample anecdotal information on human health problems on farms with stray voltage. Whether or not problems such as cancer, infertility, and miscarriages can be traced to stray voltage await the results of appropriate investigations. Clearly, physical, as well as mental, trauma, associated with exposure to stray voltage, is evident on these farms. Its only a question of time before such effects can be thoroughly documented.

Whether or not one believes that stray voltage is a human health hazard, one can use similar methodology to test (i.e., prove or disprove) either belief (hypothesis). The fact that health officials at all levels (local, state and federal) have failed to take this potential problem seriously fly's in the face of the overwhelming evidence that stray voltage continuously has an effect on farm and other domestic animals. If one doesn't believe the farmers one should at least talk to the veterinarians and electricians who have attempted to deal with the effects and causes of stray voltage. Talking with such people, has made us wonder why this problem has not been thoroughly investigated by agencies responsible for public safety and having the mandate to monitor the potential effects of environmental factors on human health.

SOLVING THE PROBLEMS

The extent of perceived control tends to play an important role on the level of concern that people have about risk factors and perceived risk [43]. For example, driving a car is clearly risky but we generally feel we are in control and that governmental standards are being enforced. Familiarity also plays a role as we tend to ignore the risks involved in things we do every day, especially if harm hasn't been experienced personally. Thus, it is not surprising that we accept the risks associated with electricity and have become confident that modern technology has eliminated much of the danger. It also is generally believed that the earth is a vast sink that can absorb all the current that we now, and in the foreseeable future, put into it. Thus, it may come as a surprise to most people that local grounds can serve as pathways to bring current out of the earth and back onto the vast utility neutral network [5], causing stray voltage to be a condition for using the earth as a return path, not a phenomenon beyond our control as indicated by Surbrook and Reese [25, 44].

One way to reduce or eliminate the problems associated with stray voltage is to eliminate or reduce ground neutral currents [26]. This option may be accomplished through lowering the electric system impedance on the neutral return conductor or by increasing voltage thereby reducing current (e.g., substituting 220 volt lines for 110 volt lines in electrical equipment). Even the power companies have suggested that this could be done by using larger wires, additional grounding or increasing voltage levels. However, the suggestion that more neutral return circuits be employed [26] seems most plausible but not necessarily a final solution,especially when maintenance of the electric system is lax. A solution could be accomplished by placing an isolated unearthed neutral return wire on the poles along with the present phase wires and the present earth grounded network. Obviously this would be expensive as the entire electrical network would require an additional wire as well as the changing of other pieces of equipment.

Other proposals to eliminating the problems associated with stray voltage have thus far not worked. For example, the proposal of Surbrook and Reese [44] doesn't cure all problems associated with such currents. Another proposed solution [45] relies heavily on the power companies doing good maintenance (e.g. ground rods must be well separated) and could increase problems if not done well. A viable option would be to not ground the neutral return line of a "Y" network to earth while at the same time increasing its size to reduce the losses. This method was originally used in providing electric service [46]. Another option would be to use ungrounded delta networks to the point of service. This requires no return neutral. Cost of safety components appears to have generally ruled out delta systems [37]. However, with today's technology and mass-production capability, along with the problem of neutral currents, it appears delta would have been the cheaper route.

USES OF ELECTRICITY IN MEDICINE

If it is true that low levels of stray voltage have profound effects on the immune response [15], development, and reproductive performance, as seems likely based on what we have observed in dogs and cats, as well as what others report in cows and other animals, then there clearly are many things that are poorly understood in this area. Our attempts to try to understand what is going on have led us to several interesting articles. For example, low-intensity direct current has been shown to affect sperm motility [47] and has actually been patented as a potential birth control device [48]. Weak electric currents have also been induced in bone with pulsing electromagnetic fields resulting in successful effects on ununited fractures and failed arthrodeses [49]. Also, transcutaneous electrical nerve stimulation has been used successfully to reduce pain in dentistry [50] and medicine [51]. In addition, pulses of relatively high voltage alternating current have been successfully utilized to treat patients with uninhibited overactive bladders [52]. The employment of electroshock treatment for depression is another well known use of electricity in medicine [53], while experimentally electric currents have been coupled with acupuncture, as well as being used to excite muscle in computer assisted walking for patients with paraplegia.

ELECTRICITY AND HOMEOSTASIS

Clearly electrical currents have an effect on the physiological makeup of living things. Considering the importance of electron transport in all aspects of cellular physiology and biochemistry, such effects are not surprising. Although the integration of physics and biology has not been an easy task, the chemistry of life has been shown to be based upon the underlying forces of electricity and magnetism [54]. For example, the probable role of free radicals in toxicology [55], including aging and cancer [56], is clearly electron mediated, further suggesting that bioelectroenergy has a major role in homeostasis. It has even been proposed that the body has biologically closed circuits, which comprise another circulatory system that switches on as the result of injury, infection or a tumor, or even the normal activity of body organs, with electric current coursing through arteries and veins and across capillary walls, drawing white blood cells and metabolic compounds into and out of surrounding tissues [57, 58]. Evidence has been obtained that local electrical currents and voltages control healing and it has been suggested that such phenomena may be part of a larger total-body DC system serving as a morphogenetic field [54]. Thus, it has been speculated that there may be a second nervous system, one that controls the most primitive functions and probably predates in evolution the nervous system with which we are so familiar. It has been further postulated that the perineural cells of the central nervous system generate DC electrical activity, with electrical potentials being passed along from one perineural cell to another. It is possible that the perineural-cell system, extending throughout the body in conjunction with nerves, functions as a primitive communication system [54]. It has been suggested further that such electrical circuits may be responsible for the seemingly inexplicable effects of acupuncture [54, 57], and, if present could be responsible for the effects resulting from electromagnetic forces and the other electrical components associated with stray voltage. In spite of the likely role of electrical currents in such phenomena, much of recent research in this area has focused on the effects of electromagnetic fields on cellular events [59-63]. Although EMF's and/or EF's are present wherever stray voltage exits, it makes no sense to us to ignore such currents altogether and focus entirely on the fields. For example, a recent attempt by a lay publication [64] to address electromagnetic forces clearly points out that current from one house can travel via the grounding wire and the underground water pipe to a neighbor's house. However, the current is then completely ignored while possible dangers associated with magnetic fields, are discussed. Thus, the fact that underground currents (stray voltage) can enter one's home via secondary grounds, and can be present on one's cold water pipes, and/or one's water even if plastic pipes are employed, is ignored while the presence of magnetic fields of low energy is proposed as a probable danger. Although stray voltage may not be a clear and present danger in such situations, one should not ignore the fact that EMF's are generated by such currents and contact with the water may have a greater potential for harm.

STRAY VOLTAGE AND HUMAN HEALTH

Attempts to associate illnesses such as cancer [36, 38], and reproductive and developmental toxicity [39] with electric and magnetic fields have failed to show consistent results. Although leukemia, especially acute myeloid leukemia, and brain tumors have been implicated in some studies that included electrical workers and/or proximity to sources of electricity [65, 66], clearly such studies are hampered by problems in measuring exposure, the ubiquity of exposure in the community, and a lack of understanding of other variables that probably are involved. These problems could be overcome to at least some extent by utilizing dairy farmers and other families living on sites shown to be experiencing consistent exposure to stray voltage. This would require that one also accept the premise that EMF's are not the only electrical components that have to be included as variables. Although AC and DC, as well as EMF's, probably play a role in the effects associated with stray voltage, this likelihood should not be a difficult problem as all three of these variables can be measured. However, these variables are hardly constant, and not all physiological indications of their presence are known. In fact, controlled research studies on the effects of such factors on dairy cows [67-70], most likely have been unsuccessful because constant currents have been used. Although exposure to EMF's at sites having stray voltage problems, AC and/or DC, may be constant, the levels of such exposures vary as intermittent spikes, sags, surges and load changes frequently occur. The fact that the female animals may be at various stages of gestation, or lactation, or in their estrous cycles further complicates such studies. Since electromagnetic energies contribute to the existing national electric transmission/distribution system such energies also cannot be ignored when studying stray voltage conditions as this radiated EMF energy from alternating and direct currents, along with the currents themselves, make up the components of stray voltage. Thus, EMF's and EF's from overhead AC power lines can induce electricity in solid metallic objects near them, such as a fence or metal siding. The resultant electric current in such objects can be expected to pass through any animal that touches that object while simultaneously touching a conductive object of lower potential including the earth or something connecting to the electric neutral ground.

Since a large fraction of the current on the neutral side of the system inadvertently ends up in the earth rather than the neutral conductor, it is probable that humans as well as animals may be at risk. Dog kennel owners and dairy farmers may be more visibly affected by stray voltage, thanks to the presence on such locations of large numbers of more sensitive and more susceptible four-legged animals. At the same time, since dairy cows are constantly monitored they also may provide us with readily available and/or easily measurable information. In addition, some dairy farmers may be more susceptible to human illnesses such as cancer, as it has been reported that farmers in general are at greater risk than the population as a whole for those cancers that may be increasing in incidence [71, 72]. Consistent with this premise is the recent proposal that cancer increases in farmers may result from some as-yet-unrecognized risk factor [73]. Thus, if it is true that the National Cancer Institute is planning a collaborative study with the Environmental Protection Agency that will enroll more than 100,000 farmers and their spouses [72], we recommend that the presence or absence of stray voltage be included as a variable. Since dairy farmers and dairy companies routinely monitor milk production and somatic cell counts (mastitis), and since declines in the former and increases in the latter have been associated with stray voltage, it shouldn't be that difficult to compare dairy farms experiencing stray voltage problems with those that do not have such problems. Certainly pesticide usage and other exposures should be included in any study involving farmers. However, just as looking up at high voltage wires may lead one to ignore what can't be seen (e.g. underground currents), the exclusion of stray voltage in such a study is inconsistent with what is happening on many farms. Wertheimer and Leper [74] for one looked beyond high voltage lines in their study that suggested that there was an association with electrical wiring configurations and childhood cancer. One should not lose sight of the fact that when distance from overhead high voltage lines are taken into consideration, the EMF's surrounding one's electric meter will be higher than those reaching the ground from overhead lines. Maybe the time has come to accept the proposal that our present priorities, in our efforts to understand the causes of cancer, haven't been consistent with the reality of the situation [75, 76]. Even the former administrator of the EPA, William K. Reilly, has seriously questioned the way governmental funds are allocated to control the incidences of cancer [77]. It probably will cost billions of dollars to upgrade our electrical distribution system (e.g. to exclusively use neutral return ground wires on the power poles instead of using the earth as a ground conductor). We could shift the funds from our monumental effort to clean up federal facilities such as Department of Energy Sites. This cleanup has been estimated to cost hundreds of billions of dollars, in spite of the negligible risks of such sites [77].

FOOD FOR THOUGHT

In science, one's prestige is often associated with the amount of grant funds awarded and/or the presence of modern laboratories and expensive modern equipment. In toxicology studies, every effort is made to keep animal rooms maintained in a way that will not allow environmental factors, such as temperature, humidity, and air quality to influence study results. Thus, it is not surprising that studies carried out by unpaid volunteers at nonlaboratory facilities, where it is next to impossible to control the environment, are infrequent. The fact that the inhabitants of locations with problems associated with stray voltage are business people trying to make a living, in spite of highly unusual occurrences and low profit margins, complicates matters even more. However, if one uses the same objectivity, and weighs the evidence as carefully as would be the case back at the laboratory, it shouldn't be that difficult to determine whether or not stray voltage is responsible for what is causing the problems at such locations.

As previously pointed out, even the power companies have concluded that they are responsible for most of the underground current [26, 28] and that the resultant stray voltage is interfering with milk production [17, 18]. Although improper or poor wiring and/or the presence of heavy electrical equipment on dairy farms may play a role on at least some affected farms, the dog kennels discussed here do not have such equipment and the wiring is consistent with what is found in most homes, i.e., there are outlets, simple lighting systems, etc., but nothing more electrically demanding than a gas or oil burning furnace. It has been found that disconnecting primary neutral grounds from secondary neutral grounds on dairy farms often has led to the significant reduction or elimination of the problems associated with stray voltage with such problems reoccurring when the grounds were reconnected [15]. However, as previously mentioned, efforts to completely reverse the problems, associated with stray voltage at the dog kennel in Gobles, MI by following the advice of the power company, The Michigan Public Service Commission Staff Engineer expert and expert electrical engineer consultants, were unsuccessful. Similarly, one of the dairy farmers mentioned in this manuscript was also unsuccessful in efforts to solve his problems by installing all new wiring, using 240 volt heavy motors and balancing the loads on his farm. The fact that significant stray voltage has been measured on these locations, even with the power to the fuse box shut off, suggests that there is a variable on these properties that is totally out of the control of the inhabitants. Similar problems have even been detected on at least one Mennonite farm that doesn't even have electrical services on the property [35].

If any industrial concern in the United States was placing any natural product or synthetic chemical into the environment in measurable quantities, such contamination of the environment would come under the scrutiny of local, state and federal regulatory agencies. This would especially be true if the environmental contaminant was documented as being lethal to humans at any concentration. However, in spite of the general awareness that under the right circumstances alternating current is lethal, one would be hard pressed to get a regulatory body at any level to address the matter of stray voltage as a potential factor in human health problems. Although intense pressure by dairy farmers has led to regulatory recognition of stray voltage in states such as Minnesota and Wisconsin [35], and to some extent in Michigan [78], virtually nothing has been done at the federal level, in spite of repeated requests for action. Simply reading reports on locations with stray voltage problems [35, 78] will provide one with ample information on the economic and health related difficulties presently widespread in the Great Lakes region of the United States. Although it may be that much of the reported information is anecdotal, there is no question that some environmental factor is influencing animal homeostasis, health and behavior at sites known to have stray voltage. If one simply concentrates on the reproductive problems in dogs at the two sites mentioned in this manuscript, it soon becomes apparent that the adverse effects are real and if stray voltage is not responsible, then some other factor is involved. The dog breeders really don't care what causes such problems, they simply want it to go away. The inhabitants of the properties reported here (dairy farmers, as well as the dog breeders) are hard working people, conditioned to adversity. They know their animals and clearly have a great deal of common sense. They have one other thing very much in common, fear. Thus, we invite anyone who isn't convinced to come out to one of the involved farms in Allegan County, Michigan for a visit. Bring your bathing suit; you can swim in an above-the-ground swimming pool. If you'd like, we'll run water from the well into the pool while you're swimming. However, don't be surprised if the farmer or his family do not join you for such a swim.

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