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STRAY VOLTAGE ASSESSMENT

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A serious problem attributed to stray voltage has existed at least on dairy farms throughout the world. There is a considerable body of literature attesting to this problem. The general symptoms include but are not limited to higher levels of mastitis. jumpy and irritable cows, uneven and slow milkout, breeding problems and lowered production. Farmers, dairy equipment suppliers, power suppliers, agricultural extension specialists, veterinarians, feed suppliers all recognize the problem. Experience on the farm attests to the noted symptoms under conditions of on-farm and off-farm AC faults, direct currents caused by cathodic protectors for manure tank and installation of farm electrical isolation devices. The problem is purported to be caused by alternating currents (AC) on the neutral-ground wire of the electrical supply system which can access the cows through a variety of paths. Consequently, researchers have concentrated their efforts on quantifying the AC shock effect on dairy cattle. They have passed short duration AC (2ma to 12ma) through various paths for relatively short period of time. The total aggregate time that current passed through the body was minutes. No experiments have been conducted that pass a continuous current through the cow. The most recent results have led to the conclusions that the shock effect caused by short duration AC up to 12ma does not directly cause the physical problems stated previously but can cause only behavioral problems. At the same time as these results were being reported, University extension people, power suppliers and electricians

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have been installing devices which were developed to limit the AC from accessing the dairy cattle. These devices are constructed and installed for the purpose of preventing the AC on the power suppliers' neutral from reaching the farm. An example is the isolation transformer. My experience from visiting sixty (60) dairy farms and in discussions with other farmers has led me to the conclusion that such devices have provided limited help for the cattle. In some cases, isolation considerably reduced the problem in the barn. In other cases, the reduction in symptoms is temporary. Within a few months or a year the problem returns at virtually the same level as before. In still other cases, the farmers have noticed essentially no change in the problems associated with their cows. One benefit of isolation which has consistently been noted is the elimination of the shock the farmer experienced when touching a bulk tank or the water cups.

A University recommendation for reducing stray voltage is the installation of the equipotential plane. My experience on farms with equipotential planes is too limited to determine its value. In the cases that I have seen, I feel its value is questionable as an effective method for solving the stray voltage problem.

The severity of the problem, the inability of the research to establish the cause-effect relationship and the inability of the corrective methodologies to eliminate the problem are pressing us to step back and take a new and broader look. Either: one, the methodology of research was poorly constructed

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so that the experimental conditions did not correspond to the conditions noted on the farm; or, two, other electrical energies are present in experimental areas which were not accounted for and which could skew the statistical results; or, three, the shock effect is not the primary cause of the stray voltage problem but other electrical energies such as continuous alternating and direct currents and fields are responsible for the effects. In order to define the alternative electrical energies possibly responsible for the problem, I would like to describe the work which I have been engaged in for the past 18 months.

EXPERIMENTS PERFORMED

In discussing the experiments I would emphasize that they are preliminary and need confirmation.

The first set of experiments to be described were conducted in a barn with an equipotential plane. Both AC and DC electrical sources were used in the experiments. A variable AC potential was applied between the equipotential plane and the ground rods external to the barn. Each time this experiment was performed, the cows demonstrated behavioral changes at times showing extreme reactions. It is important to point out that these cows were standing on the equipotential plane, in contact with nothing except the plane. In addition the cows required from 5-10 minutes from the time of application of the potential until they showed a reaction and the DC field directly above the equipotential plane showed significant changes.

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In the DC experiments, either a 12v battery or battery charger was used as the power source. Various connections were tried to ascertain any differences that could be produced. In some experiments the DC potential was applied from the equipotential plane on one side of the barn to the equipotential plane on the other side of the barn. The procedure caused a current flow through the concrete and/or earth from one plane to the other which would cause one to become more positive and the other more negative. In other cases, the DC potential was applied between the equipotential plane and a ground rod external to the barn. In both cases, the electric field mill verified the charge buildup and consequently the field changes consistent with the manner of application of the potential. Again, the cows showed behavioral changes. The changes indicated that there was a range of charge buildup which caused the greatest response and it was neither the highest nor the lowest. One unusual event was all of the cows standing on one equipotential plane stood at approximately a 45 degree angle to the normal stall direction. They were all leaning against the steel stall dividers which are welded to the equipotential plane. In all of these experiments two farmers assisted me and can testify to the results described.

An interesting bonus of these experiments was the manner in which the farmers were affected physically during the experimentation. Since we had to be on and off the equipotential plane to control the experiments and make measurements, we were exposed to the same changes that the cows were. Each of us noticed our

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bodies being affected but not necessarily the same. Some things that we individually noticed were strange sensations in the legs which made standing still difficult, headaches developing, loss of ccordination especially when bending down to make electrical connections--at times, it would be difficult to bring two wires together in order to connect them, feet suddenly becoming very warm, vision becoming blurred. Since we were busy observing, changing experimental conditions and measuring fields and potentials, we could not take time to correlate our sensations relative to the polarity of the field. Reversing the polarity of the field, however, clearly changed the sensations that we noticed.

From these experiments, I have concluded that changing either the AC or DC between the equipotential plane and grounding system produces observable behavioral changes in the cows and causes unusual sensations for the experimentors. The AC and DC potentials could not be quantified but the fact that the cows were on an equipotential plane would imply that the basic cause of the effects on the cows had to have been the change in the electric fields or the electric fields themselves. Everything that could possibly have been in contact with the cow should have been at the same potential as the floor on which they were standing. I would also emphasize that this farmer has had a stray voltage problem and was isolated. In addition, the farmer noted that when the equipotential plane was kept negative using a l2v battery, the cows milked out and responded better than normal for his barn. This favorable condition continued for

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only a few days, after which the cows returned to their normal. One might conclude that other electric forces exist which are far greater than the 12v battery which returns the ground and/or equipotential plane to its previous equilibrium state. After disconnecting the battery, it was noted that the DC potential between the equipotential plane and the barn neutral had risen to 1.5v from the normal of 0.4v. Weeks were required for that potential to return to normal. At the evening milking the farmer had the experience of temporarily losing his vision and his coordination as well as being dizzy throughout the time that he was in the barn. He had never had that experience in his barn before.

Experiments were performed in another barn that also has a significant stray voltage problem. These experiments were especially revealing of human responses but also indicated behavioral changes in cows. An experiment was set up in which the subjects were standing on steel plates which were in the stall area of the barn. An electrical circuit was set up by which either negative or positive charge could be added to the plates through the use of a 12v battery or a battery charger. The effects on people were more clearly differentiated than with cows but were conducted for only short periods of time so as not to add stress much different than was normally experienced in the barn. The results confirmed other experiments which had shown that the plates becoming more positive caused more severe reactions and more negative less severe reactions than normally experienced in the barn. The value of human

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response is significant in identifying effects on livestock because people can describe what they feel, whereas livestock can only respond through behavioral changes or physical problems. Inadvertently, some results were obtained which correlated increased AC induction fields with physical responses in cows. Qualitatively, specific physical problems correlated with increased AC induction fields. Additional work is being carried out to verify this relationship.

Experiments conducted in a third barn were more subjective because of difficulties in controlling electrical changes. A number of variations in electrical connections were made that revealed behavioral changes in the cows. The nature of these changes at least supported the contention that the cows are being affected by electricity which is accessing them in other ways than through the primary neutral AC. One change that was made also produced a significant improvement in milk let down and milking time. This improvement was short lived, however.

Long-term recordings of DC potentials and currents were made on two farms for the purpose of analyzing DC levels in the barn, understanding the DC circuits and correlating DC potentials to animal health. The recordings were especially beneficial in understanding the DC levels and circuits in the barn as well as physical parameters that caused change. The information gathered proved that the presence of the cows in the barn influenced the DC potentials, that the DC potentials in the barn were exactly inversely related to the primary neutral to ground DC potential, that there are continuous currents in the barn in the range 30-50 ma, the DC potentials vary by at least a factor of 2 over the

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period of months and increased soil moisture always increases potentials and currents. Recordings have revealed one correlation--although not perfect. The problems have some relationship with conductivity and the availability of DC.

Measurements during milking have indicated that DCs are involved in the discomfort of the cow and probably with milk letdown. Direct currents on the order of microamperes were present in the cow while being milked.

All experiments and measurements suggest that the physical effects in the cows are caused by electric fields and/or very small currents in the range of microamperes. These currents may be AC, DC or AC induction.

Experiments set up to prove the sources of the electric charge buildup which is responsible for the electric field provide only empirical evidence. Within a short period of time, a soil scientist, experienced in soil and ground electricity, will be assisting me in verifying some of the concepts discussed. General knowledge of the earth's basic structure and electrical energy use predicts a number of potential sources. The natural earth currents produced by the earth's rotation and variations in the earth's magnetic field affected by externally charged particles are a natural contributor which change with the physical state of the earth's interior structure and the density and movement of charged particles. The chemical nature of the earth materials and the additional chemicals added through human activities will contribute to DC potentials in the ground. Cathodic protection of underground pipe, electrical, and

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telephone lines and underground tanks will add DC potentials to the earth system. Return flow as part of the designed and inadvertent characteristics of the DC power lines also adds DC to the earth. Experiments which I have performed in the laboratory and in the field, as well as knowledge of the semiconducting nature of earth materials, support the contention that some portion of the large quantities of AC electrical energy in the earth is rectified to DC. Thus, the earth is a large sink of various forms of AC and DC energies which can potentially appear in many and diverse forms. Searching the literature reveals a lack of understanding of the magnitude, nature and manifestation of these electrical energies as they exist in the earth as well as how they might access and affect living systems.

GENERAL RESULTS FROM VISITATION

In addition to the experiments, I have visited and made measurements on 55 farms, 4 rural machine and repair shops and a number of businesses and residences located in numerous counties in Minnesota. The majority of farms had installed isolation devices, equipotential planes, or both. Management ranged from good to excellent on all of the farms. The farmers had attempted various feeding programs, supplements, and milking procedures to improve the dairy herd health and milk production. Some farmers had autopsies performed on cows that had developed physical problems which the farmers believed to be caused by stray voltage. In fact, the most satisfying experience has been witnessing the ingenuity of the farmer in attempting to deal with

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the problem.

AC and DC potentials and currents were measured with the traditional instruments including the VOM, VTVM, digital multimeter and osciloscope. DC fields were measured with the electric fieldmill. A variety of other instruments were also used to support the other readings. One problem that has not been resolved is the calibration of the fieldmill.

Alternating currents and potentials exist between various conducting components of the barn. The magnitudes vary according to electrical usage on the farm; isolation or no isolation; construction of the barn, including such properties as equipotential planes; and some unknown factors which have some relationship to electrical energy flow in the ground. AC is present as electromagnetic energy usually referred to as induction fields. They will induce currents in all conductors in the region of the fields and affect the livestock.

Studies of the AC in the ground revealed that there is no place--whether around the farm yard, in fields, or in pasture areas--where AC potentials and consequently currents do not exist. The earth has become a large sink of AC energy. Obviously, the higher the conductivity of material in the ground, the greater will be the currents. In addition, a study of the characteristics of the AC in the ground indicates a complex and skewed wave form which is continuously changing. At times, the basic 60Hz wave form is nearly masked out. Other higher frequencies, predominantly one MHz, are also present in the ground.

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Direct currents and DC potentials exist in the barns between various conducting components. Some of these electrical energies are caused by galvanic or battery action in and around the barn. Measurements indicate additional DC potentials which cannot be attributed to chemical reactions. These potentials have been identified as being the result of an electric field present in and around the barn. The DC field appears to be caused by a positive charge buildup near or at the surface of the ground. The magnitude and characteristics of the field vary and seem to be associated at least with water and concrete.

Preliminary measurements of magnetic fields have revealed no significant anomalies; but, some differences exist which will require further investigation.

At the same time that electrical parameters were being considered, it seemed useful to investigate the impacts of dietary supplements. Deficiencies and cravings that commonly were revealed were selenium, calcium and sugar based minerals. Those with greater experience than I (and a curiosity) may be able to develop this further.

The conditions present on the farms are--at least--the problems described in the literature. The problems which the farmers speak of first are the long milking time caused by an apparent inability of the cows to let down their milk; low milk production; high somatic cell count; outbreaks of mastitis, which seemed resistant to antibiotics; breeding problems; and behavioral problems, such as stomping continuously, kicking, fear and dislike of the milking machine, nervousness and refusal

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to enter the stall. Other problems that appeared to be related were difficulty in walking and getting up. Some farmers speak of their cows being unsteady as they leave the barn. Leg ulcers or sores, some of which will not heal, are very common. Eating habits are erratic. The cows at times will eat very well, whereas at other times they eat very little--refusing to clean the floor of the manger area. In some cases, the cows have difficulty maintaining an adequate weight, even though their milk production is not especially good. On nearly all these farms, the veterinarian costs are very high. A study of the DHIA records also show a very poor persistence in second and later lactation cows. They most often peak in production at freshening or shortly thereafter.

A sobering by-product of this investigation has been the realization of the direct physical effect on people, as well as the emotional drain on the farmers because their farm magazines implied that their main problem was poor management. Acute symptoms reported include, but not limited to, tingling feet (children speak of it as something tickling or pinching their feet--especially when barefoot), tired and aching legs, general fatigue after spending a few hours in the barn or shop, aching and swollen knees, dizziness, headaches, temporary loss of vision, disorientation, loss of depth perception, numbness in hands and feet. There may be chronic problems associated with the acute problems as well, but an assessment cannot be made within the time frame of this study. An interesting note is that, in general, the extensiveness of the human

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symptoms correlated with the seriousness of the livestock problem. I am not aware of a single farm that had stray voltage problems where there were not human health problems as well. As I visited with the various farm families, it became apparent that women are in general more sensitive to the effects in the barn than are men. Women were in general more observant. They often spoke of their hands and feet becoming numb. For example, one woman who put one hand on the back of the cow and the other hand on the steel stall divider noticed that both hands became numb. When she removed her hands, the feeling in them returned. She could experience this sensation with other cows but not with all cows in the barn. Other women expressed the fact that they have had similar experiences in the barn.

CONCLUSIONS

Experiments, discussions with farmers and other professional people, observations, measurements and study of the literature bring me to the following conclusions:

 The stray voltage research during the past number of years has considered only the shock effect on some types of livestock.

2. No university research has been reported which attempts to assess the potential effects of continuous alternating or direct currents through the livestock.

3. No university research has reported any work on measuring the potential effects from AC or DC fields or AC induction fields on livestock. 4. Research, in general, dealing with effects of small fields and low frequencies, small AC and DC, and AC induction currents is limited and not always conclusive. Sufficient research exists showing correlations of small fields to physical effects in living systems to warrant additional investigations. There is also some research that indicates that physical effects can be caused by specific magnitudes of fields--above which effects are less and below which no significant effects*appear. This is the so called "window effect". Therefore living systems could be very susceptible to very low levels of electricity and not as susceptible to higher levels.

5. No research that I can locate has been undertaken to systematically study the characteristics, the changes or the impact of electricity and electromagnetic fields placed in the earth as a result of human activities. Some impacts are recognized through empirical evidence but not through an understanding of the interaction with the entire earth electrical system.

6. The shock effect is ONLY ONE portion of the stray voltage problem.

7. Other electrical factors significantly contribute to the stray voltage problem. These include, but are not limited to, very small continuous alternating and direct currents through livestock; AC and DC fields which have the potential of changing the electrochemical system of the body; and, AC induction currents, all of which are affecting at least the central nervous system of the cow as she is either standing or lying in the barn.

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8. People are being affected in a similar manner to the livestock.

9. Region of the state, soil characteristics, ground and surface water condition and barn construction materials can impact the severity of the problem.

10. Since livestock, especially, are known to be sensitive to what is happening in the ground upon which they stand, it is most logical to take a good, long, hard look at the magnitudes and nature of electricity that reaches the livestock through the ground and how it might impact them.

11. Resolution of this problem can only be attained by admitting that there is something happening on dairy farms and possibly elsewhere which is causing significant physical impact, and through a spirit of cooperation and an eagerness to find the best solution.

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