COMMENTS

of the

Minnesota Department of Public Service

on

Stray Voltage Rulemaking

Docket No. E999/R-92-245

June 22, 1992

EXECUTIVE SUMMARY

In a notice issued April 27, 1992, the Commission solicited information or opinions on the subject of on-the-farm stray voltage from interested parties. This notice identified seven specific categories of issues for parties to consider in their comments.

The Department has divided its comments into a policy section and a technical section. The policy section is presented first and includes the issues of "Stray Voltage Definition," "Cost Issues Related to Investigation, Correction, And Damages," and "Tariff and Procedures Requirements," or categories I, V, and VII of the Commission's notice.

Below is a summary of the Department's stray-voltage policy recommendations:

- The traditional definition of stray voltage is inadequate. The Department defines stray voltage as "any out-of-place voltage or current within the animal environment, regardless of cause, source or magnitude." This definition is broader, places a greater emphasis on the presence of electric current in the animal environment, and makes no presumption about the source, cause or frequency of occurrence.

- Utilities should pay the entire cost of initial tests.

- The utility should pay the cost of isolation devices and other mitigation initiatives if problems on the utility system (off-farm) exceed a certain threshold. Farmers should bear most of the costs if problems on the utility system do not exceed this threshold.

- The Commission could offer its services as an arbitrator to the utility and farmer to determine whether stray voltage has caused economic losses, and if so, the amount of compensation to which the farmer is entitled. The process would be voluntary and both parties would have to agree to abide by the decision of the arbitrator.

- Utilities should establish low-interest loan pools to help farmers solve on-farm electrical problems.

- Utilities should expand their educational efforts by distributing handouts, holding seminars and funding a free stray-voltage hotline number. The regulatory agencies should help utilities with these efforts.

- There is no apparent need to revise utility tariff sheets at this time. However, regulated utilities may need to develop new tariff sheets to reflect whatever rules the Commission ultimately approves.

- Although utilities should recommend dairy process evaluations where appropriate, utilities should not fund these evaluations because farmers would probably not trust utility-initiated evaluations.

- The Commission should establish an appeals process to handle situations where the utility and farmer do not agree on the source or existence of stray voltage. The two parties would share the costs of further independent investigations. These cost responsibilities would be based on the ultimate assessment of the independent investigator. If the problems were mainly on the utility primary system, the utility would absorb most of the costs. If the problems were mainly on-farm, the farmer would absorb the majority of the costs.

- Utilities should maintain a log of their stray-voltage complaints and submit the results to the Commission and Department annually.

The Department hired a consultant, Mr. Gerald R. Bodman, P.E., to comment on the technical issues. Mr. Bodman is an Associate Professor and Extension Agricultural Engineer in Livestock Systems at the University of Nebraska, Lincoln. His technical comments are included as Attachment 1. Mr. Bodman first discusses the need to balance laboratory research with field findings and experiences, then includes a discussion of the definition of stray voltage that supports the definition the Department recommends in our policy section. Mr. Bodman's remaining comments cover "Investigation and Testing Procedures," "Corrective Action Thresholds," "Correction and Mitigation Practices," and "Service Standard Requirements," or categories II, III IV, and VI of the Commission's notice. Mr. Bodman's biographical sketch is included as Appendix 1 to Attachment 1.

The Department believes the initial round of comments from interested parties will provide valuable information for the Commission's rulemaking. But given the complexity of the issue and the high degree of uncertainty, the Department also recognizes the need for additional research and discussion. The Commission should consider soliciting additional comments after reviewing parties' initial comments. The Department looks forward to participating in this process.

I. STRAY VOLTAGE DEFINITION

1. *Should the rules incorporate the definition of stray voltage set forth in the USDA's draft "White Paper"? If not, how should the term be defined?*

The Department believes defining stray voltage is critical to this proceeding. We considered many different definitions before deciding on our recommendation. For example, the USDA's draft White Paper defines stray voltage as follows:

> Stray voltage is a small voltage (less than 10 V) measured between two points that can be contacted by an animal.

Also, the Wisconsin Public Service Commission (the Wisconsin Commission) defines stray voltage as "low-level voltages present across points (for example, drinking cup to rear hooves) in which a current flow is produced when an animal simultaneously comes into contact with them."

Gerald Bodman suggests using the term "extraneous voltage" instead of "stray voltage." He defines extraneous voltage as "any out-of-place voltage within the animal environment regardless of cause, source or magnitude." Mr. Bodman's discussion of this definition is included in Attachment 1.

As the USDA report notes, it is the current produced by the voltages that animals respond to, not the voltages by themselves.[1] The Department believes stray voltage can best be defined by refining Mr. Bodman's definition of extraneous voltage so that it specifically recognizes the importance of electric current in the animal environment. Consequently, the Department recommends that stray voltage be defined as "any out-of-place voltage or current within the animal environment, regardless of cause, source, or magnitude." This definition is broad, recognizes that some voltage or current in the animal environment is intentional (e.g., cow trainers and electric fences), places a greater emphasis on the presence of current in the animal environment, and does not presume any source, cause or frequency of occurrence. The Department believes the Commission should concentrate its rulemaking on stray voltage as we have defined it.

V. COST ISSUES RELATED TO INVESTIGATION, CORRECTION, AND DAMAGES

1. *How should the cost of an investigation be allocated between the utility and an individual customer? Should the answer depend on whether utility-caused stray voltage is found?*

The utility should pay for all initial investigation costs that follow the test protocol set up in this proceeding. This approach assumes that investigations will become part of a utility's standard procedure, not just a special response to a specific customer.

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[1] On-farm researchers and evaluators have stated that currents can often be measured in the animal environment despite the lack of any measurable voltages. Consequently, the Department believes the terms stray voltage and extraneous voltage could both be considered misnomers.

2. *Who should pay the cost of independent investigators?*

The utility should bear the cost of independent investigators if they are used in conjunction with the initial testing procedures, based on the test protocol identified in this proceeding. If the farmer appeals the findings of the initial investigation, the allocation of the costs of subsequent independent investigations should be based on the source of the stray voltage. This approach is further discussed in the "Tariff and Procedures Requirements" section of our comments.

3. *Who should pay for installation and maintenance of isolating devices and other mitigation techniques?*

The Department believes the guidelines developed by the Wisconsin Commission (and adapted from the formats used by Northern States Power Company-Wisconsin and Wisconsin Public Service Corporation) for determining who should pay for isolating devices are reasonable. In particular, the Wisconsin PSC states:

> Isolators should be installed at no charge to the customer when the appropriate threshold levels are exceeded and the source is the primary neutral or an off-farm problem transported over the primary system.
>
> After the off-farm problem is corrected, or where there are no off-farm problems to begin with, or where the threshold levels are not exceeded, the farmer should bear either an initial charge or a charge should be applied after some reasonable period of time is allowed to take corrective or mitigative action. A trial period at some initial non-refundable amount, with an additional sum due after some period of time, would be reasonable.

4. *What mechanism can be established to facilitate financial compensation to farmers who suffer economic loss as a result of stray voltage caused by a utility?*

The Commission could offer its services as an arbitrator to the utility and farmer to determine whether stray voltage has caused economic losses and, if so, the amount of compensation to which the farmer is entitled. The process would be voluntary and both parties would have to agree to abide by the decision of the arbitrator. The Commission does not have independent authority to determine economic losses due to stray voltage and order compensation for these losses. Therefore, absent an arbitration agreement, the courts would have to make such a determination.

5. *What financial role can the utilities play in funding wiring corrections or improvements on the farm?*

The Department believes that while on-farm wiring is the responsibility of the farmer, utilities may be uniquely positioned to offer financial resources to farmers. Utilities should set up low-interest loan pools to assist farmers with on-farm electrical improvements.

VII. TARIFF AND PROCEDURES REQUIREMENTS

1. *What programs or procedures should be established by the utilities for educating dairy and other livestock operators to the potential risk from stray voltage?*

Utilities should place a strong emphasis on educating dairy and other livestock operators about the causes, effects, and solutions to (or mitigation of) stray voltage. The Minnesota Commission and the Department should work with utilities, farmers, and university researchers to develop a handout that includes clearly defined terms and proven and available solutions. Wisconsin has developed a similar handout (see Attachment 2). Farmers are more likely to trust a publication that has several different sponsors than one published by a utility or a group of utilities. This handout should be distributed to every farmer in the state. In addition, utilities should continue to expand their seminars on stray voltage and offer them to farmers throughout the state. Finally, utilities should work jointly to fund a free hotline number where farmers can receive information about stray voltage.

2. *What types of changes to existing tariff language or new filings are necessary regarding stray voltage policies?*

The current tariffs of rate-regulated utilities do not specifically address stray voltage; therefore, there is no apparent need for revisions. New tariff sheets with rules and regulations regarding quality of service as it relates to stray voltage may need to be added later, depending on the rules the Commission ultimately approves.

3. *How can, or should, utilities assist the farmer in obtaining dairy process evaluations?*

Most of the farmers the Department has encountered complain that the utilities' first assumption is that the farmer has a management problem. Consequently, we do not believe that a farmer will trust a dairy process evaluation initiated or funded by a utility. Utilities should recommend, but not fund, dairy process evaluations.

4. *What special appeal rules should be established for circumstances where a farmer disagrees with a utility's assessment of stray voltage exposure?*

An appeals process needs to be established to protect both the farmer and the utility. The appellant should submit an appeal to the service provider and a copy to the Commission. The appeal should state the points of disagreement with the utility's assessment. The utility should then hire an independent contractor mutually agreed to by the utility and the farmer to perform an independent evaluation. The Commission should appoint an independent investigator if the utility and the farmer cannot agree on one. This contractor should use the testing protocol set forth in this proceeding. If the independent tests indicate that the utility is the source of the stray voltage, the utility should pay for the investigation. If the tests indicate that the on-farm system is the source, the farmer should pay. Since there is usually a combination of on-farm and off-farm voltage sources, the rules could provide for a sharing of costs. Relative voltages measured from the "generator power and neutrals separated" test and the "utility power and neutrals bonded" test (see the "Investigation and Testing Procedures" section of Mr. Bodman's report) could be used to apportion the costs. Specifically, the ratio of these respective voltages could be used to determine each party's share of the investigator's cost.

5. *Should utilities be required to provide periodic information updates to the Commission or the Department on stray voltage investigation activity? If so, what specific requirements, including time periods, should the rules establish?*

Utilities should be required to log the complaints they receive regarding extraneous voltage and the magnitude of voltages found in the animal environment. Utilities should submit this information to the Commission and Department on an annual basis. If a particular utility experiences a substantial level of complaints in a particular geographic area, this in itself indicates that a problem exists and that the utility should schedule corrective action within that particular area.

Comments on Stray Voltage Technical Issues

Report to the
Minnesota Department of Public Service
Stray Voltage Rulemaking
Docket No. E-999/R-92-245

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EXTRANEOUS (STRAY) VOLTAGE

Response to: Docket No. R-999/R-92-245, "Notice of Intent to Solicit Outside Information or Opinion Regarding Proposed Rules Governing Service Standards and Policies Related to Testing, Mitigation, and General Policies in the Matter of Stray Voltage on the Farm"

Balancing Laboratory Research with Field Findings and Experience

The recent publication by the United States Department of Agriculture (Agricultural Handbook No. 696 entitled "Effects of Electrical Voltage/Current on Farm Animals") was mentioned in the Minnesota PUC notice. Thus, addressing it directly seems appropriate. Much of what is stated in that publication regarding the influence of extraneous voltage runs counter to many reports of field experience and observations, including experiences reported by several of the authors. A common question is "How can that occur?" Some feel it is because we have become more sophisticated in our technology and know more about the phenomenon of extraneous voltage. I believe there is an alternative explanation. Several of the authors of the USDA publication have extensive field experience, but the USDA publication is based primarily upon two individual research projects. As I have discussed with several of the authors, the publication is a reasonably accurate portrayal of the results of those research projects. However, I believe there are several significant factors which must be kept in mind in evaluating the data and, consequently, the USDA publication.

1. The report is based primarily upon the results of just <u>two</u> laboratory-based research studies. These laboratory studies were conducted with a relatively few number of cows (six to eight) and under reasonably well-controlled laboratory conditions, i.e., stresses imposed on the cows from other sources were kept to a minimum. (Theoretically, this should lead to all measured changes being the result of the controlled and imposed stressor, i.e., voltage.) Consequently, there is serious question whether the results would be similar had the animals been exposed to the full range of stresses (handling, housing, grouping, weather, etc.) commonly encountered on a typical dairy farm where everything is not ideal and they do not get individual attention on a routine basis.

2. The authors were looking for statistically significant results--a valid scientific approach. From a scientific standpoint, statistical significance requires that in at least 95 out of every 100 events if Situation A occurs, Result B can be expected. As the variation between individual subjects increases and as the number of animals or subjects decreases, the magnitude of Cause A to achieve Result B must increase to achieve statistical significance. That, I believe, is a major factor which must be

considered in evaluating the USDA publication and the conclusions set forth therein. When a study is based upon six or eight cows and the variations in sensitivity, resistivity, etc., between cows are as great as has been reported by other researchers, there is little wonder large numbers (i.e., high voltages or currents) are required to achieve a statistically significant response.

3. Each of the two studies reported in the USDA publication began with at least two additional cows. In each instance, at least two animals reacted so violently during the initial phases of the project that they were removed from the actual study soon after it had begun. This was done because there was fear that continuing to utilize these animals could result in their permanent injury or even death. In one instance it is reported (personal conversation with one of the researchers) that a video tape taken of these animals showed such violent reactions that the research institution's legal counsel advised that the video tape be destroyed. It was. This was done for fear someone from outside the research institution would see the video and problems could result because of animal cruelty and welfare concerns. Unfortunately, neither research report includes these animals in their statistical base, though in some instances the authors of the original studies did, as an aside, footnote or "after-thought," mention that some cows were deleted from the study. Consequently, the lower range or extremes of a typical distribution or bell curve were deleted, shifting the results toward higher voltage and current requirements to achieve the same results. As I have told several of the researchers, I cannot argue with the data they presented. However, when the studies are taken in total, one can only conclude that this is not the proper way to do scientific research and then report the results as though they are totally meaningful. The reported results are, thus, badly biased and their worth must be seriously questioned.

During the preparation of the USDA publication, an apparent decision was also made to discard or avoid field-based research, which in many instances, showed results different than what had been achieved in the laboratory setting. While it can be argued that behavior modification is the primary result or manifestation of an animal being exposed to stray voltage, work with numerous herds suggests we do not always have to have explicit externally detectable changes in behavior to have an adverse effect on animal health or performance. To argue to the contrary is, I believe, analogous to saying that everyone who is suffering from the flu, aches, pains, or other medical problems or stressors must display those feelings as externally observable behavior modifications in order for them to be suffering. Does everyone who suffers from heart disease or a stroke display external symptoms or signs? Does everyone suffering from the flu and associated aches or pains publicly display that influence by sneezing, coughing, etc., at all times during the influence of the flu? Does everyone who has bone or joint problems limp or show other external manifestations, i.e., behavior changes? Does everyone suffering from digestive system upset show external modifications of behavior? The obvious answer to these questions is "no" and I believe this illustrates the point that externally detectable manifestations of stress are not necessary for a problem or adverse reaction to be present or real.

This is not to say or suggest that everyone who alleges they have an extraneous voltage problem does, in fact, have one. In my early work (the first 500 herds or thereabouts), in only about 50% of those herds did we see a performance response when the extraneous voltage was removed from the animal environment. That suggests some other factor or stressor was more significant in depressing the performance of the animals than was the extraneous voltage. That doesn't mean the voltage did not have an influence. It simply means it was not the most limiting or controlling influence. (Note: Acknowledgement of the influence of other possible causative factors has been made in several articles and papers.)

For whatever reasons, in my more recent experience, a higher proportion of the herds demonstrate improvements in udder infection levels, production, reproductive performance, milkability, etc., than the earlier herds when extraneous voltage is eliminated from their environment. Perhaps that is because many of the "simple" problems are now being solved by others and I am called upon only in those situations where the problems are more extreme and more extensive. If that is the case, our educational efforts have been worthwhile and successful for that, presumably, is the entire purpose of education--to train others to take care of the vast majority of the problems.

An interesting question then arises as to how we balance laboratory research with field findings and experiences. It is common strategy and part of the scientific approach for researchers to conduct laboratory-type experiments on a relative small number of subjects and once they have developed some theories or hypotheses, to then say "Let's take it to the field and see if it works under real, on-farm conditions." During the 1981 American Dairy Science Association meeting, Dr. Frank Dodd, retired Director of the National Institute for Research in Dairying in Reading, England, made a statement that in his 35+ years as a researcher, he had found that only 15% of what worked in the laboratory worked under field conditions. Is it possible the USDA studies reported in the publication are among the 85% of the situations where laboratory results couldn't be confirmed in the field? My own experience and reported findings under field conditions by others support this as a strong probability. My concern is too much credit and consideration will be given to the USDA study and too much field experience will be ignored as we proceed in the setting of standards and guidelines. I believe that would be most unfortunate.

I. STRAY VOLTAGE DEFINITION

To be complete, I believe any rules developed by the Public Utilities Commission must include a definition. The USDA publication on Page 2-1 defines stray voltage as follows: "Stray voltage is a small voltage (less than 10 V) that can be measured between two possible contact points." That has been a traditional definition of stray voltage. However, it requires investigators to develop at least two different sets of terminology in order to fully investigate all possible conditions which might exist in the cow environment. What do we call a voltage of 11 volts between contact points? Or 20? Or 30? Or 120 volts? For that reason I recommend and encourage use of a different term.

Stray voltage by definition implies something we cannot control and do not understand. (See dictionary definition of "stray.") However, as the USDA publication clearly points out, the phenomenon of "stray" voltage is now much better understood than it was 10 or 12 years ago. We know that for the most part the basic principles of electrical engineering apply to extraneous voltage. I say "for the most part" because there are some situations which I have encountered that I cannot fully explain by the strict application of basic electrical engineering theory, e.g., Ohm's Law. I am not ready to say Ohm's Law or the basic theories and principles do not apply. I am simply suggesting there is more to the phenomenon which remains to be discovered and understood.

As an alternative, I suggest use of the term extraneous voltage and a definition which reads as follows: "Any out-of-place voltage within the animal environment regardless of cause, source, or magnitude." Thus, an extraneous voltage might be 1 mVac (or less) or might, in fact, be line voltage. A single definition thus covers all possible magnitudes and sources. Further, the definition applies without concern over the source or cause, e.g., equipment faults, insulation leakage, harmonics, EMF's, etc., or frequency of occurrence, i.e., steady state, spikes, intermittent, etc. This is not an implication that all voltages in the animal environment are problematic.

Care is needed to assure we don't confuse the basic concept of extraneous or stray voltage with some of the causes. For example, there have been attempts made to make the term "neutral-to-earth voltage" synonymous with stray voltage. Admittedly, neutral-to-earth voltage (either primary or secondary neutral voltage) can be one possible cause. But it is just that--one possible cause. The term neutral-to-earth voltage does not adequately reflect the entire spectrum of the phenomenon of extraneous voltage. Similarly, transient voltages, tingle voltages, etc., are terms that describe certain characteristics under certain circumstances. For example, a transient voltage is one that might be there today but gone tomorrow. It might appear under certain weather conditions because of changes in conductivity of various components of the total electrical system. Care must be used to avoid incorporating such characteristics as part of the total definition.

I concur with the basic concept suggested by the USDA publication that voltage of concern is within the animal environment, i.e., between cow or animal contact points. The cow contacts might be anywhere in the milking, feeding or watering facilities, or elsewhere within the animal environment. One must use care to assure such things as an electric fence or cow trainer are not characterized as a stray or extraneous voltage. These devices are designed to specifically impose a known, controlled voltage between a piece of wire and the surrounding ground surface. Thus, the term "out-of-place" becomes very crucial to the total definition. (From my perspective, an electric fence or cow trainer does not impose an extraneous voltage if properly installed because they are in the cow environment by design. However, should they become leaky, or should a short or fault occur or if they are improperly installed, they could become a source of extraneous voltage.)

II. INVESTIGATION AND TESTING PROCEDURES

(1) Test Protocols

Most of the publications mentioned in the Public Utilities Commission document provide good, basic, sound recommendations. Enclosed you will find a flowchart and several accompanying procedural recommendations which set forth one additional set of test methodologies. These were developed at the University of Nebraska by LaVerne Stetson (USDA researcher stationed at Nebraska with whom I have worked since 1978) and myself. We believe this more fully recognizes the variability that might exist from one farm to another. Basic to these procedures are four tests which I believe should be part of all diagnostic investigations. It involves operating known loads under four specific electrical system conditions.

(a) Utility power and neutrals bonded or jumpered

(b) Utility power and neutrals separated

(c) Generator power and neutrals bonded or jumpered

(d) Generator power and neutrals separated

Admittedly, there are circumstances (although very few in my experience) where proper diagnoses can be made without the use of a stand-by generator. Unfortunately, my experience also indicates that in many instances the diagnosis is incorrect or incomplete when the generator tests are not done. For example, if the voltage disappears when farm loads or the main service have been turned off, the conclusion is often reached that the voltage must be caused by the on-farm loads or the on-farm wiring system. Similarly, false conclusions have been reached under some circumstances where the mere separation of the neutrals has resulted in the elimination of problematic voltages. That technique fails to verify that there is not some fault associated with on-farm wiring or equipment. A third scenario is where the farm power is turned off and the voltage remains. This has led, and appropriately so under some circumstances, to the conclusion that the voltages are caused by background levels of primary system loading without considering the influence of on-farm loads. As a very minimum, the generator tests serve to confirm other test results.

The testing I have proposed takes into account the fact that as we increase on-farm loads and impose a heavier load on the on-farm wiring system, we increase the likelihood that any voltage problems associated with the on-farm wiring will be reflected in a neutral-to-earth voltage or as an extraneous voltage. With the proposed testing protocols, the "worst case scenario" should be experienced when utility power is used to operate on-farm loads. This should result in any extraneous voltages being the sum of background primary system neutral-to-earth voltages, primary system neutral-to-earth voltages caused by on-farm loads, and extraneous voltages due to the on-farm wiring system or equipment.

At the other end of the spectrum would be the operation of the same on-farm loads with a generator and with the neutrals separated. In this test scenario, primary neutral voltages are not influenced by on-farm loads and only the background level of voltages on the primary would have any potential for influencing the farm. Thus in general, voltages measured during this test are the result of on-farm problems. Operating the on-farm loads with utility power and the neutrals separated should generally yield similar results.

I have been less specific than I wish I could be in responding to this last scenario because of a recent experience, which unfortunately I cannot discuss in great detail because the farm is involved in litigation. However, the basic phenomenon was that with the neutrals jumpered (bonded) and operating on-farm loads with either utility power or generator power, voltage was found to exist at two waterers in the free-stall barn. Separation of the neutrals and operation of the loads with the generator resulted in a voltage level at the waterers which was below the level anyone considers problematic (less than 0.2 Vac). Theoretically, operating the same loads with utility power and the neutrals separated should have also prevented the voltages from appearing in the animal environment if, in fact, the voltage was a result of the primary neutral system. In this instance, simply separating the neutrals did not eliminate the voltage. The voltages could be eliminated from the animal environment when operating on-farm loads with utility power only by cutting the downgrounds on the transformer pole. The exact reasons why this occurred are not clear. My judgement is that current returning via the transformer pole grounds (there were two downgrounds on the transformer pole) was flowing through the soil and becoming involved with the on-farm grounding or water system and was subsequently being reflected at the waterers.

The basic purpose in the four tests as suggested is to identify the worst-case and "best-case" scenarios with regards to on-farm and off-farm voltages. (The other two tests, i.e., utility power/neutrals separated and generator power/neutrals bonded or jumpered, assist in proportioning the relative voltages to the on-farm and off-farm sources.) The real purpose of all testing, of course, is to determine the source and, hopefully, to identify appropriate mitigation techniques. As suggested previously, however, I believe there are still some aspects of this phenomenon which remain to be properly identified.

Another example of a not-yet-fully-understood aspect of extraneous voltage involves two farms discovered in the past year (a total of six to-date) in which limited voltage could be found within the animal environment but in which current flows as high as 18 milliamps (mA) were found to exist in the animal environment. (The current through a 498-ohm resistor was 12 - 13 mA!) Two of these farms have reported very marked changes in production since the current was eliminated from the animal environment. In one instance, the producer has also been told by his doctor that for the first time in eight or ten years the arthritis condition in his feet and legs is improving. Perhaps time will tell whether this turns out to be the result of previously existing current flow through the milking system and milking center.

It is well recognized that current flow through the animals is required to cause a reaction, i.e., current causes problems, not the voltage, per se. In that regard, the use of a resistor is considered crucial to verifiable and reliable testing. The question then arises as to what value or size resistor? Work at the University of Minnesota has shown that 25% of the cows have a resistance of 302 ohms or less. They also found that 75% of the cows have a resistance of 441 ohms or less. These numbers are similar to those reported earlier by Washington researchers.

Many have recommended of a 500-ohm or a 1000-ohm resistor. Admittedly, the use of this size resistor (nominal value) makes calculation of current relatively easy. However, does it accurately reflect the true situation with respect to animals. My procedures involve use of a series of resistors--100-ohm, 358-ohm (350-ohm nominal), 498-ohm (500-ohm nominal), and 999-ohm (1,000-ohm nominal). These values were selected to more accurately reflect the actual resistances reported for animals, but also to bracket those resistances with both higher and lower values. If a single resistor is to be used, I recommend it be in the range of 350 - 500 ohms, and preferably closer to 350 ohms.

As suggested, cow contact point voltages are of most importance. One must be careful, however, and not ignore the fact that people are also animals. Thus, if voltages are existing on a bulk tank, milkline, hot water heater, or some other equipment in the barn, which are of a magnitude high enough to cause shocks, discomfort, inconvenience, and potential health hazards to humans, these voltages would still fit within the definition of an extraneous voltage. Voltages in such locations cannot be ignored.

Unfortunately, many of those involved in testing have measured and reported only the voltages from a single contact point to a reference ground. How does one determine the actual voltage between human contact points or other animal contact points since few of us have a reach in excess of 6 ft? Measuring voltages from Points A, B, C, and D--representing points which are six or more feet apart--to a reference ground 25, 50, or 100 ft. away provides little usable information.

A reference ground is a useful tool for diagnostic purposes. However, each voltage reading by itself is of limited value in assessing voltages to which a human, cow, or other animal might be exposed. When using a reference ground, the difference between voltages at two points is the primary concern. In contrast, if the reference points are both within the animal environment, e.g., rear of cow platform to waterer, the voltage reading will be a direct indicator of voltage or potential between the contact points.

Research suggests a poor correlation between primary neutral or secondary neutral voltages to a reference ground and what voltage might be reflected in the animal environment. My field experience supports this as true. Specifically, I have been on farms where voltages between animal contact points were within a few millivolts of the voltage measured on the primary or secondary neutral to a reference ground. Similarly, I have been on a number of farms with what I believe to be excessively high primary or secondary neutral to reference ground voltages (to be discussed in a later item) where little or no voltage seemed to be appearing or was measurable in the animal environment.

As a point of reference, when I do an investigation, my standard points of monitoring with a recording voltmeter are primary neutral to reference ground, secondary neutral at the barn service entrance to reference ground, and then two animal contact points, for example, water cup to rear of cow platform or gutter, feeder to grate, etc. In some instances depending upon the circumstances, I use additional meters between other contact points on the farmstead.

I believe it behooves us to encourage investigators to not start pointing fingers at each other too early in the investigation. I have seen too many instances where individuals have concluded a problem is either on-farm or off-farm and walked away as though it was someone else's problem, only to come back later and find they were wrong or to have someone else prove they were wrong. In the meantime, the farmers have spent large sums of money to make corrective actions which, while they might have been needed in a given situation, did not prove effective in helping to eliminate the problem. Consequently, the problems continued to exist, situations worsened, and frustration levels became more intense.

Such situations generally occur because of inadequate testing, use of a hit-or-miss test procedure, or pre-conceived notions as to the source of voltage--or whether a voltage problem even exists!

To be sure, it is good practice to assure all wiring on-farm complies with the *National Electrical Code*. However, it is not valid to state that the mere existence of a violation of the *National Electrical Code* means that is the cause of extraneous voltage. Admittedly, in some instances, such problems do add to or cause problematic levels of extraneous voltage. However, the mere use of NEMA-1 boxes, interconnections of grounds and neutrals, improper color-coding, failure to install a ground rod at each service entrance, etc., does not mean those necessarily are sources or causes.

We must also recognize that many of our barns were wired pre-1978. It was not until 1978 that Article 547 actually became a part of the *National Electrical Code* and the unique requirements of agricultural buildings were recognized. At the same time, one could argue that Article 300-6 required appropriate wiring or different wiring in the barns for many years. However, to this day we still have many installations including commercial facilities which are not properly wired if Section 300-6 is applied. Additionally, the electrical equipment manufacturers did not have materials available to wire a building in accordance with Article 547 in 1978. Even today, some specific components are not available or are available only at a very high price. The greatest risk in using inappropriate equipment, e.g., NEMA-1 boxes is decreased useful service life due to corrosion. This doesn't necessarily mean decreased function but does mean higher maintenance costs.

It is also important for all investigators to write down their findings. Undocumented test results are of limited value to anyone. I have received as an argument against writing things down that someone can then take those numbers and find fault with them. Admittedly, that is true. (My own experience has verified the accuracy of the concern many times!) However, our primary purpose must be to document that a problem either does or does not exist and then to eliminate the source of voltage if, in fact, one does exist. During initial investigations the question of who is at fault should be of little importance. Other rules prepared by the Public Utilities Commission or the legal system will ultimately sort those out. Putting things in writing is generally beneficial to all involved.

(2) Data and Educational Information to Be Supplied to the Farmer

As a basic reference, the University of Minnesota publication on stray voltage is probably the best available. The authors seemed to recognize the fact that even voltages of small magnitude can be problematic in some instances and corrective actions should be taken. It sets forth basic test procedures and, hence, provides a good overall balanced approach to extraneous voltage investigations. I believe the farmer has a right to know what the actual results were under the four test protocols described earlier. The actual test results should be used to help explain why corrective actions must be taken on the primary side of the system, the secondary side of the system, why neutrals should be or should not be separated, or perhaps that no problematic voltages were measured. Unfortunately, as mentioned with regards to the several recently identified situations, the mere absence of voltage does not necessarily mean an absence of problems since it was only with a milliammeter that I was able to identify some of the referenced problem farms.

The report to the producer or the individual of concern in each instance should provide a synopsis of the test data. This would include voltages at the cow contacts with and without resistors and with various loads operating. When, in fact, the voltage disappears when using a resistor, it could perhaps be followed-up by another test to show that grounding or bonding the cow contact points at which voltages were found would help to eliminate the voltage. (However, that does not eliminate the source.) Let me add another caution about making blanket statements in that regard. Another recently encountered farm (investigated in 1990) involved a situation where bonding of the waterline and milkline to the secondary neutral as required by the *National Electrical Code* markedly increased cow contact voltages. Presumably this was because of a decrease in the on-farm resistance--as the water system became part of the electrical system grounding network--and increase in current flow from the neutral system. In that situation the recommendation was to apply Section 250-21 of the *National Electrical Code* which allows separation or non-bonding when problematic currents result because of bonding. Thus, flexibility must be maintained to allow appropriate procedures to be incorporated from farm to farm. Quite frankly, that is one of the reasons the field of extraneous voltage is so difficult--there are no two farms which are identical and to develop a set of specific rules which applies to every farm is probably impossible. The best we can hope for is a combination of general and specific guidelines (whichever is appropriate with respect to a given issue or consideration) coupled with a sincere, prudent, and competent response in each instance.

The test results should also reflect the voltages in the animal environment when operating common pieces of on-farm equipment. This might include gutter cleaner, ventilation fans, bulk tank compressors, vacuum pump, feeding system, water heater, well pump, manure pump, etc. Only through a process of elimination can we assure that none of this equipment is contributing to voltage problems. The test results would help a farmer understand why problems seem worse at times and why proper--and safe--wiring is required in all instances.

(3) Role of Independent Testing

Generally speaking, if properly done, testing by independent individuals has resulted in a greater confidence level by the producer that the testing has been done without bias. The problem is basically one of perception. I have seen testing done by utility companies that was very sound and well done. However, I have also seen testing which appeared to have been done with the sole purpose in mind of "proving" that the problem was on-farm. I have also seen test results by independents which were worthless because of incompleteness.

Independent testing can be used to document what was occurring during other periods of time. This might relate to transient voltage. For example, I have encountered several instances where problematic voltages occurred during damp conditions. However, by the time I arrived at the farm, no problematic voltages were present. An example of one situation was on a farm where the electrical control boxes at the silo or feeding center were full of cobwebs and silage debris. Under damp conditions the cobwebs and dust became leaky, allowing current to flow from the phase conductors onto the grounding system causing voltages in the milking center. The solution to that particular problem was to use an air compressor and clean out all the electrical boxes. The point is that when I arrived under dry conditions a couple days later, I could not detect a problematic voltage.

Investigators should document the conditions that existed at the time of the testing as near as feasible. For example, had there been extensive rain within the past week or so? Had it been bone dry for the past few weeks or months? Was the ground frozen? Each of these things can affect the resistivity and conductivity of the various components of the electrical system. Whether the influence is positive or negative will be dependent upon the source of the voltage.

In my own situation, frequently numerous changes have been made on both the primary and secondary systems by the time I become involved and arrive at a farm to conduct my investigation. My testing can establish or document relationships between primary and/or secondary neutral voltages. Data gathered by others can then be used to extrapolate as to the situation which likely existed at some other point in time.

The knowledge and experience of the person doing the testing is ultimately of far more importance than whether he is a "company man" or independent. Understanding the primary and secondary systems, a clear and working knowledge of the concept of extraneous voltage, and appropriate test equipment are necessary in all instances.

(4) Utility Response Time to Complaints

Perhaps it is human nature, but everyone would like to have their problem solved yesterday once they decide or believe they have a problem. Realistically and practically speaking that isn't always possible. Utility companies have work to do other than to wait for someone to call with a complaint about extraneous voltage. However, if someone is getting shocked and, hence, the question must be raised--Is a potentially lethal situation present?--the response should be immediate. Judgement is required to determine the severity of the problem. A hazard demands top priority. If on the other hand, it is a situation a farmer thinks he has been living with for the past week, month, year, or several years, the need for a response on the day of inquiry is generally substantially less.

The bottom line is if the information received suggests there is a hazard to health and well-being of animals or humans, the response should be immediate. If a farmer is simply suspicious of a problem because someone suggested it might be a cause of some of his production, mastitis, or cow behavior problems, then a reasonable time period in most instances would be to respond within one week. While a producer always considers his needs urgent, the utilities must be provided the opportunity to schedule things regarding their other responsibilities. That is, allowance must be made for emergencies, work schedules, vacation schedules, etc. Nonetheless, there seems to be little reason why a response should not be made at least within a week of a complaint being received to conduct a preliminary investigation, even if it involves nothing more than using a hand-held portable voltmeter to check various contact points within the human or "animal" environment to see if a hazardous condition does exist.

(5) Utility's Obligation Regarding On-Farm Wiring

I suspect that ultimately this question will revert back to a legal consideration. No human alive can realistically inspect an on-farm wiring system and guarantee that every possible problem has been identified. Consequently, it should not be expected that any individual--or even a team of individuals--would realistically find every possible problem. However, if I as an investigator for a utility company conduct an investigation but fail to find one problematic condition which subsequently results in a person or a cow being electrocuted, or perhaps the barn burns, what level of liability do I as an individual or does my employer have? At what point does my failure to find every possible fault or problem lead to a claim of negligence?

If the utilities are going to provide an on-farm electrical inspection service, I believe it is essential that they have at least one licensed and experienced electrician on their staff who would be involved in this inspection. I have experienced too many instances where an individual has seen things which are obviously violations of the Code (for example, NEMA-1 boxes, use of Type NM cable, color coding, etc.) and jumped to a conclusion that because of these deficiencies or violations the problem, i.e., voltage source, is on-farm. In most instances, my investigations have shown that such violations of the Code do not directly contribute to extraneous voltage levels. Care must be exercised in all instances to avoid jumping to conclusions. A more thorough analysis is warranted.

Certainly, if adequate testing is done and the results show the problem to be primarily or at least in large part due to on-farm sources, it would provide a good service the customer for the utility to at least help identify some of those on-farm sources of voltage. The techniques outlined in the University of Minnesota publication, if they are followed step-by-step should help to lead to identification of the source.

An obvious instance of when recommendations should be made regarding on-farm wiring is where a hazardous condition is found to exist. This might include instances where connections have been loose enough that insulation has gotten hot and begun to melt, perhaps there is rodent damage where there are bare conductors, or perhaps voltages are found to be high enough in the animal and human contact areas as to pose severe shock or potential electrocution hazards. There should be no doubt in anyone's mind that under that set of circumstances recommendations regarding the on-farm wiring system are warranted.

Another situation that might warrant recommendations regarding on-site wiring would be where neutral and ground interconnections beyond the service entrance panel are found to exist and to be contributing to extraneous voltages. The mere interconnection of the grounds and neutrals beyond the service entrance panel increases the risk of shock hazards on any piece of on-farm equipment.

I believe appropriate recommendations could also be made regarding grounding to meet the *National Electrical Code* minimum safety standards. Here again, we must exercise caution and not get carried away with recommendations resulting in excess grounding. Depending upon the source of the voltage, improving the on-farm grounding beyond that absolutely necessary for basic safety considerations can lead to a worsening of animal contact area voltages.

III. CORRECTIVE ACTION THRESHOLDS

(a) Primary Neutral

As noted previously, correlations between primary neutral to reference ground and animal contact voltages are poor and inconsistent at best. Hence, it is difficult to make specific recommendations that are going to be valid in all circumstances. However, let me share with you my experience on the farms I have investigated.

Most utilities will experience a primary neutral to reference ground voltage in the range of 0 - 3 Vac with normal system loading and on-farm loads operating. I have stated on numerous occasions that I believe this range of voltages is reasonably normal and acceptable.

A voltage between the primary neutral and a reference ground in the range of 3 - 5 Vac becomes questionable. My experience indicates these voltages are higher than necessary or reasonable in most instances.

Primary neutral to reference ground voltages in excess of 5 Vac do, in my experience and in my judgement, indicate a definite problem with the primary neutral system. One cannot tell by looking at these voltages whether the problem is because of inappropriate balance between the various phases, excessive loads on the system, improper sizing of the primary neutral conductor, one or more poor or bad connections between the point of measurement and the substation, or inadequacy of the primary system grounding network.

As a direct response to your question, I believe the voltages between the primary neutral and a reference ground in excess of 3 Vac should be sufficient to warrant investigative procedures. This is particularly true if that voltage is reflected in the animal environment as I have documented it is in some instances. A primary neutral-to-earth voltage in excess of 5 Vac justifies corrective action regardless whether anyone has filed a complaint about extraneous voltage problems.

My documentation of the current flow on the primary neutral downground or grounding conductor at the transformer pole and on the bonding jumper between the primary and secondary neutrals is substantially less than my documentation of voltages. In those instances where I have measured the current flow in these various conductors, I have been unable to make good correlations between those measurements and the animal environment voltages and currents. Thus, at this point based on my somewhat limited data, I must conclude that these numbers are of little significance. However, as I continue to monitor and measure them at various farms, perhaps more consistent correlations will be found.

(b) Secondary Neutral

As mentioned previously, there are research data available which are consistent with my own field experience. These indicate no consistent correlation between secondary neutral to reference ground voltages and animal environment voltages. Thus, this test by itself is inadequate to determine whether a problem either does or does not exist.

My experience indicates that voltages at the barn service entrance neutral to a reference ground in excess of 2 Vac nearly always indicates a problem somewhere on the system, even if not in the cow environment. As with the primary, this can be in the length of the conductor (service drop) and resulting voltage drop, the balance between the two phase wires servicing the service entrance panel (neutral current), neutral conductor sizing, quality of connections or perhaps grounding somewhere on the farm wiring system. It could also reflect a poor bond between the primary and secondary neutrals.

As with the primary system, I have been unable, to-date, to make good correlations between current flow in the various grounding conductors and animal contact point voltages. I do monitor these in nearly all installations to some extent and perhaps with time a correlation pattern will be found to exist.

Data collected to-date do not suggest that the current flow in the grounding conductors is a good indication of the likelihood of problematic voltages existing in the animal environment, or the lack thereof. At the same time when the current flow through the grounding conductors has been sufficient to cause a discoloration (copper sulfate coloring of copper conductors), this nearly always indicates a problem with the grounding system servicing the farm. This might be indicative of poor connections, undersized conductors, interconnection of grounds and neutrals, etc., or electrically "leaky" equipment.

(c) Cow Contact Area

(1) Field experience has indicated that 0.2 - 0.3 Vac is a relatively "normal" level of voltage within the cow contact areas on most farms. Of the farms investigated or surveyed, fewer than ten have not had at least that much voltage somewhere in the animal environment. In a sense, this appears to be a "cost of having electricity on the farm" or being able to use electricity to operate on-farm equipment. It represents a combination of voltages from all sources under the typical situation.

Given the experience with many of the herds and much of the other field research and observations which have been reported over the years, an animal contact voltage of 0.5 Vac is judged sufficient to warrant corrective actions. Perhaps putting it in a different perspective, one might say that there is no reason to tolerate voltages in excess of 0.2 - 0.3 Vac. If we use a voltage of 0.3 Vac as a reasonable baseline level (a voltage of 0 volts would be desirable but is not realistically attainable), we would provide protection for those animals which have low resistance because of body chemistry or for some other reason such as wet contact surfaces, sore feet, etc., and which might be more sensitive to current. This would also provide protection for the animals which might be adversely affected internally without any external display or manifestation of stress. My own philosophy is that a voltage of 0.5 Vac is certainly worthy of investigation and mitigation because there is no reason to tolerate voltages of that magnitude. Voltages of 0.3 Vac or less are not considered problematic under most instances and normally are not investigated, i.e., attempts to mitigate are not initiated unless there is other evidence that cows are being adversely affected.

Current flow through the animal is the important criterion. Thus, the determination of current-producing capacity of the voltage source, i.e., the energy or strength of the voltage source, must be determined in evaluating the possible influences on cows. The current flow through the cow, i.e., between a simulated cow and the cow contact area, is far more important in determining potential influences than the voltage or current measured relative to a reference ground.

Based on work from the University of Minnesota and field experience plus the conclusions of the Wisconsin Public Service Commission, a reasonable and acceptable magnitude for current flow through a resistance simulating a cow is believed to be 1 mA. As stated previously regarding some of the research, we can argue whether external manifestations of irritation are necessary to cause internal problems. As a comparison, data suggest that humans generally have a threshold of perception of about 1 mA for a 1 second contact time. As part of our Electrical Wiring and Extraneous Voltage Workshops we conduct a series of voltage/current sensitivity tests on volunteers from the audience. Few, if any, individuals find currents in excess of 0.5 mA to be acceptable. Most find it irritating enough to request the demonstration to be terminated. We must recognize that in many instances, cows or other animals can be exposed to problematic voltages and currents for extended periods of time. Thus, until such time as we can more accurately determine the influence of long-term exposure to low-level voltages or currents, a maximum acceptable current of about 1 mA across a 350- to 500-ohm resistor is considered a reasonable and appropriate target level.

As noted, it is current flow through the cow that is of significance and importance. Measurements taken to a reference ground are fine for diagnostic purposes but sufficient data must be gathered to be able to calculate the actual current flow through the animal between the contact points.

(2) Research suggests that it takes approximately twice as much DC voltage as AC voltage to initiate or cause the same response in animals. In all of my studies I have only found one farm where DC voltage was, in my judgement, making a substantial contribution to adverse cow performance. Given the limited experience and data, it appears reasonable that a voltage of 1 Vdc be proposed as a maximum acceptable level before which mitigation steps are required and that the correlating current be limited to 1 mA. Thus, even DC voltages must be investigated with the use of a resistor to determine the current-producing capacity or energy characteristics of the voltage source.

Two recent reports from Michigan suggest problems due to DC voltages. In both instances, attaching a 12-volt auto battery between the well and a probe in the soil 10 - 12 feet from the well has reportedly resulted in significant changes in cow performance. Neither farm has been fitted with a long-term permanent solution. (Battery polarity must be reversed until the most positive results, i.e., cancellation of voltages, are achieved.) A third Michigan farm is reportedly being subjected to problematic DC voltages from a nearby railroad (signal controls?) and/or gas line (cathodic protection?). The use of a battery to cancel the voltage from the sources has had limited effect.

Research data and my own experience are insufficient to allow a full evaluation of the influence of harmonics on animals. What data are available suggest that harmonics--which are not measurable with the standard volt ohmmeter--may increase the problems with other voltage levels and might explain why some herds seem to be adversely affected by a measured voltage of 0.5 - 0.7 Vac, or less, while other herds require larger voltages. This might also account for some of the differences between research and field studies where the research data are generally gathered using a cleaner voltage source, which would not include harmonics in most instances.

Transient conditions must be treated much the same as steady-state conditions. Like an intermittent malfunction on a piece of equipment, they are frequently much more difficult to document. However, this is one advantage of data gathered by independent investigators. We must assure that the mere absence of voltage under one set of test conditions is not construed to mean that no voltages exist or the problems do not exist at other times. At the same time this emphasizes the importance of having all investigators document their findings so correlations can be made between the data gathered at different points in time.

IV. CORRECTION AND MITIGATION PRACTICES

Many of the mitigation techniques being employed fail in one basic aspect of problem mitigation. Namely, they tend to serve as band-aids and camouflage the real problem. The best solution in all instances is to identify the source of the problem and make the necessary changes to correct or eliminate the underlying and fundamental cause or source. Care must always be exercised to avoid delaying remedy of the real problem. Some of the techniques advocated and being used can effectively remove measurable voltages and currents from the immediate animal environment, but may not eliminate problematic levels of voltage or current from all possible human or animals contacts around the farm. In contrast, if the true source of the problem is corrected, the problem should be gone for a substantially longer time from all potential contact points.

(1a) Equipotential planes are favored by some utilities for obvious reasons. Namely, they normally provide substantially better grounding capabilities than exist on the utility lines. In that respect they are a positive solution. However, there are risks involved. If we use an equipotential plane and a lightning strike occurs near the farm or the barn, there is a risk that parts of the barn could be structurally damaged because of the intense current and voltage. The damage would not be unlike what we find when foundations and buildings are used as grounding electrodes and a lightning strike occurs nearby. Theoretically, the equipotential plane would prevent or preclude animals from being harmed by such events. Given the intensity of a lightning strike, I do not believe an equipotential plane can be guaranteed to adequately protect the animals. The use of an equipotential plane could conceivably make problems worse under extreme conditions, e.g., a lightning strike in the immediate vicinity of a plane-equipped barn.

The equipotential plane is, I believe, a vivid example of a band-aid approach to problem solving. If we have excessive voltage, and associated current, from the primary feeding onto the farm, let's identify the problem on the primary and correct it. Poor neutral connections, under-sized neutral conductors, poor balancing of loads, inadequate grounding, etc., are common examples of reasons for elevated neutral-to-earth voltages and are all relatively easy to correct. (An exception might be the size of the neutral conductor.)

An equipotential plane does or can effectively camouflage problems. Admittedly, we do not want the animals being subjected to voltages which cause adverse reactions of any kind, be they behavioral or physiological or just plain physical. At the same time, the animals do provide a good method and, compared to humans, a safer method of being able to monitor when voltage problems exist. If we protect the animals but fail to protect the entire human environment on that same farmstead, we increase the odds that when electrical problems do occur, they will go undetected until someone gets a severe shock, possibly lethal in nature.

Additionally, too many equipotential planes have been installed without full consideration of what is required to complete the installation. I have found numerous instances in tie-stall barns where the equipotential plane is installed in the cow platform and feed manger, but no consideration is given to the center service alley. I have measured as high as 2.5 Vac between the center service alley and the cow platform. The result is cows jumping across the gutter into the stalls and attempting to turn around and jump out of the stalls. This increases the risk of injury, both to the animals and to the herdsman. All equipotential planes require voltage ramps to transition animals from the level of voltage surrounding the plane to that which exists on the plane. All entrances, exits, alleyways, and anywhere else that a step voltage might exist must be equipped with a voltage ramp.

Research from Minnesota has shown that the typical and most practical voltage ramp will only reduce the on-off plane voltage by approximately 50%. Thus, questions remain. For example, if we have a voltage of 4 volts and a voltage ramp reduces the step potential to 2 volts, is a 2-volt step potential satisfactory? In my judgement it is not. The question then remains as to how we make the additional transition across the remaining 2 volts from the surrounding soil. Do we use "concentric" planes and interconnecting transitions or ramps? Are there better methods? What happens if we install a plane and a voltage which exceeds what a single transition or voltage ramp can effectively correct develops later? To date, there has been no good research and only limited field experience has been reported to offer a satisfactory solution to this problem.

Additionally, if an equipotential plane is required in the lactating cow environment, the farmstead investigation must be adequate to assure that no other part of the farmstead also requires an equipotential plane. This could include waterers, feedbunk areas, calf housing, heifer housing, etc. I have investigated two farms where such conditions existed or occurred.

Is an equipotential plane a permanent solution to a voltage problem? I believe the answer is a firm "no." I am now aware of two planes in Wisconsin barns that appear to be failing. The trend is toward increasing cow contact voltages. Both planes have been in for approximately four years. Their ultimate useful life is unknown.

(1b) Neutral isolating devices should be installed only when it has been confirmed with appropriate testing that the primary source of voltage is from off-farm and that the isolating device will, in fact, reduce voltages in the cow environment to satisfactory and non-problematic levels. Installing a neutral isolator in a situation where the problem is really on-farm could make problems worse and could result in life-threatening situations.

Where isolating devices are warranted, I strongly recommend using only the saturable reactor or electronic switch type. These limit the differential in voltage between the primary and secondary neutrals to 12 - 24 Vac and provide a safer condition to handle fault currents, especially since most services from the meter to individual buildings are not equipped with over-current protection devices. Technically, the NESC allows use of lightning arrestors, spark gaps up to 3 kVa, etc. However, as noted, there are some serious hazards associated with such equipment.

Isolation transformers pose what is perhaps the greatest of safety risks since there is no controlled interconnection of the primary and secondary neutrals in any installation I have seen. Additionally, isolation transformers are a poor choice because of their energy-inefficient operation. Utilities that refuse to consider other alternatives and require farmers to install isolation transformers at their own expense are really ignoring their responsibility to provide guidance with regard to wise use of energy.

Isolating devices should be perceived as a temporary solution until such time as appropriate corrective actions can be initiated to actually correct the true source of the problem. Under some circumstances temporary might mean two or three years until sufficient financing is arranged to allow reconstruction of older lines. On the other hand, where the only required corrections are to improve the quality of neutral connections or to improve the grounding of the neutral system, the temporary device might be in place for six months or less. However, before removal of the isolation device, sufficient testing should once again be performed to assure that removal will not cause a return of problems to the farm, i.e., that the real source of voltage has been identified and eliminated.

(1c) The electronic grounding systems have, in most instances, worked satisfactorily. However, there are examples where farmers have spent a considerable sum of money to install such a system only to find that their problem has not been completely solved. These systems, like the equipotential plane, camouflage the real problem source. They eliminate the apparent effects of voltages in the animal environment but do nothing to get to the root cause. Thus, they, too, should be perceived as an option of last resort and one which should be installed and used only on a temporary basis.

(1d) Article 547 of the NEC allows a four-wire installation to service agricultural buildings, with appropriate precautions. This also is a poor choice especially if installed underground. With a standard three-wire system, if either of the phase conductors fails or breaks, failure will be obvious because some 115-V or 230-V equipment will not operate. Similarly, failure of the neutral conductor will be obvious since most 115-V equipment will not operate. Unfortunately, the only time one will know that the grounding conductor has broken or failed is when it is needed and it fails to perform. Thus, there is an inherent safety hazard in using the four-wire system except in those instances where periodic and routine maintenance services are performed to assure grounding conductor continuity has been maintained. As with some of the other mitigation options, a four-wire system serves as a band-aid to camouflage the real source of the problem. Where appropriate testing has been performed and a determination made that the four-wire system is the only practical solution (not the first choice solution), proper installation must be assured. This includes insulated copper grounding conductors (if underground), adequate torquing of all grounding conductor connections, etc.

(1e) Several farms have been investigated where a current transformer (CT) was used as neutral isolation device. I have not been able to identify a manufacturer who recommends this use for their equipment. My test data indicate that with heavy system loading these devices yield incomplete separation. Although I do not fully understand the principle of operation of a CT used in this manner, I do know what my test data show. Despite their low price, I recommend that current transformers not be allowed to be used as a neutral separation device.

(2) As noted in Item 1b, isolating devices may, in fact, end up being a seemingly permanent fixture on some installations. However, as a general rule, they should be perceived as temporary. (The definition of temporary might vary from situation to situation.) Flexibility must be maintained to allow such determinations to be made on a case-by-case basis. In general, the safest system is still to have the primary and secondary neutrals interconnected to the maximum extent possible.

My experience with an installation in New York suggests that in those instances where a farm or other property is located near a substation and is experiencing an extraneous voltage problem, a neutral isolator might be necessary on a continuing and permanent basis. To-date, this is the only installation I have found where that has been the case. In that instance ground currents are high enough to require the neutral isolator to remain in place. Whether substantial changes in the primary neutral system will eventually change conditions at that installation is unclear. In that particular instance the primary neutral resistance was quite high and grounding was found to be very minimal.

(3) As suggested under several previous items, the response time for corrective action by utilities will vary somewhat depending upon the nature of the problem. Where it is found that additional grounding, improvement of the quality of connections, balancing of loads on the three-phase system, etc., will serve to eliminate the voltage from the primary neutral, these changes could normally and realistically be made within a time period of several weeks to six months. Some might require less time. On the other hand, where it is determined that the load on the system has simply increased beyond the capacity of the existing conductors and the line must be rebuilt, adequate time must be available to allow arrangement of financing and to get the work performed. Generally, I would think such changes could be made within a two-year time period.

(4) Changing to a different distribution system design as a way of eliminating extraneous voltage would in general, I believe, be a poor alternative. This also requires substantial cost. While it is true that an ungrounded delta system theoretically does not provide any opportunity for extraneous voltages from the primary system because there is no primary neutral, I do not believe it is the safest alternative. Use of the primary neutral as the lowest conductor does to some extent provide a safety net with regards to the movement of on-farm equipment. True, we cannot build utility lines to protect against all possible hazards on the farmstead, but I believe we must consider safety to the maximum extent possible.

As previously stated, the best remedy in each instance is to identify the source of the problem and then to take steps to eliminate it at its source. I suspect the cost of rebuilding a line to increase neutral conductor size and to improve the quality of connections and grounding will be less than changing to a different distribution system design in most instances.

Also, what is the relative level of current flow through the on-farm grounding system with an ungrounded delta system? Do we cause more on-farm voltage even though we've eliminated off-farm sources? I do not have enough test data to adequately answer these questions.

(5) I am not thoroughly familiar with the utility counterpoise system. However, I suspect that in many ways it is similar to the electronic grounding system. Does it really solve the problem for the total system or does it simply eliminate the obvious signs of problems on the particular farmstead? If the latter situation is the case, I believe that it, like some of the other alternatives, must be considered a poor choice and one of last resort.

(6) A neutral impedance test does, I believe, give a reasonable guideline for helping to determine when line upgrades or improved grounding are necessary. A high impedance system can be the result of undersized and high resistance conductors, poor quality

grounding electrodes, inadequate grounding electrodes, or poor connections--either on the neutral or on the grounding electrodes and downgrounds. The impedance of most primary neutral systems, as measured at the farm transformer, is less than 2 ohms. Two ohms appears to be a realistic target. (Many farms have an impedance of 1 ohm or less.)

The advent of the AEMC clamp-on ground resistance tester has enhanced the opportunity to quantitatively evaluate existing ground rods. As stated in the NESC, on a multi-grounded system the influence of any particular ground rod is minimal and the establishment of specific resistance to soil numbers is somewhat meaningless. Nonetheless, a lower primary system resistance, including resistance to the surrounding soil, will nearly always be beneficial. Where a problem is found to exist, one strategy might be to impose a requirement that the resistance of ground rods within one mile of the farm be a maximum of 25 ohms. A maximum of 10 ohms would be better. Another option would be to require multiple ground rods (Note: With multiple ground rods, the minimum spacing equals twice ground rod length in order to achieve maximum function on both ground rods.) and grounding every pole within one mile of a farmstead experiencing problematic voltages from an off-farm source. This requirement would apply to the first mile of line from the farm towards the substation. The goal should be a resistance of 10 ohms or less for the ground rods at each pole.

Unfortunately, as noted in the example of one farm visited recently, good quality grounding along the primary neutral in the immediate vicinity of a farm might, in selected instances, tend to make problems worse rather than better. I have not fully established in my own mind what set of conditions must exist to lead to this situations, i.e., I don't know how to predict when problems might occur. A combination of monitoring and trial-and-error appears to be the only feasible alternative. The resistivity of soils in the area, the proximity and respective locations of the primary and secondary grounds, and the relative locations of the farm in question and the substation all could influence when these strategies are most appropriate or when problems might occur. Consequently, we once again find ourselves in a situation where attempting to write a document or a rule that will adequately apply to every instance is going to be difficult at best and perhaps impossible. The rules should be written to provide guidelines but should not be considered as being the last and final word in all instances. Some flexibility must be provided to allow the most appropriate strategy to be selected in each case, depending upon test results. In some situations, trial-and-error solutions might be required. We use trial-and-error methods in many other aspects of our lives. The same strategy should be conscientiously employed to solve extraneous voltage problems where appropriate.

As an aid to troubleshooting systems, utilities should be encouraged to monitor primary neutral current as well as the load in the individual phase conductors. Periodically measuring the current at different locations along the primary--or at least at the substation--would give them a quick and ready reference as to the amount of imbalance the system is experiencing and would, I believe, serve as a fairly good barometer as to when problems might be expected to occur. Obviously, as primary neutral current increases, the voltage drop will increase also. As we increase the voltage on the primary neutral, the risk of problems at all services increases.

VI. SERVICE STANDARD REQUIREMENTS

(1) Indeed, standards beyond NESC minimums can be appropriate and should be established. We must recognize that the NESC and the NEC are both primarily safety codes and set forth <u>minimum</u> standards. The reason for the six-foot separation distance is to keep or prevent most humans from being able to simultaneously contact two ground rods which might be at different voltage levels. For maximum functional characteristics, the separation distance between ground rods must be at least the sum of the length of the two ground rods. Thus, two 10-ft. ground rods should be at least 20 ft. apart. If we must use deep grounding, for example, 50 ft., then the minimum separation distance should be 100 ft. In such instances the only extra cost is for some insulated No. 6 conductor--a relatively small cost compared to the rest of the installation and the losses imposed or incurred by farmers who have experienced extraneous voltage problems.

(2) Yes, I believe rules are required regarding primary grounding practices. Too many utilities insist on meeting just the NESC minimum requirements of four grounds per mile. A common question is related to which grounds may be counted in meeting Code requirements. Does a transformer ground serve the same function as a grounding electrode and does it count as one of the required four grounds per mile? Or, is a transformer ground a customer service ground which the NESC does not allow to be counted in meeting the minimum rule of four grounds per mile? Are guy wires acceptable grounding conductors? Can they be counted in meeting NESC requirements?

In too many instances, I have found utilities relying solely upon guy wires, guy anchors, and transformer location grounds to meet the requirements of four per mile. My interpretation of the Code is that neither of these satisfactorily and completely meets the letter of the law or the letter of intent of the NESC. Obviously, there are those who disagree with my opinion. I do believe the rules should require a higher level of grounding than the NESC, particularly on new construction and on those locations where problems have been identified.

Additionally, like the NRECA rules for grounding, the location of grounding electrodes at the poles should be specified. In too many instances the ground rods appear to have been placed in the same hole as the pole. This makes installation easy, but it does not provide for as efficient or as functional a ground rod. The NRECA requirements for grounding specify that the ground rod shall be at least two feet away from the pole. I have seen numerous installations where utilities have driven multiple ground rods within 6 - 15 in. of each other. Such exercises are futile at best and have done little or nothing to improve the overall characteristics of the grounding system. Thus, more specific guidelines or rules as appropriate are required.

(3) Common sense dictates that the primary system not be located directly adjacent to a barn or a well. While it is true that the secondary system service drop should be kept short to limit voltage drop, locating a transformer adjacent to a well or a barn significantly increases the risk that voltage or current from the primary system will be fed back onto the farm grounding system via the soil. Such installation practices make any subsequent mitigation procedure more difficult to install and employ. It would seem reasonable that a minimum separation distance of perhaps 50 or 100 ft. would be in order in most situations. Conversely, it should be written that if, in fact, a closer location is chosen and it is subsequently found that voltages are feeding from the primary onto the secondary system, the utility would be obligated to move or relocate the service without a substantial amount of fuss or delay.

(4) There is reason to establish guidelines regarding the use of primary underground wiring with a bare concentric neutral. This, of course, is a desirable type conductor for utilities so long as its integrity can be maintained since it does provide substantial contact area and is beneficial in dissipating ground currents. However, in at least one instance, which was cited earlier as an example, the underground primary with bare concentric neutral did cause a problematic current flow through the free-stall barn and the milking parlor. It was only through elimination of that underground conductor and return to above-ground conductors that the problem on this farm has been eliminated. Thus, while this type system is appropriate in some locations, the utilities must be willing and perhaps even obligated to work with producers to relocate or reconstruct sections of line where it can be shown that such conductors are contributing to problematic voltages or currents. Additionally, the utilities should be obligated to assist in testing to determine whether such conductors are providing a source of problems by being willing to disconnect or discontinue on a temporary basis the use of such conductors and re-routing of current or loads through alternative wiring systems.

(5) I have not seen any documentation nor have I been able to confirm through field studies that transient voltage level changes, i.e., voltage spikes, associated with the start of a motor cause any significant problem with dairy cattle or other livestock. As I often tell dairymen, however, if the milk pump which operates and starts/stops repeatedly during milking is causing a problematic voltage in the animal environment, it must be changed. Although there are those who differ with my opinion, I do not presently believe voltage spikes which occur only at random and with relatively infrequent occurrences and last for one cycle or less are cause for concern. However, where it has been shown that elimination of these spikes or transients will reduce a problem for dairy cattle or other livestock, then appropriate modifications to the system should be installed or made. In many instances, I believe voltage spikes are the result of the starting and stopping of equipment on adjoining pieces of property and that the primary neutral merely serves as a conduit for transmittal of those spikes, i.e., the primary neutral is not the source, per se.

I am not adequately informed about the various alternative systems available to mitigate such transient voltages from the primary system. Thus, I am not in a position to make specific recommendations regarding what standards ought to be used beyond those already made.

Prepared and Submitted by:

Gerald R. Bodman, P.E.

Gerald R. Bodman, P.E.
AGRICULTURAL SYSTEMS ENGINEERING

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

Gerald R. Bodman, P.E.

Date 6/19/92 Registration No. 17197

AGRICULTURAL SYSTEMS ENGINEERING

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Farmstead Engineering, Livestock Housing
Manure Management, Ventilation Systems
Mastitis Control, Grain Handling/Storage
Electrical Systems, Extraneous Voltage
Milking System Design/Evaluation

BIOGRAPHICAL SKETCH
Gerald R. Bodman, P.E.

Position

Associate Professor and Extension Agricultural Engineer--Livestock Systems
Department of Biological Systems Engineering, University of Nebraska--Lincoln

Owner/Engineer
Agricultural Systems Engineering, Lincoln, Nebraska

Education

B.S.	Agricultural Engineering	1966	The Pennsylvania State University
M.S.	Agricultural Engineering	1968	The Pennsylvania State University

Professional Work Experience

Associate Professor and Extension Agricultural Engineer--Livestock Systems, University of Nebraska: 1978-present
Private Consultant, Agricultural and Structural Engineering, self-employed (part-time): Space Preceptors Associates, 1970-1991; Agricultural Systems Engineering, 1991-present
Assistant Professor and Extension Agricultural Engineer, The Pennsylvania State University: 1971-78
Home Builder/Remodeling, self-employed: 1970-71
Engineer and Construction Supervisor, New England Pole Builders, Inc., Ludlow, Massachusetts: 1968-70
Instructor, Department of Agricultural Engineering, The Pennsylvania State University: 1966-68
Irrigation System Designer/Salesman/Operator, self-employed: 1964-67

Professional Registration

Registered Professional Engineer (Agricultural and/or Structural): 31 states
Licensed Land Surveyor

Professional Organizations

American Society of Agricultural Engineers
National Society of Professional Engineers
Nebraska Society of Professional Engineers
American Society of Heating, Refrigeration and Air-Conditioning Engineers
Northeast Dairy Practices Council
National Mastitis Council
American Dairy Science Association
International Association of Electrical Inspectors
Lincoln Open Forum Club (President, 1986)

Professional Honors

1990 *Packer Engineering Safety Award*, American Society of Agricultural Engineers (Farm wiring educational program; shared with L.E. Stetson)
1986 *Livestock Service Award*, Walnut Grove Feeds and University of Nebraska
1984 *International Who's Who in Engineering*, International Biographical Centre
1983 *Excellence in Extension Programming*, University of Nebraska Cooperative Extension Service (Solar livestock housing, extraneous voltage and mastitis control educational programs)
1982 *Young Extension Man of the Year*, American Society of Agricultural Engineers
1982 *Excellence in Extension Programming*, (team award), Epsilon Sigma Phi, Mastitis Control TEAM--Bodman, Rice, Kubik and Cole
1982 *Excellence in Extension Programming*, (Honorable Mention, team award), University of Nebraska Cooperative Extension Service, Mastitis Control Program TEAM--Bodman, Rice, Kubik and Cole
1981 *Men of Achievement*, International Biographical Centre
1980 *Who's Who in the Midwest*, Marquis
1980 *Who's Who in Engineering*, American Association of Engineering Societies
1975-Present: 22 Blue Ribbons, Educational Aids Competition, American Society of Agricultural Engineers

Publications

Author of over 450 technical and popular journal articles and papers
Over 1,000 news releases, TV shows and/or radio spots prepared

Primary Extension Programs

Farmstead Engineering
Livestock Housing (structural, ventilation)
Manure Management
Mastitis Control Program for Dairymen (milking systems, milking procedures, extraneous voltage, housing)--team leader since 1986
Farmstead Electrification
Solar Heating of On-Farm Livestock Structures
Grain and Crop Drying and Storage

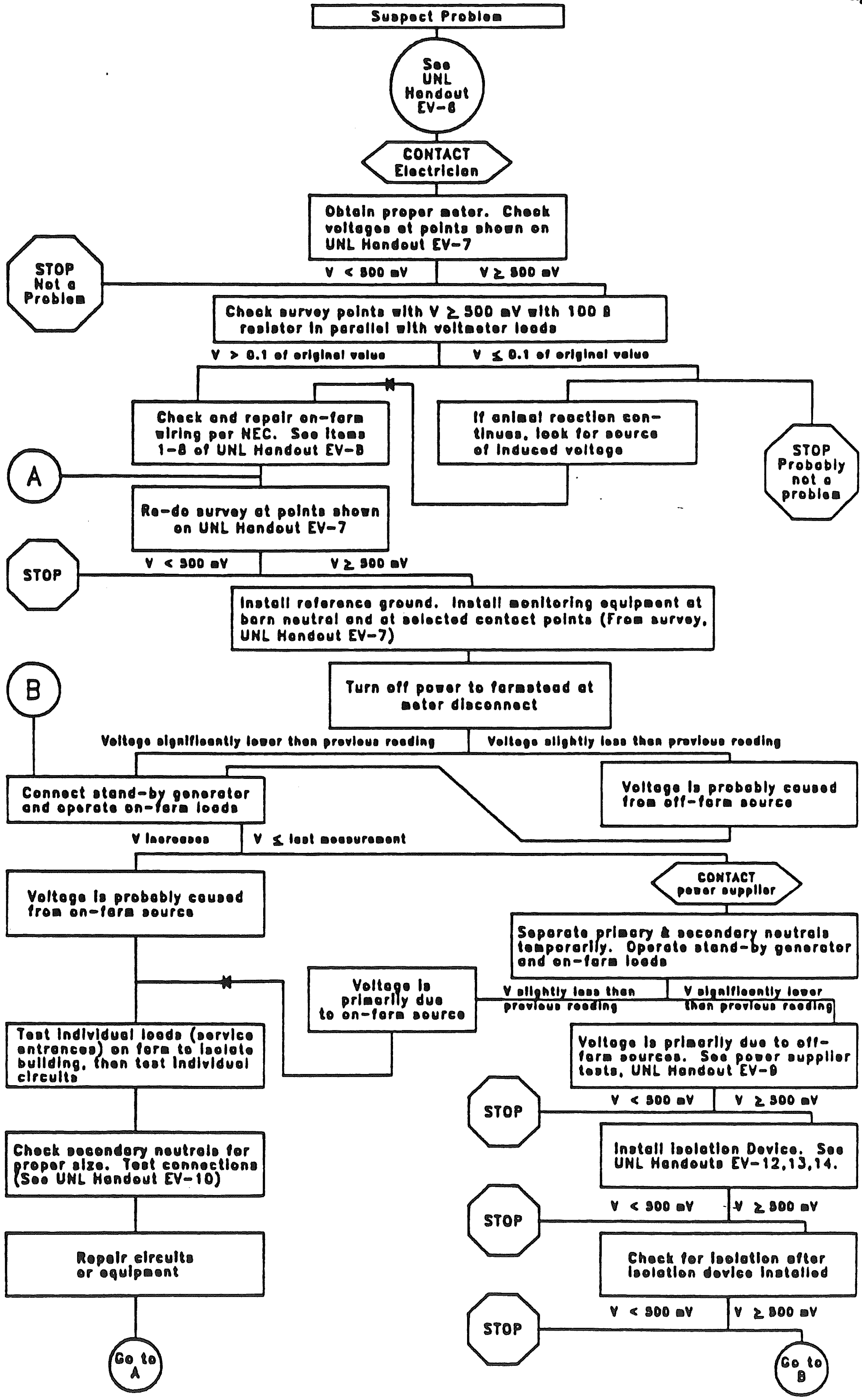
Background

Born and raised on farm, Catawissa, Pennsylvania--dairy, potatoes, swine, general crops, chickens
4-H member, 12 years--completed over 100 projects

Other

Licensed Pilot (Private Certificate, Instrument Rated)
Member, Aircraft Owners and Pilots Association
Blood Donor, Lincoln Community Blood Bank (72 pints)
Eastridge Presbyterian Church (Deacon; Board of Trustees [Chairman 1988 and 1989]; Stewardship Committee; Coordinator--adult discussion/current issues class; Commodore Mariners [Skipper 1986])

EXTRANEOUS VOLTAGE
FLOW CHART FOR DIAGNOSTIC PROCEDURES



Prepared by L.E. Stetson and G.R. Bodman R0189

EXTRANEOUS VOLTAGE PROBLEMS
PRODUCER'S CHECKLIST

by

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Terms like extraneous voltage, transient voltage, low voltage, stray voltage, and tingle voltage are used interchangeably to describe electricity present on "grounded" metal objects on the farm. Although precise definitions vary, they all generally refer to any "out of place" voltage on the farmstead.

Electricity present on "grounded" metal objects in any building, including houses, can be called extraneous electricity or extraneous voltage. The term voltage is often used to describe electricity because one of the ways to measure electricity is to measure its potential or voltage from some reference point--usually ground. Farms, and particularly dairy farms, are the usual places where extraneous voltage can become a problem because dairy farmers and cows are, at least twice each day, in contact with metal objects and surfaces such as stanchion pipes, milklines, vacuum lines, gutters, and milk claws.

Extraneous voltage is sometimes difficult to eliminate because there are many possible sources for it. Faulty electrical equipment such as motor windings shorting to the frame of the motor, a bare pulsator wire touching the vacuum line, or a heating element in a water heater shorting to the tank are some possible sources. Unbalanced 115 Vac electrical loads on your 230 Vac service in the barn may cause the neutral voltage to be excessively high. One to 10 volts is considered high, especially if measured during milking. Insufficient or improper grounding of electrical boxes and equipment may be a source of extraneous voltage. Accumulations of dust and dirt in and around electrical equipment may become sources for extraneous voltage during rainy or high humidity weather.

With all of the possibilities for extraneous voltage, a dairy farmer needs help. He has three main options for help if he thinks he has a problem. He can call:

1. A qualified, licensed electrician
2. His milking machine dealer
3. The electric power supplier

An electrician would be responsible for the distribution of ac power on the farm. Milking machine dealers are responsible for the equipment they install, and the power supplier usually accepts responsibility for its power distribution network up to the meter. Two additional handouts outlining procedures for electricians (EV-8) and procedures for power suppliers (EV-9) are available from the UNL Department of Agricultural Engineering.

Electrical equipment must be properly installed and maintained to avoid problems. Follow the Producer's Checklist to determine if your electrical equipment needs to be serviced. A check in the "yes" column means some type of repair or service by a qualified, licensed electrician is required.

Adapted from similarly titled Wisconsin Fact Sheet.

0982, R0786, R0189

CHECKLIST

	Yes*	No
Service Entrance Farm - Power Pole		
Connection to the ground rod--loose, corroded	____	____
Covers loose	____	____
Excessive rust	____	____
Barn Service Entrance		
Ground rod missing at the service entrance	____	____
Connection to ground rod--loose, corroded	____	____
Covers loose	____	____
Excessive corrosion	____	____
Wet or damp areas	____	____
Large accumulation of feed dust in or on service entrance box	____	____
Milkhouse		
Excessive corrosion on electrical boxes and conduit	____	____
Water on or in electrical boxes	____	____
Covers missing or open on electrical boxes	____	____
Wires laying in water	____	____
In the Parlor or Around the Barn		
Pulsator wiring - pinched wires	____	____
- loose, hanging wires	____	____
- scrapes, breaks or cracks in insulation exposing the conductors	____	____
- broken stall cocks	____	____
- wires taped to or wrapped around metal pipes, conduits, etc.	____	____
Badly corroded conduit or electrical boxes	____	____
Wires laying in damp or wet areas	____	____
Electrical boxes missing covers	____	____
Loose, hanging wires	____	____
Broken or bent conduit	____	____
A General Review of All Farm Electrical Equipment and Service		
Frequent fuse blowing (or circuit breakers tripping)	____	____
Ground rod missing or wire missing or loose at service entrance to _any_ building	____	____
Lights dimming when motors start	____	____
Badly corroded electrical boxes or conduit	____	____
Wires, electrical boxes, or motors in wet or damp areas	____	____
Accumulation of dust on or around electrical equipment	____	____
Bent or broken conduit	____	____
Scraped wire insulation exposing conductors	____	____
Insulated wires wrapped around metal pipes, conduits, etc.	____	____
Extension cords (cracked insulation, lamp cords)	____	____
Electrical boxes missing covers	____	____
Loose, hanging wires	____	____
Motors operating irregularly under load, sparking, etc.	____	____
Electrical receptacles without grounding terminal	____	____

*A "yes" checkmark indicates a potential problem. In most instances, a qualified electrician should be contacted for repair or replacement of electrical equipment.

EXTRANEOUS VOLTAGE
DATA SHEET FOR PROBLEM IDENTIFICATION

Date: ______________ Producer Name: ______________________________
Address: ______________________________
Phone: ______________________________

EXTRANEOUS VOLTAGE CHECK

Entrance: size _______ amps Location: ______________________________

Grounding electrode: Material (ground rod, water pipe) ______________________________

Location: ________________ Condition: ______________________________

Type connector (wire to electrode) ____________________ Wire size: _____________

Transformer: Location ______________________ Distance from milking center _____ ft

General condition of wiring and equipment (old, new well-done, corroded, professionally wired, piecemeal). Describe: ____

____

VOLTAGE CHECK:

	Milking System				
	Operating		Non-operating		Voltage w/
Checkpoints	mVac	mVdc	mVac	mVdc	100Ω resistor**
Bulk tank to floor	_____	_____	_____	_____	_____
Bulk tank to floor drain	_____	_____	_____	_____	_____
Feeders to grates*	_____	_____	_____	_____	_____
Feeder to rear rail*	_____	_____	_____	_____	_____
Floor to rear rail*	_____	_____	_____	_____	_____
Grates to rear rail*	_____	_____	_____	_____	_____
Grates to claw*	_____	_____	_____	_____	_____

*Note location (e.g., north side, 2nd feeder from west)

____

Claw to floor with milk in line _______ mVac _______ mVdc _____

Milk pump to floor base _______ mVac, peak _______ mVdc _____

Waterer: Front feet support to tank _______ mVac _______ mVdc _____

Front feet support to water _______ mVac _______ mVdc _____

** At any location where voltage exceeds 500 mV during initial check, re-check with 100Ω resistor shunted across voltmeter leads.

Prepared by L.E. Stetson and G.R. Bodman, 0983, R0786, R0189

EXTRANEOUS VOLTAGE PROBLEMS
SUGGESTED PROCEDURES FOR THE ELECTRICIAN

by

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Many dairymen have been successful in eliminating extraneous voltage problems. Others have at least reduced the severity of their problems. But the causes of extraneous voltages often are difficult to locate. This can be very frustrating, since the condition may exist even with no electrical faults. In these cases, it requires the cooperation of the power supplier because its solution may involve an alteration in the system.

The response of dairy cattle to corrective measures will vary considerably. An immediate, dramatic response is probable if a severe problem is completely solved. However, a more gradual improvement is likely with some cows or some herds depending on severity of the problem, degree of solution, and individual characteristics of the animals. The mammary glands of cows affected by extraneous voltages may have become infected with mastitis and, depending on severity, both production and milking characteristics could be permanently hampered. Experience indicates some cows respond more rapidly than others. Also, there is some indication that once some cows have been subjected to a severe case they may remain fearful of extraneous voltages and exhibit some of the symptoms after the solution has been implemented.

Voltage measurements should be made at cow contact points (UNL Handout EV-7), such as stanchion to floor grate, feeder to floor grate, waterers and/or locations where the dairyman has noted animal response. If voltages in excess of 500mV are found, the test procedure (Page 2) should be utilized to locate the source of the problem. If the test procedures indicate a problem exists, corrective actions should be taken as outlined in the ten steps given below.

1. Make sure all service entrances are properly grounded in accordance with the NEC.

2. Establish and maintain good neutral circuits and connections. Heavy use, high humidity, corrosive silage acids, urine and manure make dairy farms poor environments for electrical wiring and equipment.

3. Look for faulty equipment that may have leakage currents by measuring the current draw of operating equipment and checking the currents in the ground and neutral wires.

4. Balance as well as possible the line-to-neutral (115-volt) loads on the barn service entrance in operation during milking.

5. If possible, convert all motors to 230-volt operation. If 115-volt motors are used, they should not be starting and stopping during milking. When 115-volt motors start, the high starting current flows in the secondary neutral. The voltage drop resulting from this momentarily large current increases the neutral-to-earth (N-E) voltage at the barn. Also, check the 230-volt motors to ensure that the starters operate at 230 volts. If not, the motor starters should be changed and rewired for 230-volt operation.

6. If the problem is creased by excessive voltage drop in the secondary neutral and better balancing of 115-volt loads is not feasible, install a larger diameter neutral wire to reduce its resistance.

7. Ground all electrical equipment such as manure pumps, silo unloaders, water heaters, and pumps to the service entrance ground. Use large wire (number 10 or larger). Insulation is not needed on these grounding wires. Spot weld or use pressure clamps rather than soldering or wrapping connections.

8. Check wiring in all sub-panels and control panels to assure that the neutral has not been bonded to grounds or used for equipment grounding.

9. Provide adequate power circuits. Too many services become overloaded as more and larger equipment is installed.

10. If the former measures have not eliminated the extraneous voltage problem, the installation of an equi-potential plane in the floor of the dairy parlor or barn should be considered. For further information, see UNL Handout EV-11, 19-21.

TEST PROCEDURES

Voltmeter used: Make ________________ Model ______________ Name ______________________
Ammeter used: Make ________________ Model ______________ Date ______________________

PROCEDURE	RECORD OF RESULTS	INTERPRETATION
Step 1. Establish a reference ground rod at least 25 ft from the barn. Connect the voltmeter between this ground rod and the barn service entrance grounding conductor. Read the N-E (neutral-to-earth) voltage.	Voltmeter Reading (AC volts) / Time ______________ ____ ______________ ____	The voltmeter will now read the N-E voltage at the barn. This voltage is measured rather than voltages in the milking area itself because generally it is the maximum which would be expected between any two points in the milking area, unless a fault exists.
Step 2. N-E voltage without the barn load: Open the main disconnect at the barn service entrance. If the N-E voltage in Sept 2 is low (below 0.25 volt), skip Steps 3 and 4 and go to Step 5.	Voltmeter Reading __________________	No load is operating in the barn at this time. However, the neutral to the barn is not disconnected. Any voltage in the barn at this time is being transmitted to the barn through the neutral or grounding system and originates somewhere else.
Step 3. Removal of loads from other farm buildings: Leaving the main disconnect at the barn open, record the N-E voltage at the barn after opening each of the other service entrances on the farm. Leave the service disconnects open until all have been disconnected.	Service Disconnected / Voltmeter Reading __________ __________ __________ __________ __________ __________ __________ __________ __________ __________ __________ __________ __________ __________	After each service entrance is disconnected, the N-E voltage at the barn should drop slightly if there are any loads operating on that service entrance. If the voltmeter reading at any step is relatively high (above 0.5 volts) and drops to a much lower value (less than 0.2 volts) when the service entrance is disconnected, the loads on that service entrance should be checked out later. This drop in voltage could be caused by a faulty or heavy load on that service entrance at the specific time.

Step 4. Complete removal of farm load. Open the main disconnect to the farm and record the N-E voltage at the barn. Be sure the well is also disconnected if it is powered ahead of the main disconnect. After Step 4 is completed, reconnect the main service and all the building services.

Voltmeter Reading

The voltage recorded at the barn when all services are open is due to N-E voltage on the primary neutral created by loads at other locations on the main distribution system. When the main disconnect is open, the voltage reading should be the same as when all building services were disconnected.

Step 5. Checking 230-volt loads in the barn: Place a clamp-on ammeter around the neutral to the barn service. Be sure no 115-volt loads are added or dropped during this test. Record the voltmeter and ammeter reading after each of several 230-volt loads are added to the previous load. Also read the voltmeter and ammeter as each load is turned off in reverse sequence.

Load Added	Voltmeter Reading	Ammeter Reading
None		
None		

The increase in neutral-to-earth voltage as each load is added is due either to the increase in primary N-E voltage as a result of the increased load or to faulty equipment on that circuit. If any 230-volt load causes a current flow in the secondary neutral to the barn (as indicated by the clamp-on ammeter), it is a result of interconnected 115-volt loads or grounded faults in the equipment. Very slight changes in neutral current may be detected as a result of the increased N-E voltage forcing some current through the electrical system grounds at the barn. These will be very small and are not an indication of ground faults in the equipment.

Step 6. Checking 115-volt loads in the barn: Open all 115-volt circuits in the barn. Record the voltmeter and ammeter readings as each of the 115-volt circuits is reconnected and the loads on that circuit are operating.

Carefully observe the effects of starting and stopping 115-volt motors. They can cause serious N-E voltages when starting.

Circuit Number	Loads	Voltmeter Reading	Ammeter Reading

The secondary neutral current to the barn (read by the clamp-on ammeter) and the N-E voltage readings will increase and decrease as the unbalanced load on the secondary neutral to the barn changes.

If the N-E voltage increases significantly (perhaps 0.3 volts or higher) with a maximum unbalanced load on the barn neutral, the voltage drop in the neutral may be causing problems. The problems may be a high neutral resistance created by poor connections or the resistance of the wire itself. Improving connections, better balancing of the line-to-neutral loads, and/or a larger neutral wire may help relieve the problem. Making sure the current in the barn neutral is minimized during milking (by selection of off-setting 115-volt loads) may help solve the problem.

It is possible for the N-E voltage to decrease with an increase in secondary neutral current. This is caused by the voltage drop in the secondary neutral counteracting (subtracting from) the primary N-E voltage. This occurs when the unbalanced current is created by loads on the 115-volt leg that is 180 degrees out of phase with the primary voltage.

Step 7. Circuit checks for other farm buildings: If in Step 3 one or more of the other building services seemed to produce an excessive voltage, repeat Steps 5 and 6 for that building.

Step 8. Milking time monitoring: Have someone watch the voltmeter throughout the milking time and periodically record the readings, both the peak values and static (steady) values. (You will probably require additional space for recording this data.)

Peak	Voltmeter Reading Static	Time

Pay particular attention to major changes or fluctuations in the readings. These may occur rapidly and may last only a short time. Close attention is necessary to observe these changes. Starting of motors is the most common cause of short-term peaks (observe reading when milk pump starts). If voltages above 1.0 V are present during milking, some corrective action is necessary. If voltages in the 0.5 to 1.0 V ranges are present, the N-E voltage should be continuously monitored and some corrective measures may be necessary. If the symptoms persisted and voltages above 0.5 V are not present, the N-E voltage should be monitored to see if it is periodic due to weather, soil moisture conditions, or other systematic fluctuations.

Step 9. Isolated System Testing: If completion of Steps 1-8 has not resulted in the identification of the extraneous voltage problem, joint tests with serving power supplier and telephone utility are required. Step 1 above should be repeated after the utilities have isolated the service neutral from the primary neutral and any other connection which might defeat this isolation. A common shunt path is through normal telephone cable shielding. The telephone company can easily determine if this condition exists and change it.

Step 10. If isolation significantly reduces the N-E voltage at the barn, the power supplier should be requested to investigate the extraneous voltage present on the distribution primary or on other service drops served from the same transformer.

EXTRANEOUS VOLTAGE PROBLEMS
SUGGESTED PROCEDURES FOR THE POWER SUPPLIER

by

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GENERAL

These operating instructions are intended to provide a utility with a recommended procedure to utilize when investigating an extraneous voltage complaint. All information and readings should be recorded with appropriate documentation including the date, time, location, instruments utilized, and personnel conducting the investigation.

PRELIMINARY INFORMATION

1. History of Problem

   Interview the consumer to acquire the following information:

   a. Why he believes he has a problem.

   b. History of the problem (including any previous problems or investigations).

   c. Dates, time, values, and locations of any measurements he has made, including notes whether they were transient or steady state.

   d. Obtain a copy of the completed "Producer's Checklist" (UNL Handout EV-6) or supply a copy of that form to be completed.

   e. Obtain a copy of the report of any investigation made by a qualified electrician. If the report is not adequate, a copy of UNL Handout EV-8, "Extraneous Voltage Problems--Suggested Procedures for the Electrician" should be supplied.

   f. The dates of any electrical or equipment modifications/additions made to his system.

2. General Inspection

   Conduct a general inspection of the electrical service facilities. This inspection should include:

   a. A simple sketch showing the location and number of services, transformers, ground rods, etc.

   b. Check for adequacy of farm electrical grounds, loose connections, damaged equipment, and other items that may lead to inadequate service.

Adapted from similarly titled Wisconsin Fact Sheet.

LES & GRB, 0982, R0189

VOLTAGE MEASUREMENTS

The following voltage measurements should be made, preferably when the electrical load is at a relatively high level. A high impedance digital voltmeter should be used. However, if the problem is transient in nature, the voltmeter will probably not detect the voltage. An oscilloscope is preferred and might be required to detect transient voltages.

1. Neutral to Reference Ground

Voltage measurements (ac) should be taken from the neutral connection at the service entrance of the building or service in which a problem is suspected to a ground rod driven at least 50 ft from the building and at least 6 ft away from any other underground metallic structure, pipe, etc. These measurements should be taken with a meter both with and without a 100-ohm shunt resistor on the meter to help distinguish the magnitudes of any potential problem. (Note: The 100-ohm resistor will aid in distinguishing between low current producing induced voltages and voltage sources having a sustained current producing capability.) It should be noted whether the meter used can block the measurement of dc voltages and during which measurement the meter was "loaded" or "unloaded" with the shunt resistor. If a voltage in excess of 500 mV is obtained, repeat the measurement as the tests in "Tests to Locate Source of Problem" are performed.

2. Contact Points

Voltage measurements should be taken between cow contact points such as stanchion to floor grate, milkline to floor grate, milkline to stanchion, and from these locations to the reference ground. (See UNL Handout EV-7 "Extraneous Voltage--Data Sheet for Problem Identification.")

TESTS TO LOCATE SOURCE OF PROBLEM

1. De-energize Service

De-energize the service to the farmstead by opening the transformer cutout. If the neutral to reference ground voltage drops significantly, further investigation of the farm premises' electrical service and equipment should be undertaken. If it does not decrease below 500 mV, there may be a problem both on and off the premises.

2. Isolate Neutral

If the voltage remains after the service has been de-energized, isolate the secondary neutral and telephone shield (grounded conductor) from the primary neutral. When this test is performed, it is important that a telephone company representative be on-site for isolating the telephone shield and identifying telephone wiring which may need changing to allow complete separation of the neutrals. If the voltage then disappears, the cause may be a poor neutral connection, poor grounding on the neutral in the area, or problems on a neighboring farmstead. If it does not, go to Test Number 5.

3. Neutral Connections

If a poor neutral connection is suspected, all such connections along the distribution circuit for at least one-half mile should be checked. (See UNL Handout EV-10, "Extraneous Voltage--Evaluating Electrical Connections.") Currents along the neutral and into or out of driven ground rods can be measured with a suitable clamp-on ammeter to help locate problems. However, the direction of current flow cannot be determined with such instruments used independently. Any poor or suspect neutral connections should be replaced. After this has been done, the system and service neutrals should be reconnected and voltage readings taken.

4. Grounding

If the voltages still exist, the distribution system grounding in the area should be checked and improved as necessary. The resistance of grounds should be measured. The resistance of any high resistance ground should be improved by "stacking" ground rods or by adding additional ground rods in parallel. The on-farm voltage readings should be monitored to see if the grounding improvements are making any positive significant difference.

5. Neighboring System

If the voltage problems still persist, the problem may be due to a faulty piece of equipment on a neighboring consumer's premises. This can be checked by monitoring the neutral-to-ground voltages while nearby consumers' services are disconnected. The service to the consumer with the problem should be restored to normal before this test is made.

6. Other

a. If the problem still persists, a check should be made to determine if there is a transmission line in the immediate area that may be inducing a voltage on metal structures or fences connected to the barn. If this appears to be the case, the utility owning the transmission line should be contacted for assistance in solving the problem. Grounding of the metal structures or fences may be necessary.

b. If any or all of the above tests or checks indicate that the problem is on the consumer's premises, he should be advised to obtain the services of a competent, licensed electrician to inspect, update, and correct his wiring.

- electric fence wires or faulty equipment shorting directly onto pipes or other equipment
- undersized neutral conductors
- dusty, dirty, corroded, cobwebbed and damaged electrical connections and devices
- lack of grounding or poor water well connections
- missing ground rods
- improperly grounded cow trainer or fencer unit

CAUTION: Be careful to shut off the power and avoid contacting energized parts of equipment while making these checks.

Get outside help

If you want help taking measurements or can't identify the stray voltage cause, you should consult your electrician, local utility and/or county extension agent.

You can also obtain a stray voltage electrical check sheet from DATCP or PSC to record initial stray voltage measurements.

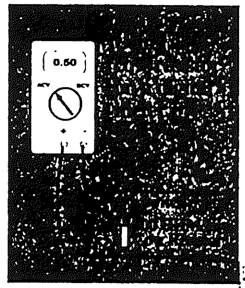
Your utility will conduct investigations to determine whether stray voltage is present. During this investigation, they may find something that you overlooked. All utilities have trained representatives that conduct stray voltage investigations.

CAUTION: Due to potential safety hazards, especially near the utility's primary (High Voltage) facilities, you should not check or test on the source side of the service entrance. Instead, rely on the utility to make or assist with such tests.

If they find stray voltage, they will offer recommendations to help you reduce the levels present. It can be as simple as rewiring a switch or more involved, like installing equipotential planes and transition zones. Many utilities also have financing plans to help you cover installation costs of these devices.

You should also install a meter in the cow contact area of each livestock facility, so you can measure stray voltage over longer periods of time and monitor changes as they arise. View the electrical system as another piece of farm equipment that needs to be monitored and periodically maintained. Monitoring the voltage (cow contact or neutral-to-earth) will allow you to note any substantial changes. Contact your local utility for more information on stray voltage meters and installation instructions.

As a general guide:



measurements made with a 500 ohm shunt resistor that are above 0.5 volts AC, or one milliamp AC, require corrective action — call your utility or electrician ; and levels below 0.5 volts AC should continue to be monitored

Make your farm stray voltage - safe

You can make your farm stray voltage safe by controlling both on-farm conditions and asking your electric utility to control off-farm conditions.

On-Farm You Can

- improve wiring and grounding: improper or outdated barn wiring can be a cause of stray voltage
- have a qualified, trained electrician inspect your wiring regularly for poor connections and load balance
- install stray voltage meters in each livestock facility
- maintain electrical equipment and supply wiring for items such as water pumps, water heaters, bulk milk tanks, milking equipment, silo unloaders and manure handling equipment
- use 240 volt equipment whenever possible
- when making changes to your electrical system, such as adding load or updating equipment, contact your utility — they may need to increase capacity of their system to assure continued adequate services
- make sure cow trainers and fencer units are properly insulated and grounded (handouts are available through the PSC on proper wiring of these devices)

Off-Farm

- have your power supplier check incoming service lines — including electric, telephone, gas and cable TV systems
- look for neighboring electric fences that may be shorting directly onto your farm

Remember that your electrician and utility want to help you, so don't be afraid to ask for their assistance.

Don't give up!

If after working with your utility, electrician and county extension agent, you are still unable to pinpoint the problem, the state's Stray Voltage Analysis Team (SVAT) may be able to help.

The SVAT is composed of an electrician, electrical engineer, farm management consultant and veterinarian. They can visit your farm and analyze any problems that may be associated with stray voltage.

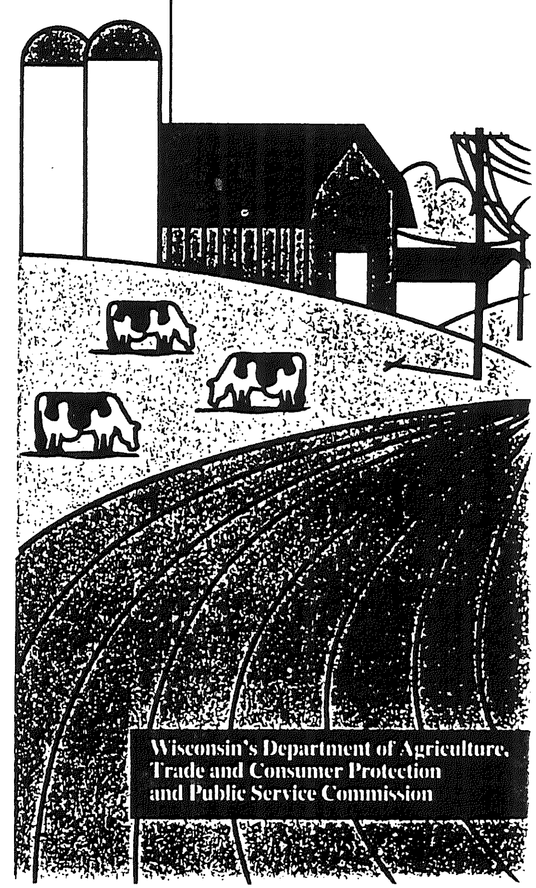
If you think you have a stray voltage problem on your farm and haven't been able to resolve the problem, request an application.

Stray voltage assessment applications are available through Wisconsin's DATCP Stray Voltage Program, P.O. Box 8911, Madison, WI 53708 or by calling the Farmer's Assistance Hotline at 1-800-942-2474.

Wisconsin Department of Agriculture
Trade and Consumer Protection Division
Madison, Wisconsin 53708

DATCP 10/90

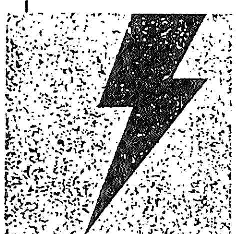
Guide to Identifying Stray Voltage on Your Farm



What is stray voltage?

Electricity is something you can't see, yet its effects can be seen almost everywhere you look. On your farm, it powers the lights, pumps the water, feeds the livestock, and cools the milk for storage. In general, it makes your daily chores a lot easier.

When electricity flows through the proper wiring and equipment on your farm, the voltage is said to be "within" the electrical system. Sometimes, however, voltage differences between two objects in the cow contact area may occur, causing what is known as stray voltage, or voltage outside the system. This is also referred to as tingle voltage and transient voltage, but the proper term is stray voltage.



The causes of stray voltage are often difficult to locate and may differ from farm to farm. Possible sources can be voltages from your own system, your neighbors' systems or your utility's system.

Stray voltage can never be totally eliminated, because it is present on all active, grounded electrical distribution systems. Its intensity can vary during the day and season, depending on moisture conditions of the soil and fluctuations of electrical loads on the system — such as during milking time. Never-the-less, stray voltage can be controlled so it doesn't cause a problem.

However, the difficulty is that stray voltage often goes unnoticed by humans; but can be detected by cows, because they are more sensitive. As a result, when a cow makes contact between an energized point and the earth — such as a feeder and the concrete floor — an electric current flows through the cow, and the cow gets shocked. In most cases, the voltage won't produce a strong shock, but it could still irritate the cow. The results of this irritation could produce negative side-effects for the cow — and for your farm.

There are some general guidelines, however, that you can follow to see if your farm operation is affected by stray voltage.

Wisconsin's Department of Agriculture, Trade and Consumer Protection (DATCP) and the Public Service Commission (PSC) offer these guidelines, so you can learn how to identify a possible stray voltage problem and what steps you can take to solve it.

What should you do about it?

Now that you know what stray voltage is, let's see if it is causing a problem on your farm.

Identify the problem stray voltage may be causing

If stray voltage is causing a problem, you might notice the following signs in your cows' behavior and milking characteristics. In addition, production performance can be affected as a result of altered behavior.

Behavior

- excessive or unusual nervousness at milking time such as kicking or tail switching
- cows must be chased into the barn or parlor and leave the barn rapidly
- increased defecation and/or urination during milking
- hesitation or refusal to approach certain waterers, feeders or metallic equipment
- "lapping" of water

Milking Characteristics

- poor milk letdown and incomplete or uneven milkout
- increased milking time

Production Performance

- increased somatic cell count and clinical mastitis
- decreased milk production

It is important to note, however, that the above signs may result from many other non-electrical farm factors. As a farm manager, you should investigate all possibilities, including cow handling methods, nutritional disorders, mastitis control methods, pesticide and herbicide use, sanitation and disease.

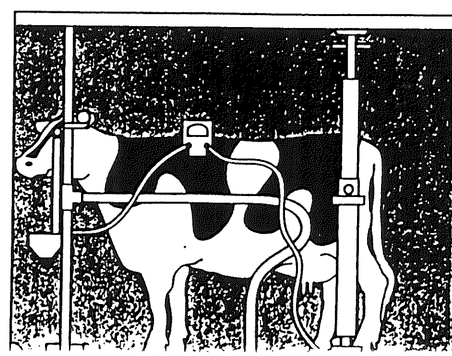
Finally, it should also be noted that just because your cows do not show any of these signs, it doesn't mean that stray voltage isn't present. Therefore, you should always monitor cow contact areas for stray voltage.

Identify the source of stray voltage

If you observe any of the above signs, the next thing you need to do is look for places where stray voltage could exist. Two pathways that stray voltage often follows are:

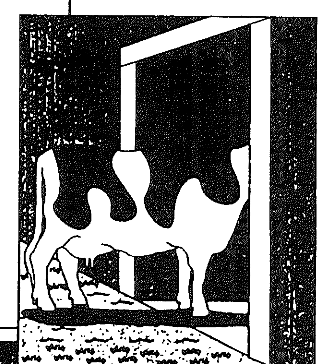
Mouth To All Hooves

- This is the most common pathway of stray voltage, because from the mouth to the hooves is where cows have the lowest resistance. Since resistance is low, the cow is sensitive to relatively low voltage. Depending on wetness, duration of contact and the level of voltage, stray voltage can be found wherever an electric current travels from a metal object — such as a waterer, feeder or stanchion pipe — through the cow to a grounded object — such as the floor. This path is a result of the potential electrical difference between where the cow's mouth is and where her hooves are. So, if the cow takes a drink of water, the current can travel from the water cup to the cow's tongue. Then it flows to the cow's feet, where it exits to the floor. When the current follows this path, the cow may receive a shock.



Front To Rear Hooves (Step Potential)

- This pathway has twice the resistance to stray voltage as mouth to all hooves, because hooves are naturally more resistant than a cow's tongue. It is found wherever there is a difference in the electrical potential where the cow is walking — like a doorway. Here, the cow's front hooves contact the higher voltage of the barn floor; while its back hooves touch the earth, so it may get a shock.



Once you find a place where stray voltage could follow one of these two paths, you should make measurements at various times to determine if stray voltage exists. If it does, you should look for evidence of a problem. Carefully examine your farm electric system for:

- loose or corroded neutral or bonding connections
- inadequately bonded metallic equipment