MN PLANNING

Stray Voltage

Report and Recommendations

of the Stray Voltage Work Group to the

Minnesota Environmental Quality Board

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EXECUTIVE SUMMARY

In late 1990, at the request of the Governor, the Minnesota Environmental Quality Board convened a work group made up of representatives of state agencies with past involvement or expertise in the area of stray voltage on dairy farms. The work group was given the task of assessing the stray-voltage problem and recommending an appropriate state response.

Stray voltages of sufficient magnitude to affect animal behavior, production, and/or health have occurred on at least 11% of Minnesota's dairy farms. This is a significant problem that can result in severe economic loss to individual dairy farmers. However, the programs now in place within the utilities and state government to deal with stray-voltage issues work reasonably well, since more than 99% of the stray-voltage complaints received by the utilities over a five-year period were reportedly resolved to the farmers' satisfaction.

The utilities have the primary role in investigating stray-voltage complaints and in correcting the problem if their equipment is at fault. It is the farmer's responsibility to correct any customer-owned defective wiring or defective farm equipment that is contributing to excessive stray voltage.

Where the problem is not resolved, several state agencies including the Departments of Agriculture and Public Service, the Public Utilities Commission, and the State Board of Electricity as well as the University of Minnesota Extension Service can provide technical assistance. In disputed cases where the farmer believes that the utility's equipment is at fault and the utility has not taken corrective action, a complaint procedure on the quality of electric service is available through the Public Utilities Commission.

There is a need among the utilities for more uniform investigative procedures and for better training of stray-voltage investigators. Uniform criteria, consistent with national guidelines, need to be applied on a statewide basis in the assessment of possible stray-voltage problems and for the application of corrective measures, particularly upgrading of distribution lines. Smaller utilities and utilities with few dairy farms in their service areas need to be able to draw on the expertise of utilities better equipped to deal with stray voltage to ensure highest quality investigations.

While a number of agencies have some responsibilities that relate to stray voltage, it does not appear reasonable to transfer responsibilities to a single agency or to designate one agency as a clearinghouse for stray-voltage complaints. There is a need, however, to make dairy farmers aware of the types of assistance available, such as the Public Utilities Commission complaint procedure.

On the farms where neutral-to-earth voltages are below apparent concern levels but symptoms suggestive of stray voltage persist, a number of possible causes and corrective actions need to be considered. A dairy herd consultant should be retained by the farmer to review production conditions. Defective wiring and equipment needs to be identified and corrected. Finally, research needs to be conducted to assess the impact of "non-traditional" sources such as direct current, ground currents, electromagnetic fields, and transients.

The work group's perception is that little additional regulatory framework needs to be established in order to effectively deal with Minnesota's stray-voltage issues. Existing agencies have authority now over most of the identified issues. Research and on-farm wiring are the notable exceptions. Some legislative or regulatory actions may be required in the future to expand the roles of these agencies, particularly if the voluntary actions proposed in this report to be taken by the agencies or by the utilities fail to materialize. Future published research may also suggest the need for additional regulation.

I. INTRODUCTION

In August 1990, the Governor requested that the Environmental Quality Board convene a meeting of representatives of state agencies that have been involved in or have expertise in the identification or correction of stray voltage on dairy farms and to provide recommendations on an appropriate state response to the stray-voltage issue. The Governor also requested a recommendation on what agency, if any, should have the lead responsibility in coordinating the state response.

A work group, formed as a result of the initial meeting of agency representatives in October 1990, has completed its investigation of stray voltage as it affects Minnesota dairy operations. This report summarizes the work group's findings, addresses the extent of the problem in Minnesota, assesses the electric utilities programs as well as individual efforts to eliminate stray voltage, and provides the recommendations requested by the Governor. The report focuses on stray voltage in dairy operations and does not consider the broader issues of low productivity.

II. WHAT IS STRAY VOLTAGE?

Many people have not heard about stray voltage or if they have, are not sure about a clear definition of the phenomenon. This text will attempt to provide a summary of what stray voltage is, how it manifests itself, and how it can be mitigated.

A definition of stray voltage is hard to come by. It is a multifaceted expression of electrical energy. The most comprehensive definition as it relates to the dairy farm is contained in a USDA draft manuscript on the subject.

"Stray voltage is a small voltage (less than 10 volts) measured between two points that can be contacted by the animal. Because animals respond to the current produced by a voltage and not to that voltage directly, the source of the voltage must be able to produce current flows greater than acceptable response levels for animals, when an animal ... touches both contact points."

The purposeful reference to low voltage values in the above definition is intended to separate this electrical manifestation from high voltages, approaching 110 volts, that result from incorrect wiring or equipment failures.

This definition points out that the voltage must exist in or around structures that the animal can contact. The definition also focuses on the fact that voltage alone cannot create a stray-voltage problem for the animal. To qualify as stray voltage, a flow of electrons through the animal must occur that is large enough to be detected by the animal or cause an unacceptable response from the animal.

A major contributor to contact voltage levels is the neutral conductor in the farm and utility electrical service. Electrical codes require that the neutral conductor of a farm service and the utility distribution line be electrically bonded to the earth through a "grounding electrode". Wiring codes also normally require that the utility neutral conductor and the farm neutral conductor be bonded together. In the real world the voltage developed on these neutral conductors and grounding system is never at the same voltage as the earth itself. Electrical resistances at many points on the two systems all work together to create small voltage levels on the neutral conductor. This is known as neutral-to-earth voltage.

All conduits, motor frames, and other electrical equipment enclosures on the farm are required to be connected to the farm grounding system. The grounding system becomes extensively distributed throughout a barn through milk lines, water pipes, light fixtures, and stanchions.

A discussion of how much voltage is acceptable on this neutral system is beyond the scope of this introduction. Elevated voltage levels on the neutral system may or may not be measurable at the animal contact areas.

Other potential contributors to contact voltage include faulty farm wiring or equipment, improper ground connections, electromagnetic fields, static charge buildup, improperly connected electric fencers, or faulty cow trainers.

Stray voltage is expressed in dairy animals by symptoms such as: elevated somatic cell counts, reduced water intake, nervousness, increased milking time, poor milk let-down, uneven milk out, reluctance to enter or leave building, and lowered milk production. Other factors in the animals' environment can also produce these types of symptoms. This is what complicates an analysis of an on-the-farm problem.

The techniques used to mitigate the stray voltage in the barn can be lumped into four categories.

These are: voltage reduction, active suppression, gradient control, and isolation of neutrals.

Voltage Reduction usually refers to troubleshooting the cause of the elevated neutral-to-earth or cow contact voltage. Action is then taken to eliminate the cause of the elevated voltage. This can be done through replacement of faulty equipment, cleaning of equipment and electrical connections, electrical load balancing, or improving the grounding system. This reduction process can be time consuming and requires a certain amount of skill in identifying the cause of the elevated voltage. The troubleshooting process can be done for both the farmer's and the utility's electrical system.

Active Suppression means using electronic equipment to create a voltage which is applied equal and opposite to the voltage on the neutral conductor. There are private firms offering equipment for sale to do this. Sufficient current is injected into the neutral system to cancel the measured neutral-to-earth voltages.

Gradient Control is a technique which attempts to reduce the voltage in cow contact areas by distributing the change in voltage levels over longer distances. The effect is a lowering of voltage differentials between contact points. An "equipotential plane" is the most common gradient control device. This is usually a grid of wires imbedded in the barn floor and connected to stanchions and other metal items in the cow area, that effectively ties all locations down to a common voltage level. Since there is little change in voltage values at contact points there is little potential for current flow through the animal.

Isolation of Neutrals refers to separating the bonding connection between the utility neutral conductor and the farm neutral conductor. This is usually done when it is suspected that the cause of the neutral-to-earth voltage levels in the barn is the utility distribution system. The disconnection of these two neutral systems makes the voltages developed on the utility "primary" system more independent of the voltages developed on the farm "secondary" system. Thus isolation is a way to try to remove a contributing factor to barn neutral voltage levels. In actuality the two systems are rarely left with an air gap between the conductors. Lightning protection and system fault protection make it prudent to tie the systems together with a switch-like device that acts as an open connection normally but automatically reverts to a closed connection under severe voltage conditions for safety. Commercially available isolation devices are designed for this purpose.

It should be recognized that an informed investigator is the key to effectively identifying the contributing factors to contact voltage levels and also to identifying the appropriate mitigative strategy.

III. STRAY VOLTAGE WORK GROUP

In response to an August 1990 request from the Governor, the Minnesota Environmental Quality Board convened a meeting of agencies with past experience or expertise relating to stray-voltage problems to provide the Governor with recommendations on the appropriate level of state response in resolving stray-voltage problems and to recommend a lead agency to coordinate the state's response. These agencies are the Public Utilities Commission, the Department of Public Service, the Department of Agriculture, the Pollution Control Agency, Minnesota Planning, and the Department of Health.

The agency representatives established an informal Stray Voltage Work Group, which initially met on October 12 and October 26, 1990. As a result of these meetings, it was evident that considerable information was needed to define the extent of the problem in Minnesota and to assess the effectiveness of utility efforts to provide solutions before attempting to develop recommendations. To this end, a detailed questionnaire was sent in December to all investor-owned and cooperatively owned electric utilities seeking historical information on each utility's experience with stray voltage.

In addition to the survey, public meetings were held specifically to hear statements from the electric utilities and from dairy farmers and other interested persons. The utility comment meeting was held in St. Paul on February 15, 1991, and the public comment meeting was held in St. Cloud on March 11, 1991. (The two previous meetings were also open to the public and were attended by dairy farmers, representatives of the electric utilities, interested persons and the press.)

The work group also consulted with the State Board of Electricity, the Stray Voltage Analysis Team established by the Wisconsin Public Service Commission, and private stray-voltage investigators.

The results of the utility survey, public and utility comments, and a review of the available literature serve as a basis for the recommendations and observations contained in this report.

IV. STRAY VOLTAGE SURVEY

The following highlights some of the findings of the Minnesota Utility Stray Voltage Survey conducted by the Stray Voltage Work Group. A complete summary and tabulation of results is found in Appendix A.

The survey provides some insight on the extent of the stray-voltage problem on dairy operations in Minnesota although responses do not allow a precise estimate of the number of farms with confirmed stray voltage. The electric utilities report that they conducted 3,533 new investigations on dairy farms during the five year survey period where herds exhibited symptoms suggestive of stray voltage. This represents about 23% of the state's 15,174 dairy farms in operation in March 1991 as reported by the Minnesota Department of Agriculture. (The Department also reports that the number of dairy farms decreased by about 5,000 during the five year survey period.) In responding to the survey, the utilities listed 25,763 dairy farms in their respective areas, an overstatement of 70%.

In addition to the dairy farm investigations, the utilities reported 992 stray-voltage investigations on other livestock operations. The majority of these investigations, or a total of 896, were reported by Otter Tail Power Company of Fergus Falls.

A total of 1,180 of the investigations were reported positive for stray voltage. This number, however, is misleading. Otter Tail Power reported 897 new dairy investigations while reporting only 300 dairy farms in their service area. The work group was unable to resolve this discrepancy with the information available. Further, Otter Tail Power did not respond to the question of how many of the investigations were positive. The same was true of Stearns Electric Cooperative with 486 investigations and Wright-Hennepin with 97 investigations. Also, the survey did not ask for a breakdown between dairy and non-dairy positive tests.

In order to make a projection of actual positive determinations on dairy farms, the data for the three utilities is normalized as follows. For Otter Tail Power, the number of new investigations exceeds the number of farms by such a large number that, for the purpose of estimating the extent of the stray-voltage problem, an assumption is made that all 300 dairy farms in their service area test positive. For the other two utilities, it is assumed that the percentage of positive determinations is the same as the other cooperatives in the state. The average for the other cooperatives is 26%. Adding 300 positive tests for Otter Tail, 128 for Stearns, and 26 for Wright-Hennepin leads to a new total of 1,634 positive stray-voltage sites. To avoid understating the number of dairy farms with stray voltage, it is assumed for this report that all reported positive tests were on dairy farms.

Based on the estimate of 15,174 dairy farms at the time of the survey, about 11% of Minnesota's dairy farms tested positive for stray voltage during the five year survey period. By comparison, the Wisconsin Public Service Commission estimates that 30% of the dairy farms in Wisconsin have stray-voltage problems. Further, it is very likely that some farms have stray voltage that has not been recognized or reported.

The number of incidents of stray voltage as reported by the electric cooperatives are shown on Map 1, Appendix B. When comparing these incidents to the concentration of Minnesota's dairy farms shown on Map 2, Appendix B, a similarity can be observed. The most incidents of stray voltage reported follows Minnesota's "dairy belt" rather closely. Dairy cattle are very sensitive to stray voltage and offer a measurable source to identify the problem. These maps indicate that the problem is not limited to certain geographical areas even though there are some significant differences in topography among the shaded areas.

The survey results indicated 11% of Minnesota's dairy farms have been found to have stray voltage. At this incidence level, it could be expected that the greatest number problems would show up in areas of heavy dairy farm concentration. However, other areas of the state should not be overlooked because stray voltage could be present as location does not necessarily become a limiting factor.

In conducting a stray-voltage investigation, the utilities reported an average of 2.4 site visits to identify the problem source. The actual time spent on a farm typically ranged from two to six hours where there was either no problem or an easily

corrected item to 16 to 24 hours when problem voltages were encountered.

In response to questions regarding criteria used for positive stray-voltage determinations, five of the 48 respondents mentioned the National Rural Electric Cooperative Association Publication 80-1 and fourteen mentioned the North Central Regional Extension Publication 125 (Same as Minnesota Extension Service Agricultural Bulletin 1359, University of Minnesota.) Nine respondents stated specific values of neutral-to-earth voltage as a reference value for positive stray voltage. The remainder of the respondents did not provide specific references.

Testing procedures varied considerably among utilities, ranging from four hours on site with a voltmeter to 48 hours of monitoring with sophisticated data acquisition systems. Some utilities test only for 60 Hz voltages while some also investigate transients, harmonics, and direct current.

Allocation of costs for investigation and mitigation also varied among utilities. Most utilities view isolation devices as a non-standard service with the cost to be born by the customer. Some charge a nominal fee for stray-voltage investigations.

The respondents to the survey report 36 unresolved stray-voltage complaints over the five year survey period. Three utilities did not provide this information because of pending litigation. This suggests at least 39 unresolved complaints or about 1% of the total investigations on dairy farms.

The low number of reported unresolved stray-voltage problems needs to be viewed with caution as the number is based entirely on utility data. The task force did not attempt to survey the state's 15,000-plus dairy farmers.

Sources of stray voltage can generally be identified as on farm or off farm although the terminology is not always applicable. As an example, the demand on the distribution system by an electrical load on the farm can impose a voltage on the primary neutral. However, in responding to the survey, the utilities report that of the farms testing positive for stray voltage, 85% of the sources were on farm while 59% were off farm. (More than one voltage source is often found.)

Based on the survey results, separation of the primary distribution neutral from the farm system by the installation of an isolation or blocking device is the most commonly applied mitigative measure. The utilities report the installation of more than 1000 blocking or isolation devices during the survey period. This represents about 7% of the state's dairy farms. It is also assumed that additional devices were installed both before and after the survey period.

While isolation often corrects the problem, it does not eliminate the actual cause of the voltage. The Wisconsin Public Service Commission views isolation as a temporary fix and allows an isolation device to remain in place only three months while other corrective measures are taken.

The qualifications and training of stray-voltage investigators varies considerably among the utilities. Qualifications ranged from an engineering background or being a master electrician to having "good electrical knowledge". Twelve utilities provided for training of investigators through seminars offered by Dr. Harold Cloud at the University of Minnesota while others noted on the job training. (Training is no longer available through Dr. Cloud and the Minnesota Extension Service.)

V. PUBLIC COMMENTS

Written and oral comments from dairy farmers, researchers, and interested public were received at the public comment meeting in St. Cloud as well as throughout this review process. Copies of the written comments as well as audio tapes of the St. Cloud public meeting are on file at the Public Utilities Commission office in St. Paul and available for public inspection. The following discussion highlights some of the comments.

Dr. Duane Dahlberg, representing The Electromagnetic Research Foundation (TERF) and who has been working with farmers on the stray-voltage issue since 1982, was an active participant in this review. He is interested in non-traditional sources such as 60 Hz harmonics, direct current potentials, ground currents and their associated electromagnetic fields, transients, and microwave and radio frequency signals that may be present on the farm and contribute to production and reproductive problems. He noted that problems persist that he believes to be electrical in nature on farms where excessive neutral-to-earth voltage have been corrected. The Wisconsin PSC is in the process of designing studies in these areas.

Dr. Dahlberg stated that human as well as animal health problems occur on many farms with stray voltage or other electromagnetic phenomena. He cites epidemiological studies by Savitz, Wertheimer and others reporting an association between chronic exposure to low-level magnetic fields and cancer in humans as evidence. He recommends a state funded research program to find the source or sources of the problem.

Several members of the public commented on threshold values of neutral-to-earth voltage that would be of concern. One person noted that he has seen voltages of over 2.5 volts that have no effect on dairy cattle while another reported effects at voltages as low as 0.05 Volts. An attorney who has represented farmers in stray-voltage litigation stressed the need for current and voltage standards. This view was supported by Dan Dasho, Wisconsin Public Service Commission. There was some consensus, however, that an arbitrary standard would not be helpful.

The economic losses associated with stray-voltage symptoms was of concern to a number of dairy farmers. Some reported that these losses resulted in severe financial hardship.

There was disagreement on the usefulness of the University of Minnesota Extension Service's published guidelines. A number of farmers, particularly those associated with TERF, believed that the Extension Service's focus was too narrow in looking primarily at neutral-to-earth voltages.

Responsibility for bearing the cost to correct stray voltage was discussed. Several farmers commented that if the utility is at fault or if the problem is electrical, the utility should cover the cost of mitigation. Farmers particularly objected to paying up to $800 for isolation devices as well as, in some cases, having to sign a hold-harmless agreement.

Dr. Dan Hartzel, DVM, Alexandria, Minnesota, has treated animals with symptoms suggestive of stray voltage on a number of farms. The symptoms are difficult to treat and, even if the treatment is successful, reoccurrence is common. He noted that the problem is both location-specific and seasonal. Certain local areas have more problems and they occur in both old and new barns. Symptoms are more common during a thaw when the ground is saturated. Dr. Hartzel also noted that sensitivity varies with the individual animal. He believes that the problem is environmental and that the cow's system is stressed triggering a hormonal or immune system response.

A number of farmers sent written comments to the work group stating that the utility had done a good job in identifying and correcting their stray-voltage problem.

VI. ELECTRIC UTILITY COMMENTS

The electric utilities provided oral and written comments at the February 15, 1991 meeting as well as throughout the process. Written Comments are on file at the Public Utilities Commission office in St. Paul and available for inspection. The following is a general summary of both oral and written comments.

Minnesota utilities recognize stray voltage as a significant problem affecting dairy farms as well as other confined livestock operations. While recognizing the need for additional training of investigators and for a more standard investigative procedures, they believe that the problem is being adequately addressed by the power suppliers in the vast majority of cases.

One utility commented that "stray voltage is a single dimension in the overall picture of dairy herd production. Nutrition, herd health, sanitation, environment, animal stress, genetics, and equipment are some other factors. Low productivity can result from any one problem or a combination of problems associated with the above factors. ....Stray voltage is a single problem which can be diagnosed and mitigated resulting in possible improvements in dairy herd production."

There is unanimous agreement among the utilities that there is no need for further state intervention or regulation in the area of stray voltage. They believe that they are responsive to complaints suggestive of stray voltage. Based on their records, only a very small number of these complaints have not been resolved to the dairy farmer's satisfaction.

A common concern expressed by the utilities is farm wiring that is not in compliance with the National Electric Code. While the State Board of Electricity can require that any new wiring be in compliance, it has no authority over existing wiring even if deficiencies are known. Farm wiring is a significant source of stray voltage.

Utility policies on the installation of isolation devices varies. Most view isolation as a special service and, as such, the cost of isolation is borne by the individual farmer. Isolation is sometimes offered the farmer only after other measures have failed to reduce neutral-to-earth voltage to an acceptable level.

The utilities generally support the development of a standard investigative and testing procedure. They do not, however, support regulations to define such procedures or to establish a threshold value to define at what level neutral-to-earth voltage affects dairy herd health and production. Most report following the guidelines published by the University of Minnesota Extension Service, the National Rural Electric Cooperative Association, or the U.S. Department of Agriculture and thus have reasonably similar practices.

Specific recommendations offered by the individual utilities include:

- The utilities and the State should work together to develop standard methods and equipment for stray-voltage investigations. The standard methods should be in the form of guidelines rather than regulations. (Cooperative Power (CP))

- Provide for better enforcement of the National Electric Code to allow correction of substandard farm wiring. Give the State Board of Electricity powers over existing wiring installations in addition to its authority over new and modified installations. (CP, United Power Association (UPA), Minnesota Power (MP))

- Amend the National Electric Code to require equipotential planes and four wire grounding systems in dairy and other confined animal facilities. (CP)

- Dairy farms should continue to be considered "special service". Costs for special equipment necessary for successful operation, i.e. isolation devices, should be the responsibility of the farmer. (CP, UPA)

- Make a more formalized training program available for utility personnel to establish standardized methods of evaluating stray-voltage complaints. (MP) Conduct a continuing program of education in the area of neutral-to-earth voltage theory, investigative procedures, and mitigation under the auspices of existing training programs offered by the Minnesota Rural Electric Association or the University of Minnesota Center for Electric Energy. (UPA)

Note: The utilities are planning additional training to standardize procedures and are discussing publishing a stray-voltage guidebook for utility use. (CP)

- If the State chooses to interject itself in the stray-voltage issue, which was not recommended, it should concentrate on problem areas making use of extensive available research. Standard stray-voltage investigations should remain in the hands of the power company experts. (UPA)

VII. WISCONSIN'S STRAY-VOLTAGE PROGRAM

The Wisconsin Public Service Commission (WPSC) has been actively involved in the stray-voltage issue for a number of years. In August 1987 the WPSC formally commenced an investigation to gather information about stray voltage. A technical conference was held to define the scope of the investigation. In 1988, a series of hearings and meetings were held around the state in cooperation with the Wisconsin Department of Agriculture to receive comments from farmers, utilities, and others.

On January 18, 1989, the WPSC issued its Findings of Fact, Conclusions, and Orders stemming from the investigation. These documents are found in Appendix C. The WPSC's decision set forth procedures, guidelines, and actions which it believed constituted an effective framework for preventing and resolving stray-voltage problems.

The WPSC has established a threshold level of concern for stray voltage. While a number of utilities have used a value of 0.5 volts as the level where a cow's behavior may be adversely affected, the Commission noted that it is actually the current flowing through the animal that affects it. Thus the threshold level of concern should be expressed in milliamperes. Using 0.5 volts and typical cow and current path resistance, the WPSC has adopted a 1 milliampere standard. The WPSC also established standard test and investigative procedures. Minnesota utilities, as well as farmers, do not generally support a specific current or voltage standard.

The WPSC views isolation of the primary and secondary neutrals, a measure commonly applied by the Minnesota utilities to reduce neutral-to-earth voltage, as a temporary fix that is allowed only while the actual source of the stray voltage is corrected. It was noted that isolation only masks stray-voltage effects. Further, the more isolators that are installed, the more likely that the safety and reliability of the distribution system will be compromised.

While the WPSC only has jurisdiction over the utilities, it did recognize farm wiring and equipment as a component of stray voltage and recommended a number of practices a farmer should follow to ensure that stray voltage does not become a problem. The need for compliance with local and state electrical codes was noted.

In early 1989, the WPSC and the Department of Agriculture announced the formation of a Stray Voltage Analysis Team (SVAT) to conduct investigations to identify and assess stray voltage on selected farms. The team includes an electric power systems engineer for assessing the utility distribution system, an electrician to evaluate the farm's electrical equipment and wiring, and a farm management consultant to analyze farm management and dairy practices.

Farmers with persistent and difficult production problems suggestive of stray voltage can apply to the Commission for this service. If selected, the farmer pays $100 for the analysis. Any actual work needed to remedy the problem is the responsibility of the farmer and the utility on their respective systems or equipment. The team visits about 50 farms each year.

The question of the possible adverse effects of electromagnetic fields and other electrical phenomena on human and animal health were raised during the hearing process. The Commission, however, did not expand its stray-voltage investigation to include human health but did agree to review potential effects on livestock. The human health issue is being considered under the Commission's Advance Plan process.

In July 1991, the Commission started an investigation to assess the potential adverse effects on dairy livestock from electromagnetic fields, ground currents, and direct current. The Minnesota Public Utilities Commission is monitoring this work and will take necessary actions as results are published.

VIII. STATE AGENCY AUTHORITIES AND RESPONSIBILITIES

A number of state agencies and boards, as well as the University of Minnesota, have authority by statute or rule to provide assistance in the identification or mitigation of stray voltage. Other agencies have participated in meetings and other stray-voltage activities in the past, but do not have statutory authority for significant involvement. The following summarizes the authorities and responsibilities of the these various agencies.

Minnesota Environmental Quality Board.

The Minnesota Environmental Quality Board is made up of the heads of nine state agencies having environmental responsibilities, a representative of the Governor's office, and four citizen members. In creating the Board in 1973, the legislature recognized that many environmental problems encompass the responsibilities of several agencies and that solutions to the problems require the interaction of those agencies. The Board is directed by Minn. Stat. 116C.04, to identify such environmental problems and to initiate investigations of those problems it deems to be in need of study utilizing the expertise of member agencies.

In late 1990, the Governor assigned the Board a coordinating role in bringing together representatives of both member and nonmember agencies with expertise in the identification and mitigation of stray voltage. This assignment is consistent with the Board's statutory authority.

Public Utilities Commission/ Department of Public Service.

Neither the Department of Public Service nor the Public Utilities Commission have statutory authority that specifically refers to stray voltage. However, several statutes grant the Commission authority to regulate electric service standards, investigate utility practices, and address customer complaints against utilities. This authority encompasses some aspects of the stray-voltage issue.

The general regulatory and investigative statutes are as follows:

216B.04 Standard of Service. Every public utility shall furnish safe, adequate, efficient, and reasonable service...

216B.08 Duties of Commission. The Commission is hereby vested with the powers, rights, functions, and jurisdiction to regulate in accordance with the provisions of Laws of Minnesota, Chapter 429 every public utility as defined herein.

216B.09 Standards: Classifications: Rules: Practices. The Commission after hearing ... may ascertain and fix just and reasonable standards, classifications, rules, or practices to be observed and followed any or all public utilities with respect to the service to be furnished; ascertain and fix reasonable standards for the measurement of the quality ... or other conditions relating to the supply of the service: ...

216B.14 Investigation. The Commission upon complaint or upon its own initiative and whenever it deems necessary in the performance of duties may investigate and examine the condition and operation of public utility ...

216B.17 Public Complaints. On its own motion or upon a complaint made against any public utility (In this section, public utility includes cooperatives.), by the governing body of any political subdivision, by another public utility, by the department (of Public Service), or by 50 consumers of the particular utility .... that any regulation, measurement, practice, act or omission affecting or relating to the production, transmission, delivery or furnishing of ... electricity or any service in connection herewith is in any respect unreasonable, insufficient or unjustly discriminator, or that any service is inadequate or cannot be obtained, the commission shall proceed, with notice, to make such investigations as it may deem necessary.

216B.23, Subd. 2. Lawful Rates; Reasonable Service. Whenever the commission shall find any ... practices, acts or service to be unjust, unreasonable, insufficient, preferential, unjustly discriminatory ... or shall find that any service which can be reasonably demanded cannot be obtained, the commission shall determine and by order fix reasonable ...acts, practices or service to be furnished ... in the future ...

Since late 1990, the Commission, and to a lesser degree, the Department have been involved in both the technical and regulatory considerations of the stray-voltage issue. The Commission has assigned a staff engineer to the issue to survey the technical literature, monitor the Wisconsin Public Service Commission's stray-voltage research, respond to public inquiries, and conduct limited on farm investigations.

No formal complaints relating to stray voltage have been received by the Department or the Commission.

Pollution Control Agency.

In February 1986, the Pollution Control Agency staff responded to a PCA Board request to investigate the issue of stray-voltage impacts on dairy cattle and dairy operation's in Minnesota. In its response, staff noted that while the agency has the power and duty to investigate and control air, water, and land pollution, the definitions of air contaminants, air pollution, and land pollution in Minn. Stat. 116.06 cannot be interpreted to include stray voltage and thus recommended that PCA not be involved in the issue.

As the staff recommendation was presented as an informational item, the Board did not take formal action either to approve or to reject the recommendation. Since that time, PCA has not taken any regulatory action on the issue. Staff, however, has participated in various task forces and informal meetings on stray voltage.

Department of Health.

Based on the characterization of stray voltage by this work group and by their past representation at meetings relating to stray voltage, the Department of Health has determined that it has no statutory authority pertaining to the issue.

Department of Agriculture.

The Minnesota Department of Agriculture is responsible for the sanitary inspection of dairy farms. Stray voltage can affect the outcome of an inspection but is not directly factored into the evaluation. The Department can help identify problem farms and disseminate information but does not have the ability to take measurements for determination of stray voltage or the regulatory power to deal with such a problem if it is found to exist.

State Board of Electricity.

The Board of Electricity is generally responsible for inspection of new premises wiring and electrical equipment on farms to determine compliance with the safety requirements of the National Electric Code, but has no authority to reinspect existing installations. Electrical distribution and metering equipment owned by the electric utilities are also exempt from inspection by the Board.

Stray voltages, where they are in fact a problem, are often related to neutral-to-earth voltages which occur normally on multiple-grounded electrical systems. The National Electric Code has no requirements specifically addressing neutral-to-earth voltages, but does have some provisions that may be helpful in some cases. Inspection for code compliance has limited impact on neutral-to-earth voltage problems, but is effective in reducing occurrences of stray voltage caused by improper equipment grounding.

The most effective means to control stray-voltage problems, in the view of the State Board of Electricity, would seem to be to provide the necessary information to persons who design, maintain, and install utility distribution systems, premises wiring, electrical equipment, and farm buildings. The farm operator must also be encouraged to properly maintain farm equipment, and to have electrical repairs and installations performed by qualified professionals.

University of Minnesota Extension Service.

The University of Minnesota will provide technical support to Minnesota's electric utilities in the investigation and mitigation of stray-voltage concerns on livestock farms. The University of Minnesota Extension Service is prepared to assist state educational agencies in the training and education of stray-voltage investigators. The University will cooperate with the utilities and state agencies to develop standard procedures and equipment for testing stray voltage and will conduct research if additional funds and personnel are made available through legislative appropriations or grants from outside funding agencies. The University of Minnesota and the University of Wisconsin plan to cooperate on all of the above items assuming staff and funds are available to do so.

IX. OBSERVATIONS, RECOMMENDATIONS, OPTIONS

Based on information gathered through public and utility comments, the Minnesota Utility Stray Voltage Survey, and a review of selected literature, the Stray Voltage Work Group makes the following observations and recommendations relating to a preferred state, utility, and individual responses to the stray-voltage issue.

Designation of a Lead Agency.

Observation:

The electric utilities have the primary responsibility to investigate stray-voltage complaints and to resolve such complaints if utility equipment is at fault. It is the farmer's responsibility to correct or replace any faulty farm wiring or electrical equipment that may contribute to excessive neutral-to-earth voltage.

Should the problem remain unresolved, several state agencies, including the Public Utilities Commission, the Department of Public Service, the Department of Agriculture, the Board of Electricity, as well as the University of Minnesota Extension Service, have responsibilities and expertise relating to different aspects of the stray-voltage problem. The Public Utilities Commission has a formal procedure in place to resolve disputes between the farmer and the utility over sources and mitigation of stray voltage.

While no agency is formally designated as lead agency to assist in the resolution of stray-voltage issues, it is not reasonable to reassign all stray-voltage responsibilities to a single agency or to make one agency a clearing house for all stray-voltage issues. The very low number of unresolved stray-voltage complaints suggests that mechanisms now in place are reasonable. Improved public awareness of the assistance available through individual agencies would help reduce the perception that a lead agency is required.

Recommendation:

The Stray Voltage Work Group recommends that a lead agency for stray-voltage issues not be designated. The work group also recommends that the electric utilities and the state agencies now involved in stray-voltage issues cooperatively

develop means to better inform farmers of the options available for investigation and resolution of possible stray-voltage problems.

The work group can remain active at the Governor's request to facilitate the implementation of the options identified in this report to more effectively achieve fulfillment of stray-voltage policies.

State, Utility, and Individual Response to Stray Voltage.

Observation:

There are no uniformly applied or accepted standards or criteria to define at what level neutral-to-earth voltage or voltage in cow contact areas become a concern and require mitigation and no standard procedures or equipment for testing stray voltage.

Options:

1. Preferred. The utilities jointly develop standard investigative procedures, including instrumentation, and criteria for the identification of problems due to stray voltage. The test procedures and criteria should be based on nationally recognized guidelines.

2. The Public Utilities Commission develop criteria and procedures for stray-voltage testing and assessment through rulemaking conducted under Chapter 14.

Observation:

There is a large variation in the quality and quantity of information given to the dairy farmer by the utility in reporting the results of a stray-voltage investigation.

Options:

1. Preferred. The utilities develop a standard reporting form for statewide use that includes a comparison of the individual test results with national stray-voltage guidelines.

2. Preferred. The utilities provide dairy farmers with information such as the Minnesota Extension Service bulletin on stray voltage with the test results. The utility also should provide information on the PUC's complaint procedure.

3. An independent stray-voltage contractor be retained by the farmer to make an independent stray-voltage assessment to provide a second opinion to the utility assessment.

Observation:

There are no uniform standards or criteria to guide the utilities or the farmer in the application of technical actions to mitigate stray voltage through improvements in the electric distribution system, equipotential planes, isolation, grounding, and other measures.

Options:

1. Preferred. The utilities, in consultation with stray-voltage experts, develop technical criteria/standards based on nationally recognized guidelines for implementation of technical mitigative actions.

2. The Public Utilities Commission develop technical criteria/standards for the implementation of technical mitigative actions. These should be developed through rulemaking procedures under Chapter 14.

Observation:

Isolation of the primary and secondary neutrals, while often providing an immediate improvement in herd performance, does not correct the actual source of the problem and does present some degree of risk. Policies on preinstallation agreements vary from utility to utility. Some utilities require a hold-harmless agreement from the farm owner. The Wisconsin Public Service Commission views isolation as a temporary "fix" that can remain in place only 3 months.

Option:

1. Preferred. The utilities, in consultation with the Public Utilities Commission and the Department of Public service, develop a uniform policy on the installation of isolation devices.

Observation:

Responsibility for bearing the costs of mitigative actions, particularly isolation, is not uniformly recognized by the utilities.

Options:

1. Preferred. The utilities, with the approval of the PUC in the case of rate regulated utilities, develop a common policy on cost responsibility.

2. The responsibility for installation and maintenance costs be reviewed by the PUC through rate hearings and/or tariff review.

3. Legislative action be taken to define cost responsibility for the non-regulated cooperatively owned utilities.

Observation:

There is no formal education and training process for utility or individual stray-voltage investigators.

Options:

1. Preferred. A formal training program for stray-voltage investigators be made available through a Vocational Technical College and other educational institutions with expertise in this area. The program would include both classroom and on-farm training.

2. The Minnesota utilities, as a group, develop a formal education and training program, including on-farm experience, for all stray-voltage investigators.

3. Implement a stray-voltage investigator certification program through the Board of Electricity or other appropriate agency or professional group.

Observation:

Utilities with few dairy operations in their service area often lack the expertise and instrumentation to adequately respond to occasional stray-voltage complaints.

Options:

1. Preferred. The larger cooperatives and public utilities develop a program to make their trained stray-voltage investigators available as consultants to utilities lacking such expertise to ensure high quality and uniform investigations.

Observation:

Faulty farm wiring and electrical equipment significantly contribute to stray-voltage problems. The farmer is under no obligation to correct poor wiring and the State Board of Electricity does not have the authority to inspect existing wiring and require that it be brought up to code if found defective.

Options:

1. Preferred. A farmer with apparent stray-voltage problems not traceable to utility equipment identifies and voluntarily upgrades wiring and equipment to meet the state electrical code.

2. Preferred. Low interest loans to upgrade wiring be included in the Rural Finance Authority Program.

3. The electric utilities provide a low interest loan program to upgrade wiring. (Such a program is offered by utilities in Wisconsin.)

4. The State Board of Electricity be given the authority and resources to review and require code compliance for existing wiring when unresolved problems suggestive of stray voltage exist.

Observation:

There are numerous reported examples of stray-voltage symptoms when neutral-to-earth voltages are well below the commonly accepted threshold level for concern of 0.5 Volts. This indicates that other potential mechanisms for impacting cow performance may exist. There is very limited research available on the effect of ground currents, electromagnetic fields, transients, and direct current potentials on dairy cattle. A number of programs to address these issues are, however, being initiated by the Wisconsin Public Service Commission.

Options:

1. Preferred. The Public Utilities Commission and the Department of Agriculture monitor and, to the extent possible, participate in the Wisconsin Public Service Commission's investigation into the possible adverse effects on dairy livestock from electromagnetic fields, ground currents, and direct currents associated with electric utility service.

2. The legislature appropriate funds to support research not related to neutral-to-earth voltage to be conducted through the University of Minnesota or independent contractors.

3. The legislature appropriate funds to support cooperative multi-state or national research programs.

Observation:

There is insufficient research on the effects of neutral-to-earth voltage on non-dairy operations, particularly swine and poultry confinement operations.

Options:

1. Legislation to fund research to be conducted by the University of Minnesota or independent contractors.

2. Legislation to provide financial support for cooperative multi-state or national research.

Observation:

There are undoubtedly dairy farms as well as other confined livestock operations in Minnesota that have not recognized possible symptoms of excessive neutral-to-earth voltage.

Options:

1. Preferred. The electric utilities provide all farm customers with general information on stray voltage, including information on symptoms in dairy herds and other confined livestock suggestive of stray voltage and options for assessment and resolution.

2. The Department of Agriculture provide information on stray voltage as part of the dairy farm inspection program.

3. The electric utilities encourage all dairy farmers to install meters, at the farmer's expense, to monitor neutral-to-earth voltage in the barn.

4. The utilities survey all dairy operations for neutral-to-earth voltage and for symptoms suggestive of stray-voltage problems and discuss options for investigation.

Observation:

Symptoms similar to those caused by stray voltage but due to conditions unrelated to electricity occur in dairy herds.

Option:

1. If the utility or an independent consultant cannot conclude stray voltage is the cause of the observed symptoms, the farmer should voluntarily review production conditions with a dairy herd consultant or a University of Minnesota Extension Specialist.

APPENDIX A

Minnesota Utility Stray Voltage Survey Results

APPENDIX B

Map 1. Number of Incidents of Stray Voltage Reported

Map 2. Concentration of Dairy Farms. July 1991

APPENDIX C

Findings of Fact, Conclusions of Law, Public Service Commission of Wisconsin, Investigation into the Practices, Policies and Procedures Concerning Stray Voltage for Electric Distribution Utilities in Wisconsin.

APPENDIX A

Minnesota Utility Stray Voltage Survey Results

MINNESOTA UTILITY
STRAY VOLTAGE SURVEY RESULTS

Prepared by

Minnesota Public Utilities Commission Staff

February 1991

INTRODUCTION

In late 1990, then Governor Rudy Perpich requested in a memo that the Environmental Quality Board (EQB) direct an inquiry into the subject of stray voltage in Minnesota with the intention of returning to the Governor recommendations as to the future direction of state policy regarding the subject.

The EQB convened a group of representatives from appropriate agencies to study the stray voltage issues. The agencies represented were Department of Agriculture, Pollution Control Agency, Department of Public Service, Public Utilities Commission, Department of Health, and State Planning Agency.

In order to understand the scope of the problem better in Minnesota, the group decided to survey all the Investor owned Utilities and Cooperatives in the state. This was a quick and comprehensive way to get a lot of information about stray voltage. The objective was to find out what was the history of utility involvement with stray voltage over the last five years. We also could get utility policy information on a number of relevant stray voltage questions.

The response from the recipients of the survey has been excellent. Every utility and cooperative receiving a survey form provided some kind of feedback. The following report is a discussion and summary of the data received from the parties.

No policy recommendations are in this report. This document is intended to serve as a guide to the understanding and interpretation of this utility stray voltage data gathering effort.

RESPONDENT DATA

The survey was sent to all those listed in Appendix A. All five investor owned utilities and forty seven cooperatives were sent forms. Some generation and transmission coop's also received copies. We received forty eight surveys from utilities serving Minnesota customers. There were four Cooperatives that sent a letter declining to participate, three because of pending litigation, and one indicating it had no stray voltage complaints in ten years and very few dairy farms in its service territory.

SURVEY RESULTS

Question #1: How many dairy farms are in your service area?

The total number of dairy farms in the service territory was not known to all respondents. Some marked "an estimate" along with their response number. The result was a gross overestimating of the number of farms in the state. Our survey total of 25,763 exceeds the number known to the Agriculture department as of March 1991 by 10,589. The actual number of dairy farms in the state has been decreasing by 600-800 per year. Another possible explanation could be that the data reported here is outdated information.

For any analysis the actual number of farms in the state, 15,174, should be used. The largest number reported was 3,500 (an estimate) from Minnesota Valley Electric. (See Appendix B for a table of results to a number of questions.)

Question #2: Report how many new stray voltage investigations were made on customer farms in each of the following years, 1985, 1986, 1987, 1988, 1989.

Appendix C shows the total number of investigations reported by each utility. The responses by year for each respondent are also shown in Appendix C. A clear declining trend in the number of investigations for the state as a whole can be seen from this data. The data show a 38% drop in calls between 1985 and 1989. Agriculture department data indicate that the number of dairy farms in the state dropped by 5,000 (24%) over the same time period. This fact tends to moderate the declining call rate data.

Nine respondents had their total number of investigations over 100. These nine conducted 79% of the investigations reported for the five year period. All nine have service territories in the central part of the state. These nine reported 12,094 farms and 3566 investigations. From this group it appears as if 30% of the farms in their area have requested stray voltage investigations. Ottertail has obviously visited the same farms in successive

years driving the reported percentage up. The 12,094 farms reported in these service areas is probably excessive based on the Agricultural Department data. This would indicate that the percentage of farms requesting investigations is probably higher than 30%. An accurate statistic would require further data clarification.

Question #3: Indicate the average number of site visits necessary to determine problem source.

The average of all the responses was 2.4 site visits. This number ranged from an average of 1 visit to 4.6 visits from one utility to the next. This is a large variation in number of farm visits required.

Question #4: Please comment on the average time required per farm to respond to a stray voltage complaint.

The wording of this question resulted in two different interpretations on the part of the respondents. Some interpreted this to mean what was the time duration of the complaint investigation. Others interpreted this to mean how long after receiving a complaint was a response initiated.

Of those reporting response times, all indicated some response within three days, some indicated same day response, most indicated response within 24 hours. Comments were received regarding travel time, backlog of complaints, scheduling the customers electrician to be present at the time of the test, and set up time limiting responses. It is not clear from the survey if response means calling the customer back to acknowledge his complaint or actually visiting the farm site.

The duration reports indicate a range of time from 2 hours to 55 hours to actually measure and correct problem voltages. Single visit investigations that discover either no problem or easily correctable items are reported as 2 to 6 hours on the farm. When problem voltages are encountered the duration typically extends to 16-24 hours on the farm.

Question #5: How many of these investigations were on non-dairy operations?

Of the 4525 investigations done 992 were reported as being non dairy investigations. Almost all the non dairy investigation were done by Ottertail Power, they reported a 50% non dairy test frequency, or 896 of the 992 reported. If Ottertail's data are excluded from the total, only 96 investigations were done over the last five years by all the other utilities combined on non

dairy operations. Ottertail's data include repeat visits for both dairy and non dairy categories. A discussion with Jerry Martens of Ottertail as to the relatively high number of investigations reported resulted in the statement that the problems can be just as severe for other animals as for cows. He feels strongly about the need to test these non dairy sites.

Question #6: Of the farms visits indicated in #2 above, how many tested positive for stray voltage?

Positive tests were reported for 1180 investigations. This is 26% of the total investigations. This is also about 8% of the total number of 1989 dairy farms in the state. Three respondents did not provide numerical answers to this question. Positive tests for these three are not in the above percentage calculation. Ottertail indicated that their objective was to satisfy the customer rather than apply a voltage standard. Stearns Coop, with 1535 farms, indicated that neutral to earth voltages above .7 volts was found on 60-80% of the farms tested. They went on to say that this is not always reflected in cow contact point measurements. Wright Hennepin Coop, with 2732 dairy farms, reported generally that neutral to earth voltages are present on every farm. They use U of M guidelines to counsel the customer. Agralite quantified their answer by defining what a "positive test" meant to them, a sustained .5v in cow contact area. Todd-Wadena reported neutral to earth potentials above .5v in all their tests. Of these, 40% had this show up in cow contact areas. It seems that the 26% of the investigations figure is a conservative percentage. There is no way to determine from the survey if all utilities are applying the same standards in the testing procedures.

Question #7: Of the farms testing positive, as indicated in #5 above, how many were: single phase_____
three phase_____

The #5 in this question was a typographical error, it should have been #6. This did not present a problem to most respondents. 1126 of the positive tests were made on single phase dairy farms. Data are missing from six respondents on this question. Overall 95% of the positive dairy farm tests were on single phase systems. Ottertail provided comments only indicating they saw no relationship between stray voltage problems and type of service.

Question #8: Describe the standard criteria used for positive stray voltage determinations. Include the test time interval (i.e. hours, days, minutes) required for your determination.If you have policies and procedures guidelines developed for stray voltage, include a copy of these with the returned survey.

This question requested three different types of information.

Positive test criteria
Amount of time for testing
Policies and procedures

Each will be discussed separately.

The standard criteria for positive tests that was reported turned out to be mostly references to either the NRECA test guidelines (five references) or the U of M publication (fourteen references) on stray voltage. Only nine respondents reported specific values for N-E voltage that they used in their decision process. No two respondents reported the same specific standard. Of the numbers that were presented the responses were ranged as follows:

We use .5 volts in cow contact area
N-E voltage over .5 requires further testing
.7 volts N-E is concern level
1 volt starts behavior changes
2 volts affect milk production

The U of M publication indicates potential problems in cow contact points "mouth to all hooves" above 1.0 volts. It also recommends continuous monitoring when levels measure .5 volts. The NRECA test manual has no quantification of acceptable voltage values.

The amount of time for testing that was reported revealed a wide disparity of testing policies and procedures. Standard test methods ranged from 4 hrs on site with a voltmeter to use of sophisticated data acquisition systems running for 48 hrs. Only seventeen respondents referenced recording for 24 hrs or more. Some practices require that the farmer have an electrician present for the testing.

Policies and procedures were submitted by eighteen respondents. Most policies are rather short (less than one page), and almost all of them refer mainly only to isolated service. They define this as a non standard service with costs to be born by the customer. Costs for isolation range from no charge to $800 for labor and materials. Almost all policies say that the isolated service will not be installed unless specifically requested by the customer. At least three Coop's have a hold harmless clause in their policy or non standard service agreement.

Some utilities charge the customer a nominal fee for stray voltage testing services while most others do not. Fees for testing services reported were in the $25-$50 range. Provisions for applying the testing fee to the cost of installing an isolator are in at least one policy.

Question #9: What types of equipment do you use for your testing?

The answers to this question indicate generally that either a utility uses very basic test tools or very sophisticated tools.

Continuous monitoring voltage recording devices were the most reported tool. Twenty seven respondents (52%) reported the use of a recording voltmeter. Most often these were Chessel (model 301D) three input channel devices. Some type of computerized data acquisition equipment is used by eight.

Only eighteen (35%) reported the use of some type of ammeter for actual current flow measurements.

The use of a "megger" (an insulation resistance tester) was reported by seven utilities. This can be used to test for faulty equipment. A ground resistance tester to test ground rod effective resistance was reported by five.

Only two reportedly use oscilloscopes. Scopes can detect transients and high frequency harmonics.

Two others indicated the use of an infrared device to look for heating induced by bad connections.

Still another uses a 110v plug in polarity tester for checking correct wiring of receptacles in the barn.

Question #10: Do you test for harmonics, transients, DC?

Harmonics are higher frequency AC signals that are typically found at frequency intervals that are multiples of the 60 cycle utility base. Only four coop's reported that they looked for harmonics in their testing methods. It is not clear how these harmonic measurements are being taken. Of these four, only one reported the use of a data acquisition system as a tool. Two reported the use of a voltage recorder.

Transient voltages are very short term deviations in the steady state value of voltage levels. Transient voltage measurements were reportedly made by 19 (37%) respondents. Four of these did not indicate that they used recording type test equipment. Several indicated that the type of transients they looked at were limited by the test equipment capabilities. In addition to the 19

that reported transient testing there were another 16 respondents who reported the use of either a data acquisition system or a voltage recording device capable of measuring transients but did not indicate they tested for transients.

DC measurements were reported by 17 of the utilities. Seven of these indicated they used no recording devices in their testing equipment list.

Question #11: How many of the positive tests had problem sources
a. On the farm
b. Off the farm
c. Not determined

On the farm sources were reportedly found for 1001 investigations. This is 22% of the total investigations made. Of the farms with problems (1180), this is 85% of the total.

Off the farm contributions were reported for 695 studies. This is 59% of the problem farms and 15% of the total investigations. The large numbers indicated for A & B indicate that many farms have problems from both on and off the farm sources.

A "not determined" source was indicated for 96 investigations. This is 2% of the total investigations. Eighty one of these were reported by one cooperative. This would indicate that problem sources are specifically identified in most cases.

Question #12: Of the investigations indicated in #2 above, how many had problems which were identified as non electric sources (feed, health, management etc.)

There were approximately 85 investigations which were reported as non electric sourced. Eighteen respondents indicated either that they were not expert on subjects like this or that they concerned themselves only with electric issues. Care must be taken in interpreting these numbers as at least one Coop's response to this question was that the failure to measure neutral to earth voltage meant the problem was identified as non electric sourced even if no specific cause was identified.

Question #13: Who made the determination of the problem sources identified in question #12?
Utility employees_____
Consultants_____
Others_____

Only two Coop's reported significant numbers of determinations of this type by their own people. Almost all the other respondents

indicated that outside people made the determinations. These were either left unidentified as "consultant" or identified as veterinarian, milk equipment specialist, dairy field representative, or U of M Agriculture department staff. In a couple of instances the farmer identified the non electric problem during the course of the utility electrical investigation.

Question #14: Of all the investigations made over the last five years, how many of the farms have problems which have not been resolved to the customer's satisfaction?

A total of 36 unsatisfied customers were found by this survey. Since three coop's decided not to participate because of litigation we can infer that there are at least three more. This is a very low percentage of the total complaints received. Only two utilities had more than three unsatisfied customers.

Question #15: Of the farms indicated in 11A above how many had problems with:

- Incorrect or improper wiring
- Faulty equipment
- Improper grounding
- Dirt or moisture
- Bad connections
- Other

The response totals for the categories are as follows

Incorrect or improper wiring	648
Faulty equipment	414
Improper grounding	630
Dirt or moisture	195
Bad connections	206
Other	277

Since there were 1180 cases of positive stray voltage determinations these numbers represent significant fractions of the total cases. It is obvious that some farms had more than one type of problem. Poor wiring practices and improper grounding account for 54% of the total. It cannot be determined if the grounding problems were caused by deterioration or incorrect wiring practices. The "other" category was not completely explained by the respondents. The most often cited other factor was unbalanced 120v secondary loads on the farm system. Other references were made to broken underground wires, non UL rated cow trainers, and faulty equipment.

Question #16: Of the farms listed in 11B above how many had problems that were solved by:

Installation of blocking devices	647
Isolation	401
Distribution system changes	91

From this survey it appears that in the last five years 1048 farms have been separated from the system primary neutral by either a blocking device or physical isolation. The question allowed for some confusion in the responses as some utilities consider the installation of a blocking device as "isolation". The relative distribution of responses to the first two options is probably not certain. The percentage of actual dairy farms thus affected, based on Dept of Agriculture estimate of 15,174 farms in the state, is 7%. Some history undoubtably exists for years prior to this study. The real total number of blocked or isolated farms is probably higher. It is worth pointing out that the total number of reported blocked and isolated farms is more than the number determined to have off the farm contributions in 11B. Possible explanations for this are that blockers could be installed for the "undetermined" category or blockers that may be installed solely because of the farmers insistence.

Question #17: Indicate the type of training is provided to your stray voltage testing people. Describe what prerequisites you require for these trainees.

Only five respondents specifically mentioned engineering level involvement with their stray voltage testing program. Two mentioned the line foreman as responsible for testing. Three respondents indicated test personnel were licensed master electricians. Six indicated that being a lineman was prerequisite for testing. Two Companies mentioned Agricultural training or experience as a prerequisite. Only one listed good customer relation skills as a prerequisite. Not all respondents answered the question regarding prerequisites. Ten utilities indicated that they selected a person with a "good electrical knowledge", and that "on the job training" was the training method. Twelve listed the University of Minnesota seminars and Dr Harold Cloud as the source for their training programs. It is interesting to note that this training is no longer available from the U of M. Seminars put on by Engineering consultants and power suppliers were also mentioned. The survey data shows a wide range of policies regarding who does the testing and how they are trained. The wide variations in number of site visits from Question 3 implies either a wide range of testing procedures or effectiveness.

Question #18: Do you use outside consultants for your investigations? If so, please provide names and addresses for these people.

Twenty three of the respondents indicated that they never used consultants for stray voltage work. Other consultants listed were as follows:

Dr Cloud & Univ of Minn Agriculture Dept	14
Otter Tail Power Co	5
Gagnon Contracting	4
Power Systems Eng	4
United Power Assoc	1
Dairyland Power Coop	1
County Extension Agent	1

Question #19: Have you ever attempted to survey all farms in your area for possible stray voltage? If so provide details.

No utility has done field measurement type surveys. Seven have done mailings or newsletter surveys which suggested the customer contact the utility if he felt he may have problems. Three indicated an annual notice or warning about stray voltage was their standard procedure.

Question #20: Do you provide customers with any educational material related to stray voltage? Please attach a copy.

The predominant educational effort reported was through newsletter articles on stray voltage. Fifteen indicated they used this newsletter method. The most reported publication used was the University of Minnesota Extension Publication #125. This was offered by fifteen respondents as the material of choice "upon request". Other materials referenced included:

1) a pamphlet by The National Food & Energy Council
2) North Dakota Power Use Council publications
3) Stray voltage facts every Dairy farmer should know- Blackburn Co.
4) Wisconsin Farm Electric Council information sheets

Five companies indicated they did not provide any material. One Coop has a slide show developed regarding stray voltage.

Question #21: Have you observed any seasonal variation to complaint frequency? If so explain your observations.

Thirteen answers were received as no variation. Nineteen responses indicated winter either alone or together with spring or fall. Eight fall responses and six spring responses were noted. Dry conditions were called out as triggering complaints in seven comments. High humidity or dampness from condensation were mentioned by two parties. One Coop indicated they did 45% of their complaint responses in the months of January, February, and March. Another indicated call frequency might be related to Dairy operation costs. Still another thought winter call frequency higher because farmers had more time to deal with stray voltage then.

Question #22: What percentage of the farms experience recurrences after corrections have been made?

The responses here were strongly weighted towards no recurrences, twenty one said there were none. Five indicated less then 1% call backs. Three indicated return visit frequencies between one and ten percent. Ten indicated recall rates above 10%. Highest reported rate was 25%. Six responses indicate primary reason for call back was at the farmer's request as a preventative measure to ensure voltage levels had not changed. This data does not indicate that stray voltage had returned in all these cases. Comments were made that these call backs did not necessarily mean that significant levels were found.

FINAL COMMENTS

The survey's are available for review. Any questions regarding this survey summary document or the survey details can be directed to Mike Michaud at:

Minnesota Public Utilities Commission.
150 E Kellogg Blvd, Rm 780
St Paul, Mn 55101

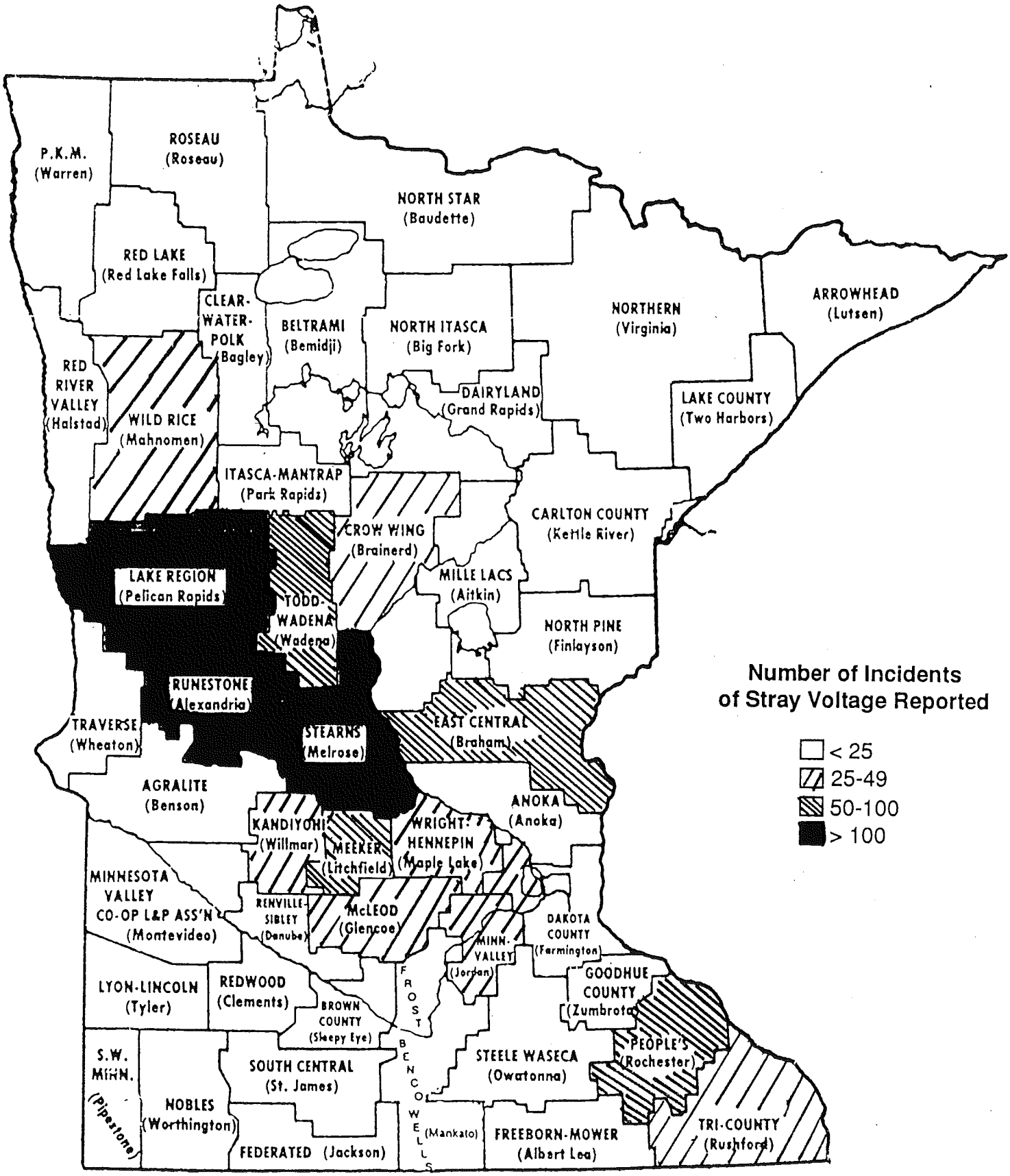
Phone: 612-297-7956

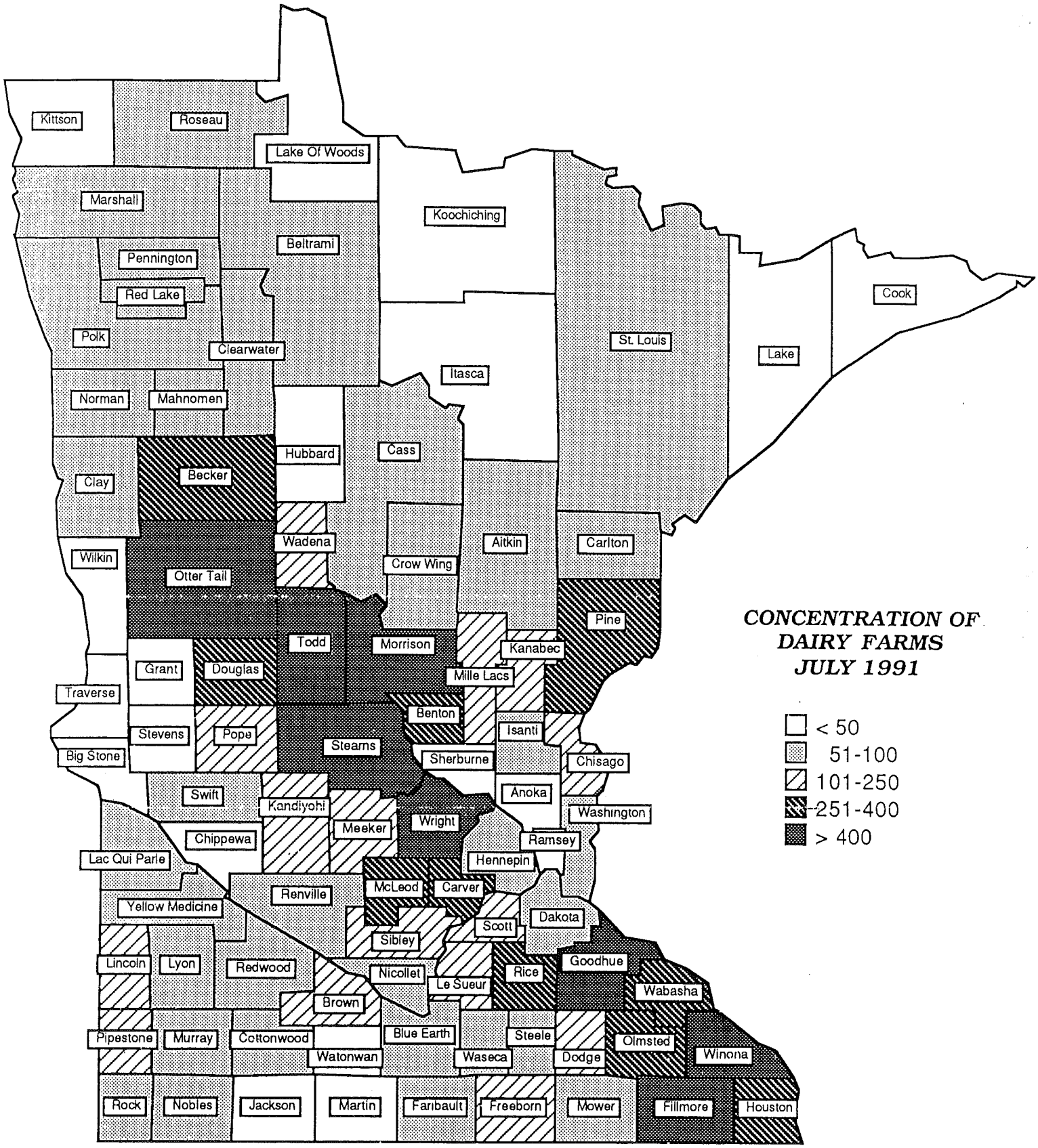
APPENDIX B

Map 1. Number of Incidents of Stray Voltage Reported

Map 2. Concentration of Dairy Farms. July 1991

MINNESOTA ELECTRIC COOPERATIVES





CONCENTRATION OF DAIRY FARMS JULY 1991

- < 50
- 51-100
- 101-250
- 251-400
- > 400

APPENDIX C

Findings of Fact, Conclusions of Law, Public Service Commission of Wisconsin, Investigation into the Practices, Policies and Procedures Concerning Stray Voltage for Electric Distribution Utilities in Wisconsin.

BEFORE THE

PUBLIC SERVICE COMMISSION OF WISCONSIN

Investigation on the Commission's Own Motion Into the Practices, Policies and Procedures Concerning Stray Voltage for Electric Distribution Utilities in Wisconsin	))))	05-EI-106

FINDINGS OF FACT, CONCLUSION OF LAW AND ORDER

Proceedings

On August 18, 1987, the commission commenced this proceeding to gather information about stray voltage by issuing a Notice of Investigation and Technical Conference. A technical conference was held on August 31, 1987, to define the issues and to help establish a hearing schedule. Subsequently, the commission issued a Notice of Public Hearings on September 29, 1987, announcing public hearings to be held around the state in cooperation with the Department of Agriculture, Trade and Consumer Protection. Public testimony from farmers, electricians, utilities and others was received at these hearings conducted by Commissioner George R. Edgar and held at 1:30 p.m. and 7:30 p.m. at the following towns and dates: Portage on October 13, 1987; Darlington on October 15, 1987; Rice Lake on October 20, 1987; Whitehall on October 21, 1987; Richland Center on October 22, 1987; Kewaunee on October 26, 1987; Ripon on October 27, 1987; Jefferson on October 28, 1987; Belgium on October 29, 1987; Merrill on November 2, 1987;

Marshfield on November 3, 1987; Burlington on November 9, 1987; Waupaca on November 10, 1987 and Oconto on November 11, 1987. A questionnaire from the commission to the major investor-owned utilities, the Wisconsin Electric Cooperative Association and the Municipal Electric Utilities of Wisconsin, was sent on November 18, 1987, to request information on stray voltage practices and policies.

On February 26, 1988, a Notice of Prehearing Conference was issued. A prehearing conference was held on March 7, 1988, in Madison to discuss the format for upcoming technical hearings concerning stray voltage. A Notice of Further Hearing was mailed on March 22, 1988. Hearings were held from April 12-15, 1988, before Commissioner George R. Edgar. Expert testimony was presented by the utilities, a series of witnesses on behalf of the Stray Voltage Task Force and the Stray Voltage Assessment Team.

The commission initially discussed this docket at its open meeting of August 9, 1988. Subsequently, a Notice to Solicit Additional Comments on neutral isolator policy was issued on August 19, 1988. The commission reviewed and discussed these additional comments at its open meeting of October 18, 1988.

A notice of appeal rights appears in the attached Appendix A. The parties, for purposes of review under sec. 227.53, Stats., are listed in Appendix B. Other persons who appeared are listed in the commission files.

Findings of Fact

THE COMMISSION FINDS:

The public and technical testimony in this proceeding has provided a great deal of information concerning stray voltage. The Commission acknowledges the serious impacts that stray voltage problems have had and can have on farmers. While various opinions have been given about the extent to which stray voltage is a problem in Wisconsin, there is little dispute about the consequences to a farmer who does have stray voltage. We will continue to seek information on the extent of the problem, but like other parties we do not need a precise answer to know that we should be involved in solving a problem which does affect Wisconsin livestock operators.

There is a history to stray voltage in Wisconsin which the parties in this proceeding have put aside to focus on what should be done now and in the future to deal with the problem. It is in that vein of cooperation that the Commission discussed its general policies in this order. We do not mean by listing requirements of what should be done to suggest that some of them are not being done. Rather, our decision attempts to set forth procedures, guidelines and actions which constitute an effective framework for preventing and resolving stray voltage problems. While we will meet our regulatory responsibilities, our decision is written from the perspective of the cow which is more concerned about not having a problem than arguing about who is responsible for it. We believe that where responsibility is clear that appropriate

action should be taken to recognize the losses caused in a timely manner.

"Stray voltage" can cause serious financial and psychological stress for a farmer and his or her family, as well as behavioral stress for livestock in confined facilities. Fortunately, stray voltage is a solvable problem in the vast majority of cases. But, all the parties involved, farmers, utilities, electricians, farm equipment producers and installers, government agencies, veterinarians and the financial community, must understand the problem and cooperate to resolve it. To date, some farmers, electricians and the utilities have attempted to respond to stray voltage concerns. The commission in this decision sets forth its policies and responses to this problem.

There are several basic principles upon which this commission decision is premised. First, it is better to prevent a problem than to solve it after it has happened. Good fundamental planning, operation and maintenance on both sides of the meter; i.e., on the utility's and the farmer's electric systems, are necessary to minimize stray voltage problems. Second, it is better to remove the source of the problem than to only mitigate it. While mitigation may be necessary for some period of time to allow the problem source to be removed, the goal should be to find and correct causes. Third, each situation must be approached and analyzed based on its specific facts. While stray voltage problems can be caused by both on and off-farm sources, only a specific analysis for each farm will indicate whether there is a

problem and what its source is. Fourth, livestock are adversely affected by many causes which manifest similar symptoms to those caused by stray voltage. While a farmer should certainly check for stray voltage, he or she needs to consider all causes, including electrical and nonelectrical ones, when his or her livestock experience production or behavioral problems.

"Stray" voltage is a term that has often been used to describe different situations. It is important to have a common understanding when terms are used to distinguish between "stray" voltage and neutral to earth voltage. Neutral to earth voltage is voltage measured from the electrical system neutral and/or any structure bonded to this neutral to earth (e.g., to a driven reference ground). Neutral to earth voltage is always present at some level on a multiple-grounded neutral primary electrical distribution system, and on a farm electrical system, as the result of the electrical current flow in a multiple-grounded electrical system. "Stray" voltage is a special case of voltage in which the neutral to earth voltage is present across points (generally grounded metal objects) in which a current flow is produced when an animal comes into contact with them. As will subsequently be discussed, these contact points can include any two conductive points which the animal may simultaneously contact to complete a circuit which allows current to flow. Stray voltages are low-level voltages and should be distinguished from painful shocks felt by humans.

Based on available research, there is insufficient evidence to conclude that stray voltage causes a direct physiological impact on animals. However, there is evidence that stray voltage can cause stress and behavioral impacts through stress on animals to the point where the animal is reluctant to eat and drink, thereby causing milk production to decrease as well as creating the circumstances for additional physical and manageability problems. These problems can cause serious economic hardship to a farmer or can indirectly result in an animal's death, and provide the reasons that corrective action should be taken if unacceptable levels of stray voltage exist. Because of evidence from farmers of the possible physiological and reproduction problems caused by stray voltage, the research as to how and what electrical factors affect livestock should be continued and commission policy will be modified as appropriate based on this new research.

1. Level of Concern

Existing research has led many of the Wisconsin utilities to use .5 volts as the level of concern (i.e. the point at which the average cow's behavior may be adversely affected) in their stray voltage investigations. As previously noted, "stray" voltage is the voltage difference between points. However, it is actually the current flowing through the animal that affects it and, therefore, the commission finds that the level of concern should be stated in milliamperes: the measurement unit of current flow. The commission finds that the existing research which underlies

the .5 V standard supports a 1 milliampere steady state standard which will be used by the commission as the level of concern. However, the commission will stay apprised of the on-going research and will raise or lower this standard as appropriate.

2. Desirability of Standardized Screening and Diagnostic Measurements and Equipment

There are several reasons to use standardized measurements, both to screen for the presence of stray voltage and to diagnose the source. First, they will provide a consistent systematic analysis which can readily be documented and duplicated. Second, they can avoid needless controversy over whether an adequate analysis was performed or whether the nature of the tests were valid. Third, they can recognize the various interests of parties working on a stray voltage analysis. For example, standard tests to determine whether a problem has an on- or off-farm source can be used to reduce the time an electrician must spend on a farm and bill a farmer.

There are many valid tests which produce useful information in a stray voltage inquiry. The standard measurement tests which this decision will establish are designed to recognize those tests which the experts have indicated are the most useful in resolving most stray voltage problems. The testimony and exhibits of Gustafson et al., Surbrook and Bodman all present well-tested and usable test formats from which the commission has borrowed. These standard measurements, plus the requirement that adequate documentation be maintained by the utilities to fully analyze the

result of each test, should provide confidence that if stray voltage was present, it would be detected and its source ascertained.

3. Standardized Screening Tests

a. Use of "Cow Contact" Areas

The most important measurement areas are "cow contact" areas where the animal can simultaneously access two points of different voltage of sufficient magnitude to cause an objectionable current to flow through the animal. These "cow contact" points or areas primarily include the milking, feed and watering areas. While measurements from the primary or secondary neutral to a reference ground can be valuable to take, the measurements of main interest should be in those areas where the cow can close a circuit to allow current to flow. Care should be taken not to take measurements where the points to be measured are bonded together by some means (e.g. water line to pipeline). In addition, measurements should be taken at various times of the day but particularly during times of high electric load (i.e., milking times) and in different locations.

The measurements taken in the cow contact areas seek to determine the strength of the current accessing the cow. This is dependent on the voltage and resistance and can be calculated by the use of Ohms Law: current equals voltage divided by resistance. For example, .001 amperes (1

milliampere) is produced by a voltage of .5 volts divided by a total resistance of 500 ohms. Since, voltage can be measured, it becomes necessary to determine the total resistance in any cow contact circuit to calculate the strength of the current. But, total resistance is in fact a composite of several distinct resistances: that of the path through the cow, that between the cow's hooves and the floor and that of the concrete floor itself. Thus, in making cow contact measurements it is necessary to use a resistance that reasonably approximates the effective resistance of the cow in the circuit.

b. Use of Resistors

Existing research indicates that a reasonable range for the resistance of the mouth to rear hooves path in a cow is from 350 to 560 ohms. Therefore, when taking cow contact measurements, resistors in the 350 to 560 ohm range should be used to simulate the resistance of the path through the cow. While higher voltage and current readings will result where a resistor is not used, the goal is to determine the sustained level of the current actually impacting the cow.

While the use of appropriate sized resistors simulates one part of the total resistance, there are other resistances which must also be addressed. Research has indicated, in order to simulate the contact resistance between the cow's hooves and the floor, that a 4-inch copper plate or some similar object under pressure be used. Simply, touching the

probes of a voltmeter to the concrete floor will only by happenstance provide a useful reading.

The resistance of the concrete floor will also vary due to factors such as the age, thickness or moisture content of the concrete. Research has indicated that this contact resistance can be neutralized by the application of salt water to the 4-inch copper plate when measurements are taken.

c. Tools to Measure

Many stray voltage problems can be detected by a simple voltmeter which can distinguish between ac and dc voltages and which is either digital or has a high impedance. However, because some stray voltage problems may only be evident at certain times of the day or when certain equipment is turned on (i.e., transient voltage), the use of a recording voltmeter may be necessary. The recording voltmeter can chart voltage levels over time (preferably at least over a 24-hour period) without interrupting the dairy operator's schedule. This meter is a valuable tool to screen for stray voltage problems when they are not immediately detected by the use of instantaneous voltage readings.

By describing these basic screening measurement tests, the commission is not saying that further investigation is not warranted if the basic tests do not indicate a problem. There is no substitute for good judgment based upon an observation of the actual behavior of the animals and the consideration of other variables, including nonelectrical

factors. The commission expects that additional efforts beyond the basic screening tests will be pursued when those observations justify such further action. We also recognize that the screening procedures used by the utilities now take a wide range of measurements in numerous locations and find these procedures to be appropriate and useful.

4. Standard Diagnostic Measurement Tests

Based on the measurement techniques recommended by the experts in this case, the commission finds that the following five tests should be basic to any stray voltage investigation seeking to find the source of a stray voltage problem. Because stray voltage is affected by daily seasonal and geologic conditions, these tests may need to be repeated at various times.

a. Primary/Off-farm

There are two tests which may indicate whether a stray voltage problem comes from the primary distribution system or from an off-farm source transmitted over the primary system. The first test requires the power to the entire farm to be disconnected by opening the main disconnect (e.g., pole top switch). Adding only 240 volt farm loads to the transformer will introduce a current flow on the primary system. This can be done with a load box or on-farm 240 V load. Both neutral to earth and cow contact voltage readings should be monitored. Readings should be taken at various times of the day as loads on the primary system change. If the 240 V

loads produce increased neutral and cow contact levels, there may well be an off-farm problem.

The second test, which should be used when all the other tests discussed in this section do not indicate the source of a stray voltage problem, is to open the connection between the primary and secondary neutrals and any other possible bonds such as the telephone or cable television connections. Both neutral to earth and cow contact voltage readings should be monitored. This test could reveal a ground fault or other problems off the farm. Utilities should cooperate with electricians who wish to conduct this test if all other tests have not revealed the source of a stray voltage problem and there are no safety concerns involved due to the secondary wiring and grounding systems, particularly the absence of grounding on the farm.

b. On-farm Tests

These three tests should be conducted after the first off-farm test using only 240 V loads. The first on-farm test is to measure from the barn panel neutral to a reference ground which is away from any other grounds or metal in direct contact with the earth. Measuring from equipment in the barn to either the secondary neutral bus or a reference rod will indicate whether the equipment is either not bonded or is inadequately grounded.

The second on-farm test is intended to find excessive neutral voltage drop on the neutral conductor to buildings on

the property. A known load such as a portable 120 V hair dryer should be used, while measurements are taken between the barn service panel and the secondary neutral of the transformer (pole ground). The simple formula of voltage drop = current x length x resistance of the conductor per 100 feet divided by 100 should be used to indicate abnormal voltage levels on the farm neutral. This test is best taken with all other loads off.

The third on-farm test checks for ground faults on the farm. Testing should be done by turning on all equipment, one piece at a time, that contacts the earth. A high reading produced on the meter connected between the barn panel and the reference ground will indicate that a ground fault may be a problem.

These five tests should identify the source of most stray voltage problems. Obviously, if they do not, other means such as recording meters to check for voltages, stand-by generation tests or the use of oscilloscopes to check for high frequency problems which might be caused by electric fencers should be performed when appropriate. Any tests performed should be documented as to what was done and the results attained.

The information gained from stray voltage investigations including the frequency of occurrences, the levels which caused the problem and the sources of the problem should be built into a data base at the commission. Therefore, the

commission will direct the utilities to supply such information as it deems appropriate and will seek to encourage electricians involved in stray voltage investigations to cooperate in this effort.

5. Prevention

Consistent with the general principle that it is better to try to avoid problems, the commission will ensure through its regulatory oversight that the utilities plan, build, operate and maintain their facilities with an aim to minimize the potential for stray voltage problems. In order to achieve this end, the commission will require the utilities under its jurisdiction to conform to the following guidelines unless they can demonstrate to the commission that said guidelines should not be applied to them.

While the commission will not establish a maximum level for primary neutral to earth voltage on a distribution line, it does note that several utilities, such as Northern States Power and Wisconsin Public Service Corporation, have internal guidelines for such levels which are useful, not only for stray voltage purposes, but also for general planning and operational management. The ranges established are from 2.5 to 5 volts on the primary neutral system, depending on the primary phase to phase voltage levels. Other utilities should submit similar guidelines or show why such guidelines are not appropriate for them. A comprehensive review process to ensure adequate planning and operation of rural distribution systems with a view to minimization of stray voltage concerns will be implemented.

The most common rural distribution systems include three-phase four-wire, two-phase three-wire and one-phase two-wire. Much attention has been focused on three-phase secondary service derived by an open delta transformation from a two-phase three-wire primary system. The open delta transformation has the same imbalance problems that occur on a single-phase system. Several of the experts in this proceeding have recommended, that, when cost-effective, three-phase four-wire systems replace two-phase three-wire systems. This was particularly recommended as three-phase loads increase on a line which serves facilities in which livestock is confined and where no long-term mitigation techniques are in place. The commission agrees that two-phase three-wire systems should be phased out according to a balance of factors such as service problems, timing of rebuilds, cost and load growth. Particular attention should be given to rural lines where multiple isolations due to stray voltage problems have been necessary or where rebuilds or upgrades are planned or needed. It is also appropriate to recognize that there are some existing two-phase three-wire primary lines which are not a problem and where it could be prohibitively expensive to both the utility and to farmers to change over to a four-wire system. Therefore, the commission will have its Engineering and Energy Planning and Programs staff review utilities' submitted policies for the replacement of two-phase three-wire lines by rebuilding or adding the fourth wire. The staff should recommend an appropriate course

of action to the commission if these policies are not adequate. Utilities' policies on this issue should be submitted within 90 days after the issuance of this order.

The commission is also concerned about whether end-of-the-line customers are more susceptible to stray voltage problems. Testimony in this docket indicates some technical concerns such as the level of primary neutral to earth voltage under certain circumstances. Also, a number of farmers who had problems indicated that they were on the end of the line. However, the commission believes more information is necessary and will expeditiously attempt to gather information on end of the line customers to determine if there are common factors which will allow a more complete evaluation of this question. A questionnaire seeking information on this topic will be sent to both the utilities and farmers before March 1, 1989.

The commission on the basis of the information in this docket finds as a general policy that the utilities should adopt the following techniques to prevent or minimize the possibility of stray voltage problems unless they can demonstrate to the commission that such actions are not appropriate on their systems.

1. The utilities should utilize guidelines for load balancing to reduce primary neutral current.

2. While nine ground rods per mile are required by code, the use of increased or special grounding such as counterpoise should be done when appropriate. However, it is

recognized that additional grounding on a distribution line may have little impact on the level of neutral voltage. Grounds should exceed code requirements and be separated, when possible, by 1-1/2 to 2 times their length.

3. The placement of the customer's central yard pole should be such as to minimize the secondary neutral voltage drop related to the service entrance. This placement should be outside of animal confinement areas. The customer's preference must also be considered in placement.

4. The use of steel conductor on primary distribution lines should be phased out. The utilities should submit reports to the commission on the amount of steel conductor it has in service and provide a schedule for its replacement. This requirement extends to distribution static wires.

5. Line reconductorings or voltage upgrades may be necessary to prevent or to aid in the correction of a stray voltage problem. Whether this level of modification is warranted should be done on a case-by-case analysis of specific lines.

6. The removal of split-bolt connectors can aid in the mitigation as well as the prevention of a stray voltage problem. Split bolt connectors are susceptible to corrosion and other problems if not properly installed and maintained. Therefore, unless a utility provides adequate proof to the commission that a quality control program is in

place, split-bolts should be phased out by replacing them at the time of investigation or maintenance.

7. Further review is necessary to determine if the new National Electric Code rule modification concerning the common bonding of multiple services to a farmstead will adequately address any potential problems. The utilities with multiple services should provide the commission with relevant information as it is developed.

The commission is strongly committed to ensuring that adequate practices and policies are in place to ensure that utility rural distribution facilities are not the source of stray voltage problems. The commission will review the practices and policies of the utilities periodically to determine if adequate efforts are being made. To ensure that the commission is fully informed of the practices of the utilities in this area, each utility will be required to submit the following: (1) its policy for future increase of primary voltage levels through upgrades or rebuilds, if any; (2) its rural line tree trimming policies; (3) its policy as it pertains to primary underground systems including the grounding procedures for these systems; (4) its policy on visual and/or more extensive inspections of rural distribution systems; (5) its policy on testing neutral isolators to ensure that they are operating effectively; and 6) its policy for periodically checking phase load balance and criteria for rebalancing loads on three-phase lines.

While the commission's jurisdiction only extends to the utility side, there are also viable and effective means to prevent or mitigate stray voltage problems on the secondary or farmer's side. For example, the following practices by a farmer would go a long way to ensure that stray voltage does not become a problem for him or her:

1. Four-wire systems are an excellent means to avoid secondary neutral drop problems.

2. Grounds at the transformer pole and at all service entrances should be of a good quality and as close to 25 ohms or less as possible. Grounds on the secondary side should be separated by 1-1/2 to 2 times their length. Equipment must be adequately grounded.

3. Wherever possible, 240 volt motors should be used and when possible and economical, soft-start motors should be used to minimize transient spikes when motors are turned on.

4. Conductors should be adequately sized for the expected load.

5. Connections on the neutral system should be checked on an annual basis or as needed and split bolts replaced.

6. Equipment should be installed in accordance with local and state electrical codes.

Information as well as financial assistance programs to encourage farmers to adopt these practices should be provided by utilities. Good wiring and equipment practices on the secondary side are important and necessary steps to prevent stray voltage problems.

6. Isolation

Neutral isolation separates the primary and secondary neutrals in order to prevent off-farm sources of stray voltage either originating on the utility line or on a neighboring farm from accessing "cow contact" areas. It should also be recognized that neutral isolation reconfigures the circuit and as a result can "solve" (i.e., mask) on-farm problems in some situations. The commission accepts that the multiple grounded system in which primary and secondary neutrals are solidly bonded is the preferred means by which to minimize primary neutral to earth voltages on rural distribution lines for both operational and safety reasons. However, neutral isolation can have a mitigative effect on stray voltage problems. Thus, while the commission realizes that neutral isolation does not enhance the quality of the electrical system, it also realizes that the neutral isolator can be a valuable tool to combat off-farm sources of stray voltage.

The multiple grounded wye system is a commonly used distribution system which seeks to ensure safety against technical failures and lightning by the bonding of utility and customer grounds. It is not the intention of the commission to encourage the use of neutral isolation except as necessary or where a safer solution is not available. Neutral isolation may be utilized as a stray voltage solution to gain time to correct the source of a stray voltage problem or as a longer term solution when the source cannot be found or easily corrected. When the source of the

problem is corrected, it is preferable that the isolator be removed.

The evidence in this docket indicates that isolation may raise the levels of primary neutral voltage on neighboring farms. However, this evidence also suggests that on a single isolation this effect is localized and can be neutralized by actions such as additional grounding. Therefore, the commission should require that where a utility does not do so already, adequate measures be taken to ensure that isolation does not adversely affect neighboring farms. This would mean informing those farms when isolation has in fact resulted in increased primary neutral levels which cannot be reduced by available means. There is a concern that widespread use of isolation on the same line can create problems to a greater degree than a single isolation. Indeed, multiple isolations on the same line may be a good indicator of the need to upgrade or rebuild an existing distribution line. The commission will seek further information on the effect of multiple isolations on the same line and take further action as appropriate.

Finally, the commission is also aware that the its determination that it is desirable to use isolation only when necessary, and as a temporary means to allow the source of the problem to be corrected, may conflict with some farmers' belief that isolators should be a permanent form of insurance. However, the more the use of neutral isolation increases the more likely that the integrity, adequacy, safety and reliability of the

distribution system will be compromised. The commission at this time believes that the solution to this problem is education and financial incentives which favor correction over mitigation, including isolation. This effort to use incentives to motivate behavior is preferable to the development of an absolute policy which denies a customer the ability to seek isolation when he or she deems it appropriate. We agree with those utilities which note that if farmers want to be isolated that there is the possibility that they may take far more dangerous actions on their own to become isolated if an isolator is not an option. However, should the incidence of isolation where there is not an underlying justification for such action increase to a level of concern, the commission will be prepared to take actions which ensure the integrity of the existing system. The goal will be to limit the widespread or indiscriminate use of isolation.

Based on the foregoing reasons, the commission will require that all utilities file neutral isolation policies for commission approval within 90 days which conform to the following guidelines, if those on file are not appropriate, or show cause why such guidelines should not be applied to them. The guidelines which follow are based on the formats used by Northern States Power Company and Wisconsin Public Service Corporation.

1. 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.

2. The customer who receives the isolator at no charge should be informed that the isolators are temporary until the off-farm problem is corrected or until the farmer corrects the on-farm problem or installs an on-farm mitigation device.

3. 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 nonrefundable amount, with an additional sum due after some period of time, would be reasonable.

4. Neutral isolation could be prohibited in the following circumstances:

(a) The removal of the farm grounds cause the primary neutral voltage to increase to unacceptable levels.

(b) The installation of the isolator causes the farm electrical system to be unsafe including because of lack of farm grounding.

5. Neutral isolation could be used only as a short-term, temporary measure in the following circumstances:

(a) An alternative mitigation device such as an equipotential plan is a more economical, safe and effective long-term solution.

(b) The off-farm problem is corrected.

We believe these isolation guidelines along with the provision of adequate information and financial assistance on available options will allow farmers to make informed choices and will provide a least cost solution to utilities. We expect these guidelines, as NSP notes, to encourage customers to compare the costs of the isolators with the costs and benefits of other corrective or mitigative action. Again, the commission reiterates its intent to implement a policy which over time will encourage the correction of problems as the first course of action. This should lead to the ultimate removal of isolators when they are no longer needed.

The commission in this investigation also was presented with evidence that there are operational differences between types of neutral isolators now in use. In a response to the commission questionnaire, Wisconsin Electric Power Company noted that saturable core isolators may not operate effectively in certain circumstances such as where there is inadequate grounding on a farm. Solid state switches do not have these problems. The commission recognizes that the utilities are now only buying solid state switches. The commission will require the utilities continuing to use saturable core isolators to ensure that they are installed in proper conditions and operate appropriately. The commission will seek further information on the relative merits of saturable core versus solid state isolators and take whatever action may be appropriate as a result of that information.

7. Other Mitigation Techniques

The same principle that causes of stray voltage should be corrected rather than simply mitigated also applies to mitigation techniques other than isolation. Several types of mitigation techniques already available to customers and utilities can provide relief to stray voltage problems. Electronic Grounding Systems are expensive but, if competently installed, can suppress the amount of current accessing animals in the "cow contact" areas.

The most used mitigative technique is the equipotential plane which is required by DILHR Volume 2, State Electrical Code, to be installed in all new livestock facilities in Wisconsin. Equipotential planes are simply a grid of conductors buried in a concrete floor and bonded to the neutral of the electrical system. The goal is to ensure that all of the metal which an animal may come into contact with are at the same voltage potential. While an equipotential plane can be an effective means to mitigate a stray voltage problem, the experts have noted three concerns. First, the areas which are planed must include waterers and feeders as well as the milking parlor floor. Second, a transition plane for animals to get on and off the plane may be necessary if the potential between the plane and the surrounding ground is great enough. Third, the effectiveness of equipotential planes may be affected by the electrical properties of the concrete floor.

As noted previously, the resistance of the floor is affected by the age and moisture content of the concrete, the thickness of the concrete and the type and moisture level of the soil in contact with the concrete. While planes can be retrofitted into existing facilities, these concerns are further reasons for all parties to concentrate on removing causes. Notwithstanding, equipotential planes can mitigate stray voltages or serve as additional insurance to ensure against future problems developing.

8. Information and Customer Complaint Procedures

The procedures which are used to explain stray voltage investigations to a customer are as important as the results of those investigations. If customers are to have confidence in the findings, they should have the opportunity, and indeed be encouraged, to participate in the investigation and be informed why things are being done and what the results of tests mean. The utilities, in their responses to the commission's questionnaire, appear to recognize the importance of good communications with the customer to both analyze and solve stray voltage concerns. In addition to these actions, the commission finds that utilities should provide the results of its testing to the farmer, in written form if so requested.

The information submitted in this docket also indicates the importance of short response times to stray voltage complaints. The utilities have made good faith attempts to respond promptly. The commission encourages the continuation of this attitude as

well as one that emphasizes trying creative approaches when normal responses do not seem to have solved a problem.

Utilities should continue to provide information to customers on the symptoms which attach to stray voltage as well as on preventive, diagnostic and mitigative techniques which are available if stray voltage is a concern. Utilities should also continue or establish regular stray voltage related trade ally and farm information programs. In addition, encouraging all dairy customers to install a voltmeter in their facilities to monitor and signal potential problems is a useful action since both the on- and off-farm electrical system is exposed to changing environments. The commission finds the utilities' continuing efforts to improve their information programs deserve recognition.

The commission also finds that an easily understood, uniform presentation needs to be developed for educating the farm community and others about stray voltage. While individual utility pamphlets or fliers are informative, the utilities and other interested parties should work with the commission staff to develop a handout which uses easily understandable or defined terms in a common manner and which includes proven solutions that are available.

The commission commends the utilities on their financial assistance programs for preventative or corrective actions to resolve on-farm problems. These programs which can develop as experience is gained will contribute to the economic health of the utilities' service territories as well as serve as effective

inducements to the correction of problems rather than the use of isolation where it is not necessary on a long-term basis.

To ensure that the commission is aware of customer service policies concerning stray voltage, the commission will require the utilities to update the policies filed in this docket as they are changed.

9. REA Cooperatives

The commission does not have jurisdiction over the many electric cooperatives in this state. They are, of course subject to the direction and control of their members. Despite this jurisdictional fact, the electric cooperatives have been extremely helpful and involved with the proceedings in this docket as well as with the entire issue of stray voltage. As the representatives of the Wisconsin Electric Cooperatives Association have stated, WECA has participated and intends to continue to follow the commission's efforts in this area including the pursuit of the recommendations in this order. In developing its statement of general policy on stray voltage, the commission has kept in mind that the electric cooperatives have indicated that they will follow the commission's lead despite the absence of jurisdiction by trying to ensure that policies are simple, easy to implement and flexible enough to deal with specific utility situations. The commission will also extend technical assistance as needed or desired by the cooperatives to detect or resolve stray voltage problems.

10. Stray Voltage Analysis Team (SVAT)

While the exact responsibilities of the new SVAT will be developed jointly by the commission and the Department of Agriculture, Trade and Consumer Protection in consultation with the Stray Voltage Task Force, we feel that it is appropriate to identify the responsibilities that the commission intends for its SVAT members to perform. These responsibilities include the following:

(a) Reviewing the planning, operation and maintenance of rural distribution systems to prevent and solve stray voltage problems;

(b) working with DILHR and electricians to ensure effective on-farm wiring and grounding practices;

(c) working as a team with the utilities, farmers, veterinarians, feed specialists and electricians to solve stray voltage problems or to resolve disputes;

(d) working with all parties affected by stray voltage problems, including bankers and insurers to ensure a good understanding of the problem and its consequences; and

(e) carrying out individual stray voltage investigations under the terms and conditions of the new state stray voltage program.

The SVAT will have the commission's full support and hopefully all parties will act to make its difficult job a success.

11. Other Commission Actions

The commission's jurisdiction is limited to the actions of the utilities under its jurisdiction. Nonetheless, the commission believes that its efforts to help resolve stray voltage problems should extend beyond its formal jurisdiction. Many issues needing to be addressed have no established procedure or organized group of sufficient size to comprehensively address them. For example, the commission believes that the training and/or state certification of rural electricians is an important matter which should be pursued. The possibility of some form of mediation in lieu of litigation is also an issue that should be explored. The ability to establish an effective farm wiring inspection program is another issue deserving more consideration. Because addressing these matters is necessary to adequately solve the stray voltage problem, the commission will work with all other parties including other government agencies and farmers to initiate and pursue solutions even if they are beyond its direct jurisdiction.

12. DC, EMF and Other Research

The commission's investigation in this docket has primarily focused on 60 cycle ac shock as the cause of commonly experienced stray voltage problems. Dc voltage levels, according to the limited evidence presented in this case, need to substantially exceed the objectionable levels of ac voltage to be of concern. Such potential levels are usually associated with such facilities

as gas pipelines or other structures using cathodic protection systems.

The impact of electromagnetic fields on livestock is currently being investigated and will be addressed by the commission in its Advance Plan order in docket 05-EP-5. The commission believes that it is important to distinguish between EMF and 60 cycle ac shock particularly since the latter is a solvable problem while the former is still being investigated to see if it is a problem.

The commission does, however, conclude that it will seek further information on the effects of dc voltages and EMF on livestock. It will also encourage utilities to become active in locally controlled research projects which concentrate on true-to-life research of 60 cycle ac shock problems. The utilities should submit recommendations to the commission on possible areas for such further research. The commission will continue to track research on dc voltages and EMF and will make adjustments in its policies as are appropriate.

This order does not presume to answer all of the questions about stray voltage. What it has tried to do is establish a set of guidelines and recommendations to help detect and resolve present stray voltage problems and to prevent new or future problems. Our concern is for these farmers who have experienced the problem and for those who might. We are also concerned that stray voltage not become a problem that farmers focus on to the exclusion of others. The standardized testing and diagnostic

procedures, the commission oversight of rural distribution lines and the guidelines for neutral isolation are intended to ensure that all farmers are treated fairly and given effective help in a timely manner. To ensure that we continue to move forward, the commission will prepare a written annual report describing the progress that has been made starting from September 1, 1988. With the continued cooperation and good faith of all parties, the conflicts over stray voltage which have sometimes arisen will hopefully become things of the past and the problems experienced mainly reasons to maintain our vigilance in the future to avoid their reoccurrence.

Ultimate Findings of Fact

THE COMMISSION THEREFORE FINDS:

1. That stray voltages are 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.

2. That stray voltages can cause stress and behavioral problems in confined livestock that can result in production losses as well as physical and manageability problems. This can result in serious financial loss and psychological stress to a farmer and his or her family.

3. That stray voltages can be caused by sources either on- or off-farm. These sources can include utility equipment or the farmer's wiring or equipment.

4. That a level of concern above which corrective or mitigative action should be taken if production and behavioral problems exist is 1 milliampere in the "cow contact" areas (i.e., milking, feeding and watering areas).

5. That most stray voltage problems can be detected and corrected or mitigated if proper screening and diagnostic tests and equipment are used, including the use of resistors to simulate the resistance of the path through the animal.

6. That the best means to avoid stray voltage problems is the proper planning, installation, operation and maintenance of both the electric utility's and the farmer's electrical systems and equipment.

7. That neutral isolation, by separating the primary and secondary bonds, can be an effective way to mitigate an off-farm stray voltage problem. However, neutral isolation because it affects the integrity of a multiple grounded electric system should only be used where it is safe and needed to allow time for the cause of the problem to be corrected.

8. That there are other means of mitigating stray voltage problems if installed properly such as the equipotential plane and the Electronic Grounding System.

9. That accurate information, education and financial assistance to construct and maintain proper electrical systems is a good means to ensure that stray voltage problems are prevented, minimized or resolved.

10. That more research is needed concerning the potential

impacts of dc voltages or electromagnetic fields on confined livestock.

11. That three-phase, open delta services derived from two-phase three-wire distribution systems can cause excess primary neutral current which might access the "cow contact" areas.

Conclusion of Law

THE COMMISSION CONCLUDES:

That it has jurisdiction under ss. 196.03, 196.28 and 196.37 to enter an order setting forth its general policies concerning stray voltage and electric utilities as defined in s. 196.01(5).

Order

THE COMMISSION HEREBY ORDERS for each electric utility subject to the commission's jurisdiction which has a distribution system which serves dairy or other confined livestock farms:

1. That such electric utility shall continue or start to implement the techniques to prevent or minimize the possibility of stray voltage problems set forth on pages 16 to 18 of the Findings of Fact above, or show to the commission within 90 days good cause why it should not implement one or more of those techniques.

2. That within 90 days each electric utility shall conform, or shall file, its tariff(s) on stray voltage/neutral isolation, if necessary, to be consistent with the guidelines and principles set forth on pp. 22 to 24 of the Findings of Fact

above, or show to the commission good cause why it should not do so.

3. That within 90 days each electric utility with three-phase open delta services to farms shall submit to the commission its policies and plans to replace these service systems by rebuild or adding the fourth wire as set forth on p. 15 of the Findings of Fact above.

4. That within 90 days each electric utility shall ensure that its stray voltage screening and diagnostic procedures are consistent with those principles and guidelines set forth on pages 6-13 of the Findings of Fact above, or show to the commission good cause why it should not do so.

5. That within 90 days Northern States Power Company-Wisconsin, Wisconsin Electric Power Company, Wisconsin Public Service Corporation, Wisconsin Power & Light Company and Madison Gas & Electric Company shall submit to the commission the following information, if it has not already done so:

a. its policy for future increase of primary voltage levels through upgrades or rebuilds;

b. its rural tree trimming policies;

c. its policy as it pertains to primary underground systems including the grounding procedures for these systems;

d. its policy on visual and/or more extensive inspections of rural distribution systems;

e. its policy on testing neutral isolators to ensure that they are operating effectively;

f. its policy for periodically checking phase load balance and criteria for rebalancing loads on three-phase lines.

Dated at Madison, Wisconsin, January 18, 1989

By the Commission.

Jacqueline K. Reynolds
Secretary to the Commission

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See attached Notice of Appeal Rights.