INVESTIGATIONS OF EXTRANEOUS VOLTAGES IN NEBRASKA DAIRIES [1/]

by

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The existence of extraneous voltages (also referred to as stray voltage, transient voltage, stray current, neutral-to-earth voltage, transvoltage and similar terms) has received much attention in the popular press during recent years. A question still remains as to whether this phenomenon is a new problem or simply better recognition of an old one. Whatever the case might be, it is recognized that as voltage levels in a milking parlor increase, mastitis incidence increases as does difficulty in achieving uniform cow movement through the facility.

The influence of low-level voltages on dairy cows is not known with any great degree of precision. Reasons for concern over extraneous voltages stem from the possibility that low-level voltages may cause a response similar to a nerve impulse signal when passed through the udder and may prevent milk let-down. The problem is accented by the fact that mastitic milk has a higher electrical conductivity than does normal or good quality milk. Consequently, efforts to treat mastitis are compounded by the existence of voltages since an important component of a mastitis treatment procedure is complete and thorough milkout of the udder at frequent intervals. If voltages in the milking center prevent milk let-down and complete milkout of the udder, the effectiveness of mastitis control efforts are diminished. The effectiveness of intramammary treatments and medications is also decreased because of dilution by residual milk.

Background

Investigations to determine the frequency of occurrence and magnitude of extraneous voltage in Nebraska milking centers began in May 1980 as part of a comprehensive, interdisciplinary mastitis control program at the University of Nebraska. Staff involved in the interdisciplinary project along with their departments and identified areas of responsibility are: Gerald R. Bodman, P.E., Agricultural Engineering, cow handling facilities, milking system design and function, extraneous voltage, and liaison with equipment dealers; Don J. Kubik, Dairy Science, administration and liaison with milk marketing outlets; Philip H. Cole, Dairy Science, milking procedures; Foster G. Owen, Dairy Science, nutrition and ration formulation; Duane N. Rice, Veterinary Science, California Mastitis Test (CMT) evaluation, general veterinary procedures, and liaison with

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veterinarians; Dennis Erickson, Veterinary Science, evaluation of milk samples; and Stan Wallen, Food Science, udder sanitation, teat dips and iodine residue in milk. This project was perceived as a three-year project. It began with a comprehensive mastitis education program in December 1979. Selection of cooperators for establishment of 32 demonstration herds took place in May 1980. The project was funded in part by a grant from Mid-Amercia Dairymen, Inc., and by fees paid by the cooperators.

Partially as a result of the mastitis control program Extension effort, additional grants were received from the University of Nebraska Calf Scour Vaccine Royalty Funds and USDA-ARS for expansion of research efforts into the frequency and magnitude of extraneous voltages on Nebraska dairy farms. During the three-year project dairy farms across Nebraska will be checked for the existence of extraneous voltages. To date, approximately 200 herds have been surveyed.

Nature of Problem

Despite the lack of specific data, nationwide it is generally felt that alternating current (ac) voltages in excess of 500 millivolts (mV) (0.5 Volts) (V) are sufficient to warrant concern and to justify corrective measures if they appear or develop within the cow's environment. Both identification of the precise threshold of concern and the actual definition of extraneous voltage are still debated. Some define extraneous voltages within a milking center to be only those associated with faulty insulation on electrical conductors, neutral currents, induced current, and similar occurrences but delete from their definition voltages which approach line voltage resulting from equipment shorts and poor equipment installation techniques. In our study, extraneous voltage is viewed as any voltage that is not part of a system design. Of particular concern are voltages which exist between any two points a cow might reasonably be expected to touch simultaneously. Hence, voltages from as little as 1 mV to levels equal to line voltage (120 Vac) are included in the definition of extraneous voltage. It is in this context that extraneous voltages are discussed in this paper.

If we accept the fact that a dairy cow may have a resistance as low as 400 ohms, then voltages as low as 2 V can result in a current flow through the cow of 5 milliamps--the safe "let go" level for most humans. Both animals and humans are distressed by current flows of about 1 mA. Hence, extraneous voltages within milking centers cause concern not only because of cow health and production, but also from a human safety standpoint.

Extraneous voltages are believed to develop within a given facility as a result of at least the following situations:

1. Induced currents. Caused by electrical wires attached to and run parallel to metallic conductors. The solution to this problem is to avoid running electrical conductors parallel to metallic objects. One investigator found such voltages developing in a tie-stall barn due to electric cow trainers which were parallel to a stainless steel milkline. Pulsator wires along a pipeline are also a potential problem as they may induce voltages as high as 24 Vdc.

2. Unbalanced load. Disregard for balancing of 110 volt loads between the legs of a 220 volt service results in greatly increased levels of current flow through the secondary neutral conductor. The solution to this problem is to use good wiring techniques and, to the extent possible, balance connected and demand loads during the milking operation between both legs of the 220 volt service. In new construction an alternative is to use only 220 volt motors or equipment within the milking center.

3. Improper grounding of services. Loose connections, undersized conductors (especially neutrals) and in some cases the total omission of a grounding electrode from an electrical service can result in voltages at various locations within the milking center. The solution to this problem is to assure that all electrical services are installed in accordance with the National Electric Code which requires that all service entrance centers have adequate grounding electrodes.

4. Equipment grounding. Improper grounding of motors and enclosures can increase current flows--and associated voltage development--through poorly defined paths. The use of neutral wires for equipment grounding on branch circuits in addition to being in violation of the NEC, can cause increased ground loop current flow. Neutrals and grounds must be kept separate outside of the service entrance. The neutral should be grounded at only one location in a building.

5. Galvanic action. Direct-current (dc) voltages may develop as a result of galvanic or battery action associated with corrosion. A solution is to incorporate ventilation systems which control relative humidity levels and hence the rate of structural rusting and deterioration within a milking center, to minimize the extent to which manure, salt, and other corrosive agents are allowed to accumulate around metallic objects and to use high quality, corrosion resistant metals. It should be noted that because of the acid wash water (low pH) used in sanitizing and cleaning milklines and because of the basic ($pH > 7$) concrete floor used in milking centers, this battery action is rejuvenated on a twice-per-day basis in those situations where wash water is permitted to drain across the concrete floor as compared to being discharged through a designed drainage conveyance system.

6. Electrical shorts. Deterioration of conductor insulation in circuits or windings of motors or poor wiring techniques in plugs and receptacles can result in the development of extraneous voltages. The only solution to this problem is to assure that the entire electrical service system is

installed utilizing appropriate wire types and good wiring techniques. Where circuits or motor windings show insulation deterioration, they should be replaced.

7. Primary Neutral Current. The primary neutral of the electric supply system is required to be grounded at specific intervals. Current indications are that if grounds are removed through corrosion, accidents, or acts of vandalism, grounding electrodes located on the farmstead will be forced to carry a larger part of the primary neutral current flow. An open or or high-resistance primary neutral conductor can also increase farmstead neutral currents. These increased neutral currents in turn cause greater voltage in undesirable locations. Still to be determined, however, is whether these cause-and-effect phenomena occur in every case.

Procedures

Survey data from individual farms are reported on a standard format (UNL Handout EV-2) for further evaluation. Although the primary checkpoints in a given system are those identified in Handout EV-2, it is standard procedure to monitor or check other points if a dairyman reports having received shocks from a given piece of equipment, if animals appear nervous around or avoid some equipment, or if the level of voltages measured between the standard checkpoints suggests that further checking should be conducted. Both ac and dc voltages are monitored with the milking system in both the milking or operational mode and in the non-operational mode or "off" position. While an effort has been made to obtain the "operating mode" voltage levels during the actual milking process, that has not been possible in all cases. In those situations where the visit to the farm did not occur coincident with the milking operation, pipelines were put into the milking position and, with equipment operating, voltage checks were made. Non-operating voltage checks were made with all milking system related equipment in the "off" position. If a voltage in excess of 500 mV is recorded during the routine checks those contact points are checked a second time with a 100 ohm resistor shunted across the voltmeter input leads. This helps to define the energy potential of a voltage source.

On installations where problems are found, efforts are made to identify the source. A local electrician makes the actual corrections. In problem cases, attempts are made to have an electrician and a local utility representative at the site during diagnostic testing.

Diagnostic Equipment[3/]

Although not all pieces of equipment are used in each case, the equipment we have used and found to be beneficial in evaluating extraneous voltages includes:

3/ Mention of company or tradenames is for identification purposes and does not imply endorsement by United States Department of Agriculture or the University of Nebraska.

1. Fluke Model 8024 (A or B) digital multimeter. Used primarily for survey purposes but also found to be very useful because of a peak voltage lock-on capability. With this feature, the highest voltage will be held, so problem voltages may be detected without a recorder or having someone watch the meter.

2. Simpson Model 465 autoranging digital multimeter. Initially used for survey purposes but because of its greater bulkiness it is now generally reserved for evaluating problem installations. Its greater sensitivity and shorter response time makes it a good complement to the Fluke unit.

3. AMPROBE ACD-1 or A. W. Sperry Digisnap (R) DSA-1000 digital clamp-on ammeter. Used to check for balance of current flow between the conductors servicing a farmstead, the dairy facility or specific equipment.

4. Hewlett Packard Model 3467A recording multimeter. This piece of equipment offers flexibility of continual monitoring of up to 4 points for time intervals ranging from 3 seconds to 3 hours. Hence, it has served well as a piece of diagnostic equipment in that loads on the electrical system can be changed without a need to continually read and record voltage levels. A built-in time printer allows later correlation of voltages and changes in loads or service wiring.

5. Associated Research-Vibroground Model 263 grounding electrode test unit. Used to evaluate grounding resistance of electrodes or systems and to evaluate electrodes for compliance with the National Electric Code.

6. Portable remote ground rod. This modified ground rod is equipped with a slide-weight and stops to allow driving and removal at a given location. The use of a remote ground as a reference is desirable in identifying sources of voltages. It is also used as part of a diagnostic survey once problems are found to exist between standard cow-contact checkpoints.

7. Extension cord. A set of 14/2, with ground, cords have been wired as extension cords (about 750 feet total). Two adaptors for each set consisting of a standard plug and receptacle plus a battery terminal type clamp and 1 ft of cord have been assembled with all conductors connected together at the clamp. This permits attachment of the cords as a single conductor between two pieces of equipment, a ground rod and volt meter, etc. All three conductors serve as parallel conductors once the short adaptor cords are installed. Since they are primarily

wired as extension cords, where required by site conditions, they can also be used for operation of equipment at locations remote from the power supply.

8. Tektronics Model 214 portable oscilloscope. The oscilloscope has been utilized in several investigative studies as a means of observing voltage patterns and transients from a given piece of equipment or location.

9. The performance of two Radio Shack digital voltmeters was evaluated (Models 22-196 and 22-198). Their lower cost makes them desirable if they are appropriate for the job. Our evaluation suggests that either meter works well if the voltages change slowly. Neither model displayed peak voltages that were apparent with the Fluke 8024, the Simpson 465 and the oscilloscope because of the sampling time. Voltages near the transient peak were observed with Model 22-198 while the logic of autoranging 22-196 did not let it display the transient. Therefore it appears that the Model 22-198 is probably useful for general work in extraneous voltages, but the 22-196 will not work well for detailed troubleshooting if the problem is transient.

Survey Results

To date, voltages within Nebraska milking centers have been found to range from 0 to 120 volts (line voltage). Voltages in excess of the 500 mV "threshold of concern" level have been measured in at least one location within the milking center on just over 50% of the 200+ farms surveyed.

A wide variety of problem areas have been identified in surveys conducted to date. Among the most frequently observed or encountered problems are:

1. Absence of grounding electrodes at service entrances.

2. Indiscriminate and incorrect use of aluminum split bolt fittings to join a combination of aluminum and copper conductors. Differences in the thermal coefficient of expansion have resulted in loosening of wires within these joints with an associated increase in resistance. In one case the main feeder wires had been improperly joined at a distribution pole installation with the result that insulation on the conductors had melted.

3. Failure to connect neutral wire at meter or distribution pole.

4. Improper grounding or lack of grounding of electrical motors and other service equipment.

5. Accumulation of dust and debris in and around service entrances with resultant increase in extraneous voltage levels with increases in relative humidity.

6. Deteriorated insulation in electrically heated stock water tanks. Wires resting directly against water lines or other metallic components of the waterers, have resulted in development of voltages around the waterer.

7. Deteriorated and corroded fan motors within the milking center.

8. Broken or otherwise short-circuited switches and receptacles in and around the milking center.

9. Damage to insulation of electrical conductors by rodents.

10. Shorts within the receiver jar electric probes resulting in rapid open-close operation of the relay prior to complete start-up of the milk pump. During this "chatter" of the relay, voltage spikes of 10-20 volts can frequently be measured within the milking center.

11. Faulty fluorescent lighting ballasts. The use of residential type lighting fixtures within a milking center is a common occurrence. However, frequent and wide variations in temperature and relative humidity and the integrity of the insulation within the lighting fixtures and of the lighting ballasts themselves frequently result in high voltage, low current leaks within a matter of 3 to 5 years after installation.

12. Shorted, corroded, or improperly grounded milk transfer pumps. Startup and operation of milk pumps frequently results in voltage levels in excess of 500 mV and in several cases have increased voltages above 3 volts. In one installation a short within the milk pump resulted in a constant 21.3 voltage reading between the milk pump and the milk house floor. A portion of this voltage was reflected in readings at several locations within the parlor.

13. Dust accumulation in electrical in-parlor feeding systems frequently results in an increase of voltages between the feeder and floor or feeder and rear parlor rail during operation of the feeding system. Feeders are frequently operated by 110 Vac motors and frequently are wired from one circuit of a 220 volt service. Feeder operation results in high neutral current flow within the electrical service and associated increase in voltages between the feeder and other metallic contact points within the parlor.

14. Improperly grounded electric fencers.

15. Deteriorated wire and corroded or loose terminals on electric pulsators. This is a common cause of dc voltages within the milking center.

16. Failure to install knock-out closures in electrical boxes when knock-outs have been inadvertently or inappropriately removed. This allows rodents to nest in and around electrical contacts. The result is extraneous voltage levels with changes in moisture conditions.

17. Poorly maintained stock watering tanks or other watering devices. Accumulations of feed materials and other organic matter frequently increase the deterioration rate of water tanks. The decomposition of the organic matter itself frequently results in dc voltages in and around stock tanks.

18. Reliance upon metal conduit to provide an equipment ground resulting in inadequate grounding of the equipment with even minimal corrosion of connections.

19. Inadequate or non-existent ventilation of the milking center with the retention of high humidity levels over long periods of time and associated high deterioration rate of metallic components causing an increased level and incidence of dc voltages.

20. Use of non-weatherproof enclosures in exposed locations and locations subjected to high levels of dust and airborne debris.

21. Improperly grounded submersible water pump installations.

22. Inadequate grounding of electric service. In many cases the water line was used as a primary ground. When metallic water lines are replaced with non-metallic piping the quality of the ground is severely diminished.

23. Shorts or poor grounding of the telephone service.

24. Shorted electric pulsators.

The majority of problems identified in Nebraska have been on-farm and due primarily to improper installation and maintenance of the electric supply system and milking system components. However, off-farm problems in the form of damaged REA ground wires, high resistance primary neutrals, and faulty transformers have also been encountered. In one installation reported to the authors voltages were being developed by an electrical wire which had rubbed through the tower on a windmill on an adjacent, abandoned farm. The distance from the service

box to the windmill tower was great enough to produce sufficient voltage drop so the current flow was insufficient to trip the circuit breaker. The result was a constant voltage through a neighboring farm milking center.

Solutions

As engineers we typically strive to develop a "cookbook" solution to routine problems we encounter. Despite the high incidence of what we believe to be problems with extraneous voltage on Nebraska dairy farms, we have not been able to develop a cookbook style solution. Further, diagnostic techniques and solutions suggested by others--though tried in a number of cases--do not always yield a solution. At the moment, interaction of various circuits appears to vary too much to permit an advocacy of a single solution technique. Our approach in identifying problem sources has been different in nearly every case because of different data and findings gathered on-site though our initial survey--cow contact surfaces--has been similar. The wisdom of advocating cookbook solutions and the general use of voltmeters by producers to attempt to identify extraneous voltage problems must be questioned based on the present status of extraneous voltage research and technology.

The seemingly "easy" solution to extraneous voltage problems is to arbitrarily bond all metallic components together. This approach is generally a solution to a symptom of the problem rather than correcting the problem itself. In some instances this may increase the magnitude of extraneous voltage. Conscientious efforts must be made to isolate and correct voltage leakage problems prior to the installation of additional ground rods and bonding of metallic equipment in and around the milking center.

New milking center installations should be constructed with a built-in grounding mat to provide an equi-potential plane. Construct the mat by utilizing 6 x 6 welded wire steel mesh within the concrete in milk house and parlor. Weld all steel in the pit floor, pit walls, and cow platform together and assure that all mesh in the parlor and milkhouse are interconnected. Additionally, all steel parlor support pipes and feeders should be connected to this mesh via welded conductors. At the holding area entrance place a 6 to 8 ft width of welded wire mesh within the holding area floor immediately outside the parlor. A gradual gradient should then be constructed to extend a further distance out into the holding area. The recommended gradient is to place bars at increasing distances apart, for example, 12, 18, 24, 30 inches as one progresses into the holding area away from the parlor for a distance of 12 to 15 ft and to interconnect these rods to the other metal structures. The entire metallic structure should be bonded to the grounding electrode at the service entrance. This procedure minimizes the potential for development of voltage gradients just as the cows step into the holding area or into the parlor from the holding area. This procedure should reduce the reluctance of cows to enter the parlor.

Regardless of the quality of wiring installation or construction techniques employed, experience suggests it is not safe to presume that extraneous voltages will not be a problem. For example, during the initial survey in the summer of 1980 two farms were found to have voltages which were below the 500 mV level.

During a follow-up check in the fall of 1980 these two farms both had voltages in excess of 6 volts within the milking center.

Electrical faults in equipment still result in current flow through the electric meter. This increases operating costs although no useful function is obtained from this energy. Thus, if we are going to serve our clientele in a truly professional manner, we must proceed in a way that eliminates problems, not just the outward signs resulting from the problem.

Summary

Consistent with findings elsewhere, extraneous voltages have been found to be a problem on Nebraska dairy farms. Poor equipment installation and wiring techniques coupled with a general lack of electrical system maintenance appear to be the major causes of problems.

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