COMMENTS

of the

Minnesota Department of Public Service

on

The Independent Stray Voltage Investigation

of the

Nelson and Franze Farms

Docket No. E119/C-92-318

January 28, 1993

Consultant's Report

I. BACKGROUND

On April 16, 1992, Mr. Lonnie Nelson and Mr. Darrel Franze filed a formal complaint against Lake Region Cooperative Electrical Association (Lake Region). The complaint expressed dissatisfaction with Lake Region's response to customer complaints of stray voltage. The complaint requested that Lake Region investigate the farm electrical environment more thoroughly, install isolating devices at the Company's expense, and eliminate primary neutral grounding in the farm yard.

On November 17, 1992, the Commission ordered a comprehensive examination of the electrical environment of the farms of Mr. Nelson and Mr. Franze. The Commission ordered the investigation because it found that it needed further information to proceed and because previous investigations on the farm did not adequately test all potential electrical problems. The Commission issued the results of the investigation on January 8, 1993 and allowed 20 days for parties to comment on the investigation.

The Department hired a consultant, Mr. Gerald R. Bodman, P.E., to comment on the results of the investigation. Mr. Bodman is an Associate Professor and Extension Agricultural Engineer in Livestock Systems at the University of Nebraska, Lincoln. Mr. Bodman is a nationally recognized expert on stray voltage, and his work formed the basis for the Department's comments in the Commission's stray voltage rulemaking proceeding (Docket No. E999/R-92-245). His recommendations for stray voltage testing protocol were used extensively in the instant investigation as a test for the protocol under consideration in the rulemaking.

The Department divided its comments into two sections. The first section:

- summarizes Mr. Bodman's observations, conclusions, and remedies based on his conclusions;
- provides comments on the test protocol; and
- recommends actions for the Commission to consider.

The second section contains Mr. Bodman's complete report on the investigation .

II. SUMMARY COMMENTS AND RECOMMENDATIONS

A. Overview of Mr. Bodman's Investigation

To assist the Commission in its review, the Department provides this summary of Mr. Bodman's investigation.

1. *Important Data Observations*

Mr. Bodman's report includes five general observations about the data contained in the investigation report. These observations are:

1. Both farms have very high voltages between the water-line and reference grounds, as shown in the chart below.

Water-Line to Reference Ground Measurements

	Peak Voltage	Average Voltage
Nelson farm	4.81 Vac[1]	> 3 Vac
Franze farm	2.31 Vac	> 1 Vac

In contrast, the University of Minnesota publication entitled "Stray Voltage Problems with Dairy Cows" (North Central Regional Extension Publication No. 25) states, "a reasonable and attainable goal on farms needing correction would be to maintain neutral voltages on the farm grounding system below 0.35 volt." The peak voltage measurements on Mr. Nelson's farm exceed this recommended standard by at least a factor of 13 and the peak voltage measurements on Mr. Franze's farm exceed this standard by at least a factor of six.

2. Both farms have very high voltages between the primary neutral and the reference ground, as illustrated below.

Primary Neutral to Reference Ground Measurements

	Peak Voltage	Frequent Voltage[2]
Nelson farm	17.5 Vac	6-12 Vac
Franze farm	12.5 Vac	> 5 Vac

In contrast, Mr. Bodman explains that voltages of 0 - 3 Vac are reasonably common and are considered normal; voltages of 3 - 5 Vac are strongly indicative of a problem; and that voltages in excess of 5 Vac are unwarranted, indicate a definite problem with the primary neutral system, and need corrective action.

3. Both farms had high levels of current flow through the water line. Mr. Nelson's farm had current levels of up to 150 mA[3] in the water line. The water line's level of current on Mr. Franze's farm reached or exceeded 500 mA and regularly varied between 100 mA and 200 mA. In contrast, Mr. Bodman's experience indicates that water line currents of 50 mA and less

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[1] Vac indicates a measure of volts in ac current. This is a measurement of electric potential.

[2] This term does not imply that these voltages were averages, only that they occurred frequently during the test.

[3] mA denotes a "milli-amp" or 1/1000 of an amp, which is a measurement of electric current.

are common. When they surpass 50 mA, he begins to look for a problem causing the high current.

In addition, the calculated cow contact current during Test No. 85 on Mr. Nelson's farm is 1.30 mA. In contrast, the Wisconsin Public Service Commission has found that current measurements greater than 1 mA need corrective or mitigative action if production and behavioral problems exist.

4. The feeders servicing both farms show a significant level of load imbalance, as illustrated below.

Levels of Load Imbalance

	Peak load-imbalance	Frequent load-imbalance
Nelson farm	28 amps	> 20 amps
Franze farm	15 amps	9 - 12 amps

5. The resistance for several of the grounds on Mr. Franze's farm is high, as shown below.

Resistance of Grounds

	Guy anchor	Secondary ground	Primary ground
Pole 1	163 ohms	44 ohms	41 ohms
Pole 2	93 ohms		34 ohms

In contrast, Mr. Bodman recommends that ground rods within one mile of a farm that is experiencing high primary neutral voltages should have a maximum resistance of 25 ohms and preferably 10 ohms or less. (See page 23 of Department's comments on stray voltage rulemaking for more information.) Similar high resistances on Mr. Nelson's farm may exist. However, the resistance for the grounds on the poles leading to Mr. Nelson's farm was not reported.

2. Conclusions

Given these observations, Mr. Bodman drew four conclusions:

1. None of the tests confirm any problems with any of the on-farm equipment of either farm.

2. The high voltages between the primary neutral and reference ground and the high voltages between the water line and reference ground are most likely the result of the significant level of phase conductor load imbalance on Lake Region's distribution system.

3. There is a high probability that under some conditions the high level of current on the water line could follow other paths and become problematic for the animals. The data strongly suggest that the current is the result of the primary neutral using the on-farm grounding as a major portion of the grounding capability of the system.

4. The high voltages on the primary neutral are accessing the animal environment.

3. Recommended Remedies

Mr. Bodman suggests the following remedies based on his data interpretation and conclusions.

1. Lake Region needs to improve the primary distribution system servicing both farms. To accomplish this, Lake Region must examine the load balance on different segments of their lines. When analyzing the loads connected to the A, B and C phases, Lake Region should look for bad connections and undersized conductors. Improvements made as a result of the voltage profile examination should result in a better balanced load and lower voltages between the primary neutral and the reference ground.

2. Lake Region must improve its grounding for both of the farms, and the primary distribution systems servicing each of the two farms needs to be improved so that each ground has a maximum resistance of 25 ohms. If high voltages (greater than three volts) between the primary neutral and the reference ground continue, grounding should be improved so that each ground has a maximum of 10 ohms.

   Lake Region can improve the grounding by ensuring that ground rods are separated by a distance of at least the sum of the two ground rods. For example, two ten-foot ground rods must be at least 20 feet apart. Lake Region can also use alternative grounding techniques such as deep grounding, multiple grounds, or burying several feet of coiled copper wire.

3. Lake Region must install an isolator on each farm. However, the isolators presently used by Lake Region are inadequate due to the high voltages measured on the primary neutral. Therefore, Lake Region must install an isolator that blocks higher voltages. In addition, all guy wires on the transformer pole should be insulated at least eight feet above ground.

The Department recommends that the Commission require Lake Region to implement these changes within 15 days of the Commission's Order.

B. Comments on Test Protocol

The Department recommended that the Commission conduct an investigation of the complainants' farms for two reasons. First, the investigation was necessary to develop the facts of the case so that the Commission could make an informed decision. The facts of the case and our recommendations for corrective action are discussed above.

Second, we believed that this investigation could test the protocol, appeal process, and mitigation procedures recommended by the Department in our comments on stray voltage rulemaking. Given the controversy surrounding the issue of stray voltage and the disagreements about how to define, test and mitigate it, we believe the stray voltage investigations on both farms were successful. We were able to establish the facts concerning the electrical environment on the two farms and the experience taught us how to improve the protocol.

1. Test and Reporting Protocol

As a result of the initial investigation, Mr. Bodman has recommended several refinements to the testing and reporting procedures used by the Commission's investigation team. The Department recommends that these changes be incorporated into future investigations and offer them as additions to our original comments on stray voltage rulemaking. Some of the improvements include:

1. When determining the points at which cow contact voltages and currents will be monitored, the investigator must, at a minimum, survey several different locations while there is an electric load equal to or exceeding the normal load on the farm during milking. The investigator should use the location which has the highest voltages to monitor cow contact voltages and currents.

   In the instant investigation, the investigators asked the complainants where the problems with the cows seemed to be the worst and set up cow contact voltage and current monitoring there. Mr. Bodman's experience indicates this is not always a valid approach because wide variations in voltages have been found to exist in most barns and the complainants' perception often does not correlate well with areas of elevated voltages and currents.

2. Investigators need to use known loads under different test conditions so that different tests can be compared more easily and appropriately. These known loads can be provided by the investigator or simply be loads already identified on the farm. Without this condition, the different test results cannot be compared because the variables affecting the measurements are different in each test.

3. Data should be collected and reported in a more usable, less compressed form. For example, one of the investigators reported 12 hours worth of data in only one-inch of graph space. In contrast, Mr. Bodman uses a strip chart which results in approximately one minute's worth of data in two centimeters

(approximately one inch). The scale used in the Commission investigators' graphing made it impossible to determine how different activities recorded in the event log correlated to the measurement being depicted in the graphs.

4. Investigators should include an interpretation of the data and recommendations for corrective and mitigative actions in their report(s). Although the investigators provided some interpretation of test data, it was incomplete and no recommendations for corrective action were included.

These four points are also discussed in Mr. Bodman's report. The Department believes that, in particular, this last recommendation is very important. We believe the process would work better if the investigators reported their recommendations and how they arrived at their recommendations, as we suggested in our comments of August 17, 1992 on the instant complaint. This recommendation is particularly important to parties such as the Department because our consultant was not present at the investigation, and was only able to base his findings on the reports of the investigators and substation data supplied by Lake Region.

2. Procedural Issues

Based on our experience with this initial investigation, the Department believes that follow-up testing should be added to the process. Follow-up testing would verify that any changes made to the farm environment have corrected the problems indicated by the investigation. This procedure, initiated at the request of the complainant, would test whether the changes made to the farm environment have corrected the problems indicated by the investigation. The Department believes the testing can be conducted by the utility to avoid the expense and time associated with independent testing; the testing should, however, follow the protocol used in the initial test for the farm.

We believe the complainant should wait a reasonable period of time after remedies are completed before requesting follow-up tests to see if the corrective and mitigative actions improve or rectify the farm problem. We believe a 30-day waiting period is reasonable. However, we also believe that the follow-up tests should be a matter of right for the farmer. Therefore, we believe the utility must initiate re-testing within 20 days of the farmer's request.

C. SUMMARY OF RECOMMENDATIONS

Although our consultant also has recommended that further testing be conducted on the two farms, we believe sufficient facts have been established to allow the Commission to order immediate remedies. The Department recommends the following action plan for the Commission:

1. The Commission should order Lake Region to implement the three remedies recommended by our consultant within 15 days of the order.

2. If 30 days after the remedies are completed, the complainants still believe their cows are suffering from stray voltage, the complainants should file with the Commission and Lake Region a request for re-testing. Lake Region

should conduct stray voltage testing using the protocol used in the original test, with changes suggested by Mr. Bodman in these comments. Lake Region should file the results of this testing with the Commission and the parties within 20 days of the complainants' request.

3. In the future, the Commission should direct the investigators to draw more explicit conclusions from the data and to make recommendations for remedies in this instant filing.

The Department is hopeful that the remedies will correct the problems identified on the Nelson and Franze farms, and that the procedural recommendations will improve the process for future proceedings.

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Milking System Design/Evaluation

EXTRANEOUS VOLTAGE

EVALUATION OF PROCEDURES AND DATA

Test Data Collected on Farms of Lonnie Nelson and Darrell Franze

Report Prepared on Behalf of and Submitted to
Minnesota Department of Public Service

ASE Project No. 702:9268

Prepared by:
Gerald R. Bodman, P.E.
January 25, 1993

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

Gerald R. Bodman, P.E.

Date 1/25/93 Registration No. 17199

The purpose of this report is to set forth the results of findings based on the review of data and pertinent documents relative to the farms of Lonnie Nelson and Darrell Franze. The test data were compiled by two external and independent contractors. Information regarding voltages within the barn was collected and reported by Riley C. Hendrickson in a report dated December 30, 1992. Data regarding the primary and secondary electrical systems were collected and reported by Gagnon Contracting and presented in a report dated December 29, 1992. In addition to the two reports, several other items were reviewed and will be considered in the preparation of this report. They include:

1. Agreement for Interim Service Adjustments--proposed agreement between Lonnie Nelson and Lake Region Coop Electrical Association.

2. Agreement for Interim Service Adjustments--proposed agreement between Darrell Franze and Lake Region Coop Electrical Association.

3. Substation performance data for the Stalker Lake and Battle Lake substations. These are the two substations servicing the Nelson and Franze farm, respectively.

The evaluation of the data and the preparation of this report were prepared under contract with the Minnesota Department of Public Service. The stated purpose of the contract was to review and evaluate electrical test procedures or protocols, data collected during on-farm testing, the investigators' interpretations of the data, and the contractors' recommendations for mitigative and corrective actions. The objective is to help ascertain and identify possible sources of extraneous voltages in the animal environment on the two subject farms. The procedures employed were to review the listed documents and summarize pertinent test data for comparison and evaluation. The summary sheets are included as an appendix to this report.

Comments and recommendations presented herein are not intended to be an evaluation of any person involved in setting up or conducting these tests. Likewise, there is no intent to evaluate their professionalism or technical competency. All comments are directed at the procedures and methods used as reported and as received by this evaluator.

BASIC TEST PROCEDURES

The reports, along with other information received, suggest that as many as four to six people might have been simultaneously involved in operating equipment, collecting data or making changes on the system. This is in addition to linemen who were on-site to assist in separating primary and secondary neutrals, removing primary down-grounds from service, etc. The reports clearly indicate that an exhaustive amount of data was collected. However, equipment malfunctions or other reasons (some of which are unknown to this evaluator) contributed to a lack of some critical data. Primary observations and findings pertinent to both farms and to the general procedures include:

1. The log of tests performed and activities taking place are often inconsistent with some of the data. This suggests that individuals were involved in making or breaking connections--for example, jumpering of primary and secondary neutrals--without fully communicating the activities to other parties involved in the testing. This appears to be a real-world example of the old adage that "too many cooks spoil the broth."

   For example, there are several intervals on the voltage graphs prepared by Mr. Gagnon which clearly indicate separation of neutrals but no indication of that event having taken place is noted in the events log. Similarly, there are instances where increasing on-farm loads, per the events log, do not show a corresponding increase in farm energy use, voltages, current levels, etc.

2. Procedures used in determining the cow contact points to be monitored appear to be inadequate. In conversation with the individuals involved in making the decision, this contractor was advised that the procedure was to simply ask the individual producer in what part of the barn problems with cows seemed to be the worst. Experience shows this is not always a valid approach, as wide variations in voltages have been found to exist in nearly every barn in which an investigation has been conducted. Also, a producer's perception often does not correlate well with areas of elevated voltages and currents.

3. The decision to use a 10-ohm resistor in series with the higher resistance (100- or 300-ohms) used to represent the resistance of a cow effectively shunted the voltmeter and resulted in the voltmeter functioning as a low impedance meter throughout the testing. Thus, open circuit voltages as commonly used for diagnostic purposes are for the most part non-existent.

4. The absence of a full data set yielded significant difficulty in making all appropriate comparisons which are felt to be important in a complete analysis. Some of the missing data fields are evident in the test summary data sheets which are part of this report.

5. The scale(s) used in graphing and presenting much of the data made for very difficult interpretation as it was virtually impossible to distinguish between the various activities recorded in the event log. This compression of data (12 hrs. of data in a 1 - 1 1/4 inch space on the graph) significantly and adversely reduces the ability to fully evaluate the events and establish correlations.

6. The absence of continual strip chart recorders and the presentation of cow contact data as one-minute averages makes it impossible to evaluate peak voltages which might have been encountered or spikes which may have occurred as a result of the operation of different pieces of equipment.

7. The use of multiple reference ground rods makes direct comparison of the data more difficult. Despite the use of a recording channel to monitor differences in voltages between the two reference points (approximately zero in all instances), there are situations where the voltages between the two reference rods were not zero. Consequently, without the ability to precisely correlate times on the graphs with the event log, complete interpretation of the data is impossible.

8. The test data presented by the utility are noted as having been "recorded at the substation voltage regulator test terminals and represents the regulated outgoing voltage level." As such, the data presented are the best and most positive data for the feeders. The voltage variations at the individual farms would have been greater than values presented by the utility company. A better method to look at voltage variations would have been to monitor the voltages at the individual farm during the actual testing. This would have given direct insight into what was happening at the farm. Consequently, the data presented are of limited value in assessing what actually took place at the farm location. (The data do indicate the voltage regulators are working!) The extent to which low voltage adversely affected or might have contributed to failure of on-farm equipment, e.g., motor burnout, could not be determined.

9. Failure to monitor and record current in the secondary neutral makes calculation of the voltage drop along the neutral impossible. That is, there is no way to compare the measured voltage drop with what should have been there given the loads. The absence of this vital piece of data also reduces the opportunity to evaluate the on-farm wiring system with respect to the balancing of 115-Vac loads. Theoretically, having monitored the voltage at the meter end of the secondary neutral and at the barn service entrance end of this conductor would allow calculation of voltage drop based on subtraction of these two values. However, the method of presentation of these data makes precise determination of the voltages at either station impossible, thereby negating the opportunity to fully evaluate the condition and sizing of the secondary neutral.

10. No information was given regarding loads on the utility system at the time of testing vs. normal loads. To what extent system load varies during the year is not known but could significantly affect voltages on the distribution system neutral and, hence, voltages which might be affected in the animal environment.

11. Methods used to evaluate the overall impedance or resistance of the primary and neutral systems are technically accurate but are considered inappropriate. Specifically, the ability to identify specific voltages with specific loads is not possible given the information as presented in the reports. A better method would have been to take direct readings of the two system resistances using appropriate ground resistance testing equipment. This is a particular concern on the Nelson farm calculations (which are incomplete) where the combined resistance of 3.53 ohms is very low compared to the measured resistances listed on Page 88 of the Gagnon Contracting report. These calculations and the numbers reported suggest that as a very minimum the grounding characteristics of the soils along the primary neutral must be significantly better than those reported as being present on the farm. (Resistance at barn is an exception.) Other data, e.g., primary neutral to reference ground voltages, do not support the idea of a significant difference in soil conductivity.

12. Failure to use known 115-Vac and 230-Vac loads for the various test conditions and wiring configurations results in less precision in comparing data. Monitoring of phase conductor current at the barn would have allowed better interpretation of the data since the possibility of varying or different loads under different test conditions could have been identified and evaluated.

13. The generally accepted practice in reporting extraneous voltage data is to use meters which record "averaging RMS" data. In conversation with Mr. Hendrickson it was learned that despite his labeling of his data as "true RMS" readings, they are, in fact, average RMS values as used in the normal nomenclature. Mr. Gagnon also noted that the "X1.414" label on his graphs is an idiosyncrasy of the Wave Rider system and has no relevance to interpretation of the data. The data are directly readable as average RMS.

14. The extremely low voltage and current measurements reported throughout testing on both farms seem inconsistent with voltages that apparently were measured at earlier times and led to the decision to install a four-wire system or Ronk Blockers. The data presented would suggest separation of the neutrals was totally inappropriate and a four-wire system was unnecessary on these two farms.

15. The decision to monitor total farm load rather than load at the dairy barn makes correlation between changes in voltages at the various locations and the operation of various loads very difficult since there are loads on the farm which are beyond the control of the investigators.

LONNIE NELSON FARM

Information in the events log suggests this farm is still wired per "standard procedures," i.e., a three-wire service with the neutrals bonded at the transformer. No other information about the basic on-farm electrical system was found in the documents reviewed.

1. None of the tests showed any voltage in the direct cow contact area (rear hoof to water line) which even approached the generally accepted threshold of concern (0.5 Vac or 500 mVac). The highest voltage recorded was 230 mVac (Test No. 12). The small variations in voltage are inconsistent with field experience--in the vast majority of installations--except where an attempt has been made to develop an equipotential plane in the animal area. (Information received and reviewed does not suggest the presence of an equipotential plane in this barn.)

2. Despite the lack of voltages of a problematic magnitude in the immediate or direct cow contact area, the voltages measured between the water line and a reference ground (Hendrickson Report, Channel 5) give reason for very serious concern about the conditions which exist in this barn and on this farm when the neutrals are bonded. The highest voltage recorded was 4.81 Vac (Test No. 24). The water line to reference ground voltage was over 3 Vac the vast majority of time when the neutrals were bonded and utility power was being used to operate the on-farm equipment. The differences in voltage between the water line and the reference ground and the water line and the rear hoof area suggest a deficiency in the testing method, the location selected for monitoring, test lead continuity, test lead attachment method or the equipment used to record the voltages. The University of Minnesota publication entitled "Stray Voltage Problems with Dairy Cows" (North Central Regional Extension Publication No. 25) as reviewed in 1992 and as set forth in previous editions as well states "A reasonable and attainable goal on farms needing correction would be to maintain neutral voltages on the farm grounding system below 0.35 volt." Obviously, voltages in excess of three volts are more than 10 times as high as the value recommended by the authors of the cited publication. If in fact these voltages represent a real-life situation, there is a high probability that under the right set of conditions, even humans could receive serious shocks if contact with the water line is made at the proper time and between the proper contact points.

3. Testing did not show any significant improvement in converting from a three- to a four-wire system. Procedures employed to convert from a three-wire to a four-wire system were not described. Unless complete freedom from neutral-ground interconnections beyond the main service panel was verified, the validity of this test is questionable. Given the additional inherent safety hazards associated with a four-wire system, retaining a three-wire system on this farm is recommended.

4. Despite the reported 80 mA leakage from the hot water heater (This evaluator was subsequently advised the leakage current was only 40 mA.), there is no documented change in voltage or current levels anywhere in the system attributable to the operation of the water heater.

5. None of the tests confirm any problems with any of the on-farm equipment. In most instances the changes in voltage are so small as to raise question about the validity of the voltage measurements.

6. Repeated instances of voltages between the primary neutral and the reference ground in excess of five volts indicates very major and significant problems with the primary distribution system. Voltages of 0 - 3 Vac between the primary neutral and a reference ground with the neutrals at the farm separated are reasonably common and are considered normal. Voltages of 3 - 5 Vac are strongly indicative of a problem. Voltages in excess of 5 Vac are unwarranted and indicate significant problems. In many instances the voltages on the primary were in the range of 6 - 12 volts and repeatedly spikes of 17.5 Vac were recorded.

7. Despite the lack of significant cow contact voltage, currents of up to 0.95+ mA were recorded on several occasions (Tests 11, 12, 17). The calculated cow contact current during Test No. 85 would be 1.30 mA. This compares with a maximum recorded current of 0.08 mA. No currents even approaching problematic level of 1 mA were found any time the neutrals were separated or while operating farm loads with a stand-by generator. This is indicative of a current being imposed on the dairy barn by the primary neutral system. The data strongly suggest the current is the result of the primary neutral using the on-farm grounding as a major portion of the grounding capability of the system. (This supports the previously stated concerns about system grounding resistance measurements.) A correlation between this current and changing on-farm loads appears to exist but is not firm, based on the data presented.

8. Removal of the transformer pole and primary down-grounds on additional utility poles had little or no influence on the in-barn voltages. This is consistent with the typical situation.

9. Current levels of up to 150 mA in the water line are reason for concern. At these levels there is high probability that under some conditions this current could bleed off along other parallel paths, possibly becoming problematic for the animals.

10. The primary neutral system shows a significant level of phase conductor load imbalance. On numerous occasions the imbalance exceeds 20 amps. The highest value recorded was 28 amps. This imbalance is likely responsible for the high primary neutral-to-reference ground voltages recorded and discussed previously.

11. Voltages at the secondary neutral in the barn service panel exceeded the 0.35 Vac recommended by the University of Minnesota publication except when the neutrals were separated. Interconnection of the neutrals raises voltages on the secondary system to levels equalling the primary neutral--frequently in excess of five volts and occasional 17.5-volt spikes. These high voltages were not reflected in the cow contact environment, once again raising questions as to the validity of the testing procedures and equipment which were employed in this instance. Alternatively, the data suggest a complete absence of any interconnection between the water line and electrical system. This is a highly unlikely situation given the electric water heater and rise in voltage between the water line and reference ground when the neutrals are interconnected.

12. Comparison of Test No. 31 with Test No. 63 shows that the voltages in the cow contact area dropped by approximately 2/3 when switching from utility power to generator power. Separating the neutrals with utility power resulted in a drop from 112 to 2.5 mVac. The voltage with the neutrals separated is 2.2% of the voltage with the neutrals jumpered or bonded. The voltage between the water line and the reference ground dropped from 4.65 Vac to 80 mVac (1.7% of bonded condition voltage) with separation of the neutrals. When using generator power with the neutrals separated, the maximum cow contact voltage was 7.4 mVac. This represents a voltage that is 6.6% of the voltage with utility power and the neutrals jumpered. Similarly, the water line to reference ground voltage with generator power and the neutrals separated was just 5.6% of the voltage with utility power and the neutrals jumpered. Separating the neutrals with generator power caused the water line to reference ground voltage to drop to a value that was just 17.0% of the voltage with generator power and the neutrals bonded. These data all indicate an off-farm voltage source.

13. Data from the power company show minimum voltages at the Battle Lake substation of approximately 122 Vac. No information was presented to indicate what the voltage was at the Nelson farm. Voltage drop would have caused a lower voltage at the farm.

14. In the Agreement for Interim Service Adjustments there was a proposal to relocate the transformer to pole No. 1 as shown on Exhibit 1. This results in a secondary neutral length from the transformer to the meter pole of approximately 590 ft. The distance from the meter pole to the barn represents an additional 82 or 92 ft. (The figure on the diagram is not clear.) Good practice would dictate that for a service drop of 600 ft. and a 200-amp service (service size assumed) the conductor should be at least 600 MCM copper or 900 MCM aluminum. This is based on a 2% voltage drop and is the procedure recommended by agricultural engineers for service to all livestock facilities. If we go to the outer extreme and allow a 4% voltage drop for a 200-amp service and 600-ft. service conductor length, the service conductor should be at least a 300 MCM copper or a 500 MCM aluminum. With copper, the proposed 4/0

conductor is at least two wire sizes too small. For an aluminum conductor the proposed 4/0 conductor is at least six wire sizes too small. Consequently, relocating the transformer without appropriate sizing of the service drop conductors is contrary to good practice and is not recommended. Installation of a four-wire service in an attempt to alleviate this deficiency in design is poor practice and also is not recommended. Under no circumstances should a down-sized neutral, i.e., smaller than the phase conductors, be allowed.

15. On Page 3 of the Proposed Interim Agreement, a warning is included regarding low voltage if a farm load is in excess of 14.1 kVa. The farm load documented by Gagnon was approximately 18 kVa. Thus, the proposal is inadequate to meet the existing farm load and does not allow for future growth or expansion.

16. Change No. 3 is to separate the primary and secondary ground rods by a distance of 20 ft. or more. Good practice dictates that ground rods always be separated by at least twice the length of the ground rods. Hence, 20 ft. separation would be the minimum recommended in any instance for two 10-ft. ground rods.

DARRELL FRANZE FARM

Information received indicates this farm is serviced by a three-wire service. A Ronk Blocker is in place yielding separation of primary and secondary neutrals.

1. Voltages in the direct cow contact area (rear hoof to water line) were for the most part insignificant. The highest voltage reported was 30.0 mVac (Test No. 66). These levels are significantly lower than the generally accepted threshold of 0.5 Vac or 500 mVac.

2. Current levels in the cow contact area failed to reach a problematic magnitude throughout the testing. The highest current level recorded was 40 mA (Test No. 60). These levels are substantially lower than the generally accepted threshold of 1 mA in the cow contact area.

3. Voltages reported between the water line and a reference ground were high enough to warrant concern despite the absence of any documented voltages of a significant magnitude within the direct cow contact area. The highest voltage recorded was 2.312 Vac (2312 mVac). Voltages between the water line and the reference ground exceeded 1 Vac at all times when utility power was being used and the neutrals were bonded (Tests 8 thru 15). The short time period (approximately one-half hour) during which the system was operated with utility power and the neutrals bonded results in an inability to evaluate this parameter at times when the normal system load would be high, i.e., later in the morning and in mid-afternoon. No

indication was given as to why the investigators chose not to document or verify conditions during the utility power-neutrals bonded operational configuration.

4. Current flow through the water line is high enough to be of concern. Overnight from December 9 - 10 the current reached or exceeded 500 mA (Test No. 5). A spike of 320 mA was recorded on Test No. 62. During other tests the current was less than 200 mA but did vary between 100 and 200 mA during the time the neutrals were bonded and utility power was being used.

5. Concern was previously expressed about the magnitude of the cow contact voltages recorded. Additional concern was found in analyzing the data from this farm in that negative values were reported on Channel 2 on repeated instances. Negative numbers would suggest that the numbers were actually direct current (dc) rather than alternating current (ac). Negative numbers have no meaning when reading alternating current voltage levels.

6. None of the tests confirmed any problems with on-farm equipment. In fact, operation of on-farm equipment often resulted in lower voltages than when the equipment was off. For example, operation of the barn cleaner (Test No. 27) caused voltages of 0.1 - 0.2 mVac. When the barn cleaner was turned off (Test No. 31), the voltage was 1.1 - 2.1 mVac (Test 32).

7. As is true in most instances, cutting of the grounding conductors on the primary system yielded no discernible or positive benefit with respect to in-barn voltages.

8. Operation of the vacuum pump resulted in lower levels of voltage in the animal environment than when the vacuum pump was not operating (Tests 56 and 57).

9. The loads on the system or the farm at the time the various resistor tests were made are different for each wiring configuration. Consequently, the ability to compare the test results is limited and realistically speaking might be impossible.

10. No significant change occurred in voltage levels within the animal environment when feeding system motors and silo loads were operated with neutrals bonded or separated. Although the data do show a numeric difference, the numbers are so small as to be insignificant. This once again raises questions as to the validity of the datalogging methodology or equipment.

11. Concern was expressed over operation of the 115-Vac tractor heater. A special note was made of this performance on the colored strip chart (Hendrickson report). The frequency of thermostat cycling is inconsistent with the experience of this evaluator. Additionally, if in fact the data are correct as represented with respect to the

variations with the heater operation, the values recorded of approximately 35 mVac are relatively insignificant compared to the repeated spikes in excess of 100 mVac shown on the graphs.

12. The conclusion that the lowest cow contact voltages and current occurred with utility power and neutrals isolated could not be confirmed by this evaluator. While 0.0 mVac is admittedly lower than 0.4 mVac, the difference is hardly worthy of note.

13. The general observations made by Mr. Hendrickson on Page 76 of his report were generally confirmed by this evaluator. Comment No. 11 (Page 76) reinforces this evaluator's evaluation of the inconsistency of loads during various testing activities and, hence, the difficulty in making direct comparisons.

14. Primary neutral to reference ground voltages were substantially better on this farm than on the Nelson farm. However, voltages up to 12.5 Vac were still reported with voltages in excess 5 Vac being very common throughout the testing period. Voltages of 0 - 3 Vac between the primary neutral and the reference ground with neutrals separated at the farm are considered normal and common. Voltages of 3 - 5 Vac between the primary neutral and reference ground are suggestive of problems. Voltages in excess of 5 Vac indicate definite problems. Voltages in excess of 10 Vac will cause saturation of most Ronk Blockers tested to-date. Thus, the elevated voltages on the primary neutral would potentially be reflected in the animal environment.

15. In general, the feeder servicing the Franze farm shows better load balance than the feeder to the Nelson farm. However, imbalances of up to 15 amps were still documented (Test No. 4). Imbalances in the 9 - 12 amp range were common.

16. Output voltage at the substation appears to be reasonably stable and within accepted norms. However, no data were presented to show what voltage was actually supplied to the Franze farm.

17. The measurement of ground resistance on both the farm and the primary neutral (Page 47, Gagnon report) shows resistances that are, with one exception, above the recommended maximum of 25 ohms.

18. No information was given regarding the conductor sizes of the distribution system.

19. In the Agreement for Interim Service Adjustments between Darrell Franze and Lake Region Coop Electrical Association, change No. 1 involves relocation of the transformer to pole No. 1. The location of pole No. 1 is not clear on the diagram received by this evaluator. However, experience suggests that 4/0 aluminum conductor is probably inadequate in size for this farm, assuming a 200-amp service. Secondary service drops should be sized to limit voltage drop from the transformer to the meter to 2%. Under no

circumstances should conductors be installed which result in more than a 4% voltage drop. The report continues and issues a warning about loads exceeding 25 kVa. This is contrasted to the documented 37 or 37.5 kW load in the Gagnon Contractor report. Consequently, the proposal is inadequate and should not be installed as proposed.

20. Installation of a four-wire system as a means of counteracting or compensating for inadequate conductor sizing is not recommended. Inherent safety problems with a four-conductor service make it a less-than-optimal alternative to proper design and installation initially. Installation of a four-wire system to compensate for the inadequacies for the proposed design and installation is not recommended.

21. In making the proposed wiring changes to the Franze farm, every effort should be made to minimize adverse effects and interference with farming operations. This evaluator is not aware of all factors which entered into some of the decisions reflected on Exhibit 1. However, locating a new pole with multiple guys in a cornfield is not considered as being appropriate under most circumstances. If conditions warrant or preclude any alternative, this may be the best way. Investigation of other alternatives appears justified.

22. Change No. 2 in the agreement was to install a Dairyland isolating device at the transformer pole. This appears to be warranted given the voltages recorded between the water line and the reference ground.

23. Change No. 3 was the proposal to separate the primary and secondary ground rods a distance of 20 ft. or more. This is appropriate inasmuch as ground rods should always be separated by a distance at least equal to their combined length. For example, two 10-ft. rods should always be separated at least 20 ft. If deeper grounding is required, greater separation distances would normally be required. In all instances the ground rods should be checked to verify a resistance to ground not exceeding 25 ohms.

CONCLUSIONS AND RECOMMENDATIONS

This evaluator was unable to fully comply with the terms of the contract inasmuch as the investigators who conducted the on-site testing did not provide full documentation. Specifically, neither of the investigators presented much in the way of interpretation of test data results or recommendations for corrective and mitigative actions. The comments and recommendations are based solely upon the information received either in written form or in conversation with the two investigators.

1. A massive amount of data was collected by the two investigators on the two subject farms. However, as pointed out in the discussion of the various farms, there is reason to question the validity of some of the methods and the equipment used to gather data.

2. Additional testing appears warranted to verify the conditions which exist on these two farms and to verify the appropriateness of the suggested test protocols.

3. Data should be collected and reported in a more usable form. The extreme data compression in these reports is inappropriate. For example, this evaluator, when conducting critical tests uses a strip chart which results in approximately one minute's worth of data in two centimeters (approximately one inch). This is contrasted to 1 - 12 hours' worth of data in approximately the same distance as presented by these investigators. Additionally, the use of one-minute averages is considered less appropriate than shorter time period intervals during critical tests. Strip chart recorders also are beneficial in helping to document events between the sampling-type meter monitoring.

4. For easier and more appropriate test comparisons, monitoring of the farm load and particularly the barn load is required. The absence of any current data for the secondary neutral makes comparison of some of the tests difficult. Additionally, it precludes the evaluation of existing wiring installations.

5. To allow comparison of various tests, known or at least the same loads should be operated during each of the principal and primary tests. Whether these are known loads provided by the investigator or simply identified loads on the farm which are run repeatedly under each of the test scenarios is unimportant.

6. A more appropriate procedure to determine the points at which voltages and currents will be monitored is required. As a minimum, this requires a survey of the animal environment with utility power, neutrals bonded, and a load equal or exceeding the normal "during milking" load on the farm. The location at which the highest voltages are recorded should then be used for monitoring. If during the survey, voltages in excess of 500 mVac are recorded, the source impedance or the current-producing capacity of this source should be verified by loading the meter with a 100 - 300 ohm resistor.

7. Resistors should be eliminated from the recording instruments inputs except for specific tests.

8. If multiple persons are involved in conducting tests and gathering data, there is a demonstrated need for improved coordination between the individual parties.

9. Unless it can be verified that the loads were similar under the various test conditions, ground resistance testing should be made with an instrument rather than calculations. An AEMC, Biddle or Vibroground earth resistance tester is preferred over the calculation method. However, the two methods could be used for comparison and verification.

10. There is a documented need for improved grounding on both of the subject farms as well as on the primary distribution system servicing each of the two farms involved in this study.

11. The data are strongly indicative of a need for improvements on the primary distribution system servicing both farms. Whether this can be achieved by simply eliminating poor or low-quality connections or whether it requires re-conductoring of the line or balancing of the load between the phases cannot be determined from the presently available data.

12. Because of the possibility of current through the guy wires and anchors circumventing the intended purpose of a neutral isolator, all guys should be insulated at least 8 ft. above ground. Below the insulator the guy wire will be grounded by virtue of being connected to the anchor. Above the insulator the guy wire will be grounded by attachment to the neutral.

13. The purpose in using multiple reference ground rods was not clear. Unless there is a documented purpose for multiple reference ground rods, e.g., two separate test setups, a single reference point should be used to facilitate comparison of data.

AGRICULTURAL SYSTEMS ENGINEERING

EV TEST SUMMARY RECAP

Project No. 702:9268 Name: Lonny Nelson

Conditions/Loads (300Ω)	Test No.	(mVac) N_P-G_R	N_S-G_R	(RH-WL) Max. Cow Contact	WL-GR
Utility Power, N jumpered	31	No Data	No Data	112	4650
Utility Power, N separated	39	No Data	No Data	2.5	80
Generator Power, N jumpered	63	2⁻(V)	1.0(V)	37.1	1530
Generator Power, N separated	68	2.5	0.3	7.4	260
Other:					
Gutter Cleaner					
Silo Unloader(s)					
Feeding System					
Cow Trainers					
Crowd Gate					
Other:					

Resistors:

TN	Ω	mV	mA	TN	Ω	mV	mA	TN	Ω	mV	mA

ASE 0192

Electrical Test S.
Lonny Nelson
ASE Project No. 70

Std: Rcow = 300Ω, unless noted

Source	Test No.	Time	Description: Loads/Conditions (Rcow = 300Ω)	Voltage, mVac: N (V) Np-GR	E/N: Ns(V)-GR	C'/H: Ns-GR Barn (V)	RH-WL Ch1 mV: Cow Contact	RH-ML Ch2 mV: Milkline	Ch5 mV: WL-GR	A: Feeder Imbalance	RH-WL Ch3 Current mA: Cow Contact	mA: Waterline	Ch6 mA: WL-GR	Farm Energy kW
Data from graphs	1	1645	VP on (sanitize)	2.0-6.0	2.1-6.0	1.6-6.0	170-175	110	–	13	0.45-0.70	0-60	–	
	2	1646	Silo unloader on				170-175	110	–	15-16	0.45-0.70		–	
	3	1655	Silo unloader off				100+	55-60	–		0.4-0.5		–	
	4	1658	VP off				92-130	47-69	–	17-22	0.37-0.53		–	
Data from Table	5	1730	4-wire (convert to)				0-0.3	0.1-0.3	–		0.01-0.02		–	
	6	1735	3-wire (convert back to)				104-128	58-72	–		0.40-0.52		–	
Data from graphs	7	1755	VP on; start milking				100-130	60-70	–	21-28	0.4+-0.5+	0-90	–	
	8	1800	Milk xfer pump on/off				150-170	60-70	–		0.5-0.65+		–	
	9	1802	4-wire (convert to)	3.0-12	0-0.3	0-0.5	150-170	60-70	–	23	0.5-0.65+		–	
	10	1813	BT on				170-180	100-105	–		0.5-0.65+		–	
	11	1841	Rcow = 100Ω (Σ=110Ω)				60-180	40-110	–	21	Up to 0.95+	0-55	–	
	12	1904	Rcow = 300Ω (Σ=310Ω)				110-230	40-110	–	19	Up to 0.95+		–	
	13	1909	VP off -- end milking				60-70	40-45	–		0.45-0.55		–	
	14	1945	3-wire (convert back to)	3.0-17.5	3+-17.5	1.0-17.5	150-170	60-70	–		0.4-0.6−	0-150	–	
	15	12/8/92												
	15	0456	VP on - sanitize	2.5-5.0	2.3-5.0	2.3-5.0	90-130	55-85	–	9-25	0.4-0.5	0-60	–	
	16	0528	VP on - start milking	1−-2.0	0.5-2.0−	0.5-2.0	90-130	75-125	–		0.45-0.5	0-55	–	
	17	0611	Rcow = 100Ω (Σ=110Ω)				45-100	30-50	–		0.7-0.95		–	
	18	0621	Rcow = 0Ω (Σ=10Ω)	1-19+	0-0.4		0-45	0+	–		0.6+-0.75		–	
	19	0631	Rcow = 300Ω (Σ=310Ω)	1+-3		0-0.4	70-140	95-100	–		0.5-0.55	0-60	–	
	20	0652	VP off - end milking				120-150	70-80	–		0.5-0.6−		–	
	21	0827	Barn cleaner on	1.5-17.5	0-17.5	0-17.5	80-130	70-100−	–		0.4-0.55	0-95	–	
	22	0840	" " off				65-85	50+-60	–		0.3-0.5		–	
	23	0917	Silo unloader on				70-130	30-80	–		0.3-0.6+		–	
	25		**Utility Power**											
Data from Table	24	1638	Silo unloader on	No data	No data	No data	84-117	60-82	3550-4810		0.31-0.43	No data	6.1-8.3	
	25	1645	" " off				67-106	42-58	2800-4080		0.27-0.43		5.1-7.4	
	26	1652	VP on -- sanitize				81-91	44-52	3020-3520		0.31-0.35		5.5-6.1	
	27	1659	VP off				67-94	33-56	2530-3390		0.26-0.33		4.6-5.9	
	28	1711	VP on - start milking				90-103	52-60	3490-3830		0.34-0.41		6.2-7.1	
	31		**Np-Ns Bonded (WC #1)**											
	29	1717	Rcow = 100Ω				35-38	21-22	3430-3590		0.39-0.40		9.5-9.7	
	30	1721	Rcow = 0Ω				3-5	2-3	3380-4680		0.38-0.54		12.7-17.7	
	31	1732	Rcow = 300Ω				90-112	71-89	3780-4650		0.35-0.48		6.7-8.6	
	32	1734	VP off				64	4−	2610		0.26		4.8	
	33	1735	Farm Power off				0-56	0-23	60-1920		0.02-0.21		0.3-3.6	

1740?? ← suggested by data

Electrical Test Summary
Lonny Nelson
ASE Project No. 702:926

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Data Source	Test No.	Time	Description Loads / Conditions	Voltage (H) Np-GR (V)	Voltage (E/H) Nsyp-GR (V)	Voltage (C/H) Ns Barn-GR (V)	Ch1 mV RH-WL	Ch2 mV RH-ML	Ch5 mV WL-GR	Feeder (A) Imbalance	Current Ch3 (mA) RH-WL	Current (mA) Waterline	Ch6 (mA) WL-GR	Farm Energy KW
Table	34	1743	Farm Power on	No Data	No Data	No Data	4.9	1.4	160	9-25	0.02	No Data	0.50	
	2		Np-Ns separated (WC2)											
	35	1744	VP + Fan on				0.4-3.4	0.2-2.6	50-140		0.01-0.02		0.3-0.5	
	36	1755	Rcow = 100 Ω				0.3-0.6	0.2-0.3	60-80		0.01-0.02		0.3-0.4	
	37	1802	Rcow = 0 Ω				0.0-0.1	0.0-0.2	spikes? 30-160		0.01-0.03		0.4-0.8	
	38	1804	115V fan on				0.0-0.1	0.0-0.2	spikes? 30-160		0.01-0.03		0.4-0.8	
	39	1810	Rcow = 300 Ω				1.8-2.5	0.4-0.9	60-80		0.02		0.3-0.4	
	40	1809	Water heater on/off				No change	No change	No change		No change		No change	
	41	1820	xfmr pole grd cut (WC3A)				1.8-5.3	0.5-2.3	80-220		0.02-0.03		0.3-0.6	
	42	1831	Fan off				1.0-1.1	0.6-0.8	70-80		0.02		0.3	
	43	1834	Rcow = 100 Ω				0.7	0.7	110		0.01		0.4	
	44	1836	Fan on				0.6-2.1	0.3-1.3	80-140		0.02-0.04		0.4-0.6	
	45	1840	Rcow = 0 Ω				0.0-0.1	0.0-0.1	80-90		0.02		0.4	
	46	1846	Rcow = 300 Ω				1.6-1.7	0.7-1.0	80-90		0.02		0.3	
	47	1849	Np downgrd cut (WC3B)				1.6-4.7	0.6-2.8	90-200		0.01-0.03		0.3-0.5	
	48	1855	Fan off				0.8	0.6	70		0.01		0.3	
	49	1857-1904	Reconnect Np/xfmr grds				0.8-1.9	0.5-0.8	60-80		0.01-0.02		0.3	
	50	1900	VP off -- end milking				1.3-6.1	0.4-2.7	70-230		0.02-0.04		0.3-0.6	
	51	1907	BT on				1.4-3.2	0.4-2.9	40-180		0.02-0.03		0.3-0.5	
	52	1925	Farm power off				1.1-4.6	0.8-3.6	90-260		0.02-0.04		0.3-0.8	
	53	1926	Np-Ns bonded				18.6-59.7	13.9-41.7	800-2550		0.08-0.25		1.6-4.8	
	54	1932	Farm power on				76.4-112.7	53.1-72.7	3250-4590		0.29-0.44		5.8-8.2	
	23	12/9/92												
Table	24		Generator Power start time = ?? (Np-Ns bonded)											
	55	0444	Arrive at farm	2-4.5	2.3-4.5	2.2-4.5	49.4-91.8	35.1-65.4	2160-3930	8-21	0.20-0.37	0-60	3.8-7.1	
	56	0527	1/2 lights + fan off	2-3	0.6-1.9	0.5-1.9	16.0-46.5	11.6-31.4	710-1960		0.07-0.21	0-50	1.4-3.8	
	57	0531	1/2 lights on again; fan on	1⁻ - 2⁻	0.7-1.0⁺	0.5-1.0	15.6-35.1	10.9-26.6	700-1540		0.07-0.15		1.4-2.9	
	58	0541	VP on -- sanitize				16.2-19.1	11.9-13.4	720-880		0.07-0.08		1.5-1.6	
	59	0549	VP off				17.9	12.5	770		0.08	0-30	1.5	
	60	0550	VP on -- start milking				18.5-22.1	12.3-14.7	800-880		0.08-0.10		1.6-1.7	
	31		Neutrals bonded (WC1)											
	61	0559	Rcow = 100 Ω				6.7-7.3	5.1-5.6	750-800		0.08-0.09		2.1-2.3	
	62	0606	Rcow = 0 Ω				0.5-0.7	0.4-0.5	630-750		0.08-0.09		2.1-2.3	
	63	0611	Rcow = 300 Ω				16.0-37.1	12.8-28.2	690-1530		0.08-0.16		1.5-3.0	
	64	0614	Neutrals separated (WC2)	1⁺ - 9⁺	0-0.2	0-0.3	3.7-7.4	0.3-5.5	130-340		0.03-0.06	50	0.4-1.0	
	65	0622	Rcow = 100 Ω	1.5-2.5			1.3-1.8	0.0-0.4	120-140		0.03-0.05	0-30	0.4-0.6	

Electrical Test Summary
Lonny Nelson
ASE Project No. 702:9268

Data Source	Time	Description: Loads/Conditions	Voltage: Np-GR	Voltage: Ns-GR YP	Voltage: Ns-GR Barn	Ch.1 mV RH-WL	Ch.2 mV RH-ML	Ch5 mV WL-GR	Current: Feeder (A) Imbalance	Ch3 Current (mA) RH-WL	Current (mA) waterline	Ch6 (mA) WL-GR	Farm Energy kW
Table 66	0623	BT on	1.5-2.5	0-0.2	0-0.3	1.3-1.5	0.0-0.2	120-130	8-21	0.03-0.05	0.50	0.4-0.5	
67	0628	Rcow = 0 Ω				0.1	0.0-0.2	110-120		0.02-0.03		0.5-0.6	
68	0636	Rcow = 300 Ω				3.4-7.4	0.1-2.5	120-240		0.02-0.04		0.4-0.6	
69	0652	xfmr grd cut (WC3A)				3.8-4.3	0.3-0.9	140-160		0.03		0.4-0.5	
70	0700	Rcow = 100 Ω				1.2-2.6	0.2-1.0	110-250		0.02-0.04		0.4-0.8	
71	0706	Rcow = 0 Ω				0.0-0.1	0.0-0.2	100-110		0.02-0.03		0.4-0.5	
72	0712	Rcow = 300 Ω				4.8	1.9	190		0.03		0.5	
73	0713	Np Grds cut (2) = (WC3B)				3.3-4.2	0.4-4.9	120-160		0.02-0.04		0.3-0.5	
74	0727	VP off -- end milking				4.8-7.0	2.1-3.3	170-250		0.02-0.03		0.5-0.6	
75	0729	VP on - wash cycle				4.3	1.2	120		0.02		0.4	
76	0730	xfmr grd re-connected				4.7-5.3	0.7-1.2	130-150		0.02-0.03		0.4	
77	0734	VP off				5.7-8.0	1.8-3.9	170-270		0.03-0.04		0.5-0.6	
78	0736	Np grds re-connected				2.5-8.7	0.5-2.8	80-260		0.02-0.04		0.3-0.6	
79	0745	All loads off (????)	↓	↓	↓	0.0-32.3	0.0-20.0	40-1230		0.01-0.14		0.3-2.4	
80	0757	Utility Power	3p-17.5 2-10+	1.1-1.2+	1.1-1.2+	0.2-4.5	0.2-2.8	50-140		0.01-0.02		0.3-0.5	
81	0814	Farm power off (??)	1-5	0-0.1	0+-0.2	0.0-32.6	0.2-24.0	50-1350		0.01-0.14		0.3-2.7	
82	0817	Np-Ns Bonded		1-5	1-5	27.3-54.7	17.2-32.2	1100-1570		0.11-0.21		2.2-4.0	
83	0828	Farm power on				40.4-68.2	28.8-46.8	1700-2610		0.04-0.19		0.3-3.7	
84	0838	Open circuit test				113.9	77.1	4120		0.04		0.3	
85	0839	BT + Barn Cleaner on				76.5-403.5	46.0-79.1	3100-4140		0.02-0.08		0.1-0.6	
86	0849	End open circuit test	↓	↓	↓	65.6-93.5	44.6-69.5	—		0.25-0.35		—	
87	0852	B.Cl. off; silo unloader on	No data	No data	No data	88.1-92.9	57.1-66.7	—	↓	0.34-0.39	↓	—	
88	0928	End Testing	↓	↓	↓								

AGRICULTURAL SYSTEMS ENGINEERING
EV TEST SUMMARY RECAP

Project No. 702:9268 Name: Darrell Franze

Conditions/Loads (300Ω)	Test No.	N_p-G_R (mVac)	N_S-G_R	Max. Cow Contact (RH-WL)	WL-GR
Utility Power, N jumpered	15	2-6 (V)	1.4-6 (V)	13.2	2291
Utility Power, N separated	19	7.5-12.5(V)	0.1-0.9(V)	0.3	254
Generator Power, N jumpered	50	0-0.5(V)	0.1-0.4(V)	15.6	197
Generator Power, N separated	55	0-0.5(V)	0.1-0.5(V)	8.7	239
Other:					
Gutter Cleaner					
Silo Unloader(s)					
Feeding System					
Cow Trainers					
Crowd Gate					
Other:					

Resistors:

TN	Ω	mV	mA	TN	Ω	mV	mA	TN	Ω	mV	mA

ASE 0192

Electrical Test Summary
Darrell Franze
ASE Project No. 702:9268

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Rcow = 300 Ω unless noted

Test No.	Time	Description (Loads/Conditions)	H: Np-Gr (V)	E/H: Nsys-Gr (V)	C/H: Ns barn-Gr (V)	Ch.1 mV RH-WL	Ch.2 mV RH-ML	Ch.5 mV WL-Gr	Current: Feeder Imbalance (A)	Ch.3 (mA) RH-WL	A (mA) Waterline	Ch.6 (mA) WL-Gr
	12/9/92											
1	1532	Begin logging data		–	–	1-9	2-3	40-190	2-3	<0.1	–	0-5
2	1738	VP on – start milking		0.15-3.5	0.15-3.5	2-3	1	~180	9	<0.1	~10	0+-3
3	1739	Feed room motors on (4)		↓	↓	2-8	1-4	~180	9	<0.1	(sp to 120) ~10	0+-3
4	1800	End for day				2-8	1-5	100-160	15	<0.1	60-20	1-3
5	12/10/92	(overnight)		0.15-3.3	0.15-3.3	3-14	0+-4	20-150		<0.1	0-500	1-3
6	0545	Arrival; feed sys. motors on	3-4.5	0.15-1.2	0.15-1.2	8-9	1-2	20-60		<0.1	30-50	1-3
7	0615	Power off	1-2.5	0	0	0.0-0.3	-0.2-0.4	19-231		0.01	~0	0.5-4.5
		Utility Power Neutrals Bonded – WC1										
8	0635	Power on	1-3	0.15-0.2	0.15-0.2	7.7-12.8	13.6-14.2	1075-1280	6	0.04-0.06	~0	21.7-27.4
9	0642	VP on – start milking – fans on	2	1.4-6	1.4-6	16.8-21.6	20.3-37.8	1486-1664	6	0.07-0.08	40-180	32.2-36.2
10	0644	Barn cleaner on	↓	↓	↓	3.6-17.0	2.1-27.9	1043-1386	5-6	0.03-0.07	40-180	21.8-29.9
11	0651	Rcow = 100 Ω				0.2-0.7	0.7-1.9	1074-1250	↓	0.01-0.02	0-40	50.4-61.9
12	0658	Barn cleaner off Feed sys. on				57	5.0	1846	9	0.06	40-50	100.1
13	0659	Rcow = 0 Ω				0.2-0.4	0.0-0.2	1627-2028	9	0.04-0.05	40-110	393-476
14	0704	S/lo unloader on				0.2-0.4	0.1-0.3	2187-2312	↓	0.05-0.06	40-140	499-500
15	0707	Rcow = 300 Ω				2.4-13.2	2.7-13.1	609-2291		0.03-0.05	40-140	11.1-47.7
16	0713	Utility Power Ron K Blocker -- Np-Ns separated -- WC2	7.5-12.5	0.1-0.9	0.1-0.9	0.1-0.2	-0.1-0.1	186-207		0.01-0.02	0-10	1.9-2.1
17	0721	Rcow = 100 Ω	7.5-12.5	0.1-0.9	0.1-0.9	0.0-0.1	-0.1	211-249	10	-0.01-0.02	<10	5.2-6.3
18	0728	Rcow = 0 Ω	↓	↓	↓	0.0	-0.3 to -0.1	205-239	↓	0.01	<10	21.7-28.9
19	0736	Rcow = 300 Ω				0.1-0.3	-0.1 to 0.5	226-254		0.01-0.02	<10	2.0-2.5
20	0742	Utility power Np-Ns separated Air gap – WC3				0.1	-0.1	202		0.01	<10	1.9
21	0743	S/lo unloader off	6-9	0-0.2	0-0.2	0.1-0.2	-0.1 to 0.3	182-199	10	0.01	<10	1.7-1.9
22	0748	TMR motor only	↓	↓	↓	0.2	0.3	190-198	↓	0.01	<10	1.8-2.0
23	0751	Rcow = 100 Ω				0.0-0.1	-0.2 to 0.0	175-190		0.01-0.02	<10	4.4-4.6
24	0758	Rcow = 0 Ω				0.0-0.1	-0.3 to -0.1	177-181	11	0.01	<10	18.2-19.1
25	0802	TMR motor off				0.0	-0.3	180-181	↓	0.01	<10	18.7-19.2
26	0805	Rcow = 300 Ω				0.1	0.0-0.1	115-174		0.01	<10	1.3-2.0
27	0810	Barn cleaner on	6-10	0.1-0.2	0.1-0.2	0.1-0.2	0.0-0.1	103-156		0.01	<10	1.0-1.1

Electrical Test Summary
Darrell Franze
ASE Project No. 702:9268

Test No.	Time	Description (Loads/Conditions)	Voltage H Np-GR (V)	E/H Nsyp-GR (V)	C/H Ns-GR barn (V)	Ch.1 mV RH-WL	Ch.2 mV RH-ML	Ch.5 mV WL-GR	Feeder Imbalance (A)	Current Ch.3 (mA) RH-WL	A (mA) Waterline	Ch.6 (mA) WL-GR
28	810	Xfmr pole grd cut (WC4A)	6-10	0-0.1		0.1-0.2	0.0-0.1	103-156	11	0.01	<10	1.0-1.1
29	816	Rcow = 100Ω	↓	↓	↓	0.1	-0.1 to 0.4	141-154	↓	0.01	<10	2.0-3.2
30	822	Rcow = 0Ω				0.0-0.1	-0.3 to -0.2	136	9	0.01-0.02	<10	8.5
31	823(?)	Barn cleaner off				0.0-0.1	-0.3 to -0.2	136-138		0.01-0.02	<10	9.5-11.1
32	828	Rcow = 300Ω				1.1-2.1	0.8-1.0	96-134		0.02	<10	1.0
33	833	Np Grd cut (WC4B)	5-8	0-0.1	0-0.1	0.2-2.8	0.1-1.7	85-211	↓	0.01-0.02	<10	1.0-2.6
34	903	Grds reconnected (WC2) Blocker back in service	Sp-17 3-7	0-0.9	0-0.9	0.4-2.6	0.0-0.7	161-178	5	0.01-0.02	0-40	2.1-2.3
35	910	Open circuit test, RH-WL	5-7	0-0.9	0-0.9	0.1-1.8	-0.2 to 0.0	144-191	5	0.01-0.02	0-40	0.3-2.5
36	924	VP off	↓	↓	↓	0.1-4.5	0.1-3.3	24-354	↓	0.01-0.04	<10	0.6-6.6
37	953	Power off		0	0	0.1-1.9	0.0-0.8	27-99	6-7	0.01	<10	0.6-1.7
38	955	Power on	3-6	0.1-0.3	0.1-0.3	1.7-3.5	0.7-1.5	108-148		0.01-0.02	0-80	1.4-2.2
39	1056	Feeding system on (staged on/off)	4-16	0.1-1.2	0.1-1.2	No Data	No Data	No Data	↓	No Data	10-85	No Data
40	1109	Tractor heater on	5-9	0.3-0.4	0.3-0.4				6		5-80	
41	1115	Silo unloader off	4-6	0.3-0.8	0.3-0.8				↓		5-80	
42	1130	TMR motor off	↓	↓	↓				7		5-80	
43	1307	Tractor heater off	Sp 3.5 0-1	0-0.2	0-0.2						40-70	
44	1328	Bulk Tank off	4-6	0.2-1.3	0.2-1.3	↓	↓	↓	↓	↓	0-50	↓
45	1343	Power off	3.5-6	0	0	2.2	-0.1	45	3	0.04	20-40	1.2
46	1346	Power on	1	0.1-0.2	0.1-0.2	35.1-35.4	7.2-7.5	132-141		0.31-0.34	20-40	5.8-6.0
47	1347	Generator power Np-Ns Bonded (WC1)	1	0.1-0.4	0.1-0.4	35.1-35.4	7.2-7.5	132-141		0.31-0.34	0-20	5.8-6.0
48	1353	Rcow = 100Ω	0-0.5			13.6-14.2	2.7-2.8	132-135	↓	0.33-0.35	0-20	13.8-14.0
49	1359	Rcow = 0Ω				0.6-1.5	-0.1 to 0.2	53-129	4	0.11-0.21	0-20	24.2-60.5
? 50	1405	Rcow = 300Ω	↓	↓	↓	14.8-15.6	3.3-3.7	46-197		0.13-0.14	0-20	2.3-5.0
vs ? ?		Generator Power Np-Ns separated--Blocker (WC2)										
51	1412	Change in readings noted		0.1-0.5	0.1-0.5	15.3-15.6	3.8-4.2	264-291		0.15	0-20	6.0-6.6
52	[illegible]	Rcow = 100Ω				6.2-6.9	1.4-1.9	246-391		0.15-0.17	0-20	13.7-22.0
53	1426	Rcow = 0Ω				0.5-0.7	0.1-0.2	219-236		0.09-0.11	0-20	55.2-55.9
54	1428	Fan off				0.4	0.0-0.2	213-218		0.07-0.08	0-15	52.4-54.6
55	1432	Rcow = 300Ω	↓			8.2-8.7	2.5-2.8	212-239		0.10-0.11	0-15	4.8-5.4
56	1438	VP on	1-2			8.0-12.7	2.2-3.1	200-238	↓	0.10-0.15	0-20	4.6-5.4
57	1442	VP off	1-2			14.8-15.1	3.2-3.3	212-235	5	0.16-0.17	0-20	4.8-5.5
58	1445	Feed sys motors on	2-3			15.1-16.0	3.1-3.4	231-270		0.17-0.18	10-20	5.5-6.5
? ? 59	1454	Normal Ronk configuration (N separated)	↓	↓	↓	9.1-15.6	1.6-2.9	33-187	↓	0.12-0.17	10-20	2.0-4.9

Electrical Test Summary
Darrell Franze
ASE Project No. 702:9268

Test No.	Time	Description (Loads/Conditions)	H: Voltage Np-GR (V)	E/H: Voltage Ns-GR VP (V)	C/H: Voltage Ns-GR barn (V)	Ch.1: mV RH-WL	Ch.2: mV RH-ML	Ch.5: mV WL-GR	Feeder (A) Imbalance	Ch 3: Current (mA) RH-WL	A: Current (mA) waterline	Ch 6: Current (mA) WL-GR
60	1512	Utility power	2-3-6	0.1-0.4	0.1-0.4	8.6-22.2	0.4-7.3	21-83	4-8	0.10-0.21	-40 0-20	6.3-3.3
		Np-Ns separated										
61	1720	Fan off	4-6	0.1-0.4	0.1-0.4	10.3-10.7	0.5-1.7	78-92	8	0.10	0-20	1.5-1.7
62	1723	VP on -- start milking	4-8	SP=3.5+ 0.2-1.2	SP 3.5+ 0.2-1.2	10.5-11.2	1.6-1.7	66-89	↓	0.11-0.12	SP=320 0-20	1.7-2.1
63	1726	Fan on/off	↓	↓	↓	10.7-13.1	1.0-1.9	52-87	↓	0.11-0.13	0-10	1.4-2.2
64	1740	Fan on	↓	↓	↓	10.4-21.3	1.1-2.6	29-106	9	0.10-0.19	0-10	1.3-3.4
65	1809	Bulk tank on	SP-17.5 8-13	↓	↓	7.9-8.4	0.8-1.0	113-160	↓	0.08	0-15	1.2-1.5
66	1812	Feeding sys + Roller mill on	↓	↓	↓	13.2-30.0	1.5-3.8	144-146	↓	0.11-0.25	0-15	2.2-5.9
67	1814	Augers off	↓	↓	↓	28.2	3.3	97	↓	0.24	0-15	4.0
68	1815	Silo unloader on	↓	↓	↓	26.8-27.6	3.4-3.5	111-132	↓	0.22-0.23	0-10	0.12-0.13
69	1818	Harvestore off	6-9	↓	↓	7.1-20.5	0.8-2.6	85-217	8	0.07-0.19	0-10	1.1-3.8
70	1841	Conveyor off	↓	↓	↓	8.3-18.3	1.2-3.0	86-138	9	0.08-0.16	0-10	1.6-2.5
71	1845	Fan off	↓	↓	↓	7.5-8.5	0.0-1.4	125-173	↓	0.08	0-10	0.7-1.8
72	1906	Fan on	↓	↓	↓	10.9-12.4	0.3-0.7	110-112	10	0.11-0.13	0-10	1.6-2.1
73	1907	Mixer off	4-8	↓	↓	8.0-20.5	0.0-0.8	66-148	↓	0.08-0.18	0-10	1.0-3.0
74	1943	End Tests -- overnight	↓	↓	↓	7.1	1.0-1.2	234-236	↓	0.08-0.09	0-10	3.3
	12/1/92	overnight							2-11			
75	0820	Arrive -- Barn cleaner on	No Data	No Data	No Data	No Data	No Data	No Data	9	No Data	No Data	No Data
		Milking in progress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
76	0821	Begin disassembly	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
77	0828	VP off	↓	↓	↓	↓	↓	↓	5-6	↓	↓	↓
78	0935	End Testing	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓