AGRICULTURAL SYSTEMS ENGINEERING

Agricultural and Structural Engineering

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

EXTRANEOUS VOLTAGE

EVALUATION OF TEST DATA

Farms of Lonnie Nelson and Darrell Franze

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

ASE Project No. 702:9307

Prepared by:
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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.

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Date 7/12/93 Registration No. 17199

Consultant's Report

The purpose of this report is to set forth the results of a review of test data collected on the farms of Lonnie Nelson and Darrell Franze. The testing was conducted to determine what influence electrical changes made in the electrical service to the farms by order of the Public Utility Commission had on voltages in the animal environment. The changes were made on March 19, 1993. The tests were conducted May 24 - 25, 1993.

The evaluation of the data and the preparation of this report were conducted under contract with the Minnesota Department of Public Service. The document submitted for review is captioned "Docket E-119/C-92-318" and is dated June 11, 1993.

BACKGROUND

Following completion of tests in December 1992, the Public Utilities Commission specified that various changes be made on the service to the two subject farms. The specified changes included relocation of the transformer pole, installation of appropriate secondary service conductors, and modification of the grounding along the service conductors. A spark gap isolation device was ordered to be installed at both farm sites to provide separation of the primary and secondary neutrals. The neutral separation was to be accomplished in accordance with procedures specified by the *National Electrical Safety Code*. These changes were completed on March 19, 1993, based on information presented.

The testing procedures used during this evaluation were those set forth via an April 19, 1993 letter, as prepared by staff members of the Public Utilities Commission. The referenced document indicates that the protocols were modified slightly during the field work because of constraints encountered during the on-site testing.

FINDINGS

For ease of identification, specific comments will be referenced to various pages as found in the June 11, 1993 document. No specific evaluation of testing procedures will be made except as it is believed pertinent to the findings and conclusions.

Comments Relative to Both Farms

Under description of the test set-up (Paragraph 2, Page 4), it is noted that the secondary neutral current was measured at both the barn service panel and at the transformer pole. The reason for measuring current at both ends of the secondary neutral is unclear. The test data do not indicate compliance with this stated procedure. The data suggest that the statement set forth in this paragraph is in error, i.e., voltage, not current, was measured at both ends of the secondary neutral in order to determine voltage drop.

Re-location of the transformers would have required installation of new secondary service conductors. In the report submitted by Agricultural Systems Engineering following the December 1992 testing, concern was expressed over the proposed sizing of these conductors. No information was presented in the current report regarding the sizing of the various components of the electrical system. Therefore, no opportunity to compare measured values with expected values under the various test conditions was provided. The absence of these data compromised the opportunity to evaluate the newly installed electrical service.

Nelson Farm

One objective of this testing was to determine the influence of the changes on animals within the two dairy herds. Upon arrival at the site, the investigators found that the primary system downgrounds at the Nelson farm had been cut. This will result in an inability to evaluate the effects of the modified electrical distribution system on the dairy herd (Page 5).

It was also noted that the grounding and grounded conductors at the barn service panel on the Nelson farm had been separated and attached to separate bus bars, but that no jumper conductor was installed between the grounding and grounded buses, as required by *National Electrical Code* (NEC 250.24). The jumper is required when individual termination buses are provided for grounding and grounded conductors and only three-wire service is provided to the panel. As pointed out in the report (Page 5), this creates an extremely hazardous condition in the event the on-farm equipment faults or fails. Equally important is that if the neutral conductor should fail either mechanically or through development of a poor connection, the "floating" voltage conditions which would result could cause either high or low voltage to be present at the electrical equipment, thereby leading to overheating or other modes of improper operation and premature failure. One can only presume that the equipment was operating properly at the time of the arrival of investigators and during the testing. This points out one of the disadvantages of an electrical system as we install them in the United States. That is, systems can operate without being safe. Systems which have been modified as was done on the Nelson farm create a serious risk of property loss (including animals, personnel, and physical property) because they will not fail safe.

A note was added (Page A3.5) that "There was no visible means where the waterline in the barn was making electrical contact with the neutral bus in the barn electrical panel." The failure to determine the electrical continuity between the waterline and the electrical panel through use of an ohmmeter constitutes a deficiency in the testing procedures. Despite the absence of a visible interconnection, the numerous alternative and parallel paths which exist on most dairy farms require that a specific measurement be made to determine whether continuity does exist. Similarly, the stainless steel milkline is generally supported on nylon or other materials which serve as an insulator from the support brackets. A single measurement with an ohmmeter can be used to determine if the insulators are, in fact, intact or whether some inadvertent connection has been made. For example, commonly there are connections between the milkline and the electrical panel via the milk transfer pump. Although this circuit might not be evident on visual inspection because of a glass receiver unit, once milk flows into the receiver, continuity can be established via the milk film. The continuity of the milk film is consistent with the use of the milk as a conductive medium with some milk pump control systems currently in use on milking systems throughout the United States and the use of changes in milk conductivity as an indicator of mastitis.

As noted previously, the service panel in the barn at the Nelson farm was found to be wired in an unsafe and improper manner. The report indicates that at the completion of testing the electrical panel was restored to the condition in which it was found upon arrival. This presumably means the panel was left in an unsafe condition. No indication was given in the report whether Mr. Nelson was adequately advised of this deficiency. In the event he was not so informed, it is recommended that he be so advised of this deficiency and the lack of safety inherent in the current system via certified letter to assure that all investigators are adequately protected in the event of a failure which leads to loss of property or life (Page A3.7).

Figure N2 (Page A3.8) gives the approximate location of the various major electrical system components on the Nelson farm. Unfortunately, specific distances and conductors sizes were not identified. Consequently, evaluation of the appropriateness of the various conductors when giving consideration to ampacity, current-carrying capacity and voltage drop was not possible. These omissions constitute a deficiency in the overall report.

Measurement of the resistance to soil of the reference ground rods reflects a soil with poor conductivity. The recorded values of 100, 130, and 150 ohms suggest that in all cases multiple ground rods would be required at all secondary system service panels to comply with NEC requirements (maximum of 25 ohms or two grounding electrodes in parallel). For safety and system functional reasons, procedures should be used on both the primary and secondary systems which assure better grounding. This would include the use of deep grounding techniques or alternative systems to improve, i.e., reduce, the resistance of the grounding electrodes to the surrounding soil. Attempting to achieve reduced resistance through addition of salt water is not recommended due to corrosion of copper ground rods and because of the temporary nature of such methodologies.

Test data reflect an unacceptably high level of secondary neutral current during operation of the milking system (Page A6.3.1). The data indicate an imbalance between the two phase conductors in the range of 8 - 14 amps during much of the milking operation. Loads should be balanced within the service panel to limit secondary neutral current to 5 amps or 5% of the phase conductor current, whichever is less.

Frequently, 115 V loads can be balanced by installing split wiring and double pole switches for operation of lights, feeders, and other equipment which is commonly operated with a single switch and results in significant load imbalance. This wiring method allows use of a single switch to operate the lights, but minimal neutral current occurs because the lights are connected to both sides of the service panel. The result is reduced risk of extraneous voltage due to voltage drop on the secondary neutral system. (This procedure is permitted by NEC 210-4, Exception 2.)

The voltage between the phase conductor and the grounded conductor at the barn (Page A6.3.2) reflects voltages which exceed the permitted variation as established by the Rural Electrification Administration. The standard operating guideline is a voltage at the transformer of 120 V ±5%. Thus, the acceptable range is 114 - 126 V. The service voltage at equipment is to be 115 V ±5%. Thus, the acceptable range is 109 - 121 V. The voltage reflected in the data approaches 130 V on numerous occasions. The supplying of a higher-than-standard voltage is generally not a problem, as it does not result in any particular adverse effects on most equipment. This is contrasted to a low voltage situation which will cause motors to draw more current and overheat. The potential drawback of the excess voltage relates to voltage-sensitive electronic equipment, such as automatic milk detachers, various computer systems, and other electronic components used in modern-day milking systems. Better control of supply voltage should be evaluated particularly if there are reports of premature or frequent failure of electronic components on this farm.

According to the monitoring equipment installation description, comparison of WaveRider Graph C and WaveRider Graph F should allow determination of the voltage drop along the secondary neutral conductor. Comparison of these two graphs (Page A6.3.3 and Page A6.3.6) shows very little voltage on the secondary neutral at the barn panel but significant voltage on the secondary neutral at the transformer (Graph F). The voltage is routinely in the range of 0.4 - 0.5 Vac with numerous spikes in excess of 1 Vac. This elevated voltage is particularly evident during the milking operation where frequent spikes approaching or exceeding two volts are present. The highest spike observed is approximately 3.5 Vac. These voltages suggest an undersized neutral conductor, a poor connector, or as previously noted, the influence of substantial load imbalance on the secondary neutral system. Potential exists for these voltages to be reflected in the animal environment under appropriate weather, soil moisture, and other conditions at the farm.

WaveRider Graph D (Page A6.3.4) shows minimal voltage in the cow contact area, i.e., waterline to rear hoof area of the stall. The voltages reflected on this graph are not of a problematic magnitude.

WaveRider Graph E (Page A6.3.5) reflects little or no voltage between the waterline and the reference ground rod. This is a distinct change from the December 1992 data. The reason for the improvement is unclear based on the data presented. However, since the only reported changes were in the primary service to the farm, it seems reasonable to look to this change in the electrical system as the reason for the reduced voltage.

WaveRider Graph H (Page A6.3.7) reflects the primary neutral to reference ground voltages. As noted in our prior report, tests on numerous systems across the country suggest that voltages in the range of 0 - 3 V are quite normal under an isolated condition. Voltages in the range of 3 - 5 V are suggestive of problems along the primary neutral. Voltages in excess of 5 V are considered indicative of deficiencies with the primary neutral system and greatly increase the risk of voltages being reflected in the cow environment under appropriate weather or soil conditions. This graph shows that the vast majority of time during the testing on this farm voltages were in excess of 3 V. This likely is due to the poor conductivity of the soils in the vicinity of this farm as reflected by the resistances of the reference ground rods as previously discussed. These data strongly suggest the need for improved grounding along the primary system to reduce the overall system impedance. Other potentially contributing factors to this elevated voltage are inadequate primary neutral conductor sizing for the type conductor and loads being imposed on it and inadequate or poor electrical connections between the Nelson farm and the substation. The elevated voltages can also be reflective of load imbalance on the three-phase feeder circuit from the substation.

The graphs on Page A6.4.1 show substantially reduced current flow on the waterline compared to the December 1992 test. This reduction in current flow is presumably the result of the reconfiguration of the electrical service to the farm.

The current flow in the secondary neutral (Page A6.4.2) is similar to that recorded with the other instrument. As noted previously, the data indicate the need for improved balancing of the 115 V loads.

The data presented on Page A6.5.2 indicate two impulses which were potentially problematic for the cows. Channel 1 reflects a voltage of 3.3 Vac (peak) from the waterline to the floor (correction factor of 10 applied to the recorded 33 V listed on the sheet). Similarly, a voltage of 2.9 Vac was recorded from the hoof-to-hoof contacts on Channel 2. The other data do not appear to be of a problematic magnitude.

The data on Page A6.5.3 reflect voltages of a potentially problematic magnitude. The step potential voltage of 0.67 Vac could be problematic, particularly if animals have tender or sore feet. The waterline-to-floor voltage in excess of 1.0 Vac (a voltage in excess of 10 Vac was recorded) could also be problematic to some cows. The frequency of these elevated voltages was not evident from the data. The hoof-to-hoof voltages (Channel 2) similarly had elevated voltages of a problematic magnitude. Fifty-eight occurrences of impulses in the range of 2.4 Vac were recorded. The time period over which these impulses occurred was not evident.

The data on Page A6.5.4 reflect a peak voltage of 0.98 Vac. As noted, this could be problematic as a step potential voltage for some animals.

The data for this recorder are noted as being "uncalibrated data." The printed data also contain a statement "Calibration module has expired." The extent to which this influenced the voltages recorded is not clear. Depending upon the characteristics of the machine, allowing the calibration module to expire could result in totally meaningless data or could have little or no influence other than to fail to provide verification of reliability. The characteristics of this particular machine are not known and are not reported.

The waterline-to-reference ground voltages reflected on Page A6.5.5 are substantially less than were recorded in the December 1992 test. The reduced voltage is presumably the result of reconfiguration of the primary distribution system servicing this farm.

The data on Page A6.5.7 reflect a waterline-to-reference ground voltage with a magnitude of 0.89 Vac and a 16.1 second duration. Because this voltage is measured to a reference ground, its significance with respect to the cows is unclear. However, similar voltages recorded in December 1992 were in the range of 3 - 5 Vac. The exact reason for the marked decrease is unclear.

No interpretation of the Yokogawa strip chart recorders was possible. The data presented were not legible and the three colored lines could not be differentiated on the black-and-white copies provided.

Data presented on Page A6.8.1 are consistent with the data presented graphically and discussed earlier. Of particular importance and concern are the six voltages which are over 5 V. In particular, a voltage of 15.6 V was recorded on the primary neutral at 1530 hours. Voltages of this magnitude are reflective of deficiencies on the primary distribution system.

Data presented on Page A6.8.2 regarding system impedance suggests that the soils conductivity in the immediate vicinity of the Nelson farm is substantially lower than the conductivity of the soil elsewhere along the primary distribution system. (Do soil maps show a sharp contrast in soil types?) This is reflected in the primary system impedance of 1.63 ohms and a secondary system impedance of 6.67 ohms. As noted in previous reports, a direct measurement of these values would reduce the risk of error inherent in using voltages and currents to calculate the same value. This is particularly true of the primary system impedance where control of the load on the system and, consequently, the voltages is next to impossible.

The data on Pages A6.9.1 thru A6.9.3 reflect a substantial improvement in load balance on the primary distribution system (three phase), as contrasted to the data presented and recorded in December

1992. Whether this improvement is a result of seasonal variations or changes on the part of the electrical coop to improve balance of their system could not be determined from the data presented.

The data presented on Page A6.10.1 show a lower voltage at the substation than was recorded at the Nelson farm. This suggests that a voltage regulator between the substation and the Nelson farm is perhaps incorrectly set or is subject to intermittent failure.

Subsequent to receipt of the original report, additional data were obtained which showed a blow-up of selected data, i.e., the data were presented on a larger scale. Graph C shows voltages of approximately 0.5 Vac between the barn secondary neutral and the reference ground. These voltages, most likely, are the result of equipment operation and neutral current imbalance. The voltages are of a non-problematic magnitude.

Graph D shows voltages between the waterline and the rear hoof area approaching 1 Vac. The duration of these voltages is very short, suggesting they are related to equipment starts. Such voltages can be problematic to cattle if they occur on a repeated basis. The overall data do not indicate such to be the case in this instance, that is, these appear most likely to be isolated events as compared to repetitive occurrences.

Graph E shows waterline to reference ground voltages of approximately 0.9 - 0.95 Vac. The significance of these voltages is unclear as the cow contact voltages do not reflect similar readings.

Graph F shows secondary neutral voltage. The spikes and subsequent reduced magnitude voltage indicate a starting load impulse with voltages of a higher level until operating speed is achieve. A starting load spike is normal because of the in-rush of current during the starting phase of motor operation. The sustained voltage at a lower magnitude is supportive of the previously stated concerns regarding load imbalance of the 115 V loads.

A replacement chart for Page A6.3.5 was also received in a subsequent mailing. This graph shows substantially more activity than the original data. The reason for the difference is unclear. However, in this instance the waterline to reference ground voltages are similar to those shown on the expanded graph and as discussed above, i.e., voltages in the range of 0.9 - 0.95 Vac. The significance of these voltages is unclear but they appear to be of little consequence since similar voltages were not reflected in the direct cow contact area. However, a comparison with the original Graph F (Page A6.3.6) shows a high elevation of voltage on the secondary neutral. This correlation indicates that voltage drop on the secondary neutral is being reflected on the waterline thereby suggesting that, in fact, an interconnection does exist between the neutral and the water system. This correlation also reaffirms the importance of limiting voltage drop on the secondary neutral through proper conductor sizing, maintenance of all connections, and balancing of all 115 V loads.

Franze Farm

The resistance of the three reference ground rods to the surrounding soil indicate good to excellent soil conductivity characteristics at the Franze farm. Only one of the three ground rods would have required alternative grounding methods to comply with NEC requirements. The three recorded resistances were 25, 30 and 11 ohms.

Graph B (Page A5.3.2) shows a supply voltage with good stability. The voltage is generally in the range of 120 - 125 V with occasional short-term decreases to a lower voltage. These decreases in voltage appear to be correlated with the starting of on-farm loads and, hence, are of a temporary nature. Such decreases are part of the normal operation of an electrical system during starting of large loads.

Voltages reflected on Graph C (Page A5.3.3) between the barn neutral and reference ground are substantially lower than those recorded during December 1992 tests. The decreased voltage presumably is the result of changes made to the primary distribution system since those changes are the only ones which have been noted as having occurred between the two sets of tests.

The waterline to rear hoof voltage (Page A5.3.4) does not show any voltages of a problematic magnitude. In fact, the graph received suggests that the voltage was at or near 0. Such voltages would be very similar to those reported in December 1992.

Voltage recorded between the waterline and the reference ground (Graph E, Page A5.3.5) are significantly lower than those recorded in December 1992. Aside from three short-term spikes of approximately 0.15 - 0.2 Vac, all voltages are less than 0.1 Vac. This compares with voltages in excess of 2 Vac measured during the previous tests.

Aside from voltage spikes associated with the starting of various pieces of equipment, Graph H (Page A5.3.7) shows voltages of a significantly lower magnitude on the primary neutral than were recorded during the December 1992 tests. The reason for the reduced voltages is unclear. The changes which were made to these farms with respect to transformer location and modification of the secondary system would not have influenced these particular voltages. The data reflect a primary neutral system operating well within what I believe to be satisfactory and normal ranges of voltage.

The graph presented on Page A5.3.8 reflects a problematic and very undesirable level of secondary neutral current flow (approximately 22 amps). This imbalance occurred only during the early stages of the testing and does not appear to correlate well with any of the activities recorded on the event log. The information received does not clearly establish any reason for this elevated neutral current. One plausible hypothesis is that it occurred during some initial testing and during the set-up of the test equipment. The current appears to be unrelated to operation of the on-farm equipment.

The supply of voltage at the barn (Graph B, Page A5.3.9) indicates voltages ranging from approximately 118 - 122 V. These voltages are well within the accepted range.

Voltage reflected on Graph C (Page A5.3.10) between the barn neutral and the reference ground are generally less than 0.1 Vac. The exceptions are elevated voltages which appear to correlate with the conduct of the impedance test. This appears to be an unusual situation on the farm and contrary to normal operation of the system. Thus, despite the elevated nature of these voltages during a short time period, they are believed to be insignificant because they were conducted and recorded during unusual testing events.

Graph D (Page A5.3.11) reflects voltages measured between the waterline and the rear hoof area. No voltages of a problematic magnitude were recorded. These results are very similar to those reported in December 1992.

Voltages between the waterline and the reference ground, reflected on Graph E (Page A5.3.12), are generally of a non-consequential magnitude. The exception is during the time period when the impedance tests were being conducted. The correlation between the secondary neutral (Graph B) and waterline voltages does indicate that at least a partial, though possibly high resistance connection, exists between these two reference points. The fact that the elevated voltages (up to 0.6 Vac) with spikes to 1.6 Vac which occurred during special testing are considered non-consequential.

The secondary neutral voltages as reflected on Graph F (Page A5.3.13) are generally of an acceptable magnitude (up to 0.75 Vac) except during the impedance testing procedures. Because of the unusual nature of the tests to determine impedance, these elevated voltages are believed to be non-problematic and non-consequential. It should be noted that the elevated secondary neutral current mentioned previously is also reflected as an elevated voltage on this graph. This indicates voltage drop due to the high current. This reinforces the recommendation and need to maintain good balance between the 115 V loads on the two sides of the service panel.

The primary neutral voltages reflected on Graph H (Page A5.3.14) show that the primary neutral system is very responsive to on-farm loads. The voltages recorded are substantially lower than those recorded in December 1992. However, the magnitude of the voltages (commonly 4 - 5 V and occasionally up to 7.5 V with occasional higher spikes associated with equipment starts) is still suggestive of deficiencies on the primary distribution system. Additional investigation of load balance, evaluation of conductor size, testing of connections, and assessment of grounding system quality appear warranted.

The graph on Page A5.3.15 reflects secondary neutral current. Except for a current of approximately 4 amps in the initial time frame, the current the balance of the time is recorded as 0. This is unrealistic and suggests an equipment malfunction. While it is theoretically possible to balance a system so there is zero current on the secondary neutral at all times, in actuality maintaining this balance over an extended period of time (approximately one hour in this instance) is improbable.

The voltage supplied to the barn, as reflected on Graph B (Page A5.3.16), is well within the normal range of 109 -121 V (115 ±5%). However, the reason for the change in voltage on this graph compared to the earlier graph is unclear. One possibility is that being later in the day overall system loads are greater and the resulting voltage is lower because of voltage drop on the distribution system.

Graph C (Page A5.3.17) reflects voltages between the secondary neutral at the barn and the reference ground. The graph is completely void of any recordings except for the first three minutes. The probability of the voltage on the secondary neutral being zero over this one-hour time period, while theoretically possible, is unlikely. The graph suggests that a equipment malfunction had been experienced or occurred. During the December 1992 tests, voltages were commonly in the range of 0.1 - 0.9 V and were as high as 6 V.

Graph D (Page A5.3.18) shows voltages between the waterline and the rear hoof area. The graph is unremarkable, as no voltages are reflected. This is consistent with the voltage of zero to slightly above zero recorded during the earlier tests.

Graph E (Page A5.3.19) is generally non-remarkable. Reflected on this graph are voltages between the waterline and the reference ground rod. With the exception of two or three occurrences of voltages slightly above zero, the graph basically shows the total absence of voltage between these two points. This is contrasted to the voltages reflected in the December 1992 tests which were generally in the range of 0.2 Vac and reached magnitudes of 2.3 Vac. This is a marked improvement over the earlier tests. Since the only reported changes to the electrical system were those associated with the service to the farm, it seems reasonable to conclude that the changes in the transformer location and conductor installation along with other associated modifications have had a very positive effect on the voltages in this barn.

Comparison of Graph F (Page A5.3.20) with Graph C (Page A5.3.17) gives an indication of the voltage drop along the secondary neutral. Graph C showed voltages at or near zero at the barn. This is contrasted to voltages typically in the range of 0.25 - 0.5 V at the transformer.

However, Graph A (Page A5.3.15) shows zero current in the secondary neutral. With zero current, there will be no voltage drop developed. Consequently, comparison of these graphs strongly suggests that an equipment malfunction occurred during this testing. Alternatively, depending upon the point of connection of this recording instrument, the voltages reflected on Graph F could indicate voltages on the neutral due to operation of other parts of the on-farm electrical system, i.e., voltages which are caused by loads other than those operating in the barn.

Graph H (Page A5.3.21) once again reflects that the primary neutral is very sensitive to on-farm loads. Likewise, the voltages which are typically from slightly less than 5 V to slightly less than 10 V also indicate and reinforce the earlier statement that problems still exist along the primary distribution system.

The secondary neutral amperage at the transformer as reflected on the top graph on Page A5.4.1 suggests that one piece of equipment had failed (Graph A of the WaveRider equipment) or that the secondary neutral current measured in this instance in fact reflects total on-farm load. The currents reflected are in excess of 10 amps at some points in time. If these currents are reflective of those on the neutral servicing only the barn, then there is a definite error in the data as the two sets of data are incompatible and inconsistent. If, in fact, the data on this page reflect current on the secondary neutral upstream towards the substation from the interconnection of all on-farm neutrals, the data would be realistic and not particularly abnormal.

The data reflected on Channel 2 (Page A5.4.1) show current in the primary neutral grounding conductor up to 0.4 amps. The exceptions are several elevated spikes up to 1.6 amps, which occurred during the impedance tests. The impedance tests were not reflective of normal on-farm load operation and, thus, the elevated currents are believed to be of little or no consequence.

The waterline amperage reflected on Channel 1 (Page A5.4.2) is markedly less than was recorded in December 1992. The improvement is presumably the result of modifications to the electrical service to the farm. Currents reflected on this graph are generally in the range of 10 - 20 mA. This is contrasted to currents of 40 and up to 500 mA during the previous tests.

Channel 2 (Page A5.4.2) reflects current in the grounding electrode conductor at the barn service panel. The currents are generally less than 8 mA except during impedance tests. These currents are considered normal and of no consequence.

The data presented on Page A5.5.1 through A5.5.4 do not reflect any currents or voltages which would generally be considered to be of a problematic magnitude. However, the data on Page A5.5.5 reflect a peak step potential voltage of 2.9 Vac (multiplier of 10 applied to recorded data). Voltages of this magnitude can be problematic to some cows.

The data on Page A5.5.6 reflect a step potential voltage up to 0.52 Vac. Except for a few cows which might be sensitive to this magnitude of voltages, the data presented on this page are otherwise considered non-problematic and non-consequential.

The graphs on Page A5.5.7 illustrate the previously noted step potential voltage up to 0.5 Vac. The graph shows that, in fact, the voltage existed at a level of 0.4 - 0.45 Vac for an extended period of time. The longer duration of this voltage increases the risk that a greater proportion of the animals would be sensitive and would be reluctant to enter the barn under some conditions.

The data on Page A5.5.8 indicates a step potential voltage of 0.97 Vac with a duration of 16.0 seconds. This voltage is sufficient to adversely affect a large number of the dairy cows. The event log does not reveal any specific event which transpired during this time period which would account for this magnitude of voltage. The voltage is of a magnitude and duration sufficient to warrant further investigation.

A similar voltage was reflected as a step potential on Page A5.5.9. In this instance, the voltage of 0.98 Vac lasted 2.4 seconds. This event appears to have occurred shortly after the surge recorded on Page A5.5.8. A voltage of 0.69 Vac with a duration of 0.1 seconds was also recorded as a step potential.

Another step potential voltage surge of 0.98 Vac was reported on Page A5.5.11. The duration of this surge was not noted. The graph suggests it was a fraction of a second.

A similar voltage surge is reflected on Page A5.12. In this instance, a voltage of 0.61 Vac with a duration of 16.1 seconds was reflected between the waterline and the reference ground rod. No similar voltage was found to be reflected in the immediate cow environment. The data suggest this could be associated with the beginning of the impedance tests. If that is in fact the case, the voltage is probably of little or no significance. A similar analysis would apply to the voltage reflected on Page A5.5.13 in which case a voltage in excess of 1.0 Vac with a duration of 0.4 seconds was recorded between the waterline and the reference ground rod. A second voltage surge with a magnitude of 0.65 Vac and a duration of 16.1 seconds is reflected on that same page. Any evidence that these voltages are reflected within the immediate cow environment would suggest a need for further corrective actions.

Page A5.5.15 does reflect a waterline to floor voltage spike of 0.39 Vac with a duration of approximately 2.5 seconds. This voltage surge also occurred during the time period designated on the event log during which the system impedance tests were being conducted. As such, the voltage surge is probably of little or no consequence.

The voltage surge reflected between the waterline and the reference ground rod on Page A5.5.16 has potential for being more problematic. This voltage had a magnitude of 0.64 Vac with a duration of 16.1 seconds. This voltage surge occurred following the system impedance tests. There are no activities recorded on the event log which correlate with the time during which this voltage occurred.

Voltages recorded on Pages A5.5.18 through A5.5.23 do not appear to be of any significance. All voltages are less than 0.5 Vac.

The Yokogawa strip chart data could not be analyzed. The charts provided were non-legible and no ability existed for differentiating between the three colored lines on a black-and-white copy.

The primary neutral voltages recorded on Page A5.8.1 are suggestive of deficiencies with the primary distribution system. Some, but not all, of these voltage occurred during the system impedance tests. According to the event log, the two highest voltages (over 5 V) occurred following the completion of the impedance tests.

The system impedance tests calculated and illustrated on Page A5.8.2 are consistent with the perception that the primary neutral system still has some inherent difficulties or deficiencies. The primary system impedance of 1.57 ohms is nearly double the 0.8 ohms impedance of the secondary system. The net effect of this difference is that approximately 2/3 of the current present at the transformer will tend to flow through the farm grounding system with only 1/3 returning through the primary neutral system.

In general, the current balance between the three phases is better than was reported during the December 1992 tests. The stability of the C-phase voltage still raises questions as to the validity of the data or the functioning of equipment on this circuit. If the system layout will permit, it appears appropriate that some loads from the B-phase be switched over onto the C-phase.

Voltages at the Battle Lake substation (Page A5.10.1) show good voltage stability within the accepted range of 120 V ±5%. The voltage range recorded for all three phases varied from slightly above 122 V to just under 126 V.

The extended scale graphs which were received relative to the Franze Farm data do not reflect any voltages different than those previously discussed. However, Graph A is labeled secondary neutral amperage, but the scale is RMS voltage. No voltage-to-amperage conversion is given for this graph. In any event, the system appears to be reasonably well balanced with respect to 115 V loads. In that regard, these data are consistent with the previously discussed data.

Additional data to replace Pages A5.3.8 through A5.3.13 were received. The data are generally non-remarkable except for Graph A. In contrast to Page A5.8, this graph does show the presence of secondary neutral current. Using the same conversion factor of 1 volt = 20 amps, which was printed on Page A5.3.8, the imbalance appears to have reached a maximum of about 5 amps. Again, this suggests that the 115 V loads on the Franze farms are reasonably well balanced.

MILK PRODUCTION DATA

A variety of milk herd production data was obtained for the Franze and the Nelson farms. The data included such parameters as water consumption per cow and somatic cell counts. Some of the data could not be evaluated because of lack of clarity as to which farm it represented. For example, one set of data included a sheet labeled "Franze Dairy Farm Water Meter Readings for the Month of December." This set also included milk production for 28 cows, somatic cell counts for just over a two months' time period, water meter readings, and two copies of milk pick-up tickets. Despite the identification as the Franze farm, the verification statement was signed by Lonnie Nelson. In each instance, the herd performance data provided are insufficient to allow drawing of any firm conclusions.

Variations in water intake appear to be within reasonable limits although both are on the low side for herds that are supposedly producing 50+ lbs. of milk per cow per day. Somatic cell count data are insufficient to establish any trends. However, the data do indicate that both herds have a very severe level of udder infection, i.e., mastitis.

Meaningful evaluation of the effects of any electrical system changes (no data were obtained for the time period since the electrical system was changed) will require that production and milk quality data for at least two years prior to the changes be provided. That is, data should be provided beginning January 1991 or earlier through the present time. As can be seen through the one set of somatic cell count data which was plotted (presumably Lonnie Nelson farm), there are variations across the two-month period. However, the beginning point and the ending point are essentially the same. One could argue that the data indicate a downward trend in somatic cell counts beginning in late January. However, a period of one week is inadequate to establish any meaningful trend line.

In evaluating herd performance data, it is important to realize that long-term trends are far more important than any individual value, be it high or low. Frequently, 6 - 12 months are required following removal of an external stressor before the influence can be seen in the dairy cows. That is, the change is not evident and does not become apparent until the cows go through a dry period and freshen with a new lactation. Despite this general rule and the general observation made in the industry, the author of this report does recognize that there are exceptions, i.e., there have been instances with which he has worked personally where changes in performance were dramatic and occurred within days or weeks of the removal of external stressors. As noted, these are the exceptions, not the general rule.

In order to provide a more complete evaluation of both herds, copies of the actual DHIA test day and herd summary sheets will be required. Attempting to draw conclusions on a herd basis from one or two parameters will more often than not lead to erroneous conclusions. A meaningful evaluation of herd performance data requires that as a minimum the following parameters be evaluated: herd size, percent of herd in milk, average days in milk, average age of herd, percent first-calf heifers, production per cow, rolling herd average, average days dry, average days open, days to first breeding, somatic cell counts, bacteria counts, etc. Thus, the data provided in this instance, while interesting, is of little value with respect to drawing conclusions as to any cause-and-effect relationship.

In evaluating herd performance, it is also necessary to recognize that milk production and milk quality are influenced by many factors beyond extraneous voltage. These include design and maintenance of the cow environment, milking system function, milking procedures, veterinary practices, cow management program, nutrition, and genetics. Serious deficiencies in any one of these could result in failure for changes in the extraneous voltage situation to be reflected in herd performance. This can occur when extraneous voltage is not the most limiting stressor present in a dairy herd.

CONCLUSIONS AND RECOMMENDATIONS

1. The data presented were inadequate to allow evaluation of the newly installed secondary system conductors for compliance with accepted design standards for wiring agricultural installations.

2. The service panel at the Nelson farm was unsafe as found and presumably as it was left at the completion of testing. Appropriate notification should be issued to limit liability of all parties.

3. The supply voltage at the Nelson farm exceeds accepted standards. In most instances, the higher than normal voltage should pose no problems.

4. The supply voltage at the Franze farm is within accepted and normal standards.

5. The 115 V loads in the Nelson barn are not properly or satisfactorily balanced. The imbalance contributes to or causes excessive voltage drop on the secondary neutral. This voltage could be reflected as a problematic extraneous voltage in the cow environment under some condition.

6. The data reflect repeated impulse voltages of a problematic magnitude on the Nelson farm.

7. At least one of the instruments is noted as recording "uncalibrated data." The precise meaning of this note and its influence on the data should be determined.

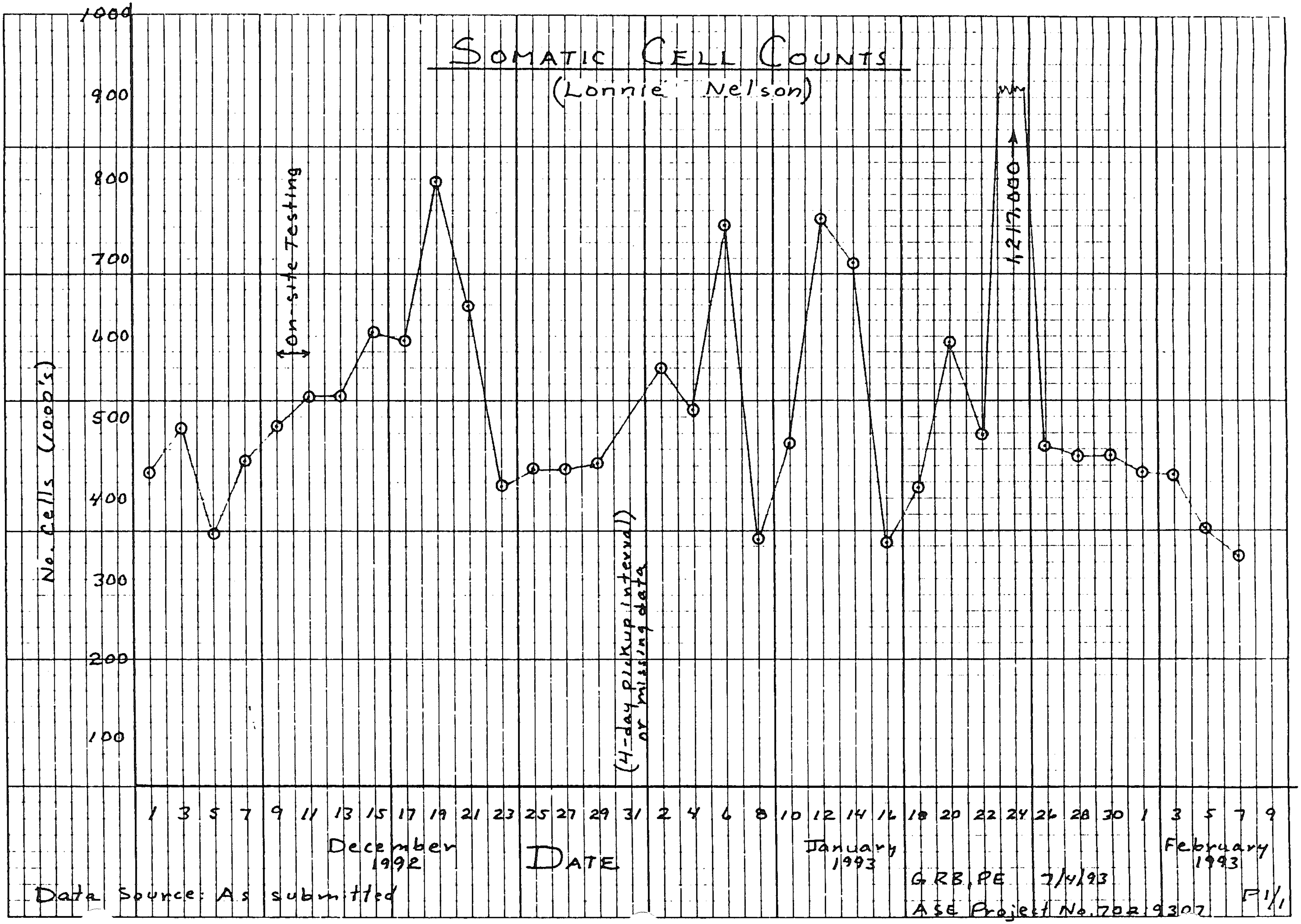
8. Primary neutral voltages reflect a high degree of sensitivity to on-farm loads at both farms. The voltages reflect a need for further evaluation of the primary system, including load balance, neutral conductor type and size, and grounding.

9. The voltage surges approaching 1 Vac and measured as a step potential are sufficient to warrant further diagnostic work on both farms.

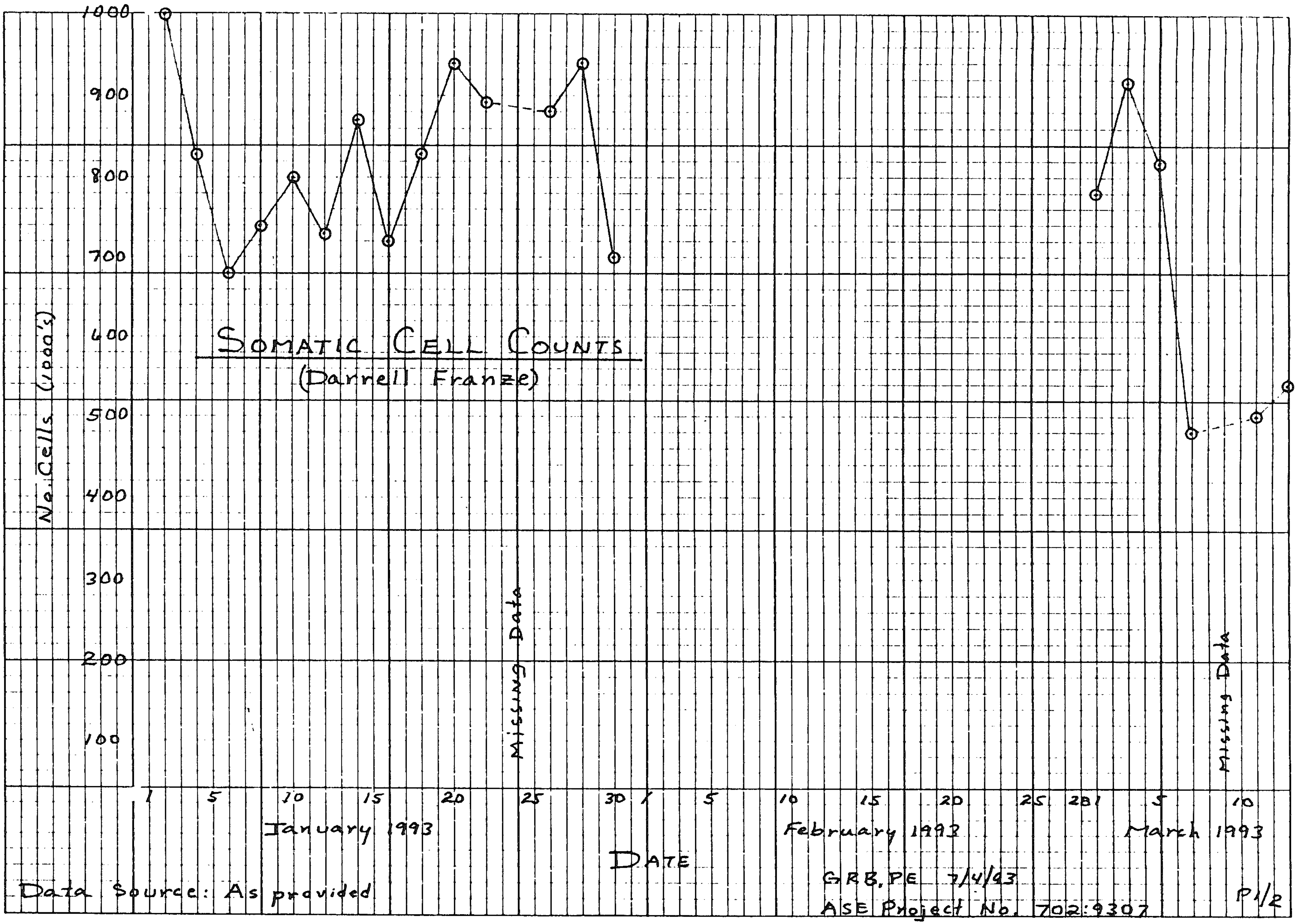
10. Herd performance data provided are insufficient to draw any meaningful conclusions. Data beginning at least two years prior to changes in the electrical system and continuing for six months to one year beyond the changes will be required to determine if, in fact, the wiring changes had any detectable influence on the herd. Meaningful evaluation will require much more extensive data. The minimum data to be provided include DHIA test day sheets, DHIA herd summary sheets, and milk market milk quality data.

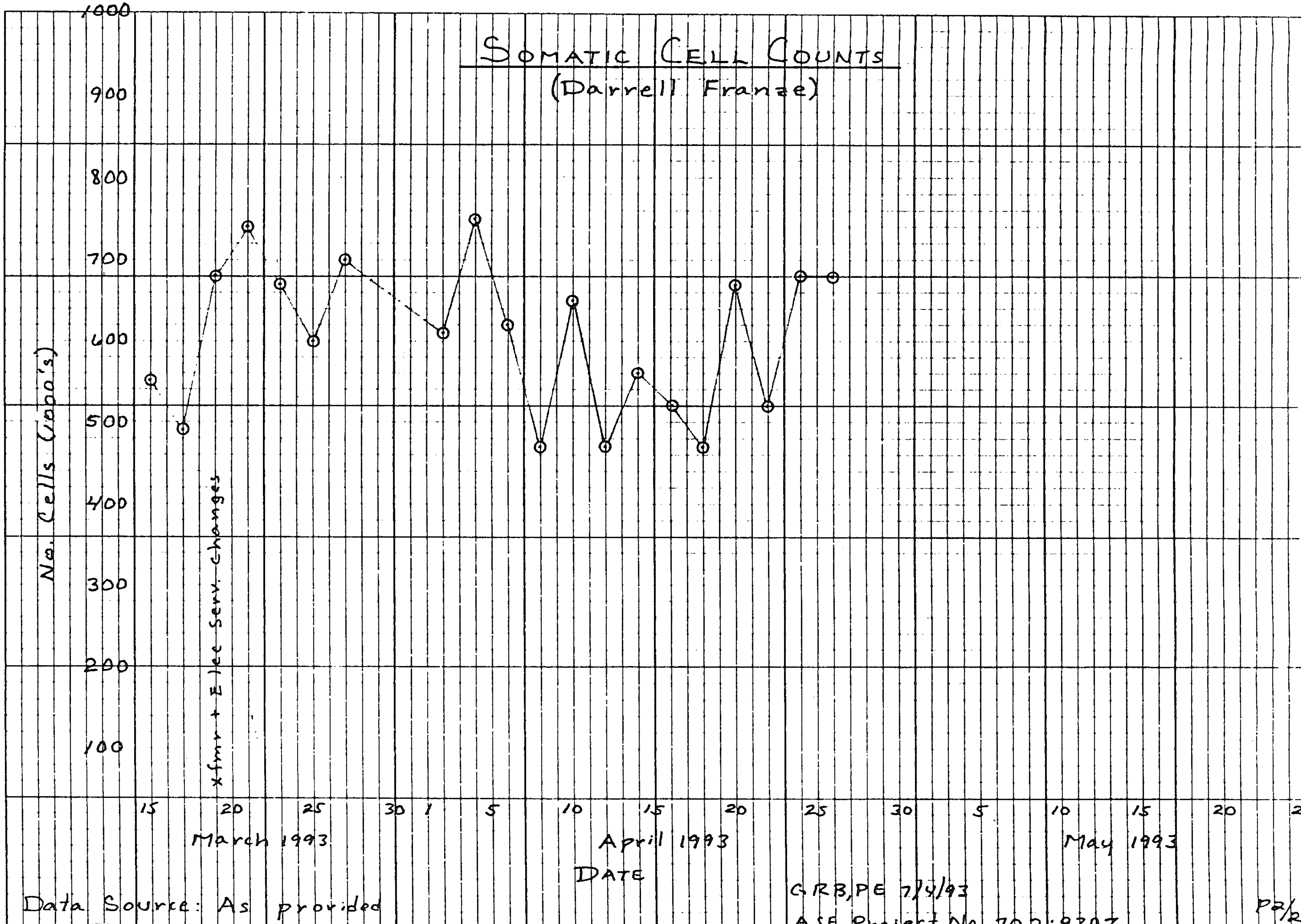
11. The changes in the distribution systems servicing the farms appear to have had a positive effect on some parameters. This is particularly true of the waterline current levels measured at the two farms.

12. Overall, the data indicate a need to retain the neutral separation at both farms. For improved safety, a neutral separation/interconnection device with a lower saturation or re-connect voltage should be installed.



SOMATIC CELL COUNTS
(Lonnie Nelson)
No. Cells (1000's)
1000
900
800
700
600
500
400
300
200
100
On-site Testing
(4-day pickup interval) or missing data
1,217,000
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 1 3 5 7 9
December 1992
DATE
January 1993
February 1993
Data Source: As submitted
G.R.B., PE 2/4/93
ASE Project No. 702-9307
F1/1


SOMATIC CELL COUNTS
(Darrell Franze)
No. Cells (1000's)
1000
900
800
700
600
500
400
300
200
100
1
5
10
15
20
25
30
1
5
10
15
20
25
28 1
5
10
January 1993
February 1993
March 1993
DATE
Missing Data
Missing Data
Data Source: As provided
GRB, PE 7/4/93
ASE Project No. 702:9307
P1/2


SOMATIC CELL COUNTS
(Darrell Franze)
No. Cells (1000's)
1000
900
800
700
600
500
400
300
200
100
xfmr + Elec Serv. changes
15
20
25
30
1
5
10
15
20
25
30
5
10
15
20
25
March 1993
April 1993
May 1993
DATE
Data Source: As provided
GRB,PE 7/4/93
ASE Project No. 702:9307
P2/2