AGRICULTURAL SYSTEMS ENGINEERING

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Farmstead Engineering, Livestock Housing
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Electrical Systems, Extraneous Voltage
Milking System Design/Evaluation

EXTRANEOUS VOLTAGE

WOLBECK DAIRY
Sam, Jeanine, and Donald Wolbeck
Sauk Centre, Minnesota

Analysis of Data Pertaining to Extraneous Voltage

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

ASE Project No. 702:9307

Prepared by:
Gerald R. Bodman, P.E.
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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.

Gerald R. Bodman P.E.

Date 5/25/93 Registration No. 17199

Consultant's Report

The purpose of this report is to set forth findings of a review of assorted documents pertaining to the alleged extraneous voltage problem at the Wolbeck dairy farm. Data have been collected over a period of time by various individuals. The documents reviewed included limited data on milk production and quality, a variety of electrical tests, and several letters which have been exchanged regarding the situation on this dairy farm.

EXTENT OF PROBLEM

The June 16, 1992 letter from Robert G. Essler, Superintendent, Sauk Centre Water, Light and Power Commission, indicates that work has been done on the Wolbeck dairy on numerous occasions throughout the past years in response to an alleged extraneous voltage problem. The letter also notes that many construction changes have been made in the past to reduce the cow contact voltages to industry-accepted levels. (The level considered acceptable is not specified.)

The reason for the continuing concern over extraneous voltage is not clear. Whether this is the result of inadequate diagnostic procedures or of an intermittent problem which has not been fully diagnosed is unclear.

The referenced changes were not delineated. Thus, the influence and the probable benefit to be derived or expected from the changes could not be assessed.

The letter suggests a lack of understanding of the electrical distribution system. Several times mention is made of a combination Wye and Delta bank system. Although this might indicate a system unique to this Cooperative, the standard installations would be either a Delta or a Wye system. They describe two distinctly different systems and, to my knowledge, are seldom if ever integrated into the same system.

The letter also suggests a lack of understanding of the relationship between conductor size, current load, and voltage drop as they would affect the secondary neutral system. Concerns over power quality and light flickering suggest that the relationship between such characteristics and changes in the length of the secondary neutral are not perceived as requiring changes in load balance or conductor size.

The June 22, 1992 letter from John P. Whitten, DVM, Alexandria Veterinary Clinic, supports the allegation that extraneous voltage has been a problem on the Wolbeck dairy and has contributed to animal health and production problems. Dr. Whitten notes that the response to treatment has been consistently less than anticipated. He believes this is a result of stress on the animals due to extraneous voltage causing immune system function depression.

In his July 29, 1991 letter Mr. Dan D. Mairs notes that the cows at the Wolbeck dairy do not exhibit what he characterizes as the classic symptoms associated with extraneous voltage. Despite the lack of these apparent outward signs of adverse effects, it must be remembered that cows can be affected adversely by various stresses and not exhibit outward signs of problems. This is similar to a human being affected by a heart condition, a cold, or some other ailment, and not necessarily displaying externally identifiable symptoms or problems.

Although no voltages, per se, were given, Mr. Mairs notes that a 10:1 reduction in voltages was achieved. He, therefore, concludes that the farm is effectively isolated. Depending upon the magnitude of the voltages prior to installation of the Dairyland neutral isolator switch, a 10:1 reduction may or may not be sufficient to reduce voltages to the point where cows are no longer adversely affected. The failure to achieve a more complete isolation could reflect the presence of a parallel path which is circumventing the neutral isolator. Parallel paths which must be investigated on a farm include water system, telephone system, natural or propane gas lines, telephone, etc.

The primary neutral-to-earth resistance was noted as being 0.14 ohms under one set of tests conditions and 0.84 ohms when the neutral on the "riser pole" was disconnected. Although the specific condition or characteristics of the system at the time of these two tests is unclear as described in the letter, both values are extraordinarily low. No information was given as to how these resistances were determined. Thus, the accuracy of the numbers cannot be assessed.

Mr. Mairs also appropriately recognizes that a production level of 13,000 lbs. per cow is well below state average and suggests there are problems from some source on the Wolbeck dairy. He does appropriately identify the fact that other factors, such as feed, water, and equipment problems, can contribute to reduced production. No data indicating evaluation of these aspects of the dairy production system have been received.

The diagnostic procedures used in evaluating the extraneous voltage problem have not been clearly defined. Much information has been omitted from the various reports thereby making assessment of the actions difficult. Further, some of the tests which apparently have been conducted are deemed inappropriate and in and of themselves are unlikely to have led to a correct diagnosis of the source of the problems.

In a letter dated July 30, 1992 Mr. Mike Michaud, Staff Engineer with the Public Utilities Commission, addressed some of the questions raised by Mr. Essler in his earlier letter. Mr. Michaud states that effective isolation is best determined by whether the objectives of the isolation are, in fact, achieved. He correctly notes that the apparent presence of some primary neutral voltage component on the secondary side of the transformer implies one of three possible scenarios. Those three scenarios are (1) that the primary voltage is sufficiently high to trigger the device to an "on" condition; (The trigger voltage on a Dairyland neutral isolator switch is typically 24 Vac.) (2) that a parallel path exists; or (3) that the device is faulty. None of the data suggests that the voltages are high enough to exceed the trigger voltage of the isolator. The fact that at 10:1 voltage reduction is achieved suggests the device is also operating appropriately. Thus, the most likely scenario for the continued existence of primary neutral voltage on the secondary system is the existence of a parallel path. In addition to those previously mentioned, Mr. Michaud notes that the use of an underground primary distribution cable assembly with a bare exposed neutral conductor can result in leakage of primary current to on-farm equipment either directly or through the conductive soils. Although it was noted that the system was installed in accordance with the *National Electrical Safety Code* (NESC) minimum standards, it should be noted that the NESC requirements are based on safety considerations with limited concern of the actual functioning of the system. When parallel ground rods are installed, the minimum separation distance between rods to achieve maximum effectiveness of each of the rods is twice the length of the individual ground rods. For example, if two 10-ft. ground rods are driven, the minimum separation distance should be 20 ft. When isolation is the desired effect, the ground rods should be separated by at least an additional 50%. Removal of the buried cable or replacing it with one having an insulated neutral is an appropriate recommendation given the continued existence of voltage from the primary system on the secondary.

Mr. Michaud notes that he does not believe a change in the service to the house is required. This is contrary to the observations of Mr. Gagnon. This issue will be discussed in more detail under the section on system design.

As mentioned previously, as the length of the secondary neutral changes care is necessary to assure that voltage drop both on the phase conductors and on the neutral stay within acceptable limits. This is accomplished by designing for a 2% voltage drop. The easiest way to accomplish proper sizing is to use the voltage drop tables which are prepared and published as part of the "Agricultural Wiring Handbook." A copy of Tables 16 and 17 from the 1993 "Agricultural Wiring Handbook" is attached as an Appendix to this report. The wire or conductor sizes to the left of the double vertical line indicate conductor sizes based on ampacity. These sizes in general are satisfactory for distances up to 60 - 75 ft. At greater conductor lengths, voltage drop becomes the governing design parameter. In using the voltage drop portion of the table, the length of run is the one-way distance. As an example, for a load of 100 amps, a No. 4 aluminum triplex would be satisfactory for distances up to 75 ft. Similarly, at a distance of 100 ft., a No. 3 triplex would be required, while at 150 ft., a No. 1 triplex would be required. The load in amps is the design load of the service panel. If there are two 100-amp panels being serviced by a conductor, the service conductors must be designed for a 200-amp load. This procedure is consistent with requirements of the *National Electrical Code* (NEC).

The recommendation to provide a full three-phase service is an appropriate method of line upgrading. The incidence of problems with V-phase services is much higher than with full three-phase service. Mr. Michaud also appropriately identifies improved grounding effectiveness and larger diameter conductors as other possible line improvements. Not mentioned was the importance of assuring that all connections on the primary system between the farm and the substation are electrically of good quality. Although the quality of connectors near the farm are generally of most importance, a poor quality connector anywhere between the farm and the substation can result in additional primary neutral current returning to the substation via the farm as a low resistance path and will increase the level of primary neutral voltage.

A number of graphs of tests made over the past few years were provided. An evaluation of each graph or data set follows:

a. November 7, 1989--This series of graphs was prepared by Gagnon Contracting.

- Water line to floor voltage--With two exceptions, the voltages are always of a magnitude which is below the level generally considered to be problematic. Just prior to the 19:54 time line, there is a voltage spike to approximately 3.5 Vac. According to the time log of events, this likely was associated with the starting of the vacuum pump as a part of the wash cycle. A spike of approximately 1.5 Vac occurred just prior to the 20:12 time line on the graph. Given the time log of events, this also appears to be associated with a starting of some piece of equipment.

- Line voltage--The graph shows voltages varying from approximately 119 - 125 or 126 Vac. Several spikes of a wider variation are evident on the graph. These most likely are associated with the starting of electrical equipment and are believed to be or no consequent. The line voltage is within normal limits, i.e., 120 Vac ±5%.

- Barn neutral to reference ground--With the exception of a voltage spike to approximately 1.6 Vac just prior to the 20:12 time line, all voltages are of a magnitude generally considered non-problematic, i.e., less than 0.5 Vac. There are several spikes to 0.7 - 0.8 Vac. The relative infrequency of these voltages and their magnitude, plus the location of measurement, leads to a judgement that they are of little or no consequence.

- Stalls to reference No. 2--All voltages reflected on this graph are of a non-problematic magnitude except for a spike to 1.5 Vac, which occurred just prior to the 20:12 time line.

- Yard pole to barn neutral--This graph effectively measures secondary neutral voltage drop. The system appears to be well balanced or the conductors reasonably well sized, as evidenced by a voltage drop of approximately 0.1 Vac. The exception is a voltage spike to approximately 1.8 Vac just prior to the 20:12 time line. This single spike is believed to be of no consequence.

- Secondary neutral to reference No.1--With the exception of one spike just prior to the 19:54 time line, which possibly is associated with the starting of the milking system as part of the wash cycle, all voltages appear to be of a non-problematic magnitude. This conclusion is supported by the location of measurement and the fact that voltages were measured to a reference ground rod.

- Primary neutral to reference No. 1--With the exception of several voltage spikes, which likely are associated with the starting of various pieces of equipment, all voltages appear to be within the normal range. The maximum voltage recorded is in the vicinity of 1.5 - 2.5 Vac. The exception is several spikes which reached a voltage of approximately 3.0 Vac. These voltages are believed to be non-consequential.

b. July 26, 1991--These Chessell graphs were provided in black and white only, thus making complete identification of the voltages at the various locations difficult to interpret. Despite the lack of contrast, the graphs do not appear to show any appreciable voltages in the cow contact area. Voltages appear to be less than generally recognized or accepted problematic magnitudes throughout the test period. Separation of the primary and secondary neutrals resulted in a substantial increase in the primary neutral voltage, but had limited influence on the secondary system voltages. Except for spikes associated with the starting of a 7-hp feed motor, the voltages in the cow contact area appear to be less than 0.4 Vac throughout the test interval. As noted, voltages of this magnitude are generally considered to be non-problematic.

c. July 19, 1991--This graph of current levels is of limited values because the point of measurement was not identified. The significance of spikes which appear to be related to the starting of equipment or the energizing of the farm electrical system cannot be fully assessed without additional data.

d. July 19, 1991--This graph of line voltage shows substantial variation in the supply voltage on the system. Also evident from the graph is the fact that the supplied voltage is generally higher than the standard 120 Vac. This should serve to reduce current slightly, thereby reducing voltage drop on the conductors. The standard for voltage is design voltage ± 5%. Thus, voltages between 114 and 126 Vac are considered normal and acceptable. Maintaining voltages within this range will still result in satisfactory operation of nearly all on-farm equipment. The substantial variations shown as voltage spikes most likely are associated with sudden changes in system load as various pieces of equipment or farmsteads are energized.

e. July 24, 1991--This graph is labeled as reflecting voltages between the secondary neutral bus in the barn and a reference ground. Notes indicate the jumper wire on the pole is connected. This, presumably, means the neutral isolator has been taken out of the system, i.e., bypassed. The graph shows a maximum voltage of 0.4 Vac. To what extent voltages varied beyond this is unclear. The particular piece of equipment used to prepare these graphs apparently does not show individual variations since the majority of the voltages are bar lines between 0.0 and 0.1 Vac. Nonetheless, these voltages are generally of a magnitude considered to be non-problematic.

f. August 1, 1992--This graph reflects voltages between the stanchion and some unidentified point. Presumably, the voltages reflect cow contact measurements. All measurements shown on the graph are of a magnitude that is generally considered to be non-problematic, i.e., the maximum voltage shown is 0.4 Vac. As noted previously, the ability of this particular piece of recording equipment to show real-time voltage variations is unclear since the consistency of voltages is atypical of most electrical systems.

g. August 7 - 12, 1992 generator tests--A question was raised as to whether the bare, concentric neutral on the primary distribution system was drawing current from the Amoco Oil Company cathodic protection system and, thus, causing a dc voltage to be present. There is no indication of any measurements having been taken with a resistor to determine current-producing capacity. Given the University of Minnesota research showing that it takes approximately twice as much dc voltage (1.0 Vdc) as ac voltage (0.5 Vac) to cause problems with cows, all recorded values are still of a non-problematic magnitude. The highest levels were read on the primary neutral. All secondary neutral voltages were of a nearly negligible value. One would expect the cow contact voltages to be even lower.

h. August 25, 1992--This graph reflects line voltage between L_1 and L_2. The standard supply voltage would be 240 Vac at the transformer or 230 Vac at the barn service entrance. The point of measurement was not noted. The graph shows a supply voltage ranging from 240 to slightly more than 250 Vac. All voltages appears to be within the normal range.

i. August 25 - 26, 1992--This graph represents voltages between L_1 and L_2, i.e., 230 or 240 Vac, depending upon point of measurement. The graph shows that the supply voltage is generally higher than the standard. This should not cause a problem with most on-farm equipment. The variations are perceived as normal variations for the starting of various loads along the distribution system or on the farm. All voltages are within the accepted range of ± 5% from standard of 240 or 230 Vac, depending upon point of measurement. The point of measurement of these voltages was not indicated on the graphs or in the data received.

j. August 25, 1992--This graph represents a 45-minute time interval and shows a sag in voltage from a typical 250 Vac level to approximately 241 Vac. The sag is typical of power variations in a distribution system as loads change. All voltages are within the accepted range.

k. September 8, 1992--Notes indicate this graph was developed by monitoring the primary neutral prior to isolation. The recordings are noted as being made on the north farm. A handwritten note indicates a date of 9/8/93. This is an obvious error. Data show voltages ranging from approximately 0.4 - 1.8 Vac with several spikes in excess of 2.0 Vac and a few traces below 0.4 Vac. This graph shows a more typical elevation of primary neutral voltages in the late afternoon to early evening hours. However, none of the voltages recorded are considered atypical of utility systems.

l. September 10 - 11, 1992--The graph reflects data taken from approximately 8:00 a.m. on September 10 to 8:00 a.m. on September 11. Voltages were measured between the primary neutral and some unidentified reference point. Notes indicate the voltages were made prior to isolation on the north farm. The graph and accompanying data print-out show voltages varying from approximately 0.4 - 1.9 Vac. However, notes indicate that there was a minimum voltage of 0.2 Vac and a maximum voltage of 2.3 Vac. Of particular interest is the fact that the voltages on the primary are lowest during the late afternoon and early evening periods and highest during the overnight time interval. This is contrary to a typical system loading profile. One possible explanation for this abnormal voltage profile is that other pieces of equipment or other loads along the system were cycled, which resulted in a change in the balance of the three-phase lines, thereby modifying primary neutral current flow and primary neutral voltages.

m. September 10, 1992--This graph and the accompanying data print-out reflect voltages measured between two unidentified points from approximately 2:00 p.m. until approximately 10:00 p.m. As with the previous graph, the voltages reached their highest level after 8:00 p.m. The voltages are lowest during the late afternoon and early evening hours. This possibly is another reflection of the primary neutral voltages. If, in fact, the graph represents primary neutral voltage, this graph--like the preceding one--indicates a voltage profile which is contrary to what is typically found on utility systems.

n. October 8 - 9, 1992--This graph shows voltages ranging from approximately 1.0 - 2.5 Vac. The point of measurement was not identified. If the graphs represents voltages made in the cow environment and reflect cow contact point measurements, the voltages are of a problematic magnitude. If they represent voltages on the secondary neutral, they are extraordinarily high and are cause for concern. If they represent voltages on the primary neutral, they would be considered normal and of little significance. The graph does show one spike of approximately 10 Vac. This appears to be correlated with the energizing of the system. The notes indicate the measurements were made on the north Wolbeck farm before the isolator was installed. Without additional information, the full significance of this graph cannot be determined.

o. October 8 - 9, 1992--This graph is noted as having been made on the north Wolbeck farm after the isolator was installed. Given the type graph and the presentation method, these data were apparently graphed with a different system than used for the preceding graph despite the similarity in the tabular data which accompanied the graph. The sensitivity of this particular recording equipment to voltage variations is unclear since it appears to be an averaging type machine given the consistency of the data. As presented, the maximum voltage is shown as 0.4 Vac. Regardless of point of measurement, these voltages would generally be considered to be of a non-problematic magnitude. However, without knowing what voltages actually contributed to the calculation or the development of these data which appear to represent 10-second averages, the full significance of the data cannot be assessed. No determination was possible as to whether these voltage spikes are characteristic of the electrical system or possibly of the recording method used. A handwritten note on the graph indicates the graph was developed after the isolator was installed. As such, the voltages suggest either an on-farm problem or an interaction between the primary and secondary neutrals, possibly due to coupling through the soil.

p. February 17, 1993--This page of handwritten notes indicates voltages within the animal environment and on the primary and secondary neutrals which are generally considered to be in the normal range and of a non-problematic magnitude. No indication is given as to whether a resistor was used to determine the current-producing capacity of the voltage source. A note indicates that when the power was restored, six to eight cows in the barn bellowed at the same time. This very possibly is related to a voltage spike associated with the starting of on-farm equipment. The magnitude of the load at the time electrical power was restored was not indicated. These notes relate to information presented in the two graphs addressed in the following two items.

q. February 17, 1993--This graph reflects voltages measured between the primary neutral to a reference ground and is noted as having been taken with the utility power turned off. The printed text on the graph is inconsistent with the time scale shown along the graph. Specifically, the noted indicates the test started at 12:30 p.m. but the 12:30 p.m. time is one-third of the way across the graph. Thus, it appears the graph is in error by approximately 30 minutes. Shown at a time of approximately 12:38 when power was restored, a 58 Vac voltage spike was recorded. This suggests substantial loads on the farm at the time power was restored. The notes also indicate a voltage of 0.0 Vac on the primary as a minimum level. This number in itself suggests an error in the recording equipment since 0 voltage on the primary is possible only when the system is totally de-energized, i.e., the power is turned off at the substation or at a switch or over-current protection device in the circuit and the entire community is without power. Except for the spike associated with the energizing of the farm electrical system, all voltages are considered normal for a primary distribution system neutral.

r. February 17, 1993--These voltages were measured from the secondary neutral to a reference ground rod. As noted in the previous item, the time scale appears to be off by about 30 minutes. Assuming that is correct, at the time the farm was re-energized, a voltage spike measuring 6.2 Vac was recorded. This probably is associated with the reaction of the cows noted in the previous handwritten notes (Item p). The print-out indicates a minimum voltage of 0.0 Vac. This is inconsistent with the graph. Except for the spike which is expected at the time the farm was re-energized, voltages were less than 0.5 Vac. This magnitude of voltage is considered very normal for a secondary neutral system when measurements are made to a reference ground rod.

s. March 22, 1993--The graph reflects voltages measured between the secondary neutral and a reference ground rod. A maximum voltage of 0.6 Vac was recorded when power to the farm was restored. The data appear to have been taken with an averaging type meter. Hence, the consistency of the numbers. With the farm energized, voltages are shown as varying between 0.3 and 0.4 Vac. With the power to the farm turned off, voltages varied between 0.2 and 0.3 Vac. The presence of voltage with the power to the farm turned off indicates either a parallel path or an interaction of some other form between the primary and secondary systems. Whether this is because of the parallel path or interactions from the exposed concentric neutral cannot be determined from the data presented. However, none of the voltages are considered to be of a problematic magnitude given the point of measurement.

t. March 23, 1993--This graph reflects voltages measured between a copper water line and an aluminum plate in the gutter. The location of the copper water line is not indicated. Assuming the copper water line is attached to the water line servicing the drinking cups in the barn, the graph does show voltages of a problematic magnitude even with farm power turned off. The maximum voltage recorded was 1.7 Vac with a minimum voltage of 0.1 Vac indicated. Generally, spikes are considered to be non-problematic. However, in this instance spikes appear to be occurring every two to three seconds. This frequency is sufficient to be problematic to cows. The minimal change between power on and power off time frames indicates the isolator is being exposed to voltages above the 24 Vac trigger voltage; a parallel path is still in existence; or there is an interaction between the buried primary distribution line and the secondary system. Failure to use a resistor to check the current-producing capacity of the voltage source still leaves question as to whether these spikes are, indeed, of a problematic magnitude. Further evaluation is necessary.

In his letter of August 10, 1992, Mr. Ed D. Wuthrich with the Amoco Pipeline Company states that a timed switch or current interrupter was temporarily installed in the cathodic protection rectifier near the farm. Mr. Wuthrich states that there is no indication of problems caused by the cathodic protection system. However, the method used to monitor voltages and determine whether the system was on or off when the readings were taken is not clear. The graph simply shows that the on/off switch was operating as intended. Notes on the data sheet do indicate that a faulty rectifier was found. The tests were conducted after the rectifier was corrected, i.e., repairs were made. Thus, there is no way of knowing what voltages were present prior to these corrective actions. Nonetheless, dc voltages measured between the stanchion and floor do reach a magnitude of 0.992 Vdc. While these voltages admittedly are not equal to the 1.0 Vdc found to be problematic by the Minnesota researchers, they are consistently of a magnitude high enough to be problematic to some cows. The significance of the voltages is reduced by the fact that all readings were taken from the stanchion, milkline, or water line to reference rods. Nonetheless, contrary to Mr. Wuthrich's statements, the data do not confirm that the pipeline is not imposing voltages of a problematic magnitude on the Wolbeck farm. Further, because the data were taken after correction of the faulty rectifier, it is possible that voltages of a greater magnitude were originally present to this source.

In his letter of October 7, 1992 to the Wolbeck family, Mr. Robert G. Essler responds to an apparent shock received by Mr. Sam Wolbeck when he touched one of the cows. Contrary to the first point in Mr. Essler's letter, the reaction could very well have been electrical in nature. This could easily have been a static shock, i.e., an electrical discharge due to a build-up of static electricity. In that regard points No. 1 and 2 in the letter are inconsistent. Nonetheless, Mr. Essler is correct that the problem could be associated with operation of the cow trainers. There are, of course, other reasons for the development of static electricity.

Mr. Essler is correct in his third point that if the voltage was sufficient to shock a human, given the relative sensitivity and resistance of cows, the cow probably would have been incapacitated by a voltage of this magnitude. However, characterizing the required voltage as being ten's or hundred's of volts is incorrect.

Mr. Essler is correct, however, that any faulty wiring or equipment in the barn should be corrected. This same recommendation applies to any faulty equipment on the primary side of the system.

Job invoice No. 3724 by Ralph's Electric suggests that a motor was checked for a possible fault. The readings suggest a voltage test between the motor frame and the phase conductor and comparison of that voltage to one measured between the phase conductor and the neutral in the service panel. The voltages were noted as being the same. This test does not confirm the absence of current leakage within the motor itself. Thus, the test is inconclusive. The purpose for which it was conducted is unclear.

SYSTEM DESIGN

In the November 9, 1989 letter from Gagnon Contracting to Mr. Donald Wolbeck a series of items is listed which were recommended to be corrected before conducting additional extraneous voltage tests or initiating additional corrective measures. Some of these were noted as being for reasons of safety. Recommendation No. 1 regarding the use of only a UL-Listed electric fencer and separation of the ground rods is appropriate. The second recommendation to keep dirt and whitewash off the cow trainer insulators is similarly correct. Under damp conditions these materials can become conductive and allow current leakage to the immediate cow environment. Although most such voltages have little current-producing capacity, the possibility does exist that some animals would respond adversely to the intermittent voltage imposed by the fencer operation.

The recommendation to use only three-wire grounded extension cords is appropriate. Additionally, all extension cords should be designed for use in a wet environment and carry the designation of "W" in the type listing.

Item No. 8 in the Gagnon Contracting letter appears to be contrary to Mr. Michaud's observations when he was on the farm. The letter states that there is 1/4 mile of overhead and several hundred feet of underground secondary conductors on the farm. The length of conductor to each service was not listed. However, the combined voltage drop on the interconnected neutrals poses a high risk of extraneous voltage if all conductors are not properly sized. Additional information is needed to allow evaluation of these diverse observations and recommendations.

As noted previously, requirements set forth in the NEC and NESC are minimums intended to promote safety with the electrical system. In contrast, when looking at actual field installations the function of the electrical system must also be considered. As stated in a preceding section, when looking at the separation distance between ground rods, the minimum distance for safety is 6 ft. This is contrasted to a functional separation distance of at least twice the length of the individual ground rods. This is further contrasted to the separation distance needed for isolation which is at least 1.5 times the separation distance required for maximum function or at least three times ground rod length.

In his June 16, 1992 letter Mr. Essler states that converting to a full Delta three-transformer bank system could increase the exposure of neighboring farms to other problems with the electrical system. As suggested by Mr. Michaud, the drawbacks of going to a full Delta bank are substantially less than the advantages in providing full three-phase service. If the risks are as great as suggested by Mr. Essler--and their consultants--three-phase distribution systems would seldom be used. Such is not the case as nearly all distribution circuits leave the substations as three phase with individual phases then used to service small loads and service areas.

In designing systems, voltage drop must be taken into account in all instances. Proper operation of electrical equipment requires that voltage drop on the phase conductors be limited to 5%. This is the voltage drop from the supply to the most distant load. Thus, to allow for design of conductors and voltage drop which occurs from the service entrance panel to other pieces of equipment, the service conductors from the meter to the service panel should be sized for 2% voltage drop. The sensitivity of animals to voltages and the interconnection of the grounded conductor (neutral) system with the grounding system requires that voltage drop on the secondary neutral also be considered. Under no circumstances should the neutral conductor be down-sized on services to agricultural buildings. These recommendations are consistent with recommendations found in the NEC and the "Agricultural Wiring Handbook." Use of the tables in the "Agricultural Wiring Handbook" is encouraged to facilitate simplification of the design process coupled with good design. All agricultural services should use a full-size neutral conductor, i.e., the same size as the phase conductors.

The August 25, 1992 letter from Mr. Thomas J. Mayer to Mr. Donald Wolbeck indicates that repositioning of the service to the Wolbeck dairy will result in additional neutral-to-earth voltage. This will occur only if the system is not properly designed using strategies previously discussed. The exact nature of the system reconstruction was not clearly delineated in Mr. Mayer's letter. Consequently, a full evaluation of the proposal cannot be accomplished.

Power quality is an important consideration in providing service to any electrical equipment. Several of graphs which are a part of this file have been discussed and show variability in the supply voltages at the Wolbeck farm. Although these voltages do vary with time, they are not considered abnormal. Overall, the quality of the power being delivered to the Wolbeck dairy appears to be quite satisfactory.

The desirability of maintaining low system resistances should be emphasized. This can be accomplished by using appropriately sized conductors, assuring that all connectors on the primary distribution system are of good quality, and using good grounding methods. The grounding system resistances noted by Mr. Mairs in his July 29, 1991 letter sound artificially low. They also suggest a significant influence due to the installation of the neutral separation device. Unfortunately, the lack of detail as to how these measurements were made prevents complete evaluation as to the meaningfulness of the individual values reported.

The potential for parallel paths to exist and for current leakage to occur from an exposed concentric neutral primary conductor to components of the on-farm electrical system strongly support the position that such conductors should not be used in the vicinity of agricultural buildings used for the production of animals. Other methods are available and should be employed in such situations.

MILK QUALITY AND HERD MANAGEMENT

A limited quantity of herd management data was provided. Full evaluation of this herd and the influence of extraneous voltage will require that additional data be evaluated.

Somatic cell count data were provided for the interval from January 1992 through February 1993. The source of these data was not indicated. Further, no indication was given as to whether these are DHIA or bulk tank sample data provided by the milk market. Additionally, the data were not identified as to whether they represent monthly averages, monthly highs, monthly lows, or some other value. Nonetheless, the data do suggest the herd has suffered from a mastitis problem during most of 1992. While there is an appearance of a downward trend beginning in late 1992, the upward turn from December 1992 through February 1993 cannot be fully evaluated. More specifically, it is unclear whether the drop in SCC levels in late 1992 is, in fact, an indication of a beginning of a trend or simply an aberration of the data. A copy of the graph of the data provided is attached as part of the Appendix.

Generally, the percent of the herd in milk in a well-managed herd should be in the range of 80 - 85%. Data for the Wolbeck dairy were provided for January 1992 through February 1993. During eight of the 14 months for which data were provided the percent of the herd in milk was less than 80%. This suggests there are some difficulties with breeding or reproductive program management.

The milk sales data would, at first glance, suggest a substantial increase from mid-1992 into late 1992 and early 1993. However, when the data are translated into an annualized milk sold per cow in the herd, the production in February 1993 (13,888 lbs.) is very little different than the production in January 1992 (13,500 lbs.) A graph depicting the annualized milk sold per cow in the herd is enclosed as part of the Appendix. The variations shown from late 1992 to late 1993 are most likely related to changes in herd size and the percent of the herd in milk. The stage of lactation of the various animals could not be assessed from the data provided. Further, sufficient data were not available to allow calculation of a 12-month rolling average of milk sold per cow over a meaningful period of time.

The percent butterfat shows some variations across the 14 months for which data were provided. The variations appear to correlate well with changes in feeding programs. For example, if green chop or pasture is used as part of the diet for the cows during the summer months, this would be reflected by a lower quality fiber and perhaps lower fiber intake. The result is lower butterfat or, if you will, a mid-summer slump in butterfat production. This is contrasted to wintertime butterfat production where more of the feed is provided with baled hay and a higher quality fiber.

On the herd replacement data sheet, a note was added that more first-calf heifers were being marketed, i.e., culled, since 1989. When looking at the total cull rate for the herd, it was found to range from 13.7 - 35.6% for the years for which data were submitted. The normal range for a dairy herd is 25 - 35%. If the trend for the first three months of 1993 continues, the cull rate during 1993 will be abnormally high. The reason for needing to cull more first-calf heifers was unclear. However, without more information regarding the reproductive program, it cannot be fully assessed. If a bull was being used as a herd sire, as contrasted to using AI reproductive methods, the increase in number of first-calf heifers culled could reflect the use of a poor or low quality bull sometime in the 1986 - 1987 time period. Thus, the data overall appear to be reasonable and normal. Review of additional herd reproductive data will be necessary to fully evaluate this aspect of the dairy production system.

The body score herd evaluation sheet dated October 20, 1992 reflects a few cows that at first glance appear to be undernourished or to have exceedingly low body scores. However, without knowing the stage of lactation of these animals, full evaluation cannot be accomplished. Overall, the herd appears to be reasonably normal. For comparison purposes, a Michigan State University publication lists the following as appropriate body scores.

Time of Scoring	Desired Score	Reasonable Range
Calving	3.5	3.0 - 4.0
Peak Milk	2.0	1.5 - 2.0
Mid-Lactation	2.5	2.0 - 2.5
Dryoff	3.5	3.0 - 3.5

Whether the body scores listed reflect deficiencies in the overall nutritional program, depression of feed intake due to some external stressor, such as extraneous voltage, or simply normal variations for this herd given stage of lactation and production levels cannot be determined from the information provided.

RECOMMENDATIONS FOR MITIGATION

The following are considered appropriate strategies for mitigation of any residual extraneous voltage problems on the Wolbeck dairy.

1. Eliminate the buried primary distribution line with exposed concentric neutral. Removal of this type conductor within 500 ft. of the cow environment--exclusive of pasture areas--is recommended.

2. Assure a minimum separation between primary and secondary grounding systems that is at least three times the length of any ground rod or equivalent. This applies to separation between the distribution line with exposed neutral and any grounding component on the farm.

3. Verify the absence of any parallel path which might circumvent the neutral isolator. Such possible paths include telephone system, intercom system, water lines, gas lines, etc.

4. Install a full three-transformer, three-phase system to provide better power quality.

5. Identify all changes made to-date to allow more complete evaluation of the possible influence of those changes.

6. Verify the electrical quality of all connectors between the Wolbeck dairy farm and the servicing substation.

7. Verify that all grounding connections along the primary system are installed with a resistance to ground of 25 ohms or less.

RECOMMENDATIONS FOR FURTHER ACTION

1. Provide additional herd production and performance data to allow evaluation over a longer period of time and to more accurately evaluate any possible trend lines. This will help to establish the possible presence of correlations between electrical system changes and herd performance.

2. Additional investigation of this farm is warranted. There is little doubt that production at the present time is of a problematic and abnormally low level. However, given the data which are currently part of this file, it is unclear that the problem is electrical in nature.

3. Additional electrical system testing appears to be warranted. The data available thus far is very fragmented due to the methods used, incomplete identification of monitoring points. The graphs vary from showing a problematic voltage level in March 1993 with neutral separation in place to what appear to be non-problematic voltage levels at earlier times with the neutrals interconnected. The reason for these inconsistencies cannot be determined from the data currently available.

4. Further testing must include the use of resistors to determine the current-producing capacity or capabilities of the voltage source(s). No data showing the use of resistors have been provided.

5. Additional testing of the Amoco gas line appears warranted. The data do not verify the absence of voltages in the Wolbeck dairy farm due to the cathodic protection system even with the corrected or repaired rectifier operating.

16 Minimum Allowable Size of Conductor

Copper up to 400 Amperes, 230-240 Volts, Single Phase, Based on 2% Voltage Drop

Length of Run in Feet — Compare size shown below with size shown to left of double line. Use the larger size.

Load in Amps	In Air Cable or Conduit			Direct Burial		Overhead in Air*		Length of Run in Feet																					
	UF**	RH, RHW THW, THWN, USE, NM, SE	THHN	UF**	USE	Single	Triplex	50	60	75	100	125	150	175	200	225	250	275	300	350	400	450	500	550	600	650	700	750	800
5	14	14	14	14	14	10	8	14	14	14	14	14	14	14	12	12	12	12	10	10	10	10	8	8	8	8	8	6	6
7	14	14	14	14	14	10	8	14	14	14	14	14	12	12	12	10	10	10	10	8	8	8	8	6	6	6	6	6	6
10	14	14	14	14	14	10	8	14	14	14	12	12	10	10	10	10	8	8	8	8	6	6	6	6	4	4	4	4	4
15	14	14	14	14	14	10	8	14	12	12	10	10	10	8	8	8	6	6	6	6	4	4	4	4	4	3	3	3	2
20	12	12	12	12	12	10	8	12	12	10	10	8	8	8	6	6	6	6	4	4	4	4	3	3	2	2	2	1	1
25	10	10	10	10	10	10	8	12	10	10	8	8	6	6	6	6	4	4	4	4	3	3	2	2	1	1	1	0	0
30	10	10	10	10	10	10	8	10	10	10	8	6	6	6	4	4	4	4	4	3	2	2	1	1	1	0	0	0	00
35	8	8	8	8	8	8	8	10	10	8	8	6	6	4	4	4	4	3	3	2	2	1	1	0	0	0	00	00	00
40	8	8	8	8	8	8	8	10	8	8	6	6	4	4	4	4	3	3	2	2	1	1	0	0	00	00	00	000	000
45	6	8	8	6	8	8	8	10	8	8	6	6	4	4	4	3	3	2	2	1	1	0	0	00	00	00	000	000	000
50	6	8	8	6	8	8	8	8	8	6	6	4	4	4	3	3	2	2	1	1	0	0	00	00	000	000	000	4/0	4/0
60	4	6	6	4	6	8	6	8	8	6	4	4	4	3	2	2	1	1	1	0	00	00	000	000	000	4/0	4/0	4/0	250
70	4	4	6	4	4	6	6	8	6	6	4	4	3	2	2	1	1	0	0	00	00	000	000	4/0	4/0	4/0	250	250	300
80	3	4	4	3	4	6	4	6	6	4	4	3	2	2	1	1	0	0	00	00	000	000	4/0	4/0	250	250	300	300	300
90	2	3	4	2	3	4	4	6	6	4	4	3	2	1	1	0	0	00	00	000	000	4/0	4/0	250	250	300	300	350	350
100	1	3	3	1	3	4	4	6	4	4	3	2	1	1	0	0	00	00	000	000	4/0	4/0	250	250	300	300	350	350	400
115	0	2	2	0	2	3	3	6	4	4	3	2	1	0	0	00	00	000	000	4/0	4/0	250	300	300	350	350	400	400	500
130	00	1	2	00	1	2	2	4	4	3	2	1	0	0	00	00	000	000	4/0	4/0	250	300	300	350	400	400	500	500	500
150	000	0	1	000	0	1	1	4	4	3	1	0	0	00	000	000	4/0	4/0	4/0	250	300	350	350	400	500	500	500	600	600
175	4.0	00	00	4 0	00	0	0	4	3	2	1	0	00	000	000	4/0	4/0	250	250	300	350	400	400	500	500	600	600	600	700
200		000	000		000	00	00	3	2	1	0	00	000	000	4/0	4/0	250	250	300	350	400	500	500	500	600	600	700	700	750
225		4/0	000		4/0	0	000	3	2	1	0	00	000	4/0	4/0	250	300	300	350	400	500	500	600	600	700	700	750	800	900
250		250	4.0		250	00	4/0	2	1	0	00	000	4/0	4/0	250	300	300	350	350	400	500	600	600	700	700	750	800	900	1M
275		300	250		300	000	4/0	2	1	0	00	000	4/0	250	250	300	350	350	400	500	500	600	700	700	800	900	900	1M	
300		350	300		350	000	250	1	1	0	000	4/0	4/0	250	300	350	350	400	500	500	600	700	700	800	900	900	1M		
325		400	350		400	4/0	300	1	0	00	000	4/0	250	300	300	350	400	500	500	600	600	700	750	900	900	1M			
350		500	350		500	4.0	300	1	0	00	000	4/0	250	300	350	400	400	500	500	600	700	750	800	900	1M				
375		500	400		500	250	300	0	0	00	4/0	250	300	300	350	400	500	500	600	600	700	800	900	1M					
400		600	500		600	250	400	0	00	000	4/0	250	300	350	400	500	500	500	600	700	750	900	1M						

*; ** See footnotes common to all selection tables

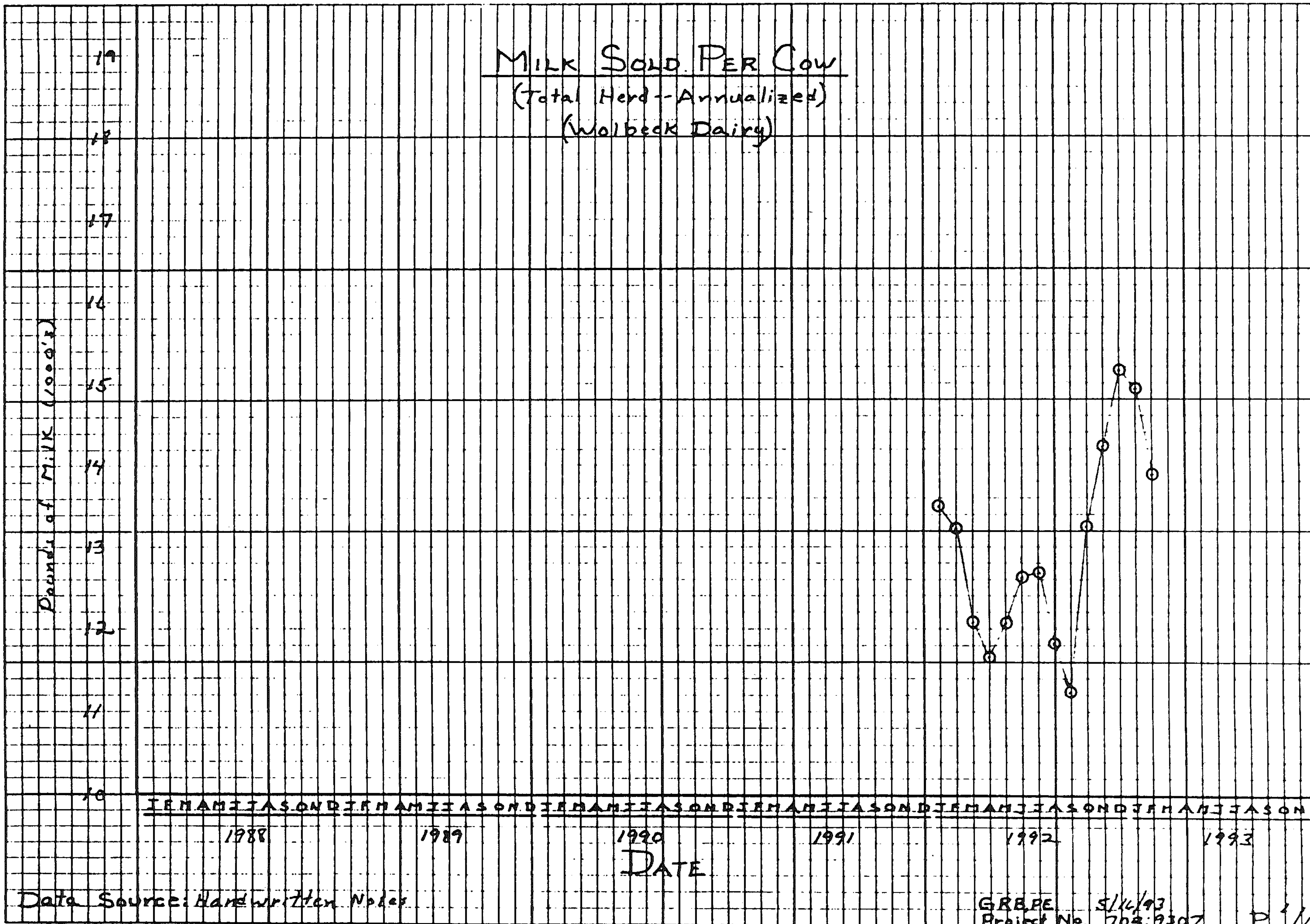
.7 Minimum Allowable Size of Conductor

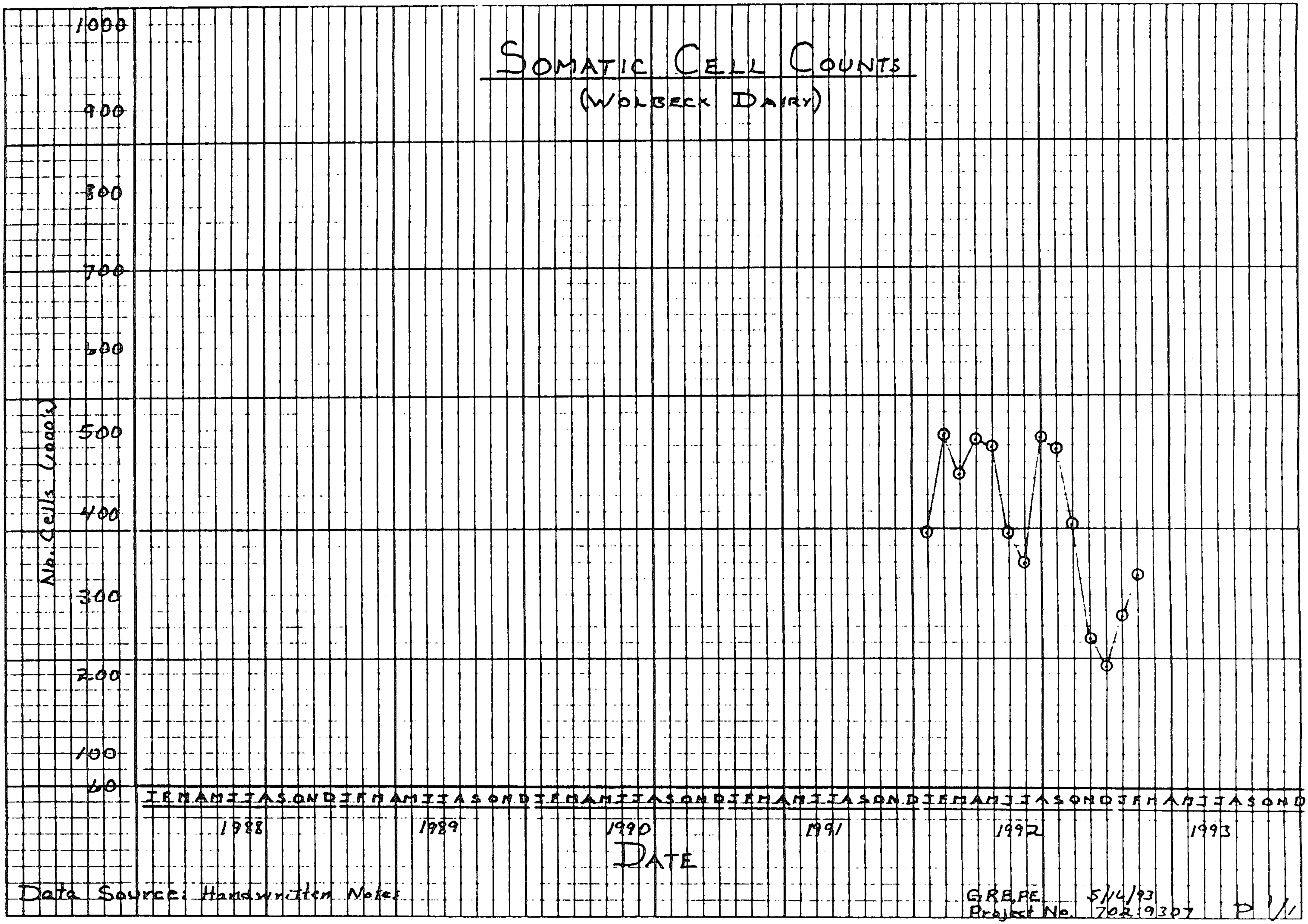
Aluminum up to 400 Amperes, 230-240 Volts, Single Phase, Based on 2% Voltage Drop

Length of Run in Feet — Compare size shown below with size shown to left of double line. Use the larger size.

Load in Amps	In Air Cable or Conduit			Direct Burial		Overhead in Air*		Length of Run in Feet																					
	UF**	RH, RHW THW, THWN, USE, NM, SE	THHN	UF**	USE	Single	Triplex	50	60	75	100	125	150	175	200	225	250	275	300	350	400	450	500	550	600	650	700	750	800
5	12	12	12	12	12	8	8	12	12	12	12	12	12	12	10	10	10	10	8	8	8	8	6	6	6	6	6	4	4
7	12	12	12	12	12	8	8	12	12	12	12	12	10	10	10	8	8	8	8	6	6	6	6	4	4	4	4	4	4
10	12	12	12	12	12	8	8	12	12	12	10	10	8	8	8	8	6	6	6	6	4	4	4	4	3	3	3	2	2
15	12	12	12	12	12	8	8	12	12	10	8	8	8	6	6	6	4	4	4	4	3	3	2	2	2	1	1	1	0
20	10	10	10	10	10	8	8	10	10	8	8	6	6	6	4	4	4	4	3	3	2	2	1	1	0	0	0	00	00
25	10	10	10	10	10	8	6	10	8	8	6	6	4	4	4	4	3	3	2	2	1	1	0	0	00	00	00	000	000
30	8	8	8	8	8	8	8	8	8	8	6	4	4	4	3	3	2	2	2	1	0	0	00	00	00	000	000	000	4/0
35	6	8	8	6	8	8	8	8	8	6	6	4	4	3	3	2	2	1	1	0	0	00	00	000	000	000	4/0	4/0	4/0
40	6	8	8	6	8	8	8	8	6	6	4	4	3	3	2	2	1	1	0	0	00	00	000	000	4/0	4/0	4/0	250	250
45	4	6	8	4	6	8	6	8	6	6	4	4	3	2	2	1	1	0	0	00	00	000	000	4/0	4/0	250	250	250	300
50	4	6	6	4	6	8	6	6	6	4	4	3	2	2	1	1	0	0	00	00	000	000	4/0	4/0	250	250	300	300	300
60	3	4	6	3	4	6	4	6	6	4	3	2	2	1	0	0	00	00	00	000	4/0	4/0	250	250	300	300	350	350	350
70	2	3	4	2	3	6	4	6	4	4	3	2	1	0	0	00	00	000	000	4/0	4/0	250	300	300	350	350	400	400	500
80	1	2	3	1	2	4	3	4	4	3	2	1	0	0	00	00	000	000	4/0	4/0	250	300	300	350	350	400	500	500	500
90	0	2	2	0	2	4	3	4	4	3	2	1	0	00	00	000	000	4/0	4/0	250	300	300	350	400	400	500	500	500	600
100	0	1	2	0	1	4	2	4	3	2	1	0	00	00	000	000	4/0	4/0	250	300	300	350	400	400	500	500	600	600	600
115	00	0	1	00	0	3	1	4	3	2	1	0	00	000	000	4/0	4/0	250	300	300	350	400	500	500	600	600	600	700	700
130	000	00	0	000	00	2	0	3	2	1	0	00	000	000	4/0	250	250	300	300	350	400	500	500	600	600	700	700	750	800
150	4 0	000	00	4 0	000	1	00	2	2	1	00	000	000	4/0	250	250	300	300	350	400	500	500	600	600	700	750	800	900	900
175		4 0	000		4.0	0	000	2	1	0	00	000	4/0	250	300	300	350	400	400	500	600	600	700	750	800	900	900	1M	
200		250	4 0		250	00	4.0	1	0	00	000	4/0	250	300	300	350	400	400	500	600	600	700	750	900	900	1M			
225		300	250		300	000	250	1	0	00	000	4/0	250	300	350	400	500	500	500	600	700	750	900	1M	1M				
250		350	300		350	4.0	250	0	00	000	4/0	250	300	350	400	500	500	500	600	700	750	900	1M						
275		500	350		500	4.0	300	0	00	000	4/0	250	300	400	400	500	500	600	600	750	900	1M							
300		500	400		500	250	350	00	00	000	250	300	350	400	500	500	600	600	700	800	900	1M							
325		600	500		600	300	400	00	000	4/0	250	300	400	500	500	600	600	700	750	900	1M								
350		700	500		700	300	500	00	000	4/0	300	350	400	500	600	600	700	750	800	900									
375		700	600		700	350	500	000	000	4/0	300	350	500	500	600	700	700	800	900	1M									
400		900	700		900	400	600	000	4/0	250	300	400	500	600	600	700	750	900	900										

*; ** See footnotes common to all selection tables


MILK SOLD PER COW
(Total Herd - Annualized)
(Wolbeck Dairy)
Pounds of Milk (1000's)
19
18
17
16
15
14
13
12
11
10
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1988
1989
1990
1991
1992
1993
DATE
Data Source: Handwritten Notes
GRB,PE 5/14/93
Project No. 702-9307
P 1/1



SOMATIC CELL COUNTS
(WOLBECK DAIRY)
1000
900
800
700
600
500
400
300
200
100
0
No. Cells (1000's)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1988
1989
1990
1991
1992
1993
DATE
Data Source: Handwritten Notes
GRB, PE. 5/14/93
Project No. 702-9307
P 1/1