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STRAY VOLTAGE PROBLEMS WITH DAIRY COWS

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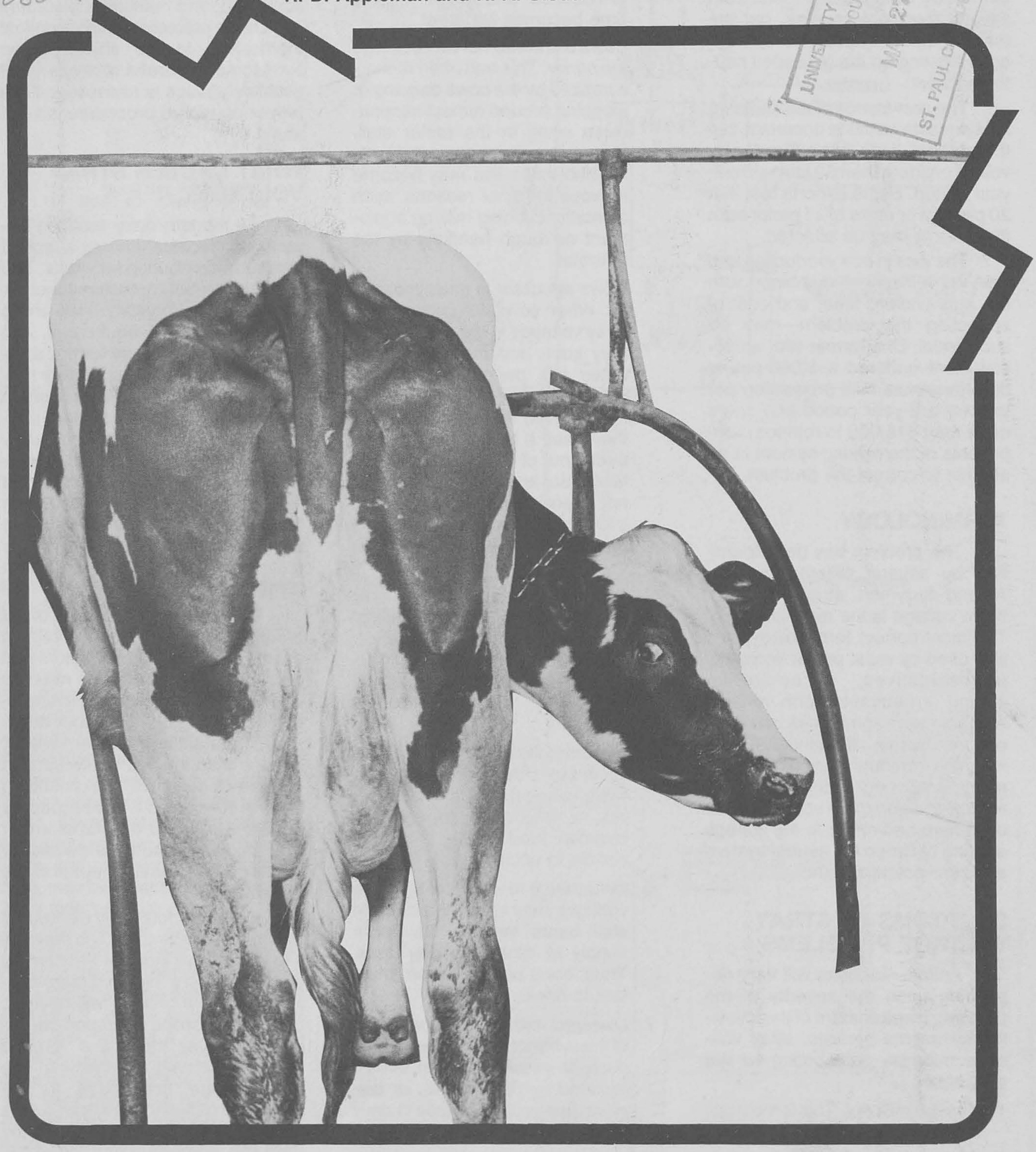


Many dairymen are losing milk production and experiencing cow health problems at milking time due to small currents of electricity passing through the cows' bodies. This condition may be caused by low voltages existing on the grounded neutrals of the farm electrical system. Stray voltages can result from several electrical sources, but the major problem appears to be voltages existing on the grounded neutral network.

The prevalence of this problem in Minnesota remains uncertain, but the authors have been directly involved on more than 50 farms in a 2-year period. Some experts feel that 20 percent or more of all parlor barn dairy farms may be affected.

The loss in milk production and dairy farm income—combined with the aggravation, time, and cost of correcting the problem—may be substantial. One farmer with an 80-cow herd suffered a 3,000-pound drop in annual milk production per cow for a 2-year period and spent more than $15,000 to replace components of the milking system in an attempt to correct the problem.

TERMINOLOGY

The problem has been identified by several different names. Among dairymen, stray voltage or tingle voltage is the most common. The most correct terminology, and that used by most power company representatives, is neutral-to-ground or neutral-to-earth voltage. Another name sometimes used, but one that has an altogether different meaning among electrical engineers, is transient voltage. The term *neutral-to-earth (N-E)* voltage will be used here and refers to the voltage existing between the neutral system and zero-potential earth.

SYMPTOMS OF STRAY VOLTAGE PROBLEMS

Animal reactions will vary depending upon the severity of the problem. If one or more of the following symptoms persists, stray voltages may be contributing to the problem:

1. *Uneven milk out.* This is the most common symptom expressed by dairymen. The number of cows affected and the severity of the milk let-down problem appear to be dependent on the level of stray voltage present. The mechanism of how this occurs is not understood. When milk out is uneven, more machine stripping is required and longer milking time becomes apparent.
2. *Cows extremely nervous while in the parlor.* This trait often is characterized by the cows dancing or stepping around almost continuously while in the parlor stall. However, dairymen are reminded that cows may become nervous for other reasons, such as malfunctioning milking equipment or rough handling by the operator.
3. *Cows reluctant to enter the parlor.* When cows are subjected to stray voltages in the parlor stalls, they soon become reluctant to enter the parlor. In extreme cases, nearly all cows have had to be driven into the parlor and there was a tendency to "stampede" out of the parlor upon release. But again, this symptom is not specific since cows may be trained to expect the parlor operator to chase them into the milking stalls.
4. *Increased mastitis.* When milk out is incomplete, more mastitis is likely to occur. All that is required is the presence of infectious bacteria. This, in turn, will result in an increased somatic cell count.
5. *Reduced feed intake in the parlor.* If cows detect stray voltage while eating from the grain feeders, a reluctance to eat and reduced feed intake is almost certain to occur.
6. *Reluctance to drink water.* Stray voltages may reach the cows in stall barns through the water supply or metal drinking cups. Thus, cows soon become reluctant to drink.
7. *Lowered milk production.* Each of the symptoms described previously is associated with stress, reduced nutrient intake, or disease. In any case, a drop in daily milk production is to be expected.

Even when the stray voltage problem has been corrected, milk production may remain abnormally low for awhile because of the associated problems.

It must be remembered that other factors such as mistreatment, milking machine problems, disease, sanitation, and nutritional disorders can create problems which manifest themselves in the above seven symptoms. A careful analysis of all possible causes is necessary if the proper corrective procedure is to be found.

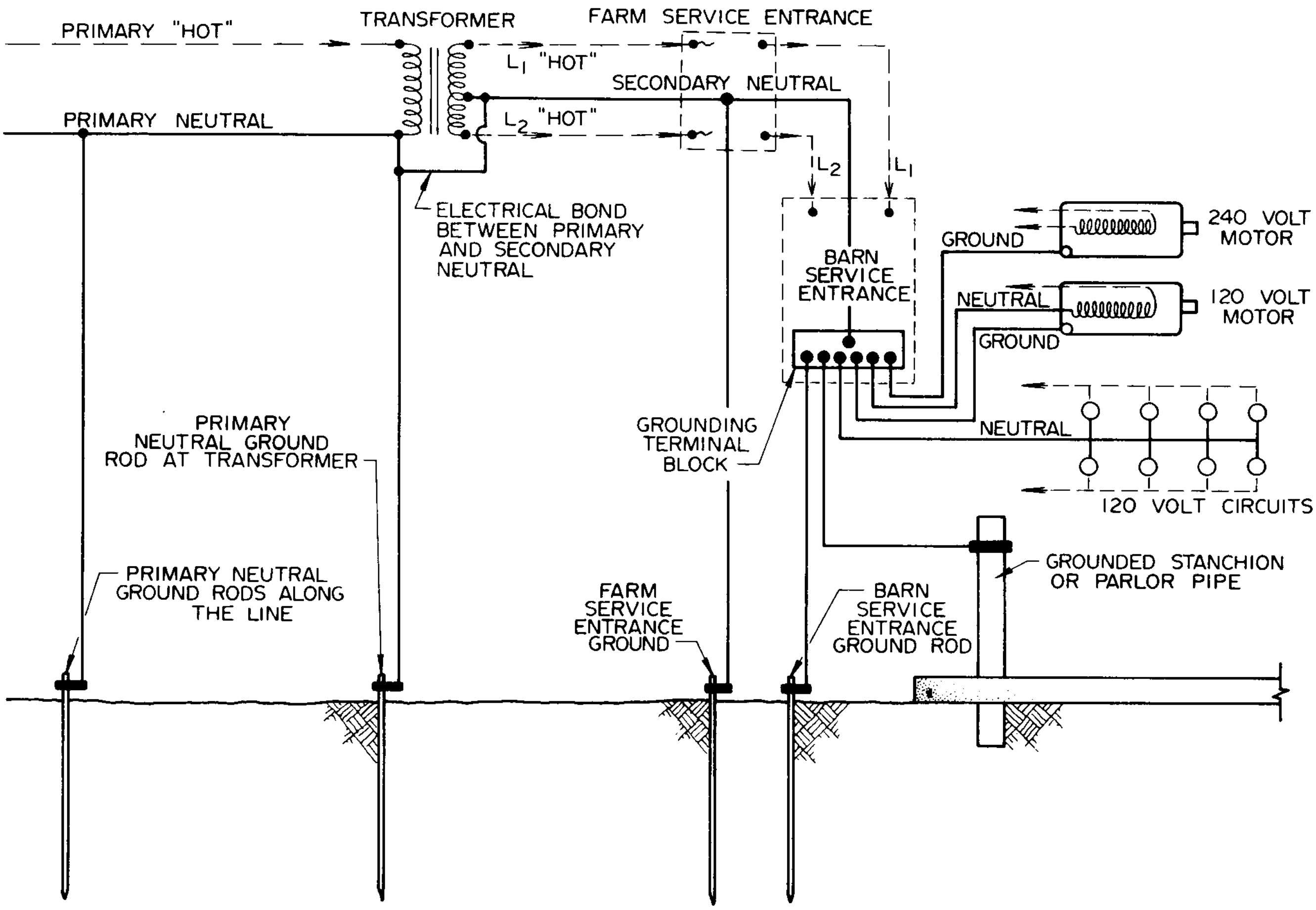
WHAT CAUSES STRAY VOLTAGE?

All modern dairy facilities depend on electrical energy supplied over rural distribution networks. The primary distribution system together with the secondary farmstead wiring and all electrical equipment and grounded components form a complex network. All parts of this network are interconnected through an electrically conductive system consisting of the primary and secondary neutrals and all grounded equipment and facilities. The grounded neutral system is connected to earth through "ground rods" driven into the soil and through electrically grounded equipment and facilities in contact with the soil.

Figure 1 shows a portion of the grounded neutral system containing examples of neutral conductors and grounding conductors. All neutrals and all grounding conductors are attached to the grounding block at the service entrance of the barn which, in turn, is connected to the service entrance ground rod. The grounding block is connected to the secondary neutral leading to the transformer. The secondary neutral is electrically bonded to the primary neutral at the transformer.

Figure 1 shows only the neutral and grounding circuits. The dashed-line and arrows indicate the primary and secondary high voltage connections. This circuitry will have no direct effect on the grounded neutral system unless there is a "ground fault" electrically connecting the high voltage conductors to the grounded network. However, as we will see later, loads added to the

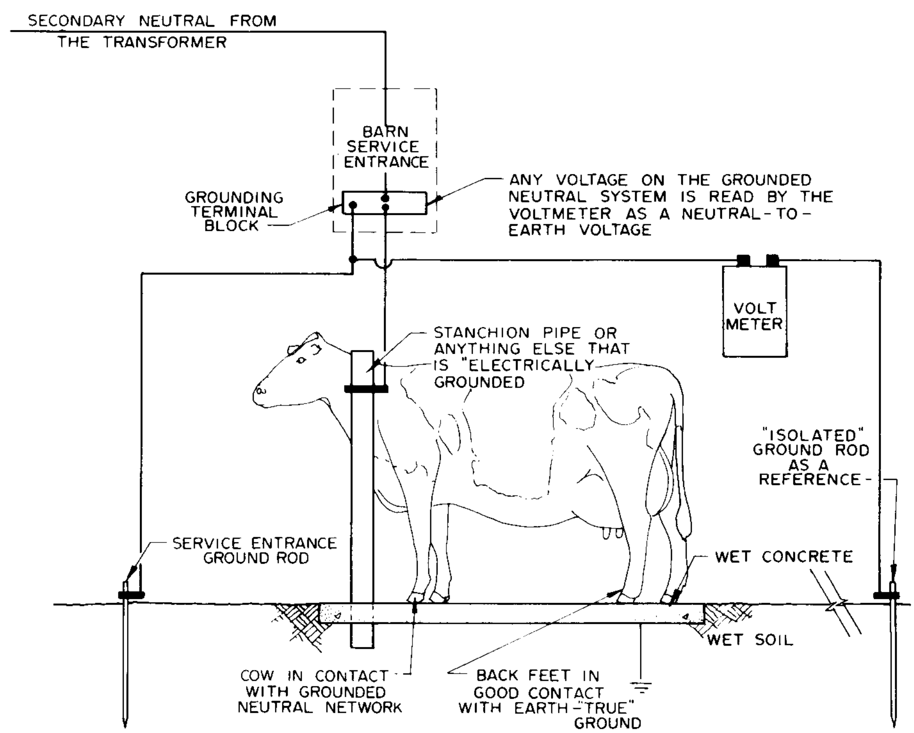
Figure 1. The grounded neutral network on a single-phase distribution line



system create various effects on the grounded neutral network.

Every part of the grounded neutral network including the conductors, the connections, the earth, and the contact between the ground rods and the earth, has some resistance to the flow of electric current. Due to these resistances, whenever there is a current in the neutral system a voltage exists between it and earth. These voltages are reflected to all parts of the interconnected network and, if they are sufficiently high, may be detected by an animal. They exist as neutral-to-earth (N-E) voltages and will cause a current flow through the body of an animal bridging the gap between the neutral network and the earth, as shown in figure 2. In this case, the cow's back feet provide a connection to "true ground" through the wet concrete and the wet soil underneath. The front portion of her body is in contact with the grounded neutral system through the pipe, wet con-

Figure 2. A dairy cow subjected to a neutral-to-earth (N-E) voltage



crete, feeder, etc. She may be subjected to the same N-E voltage read by the voltmeter in figure 2. This voltage causes a current to flow through her body and can result in serious problems when it is high enough to cause discomfort.

Neutral-to-earth voltages result from the voltage differential created by current flowing in any part of the neutral network. The voltage depends on the resistance of and the current flowing in all parts of the interconnected neutral system. Many factors affect this:

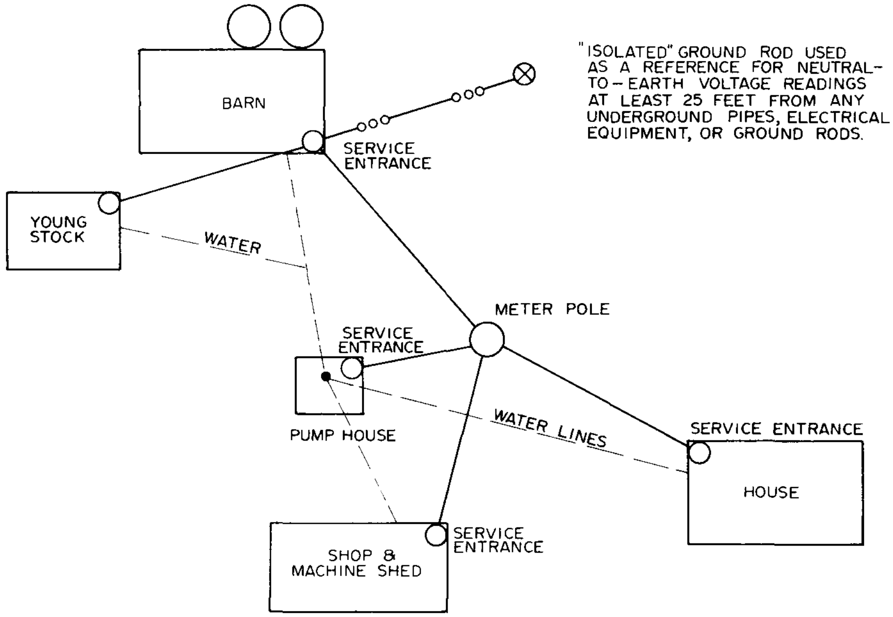
1. loads on all parts of the distribution system
2. length and size of the primary neutral
3. grounding resistances on the primary neutral
4. resistances of all connections on the primary neutral
5. grounding resistances on the farm
6. length and size of all secondary neutrals
7. current in the secondary neutrals, as affected by balancing of line-to-neutral loads (120 volts)
8. resistance of connections on the secondary neutrals
9. ground fault currents

The effect of these voltages on dairy cattle is influenced greatly by other conditions. The current through a cow's body depends on the voltage as well as the resistance of the current path through her body to "true" ground. This depends on:

1. resistance of the cow's body
2. resistance of her contact points
3. the soil moisture conditions affecting the "grounding" resistances
4. the soil-concrete contact
5. conductivity of the concrete and the soil

Soil moisture conditions affect both the N-E voltage and the resistance of the electrical path through the cow's body to earth. As a result, the problems and symptoms vary greatly with time and weather conditions. The wide variability of all the factors which affect N-E voltage, as well as the reaction of the cow to these voltages, partially explains

Figure 3. Location of an "isolated" ground rod used as a reference in neutral-to-earth voltage measurements



the intermittent "here today, gone tomorrow" nature of the problem.

The cause of excessive N-E voltages often is very difficult to locate. Its source may be on the farm, off the farm, or a combination of the two. The problem occurs whenever the combination of neutral resistances and currents creates a voltage large enough to cause the cattle discomfort. This condition can exist because of the inherent characteristics of the electrical distribution system and is not necessarily the result of electrical faults or poor wiring.

The following examples show several N-E voltage conditions and will help develop a better understanding of the problem. Figure 3 shows the location of an "isolated" ground rod used as a reference when measuring N-E voltages. If one lead of a voltmeter is attached to the service entrance ground of the barn, as shown in figure 2, and the other lead is attached to the "isolated" ground rod, it will read the N-E voltage existing on the network at this location. The location and use of this "isolated" ground rod and voltmeter will be discussed in the section entitled "Standardized Measurements." In this position the voltmeter reads the maximum voltage to which a cow could be subjected if one contact point is touching the grounded neutral system and another is in good contact with the earth.

Figure 4 illustrates how the N-E voltage on a farm can be affected by the electrical load of other farms on the same distribution system. The load on the neighboring farm is accompanied by a current in the primary neutral. The voltage required to move this current through the grounded neutral system is partially reflected onto the secondary neutral on the farm system and exists as N-E voltage. Experience indicates that farms near the end of the distribution line are more likely to suffer from N-E voltages.

Figure 5 illustrates how added farm loads increase N-E voltage on the same farm. The added load is accompanied by an increased cur-

Figure 4. Neutral-to-earth voltages on a farm due to other farm loads on the same line

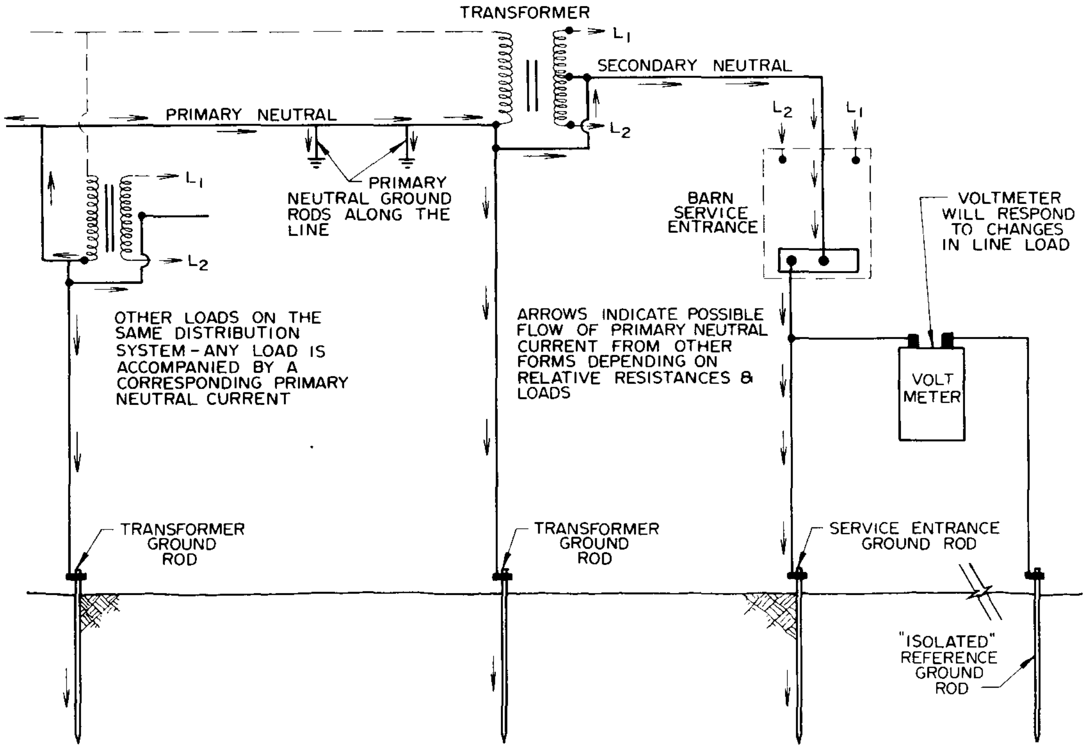


Figure 5. Increase in neutral-to-earth voltage due to increasing loads on the same farm

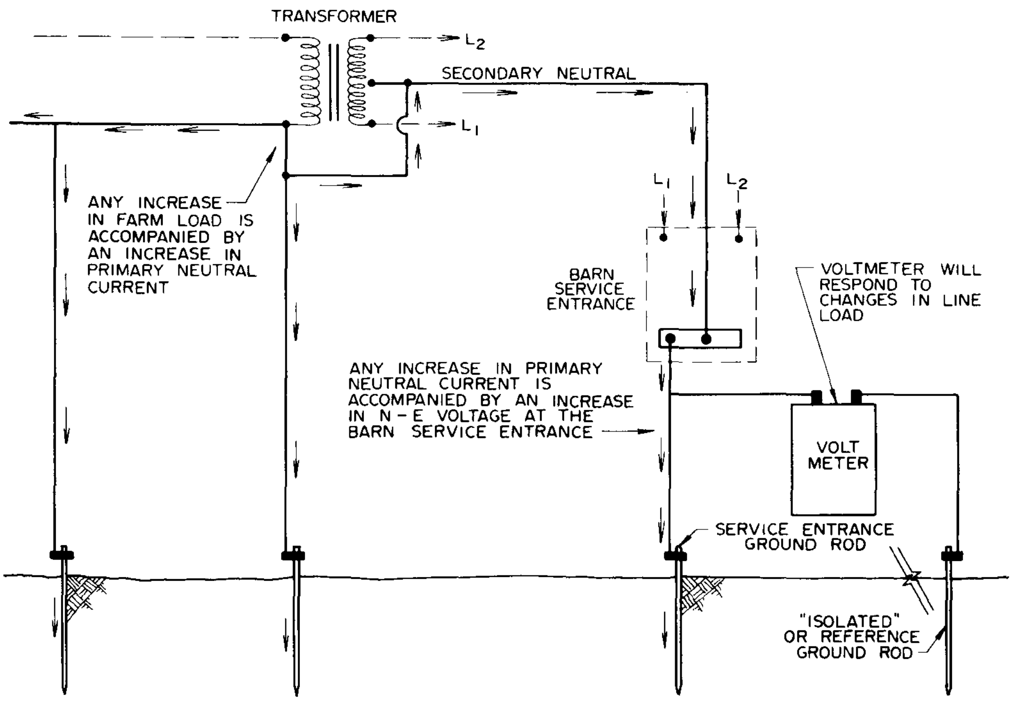
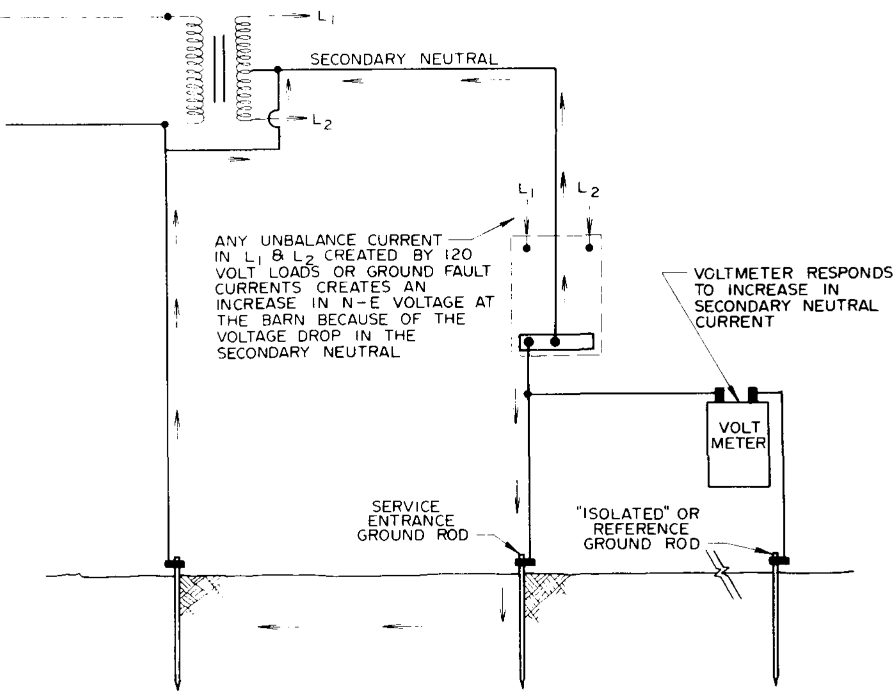


Figure 6. Neutral-to-earth voltages created by the voltage drop in the secondary neutral to the barn



rent in the primary neutral at the transformer. The increased voltage accompanying the increased current is reflected onto the farm neutral system through the bond between the primary and secondary neutrals at the transformer.

Figure 6 illustrates how the N-E voltage at the barn can be affected by the current in the secondary neutral from the transformer. An increase in unbalanced line-to-neutral (120-volt) loads at the barn is accompanied by an increase in neutral current. The increased voltage to move this current through the neutral is reflected onto the grounded neutral system at the barn service entrance. Excessively high N-E voltages at the barn can be created by large, unbalanced 120-volt loads and high neutral resistances caused by poor connections, long secondary neutrals, or conductors that are too small. These create increased voltages on the secondary neutral at the barn and can cause an excessive N-E voltage at the barn service entrance.

Ground fault currents in the barn will increase the N-E voltage as a result of the increased load on the primary neutral and the increased current in the secondary neutral.

WHEN CAN STRAY VOLTAGE BE A PROBLEM?

On any electrical distribution system it is necessary to have some voltage existing between all electrically grounded equipment and the earth. These N-E voltages exist on all grounded motor casings, water pipes, sinks, bulk tanks, stall and stanchion pipes, feeders, milking equipment, etc. As described earlier, these voltages will force an electric current through any conductor, including a cow's body, providing a pathway to earth.

Since all metal pipes and feeders are connected to the neutral system, there are a number of possible contact points between which these N-E voltages may cause a current flow through the cow's body. Some of those contact points are the feeder, waterer, stanchion, metal stall, metal grate, milk pipeline, concrete floor on which the cow stands, and concrete parlor floor on which the operator stands. Although scientists still are uncertain which contact points are more important, the milk pipeline may be extremely important since milk in the long milk hose, claw, and inflations will conduct currents from the pipeline to the inner tissue of the teat.

If the N-E voltage (AC) exceeds 1.0 volt (using the test procedure described later) a problem may exist. Larger voltages will cause increasingly severe problems. When readings are obtained at midday, while system loads are normally reduced, and the AC voltage is in the 0.5- to 0.9-volt range, the system should be monitored at milking time when system loads usually are higher. Neutral-to-earth voltages of less than 0.5 volts generally are not considered cause for concern.

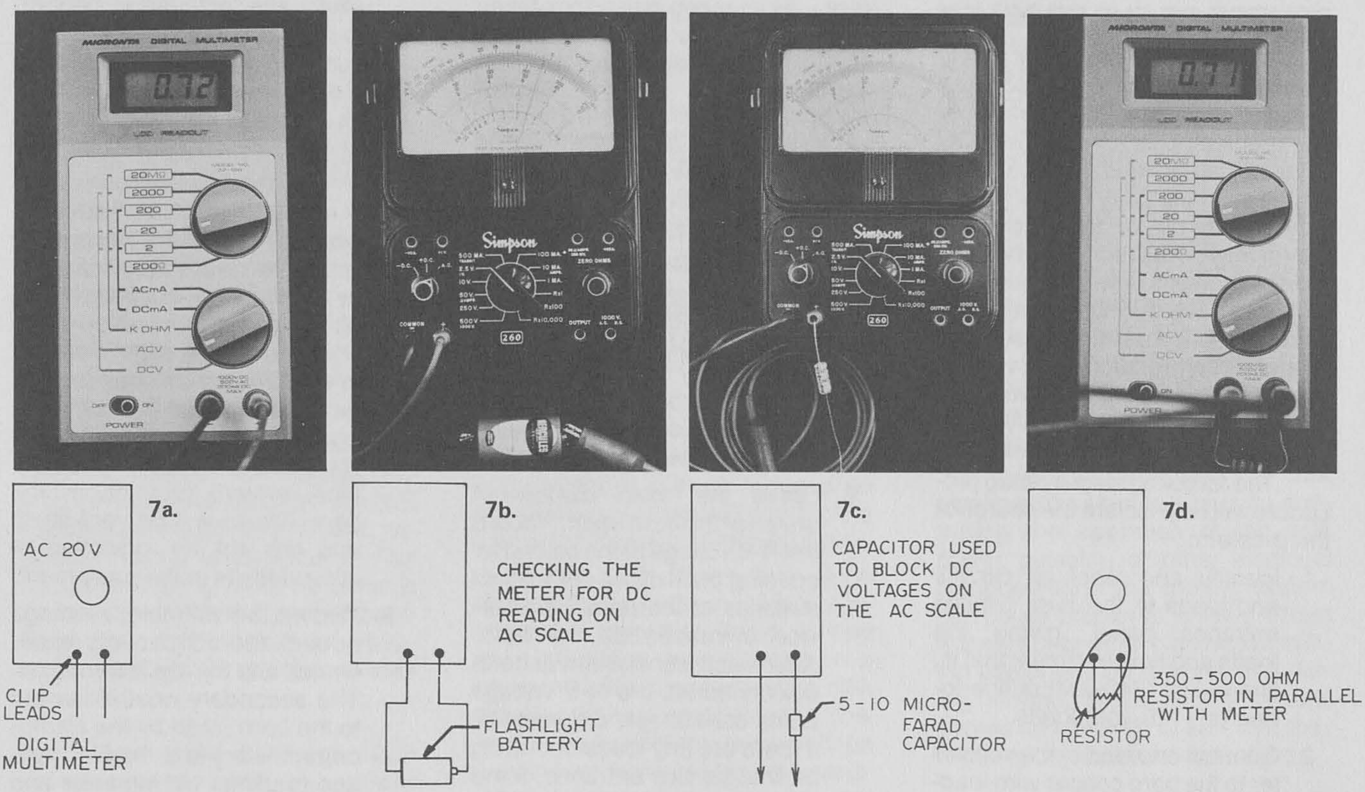
> Cause for Concern—
> 1.0 or more AC volts
>
> Monitor and Watch—
> 0.5 to 1.0 volts
>
> Consider to be Normal—
> Less than 0.5 volts

HOW TO MEASURE STRAY VOLTAGE

Confusion exists because inappropriate and poor quality voltmeters sometimes are used to determine whether a problem exists. The voltmeter should:

1. be equipped with an AC voltage scale having a full scale reading of 2 to 5 volts, with the capability of reading to the 0.1-volt level, as shown in figure 7a.
2. have a relatively high resistance (above 5,000 ohms) and be battery operated, so it does not require connection to electrical service.
3. *not read DC voltage on the AC scale.* To test this capability, connect the two voltmeter leads to each terminal of a conventional dry cell battery (1½ to 6 DC

Figure 7. Equipment for measuring stray voltages



volts), as shown in figure 7b. If a positive reading is obtained, install a 5 or 10 micro-farad capacitor "in series" with one of the leads from the voltmeter, as shown in figure 7c.

4. be able to estimate the potency of the voltage source and the resistance of the "isolated" ground rod. To accomplish this, a 250- to 350-ohm resistor must be available to parallel the input leads of the voltmeter as shown in figure 7d.

Several digital read-out AC voltmeters have proven very satisfactory for detection of stray voltages. The purchase price of these meters, which will not read DC on the AC scale, is approximately $80. An example of such a meter is Catalog Number 22-198, available from Radio-Shack. Digital read-out meters allow a technician to observe short period spike voltages considerably higher than normal readings frequently observed on Minnesota dairy farms. This occurs most frequently when a motor or other electrical device is started. Its significance and effect on the cow has not yet been determined.

Most milking machine company representatives, many power company employees, some milking equipment dealers, and some veterinarians and county extension agents have equipped themselves with suitable voltmeters and are prepared to lend assistance. *Someone familiar with electrical systems, wiring, and equipment should be consulted and, if possible, be present when measurements are made.*

STANDARDIZED MEASUREMENTS

To provide a common reference and to standardize measurements, the authors recommend the use of a copper-clad ground rod located 25 feet or more from the barn and isolated from any other component such as water piping. The ground rod should be at least 4-feet deep and in moist soil. Connect one insulated lead of the voltmeter to the "isolated" ground rod and the other insulated lead to the bare ground wire leading from the barn entrance box to the ground rod at the barn (service entrance grounding conductor). In this position the voltmeter will read the voltage between the grounded neutral system and an isolated or true ground (see figures 2 and 3).

This voltage is measured rather than voltages within the milking parlor itself because generally this voltage is the maximum expected between any two locations in the milking parlor, unless an electrical fault exists. If this voltage reaches a problem level, as discussed earlier, it is possible it exists in the milking parlor or barn and may be difficult to locate.

When measuring N-E voltages, the effect of the resistance of the "isolated" ground rod can be determined by placing a 350- to 500-ohm resistor across the input terminals of the voltmeter (resistor in parallel with meter) as shown in figure 7d. Normally there will be a slight reduction in voltage. This is partially caused by the resistance of the "isolated" ground rod. If there is a large reduction in the voltmeter reading (more than 20 percent of the reading) the resistance of the "isolated" ground rod is too high. In this case relocate the rod or reduce its resistance by saturating the surrounding soil with water.

HOW TO DETERMINE THE SOURCE OF THE PROBLEM

It is necessary to follow a well-organized, step-by-step procedure to successfully analyze a stray voltage problem. Low level AC and DC voltages can be read practically any place within the dairy facility. These may or may not be significant and may or may not be related to the stray voltage problem. The voltage levels will vary widely during the day, from day to day, or from season to season. Proper interpretation of voltage readings and changes in voltages are necessary for successfully analyzing a stray voltage problem.

The following step-by-step procedure will help isolate the source of the problem:

1. Identify and label all circuits and loads in the barn service entrance panel, giving the loads and type of circuit; that is, line-to-line (240-volt) or line-to-neutral (120-volt) loads.
2. Connect one lead of the voltmeter to the bare copper wire leading to the service entrance ground rod at the barn. This wire connects the service entrance ground rod to the grounding block in the service entrance panel. Connect the other lead of the voltmeter to the insulated wire leading to the "isolated" ground rod described in the previous section. If the "isolated" ground rod is truly isolated and not influenced by the voltage gradients in the earth surrounding the electrical system grounds, the voltmeter will now read the N-E voltage existing at the barn.
3. A clamp-on ammeter on the secondary neutral to the barn will help identify electrical faults if they are contributing to the problem. This can be done later if subsequent voltage readings indicate suspected faults.

Steps 4 through 9 may take several hours and should be done during periods of low electrical usage, possibly in mid-morning or mid-afternoon. Neutral-to-earth voltages recorded during this time will be considerably lower than at high load periods and may not be high enough to indicate a serious problem. However, any changes in readings taken during these times will help identify the cause of a stray voltage problem if it exists.

4. After connecting the voltmeter as described in step 2, record the voltmeter reading.
5. Record the voltmeter reading after opening the main disconnect at the barn service entrance. Since the secondary neutral to the barn is not disconnected, any N-E voltage is being transmitted to the barn through the secondary neutral and originates someplace else.
6. Leave the main disconnect switch at the barn open. Record the N-E voltage at the barn after opening each of the disconnect switches at the remaining service entrances on the farm. After each service entrance is disconnected, the N-E voltage at the barn should drop slightly if there are any loads operating on that service entrance. If the voltmeter reading at any step is relatively high (above 0.5 volts) and drops to a much lower value (less than 0.2 volts) when the service entrance is disconnected, the loads on that service entrance should be checked out later. This drop in voltage could be caused by a faulty load on that service entrance or it may be the result of a heavy load on the entrance at the specific time.

   The voltage recorded at the barn when all service entrances are open is due to N-E voltage on the primary neutral created by loads at other locations on the main distribution system. A check should be made at this time by opening the main disconnect to the farm. There should be no change in the N-E voltage at the barn.
7. Reconnect all service entrances on the farm and disconnect each individual circuit in the service entrance at the barn.
8. Record the voltmeter reading when each 240-volt circuit in the barn service entrance is closed and the loads are operating. The increase in neutral-to-earth voltage as each load is added is due either to the increase in primary N-E voltage as a result of the increased load or to faulty equipment on that circuit.

   If any 240-volt load causes a current flow in the secondary neutral to the barn (as indicated by the clamp-on ammeter) it is a result of ground faults in the equipment. Very slight changes in neutral current may be detected as a result of the increased N-E voltage forcing some current through the electrical system grounds at the barn. These will be very small and are not an indication of ground faults in the equipment.
9. Record the voltmeter readings as each 120-volt circuit is reconnected and the loads turned on. The secondary neutral current to the barn (read by the clamp-on ammeter) and the N-E voltage readings will increase and decrease as the unbalanced load on the secondary neutral to the barn changes.

   If the N-E voltage increases significantly (perhaps 0.3 volts or higher) with a maximum unbalanced load on the barn neutral, the voltage drop in the neutral may be causing problems. The problems may be a high neutral resistance created by poor connections or the resistance of the wire itself. Improving connections, better balancing of the line-to-line loads, and/or a larger neutral wire may help relieve the problem. Making sure the current in the barn neutral is minimized during milking (by selection of offsetting 120-volt loads) may help solve the problem.
10. Have someone watch the voltmeter throughout the milking time and periodically record the readings. Pay particular attention to major changes in fluctuations in the readings. These may occur rapidly and may last only a short time. Close attention is necessary to observe these changes.

If voltages above 1.0 volt are present during milking, some corrective action is necessary. Refer to the section "When Can It Be A Problem?" If voltages in the 0.5- to 1.0-volt range are present, the N-E voltage should be continuously monitored and some corrective measures may be necessary. If the symptoms persist and voltages above 0.5 are not present, the N-E voltage should be monitored to see if it is periodic due to weather, soil moisture conditions, or other systematic fluctuations.

If the N-E voltages obtained in steps 4 through 10 indicate the problem may be a result of high N-E voltages on the primary neutral, additional testing is necessary. *This additional testing must be done in cooperation with the power company because it involves an alteration in their system which only they can do.*

11. Repeat steps 4 through 10 *in cooperation with the power company after their employees, under the direction of their supervisors and engineering consultants, have disconnected the bond between the primary neutral and the secondary neutral at the transformer.* The disconnection of this bond is not possible with single bushing transformers in common use today and requires changing transformers. *This step requires disconnecting the bond only; it is critical that the primary neutral and secondary neutral connections to the transformer remain intact and are not disconnected.* This bond is shown schematically in figure 1. After the bond between the primary and secondary neutrals has been disconnected, there should be no change in the N-E voltage at the barn when 240-volt loads are operated. If this voltage increases with these loads, there is either an electrical fault in the equipment or the voltage on the primary neutral is feeding back onto the secondary neutral through the earth or some other electrical connection (primary and secondary neutral systems have not been truly isolated).

If the tests outlined in steps 4 through 11 show an N-E voltage problem, the results should indicate whether the problem originates on the farm, off the farm as a result of an excessive primary N-E voltage, or a combination of the two.

STRAY VOLTAGES NOT RELATED TO N-E VOLTAGES

If these tests do not indicate a problem originating from the N-E voltage, further checks are necessary. Voltages can be induced on isolated (non-grounded) conductors located in the barn or milking parlor.

Two such cases have been documented, both involving cow trainers in stanchion barns. In one case a voltage was induced on a non-grounded, stainless steel milk pipeline running parallel to the cow trainer. In the other case a voltage was induced on a water pipe paralleling the cow trainer about 2 feet away. The pipe was isolated from the well and pump by a section of rubber garden hose. In each case a voltage of 2 to 4 volts was measured between the pipes and the floor or other grounded surface. When a 350-ohm resistor was inserted across the input terminals to the voltmeter the voltage dropped to near zero. This indicates the source is not capable of delivering significant current. However, the current flow when the cow made initial contact was enough to cause discomfort. In the case of the water line, the cows were reluctant to contact the waterers to drink. However, the farmer noted, if one cow was drinking the others would drink with no apparent discomfort.

Induced voltages of this type may not be indicated by voltmeters with low input impedance. In both of the above cases the voltages were detected by meters with input impedances of 10 megohms.

Another potential problem voltage source is leakage from improperly grounded, faulty electrical equipment. *In this case, a hazardous condition exists to both humans and animals.*

The only way to detect these N-E voltages is to measure the voltage between the equipment or facilities and earth. A voltmeter reading between the equipment and the floor may be adequate. However, the best measurement is between the equipment and the "isolated" ground rod used as a reference for measuring N-E voltages.

If the voltage is an "induced" voltage, grounding the isolated equipment should solve the problem. If the problem is faulty, non-grounded electrical equipment *the fault must be corrected and the equipment properly grounded.*

Voltages imposed on milk pipelines by electrical circuits controlling the operation of the milk pump, pulsator, or other electrical components of the milking system can cause problems. If the problem appears only when placing the milking equipment on the cow and during milking, these control circuits should be checked to see that they are properly installed and wired.

WHAT TO DO IF THE PROBLEM ORIGINATES ON THE FARM

The results of the tests outlined in the previous sections should help identify the problem if it occurs on the farm. If these tests suggest faulty equipment or large voltage drops on the secondary neutral, corrective action should be taken as indicated. The following guidelines will help reduce the effect of problems created on the farm:

1. Have a licensed electrician or a representative of the power company check the electrical system to make sure all farmstead wiring meets the proper code requirements.
2. Check to make sure all service entrance grounds are adequate.
3. Establish and maintain good neutral circuits and connections. Heavy use, high humidity, corrosive silage acids, urine, and manure make dairy farms poor environments for electrical wiring and equipment.
4. Look for faulty equipment that may have leakage currents by measuring the current draw of

operating equipment and by checking the currents in the ground and neutral wires.

5. Make every effort to balance, as well as possible, the line-to-neutral (120-volt) loads on the barn service entrance in operation during milking.
6. If the problem is created by excessive voltage drop in the secondary neutral and better balancing of 120-volt loads is not feasible, install a larger diameter neutral wire to reduce its resistance. Another proposed solution is to separate the neutral (grounded conductor) from the grounding conductors at the barn service entrance and run a separate, insulated grounding conductor which is grounded only at the transformer. *This modification must be checked out with the proper authorities.* It is discussed in Section 250-21 of the National Electrical Code and may or may not be acceptable.
7. Ground all electrical equipment such as manure pumps, silo unloaders, water heaters, and pumps to the service entrance ground. Use large wire (number 9, 10, or 12). Insulation is not needed on these grounding wires. Spot weld or use pressure clamps rather than soldering or wrapping connections. *Improperly grounded equipment is extremely dangerous in milking parlor and dairy barn environments.*
8. Provide adequate power circuits. Too many service entries become overloaded as more and larger equipment is installed.
9. If it is possible, consider converting to three-phase service.

Figure 8. Interconnection of the primary and secondary neutrals through a spark gap with the secondary neutral grounded at the transformer (Section 97D, National Electrical Safety Code)

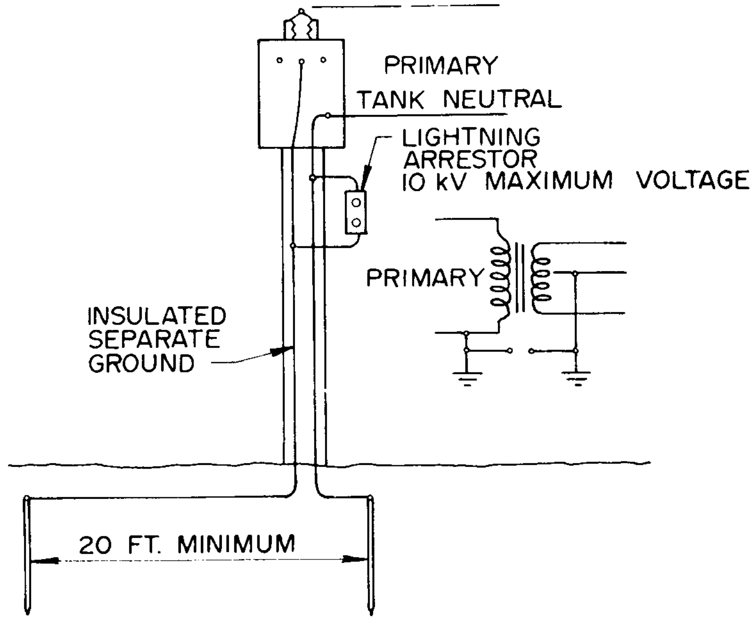
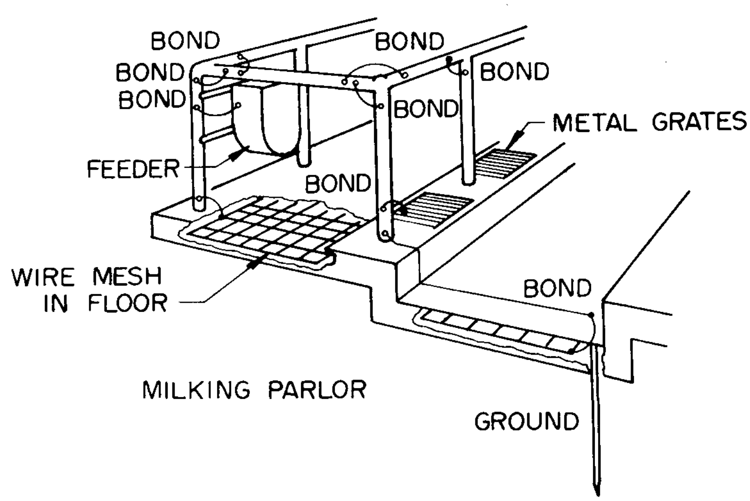


Figure 9. Bonded wire mesh used to form an equi-potential plane



WHAT TO DO IF THE PROBLEM ORIGINATES OFF THE FARM

If the problem originates off the farm it is a result of excessively high N-E voltage on the primary neutral. *In this case the solution must be a cooperative effort between the power supplier and the dairy farmer.* The following steps should be considered if the problem originates off the farm:

1. The power company should thoroughly check the primary neutral on the entire distribution system to be sure of proper grounding, no high resistance connections, and no large-fault loads on neighboring farms.
2. The power company should check the load balance on the three-phase service serving the single-phase distribution line.
3. Consult with the power company about leaving the farm neutral disconnected from the primary neutral at the transformer. This procedure will provide relief if the problem voltage originates on the primary neutral. *Operation under these conditions must be under the direction of the power company.* Section 97D of the National Electrical Safety Code provides for this if interconnection is made through a proper spark gap and the secondary neutral is properly grounded (shown in figure 8). However, some power companies, because of company safety policies, will choose not to op-

erate with non-interconnected neutrals.

4. In consultation with the power company, install an isolation transformer to serve the farm—a procedure used in hospitals, where the problem is fairly common. In doing this the dairyman assumes responsibility for maintaining proper neutral grounding on the isolated system. Complete isolation is required, and tests should be run to document this by showing no increase in N-E voltage at the barn when 240-volt loads are operated.
5. Provide an equi-potential plane as shown in figure 9. This procedure is practical in milking parlors but probably is impractical in stall-barn facilities. If the entire milking parlor—including floor, stalls, and feeders—is at the same potential, there can be no electrical shock (as in the "bird on a wire" phenomenon). A 2-inch by 2-inch, 9- or 10-gauge, galvanized, welded wire mesh is imbedded in the concrete floor over the entire milking parlor including cow stalls and operator pit. The wire mesh should be covered with a layer of concrete not thicker than 2 inches. Weld or clamp the mesh at all possible locations to other conductors such as stalls, floor grates, and feeders. It is important that the complete interior of the milking parlor be electrically connected. Use stainless steel clamps when connecting to stainless steel milklines. *Installation of an equi-potential grounding mat is highly recommended in all new milking parlors.* This method when installed correctly removes the shock potential for the cow in the parlor. It does not prevent a differential voltage from occurring when the cow enters the parlor from the holding corral, which is not a part of the equi-potential plane. In these cases, there may be a reluctance for cows to enter the milking parlor.
6. An equi-potential plane can be approximated by placing a heavy metal base over the concrete portion of the cow platform and electrically bonding it to all metal structures in the parlor. Another way is to embed 10-gauge copper wire in slots cut in the floor and grout them over. These must be bonded together and to all metal structures in the parlor.

SUMMARY

Many dairymen have been successful in eliminating stray voltage problems. Others have at least reduced the severity of their problems. Sometimes the response has been a dramatic reduction in the incidence of mastitis and number of cows culled, frequently followed by an impressive increase in production. But remember that the causes of stray voltages often are difficult to locate. This can be very frustrating since the condition may exist even with no electrical faults. In these cases, it requires the cooperation of the power company because its solution may involve an alteration in their system.

The response of dairy cattle to corrective measures will vary considerably. An immediate, dramatic response is probable if a severe problem is completely solved. However, a more gradual improvement is likely with some cows or some herds depending on severity of the problem, degree of solution, and individual characteristics of the animals. The mammary glands of cows affected by stray voltages may have become infected with mastitis and, depending on severity, both production and milking characteristics could be permanently hampered. Experience indicates some cows respond more rapidly than others. Also, there is some indication that once some cows have been subjected to a severe case they may remain fearful of stray voltages and exhibit some of the symptoms after the solution has been implemented.

Up to now, progress has been hampered by the lack of cooperative interchange. Those involved with livestock have not fully recognized the complexities of the electrical system. Similarly, power company engineers frequently have failed to recognize the sensitivity of dairy cattle to low level stray voltages.

Proper measurement techniques, identification of stray voltage sources, and appropriate corrective action, combined with recommended bonding procedures during construction of new parlors provide the most satisfactory approach for eliminating stray voltage problems.

THREE CASE HISTORIES

Number 1

This dairyman had 80 cows and had experienced a drop in milk production of nearly 3,000 pounds annually per cow for a 2-year period. After seeking advice from nutrition consultants, extension agents, veterinarians, and milking equipment dealers, and after spending more than $15,000 in replacing component parts of his milking system, he became aware of the stray voltage problem.

His case was a classical example of low level voltages entering his parlor from off-farm sources through the power company primary neutral and his farm's secondary neutral electrical systems. Disconnecting the farm secondary neutral from the primary neutral at the transformer and installing a lightning arrester (gapper) corrected this problem (see figure 8). The results of measurements taken at several cow contact points before and after disconnection of this bond are shown in table 1.

Cows soon became calmer and milked out more completely and easier within only a few days. The occurrence of new mastitis infec-

Table 1. AC Voltage Readings With and Without Electrical Bond at Transformer Connected Between Primary and Secondary Neutrals (Case History Number 1)

Location	Voltage when: bonded	isolated
Walk-way behind cows	0.8	0.28
Stall, at front feet	1.0	0.32
Stanchion and feeder	1.2	0.35
Stanchion spike, when water heater kicked on	4.0	0.85

tions dropped noticeably. While there was a 4- to 5-pound increase in daily milk production per cow within 10 days, several cows did not respond until they went through a dry period and freshened again several months later.

Number 2

This farmer found that his stray voltage problem originated on the farm. This conclusion was drawn when the stray voltage measurements remained high after the bond between the power company primary neutral and the farm secondary neutral had been temporarily disconnected by power company representatives.

With the assistance of his local electrical contractor, several improvements in his electrical system were made:

1. A fault in a submersible water pump motor was corrected.
2. The balance of the electrical load on his two 120-volt lines to the service entry of his barn was improved.
3. A larger-diameter secondary neutral wire was installed between the service entry and transformer pole to reduce the secondary neutral resistance.
4. The neutral system connections were repaired and replaced to provide a better path for the neutral currents.

Cow behavior response and improved milk production were apparent within a few days. Still, his mastitis problem did not simply disappear. His mastitis infections, primarily *Streptococcus agalactea* and *Staphylococcus aureus,* did not disappear until he established a sound mastitis prevention program involving dry cow treatment and culling of chronically infected cows.

Number 3

This dairyman with 120 cows in a new, cold free-stall and parlor system did not have a stray voltage problem, even though the authors detected 1.5 volts when a voltmeter was connected between the service entry ground wire and an isolated reference ground.

The reason was apparent when it was learned that this dairyman had installed an equi-potential plane in his new milking parlor. He had brought the potential of the parlor floor and all metallic structures to the same levels by embedding a 2-inch by 2-inch, number 9, galvanized, welded wire mesh about 2-inches below the floor surface (see figure 9).

It was necessary to provide a gradual transition between the parlor floor and entrance areas to the milking parlor by tapering the mesh depth. The added cost of making this equi-potential plane in his new parlor (in 1978) was approximately $1,000. There is little doubt, however, that this investment saved him many problems and considerable financial loss.

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