Stray Voltage and Robotic Milking

Jack Rodenburg, DairyLogix

email jack@dairylogix.com, phone 519-467-5294

Having studied stray voltage extensively during the 1980's I am somewhat skeptical about the real potential for harm from this phenomenon. Although many producers claim to suffer disastrous effects, controlled research studies have never succeeded in duplicating these large detrimental impacts. Nevertheless there is no doubt that some behavioural responses to "getting a shock" are real enough. The paper below will explain "neutral to earth voltage" as it commonly occurs on North America's grounded neutral electrical distribution systems. In summary when cows come in contact with metal that is bonded or case ground to the neutral they can get a mild shock from this contact. While I think most cows adapt to this mild irritation in a short time, it may change their behavior and if the shock occurs in or near the robotic milking stall it may reduce traffic to the robot. This is only one form of electrical disturbance that has become lumped together with others that are less easily supported by science, but it is well understood and can be mitigated with known solutions.

Except for the Lely A4 all robots have a metal floor that is case ground and at the same potential as the entrance and exit gates so cows cannot get a shock during milking. Since this is likely the most critical time, the A4 is unique in this regard and when installed in a barn with a solid floor it should be protected from stray voltage. Unless there is an overall strategy to mitigate stray voltage for the entire barn area, it is important to include a welded wire mesh (known as an equipotential grid or equipotential plane) in the concrete where the cow stands in the A4 and bond it to the robotic milking stall so that there is no risk of a shock from contact with the gating during milking.

In all robotic milking stalls the cow might be exposed to a shock between her front and rear legs when she steps into the milking stall. While this exposure would be shorter in duration and generally less irritating than other types of contact (for example from her wet nose on metal to all four feet) it is still a potential concern. If the area around the robot is slatted there is no potential for them to get a shock. If the area is a solid concrete or rubber over concrete floor (a layer of rubber in a wet environment does not isolate the cow from earth and does not prevent her getting a shock) it may be beneficial to include a "transition grid or transition plane" so that cows transition from earth potential to neutral potential gradually over several steps. This transition plane can be constructed by driving 12 foot ground rods into the earth at a 45 degree angle in the area where the cow approaches the robot and exits from it. These ground rods should be bonded to the metal of the robot or to the edge of the equipotential plane. Since this is the most complicated construction it is logical to place this in the most confined part of the entry or exit. This would be near the robot for free traffic situations as shown in Fig 1 and 2 and at the entry to the holding area (with the whole holding area gridded with bonded mesh) for forced traffic as shown in Figure 3 below. Figure 4 is an illustration of an equipotential plane and transition suitable for a Lely A4.

Lastly the solutions suggested above only impact on the potential for stray voltage impacts at the robot. If metal stabling for free stalls, and feed fence and metal water troughs are bonded to the neutral (as required by the code, and as is highly beneficial to electrical safety if mobile electrical equipment used in the barn shorts onto stabling) then these areas also become a potential source of shock in barns with solid floors. But I find that in many barns these things are not bonded and even water troughs supplied by plastic water lines have no measurable connection to the neutral and no stray voltage on them. Since it is not practical to grid entire barns, one of the other solutions (3 through 7) would be more appropriate.

Below is a detailed excerpt from a paper I presented at the 2001, National Mastitis Council Meeting:

Stray Voltage

The most common source of stray voltage is neutral current generated by normal power consumption in the grounded neutral electrical distribution system used throughout Canada and the USA. Electrical distribution in Europe is phase to phase and with the rare exception of electric shock from ground faults, stray voltage as we know it does not exist on European farms.

Although most recent research suggests that the practical significance of low levels of stray voltage is minimal, a behavioral, “avoidance” response is recognized to be the most likely first effect of exposure (Southwick 1995). This effect has been observed in farm situations involving refusal to use computer feeders in which cows were exposed to shocks of 2 to 3 milliamps, or 1 to 1.5 volts in a mouth to hooves pathway. Robotic milking systems are highly dependant on voluntary visits by cows to the milking stall (Lind 2000). If cows experience electric shocks when visiting the milking stall, it is predictable that they will reduce their voluntary visits. Measurements taken from cow contact points on both types of robotic milking systems in Ontario indicate the metal equipment is case grounded and provides a potential cow contact for stray voltage. Since the metal floor is an integral part of the milking box, the cow is on an equi-potential plane while in the stall and therefore protected from stray voltage during milking. Cows are exposed to a “step potential” when entering and leaving the box. While measurements on Ontario robot farms demonstrate the potential for stray voltage problems, limited testing on 8 of the farms found voltage ranging from 0 to 0.4 volts. In all probability this level is too low to be of concern. On several of the farms the area beside the milking stall is slatted and provides minimal grounding to the cows thereby alleviating any risk of stray voltage. In solid floor barns, installation of transition gradients (Gustafson 1984) at the time of construction may be a worthwhile preventative measure. Since the stray voltage issue is unique to North America, proper monitoring of stray voltage and mitigation when required may be important to robotic milking installations.

The intent of this was to create awareness that this may be of concern in North American installations. It has prompted requests for more detailed discussion on appropriate testing, correction and prevention. The following is written in response to these requests:

Mitigation

For more detailed explanation of testing procedures, causes and solutions please refer to the paper "Stray Voltage Problems in Livestock Production" found on the web page www.gov.on.ca/OMAFRA/english/livestock/dairy/herd/house under "Infosheets".
An appropriate test of a robot site for stray voltage would be to place a metal plate firmly on wetted concrete at the point where cow's rear feet will be when entering the existing or proposed robotic milking stall. Connect one of the meter leads to this plate. Connect the other lead to a clean metal contact on the stall. If the stall is not yet installed, use a long lead or wire to connect tothe grounding block in the service entrance panel of the barn. Use a high impedance, digital voltmeter with a 300 to 1000 ohm resistor between the leads in parallel to the meter. Better yet use an oscilloscope that has the added ability to look at short duration spikes. Readings taken between the contact points described will represent exposure the cow has when entering the robotic milking stall. Since voltage fluctuates widely with time of day measurements should be taken over 24 hours with a recording meter or repeated frequently over the same period with a standard meter. Expect highest readings during times of peak electrical use on the farm and in the neighbourhood. Voltage may also fluctuate seasonally so repeat testing may be needed.

In practical terms it is rarely possible to solve a stray voltage problem with improved grounding, or correction of electrical faults. That does not mean these things can't play a role but in most cases either an equipotential grid or piece of separation/correction equipment will be needed. Each of the choices available has advantages and disadvantages which may make it appropriate in a specific situation. The following options are of interest in relation to robotic milking:

1. Strategic use of Slatted Floor

Slatted floors are in very poor contact with earth and provide effective isolation so that cow's entering a robotic milking stall from a slatted area cannot get a shock because their rear feet are not grounded. Slatting the area beside the robot has other benefits since a pit here would help to keep the area drier and cleaner and provide a convenient place to drain wash water and waste milk. The slatted area would have to be large enough to allow cows to exit the robotic milking stall completely and have all four feet on the slatted area, before their front feet touched the solid floor (requires about 6 feet). In the transition from metal floor in the stall, to slats the cow doesn't get a shock because she is not grounded. In the transition from slats to solid floor she gets no shock because there is no contact with bonded metal. This is one of the best solutions I can think of because there is no maintenance. I see two possible disadvantages. From a cow comfort standpoint, observation suggests cows prefer to walk on solid floors and avoid slats if they can. If cows are reluctant to step onto the slats, all we have done is replace one avoidance problem with another. The aversion to slats is minimal on a good quality waffle slat, so this would be the best choice. The second disadvantage would be the cost of the pit which would be high if it was there for no other reason, and minimal if it was needed anyway for manure handling. In a new barn, I think this is my favourite solution.

2. Equipotential Plane

A welded wire mesh grid, bonded to the robot milking stall and extending into the concrete area on which the cow approaches and departs from the robot, will prevent her from getting a shock when she steps onto the metal floor. If this "plane" ends abruptly the cow is exposed to a front to rear hoof shock at the point she steps onto and off of the plane, so it is necessary to create a "gradient" that ensures a gradual change in the exposure. At milking parlor entrances, this is done with 12 foot ground rods driven at a 45 degree angle at the edge of the grid and bonded to it. Rods are normally space 6 inches to 1 foot apart. This "gradient reduces the level of voltage between two points over the length of the cow by approximately 50%. As illustrated in Fig. 1 and 2, the same gradient can be created immediately beside a robotic milking stall with ground rods driven in a fan shape around the stall at 45 degrees off horizontal.

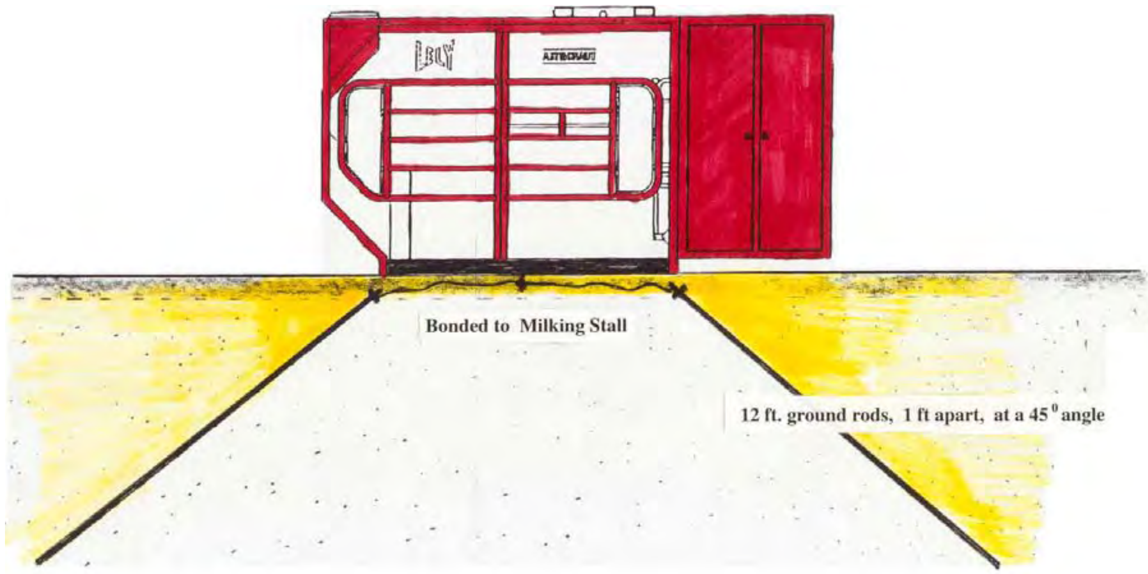

Fig. 1 cross-section view of an equipotential gradient in association with a robotic milking stall.

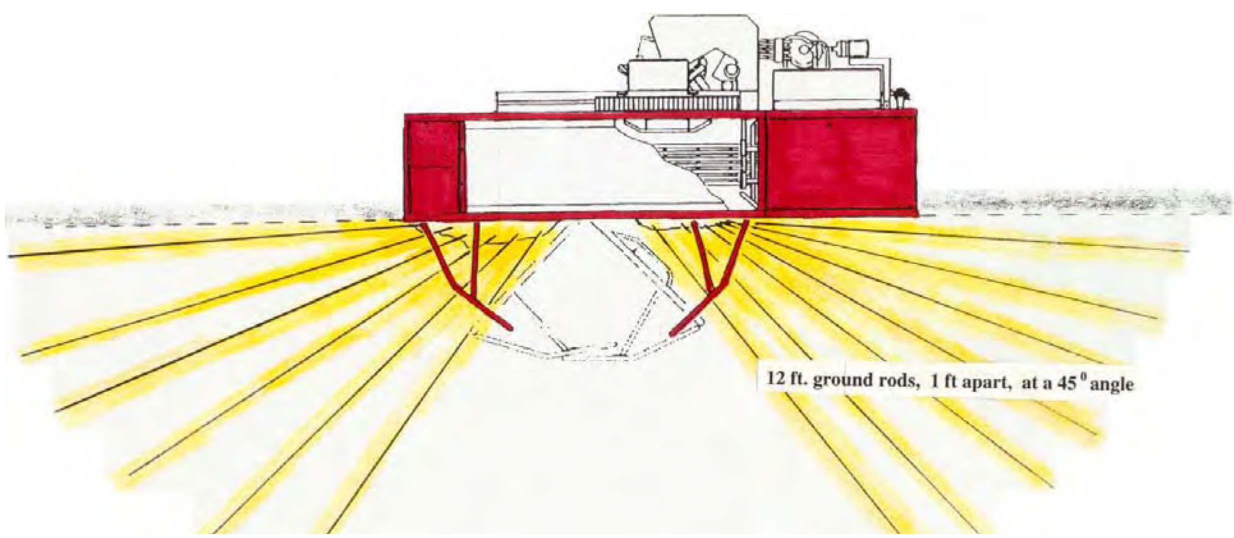

Fig. 2 top view of an equipotential gradient in association with a robotic milking stall.

If the stall includes a holding area and exit lane, it may be advisable to grid this area with a welded wire mesh and locate the gradient at the entry and exit points as shown in Fig. 3. This would move any mild shock which still occurs to a point further from the stall.

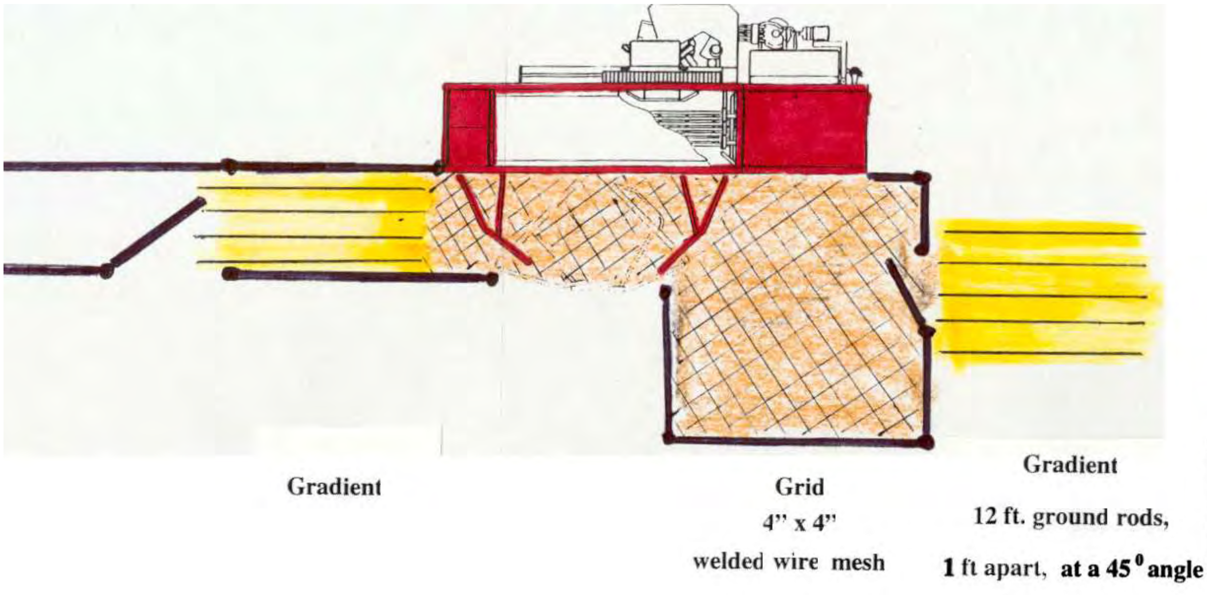

Fig. 3 Top view of an equipotential plane and gradient for a robotic milking stall with a holding area and exit lane.

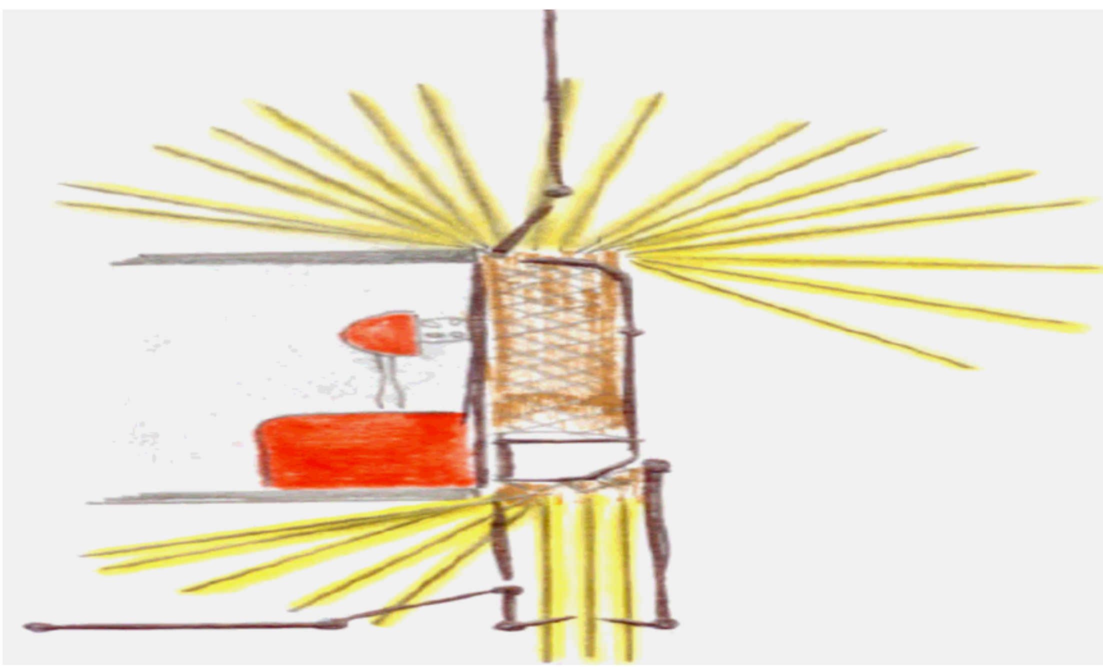

Fig. 4 An illustration of an equipotential plane (brown mesh area) and gradient (yellow angled ground rods) applied to a Lely A4 with split entry and separation at the exit.

Disadvantages of equipotential planes include: 1. They are difficult and high cost in a retrofit. 2. They only reduce voltage to half, on the gradient and may still leave a problem level. On the plus side they also have no moving parts or maintenance needs.

3. Tingle Voltage Filter

This solution is thoroughly discussed in the paper referred to above. It normally reduces the level of voltage by 85 to 95 %, which is usually enough to ensure no problem remains. In the case of robotic milking the filter would be installed on the service entrance panel from which the robot is supplied with power. Currently no one manufactures this device, so no new filters are available. Many electricians have difficulty installing these devices, which require complete electrical separation of the grounding system from the neutrals. This is a low cost solution if you can find a used one and an experienced electrician that installs it right the first time.

4. Separated Neutrals at the Transformer

Since most of the time, the majority of the voltage measured originates on the utility neutral, separating the farm neutral from it at the transformer usually results in a dramatic reduction in the voltage measured on the farm. Since the utility owns the transformer this procedure can only be done by the utility. They don't like to do it because the distribution system benefits from customer grounding and bonded neutrals improve electrical safety. Ontario Hydro policy does not normally permit neutral separation. They may allow it on a temporary basis. If the utility can be convinced to agree to this it is a highly desirable way to solve an existing problem since there is little cost (an extra ground rod, a spark gap, and an hour to install them.) If a few months of operation with separated neutrals results in improvement in cow behaviour, a more permanent and more costly solution can be implemented. Separated neutrals do not address voltage caused by neutral resistance or faults on the farm and may not effectively address all problems.

5. Ronk Blocker

This device is essentially the same as a tingle voltage filter but it is installed between the primary and secondary neutral. Like the filter it results in a percentage decrease only and like separation it does not address on farm sources. Since it is installed at the transformer the utility must be involved in the installation. The device is approved for use in Canada but is not officially permitted by Hydro policy. There are a number of these devices installed in Southwestern Ontario. The distributor is L and B Stray Voltage Services, RR # 1, Palmerston, N0G 2P0, 519-638-3680

6. DEI Variable Threshhold Neutral Isolator

This device also separates neutrals at the transformer. While slightly more costly than the Ronk, it is also slightly more effective because isolation of the neutrals is complete. Like other pole top solutions it does not address on farm sources, and requires utility cooperation. This device was developed by David Rogers, BC Hydro (david.rogers@bchydro.com) and is manufactured and distributed by Dairyland Electrical Industries. P.O. Box 187, Stoughton, Wisconsin, 53589 USA, 608-877-9900. To date I know of one installation in Ontario.

7. Other Devices

There are at least three other options which are poorer choices than those offered above. One company in Eastern Ontario uses separation devices that isolate individual sections of stabling from the rest of the grounding system. Since the robotic milking stall involves electrical components and has current carrying conductors in it, it must be case ground for safety reasons so this is not an appropriate approach for this situation. Isolation transformers can be used to isolate a barn from the primary neutral, but these are expensive and limit future expansion of the service. Lastly at least two companies market very costly active suppression devices. While these are effective the cost is prohibitive.

In summary, there is reason to believe that electric shocks caused by stray voltage on the robotic milking stall has the potential to influence cow behaviour and reduce voluntary use of the automatic milking system. Thorough testing is advised and where levels in excess of 1 to 1.5 volts are found, corrective action is recommended. The most appropriate solution may depend on the level of voltage found, the policies of the utility and whether it is new construction or renovation.