PLAN M-9611

STRAY VOLTAGE

COMPLETE INSTRUCTIONS

NEW 87:07

R. G. Winfield and JA. Munroe

Stray voltage (also known as "tingle" voltage) is any voltage that appears in metal work, stanchions, pipes, conduits, etc. It is usually caused by current trying to get back to the transformer by the easiest route. Stray voltage can cause discomfort to farm animals; for example, if a cow touches a metal feeder that is charged with stray voltage, it gives her a shock as the current passes through her body.

Most farm animals react to voltages too low for humans to notice. They may lap at water rather than drink normally or leave a layer of feed in a steel trough. They sometimes hesitate or refuse to enter areas where they previously felt shocks (stall hardware, for example) while standing on wet concrete. When confined, they may jump, defecate and kick, creating problems for handlers.

A change in an animal's behavior is usually the first sign of stray voltage. However, as other things can cause similar reactions, have an electrician or other specialist run thorough tests with equipment that is sensitive enough to detect low voltages. Choose someone experienced in stray voltage measurement.

Although research has not proven that stray voltages directly effect production, animals may well suffer indirect effects that lower their productivity. For example, erratic behavior may mask heat detection and prevent timely breeding.

VOLTAGE LEVELS THAT CAUSE TROUBLE

The bodies of most farm animals have a much lower electrical resistance than those of humans. For example, a cow's resistance is about 360 ohms for a current path from the mouth to all four hooves. This lets her feel much lower voltages than you can - most cows respond to only 4 mA (milliamperes); some can feel 2 mA.

Consider a cow that can feel as little as 2 mA (0.002 A). We can use Ohm's law (amperes x ohms = volts) to calculate the voltage that will give her a shock: 0.002 x 360 = 0.72 V If she attempts to eat or drink from a metal bowl, she will be able to feel only 0.72 V between the bowl and the concrete floor!

A 45 kg growing pig has mouth-to-hoof resistance of about 930 ohms, or about 2.5 times that for a cow. In this case, it takes 1.86 V to cause a 2 mA current. Given a choice, growing pigs avoid drinkers that give them more than 0.5 mA. If not given a choice, they will tolerate 5 mA, but may not drink enough water.

Try to eliminate stray voltages above 0.5 V; you may not feel them (especially if wearing rubber boots) but the animals might.

CAUSES

Contrary to popular belief, stray voltage seldom comes from the "hot" wire in an electrical circuit unless there is a ground fault. Ground faults occur when insulation fails in wiring or equipment (for example, between the copper windings and magnetic core of an electric motor) and can create potentially lethal stray voltages. For this reason, the Canadian Electrical Code demands that all metal in animal buildings be connected (bonded) to the electrical ground at the service entrance.

High-voltage devices (such as cow trainers, electric fences and poultry antiroosting wires) can induce a nuisance form of stray voltage on nearby unbonded metal hardware. An animal or human touching the metal feels a mild shock similar to that from static electricity on a dry winter day. The solution is simple - bond the metal to ground at the barn's electrical service as required by the code.

The most common and troublesome stray voltage is caused by the currents that normally flow through the neutral wire in an electrical circuit. Theoretically, the neutral conductor has a

CANADA PLAN SERVICE

The Canada Plan Service prepares detailed plans showing how to construct modern farm buildings, livestock housing systems, storages and equipment for Canadian Agriculture.

To **obtain another** copy of **this leaflet, contact your local provincial agricultural engineer or extension** advisor.

zero or "true-earth" potential. However, the best conductors always have some resistance, so that any current flowing through the neutral wire needs a small voltage to drive it, referred to as the neutral-to-earth (N-E) voltage.

Excessive N-E voltages can be created in the power supplier's primary system before electricity reaches the farm transformer, in the farm wiring itself, or by both. When both are at fault, the effects may be additive or may cancel out, making it difficult to identify the problem's source. Therefore, this leaflet will dis cuss both sources individually.

Power supplier

Most power suppliers provide farms with single phase service. They send high-voltage (primary) power from their distribution system to a step-down transformer in the farmyard, using two conductors -one hot and one neutral. The neutral is grounded at regular intervals along the line as well as to the farm's neutral conductor (secondary) at the farm trans former.

When power flows, the neutral conductor returns the current to the source, completing the circuit. However, some N-E voltage is unavoidable, as discussed earlier. Most customers consider 10 V or less acceptable, but this is far too much for farm animals.

Again, Ohm's law applies. As the load on the hot wire increases, the N-E voltage will also likely increase. Therefore, stray voltage becomes most troublesome when the farmer is making the greatest demands for power (during milking, for instance).

In some low-density rural areas, power suppliers string only one primary conductor-the hot or feeder cable. The neutral current returns to the suppliers' dis tribution transformer through the ground. In such cases the N-E voltage from the power source is eliminated.

Most power suppliers are aware of the problems stray voltages can create for livestock farmers, and are generally prepared to test their systems for faults.

On the farm

The farm's step-down transformer provides three wire service (Figure 1). One conductor, usually bare wire if overhead, is the neutral. It connects to the power supplier's neutral at the

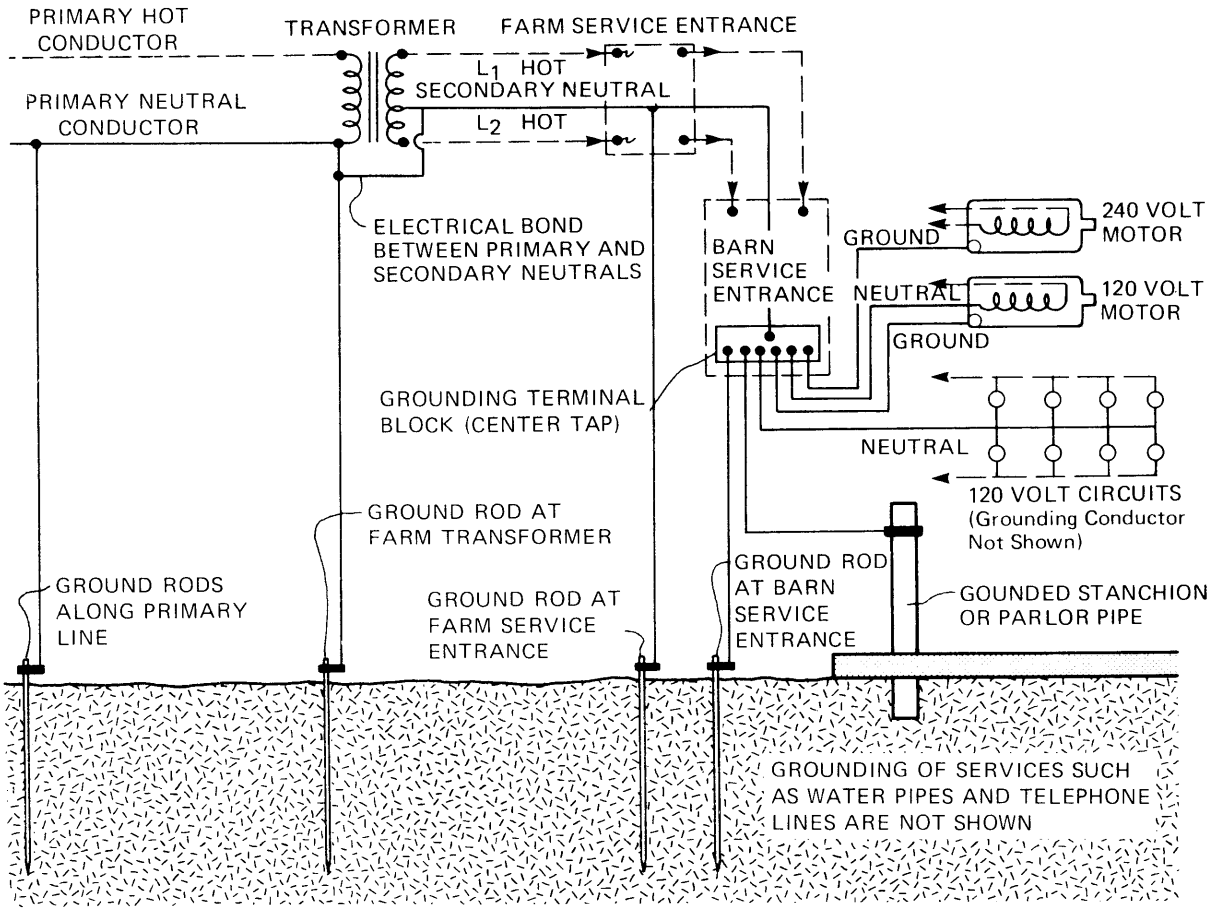


Figure 1 The grounded neutral network on a single-phase primary distribution line and secondary farm service

transformer's center tap. The other two are always insulated and each carry 120 V. The farmer then has the choice of 120 V (hot to neutral) or 240 V (hot to hot) service.

For safety, the neutral conductor is connected to a ground rod driven into the earth at each building's service entrance.

With 240 V loads, the current in both hot lines is the same and no current flows back through the neutral conductor. With 120 V loads (such as lights), some current flows back to the fuse panel through the neutral. In this case, load balance is important; if equal loads are flowing in both legs of the barn service the net current flowing back through the neutral is zero. However, if the load in both legs is not the same, the current difference must flow back to the transformer through the neutral.

Where a current from a small imbalance flows through a neutral wire of low resistance, the N-E voltage will be negligible. But what happens if either the unbalanced current or the resistance is high?

Assume the unbalanced difference in the neutral conductor is 10 A and the conductor has a resistance of only 0.2 ohms. Ohm's law shows that we have an N-E voltage of 2 V However, if a corroded neutral connector increases resistance to 2 ohms, the same current will correspond to 20 V!

In theory, mild currents should flow to earth through the service ground rod via the neutral conductor, and all metal equipment in the animal barn is bonded to this conductor. But ground rods always have some electrical resistance, which leaves a portion of the N-E voltage on the metal equipment. If an animal standing on a good ground (such as wet concrete or soil) touches the equipment, its body completes the circuit by providing an alternate current path.

Figure 2 shows how this can happen to a cow standing on a wet concrete floor when she contacts an electrically bonded stanchion. The portion of N-E voltage felt by the cow will vary from negligible to 100%, depending on the difference in resistance between the service entrance ground rod and the wet concrete. If the rod's resistance is high because of a corroded wire or connection, the stray voltage she feels will likely be higher.

Even though good bonding within animal buildings may increase stray voltage, never eliminate this grounding as a

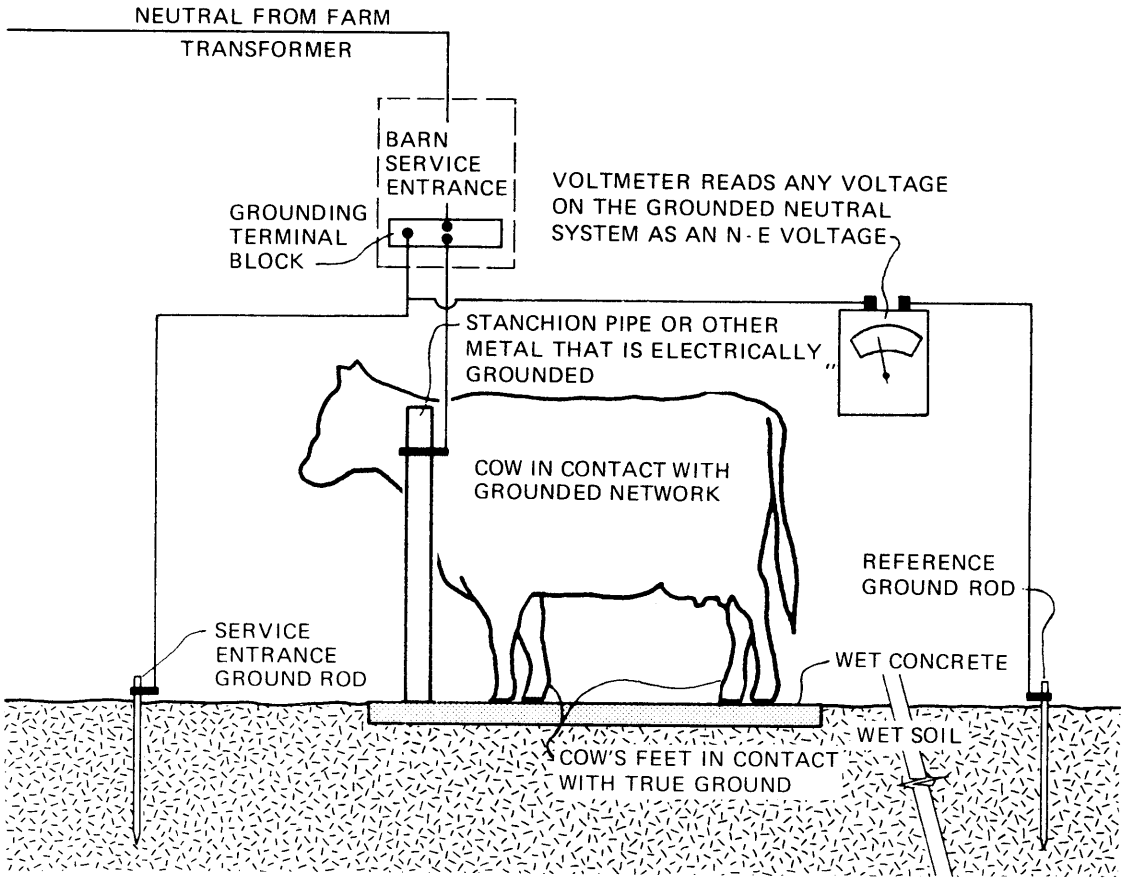


Figure 2 A dairy cow subject to shock from stray (N-E) voltage

cure. All metal, such as feeders, waterers and pen dividers must be bonded to prevent lethal voltages if ground faults occur in electrical equipment. The Canadian Electrical Code requires bonding with not less than No. 6 AWG stranded copper wire.

While good grounding of the barn's service entrance is important, a sophisticated ground-rod system might pick up stray earth-borne current from nearby services with high neutral resistances or serious ground faults. This would actually increase stray voltage in the barn.

INTERACTION OF N-E VOLTAGES

All neutral currents on the farm should return through the neutral conductor to the center tap of the farm transformer. If any service has a neutral conductor of high resistance, its neutral current will seek an alternate path. Commonly, this path is down that service's own ground rod, through the earth and to the ground rod of another building's service that has lower neutral (and grounding) resistance. The two services are usually on the same farm, but the interconnected power-supply and farm neutrals common in Canada can indeed let stray current travel through earth to a neighboring service and return via the power supplier's neutral to the initiating transformer. Most farms fortunately have at least three and in many instances five or six ground rods - one of which should pick up the stray current.

Figure 3 illustrates how neutral current can flow from the ground rod at the service entrance to the one at the transformer. For example, if each rod has a resistance of 2 ohms (for a total of 4 ohms), Ohm's law shows that a stray current of only 2 A will correspond to an N-E voltage of 8 V.

For these reasons you must check all electrical services on the farm (including your house) for good grounding, minimal neutral currents and equipment with ground faults.

DETERMINING THE PROBLEM'S SOURCE

(f you suspect stray voltage problems in a barn, you need a specialist to help isolate the sources) and make necessary corrections. The tests may take several hours, especially if the problem voltage comes and goes. The specialist can determine when the problem peaks during the day and pinpoint sources, although diagnosis can be difficult if more than one source exists. For qualified help, contact your power supplier or provincial agricultural extension office.

N-E voltages from two or more sources may be additive, increasing the problem. On the other hand, they may be out of phase and cancel each other out; in extreme cases, those from the farm can fully mask or even reverse those from the power supplier.

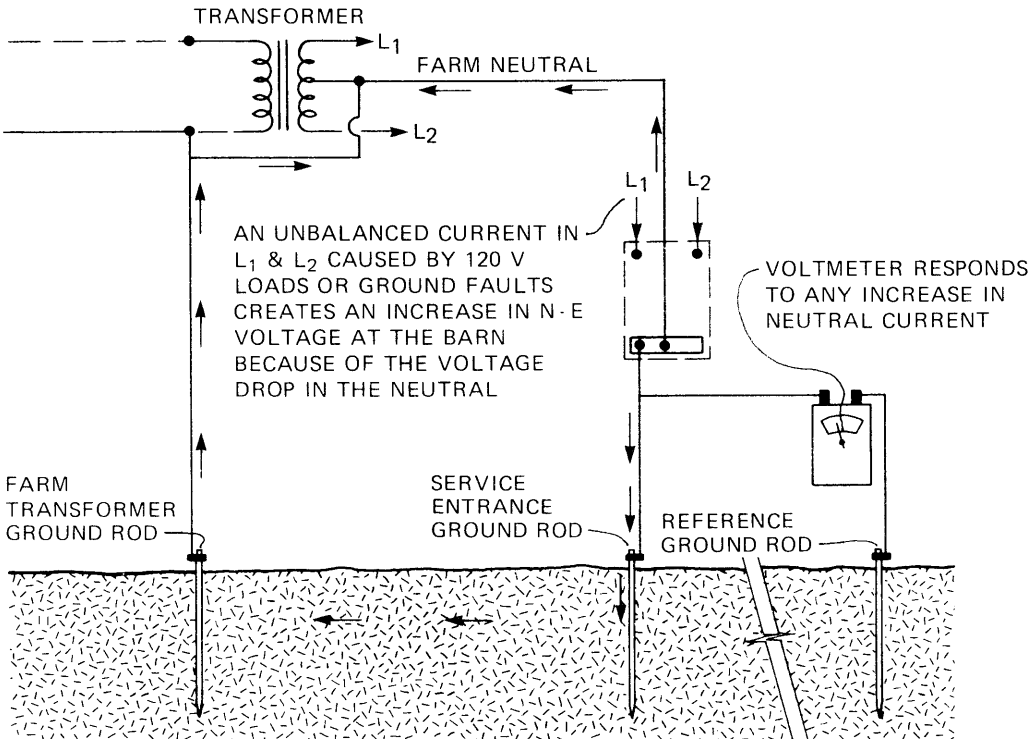


Figure 3 N-E voltages on the secondary neutral resulting from unbalanced 120 V loads

To check if the power supplier's system is responsible for N-E voltages, test at the time of day when you use most electricity or when you notice problems. If you find N-E voltage approaching or exceeding 5 V, try switching off all the main circuit breakers on the farm at the time the problem is greatest. If the N-E voltage persists, the farm's electrical load is probably not the major cause. In any event, contact your power supplier for advice.

Most power suppliers will cooperate in lowering N-E voltage if the cause is off-farm or created solely by normal no-fault loads on the farm. Most will check the primary line for an imbalance, inadequate neutral conductors, imperfect grounding and high-resistance neutral splices.

If stray voltages persist, the power supplier may be prepared to temporarily separate the primary and secondary neutrals at the farm transformer (but only after an alternate neutral grounding and lightning surge system has been installed?. This is the ultimate test of off-farm influence; if it solves the problem consider installing permanent control devices acceptable to the supplier.

However, most suppliers will not permanently separate neutrals, both for safety and because the farm grounding system no longer helps lower the N-E voltage on their primary lines.

STRAY VOLTAGE CONTROL

No one solution works for all stray voltage situations. N-E voltage and resultant stray voltage are easily explained but their movement and interaction can be very complex.

However, to help eliminate possible problems, make every effort to ensure that:

- good grounding is maintained at the transformer and at each electrical service;
- all metal in animal buildings is bonded to the service ground - but only at the service entrance;
- neutral conductors are not interconnected with or used as ground conductors for electrically operated equipment;
- all defective electrical equipment and wiring is replaced to eliminate small ground faults that may not be large enough to blow fuses or trip breakers;
- all electrical equipment is approved by the Canadian Standards Association;
- 120 V loads on both legs of any service are balanced to minimize neutral current; and
- electric motors and other big loads are operated on 240 V whenever possible to minimize neutral current and, especially, high-amperage starting currents.

This list is only a guide and should not be considered as complete or comprehensive.

EQUIPOTENTIAL GRIDS

A bird perched on a high-voltage conductor is safe as long as it does not move one foot across the insulator to the pole, thereby touching two surfaces of different voltage.

Equipotential grids give animals the same protection; they equalize the voltage of all conductive objects an animal may touch at one time. Install properly grounded grids in wet, high-risk areas of animal housing. In new installations, the added cost can be relatively small.

Figures 4 and 5 show equipotential grids in a milking parlor and around an electrically heated waterer. Note the driven rods in Figure 5. These create a "gradient ramp", which reduces shocks by gradually changing the potential of the surrounding ground as the animals walk onto the grid area. Install these where animals enter and exit areas equipped with equipotential grids. Without them, the animals may feel a change in potential and jump onto or off of the grid, risking injury.

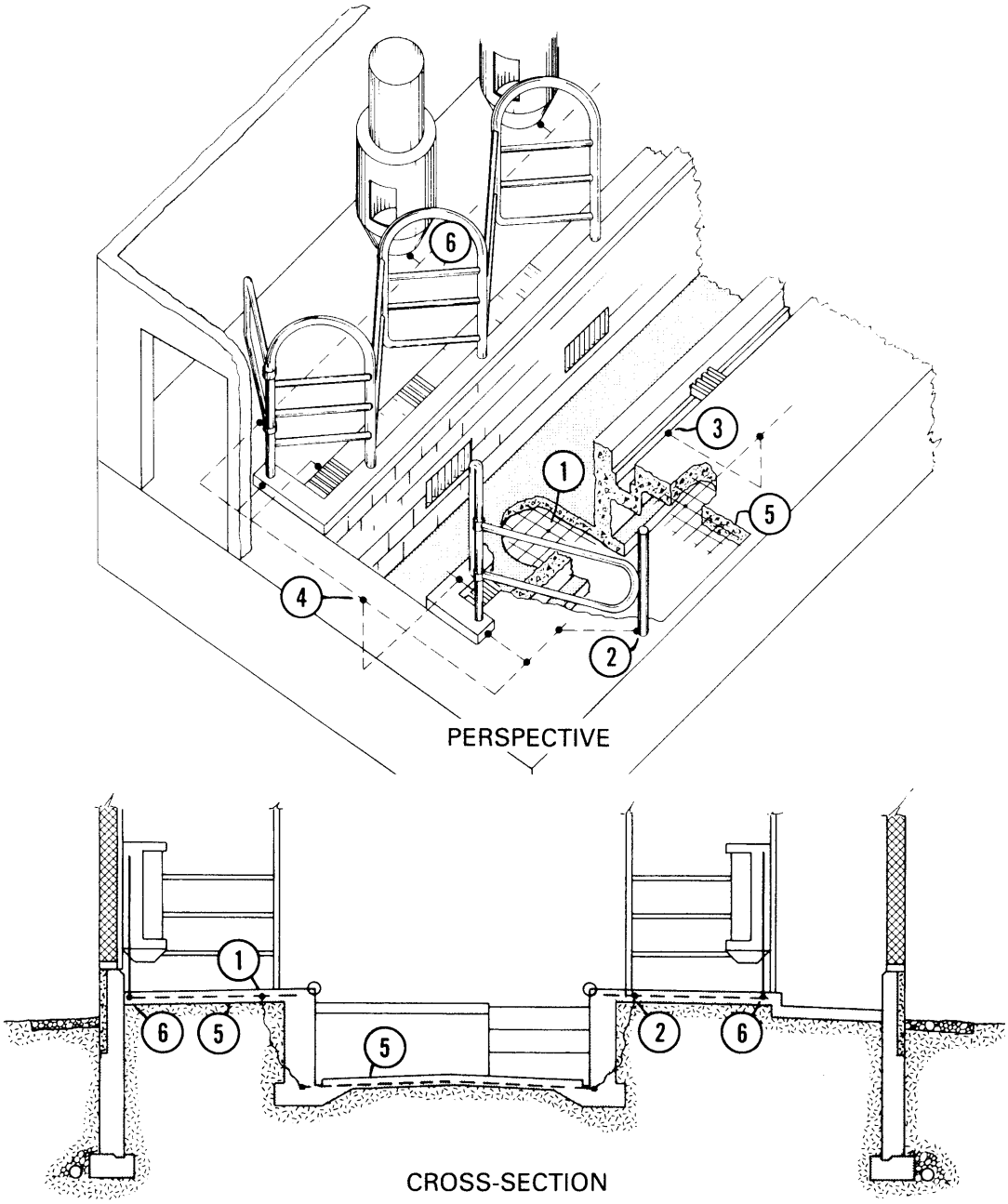
CONTROL DEVICES

Before buying or installing any of the following devices, get the approval of your power supplier and/or inspection authority. Have an experienced electrician or manufacturer's representative install and performance-test the equipment.

ISOLATION TRANSFORMERS Dry-type isolation transformers have been used for years in hospitals and occasionally in dairy barns. They separate the farm and barn neutrals, thus eliminating direct transfer of N-E voltage. As they must carry the total kilowatt capacity of the load, they tend to be expensive ($1000-2000) and are not expandable if the building's electrical load increases. To be effective, any grounding of other services to the building (metal water pipes, telephone lines, etc.) must be interrupted so it can't impose voltage on the barn grounding system.

NEUTRAL SEPARATORS At present, two devices are available; one is a saturable reactor, the other an electronic switch. Both contain lightning surge arrestors. When wired between the incoming and farm neutrals at the farm transformer, a separator blocks low-voltage currents, but conducts like a closed switch when the voltage reaches 10-12 V. It needs a separate ground rod for the farm neutral, at the farm's transformer pole.

Neutral separators can prevent incoming N-E voltage from influencing on-farm N-E voltage (unless there's a ground fault); they cannot control N-E voltages created on the farm. These devices are relatively inexpensive - about $500 installed.



1 Bond copper ground wire to wire mesh in concrete floor at 3 m intervals maximum.
2 Bond all steel posts, gate posts, support posts, feeder brackets, etc. to copper ground conductor (weld a 100 mm length of rod to posts at least 50 mm below concrete surface to facilitate connection).
3 Bond steel-angle grate supports for floor drains at both ends of parlor and at both sides of grate.
4 Connect copper ground loop in pit floor and return alley (if adjacent) to ground loop in cow platform floor at no less than six locations or at 3 m intervals.
5 Make concrete cover and underlay for wire mesh both 50 mm thick, to minimize corrosion.
6 Weld one end of steel rod to feeder, and either weld or clamp other end to mesh and bonding connector; install two rods per side of parlor if all feeders are interconnected by metal components.
7 Install gradient ramps where cows enter or exit; drive 2.4-3 m rods 300 mm apart, and angled 45° toward holding area. Weld rods to mesh.

Figure 4 Equipotential grid system in a milking parlor

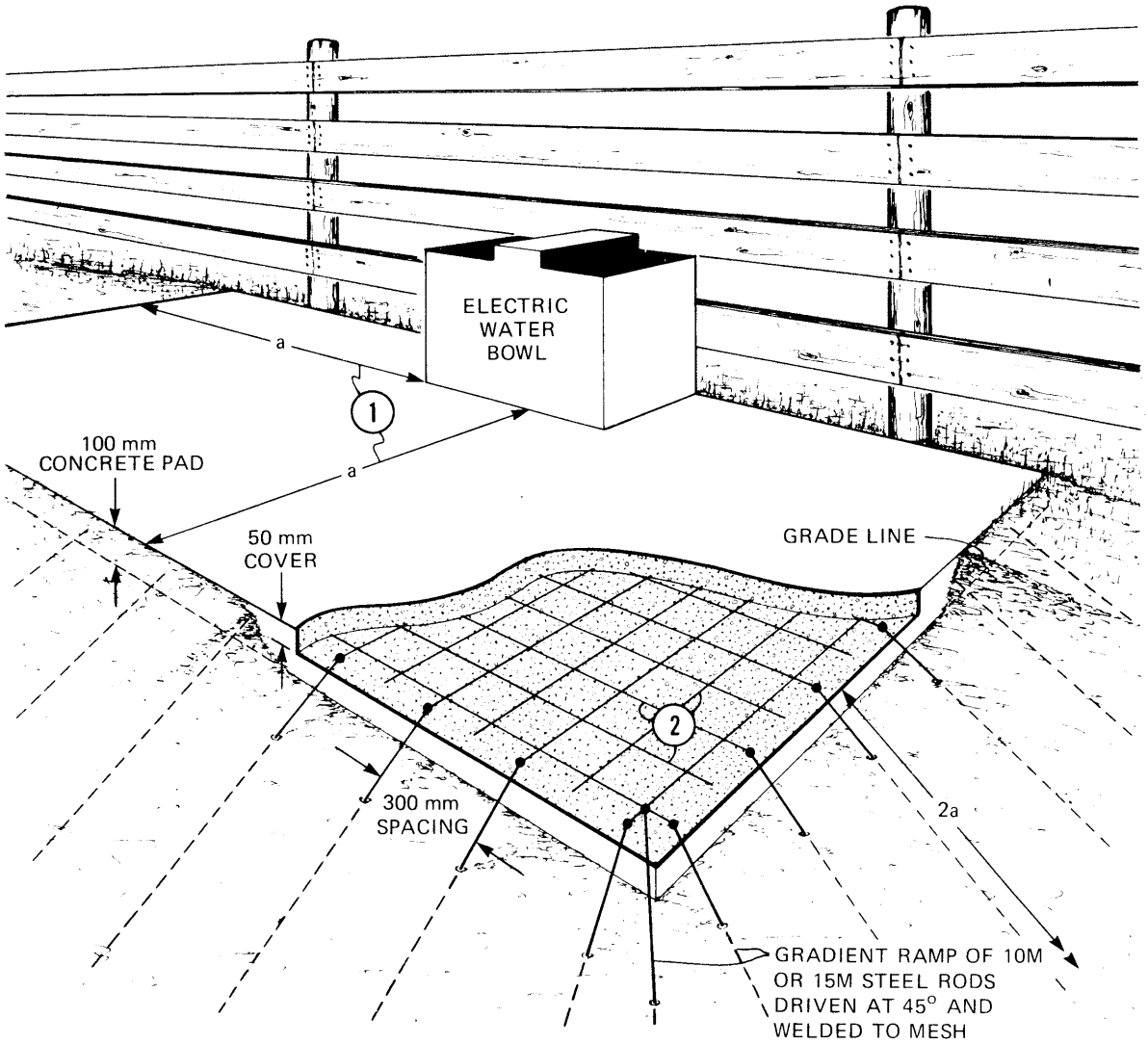
NEUTRAL GROUND SEPARATOR The only type now available (Hammond Mfg. Co. Ltd.) is a saturable reactor with a built-in lightning surge arrestor. It is wired between the barn's neutral and the ground rod at the animal building service. Saturable reactors act like a switch; they block low-voltage currents but conduct if they go above 10-12 V. In this manner, the separator permits N-E voltage at the barn service to rise without causing stray currents in the barn grounding system. As with isolation transformers, all grounding of other services to the building must be interrupted.

In the event of a powerful ground fault voltage, the separator conducts current to prevent lethal shocks. Since this form of separation may be bypassed by future wiring or faults to ground, a monitoring device (available commercially) is recommended. The separator is relatively inexpensive - about $500 installed.

ACTIVE SUPPRESSION DEVICES One system is now available and another is being developed. Suppression requires an active device such as a differential amplifier working with a remote grounding system. The amplifier monitors N-E voltage at the barn service entrance using a reference ground. It then redirects current caused by N-E voltage from the service ground to the remote grounding system.

The major advantages are that neutrals need not be separated and the system can compensate for N-E voltage from any source (e.g., starting surges from motors within the building).

Disadvantages are that the system consumes some electrical power and is relatively expensive - about $8000-10 000.



(1) Dimension "a" equals distance between animals' front and rear feet.

(2) Weld mesh sections (152 × 152 MW18.7 × MW18.7 steel) together and bond to electrical service ground block with #6 AWG stranded copper.

Figure 5 Equipotential grid with gradient ramp around an electrically heated waterer

SUMMARY

Greater use of electricity in rural Canada has increased the load on power distribution systems. The higher this load, the higher the neutral current that must flow; some voltage potential must exist to return the neutral current to the initiating transformer.

When the neutral system is grounded to control N-E potential, some current must flow to ground. With less-than-perfect grounding, this current gives rise to stray voltages.

Cows can feel currents of 2-4 mA, corresponding to about 0.5 V; other animals may suffer discomfort from even lower currents.

While electrical bonding of all metal equipment in animal housing will likely spread the influence of stray voltage, the Canadian Electrical Code requires it. Otherwise, ground faults could create voltages lethal to animals and humans.

Power suppliers will usually cooperate in lowering N-E voltages if the cause is off-farm or created solely by normal no-fault loads on the farm. However, most will not solve the problem by permanently separating primary from secondary neutrals.

Remember that no single solution solves all stray voltage problems and that the animals' reactions may also stem from other causes. So before investing in control equipment, have the farm's entire electrical system tested by a qualified specialist. Repair or replace faulty wiring or equipment. Balance 120 V loads or rewire them to 240 V (which produces no secondary neutral currents).

Consider installing gradient ramps in all high-risk areas of new animal buildings; the cost increase over that of ordinary bonding can be relatively small.

When necessary (or for added protection), buy control devices that install on existing electrical systems. However, first get the approval of your power supplier and/or inspection authority.