Stray voltage

1. Introduction

Stray voltage is defined and described as "a small voltage, less than 10 volts (V), that can be measured between two possible contact points. A current will flow if these points are contacted by an animal or person. The amount of current through an animal depends on the contact voltage and the circuit impedance. The circuit impedance includes the source, contact and body impedances. Animals or persons respond to the resulting current flow and not to the applied voltage."

This definition illustrates several key points:

- Stray voltage is generally measured as a voltage but it is the **current flow that can be sensed by the animal**.
- Stray voltage that may be causing problems **can be measured between two possible cow contact points**. Cow contact points are any point on a cow that comes into contact with a conductive surface, eg. hooves, mouth, rump or nose.
- **Source, contact and body impedances** all affect the level of current that can flow through an animal as the result of coming into contact with a stray voltage.
- The fact that impedance is used in the definition, rather than electrical resistance, implies that stray voltage currents can also have an associated **pulse duration and/or frequency**.

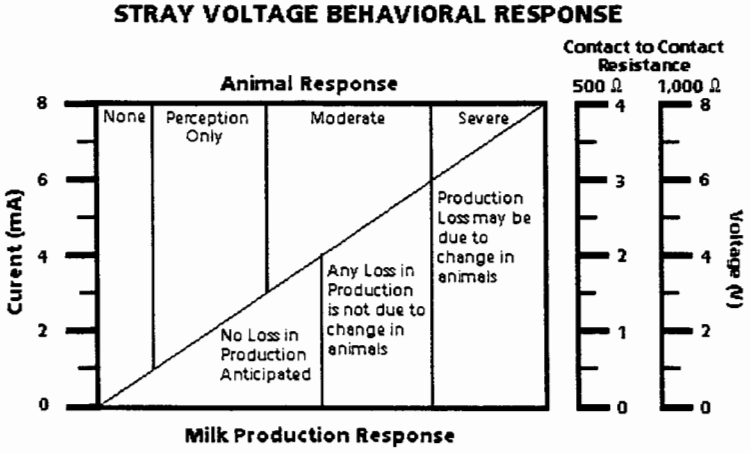
Thus, stray voltage is a very mild electric shock. If you can feel a mild tingling (through a cut or scratch on your hands, for example, or if your tongue or lips touch against a metal fitting in or around the farm dairy), it is possible that the dairy herd may be experiencing a similar sensation.

2. Interpretation and relevance to Australian conditions

Stray voltage can come from on-farm as well as off-farm sources. Electricity is supplied to most Australian dairy farms via 415V 3-phase, 480V 2-phase, or 240V SWER (Single Wire Earth Return) power distribution systems. Stray voltage can occur with each of these distribution systems. The Multiple Earthed Neutral (MEN) system used in Australia may result in a lower incidence of stray voltage problem herds in Australia compared with the USA and on-farm sources of stray voltage are likely to be more common than off-farm sources in this country.

Although the percentage of Australian dairy farms with a stray voltage problem is likely to be very low, the effects can be severe. Controlled research in NZ, and later in the USA, has indicated that stray voltage can be a problem if voltage levels are high enough and cows are able to contact this voltage. Threshold levels for behavioural and milk production responses of the most sensitive dairy cows to an increasing level of electrical current are illustrated in the diagram below. Voltages (right vertical axis) were estimated for a "worst-case" impedance of 500 ohms for an average cow and a more realistic impedance of 1000 ohms. The Public Service Commission of Wisconsin, USA, has identified a level of 1 volt measured across a 500 ohm resistor as a level above which action should be taken. This conservative guideline appears to have been effective in mitigating the adverse effects of voltage and current on dairy cows in Wisconsin dairy herds.

Figure:
The affect that stray voltage has on dairy cows.



3. Relationship to CowTime goals

Stray voltage can make cows more reluctant to enter the farm dairy and can induce more frequent dunging and urination in the holding yards or during milking. Milk production may be reduced if avoidance behaviours are severe. A real or even a perceived problem of stray voltage can make cow handling unpleasant and stressful for the herd owner or manager. Therefore, if stray voltage is suspected it should be investigated carefully and methodically.

4. Features of stray voltage

Common sources

On-farm sources of stray voltage include:

- Poor grounding (high resistance) at the electrical sub board.
- Incorrect cable sizing especially on high current usage devices such as larger electric motors.
- Insulation breakdown on wiring due to ageing or wear.
- Loose connections and corroded wires.
- Electrical faults, especially in equipment that is installed under unfavourable conditions such as submersible pumps and underground wires.
- Inadequate electric fence grounding and poor electric fence conductor installation can result in fencer pulses appearing in unintended locations.

Getting a diagnosis

If you think you might be dealing with a stray voltage problem then:

- Take the time to observe the cows. The behavioural responses of the herd can be a very good indicator as to the source of the voltage, eg. cows stepping or fidgeting at the instant when an electric motor is switched on.

- Ensure the right equipment and procedures are used to measure voltage and find the source.

Consider other possible reasons for poor behaviour or low milk production, recognising that:

- stray voltage can be a problem;
- if it is there, it can be measured; and
- stray voltage is not always the problem.

Procedures for stray voltage testing

A combination of two basic measurement methods, 'cow contact point-to-point' and 'point-to-ground', is preferred when trouble-shooting for stray voltage problems. Cow contact point measurements are the only reliable way to assess exposure levels while point-to-ground measurements provide diagnostic value.

Cow contact point-to-point

Measurements are made with a suitable voltmeter between any two points that a cow could contact simultaneously, such as the entry race and cow platform of a rotary dairy. A 500 ohm resistor must be connected in parallel across the voltmeter probes to simulate the impedance of the cow. A disadvantage of this method is that poor contact resistance and condition of the floor may cause variable readings.

Point-to-reference

A 1.25m ground rod and 10-20m length of 1.5mm^2 multi-strand copper connecting wire is used to establish a reference point. The ground rod is driven into the soil at least 7.5m away from anything that may be connected to the electrical grounding system (eg, underground water pipes) Measurements are made between the ground rod and selected cow contact points. This is a good method for tracking down the source(s) of any stray voltage. A 500 ohm resistor cannot be used to determine current flow with this method because the resistance of the grounding rod interferes with the readings.

Connection points

Connections to clean metal surfaces can be made with an electrical clip or clamp. Connections to a concrete floor can be made with a 1.2 or 1.6mm sheet metal plate (100 x 100mm square of stainless steel or copper with a 6mm bolt welded on with nuts to allow a terminal wire to be attached tightly). The plate can be placed directly on the floor if the surface is wet with manure or urine. If the floor is dry, a saline solution (1 cup of salt dissolved in 4 L of water) should be poured on the floor and the plate placed on several layers of wet paper towels.

Equipment for stray voltage testing

Voltmeters

A suitable voltmeter must:

- be capable of distinguishing between alternating current (ac) and direct current (dc);
- have an impedance of at least 5000 ohms per volt; and
- have a voltage resolution of at least 0.1V.

Digital voltmeters are easy to read, have good resolution and an impedance of 10,000 ohms or more. Some models are able to capture and store transient voltage spikes (eg, Fluke 87). Analogue meters tend to have poor

resolution at the lower voltage scales. Perhaps the best equipment to use is a good portable oscilloscope (such as a Fluke) with data capture and storage capability. On problem farms in the USA, a recording of voltages at suspected contact points over a continuous period of 1-7 days is recommended because stray voltage tends to vary over time.

5. Potential challenges with implementation

Stray voltage investigations

Competent stray voltage investigations can be costly and this should be discussed and agreed with the farmer before any work is undertaken. It is not uncommon to spend 4-8 hours on an initial investigation which does not include any costs involved in rectifying the stray voltage problem if one is found.

Competent stray voltage investigations require a considerable level of skill and electrical knowledge so don't be afraid to enlist help if required. This is not to say that stray voltage detection and correction is a "Black Art" known only to a select few. Perhaps 99% of stray voltage problems can be detected with simple tools used properly and often they can be corrected easily. Avoid trying to implement quick fixes without knowing the source of the problem because this only leads to added expense and frustration when the problem is not solved. If you can't fully identify the source of the stray voltage then you have not finished the investigation.

Use the correct testing equipment. A digital auto-ranging voltmeter with a high internal impedance or a portable oscilloscope is preferred. A portable oscilloscope is especially useful for picking up transient spikes (from an electric fence, for example) that are missed with a digital meter or because inexperienced electricians might not see the slight flick of an analogue needle.

Make sure a resistor was used with suitable resistance. A 500 ohm resistor connected in parallel will load the circuit and give a fair indication of the voltage to which a cow may be exposed. Point-to-point measurements made without a 500-1000 ohm resistor are flawed.

Make sure good contact with concrete floors was achieved. See advice in the previous section.

Test suspect areas at different times. Places that cows appear to avoid should be tested as well as any areas in the farm dairy where cows seem nervous.

Effects of pulse duration or frequency

As the stray voltage frequency increases or phase duration decreases so does the level of current required to induce a response. For example the peak current produced by a typical electric fence pulse (10 - 100uS pulse duration) required to induce a response in a cow would be 80mA or greater which converts to a worst case voltage of 40V peak. Tests done on cows using higher frequency single and multiple cycle signals show that the strength frequency relationships agree well with the large body of research on human sensitivities to high frequency voltage.

Uncommon sources of stray voltage

A common misconception is that the small voltages generated by the sensors of electronic milk flow monitors (such as those used in electronic cup removers) can be conducted down the long milk tube during milking, thereby causing a shock to the cow through her teats. This is simply not true. Tests conducted at the University of Wisconsin demonstrated that the sensing voltage, on one of the metal probes of an electronic milk flow sensor at one end of a long milk tube, had to be raised to more than 1000V to induce a cow response. Most electronic sensors use sensing voltages well below 10V.

Similar studies have shown that rubber or plastic milk tubes have very high impedance (in excess of 15,000 ohms per meter), even at peak milk flow rates. Using this value, it is easy to see that a voltage of 15V or more (measured with a 500 ohm load) must be present between the milkline and another cow contact point during milking for a small percentage of cows in the herd to even sense a problem. Given that the milkline is usually mounted using metal brackets connected to the steel work of the parlour, a voltage of 15V would be causing other electrical problems (eg. tripping circuit breakers) that would be noticed before cow behavioural changes.

If you experience a painful personal shock when a metal object is touched, you are <u>not</u> feeling stray voltage. Such shocks usually indicate a dangerous situation involving defective wiring or equipment. They should be reported to, and corrected by, a competent electrician immediately.

High voltage power lines have been a contentious issue in recent times with respect to long term exposure of humans to electromagnetic fields. The same sort of questions can be raised about the exposure of cows to such fields but, to date, no research has been able to demonstrate any links nor can any stray voltage effects due to induced currents be detected using techniques and guidelines outlined in this summary.

Ground currents (the currents that flow through the ground on their return to the power station to complete the circuit in SWER systems for example) are another source of confusion in the stray voltage debate. As described

previously, if a voltage of 0.5V can be measured between two possible cow contact points using a 500 ohm resistor to simulate body and contact resistance then, and only then, there is a problem that requires attention.

6. Robustness of this information

This Quick Note is based on an excellent practical paper by Southwick (1995) from Cornell University (available from AMMTA as publication Number 2/95) together with additional, more recent information from Reinemann (1997 & 2002) at the University of Wisconsin. Advice from D. Chapman of Westfalia, Australia is also acknowledged.

7. References and further reading

Albright, J.L. & Arave, C.W. (1997) The Behaviour of Cattle. CAB International, Oxon, UK.

Brightling P. et al (2000) Countdown Downunder : Technotes for mastitis control; Technote 6.1 (assessment of cow behaviour at milking). Dairy Research and Development Corporation. 3/84 William St. Melbourne 3000.

Southwick, L.H. (1995) Testing for Stray Voltage - was it done properly? Proceedings, 34th Annual Meeting of the US National Mastitis Council, Texas, USA, pages 89-99.

Reinemann, D.J. et al. (1997) Stray Voltage Update 97. UW website: www.uwex.edu/uwmril

Reinemann, D.J. (2002) What do we know about Stray Voltage? www.uwex.edu/uwmril

Information on research conducted at other universities and useful publications to help detect stray voltage is available at the following web sites:

www.uwex.edu/uwmril
www.mrec.org

CowTime Guidelines for milk harvesting - Chapter 2, 4 & 5. edited by Klindworth, D. et al (2003). Available on the CowTime website www.cowtime.com.au

Quick Note 1.1: Cow behaviour and milk let-down

Quick Note 1.2: Cow handling – interactions between people and cows

Quick Note 1.3: Key factors to ensure a calm, consistent milking routine