Report of the

Ground Current Working Group

to the Utility Advisory Council

September 20, 2007

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1) Ground Current Pollution

For a variety of reasons, electric current flowing through the ground is a common occurrence in the vicinity of modern electricity distribution systems. Utility electrical distribution systems in Ontario include a multi-grounded neutral meaning the system neutral is grounded periodically via ground rods connected to the system neutral at key locations along power distribution feeders. The system neutral is grounded for safety reasons among others. Grounding the neutral limits the voltage that can exist on the system neutral, and allows protection systems to operate quickly in the event of a ground fault.

Normal system operation includes neutral return current that flows back to the source via the neutral and ground paths. Therefore, some current can be found on most utility grounding installations.

Sources of ground currents outside the utility power distribution system include: ground faults or partial ground faults associated with customer owned equipment or improperly wired installations, communication utility ground faults, gas line cathodic protection systems, natural ground current flow, or ground faults from other areas in the power distribution system including other customers.

When ground current produces stray voltages that are discernible by humans or livestock, the phenomenon has been described as "ground current pollution" or "tingle voltage". Some utilities in Ontario, particularly Hydro One have been dealing with stray voltages associated with ground current pollution for many years. Processes exist to assess the problem and mitigating measures can be taken to address issues in existing installations.

Many other Local Distribution Companies (LDCs) in Ontario, particularly those with relatively few farm customers, have little experience investigating or addressing tingle voltage complaints. Because of this, there is comparatively little expertise in this area within the LDC and some customers are left on their own to deal with problems possibly originating from the utility power distribution system.

For new installations, the latest Ontario Electrical Safety Code (OESC) provides grounding system requirements that prevent the occurrence of stray voltage for the most part. New equipment manufacturers also need to be cognizant of the fact that internal equipment wiring and operation can also produce stray voltages in power systems.

2) Working Group Background

The Utility Advisory Council (UAC) was established by the Electrical Safety Authority (ESA) to act as an advisory body making recommendations and providing industry feedback to the ESA during the implementation of Ontario Regulation 22/04 – Electrical Distribution System Safety.

Bill 143 - the Ground Current Pollution Act, 2006 - was a private members bill initiated due to concerns arising from the farm industry. The Act received second reading on October 19, 2006 and was then referred to the Standing Committee on Justice Policy. The intent of the Bill was:

a) To define objectionable current flow on ground rods, commonly known as stray voltage, and to prohibit electricity providers from causing occurrences of objectionable current flow.

b) To establish a time frame for electricity providers to respond to complaints about objectionable current flow, to require an investigation of complaints and, if an investigation shows that an electricity provider is responsible for an occurrence of objectionable current flow, to require the provider to remedy the problem in a timely manner.

c) To create an offence and penalty for failing to remedy the problem that gave rise to a complaint in a timely manner.

d) To provide that the Ministry of Government Services develop and implement a plan to eliminate objectionable current flow in Ontario.

As drafted, this Bill would have imposed requirements on LDCs and the Ministry of Government Services which would have been impossible to fulfill. The UAC therefore felt it necessary to create a working group to suggest changes to the Bill to make it more practical and useful. The UAC passed a motion on Wednesday, February 7, 2007 to form a working group to discuss the issues and concerns arising out of Bill 143 The Working Group was given the task of providing advice on overall direction and understanding regarding stray voltage and stray current issues in Ontario.

Members of the UAC working group include:

Owners/Operators: Mike Bell, Irv Klajman, Emilija Stupar, Erik Veneman (chair), Margaret De Fazio, Llyod Frank, Lynn Girty, William Schwarz, Paul Forster, Joan Pajunen, Michael Wittenmund, Wayne Corrigan, Arlen Molyneaux, and Brian McMillan.

Regulators: John Savage.

ESA: Martin Post, Jason Hrycyshyn, Aldo Mastrofrancesco, and Jeff Thomson.

The working group met four times over the past several months to come up with recommendations for the UAC to consider.

Before the Standing Committee on Justice Policy could begin its review of Bill 143, Parliament was dissolved, so the Bill will not become law. On June 22, 2007, the Minister of Energy announced he was referring the stray voltage issue to the OEB, in order to ensure measures to address the problem were implemented.

The OEB has now begun consultations on the issue and some members from the UAC working group are also on the OEB's Farm Stray Voltage Consultative Group. The OEB has suggested that these consultations may lead eventually to changes to the Distribution System Code to deal with this issue.

3) Terms of Reference

The UAC working group was to provide:

i. Definitions for terms such as "stray voltage" and "stray current".
ii. Results of Investigating previously documented ranges of what is "objectionable" and how that is measured including information from other jurisdictions.
iii. Identify the potential size of the problem in Ontario for example by identifying the number and types of farms potentially affected.
iv. Review of mitigating procedures to address stray voltage issues such as increasing neutral sizes, isolators, and additional grounding and bonding.

The working group has kept the UAC informed of its progress via presentations to the council at regular council meetings.

i. Definitions:

Stray Voltage – An unexpected voltage difference between two or more contact points

Tingle Voltage – A level of stray voltage that can be sensed by human or animal contact (also known as Contact Voltage)

Objectionable – Sensed is deemed objectionable

Neutral to Earth Voltage – Voltage measured between the earth and neutral conductor in either the customer's or utility's distribution system (OESC rule 75-414 states 10V maximum)

ii. Other Jurisdictions:

Research was done by working group members to see what other regions have in place for neutral voltage standards, guidelines, etc. Areas checked include other provinces and states where dairy farming operations prevail. Summary charts are provided outlining acceptable thresholds and limits. Tables have also been provided with more detailed information on who was contacted and what their processes involve - See Appendix 'A' of this report.

iii. Potential Size of Issue in Ontario

Statistics are available on the number of dairy and other farms in Ontario through organizations such as The Ontario Ministry of Agriculture, Food, and Rural Affairs. It is difficult, however, to determine how many complaints LDCs get per year related to stray voltage on dairy farms.

The Ground Current Working Group was not able to compile adequate information on this topic in time to be included in this report, however, through the OEB working group, the EDA has posted a survey to establish the number of dairy and other farms in the province and the number of complaints that LDCs receive to help assess the magnitude of the stray voltage issue. This item will be included in the OEB working group documentation.

iv. Mitigating Procedures

Appendices 'B' and 'C' provide recommended mitigating procedures for LDCs and customers respectively. Appendix 'D' provides more detailed information for customers and has been included for reference.

4) Recommendations

The UAC working group has agreed on the following recommendations to the UAC:

5.1 That the following be implemented as voltage limit guidelines, recognizing that specific limits may not be attainable in certain situations:

10 volts be adopted as a guideline limit for neutral to ground potential on utility power distribution systems. This is a steady state, RMS value measured on the utility distribution system between the verified system neutral and the local grounding system at the supply to the customer owned poleline or equipment.

In addition, if a livestock contact voltage limit is required, a 1 volt contact voltage limit guideline is adopted, measured at points within the customer's premises.

5.2 That a cost recovery mechanism be put in place for utilities dealing with complaints and working on electrical equipment downstream of the customer's ownership demarcation point.

5.3 That the final version of the draft document in Appendix 'B' - Stray Voltage Mitigation Distribution System Standard Test Procedure - be adopted as a guideline by all LDCs in Ontario. In addition and upon inquiries by customers, LDCs would provide customers with final versions of draft documents in Appendix 'C' to assist in their work in dealing with the issue.

5.4 That the UAC submit this report including the recommendations above to the OEB.

5.5 That, effective immediately, the UAC Ground Current Working Group holds no further meetings unless later advised otherwise by the UAC or the OEB.

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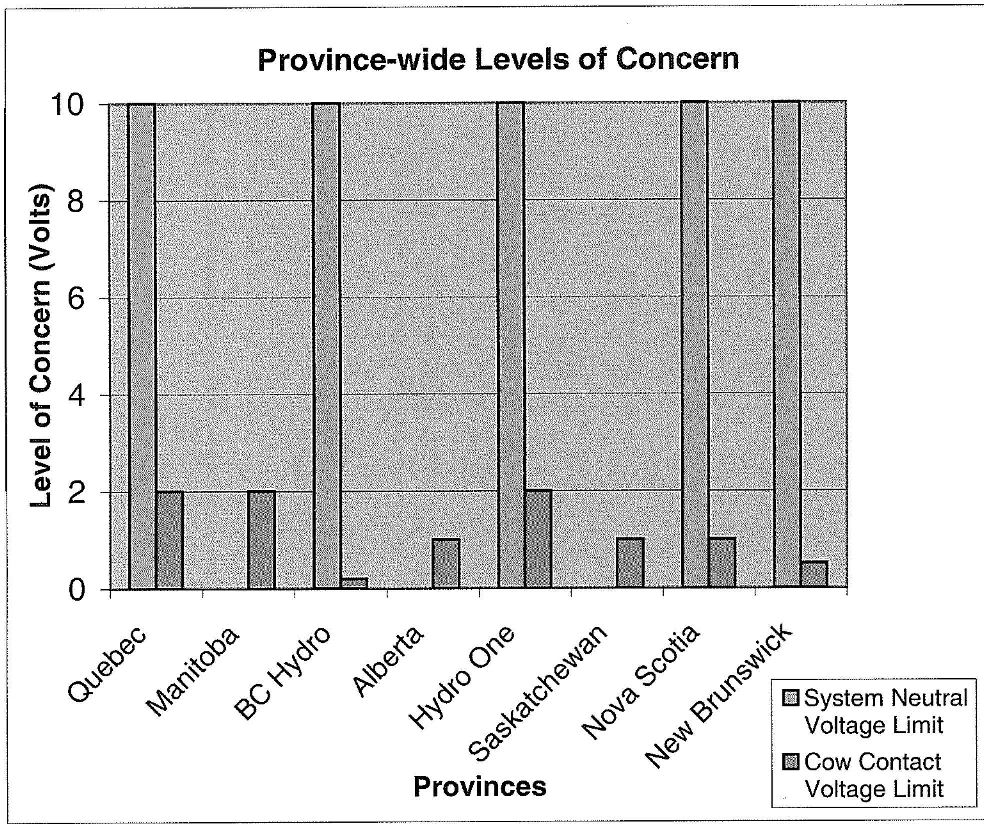
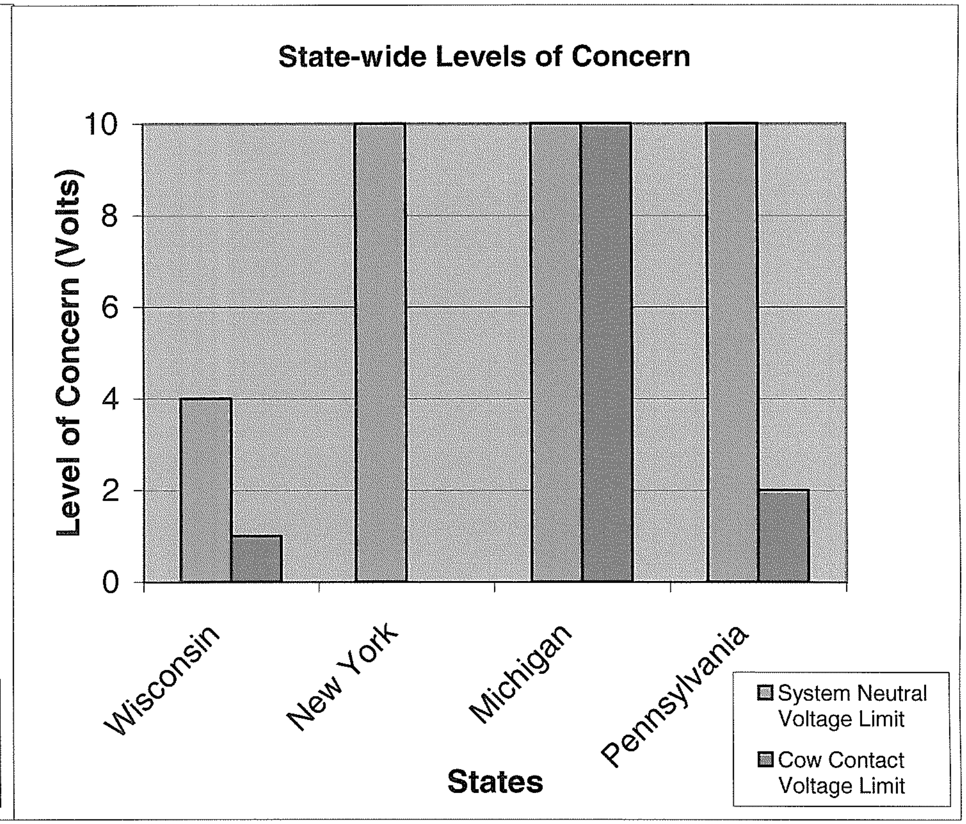
Appendix 'A'

- Other Jurisdictions

Stray Voltage Summary





***Note:**

i) Manitoba, Alberta, Saskatchewan specify a resistance limit, not voltage, on the System Neutral.
ii) Manitoba's limit is 25 ohms for single-rod and 5 ohms for multi-grounded neutrals.
iii) Alberta targets 6 ohms, or 10 ohms under winter conditions.
iv) Saskatchewan has a system neutral requirement of max 2 ohms for circuits with transformers > 25kVA, 10 ohm (will be revised to 6 as a result of latest issue of CSA C22.3 #1) for < 25kVA

**Cow Contact Voltage Limit represents a value recognized by each utility as objectionable.*
**Since this voltage is measured beyond the demarcation point, the utility typically works with the customer to reduce the voltage below the limit specified in the table.*

***Note:**

i) New York state does not specify a Cow Contact Voltage Limit.
ii) Wisconsin is the only state with a formal System Neutral Voltage Limit.
iii) Most other states use 10V as their System Neutral Voltage Limit.

For more detailed information, please refer to Table 1 and Table 2.

Province-by-province Levels of Concern for Stray Voltage

Province	Primary Contact	Standardized Test Procedure	Level of Concern		Mitigation
			System Neutral Voltage Limit	Cow Contact Voltage Limit	
Quebec	Ministry of Agriculture MAPAQ	Yes	5V target, with a 10V maximum	Not formally established – try to achieve 1V or 2V	Mitigation brochure on public website (in French only): http://www.hydroquebec.com/publications/fr/autres/pdf/tension_parasite.pdf
Saskatchewan	Marvin Ereth @ SaskPower: 306 566-3580	Yes	Requirement for maximum 2 ohm for circuits with transformers > 25kVA, 10 ohm (will be revised to 6 as a result of latest issue of CSA C22.3 #1) for < 25kVA	1 Volt is considered tolerable limit for cattle	Inspection and correction of any deficiencies in the grid at the transformer, installation or reinforcement of a ground grid at the barn, would consider a larger secondary neutral, standard mentions use of a filter, but not many have been used. There is no neutral return, just the primary (Earth return system).
Manitoba	Rob Kolt from Manitoba Hydro: 204-474-4149	Yes	Multi-grounded neutral resistance - 5 ohms (impedence is 25 ohms for a single rod)	2 V (unofficial target)	Whatever works to reduce stray voltage. Consider isolation, try to improve local system grounding, local grounding for farmer, or adjacent customer investigation. Have six Variable Threshold Neutral Isolators installed - have installed them free of charge for customer, still deciding who will maintain it.
BC Hydro	David Rogers: BC Hydro: 604-453-6477	No	10 V	0.2 V target	Isolation on request depending on level of voltage - install Dairyland Electrical Industries neutral isolator. Installed about 200 so far, and did not have any fail. Also have contractors working independently with their own isolators. Looked at 10 different ways of isolating, and this was the preferred method - works very well. Use a Variable Threshold Neutral Isolator which seperates Primary and Secondary Neutrals to ensure that the farm and the system neutral are always isolated.
Alberta	AltaLink: David Mildenberger 403-267-3458 Fortis: Wayne Parent 403-514-4224	Yes	No official limit for system neutral voltage. Requirement is system neutral resistance to remote earth. Target is 6 ohms (or 10 Ohms under winter conditions)	Have determined that 0.5 V - 1V may be a problem, and >1V is a problem.	Use Ronk Blocker (isolator). Information can be found in voltage manuals (soft copies are available).

Hydro One	Andre Perron: (705) 840-3039 Dale Williston: 613-323-5389	Yes	10 V	Do not have defined limit - generally considered problem between 1-2V; anything below should not be a problem	When a stray voltage inquiry is received, Hydro One measures the voltage and determines the source. If the source is On Farm, the customer's electrical contractor makes the necessary repairs or upgrades; if the source is Off Farm, and the Hydro One system is up to standard, NEV<10 V, isolating devices are used for existing barns to reduce stray voltage to an acceptable level (customer absorbs cost). A voltage of 1V or less between animal contact points is considered acceptable. 3 isolating devices used: Ronk Blocker (on transformer pole), Dairyland VT/NI (on transformer pole), and Hammond Filter (installed in barn service entrance). When the Hydro One system is not up standard, NEV>10 V, Hydro One will absorb the cost of an isolating device until upgrades are made to bring the system up to standard. We estimate there are 3500 isolating devices installed in Ontario and 3000 of those are Hammond Tingle Voltage Filters, installed primarily in the 80s & 90s. Hydro One is updating its test procedures and processes and plans to offer stray voltage training for electrical contractors in ON
Nova Scotia	Brad Fiander: 902 / 928-4400 extension 4455	No	10 V	Recommended 1V	No further information available.
New Brunswick	Don Anderson: 506-433-3188	No	No official limit, cannot specify a level but industry standard seems to be 10V	No official limit, aim for under 0.5 V	No further information available.

***Note:**
"Isolation" refers to the installation of a device that separates the utility's neutral from the customer's neutral.

Province/State	Primary Contact	Standardized Test Procedure	Level of Concern		Mitigation
			System Neutral Voltage Limit	Cow Contact Voltage Limit	
Wisconsin	Contractor - Mark A. Cook, 608-423-7151, mark.cook@psc.state.wi.us (REPS Program Manager)	Yes	No requirement on the neutral. Try to aim for 2-4 V; average neutral-to-earth voltage is 1.4 V based on measurements on the farm.	1 V	Isolation is optional. The protocol for mitigation comes from Public Service Commission. Who pays for the isolator depends on where the source of cow contact voltage is. If the utility is contributing over a certain level, it is required to provide an isolator temporarily, and then fix the Dx system within 90 days, and then remove the isolator. The farmer can choose to retain the isolator and pay ongoing cost of it. If the cause is determined to be the farmer's fault, there are farm re-wiring programs with low interest loans. Loans are granted by Utilities for the re-wiring program, and the utility inspects the work to ensure it is up to code.
New York	NY state Stray Voltage Committee	Yes	n/a*	No level specified	Isolation at 30V or less available on request.
Michigan	Michigan Dept of Agriculture Food & Dairy Inspectors	Yes	n/a*	2 V, 10 V-immediate action required	Isolation upon request.
Pennsylvania	Pennsylvania Dept of Agriculture	No	n/a*	0.5 to 2 V – depending on utility	Isolation upon request.
Vermont	Vermont Dept of Agriculture	Yes	n/a*	0.5 V	Isolation above the level of concern.

***Note:**

i) "The standards for the allowable operating neutral to earth voltage for most North American Utilities is 10 volts"
Source: "Tingle Voltage Guide" by Dr.Hill (a Professor at University of New Brunswick)

ii) U.S. NESC - Grounding Section - does not site any system neutral voltage limits

iii) "Isolation" refers to the installation of a device that separates the utility's neutral from the customer's neutral.

Appendix 'B'

- Stray Voltage Mitigation Distribution System Standard Test Procedure DRAFT (Hydro One)

Stray Voltage Mitigation

Distribution System

Standard Test Procedure

September 2007

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1.0 SCOPE

This document is the standard test procedure for resolving stray voltage, also known as tingle voltage, when the source of the problem is believed to be the primary distribution system. The objective of the procedure is to isolate any faults or deficiencies that result in the primary neutral-to-earth voltage exceeding the design limit. This procedure is to be performed by Local Distribution Companies (LDCs). The complementary test procedure for the secondary customer system is titled "Electrical Contractors Stray Voltage Test Procedure". That procedure is to be performed by the customer's electrical contractor and is designed to isolate any faults or deficiencies on the customer's system.

2.0 INTRODUCTION

Neutral-to-earth voltage (NEV) is the voltage measured between the primary distribution system neutral, or the customer's system neutral, and remote earth. Stray voltage is the voltage measured between contact points in a residence, commercial building or a building housing livestock. Stray voltage is typically 40-60% of the NEV. In Ontario, the utility is required to design and maintain their primary distribution system so that the NEV does not exceed 10 volts under normal operating conditions.

Small electrical potentials or voltages between any metal structure or equipment and floor surfaces, are natural, explainable and expected phenomena in buildings served by grounded neutral electrical systems. The voltage is developed as a result of current returning to the source through the grounded neutral conductors. The neutral conductors on both the primary distribution system and the secondary customer system are connected to earth through ground electrodes or rods. It is the flow of current through these connections to earth that generates NEV and stray voltage. Any metal structure in a building, water lines and case grounds on electrical equipment are all bonded back to the neutral of the system at the service entrance panel, for safety reasons. As a result of these bonds, all of the structure, etc., becomes an integral part of the return path of electrical current to the transformer from which it originates. A human coming in contact with this structure, for example a showerhead, may receive a mild shock which is uncomfortable although it is well below the level considered a hazard. Similarly, livestock which come in contact with stabling, water bowls, etc., can receive a shock, as they become part of this complex configuration of electrical pathways for current flow (see Figure 1).

The "threshold of perception" for humans is defined in terms of current. For the adult male, the literature suggests 1 mA. The adult female and children are more sensitive, 0.6 mA and 0.5 mA respectively. The "threshold of perception" should not be confused with hazard levels which are an order of magnitude higher. To translate the "threshold of perception" from levels of current into levels of voltage, it is necessary to consider the total resistance of the pathway from the electrical source, through the body and back to the source. Skin resistance is the largest component of the total body resistance. Skin resistance varies widely and depends on skin condition and the path through the human body. The most frequent complaints originate from individuals receiving shocks in the shower or in the area of swimming pools where the pathway through the body is from the hands to the feet. In these wet environments, a skin resistance as low as 10,000 is possible. At that body resistance, and a threshold of perception of 1 mA, the voltage that would be required to initiate a response would be 10 volts. Lower resistances are possible but only under abnormal skin conditions such as a cut where the flesh is exposed. **Experience has shown complaints involving humans originate from customer sites where the voltage between contact points exceeded 3 volts.**

The body resistance of livestock is substantially lower than humans. According to one study, the average body resistance of a dairy cow is 359 ohms from the mouth to the all-hooves pathway. It is 738 ohms from the front to rear hooves pathway. See reference /3/. For the purpose of testing, a value of 500 ohms has emerged as a standard in Canada and the US to simulate the body resistance of an animal when making stray voltage measurements. See section 5.0 below for instruction on making voltage measurements.

Earlier studies, which focused on defining the "sensitivity" of livestock, resulted in recommendations for corrective action at very low voltage levels. A further understanding of tolerance levels resulting from more recent trials indicates that there is little cause for concern in the 0.5–2 volt range commonly found between surfaces contacted by livestock. The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) are recommending a level of 1 volt as the safe exposure limit. The vast majority of research to date supports this limit. **In many cases, this level can only be achieved and maintained by the addition of mitigating devices installed on the customer's secondary system or at the supply transformer.** For additional information on the effects of stray voltage on livestock see the OMAFRA site, www.omafra.gov.on.ca/english/livestock/dairy/facts/strayvol.html.

3 0 NORMAL LEVELS OF NEV AND SYSTEM DESIGN

Levels of NEV on the primary distribution system are directly proportional to neutral current. On single phase lines, this translates into being directly proportional to line loading. On three phase lines, it is the degree of unbalance that determines the neutral current and hence the NEV. The level of current to supply a specific load is inversely proportional to voltage level. For example, a 100 kVA single phase load supplied at 4.8 kV will draw 22.3 A. The same load supplied at 16 kV will draw 6.25 A. If all other parameters were equal, converting the customer to 16 kV would reduce the NEV to 27 % of the value measured on the 4.8 kV supply. Other factors that determine the level of NEV are the impedance of the neutral conductor and the number and resistance of the ground rods. The impedance of the neutral conductor is related to size and condition. The resistance of a ground rod depends on the type and condition of the soil where it resides. Wet soil will have a lower resistance than dry soil; rocky soil will have a higher resistance than clay or loam. Because of all the variables, the only way to determine what the normal level for NEV at a particular point on the system is through a series of tests. **The NEV design limit is 10 volts. This limit is established by the Electrical Safety Authority. See reference /8/, Rule 75-414. However, on most lines the NEV peaks at less than 5 volts. Any NEV over 5 volts requires additional investigation in a timely manner. In this way, any necessary improvements can be made before the 10 volt limit is exceeded**.

4.0 TEST EQUIPMENT REQUIREMENTS

The following test equipment is required:

- 2 x True RMS responding voltmeter, the Fluke 187 multi-meter or equivalent.

- 2 x 10 Kilo-ohm resistors, 2 watts, ≥5% accuracy. Each resistor must be mounted on a dual banana plug such as a HH Smith 1676 or equivalent. This is referred to as a bridging resistor in the procedure and is used when taking neutral-to-earth voltage measurements.

- 1 x Stainless Steel portable ground rod. The rod must be at least 1 M in length and 1.5 cm in diameter. It should be sharpened at one end to ease the insertion into the earth. The 0.5 M point from the sharpened point should be marked. The rod should be equipped with an appropriate terminal that permits connection to it via an alligator clip.

- 2 rolls of insulated #18 stranded wire, 50 M in length. One end should be equipped with an alligator clip of suitable size to connect to the ground rod. The other end should be equipped with a banana plug to connect to the multimeter.

- True RMS responding Clip-On Ammeter with switch stick attachment. Scale should be 0-10 A AC and 0-100 A AC **(Model to be determined.)**

- Digital Earth Test Clamp, Megger Model DET10C or equivalent.

- Candura Power Pro

- Electronic Recording Voltmeters (ERV) with a scale of 0-10 VAC and 0-30 VAC. **(Model to be determined.)**

- Pocket calculator.

5.0 TEST MEASUREMENTS

Throughout this procedure, the following measurements are required:

5.1 NEUTRAL-TO-EARTH VOLTAGE (NEV) MEASUREMENTS.

Refer to the Flukel manual for instruction on the use of the multi-meter to measure voltage. Connect one lead of the voltmeter to the ground wire that connects the neutral to the ground rod at the service entrance serving the problem area. Insert a portable ground rod 0.5 M into the earth 15 M from the ground rod under test. This becomes the remote ground reference point. Using the #18 test lead wire to extend the second voltmeter lead, connect it to the portable ground rod. Install a 10 K resistor across the input of the meter. Note the reading. Install a second 10 K across the input of the meter. The reading should not decrease by more than 10%. A reading of more than 10% indicates that the portable ground rod is a high resistance. Move the rod to another location to reduce the resistance. When a good connection to earth has been established, remove the second 10 K resistor from the meter. Read and record the NEV. When performing NEV measurements at a substation, the remote reference ground rod should be placed a distance of 100 M from the station fence. To install the Candura Power as a recording voltmeter to measure NEV, see section 5.3 below.

5.2 STRAY VOLTAGE (SV) MEASUREMENTS

Refer to the Flukel manual for instruction on the use of the multi-meter to measure voltage. To measure SV for humans, insert a 10,000 ohm bridging resistor across the input of the multi-meter. To measure SV for animals, use a 500 ohm bridging resistor. Connect one lead of the multi-meter to one contact point. This could be a shower head for a complaint involving humans, or a water bowl for a complaint involving livestock. Connect the second lead of the meter to the floor contact plate placed where the human or animal would stand. Move the plate around the site to obtain the highest reading and record. Measure the NEV again and calculate the ratio between the stray voltage and NEV. These two readings should be taken simultaneously to achieve maximum accuracy which requires two multi-meters. The stray voltage should always be less than the NEV. If it is not, this is an indication of a secondary ground fault. To install the Candura Power as a recording voltmeter to measure SV, see section 5.3 below.

5.3 RECORDING VOLTMETER (RVM) MEASUREMENTS

At the customer's premises, the Candura Power Pro is used to obtain a 72 hour record of both the primary and secondary neutral voltage and the secondary current. Currents are setup as per the diagram on the cover to measure both line currents and neutral current assuming a standard 120/240 volt service.

1. Channel 1 voltage (red) setup as per the diagram. This supplies power to the unit and measures the line-to-neutral voltage.

2. Drive a remote ground rod 15 M from any service ground. All other voltage measurements are to this remote ground.

3. Channel 2 voltage (yellow), connect the input lead to the primary neutral at the transformer pole and the common to remote ground.

4. Channel 3 voltage (blue), connect the input lead to the secondary neutral at the service panel and the common to remote ground.

5. The neutral channel (white) may be used to measure voltage between contact points. For example, connect the channel between a shower head and the floor for a complaint involving shocks in the shower. For installations where a Hammond Tingle Voltage Filter is installed, connect the input lead to the ground at the service panel and the common to remote ground.

6. Set the trigger levels to the minimum, 1.2 V, on voltage channels 2 and 3 to obtain a waveform capture. The neutral channel does not have a waveform capture trigger.

7. Set the recording period to obtain the desired record length. This should be 72 hours minimum.

5.4 MEASURE GROUND ROD & NEUTRAL RESISTANCE.

Refer to the Megger DET10C manual for instructions.

5.5 MEASURE GROUND ROD CURRENT.

Refer to the Megger DET10C manual for instructions.

5.6 MEASURE PRIMARY PHASE AND NEUTRAL CURRENT.

Refer to the XXXX manual for instructions. If the current is too low, it may be necessary to use the DET1OC or a current clamp with a multi-meter.

6.0 TEST PROCEDURE

All test results are to be recorded on the Excel spreadsheet forms in Appendix 1. They can be recorded on a paper copy in the field and transferred to the electronic copy in the office. Both the original and a printout of the electronic copy should be retained in the job file. The electronic copy should be filed locally for future reference and forwarded to the Distribution Planner.

6.1 INFORMATION VERIFICATION & VISUAL INSPECTION

When the complaint is received, review all the information provided by the Distribution Operations Management Centre (DOMC). Verify that this is a stray voltage problem and make arrangements with the customer for a site visit. Obtain any additional relevant information from the customer not contained in the information provided by the DOMC. While enroute to the site, perform a visual inspection of the distribution system for signs of problems. Note the size of the neutral conductor. Look for broken neutrals, the location and condition of splices, especially McIntyre splices which have a high failure rate, and broken neutral-to-ground rod connections. The inspection should be carried out for a 5 km radius from the site of the complaint.

Upon arrival at the site of the complaint, perform a visual inspection of the property and all the services. Look for signs of damaged or defective wiring and the general condition of the electrical service and equipment. Inquire about any recent wiring changes or equipment changes that could impact on the level of SV.

6.2 INITIAL NEV & SV MEASUREMENTS

6.2.1 Measure the NEV at the service entrance with the problem.

6.2.2 Measure the SV in the problem area.

6.2.3 Calculate SV /NEV ratio.

6.2.4 Install a recording voltmeter (RVM) to measure the NEV. The RVM should be located indoors at the service entrance in the building with the SV problem in an area where it is secure and will not interfere with the customer's normal activities. The RVM may also record the stray voltage directly if it is practical to place test leads in the problem area. The RVM should be left on for a period of 72 hours minimum to ensure all load cycles on both the primary and secondary systems are recorded.

6.3 INTERPRETATION OF THE 72 HOUR RECORD

Retrieve the records from the RVM. Convert the NEV readings to stray voltage readings by using the ratio obtained in 6.2.3 above. If the highest stray voltage is less than the acceptable limit, inform the customer that there is no stray voltage problem. If the limit is exceeded, proceed to section 6.4.

6.4 AS FOUND GROUND RESISTANCE & CURRENT DISTRIBUTION TESTS

Prior to making any changes or improvements to the primary system or the secondary system, conduct the following "as found tests" at the transformer pole. Because of changing loads, measurements of NEV and current should be taken simultaneously. If the load is changing rapidly, readings should be repeated to ensure accuracy. Record all measurements in the forms contained in Appendix 1.

With the system on load,

6.4.1 Measure the NEV.

6.4.2 Measure the transformer ground rod current.

6.4.3 Calculate the transformer ground rod resistance. It is the NEV divided by the ground rod current.

6.4.4 Measure the primary phase current.

6.4.5 Measure the primary neutral current.

6.4.6 Measure the secondary neutral current.

6.4.7 Measure and record the transformer ground rod resistance.

Take the system off load,

6.4.8 Measure the NEV.

6.4.9 Measure the secondary neutral current.

6.4.10 Calculate the composite secondary ground rod resistance by dividing the NEV by the secondary neutral current.

6.5 AS FOUND PRIMARY NEUTRAL RESISTANCE TESTS

6.5.1 Open all service entrance main circuit breakers except the service under test.

6.5.2 At the service under test, energize **only** 240 loads. For this test, the larger the load, the more accurate the result.

6.5.3 Measure the secondary neutral current.
Note: The secondary neutral current should be very small, it should be equal to the NEV divided by the composite secondary ground rod resistance obtained in 6.4.10. If the current is larger, this indicates some 120 volt load is energized. Investigate and correct as required.

6.5.4 Measure the NEV.

6.5.5 Measure the primary neutral current on the line side of the transformer ground rod. The current should be at least ten times the off load value obtained in 6.1.1 above to get accurate results.

6.5.6 Calculate the primary neutral resistance by dividing the NEV by the neutral current. The resistance should be 1 ohm or less.

6.5.7 De-energize the transformer and check the primary neutral current to ensure the current is no more than 10% of the on load value.

6.6 POLE TOP INSPECTION

With the transformer isolated and de-energized:

6.6.1 If the resistance measurement of the transformer ground rod of 6.1 above indicates the resistance is greater than 25 ohms, inspect the connection to the rod at the neutral and at the rod. If repairs are required, make the repairs and re-test the ground rod resistance. If resistance is still above 25 ohms, drive additional ground rods to obtain 25 ohms or less. When adding additional rods, they should be spaced apart a distance of 3 times their length to get maximum effect.

6.6.2 Bring all neutral connectors up to present standards.

6.6.3 Check the switch (cut-out) for signs of tracking. Replace as required.

6.6.4 Check the dead-end assemblies for signs of tracking. Replace as required.

6.6.5 Check the surge arrester for signs of leakage. Replace as required.

6.6.6 If any changes were made, repeat the tests in 6.4 and 6.5 above.

6.7 NEUTRAL POTENTIAL SURVEY

If the NEV measured in 6.5 above is 5 volts or greater, or the primary neutral resistance is greater than 1 ohm, a neutral potential survey is required. The survey should be carried out in both directions, towards the supply DS and away from it for a distance of 5 kM or until a cause for the high NEV and/or the high primary neutral resistance is determined.

While performing the survey, a visual inspection of the neutral should be carried out. The most common problem on the neutral is defective splices. The splice can be checked by measuring the current through the splice with an ammeter, and the voltage across the splice with a multi-meter. The voltage across the splice should be practically

0 regardless of the level of current. The purpose of measuring current is to verify that current is flowing through the splice at the time of the test. All splices should be checked.

At each ground rod location along the line measure:

6.7.1 The ground rod resistance.

6.7.2 The ground rod current.

6.7.3 The NEV.

6.7.4 The neutral resistance towards supply station.

6.7.5 The neutral resistance away from supply station

6.7.6 The red phase current.

6.7.7 The white phase current.

6.7.8 The blue phase current

6.7.9 The neutral current.

Because the load is always changing, it may be necessary to repeat the voltage and current readings more than once to ensure accurate results.

6.7.10 On single phase lines, calculate the ratio of neutral current/phase current.

6.7.11 Calculate the ground rod resistance which is NEV/ ground rod current.

6.7.12 Due to the changing load, it is difficult to compare NEV readings from one location to another and draw any conclusions. The NEV at any particular location is a function of the neutral current, the neutral to ground resistance and the neutral conductor impedance. To correct for the changing neutral current, the neutral current reading at the first location is used as the base value. The NEV readings at the other locations are adjusted to this base value by dividing the reading by the current at that location. For example:

Location 1 NEV= 4 V, Neutral Current = 7A
Location 2 NEV =5 V, Neutral Current = 10 A
Location 2 Adjusted NEV = 5 V x (7 A/10 A) = 3.5 V.
Location 3 NEV = 3 V, Neutral Current = 5 A
Location 3 Adjusted NEV = 3 V x (7 A /5 A) = 4.2 V

The spreadsheet in Appendix 1 performs this calculation automatically.

Interpreting NEV survey results can be a challenge. Some points to keep in mind are:

- NEV should follow the load. Sudden increases in NEV without a corresponding increase in neutral current indicate a ground fault condition which could be on the primary or secondary system. In that case, it is necessary to sectionalize to isolate the fault. The adjusted NEV will be highest near the fault.

- On a single phase line, the percentage of current returning on the neutral versus the earth is an indicator of the function of these two paths. There is no absolute norm for this ratio. In areas of high resistivity soil, more current will return by the neutral than the earth as compared to an area where there is low resistivity soil.

- A defective splice will be characterized by a high NEV and a higher ratio of current returning through the earth near the defect.

- The neutral resistance measurement is the parallel combination of all the ground rods on one side of the test point in series with the parallel combination of all the ground rods on the other side of the test point. If the neutral to earth resistance of each parallel combination were 1 ohm, the DET10C would indicate 2 ohms.

7.0 DISTRIBUTION SYSTEM IMPROVEMENTS TO RESOLVE STRAY VOLTAGE PROBLEMS

Where the NEV is above acceptable limits on the primary distribution system, the most economical method of reducing the voltage should be employed. Listing the alternatives from least costly to most costly, the solutions are:

- Repair any defects such as defective splices.
- Improve load balancing on three phase lines.
- Improve the grounding by adding more ground rods.
- Increase the neutral conductor size.
- Convert single phase lines to three phase lines.
- Convert lower voltages to higher voltages, e.g. 8/4.8 kV to 27.6/16 kV.

Where it is not possible to meet the 10 volt NEV standard within a period of **one month,** the primary and secondary neutrals may be separated as a temporary measure until a permanent solution is put in place.

REFERENCES

/1/ PSC White Paper Series, "On distinguishing various contributors to Stray Voltage" M. Cook, D. Dasho, R. Reines, D. Reineman, Mar. 1994.

/2/ Public service Commission of Wisconsin, PSC Staff Report: The Phase II Stray Voltage Testing Protocol, R. Reines, M. Cook, Feb. 1999.

/3/ Review of Literature on the Effect of the Electrical Environment on Farm Animals, 6 November 2003 Draft, Douglas J. Reinemann, Ph. D., University of Wisconsin-Madison

/4/ Hydro One, Resolution of Tingle Voltage Complaints, PR 0273 R0, Oct. 2002.

/5/ Ontario Hydro, Tingle Voltage, Customer Service Reference Manual, Section 10, , May 7, 1987.

/6/ OMAFRA Publication, "Stray Voltage Problems in Livestock Production", Jack Rodenburg, Fall Seminar,1998.

/7/ Ontario Hydro, The Resolution of Tingle Voltage Complaints, Line Trade Reference and Work Methods Manual, Section 14, January 30, 1984.

/8/ Ontario Electrical Safety Code, 23rd Edition/2002.

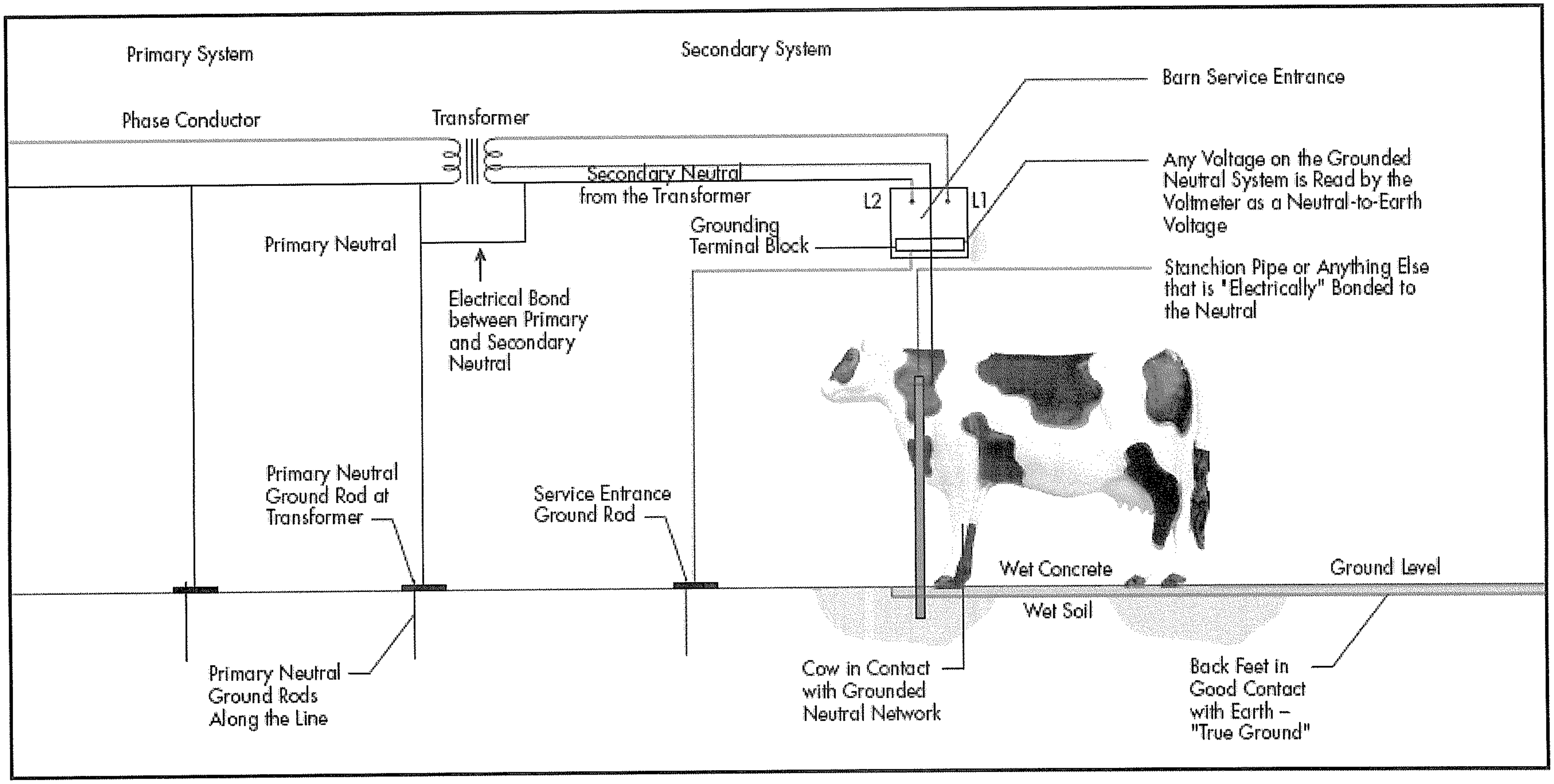

Figure 1
Dairy Cow Subjected to Neutral-to-Earth Voltage

APPENDIX 1
SOLUTIONS FOR THE MITIGATION OF TINGLE VOLTAGE

Customer Name						Comments
Address						
Contractor's Name						
			Year	Month	Date	
Investigation						
Previous Investigations						
6.0 In Service Tests for Isolating Devices						
Hammond TVF						
		Time of Tests				
Site Power Off Tests						
6.1	Neutral-to-Earth Voltage (NEV)					
	Ground-to-Earth Voltage (GEV)					
	Calculated NEV/GEV Ratio					
	NEV/GEV Ratio ≥ 20? (Y/N)					
	GEV < 0.5 V? (Y/N)					
Service Power Off Tests						
	Neutral-to-Earth Voltage (NEV)					
	Ground-to-Earth Voltage (GEV)					
	Stray Voltage (SV)					
	NEV < 5.0 ? (Y/N)					
	GEV < 0.5 V? (Y/N)					
	SV < 0.25 V? (Y/N)					
Service Power On Tests						
	Neutral-to-Earth Voltage (NEV)					
	Ground-to-Earth Voltage (GEV)					
	Stray Voltage (SV)					
	NEV < 5.0 ? (Y/N)					
	GEV < 0.5 V? (Y/N)					

APPENDIX 1

SOLUTIONS FOR THE MITIGATION OF TINGLE VOLTAGE

	SV < 0.25 V? (Y/N)					
Dairyland (VT/NI) or Ronk Blocker						
Site Power On Tests						
6.1	Primary Neutral-to-Earth Voltage (NEV)					
	Secondary Neutral-to-Earth Voltage (NEV)					
	Calculated Primary NEV/Secondary NEV Ratio					
	Primary NEV/Secondary NEV Ratio ≥ 40 (Y/N)					
	Secondary Neutral-to-Earth Voltage (NEV) < 0.25 V? (Y/N)					
Site Power Off Tests						
6.1	Secondary Neutral-to-Earth Voltage (NEV)					
	Stray Voltage (SV)					
	NEV < 0.5 ? (Y/N)					
	SV < 0.25 V? (Y/N)					

Appendix 'C'

- Electrical Contractors Solutions Guide to Stray Voltage
- Electrical Contractor's Stray Voltage Test Procedures
  DRAFTS (Hydro One)

September 2007

Electrical Contractors Solutions Guide to Stray Voltage

TABLE OF CONTENTS

1.0 SCOPE

This document provides application guidelines for the resolution of stray voltage, also known as tingle voltage, when the source of the problem is determined to be the inherent voltage of the primary or secondary multi-grounded distribution system. The test techniques required to determine the source of the problem are included in "Stray Voltage Test Procedures for Electrical Contractors". This is alluded to as reference /1/ throughout this document.

2.0 INTRODUCTION

Neutral-to-earth voltage (NEV) is the voltage measured between the primary distribution system neutral, or the customer's system neutral, and remote earth. Stray voltage is the voltage measured between contact points in a residence, commercial building or a building housing livestock. Stray voltage is typically 40-60% of the NEV. In Ontario, the utility is required to design and maintain their primary distribution system so that the NEV does not exceed 10 volts under normal operating conditions.

Small electrical potentials or voltages between any metal structure or equipment and floor surfaces, are natural, explainable and expected phenomena in buildings served by grounded neutral electrical systems. The voltage is developed as a result of current returning to the source through the grounded neutral conductors. The neutral conductors on both the primary distribution system and the secondary customer system are connected to earth through ground electrodes or rods. It is the flow of current through these connections to earth that generates NEV and stray voltage. Any metal structure in a building, water lines and case grounds on electrical equipment are all bonded back to the neutral of the system at the service entrance panel, for safety reasons. As a result of these bonds, all of the structure, etc., becomes an integral part of the return path of electrical current to the transformer from which it originates. A human coming in contact with this structure, for example a showerhead, may receive a mild shock which is uncomfortable although it is well below the level considered a hazard. Similarly, livestock which come in contact with stabling, water bowls, etc., can receive a shock, as they become part of this complex configuration of electrical pathways for current flow. See Figure.1 below.

The "threshold of perception" for humans is defined in terms of current. For the adult male, the literature suggests 1 mA. The adult female and children are more sensitive, 0.6 mA and 0.5 mA respectively. The "threshold of perception" should not be confused with hazard levels which are an order of magnitude higher. To translate the "threshold of perception" from levels of current into levels of voltage, it is necessary to consider the total resistance of the pathway from the electrical source, through the body and back to the source. Skin resistance is the largest component of the total body resistance. Skin resistance varies widely and depends on skin condition and the path through the human body. The most frequent complaints originate from individuals receiving shocks in the shower or in the area of swimming pools where the pathway through the body is from the hands to the feet. In these wet environments, a skin resistance as low as 10,000 is possible. At that body resistance, and a threshold of perception of 1 mA, the voltage that would be required to initiate a response would be 10 volts. Lower resistances are possible but only under abnormal skin conditions such as a cut where the flesh is exposed. **Experience has shown complaints involving humans originate from customer sites where the voltage between contact points exceeded 3 volts.**

The body resistance of livestock is substantially lower than humans. According to one study, the average body resistance of a dairy cow is 359 ohms from the mouth to the all-hooves pathway. It is 738 ohms from the front to rear hooves pathway. See reference /3/, page 6, item 12. For the purpose of testing, a value of 500 ohms has emerged as a standard in Canada and the US to simulate the body resistance of an animal when making stray voltage measurements. See reference /1/ for instruction on making voltage measurements.

Earlier studies, which focused on defining the "sensitivity" of livestock, resulted in recommendations for corrective action at very low voltage levels. A further understanding of tolerance levels resulting from more recent trials indicates that there is little cause for concern in the 0.5–2 volt range commonly found between surfaces contacted by livestock. The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) are recommending a level of 1 volt as the safe exposure limit. The vast majority of research to date supports this limit. **In many cases, this level can only be achieved and maintained by the addition of mitigating devices installed on the customer's secondary system or at the supply transformer.** For additional information on the effects of stray voltage on livestock see the OMAFRA site, www.omafra.gov.on.ca/english/livestock/dairy/facts/strayvol.html.

3.0 MITIGATION TECHNIQUES

Your local electric utility will perform tests on the primary or utility distribution system to eliminate any problems on it prior to the customer making expenditures on mitigation devices. In addition, the tests outlined in the "Stray Voltage Test Procedure for Electrical Contractors" document should be completed to ensure there are no faults or deficiencies on the secondary or customer distribution system. Ignoring this step jeopardizes the safety of humans and livestock served by the customer distribution system. Furthermore, the mitigation devices are designed to work on a fault free system and may not function if faults exist.

All solutions to reduce stray voltage fall into one of three categories. The solutions and the categories are:

1) Bonding. All the conductive components of any structure are electrically connected together or bonded thereby reducing the step and touch potentials to minute values below the level of concern, or in most cases, the level of perception. The equipotential grid falls into this category.

2) Isolation. A device is installed at the supply transformer or at the service panel to reduce the flow of ground current into the problem area under normal operating conditions while allowing high levels of current to flow under fault conditions. The Dairyland Neutral Isolator (VT/NI), the Hammond Tingle Voltage Filter and the Ronk Blocker all fall into this category. An isolation transformer which isolates the service from the primary and secondary components of stray voltage also falls into this category. However, it is not recommended due to its high cost and will not be discussed.

3) Active Suppression. A ground current is produced by an active system to negate the ground current from the primary or secondary distribution systems. These solutions are not recommended due to their high cost and will not be discussed.

4.0 SELECTING THE STRAY VOLTAGE SOLUTION

Selecting the most appropriate solution depends on the particular situation. Is the problem in a residence, a recreational facility, or a livestock facility? Does it involve humans or only animals? Is a solution being considered for a new installation as an insurance measure to avoid a stray voltage problem? The objective is to select the most economic approach to solve the problem.

Stray voltage complaints involving humans are most often reports of people getting shocks in showers or around swimming pools. In those instances, the individual is wet which lowers the body resistance. Contact is made with a metal object that is bonded to the multi-grounded neutral resulting in a current flow through the body high enough to produce discomfort.

In the case of the shower, the voltage is between the floor or shower drain and the shower head and taps. The options are:
a) If the shower drain is metallic, bond the drain to the shower head and taps.
b) Insert a 0.5 M piece of non-metallic pipe in the water supply to isolate the shower head and taps from the multi-grounded neutral.
c) If the floor is concrete and contains steel reinforcing bars, access the bars and bond them to the shower head and taps.
d) Install an isolation device on the service or the supply transformer. See 5.0 below for instructions on installing these devices.

In the case of the swimming pool, the voltage is usually between a metal object such as the pool ladder and the pool interior or deck. The options are:
a) Where reinforcing steel is used in the construction of the pool, bond the steel to all metal components that a person could contact, and bond the steel to the multi-grounded neutral to create an equipotential plane. See the Ontario Electrical Safety Code, 23rd Edition/2002, Rules 68-058(4) and 68-058(8) for more details.
b) Install an isolation device on the service or the supply transformer. See 5.0 below for instructions on installing these devices.

For buildings housing livestock, the choice of solution depends on whether the building is new or existing. For a new milking parlour in a dairy barn, the Ontario Electrical Safety Code requires the installation of an equipotential grid. See rule 75-412. The equipotential grid may also be an economic approach for tie stall or free stall barns at the time of construction. Although techniques have been developed to install a grid in an existing barn, it is often impractical because the installation of the grid will require the animals to be housed elsewhere during the construction phase. For more information on the installation techniques for equipotential grids, see "Equipotential Planes for Stray Voltage Reduction". This document is produced by the Midwest Rural Energy Council and is available on their website, www.mrec.org/sv-info.html.

For existing barns, the most economic approach is usually to install one of the isolating devices. The three devices currently available and approved for use in Ontario are:

Hammond Tingle Voltage Filter (TVF). This device is installed at the service panel on the service where the stray voltage problem persists. It separates that service panel neutral from the ground at that point. Because it is installed at this point on the secondary electrical system, it mitigates all off-site sources, on-site sources from other service panels, and secondary neutral voltage. It is rated for a service size of 200A. For a 400 A service, two units connected in parallel are required. The TVF is no longer manufactured by Hammond but is available in the after market. One supplier is:

Sussex Farm Supplies
3292 Route 121st
Sussex, NB
E4E 5L2
Phone: (506) 433-1699
E-mail: sussexfarm@nb.aibn.com

The current price as of January 2007 is $500.

Dairyland Neutral Isolator (VT/NI). This device is installed by your local electric utility personnel at the transformer pole between the primary (utility) distribution system neutral and the secondary (customer) distribution system neutral. Because it is installed at this point, it mitigates all off-site sources for the entire site. This can be ordered directly from the manufacturer at:

Dairyland Electrical Industries, Inc.
P.O. Box 187
Stoughton, WI. 53589
USA
Phone: (608) 877-9900
Fax: (608) 877-9920
Website: www.dairyland.com/index.php?page=products_vtni.html

The current price as of January 2007 is $900 CDN.

Ronk Blocker. This device is installed by your local electric utility personnel at the transformer pole between the primary (utility) distribution system neutral and the secondary (customer) distribution system neutral. Because it is installed at this point, it mitigates all off-site sources for the entire site. One supplier is:

L & B Stray Voltage Services
17 Edward
Drayton Moorefield, ON
N0G 1P0
(519) 638-3680

The current price as of January 2007 is $1700.

5.0 INSTALLATION INSTRUCTIONS FOR ISOLATING DEVICES

Prior to installing any of the isolating mitigation devices, it is necessary to eliminate any sources that could bypass the mitigation device by re-connecting the primary and secondary neutrals. The two most common sources are Bell Canada and the Cable TV Company. On some installations, Bell Canada uses a shielded cable to provide the telephone circuit. The shield of this cable is connected to the utility primary distribution neutral for safety and operational reasons. The cable runs from the Bell Canada pedestal to the lightning protector which is normally mounted outside the building which is to be served. The ground on this protector is often connected to the service entrance ground in the building. This will bypass the isolating device mounted at the transformer or the Hammond TVF in the service panel. Cable TV suppliers have similar practices. Contact these service providers for a solution to isolating their conductor grounding from the service ground. Bell Canada prefers to add a spark gap to break the continuity of the sheath. Another option is add a separate ground rod for the protector.

Another potential bypass is the water supply. If metallic pipe is used throughout, it will be bonded to the secondary neutral at the service panels on the site. If for example, the house and the livestock barn have a common water supply, and a Hammond TVF was installed in the livestock barn, then the TVF would be bypassed. This can be remedied by installing a 0.5 M section of non-metallic pipe in the line between the house and the barn.

5.1 HAMMOND TINGLE VOLTAGE FILTER (TVF)

The TVF is installed at the service panel which is to be isolated. The installation should be performed by a qualified electrical contractor, who is familiar the *"Contractor Stray Voltage Test Procedure"* document for the secondary or customer system. This document is available from ???

Figure 2 below shows the most common application - an installation in a livestock barn. The bonding screw must be removed from the neutral bar. The neutral terminal of the TVF is connected to the neutral bar of the service panel, and the ground terminal of the TVF is connected to the ground bar of the service panel. In order for the TVF to function correctly, all bonding sub-panels supplied by the main panel must be removed and all neutral-to-ground faults and all line-to-ground faults must be located and repaired.

The effectiveness of the TVF also depends on the value of the service grounding as the unit acts as a voltage divider. See Figure 3 and 4 below. For example, if the neutral-to-remote earth voltage is 5 volts, the ground-to-remote earth voltage will be approximately 0.06 volts if the ground resistance is 10 ohms. If the ground resistance measured 100 ohms, then the ground-to-remote earth voltage would be 0.68 volts. The ground resistance of a typical livestock facility is under 10 ohms. If it is not, then improvements should be made.

5.2 DAIRYLAND NEUTRAL ISOLATOR (VT/NI)

Your local electric utility will install the VT/NI on the transformer pole. The customer is expected to have his or her electrical contractor on site at the time to perform the in-service tests and deal with Bell Canada or the Cable TV Company, if required. The contractor should be qualified and have completed the test procedure for the secondary or customer system. This test procedure can be found in the *"Contractor Stray Voltage Test Procedure"* document available from ???. For more information on installation requirements, contact Dairyland Industries. The performance of the VT/NI in reducing stray voltage does not depend on the value of ground resistance. However, for safety reasons, any ground resistance over 10 ohms should be improved.

5.3 RONK BLOCKER

Your local electric utility will install the Blocker on the transformer pole. The customer is expected to have his or her electrical contractor on site at the time to perform the in-service tests and deal with Bell Canada or the Cable TV Company, if required. The contractor should be qualified and have completed the test procedure for the secondary or customer system. This test procedure can be found in the *"Contractor Stray Voltage Test Procedure"* document available from ???. For more information on installation requirements, contact L & B Stray Voltage. The performance of the Blocker is less sensitive to ground resistance than the TVF. However, for safety reasons, any ground resistance over 10 ohms should be improved.

5.4 TESTS FOR ISOLATING DEVICES

Any of the isolating devices referred to above, can be tested with a resistor to simulate the ground resistance, a variac, and a multi-meter. Connect the resistor in series with the unit under test. Using the variac, apply a voltage to the series combination. See Figure 5 below. Measure the applied voltage, $V_{in,}$ and the voltage across the resistor, $V_{OUT,}$. With 10 volts applied, the voltage across the resistor should be < 0.15 volts for the Hammond TVF, <0.07 for the Ronk Blocker and <0.05 for the Dairyland VT/NI.

6.0 IN SERVICE TESTS FOR ISOLATING DEVICES

Refer to the *"Contractor Stray Voltage Test Procedure"* document, /1/, for instructions on measuring Neutral-to- Earth Voltage (NEV) and Stray Voltage (SV).

6.1 TESTS FOR THE HAMMOND TVF

With the power off at the site, measure the secondary NEV and the ground-to-remote earth voltage at the service entrance panel where the TVF is installed. The ratio secondary NEV/ ground-to-remote earth voltage should be ≥ 20 and the ground-to-remote earth voltage should be < 0.25 V. If either of these tests fails, this indicates a bypass, neutral-to-ground fault on the service where the unit is installed, incorrect installation, deficient grounding, or a defective unit. To correct the situation, refer to /1/ for troubleshooting faults or deficiencies, re-check that the unit has been installed correctly, check for bypasses, and lastly, check the TVF as described in 5.4 above.

If the "power-off" tests are successful, turn on the power at all service entrances except the service where the unit is installed. Measure the secondary NEV, the ground-to-remote earth voltage and the SV. The secondary NEV should be < 5.0 V. If not, this indicates a primary neutral problem, a secondary neutral problem, or a ground fault on another service on the site. The ground-to-remote earth voltage should be <0.5 V and the SV should be < 0.25 V. To correct the situation, refer to /1/ for troubleshooting faults or deficiencies. If no problems are found on the secondary or customer system, contact your local electric utility.

If all the tests above are successful, turn the power on at the service where the TVF is installed. Measure the secondary NEV, the ground-to-remote earth voltage, and the SV. The secondary NEV should be < 5.0 V. If not, this indicates a secondary neutral problem on the service where the unit is installed. The ground-to-remote earth voltage should be <0.5 V and the SV should be < 0.25 V. If not this indicates a fault in the service where the unit is installed. Refer to /1/ for troubleshooting.

6.2 TESTS FOR THE VT/NI OR THE RONK BLOCKER:

With the power off at the entire site, measure the primary NEV and the secondary NEV at the transformer pole. The ratio primary NEV/ secondary NEV should be ≥ 40 and the secondary NEV should be < 0.25 V. If either of these tests fails, this indicates a bypass, incorrect installation or a defective unit. To correct the situation, re-check that the unit has been installed correctly, check for bypasses, and lastly, check the isolating device as described in 5.4 above.

If the "power-off" tests are successful, turn on the power at all service entrances. Measure the secondary NEV at the service entrance of the building with the SV problem. Measure the SV in the problem area. The secondary NEV should be < 0.5 V and the SV should be < 0.25 V. If either of these tests fails, this indicates a secondary neutral problem or a ground fault on one of the services. Refer to /1/ for tests to locate and correct the problem.

6.3 RECORDING VOLTMETER TESTS

When all tests are complete, install a recording voltmeter (RVM) to measure the ground-to-remote earth voltage at the service entrance in the problem area. Your local electric utility will provide this service upon request. The RVM should be left on for a period of 72 hours minimum to ensure all load cycles on both the primary and secondary systems are recorded.

7.0 MAINTENANCE TESTS FOR ISOLATING DEVICES

The isolating devices are highly reliable passive devices. Failures are possible due to lightning but the most likely problem is the device being bypassed. Therefore, anytime that electrical improvements or changes are made on the property, it is recommended that the stray voltage be measured after the work is complete. Similarly, if changes are made to the telephone or cable TV service on the property, the stray voltage should be measured upon completion of the work. As an insurance measure, periodic checking is recommended. The level of stray voltage measured should be within 20% of the highest value recorded during the in-service tests. If this level is exceeded, the in-service test should be repeated to determine the problem.

REFERENCES

/1/ Electrical Contractors Stray Voltage Test Procedures, September 2007.

/2/ Customer Service Reference Manual, Section 10 - Tingle Voltage, May 7, 1987.

/3/ Review of Literature on the Effect of the Electrical Environment on Farm Animals, 6 November 2003 Draft, Douglas J. Reinemann, Ph. D., University of Wisconsin-Madison.

/4/ OMAFRA Publication – "Stray Voltage Problems in Livestock Production", Jack Rodenburg, Fall Seminar,1998.

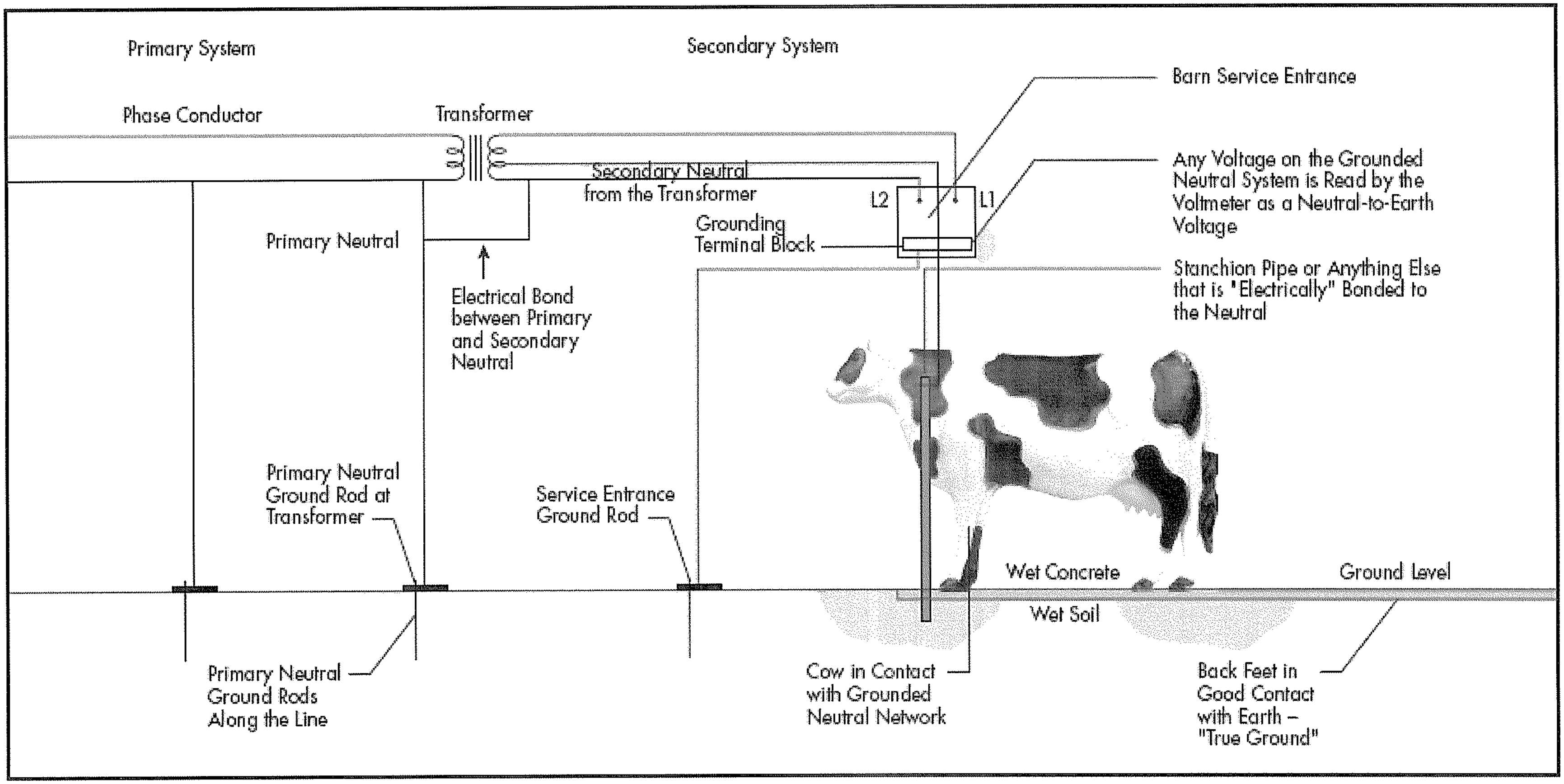

Figure 1
Dairy Cow Subjected to Neutral-to-Earth Voltage

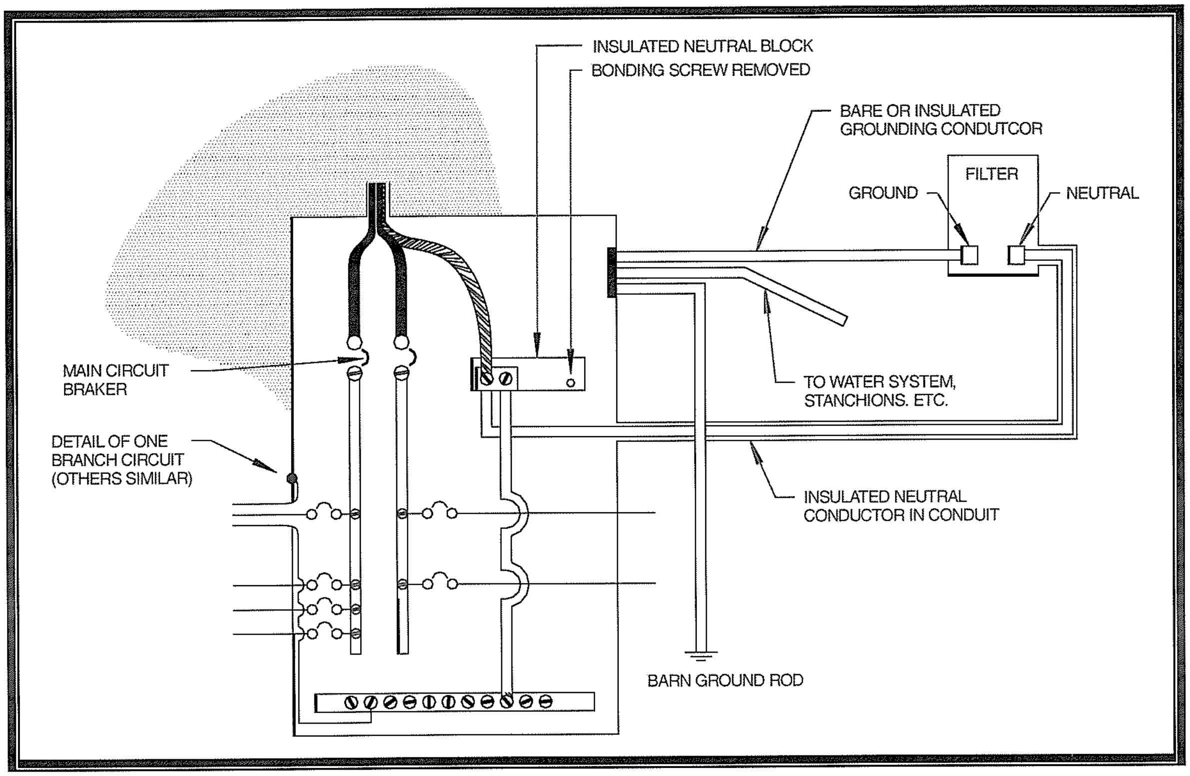

Figure 2
Hammond Tingle Voltage Filter Installation

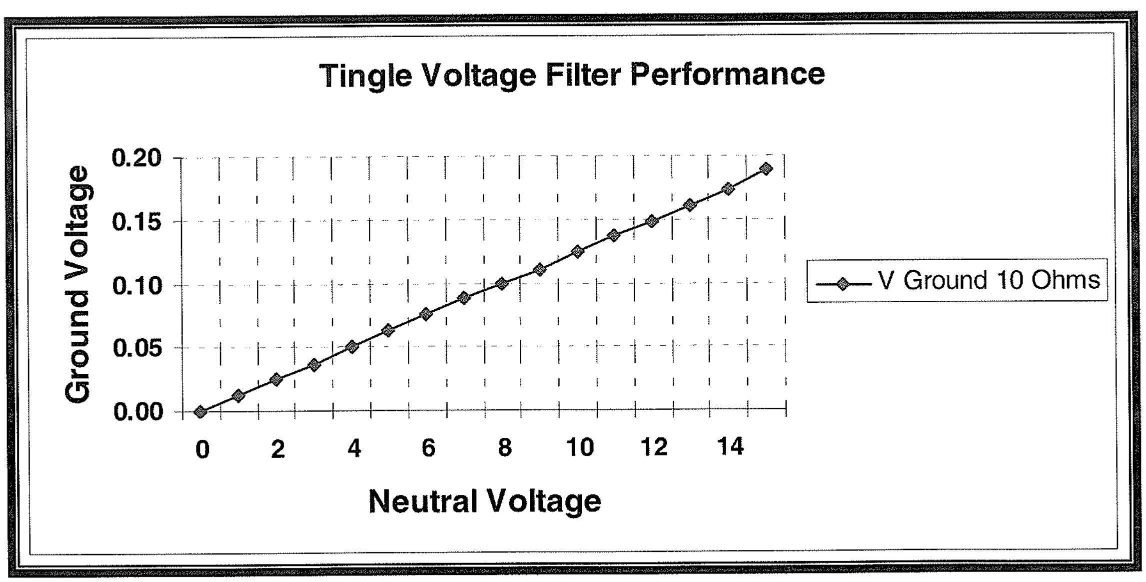

Figure 3
Hammond Tingle Voltage Filter Performance 10 Ohm Ground

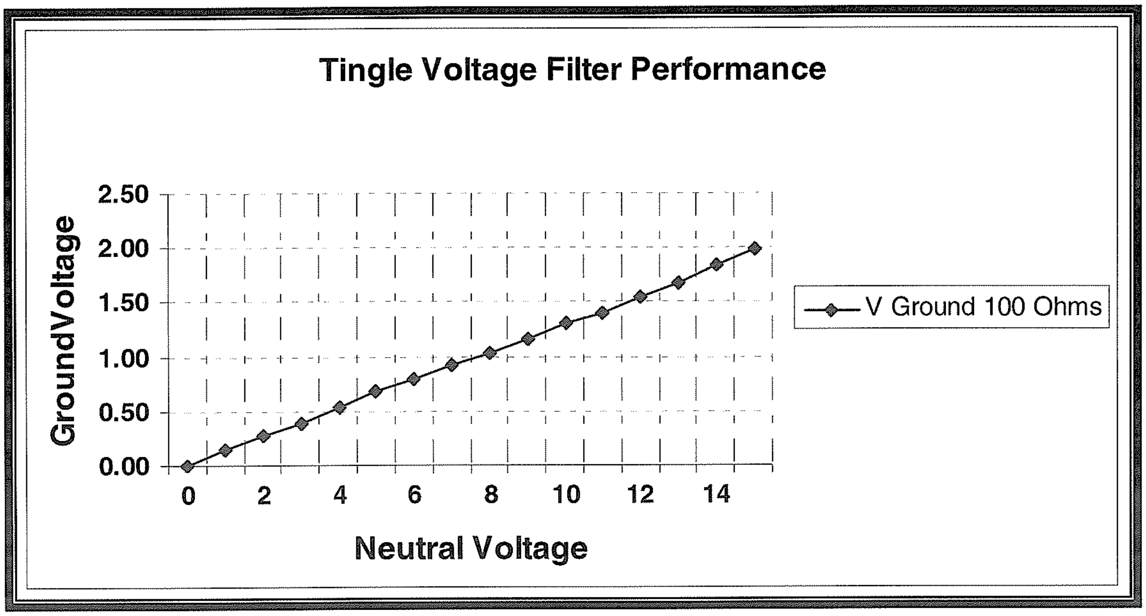

Figure 4
Hammond Tingle Voltage Filter Performance 100 Ohm Ground

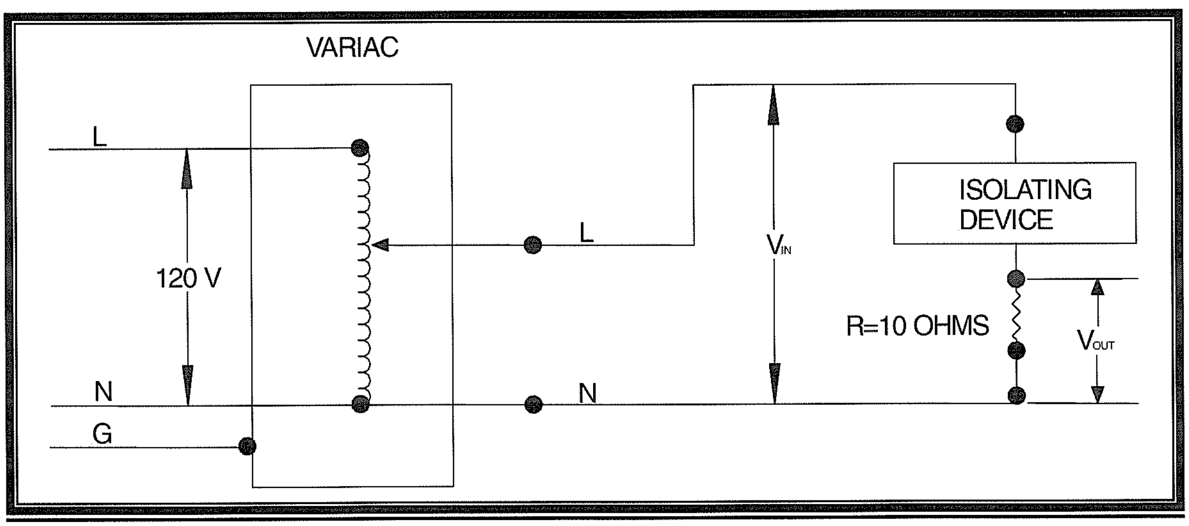

Figure 5
Isolating Device Tests

APPENDIX 1
SOLUTIONS FOR THE MITIGATION OF TINGLE VOLTAGE

Customer Name						Comments
Address						
Contractor's Name						
			Year	Month	Date	
Investigation						
Previous Investigations						
6.0 In Service Tests for Isolating Devices						
Hammond TVF						
		Time of Tests				
Site Power Off Tests						
6.1	Neutral-to-Earth Voltage (NEV)					
	Ground-to-Earth Voltage (GEV)					
	Calculated NEV/GEV Ratio					
	NEV/GEV Ratio ≥ 20? (Y/N)					
	GEV < 0.5 V? (Y/N)					
Service Power Off Tests						
	Neutral-to-Earth Voltage (NEV)					
	Ground-to-Earth Voltage (GEV)					
	Stray Voltage (SV)					
	NEV < 5.0 ? (Y/N)					
	GEV < 0.5 V? (Y/N)					
	SV < 0.25 V? (Y/N)					
Service Power On Tests						
	Neutral-to-Earth Voltage (NEV)					
	Ground-to-Earth Voltage (GEV)					
	Stray Voltage (SV)					
	NEV < 5.0 ? (Y/N)					
	GEV < 0.5 V? (Y/N)					

APPENDIX 1
SOLUTIONS FOR THE MITIGATION OF TINGLE VOLTAGE

	SV < 0.25 V? (Y/N)		
Dairyland (VT/NI) or Ronk Blocker			
Site Power On Tests			
6.1	Primary Neutral-to-Earth Voltage (NEV)		
	Secondary Neutral-to-Earth Voltage (NEV)		
	Calculated Primary NEV/Secondary NEV Ratio		
	Primary NEV/Secondary NEV Ratio ≥ 40 (Y/N)		
	Secondary Neutral-to-Earth Voltage (NEV) < 0.25 V? (Y/N)		
Site Power Off Tests			
6.1	Secondary Neutral-to-Earth Voltage (NEV)		
	Stray Voltage (SV)		
	NEV < 0.5 ? (Y/N)		
	SV < 0.25 V? (Y/N)		

Electrical Contractors Stray Voltage Test Procedures

September, 2007

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1.0 SCOPE

This document is the standard test procedure for resolving stray voltage, also known as tingle voltage, when the source of the problem is believed to be on the secondary or customer's electrical system. The objective of the procedure is to isolate any faults or deficiencies on the customer's electrical system.

2.0 INTRODUCTION

Neutral-to-earth voltage (NEV) is the voltage measured between the primary distribution system neutral, or the customer's system neutral, and remote earth. Stray voltage is the voltage measured between contact points in a residence, commercial building or a building housing livestock. Stray voltage is typically 40-60% of the NEV. In Ontario, the utility is required to design and maintain their primary distribution system so that the NEV does not exceed 10 volts under normal operating conditions.

Small electrical potentials or voltages between any metal structure or equipment and floor surfaces, are natural, explainable and expected phenomena in buildings served by grounded neutral electrical systems. The voltage is developed as a result of current returning to the source through the grounded neutral conductors. The neutral conductors on both the primary distribution system and the secondary customer system are connected to earth through ground electrodes or rods. It is the flow of current through these connections to earth that generates NEV and stray voltage. Any metal structure in a building, water lines and case grounds on electrical equipment are all bonded back to the neutral of the system at the service entrance panel, for safety reasons. As a result of these bonds, all of the structure, etc., becomes an integral part of the return path of electrical current to the transformer from which it originates. A human coming in contact with this structure, for example a showerhead, may receive a mild shock which is uncomfortable although it is well below the level considered a hazard. Similarly, livestock which comes in contact with stabling, water bowls, etc., can receive a shock, as they become part of this complex configuration of electrical pathways for current flow (see Figure 1).

The "threshold of perception" for humans is defined in terms of current. For the adult male, the literature suggests 1 mA. The adult female and children are more sensitive, 0.6 mA and 0.5 mA respectively. The "threshold of perception" should not be confused with hazard levels which are an order of magnitude higher. To translate the "threshold of perception" from levels of current into levels of voltage, it is necessary to consider the total resistance of the pathway from the electrical source, through the body and back to the source. Skin resistance is the largest component of the total body resistance. Skin resistance varies widely and depends on skin condition and the path through the human body. The most frequent complaints originate from individuals receiving shocks in the shower or in the area of swimming pools where the pathway through the body is from the hands to the feet. In these wet environments, a skin resistance as low as 10,000 is possible. At that body resistance, and a threshold of perception of 1 mA, the voltage that would be required to initiate a response would be 10 volts. Lower resistances are possible but only under abnormal skin conditions such as a cut where the flesh is exposed. Experience has shown complaints involving humans originate from customer sites where the voltage between contact points exceeded 3 volts.

The body resistance of livestock is substantially lower than humans. According to one study, the average body resistance of a dairy cow is 359 ohms from the mouth to the all-hooves pathway. It is 738 ohms from the front to rear hooves pathway (see reference /3/). For the purpose of testing, a value of 500 ohms has emerged as a standard in Canada and the US to simulate the body resistance of an animal when making stray voltage measurements. See section 5.0 below for instruction on making voltage measurements.

Earlier studies, which focused on defining the "sensitivity" of livestock, resulted in recommendations for corrective action at very low voltage levels. A further understanding of tolerance levels resulting from more recent trials indicates that there is little cause for concern in the 0.5–2 volt range commonly found between surfaces contacted by livestock. The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) are recommending a level of 1 volt as the safe exposure limit. The vast majority of research to date supports this limit. **In many cases, this level can only be achieved and maintained by the addition of mitigating devices installed on the customer's secondary system or at the supply transformer.** For additional information on the effects of stray voltage on livestock see the OMAFRA site, www.omafra.gov.on.ca/english/livestock/dairy/facts/strayvol.html.

3 0 NORMAL LEVELS OF NEV AND STRAY VOLTAGE

The design limit for NEV on the primary distribution system for all electrical utilities in the province of Ontario is 10 volts. This limit is established by the Electrical Safety Authority. See reference /7/, Rule 75-414. However, on most lines the NEV peaks at less than 5 volts. Whatever the level, the primary NEV will be transferred into all electrical service panels on the site via the secondary neutral. In addition, there will be contributions from the secondary or customer's system even with a fault free system. Levels of stray voltage above 5 volts may be an indication of a fault on the secondary customer system or on your local electric utility primary distribution system.

4.0 TEST EQUIPMENT REQUIREMENTS

The following test equipment is required:

- 2 x true RMS responding multi-meters, such as the HIOKI 3805 multi-meter or equivalent. One meter should be equipped with a current clamp to measure current.

- 2 x 10 kilo-ohm resistors, 2 watts, ≥5% accuracy. Each resistor must be mounted on a dual banana plug such as a HH Smith 1676 or equivalent. This is referred to as a bridging resistor in the procedure. It is used when taking neutral-to-earth voltage measurements and stray voltage measurements where humans are concerned.

- 1 x 500 ohm resistors, 2 watts, ≥5% accuracy. The resistor must be mounted on a dual banana plug such as a HH Smith 1676 or equivalent. This bridging resistor is used for the stray voltage measurements where livestock is concerned.

- 1 x stainless steel portable ground rod. The rod must be at least 1 M in length and 1.5 cm in diameter. It should be sharpened at one end to ease the insertion into the earth. The 0.5 M point from the sharpened point should be marked. The rod should be equipped with an appropriate terminal that permits connection to it via an alligator clip.

- 2 rolls of insulated #18 stranded wire, 50 M in length. One end should be equipped with an alligator clip of suitable size to connect to the ground rod. The other end should be equipped with a banana plug to connect to the multi-meter.

- Insulation Tester, HIOKI 3454-10 or equivalent.

- Floor contact plate for measuring stray voltage. Plate must be copper or stainless steel 15 cm x 15 cm x 1.5 cm. The plate should be equipped with an appropriate terminal that permits connection to it via an alligator clip.

- Pocket calculator.

5.0 NEV AND STRAY VOLTAGE MEASUREMENTS

Throughout this procedure, the following voltage measurements are required:

- Measure Neutral-to-Earth Voltage (NEV). Refer to the HIOKI manual for instruction on the use of the multi-meter to measure voltage. Connect one lead of the voltmeter to the ground wire that connects the neutral to the ground rod at the service entrance that serves the problem area. Insert a portable ground rod

0.5 M into the earth 15 M from the ground rod under test. This becomes the remote ground reference point. Using the #18 test lead wire to extend the second voltmeter lead, connect it to the portable ground rod. Install a 10 K resistor across the input of the meter. Note the reading. Install a second 10 K across the input of the meter. The reading should not decrease by more than 10%. A reading of more than 10% indicates the portable ground rod is a high resistance. Move the rod to another location to reduce the resistance. When a good connection to earth has been established, remove the second 10 K resistor from the meter. Read and record the NEV.

- Measure Stray Voltage (SV). Refer to the HIOKI manual for instruction on the use of the multi-meter to measure voltage. To measure SV for humans, insert a 10,000 ohm bridging resistor across the input of the multi-meter. To measure SV for animals, use a 500 ohm bridging resistor. Connect one lead of the multi-meter to one contact point. This could be a shower head for a complaint involving humans, or a water bowl for a complaint involving livestock. Connect the second lead of the meter to the floor contact plate placed where the human or animal would stand. Move the plate around the site to obtain the highest reading and record. Measure the NEV again and calculate the ratio between the stray voltage and NEV. These two readings should be taken simultaneously to achieve maximum accuracy which requires two multi-meters. The stray voltage should always be less than the NEV. If it is not, this is an indication of a secondary ground fault.

6.0 INITIAL MEASUREMENTS

Test results may be recorded on the Excel spreadsheet forms in Appendix 1. It is recommended that they be recorded on a paper during the test and transferred to the spreadsheet when the tests are complete. This provides a high quality record that can be transferred by email and stored electronically.

6.1 AS FOUND NEV & STRAY VOLTAGE MEASUREMENTS

6.1.1 Measure the NEV at the service entrance with the problem.

6.1.2 Measure the stray voltage in the problem area.

6.1.3 Calculate stray voltage /NEV ratio.

6.1.4 If the stray voltage measured is above acceptable levels, contact your local electric utility. If the stray voltage measured is between 50% and 100% of the acceptable level, it is recommended that a recording voltmeter (RVM) be installed to measure the NEV and stray voltage. The RVM should be left on for a period of 72 hours minimum to ensure all load cycles on both the primary and secondary systems are recorded. Your local electric utility will install an (RVM) upon request.

6.2 INTERPRETATION OF THE 72 HOUR RECORD

Retrieve the records from the RVM. Convert the NEV readings to stray voltage readings by using the ratio obtained in 6.1.3 above. If the highest stray voltage is less than the acceptable limit, then there is no stray voltage problem. If the limit is exceeded, contact your local electric utility. Your local electric utility will perform tests on the primary distribution system to determine if there any faults or deficiencies on the utility system. If your local electric utility does not uncover any problems or make improvements that lower the stray voltage, proceed with the tests in section 7.0 below.

7.0 SERVICE ENTRANCE TESTS

The tests below are performed on the service entrance of the building where the stray problem exists. If there is reason to suspect a problem on one of the other service entrances on the site, these entrances should tested also.

7.1 BONDING TEST

Bonding all the metal structure in building to the neutral at the service panel provides a low impedance path for sufficient current to flow to operate the fuse or circuit breaker if a fault occurs. It also prevents stray voltage from developing on an un-bonded piece of equipment when a low level, high resistance, fault is present. It also lowers the barn grounding resistance.

7.1.1 Open the service entrance main breaker.

7.1.2 Connect one terminal of the multi-meter to the service entrance panel ground. Connect the second terminal of the meter to a test lead long enough to reach throughout the building. This lead should have a sharp probe on the end to penetrate the rust and dirt commonly found in buildings.

7.1.3 Touch the sharp probe to the service entrance panel and measure the lead resistance. This should be less than 5 ohms.

7.1.4 Move around the building and contact each metal part. The readings should be no greater than 1 ohm above the lead resistance measured in 6.3.4 above. Note and repair any improperly bonded equipment.

7.2 SERVICE GROUNDING RESISTANCE TEST

Lowering the service ground resistance will lower the stray voltage. Other benefits are improved electrical safety by reducing voltage rise on faulted equipment, and improved lightning protection by providing a low resistance path for lightning to discharge. Experience has shown that 10 ohms or less is readily attainable in most locations in Ontario on a well bonded system.

7.2.1 Remove all the load on the service panel by opening the main service entrance circuit breaker or disconnect.

7.2.2 Remove the service panel cover to access the two line buses and the neutral bus.

7.2.3 Verify that the panel is de-energized by checking the voltage on the line buses with the multi-meter.

7.2.4 Remove the supply side (transformer side) neutral conductor from the panel and connect the multi-meter between the conductor and the panel. Select milliamps on the multi-meter. Measure and record the current.

7.2.5 With the second multi-meter, measure the NEV.
Note: The readings for voltage and current must be taken simultaneously to be accurate. If only one multi-meter is available, then the readings should be repeated 3 times and the average taken for better accuracy.

7.2.6 Calculate the service grounding resistance, which is the NEV divided by the neutral (ground) current. This should be less than 10 ohms. If not, improvements are recommended.

7.3 INSULATION TEST

Insulation failure that results in a fault current level below the operating point of the circuit breaker or fuse will cause stray voltage if the fault results in a flow of ground current. Faults can be from line-to-neutral, line-to-ground, neutral-to-ground or line-to-line for 240 volt equipment. The test below will not detect line-to-neutral or line-to-line faults which do not cause stray voltage because they do not result in a flow of ground current.

Refer to Figure 2.

7.3.1 Open the service entrance main breaker and leave the branch circuit breakers closed.

7.3.2 Close all switches at the equipment including lights.

7.3.3 Remove the distribution panel cover.

7.3.4 Check with a voltmeter to ensure the panel is completely de-energized.

7.3.5 Remove the supply side (transformer side) neutral conductor. Remove the bonding screw from the neutral bar. Remove any other ground connections on the neutral bar such as connections to the water system or ground rod. Temporarily connect these to the ground bar in the panel.

7.3.6 Refer to the instruction manual of the tester for directions on performing tests. Connect one lead of the insulation tester to the service entrance ground bus and the second lead to the neutral bar. Perform the insulation test on the 500 V range. The readings should be 50 kilo ohms or greater.

7.3.7 Test each bus (line) of the distribution panel. The reading should be 50 kilo ohms or greater.

7.3.8 Any 240 volt equipment which is turned on and off by magnetic contactor or motor starter, or any other equipment which is not connected to the distribution panel bus at the time of the test, must be tested separately. To perform this test, remove the cover of the contactor and connect the insulation tester on the load side of the contactor. The reading should be 100 kilo ohms or greater.

7.3.9 If the insulation measured is less than 50 kilo ohms in 7.3.6 or 7.3.7 above, it is necessary to test each branch circuit individually (see Figure 3). All readings should be 100 kilo ohms or greater.

7.4 SECONDARY NEUTRAL TEST

Voltage drop on the secondary neutral will be split between the grounding of the service under test and the composite value of all the other grounding connected to the neutral, both primary and secondary. For example, if the voltage drop on the secondary neutral was 3 V, the service grounding measured 10 ohms, the composite value of all other grounds measured 5 ohms, then the NEV at the service under test would measure 2 V, ignoring any contribution from the primary system. The voltage drop can be due to a poor connection, an undersized neutral or excessive unbalance.

To test for stray voltage caused by secondary neutral drop:

7.4.1 Remove the entire load from all service entrances except the service under test.

7.4.2 Determine what equipment is likely to be operating during peak use in the service under test. Operate the equipment.

7.4.3 Measure the neutral current with the multi-meter and a current clamp.

7.4.4 Turn off all branch circuit breakers on the distribution panel.

7.4.5 While measuring the neutral current, turn on the branch circuits on one leg of the distribution panel until the neutral current is within ± 10% of the value measured above in 7.4.3 above.

7.4.6 Measure the stray voltage.

7.4.7 Remove the entire load and note the change. If the voltage change is 0.25 V or less, proceed to section 8 below.

If the voltage change measured is greater than 0.25 volts:

7.4.8 Refer to Figure 4. Connect the voltmeter and ammeter as shown.

7.4.9 Create the same unbalanced condition as in 7.4.5 above.

7.4.10 Measure the neutral voltage and current.

7.4.11 Determine the approximate length of the secondary neutral conductor and conductor size. Refer to the table in Appendix 1 for conductor impedances. Calculate the voltage as shown. If the measured voltage is greater than calculated value by 5 %, this indicates a poor connection. Check connections and repair as required.

7.4.12 If the measured voltage is equal to or less than the calculated value, the problem is an undersized neutral for the amount of neutral current and the length of run. The solutions are:

- Improve the load balancing on the service. A level of 20% of the service rating should be achievable by rearranging circuits in the panel, or by converting some of the 120 V equipment to 240 V equipment.
- If the secondary neutral drop exceeds 3 volts after the load balancing has been improved, the secondary neutral size should be increased.
- If the secondary neutral drop is less than 3 volts, some solutions such as the Hammond Tingle Voltage Filter may be used to reduce the stray voltage to acceptable levels.

8.0 STRAY VOLTAGE SOLUTIONS

The tests performed in this procedure, and your local electric utility's distribution system test procedure, are designed to uncover any faults or deficiencies on either the customer's system or the utility's system. If after these sources are eliminated by improvements, and the stray voltage is still above acceptable levels, then the stray voltage must be reduced by employing one of the mitigation techniques. This includes bonding, special isolation procedures or the use of an isolating device. For a description of these solutions, refer to *"Electrical Contractors Solutions Guide to Stray Voltage"* available from XXXX.

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/4/ Ontario Hydro, Tingle Voltage, Customer Service Reference Manual, Section 10, May 7, 1987.

/5/ OMAFRA Publication, "Stray Voltage Problems in Livestock Production", Jack Rodenburg, Fall Seminar,1998.

/6/ Ontario Hydro, The Resolution of Tingle Voltage Complaints, Line Trade Reference and Work Methods Manual, Section 14, January 30, 1984.

/7/ Ontario Electrical Safety Code, 23rd Edition/2002.

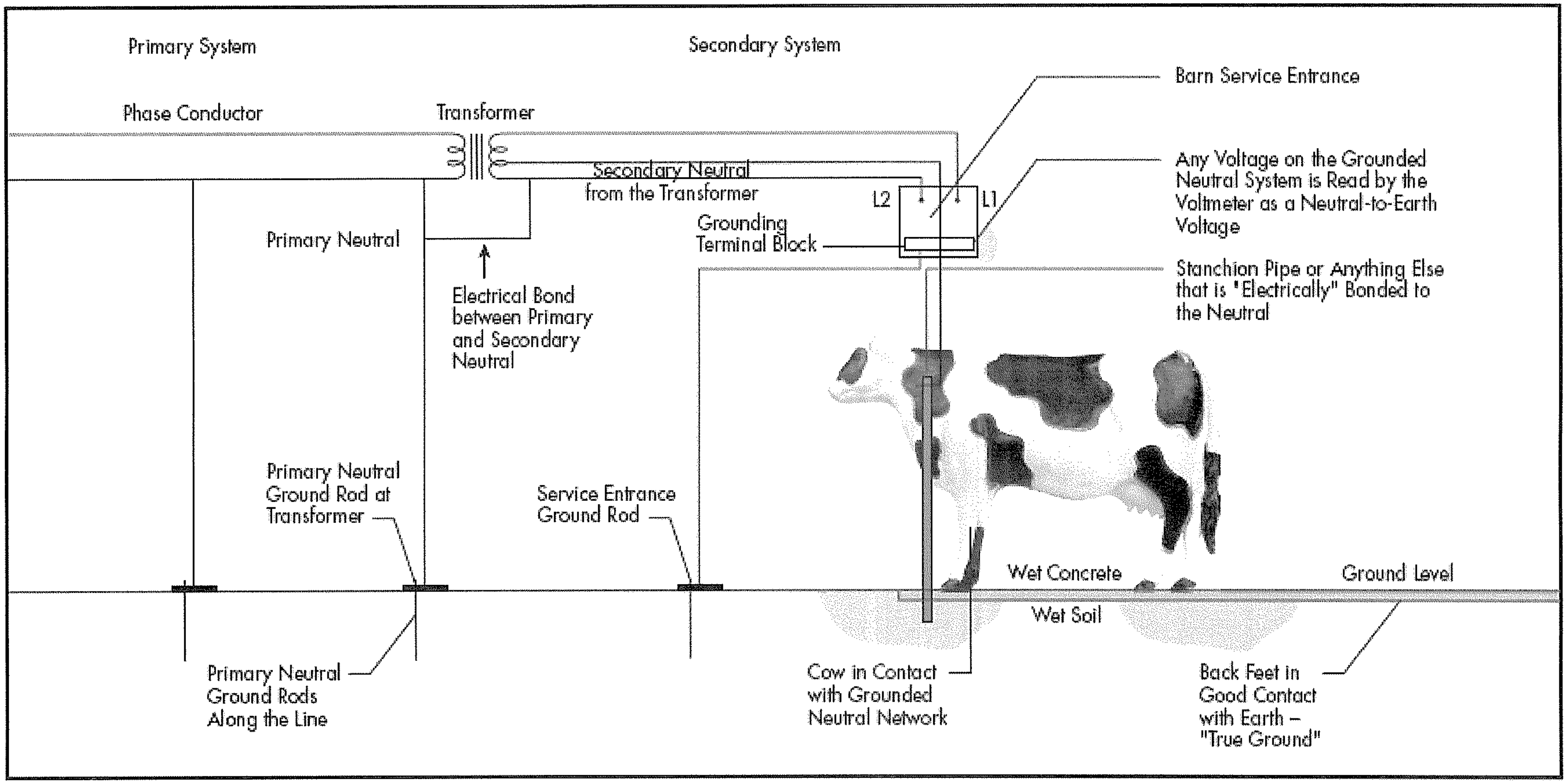

Figure 1
Dairy Cow Subjected to Neutral-to-Earth Voltage

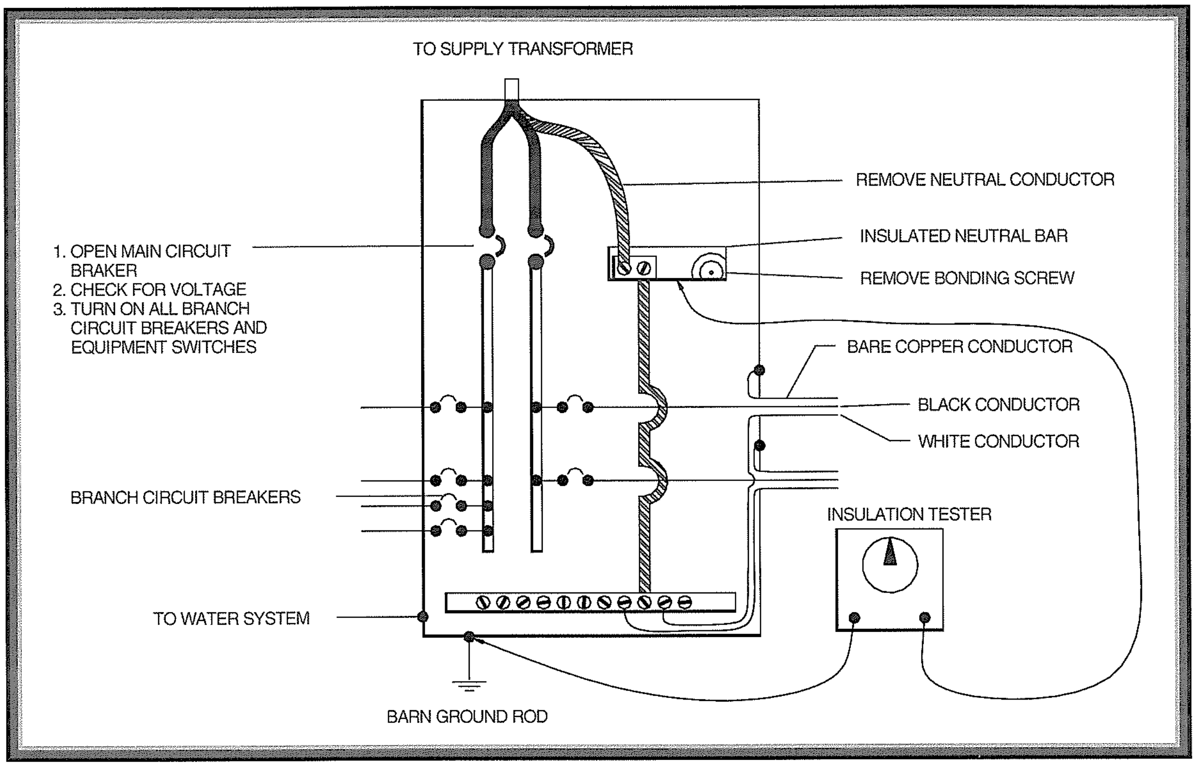

Figure 2
Insulation Test Complete System

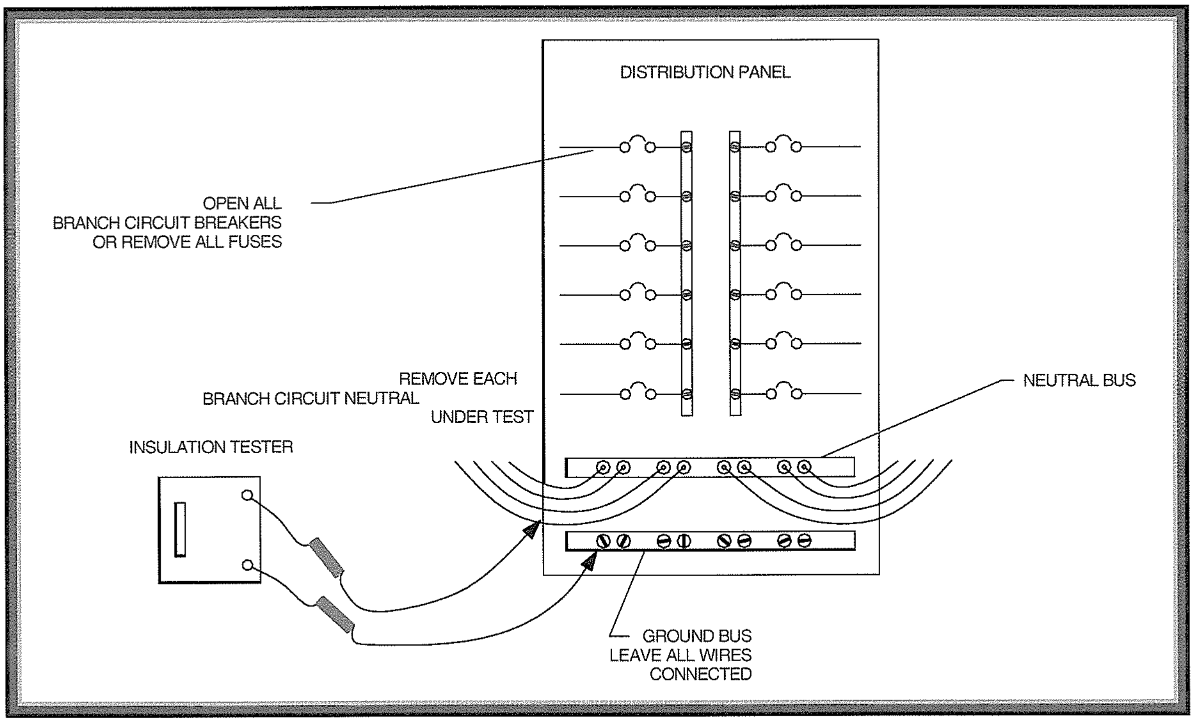

Figure 3
Insulation Test Individual Circuits

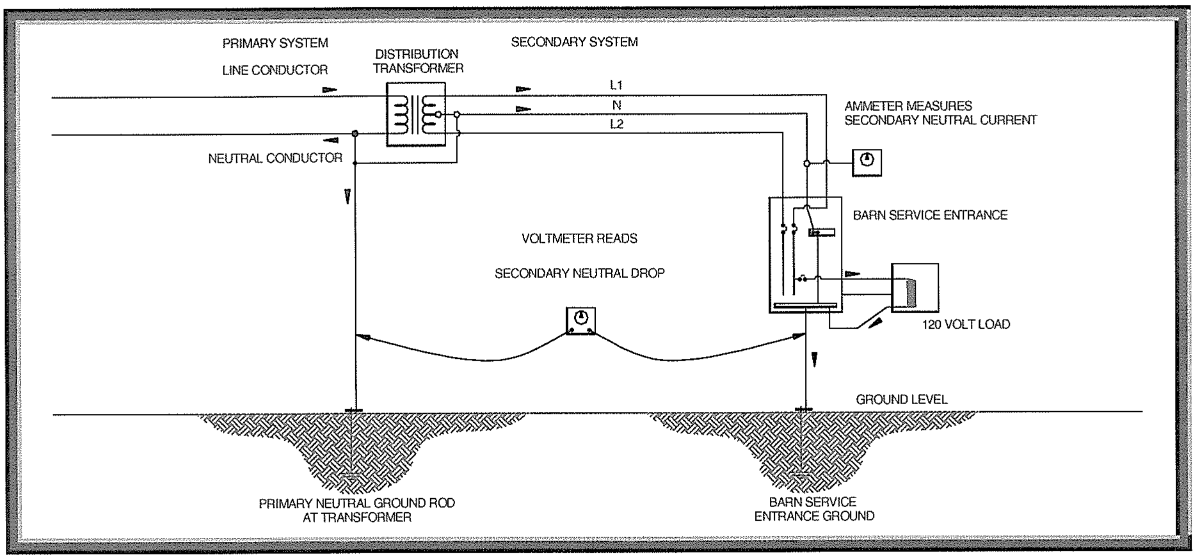

Figure 4
Secondary Neutral Test

APPENDIX 1
CUSTOMER SYSTEM TEST PROCEDURE

Customer Name						Comments
Address						
Contractor's Name						
			Year	Month	Date	
Investigation						
Previous Investigations						
6.1 AS FOUND NEV & STRAY VOLTAGE TESTS						
On-Load Tests						
Time of Tests						
6.1.1	Neutral-to-Earth Voltage (NEV)					
6.1.2	Stray Voltage					
6.1.3	Calculated Stray Voltage/NEV Ratio					
6.2 INTERPRETATION OF 72 HOUR RECORD						
6.2.1	Max Neutral-to-Earth Voltage (NEV)					
6.2.2	Date of Maximum NEV					
6.2.3	Time of Maximum NEV					
6.2.4	Calculated Stray Voltage					
6.2.5	Stray Voltage Problem (Y/N)					
6.2.6	Hydro Contacted (Y/N)					
7.1 BONDING TEST						
7.1.3	Lead Resistance					
7.1.4	Locations Requirng Improvements					
7.1.4	Locations Requirng Improvements					
7.1.4	Locations Requirng Improvements					
7.1.4	Locations Requirng Improvements					

APPENDIX 1
CUSTOMER SYSTEM TEST PROCEDURE

7.2 SERVICE GROUNDING RESISTANCE TEST				
7.2.4	Service Neutral Current			
7.2.5	Neutral-to-Earth Voltage (NEV)			
7.2.6	Calculated Barn Ground Resistance			
7.3 INSULATION TEST				
7.3.6	Insulation Resistance of Neutral Bus			
7.3.7	Insulation Resistance of Line 1 Bus			
7.3.7	Insulation Resistance of Line 2 Bus			
7.3.8	Insulation Resistance of 240 V Equipment			
7.3.8	Insulation Resistance of 240 V Equipment			
7.3.8	Insulation Resistance of 240 V Equipment			
7.3.8	Insulation Resistance of 240 V Equipment			
7.3.8	Insulation Resistance of 240 V Equipment			
7.3.8	Insulation Resistance of 240 V Equipment			
7.3.9	Insulation Resistance of Circuits <100 KOHMS, Identify Circuit			
7.3.9	Insulation Resistance of Circuits <100 KOHMS, Identify Circuit			
7.3.9	Insulation Resistance of Circuits <100 KOHMS, Identify Circuit			
7.3.9	Insulation Resistance of Circuits <100 KOHMS, Identify Circuit			
7.3.9	Insulation Resistance of Circuits <100 KOHMS, Identify Circuit			
7.3.9	Insulation Resistance of Circuits <100 KOHMS, Identify Circuit			
7.3.9	Insulation Resistance of Circuits <100 KOHMS, Identify Circuit			
7.3.9	Insulation Resistance of Circuits <100 KOHMS, Identify Circuit			

APPENDIX 1
CUSTOMER SYSTEM TEST PROCEDURE

7.4 SECONDARY NEUTRAL TEST						
7.4.3	Neutral Current					
7.4.6	Stray Voltage					
7.4.10	Neutral Current					
7.4.10	Secondary Neutral Voltage					
	Impedance of Neutral Conductors					
	Bare Copper		Aluminum			
Size AWG	MilliOhms/Ft	MilliOhms/M	MilliOhms/Ft	MilliOhms/M		
#8	0.640	2.101	1.050	3.445		
#6	0.410	1.345	0.674	2.211		
#4	0.259	0.850	0.424	1.391		
#2	0.162	0.531	0.266	0.873		
#1/0	0.102	0.335	0.168	0.551		
#2/0	0.081	0.266	0.133	0.436		
#3/0	0.064	0.211	0.105	0.344		
#4/0	0.051	0.167	0.084	0.274		
7.4.11	Calculated Voltage Drop					
	Eg. Length = 35 M, #4 Alum., Current - 23 A					
	Voltage Drop = 35 x 1.391/1000 x 23 = 1.20 Volts					
7.4.12	Secondary Neutral Acceptable (Y/N)					
	Implemented Improved Balancing (Y/N)					
	Increased Conductor Size (Y/N)					
	Other - Describe in Comments					
8.0 Stray Voltage Solutions						
	Solution Required (Y/N)					

Appendix 'D'

- Stray Voltage Manual for Electrical Contractors DRAFT (ESA)

Stray Voltage Manual
For
Electrical Contractors

Electrical Safety Authority, September, 2007

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Appendices:

1.0 Introduction

The concept of tingle voltage (T.V.) is relatively simple electrically, although the sources can be varied and complex. As farm operations increase in size and sophistication, as farmstead electrical wiring systems become obsolete or deteriorate, and as electrical loads on rural distribution systems increase, it is likely that T.V. problems also will increase. However, with a good understanding of the sources and their interactions, the electrical nature of the problem, and the effects of the electrical characteristics of the system, the T.V. problem can be analyzed and corrected. ESA offers the following guideline in the effort to mitigate tingle voltage.

2.0 Objective

The objective of this document is to provide guidelines for the Tingle Voltage Filter (T.V.F.) or similar devices as a long term solution to the Tingle Voltage (T.V.) problem. It also includes more detailed testing and installation instructions for the T.V.F., installation instructions for two additional T.V. solutions, results of agricultural research into T.V. and appendices. This document is a guideline only as there may exist others solutions that could be implemented. ESA recommends the services of a licensed electrical contractor.

3.0 Solutions to Tingle Voltage

The solution to any problem that exists on the customer's system is to repair the defective circuit or make any necessary upgrade. Generally, most problems on the customers system can be eliminated by adopting today's wiring practices. Up-to-date wiring is recommended not just for solving T.V. problems on the farm but also to help eliminate potential fire and shock hazards.

The customer has three solutions available at present, the Tingle Voltage Filter, the Equipotential Grid, and the Isolation Transformer.

All three solutions have the ability to reduce the T.V. to a level of less than the one volt maximum (established by the Ontario Ministry of Agriculture and Food) Assuming all faults on the customer's system are located and repaired, and the particular solution is properly installed.

The Equipotential Grid is now mandatory for new milking parlours and should be considered for new tie stall barns also. It should be located in all areas where livestock could be affected. (e.g., near water bowls). This grid however, is not easily retrofitted into existing barns.

Isolation Transformers are generally dry core type transformers that are sized to the load and cannot withstand overloads. They tend to be inefficient, inflexible and costly.

The T.V.F. is the most economical solution for existing barns and is therefore recommended for these installations.

All three solutions will protect livestock from sources of T.V. from "off-the-farm" and "on-the-farm" sources such as voltage drops on secondary neutrals and faults in other buildings. The Grid is the only solution that protects from faults in the same building.

4.0 Installation Instructions for the Tingle Voltage Filter

The following instructions are adequate, in the majority of cases, to install the filter satisfactorily. However, the references listed at the end of each of the instructions will contain more detailed information, should it be required e.g., Section A.

1. Measure and record the T.V. between animal contact points. If the value of voltage measured is greater than or equal to 5 volts, contact your Local Distribution Company (LDC). (A.1.2.1)
2. Turn all power off. (A.2.5)
3. Ensure that all circuits are de-energized. (A.2.5)
4. Remove the grounding conductor from the neutral block. (A.2.5)
5. Remove the neutral block bonding screw or bonding strap. (A.2.5)
6. Remove all bonding cables from the neutral block. (A.2.5)
7. Connect the bonding cables to the service box enclosure with the grounding strip supplied with the filter. This strip is to be mounted inside the service entrance enclosure. (A.2.5)
8. Mount the T.V.F. as near as practicable to the main service equipment. (A.2.7)
9. Connect the service neutral block to the neutral terminal of the T.V.F. with a white insulated conductor sized according to Table 17 of the Ontario Electrical Safety Code. This conductor must be run in a non-metallic raceway.. (A.2.7)
10. Connect the ground terminal of the T.V.F. to the grounding electrode and to the service entrance enclosure with a grounding conductor selected according to Table 17 of the Ontario Electrical Safety Code. (A.2.7)
11. Check all work and replace covers. (A.2.7)
12. Close the service switch, and any other isolation switches previously opened. Close all branch breakers and/or replace all branch circuit fuses. (A.2.7)

In order to verify that the T.V.F. is working, take voltage readings as follows:

1. Short out the filter with a wire jumper (or clip cord) by connecting the "Ground" and "Neutral" terminals together. (A.2.8.1)
2. Measure the T.V. between animal contact points in the barn. Turn on various loads in the barn to obtain the highest reading. Note this value. (A.2.8.2)
3. While monitoring the T.V., remove the wire jumper (clip cord) installed in (1) above. The voltage should decrease by a ratio of 10:1 and should not be greater than 1 volt. (A.2.8.3)
4. If the value of voltage is greater than or equal to 5.0 V, contact your LDC. (A.2.8.4)
5. If the ratio in (3) above is less than 10:1 refer to Section 5.0 Trouble Shooting and make repairs as necessary. (A.2.8.5)

5.0 Trouble Shooting the Tingle Voltage Filter

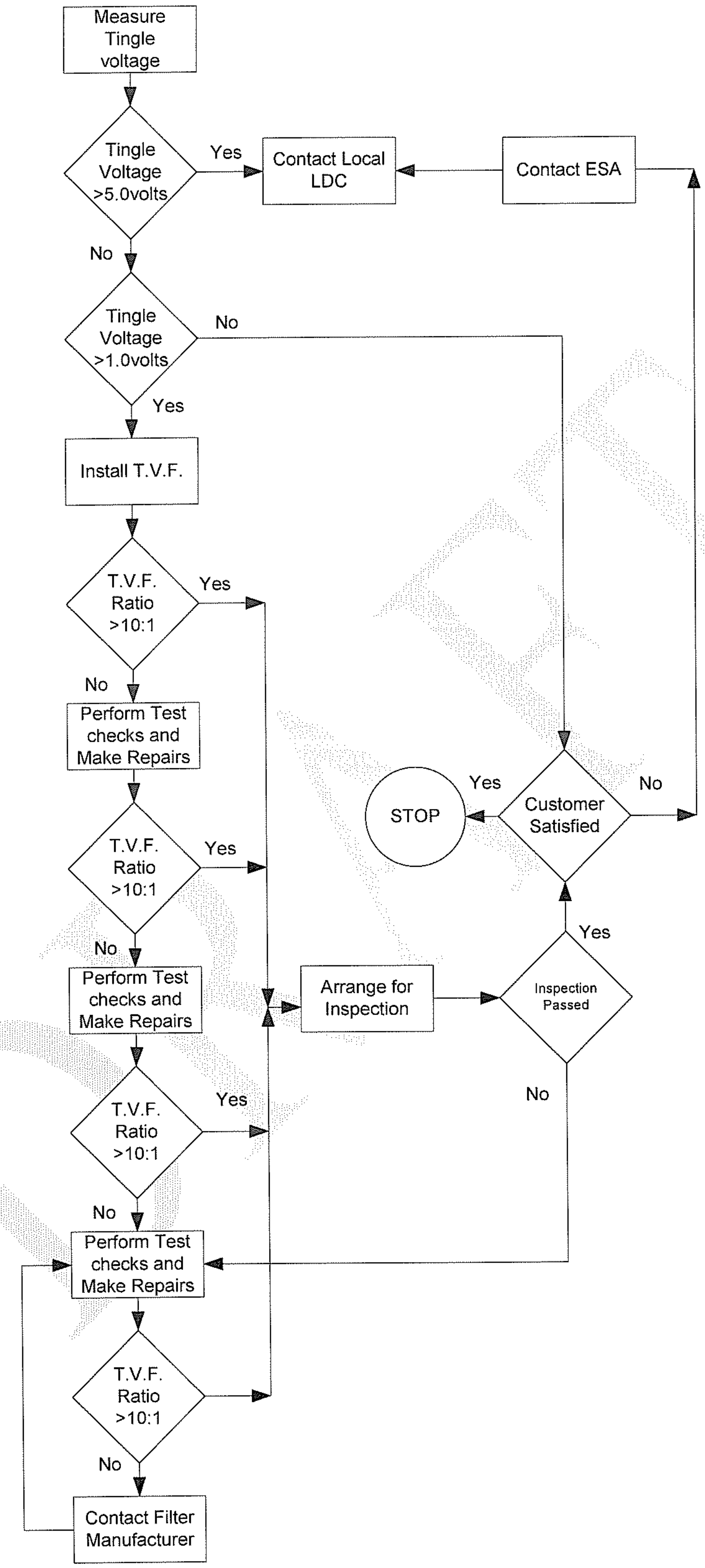
5.1 Visual Checks (A.2.9.1)

The references listed at the end of each section will contain more detailed information should it be required.

1. Bonding screws and/or straps left in sub panels and disconnects. (A.2.9.1.a)
2. Wiring errors. (A.2.9.1.b)
3. Poor workmanship. (A.2.9.1.c)
4. Deteriorated insulation in equipment. (A.2.9.1.d)
5. Metallic water pipe from barn to another building. (A.2.9.1.e)
6. Neutral of service triplex touching metallic service mast. (A.2.9.1.f)
7. Neutral block in meter socket grounded. (A.2.9.1.g)
8. Neutrals of different circuits in contact with each other. (A.2.9.1.h)
9. Circuit from other building touching barn grounding. (A.2.9.1.i)
10. Telephone fed by underground cable. (A.2.9.1.j)
11. Bare neutral in metal service entrance conduit. (A.2.9.1.k)
12. Connection between the neutral and ground other than through the filter. (A.2.9.1.l)
13. Two services in the same barn. (A.2.9.1.m)

5.2 Test Checks

1. Insulation resistance. (A.2.9.2.a)
2. Bypass external to the barn. (A.2.9.2.b)
3. Ground system resistance for the service. (A.2.9.2.c)
4. D.C. current. (A.2.9.2.d)



T.V.F.: Test Procedure for Electrical Contractors

A.1 Detailed Tingle Voltage Test Procedure For Livestock Barns

The following procedure was developed by Ontario Hydro to:

a) test for the presence of T.V., and
b) find the source of T.V. in livestock barns.

It is assumed that the procedure will be executed by a qualified person who:

a) has a good understanding of basic electrical theory and customer wiring
b) has a basic understanding of T.V. problems
c) is skilled to safely disconnect and restore distribution panel wiring.

A.1.1 Test Equipment

The equipment listed below is required and/or recommended to perform the testing.

1) Multimeter

- Beckman model 310
- Hioki 3200
- Simpson Model 234, (A. 5-10 MFD capacitor rated for AC voltage must be added in series with test leads to block D.C.)

(NOTE: All discussions contained in this test procedure assume the Beckman 310 is USED).

2) Bridging Resistor*

2 -Ohmite type 2918 (10K, 51/4 W)
2 -mounted on plug H.H. Smith type 1677-102

*The purpose of the bridging resister is:

- to offset the effects of voltages induced in stanchion or voltmeter leads from adjacent power circuits
- to provide a standard measurement technique

3) Insulation Tester (Megger)

- 0-100 MΩ insulation, 0-100 Ω cont., 500 V test, battery operated, electronic or manual driven.

4) Long Test Lead (three required)

- 100m or #18 stranded wire
- with wind-up device, large alligator clip on one end, banana plug on the other end.

5) Sharp Test Probe (or equivalent)
   - used to penetrate paints, rusts, etc.

6) Floor Contact Probe
   - 10 x 10 x 3 cm piece of styrofoam, wrapped in aluminum foil works well, when stood on. A piece of steel heavy enough to remain stationary with a facility for a lead attachment also has been found to be satisfactory.
   - connect to foil with alligator clip

7) Ground Probe Rod
   - standard ground rod. A sledge hammer or ground rod driver will also be required.

8) Miscellaneous Hand Tools
   - required to remove covers, wires, etc.

9) Pocket Calculator (optional)

10) Earth Resistance Tester (Earth Megger) (optional)
    - Range 0 – 10 kV, Type ET5, Battery operated

11) Variable Resistor
    - Range 0 – 25 ohms (3 watts)

A.1.2 Tingle Voltage Test Procedures

This procedure consists of three tests.

The three tests are as follows:

- Tingle Voltage Test
- Customer Barn Grounding System Resistance Test
- Bonding Test

Experience has shown that the barn grounding system resistance of a modern barn with all the metal structure properly bonded is rarely above 10 Ω. This means that the grounding test is rarely required. When a T.V.F. is installed, proper operation of the filter depends on the barn grounding system resistance being less than 10Ω. If the electrical contractor wishes to verify the value of the resistance and is not equipped with an earth megger, he should refer to Section A.1.2.2 Method 2 (Method 2 does not require an earth megger).

BONDING IS MANDATORY WHERE MAJOR WIRING MODIFICATIONS ARE BEING MADE, OR A NEW BARN IS BEING WIRED. THE INSTALLATION OF T.V.F IS IN ADDITION TO THE REQUIREMENTS FOR BONDING AND, THEREFORE, THE COST OF BONDING SHOULD NOT BE RELATED TO THE INSTALLATION OF THE FILTER.

Throughout this procedure:

i) voltage between any neutral conductor and remote earth is referred to as Neutral to Earth (N-E-V) Voltages.

ii) voltage between animal contact points (e.g. Metal stanchion and the concrete floor under the back feet of animal) is referred to as T.V.

These procedures assume that all tests will be performed with the primary and secondary service neutrals connected.

If the primary and secondary neutrals at the transformer have been disconnected by your LDC refer to Appendix 9 for direction, otherwise some of the Service Preparation, Pre-Installation, and Final Tests results will be meaningless.

A.1.2.1 Tingle Voltage Test

Objective: To measure the level of T.V. the livestock is being subjected to.

Procedure:

1.1 Select the 2.0 V AC range on the multimeter. Plug in the bridging resistor. Note: Throughout this procedure, when measuring voltage, the reading should be taken on the lowest scale that does not produce an overload (OL) indication. The bridging resistor should always be used to avoid incorrect readings due to pick-up.

1.2 Connect one lead of the voltmeter to the floor contact probe (this could be a metallic plate positioned on the stables concrete floor or gutter), connect the other lead to a typical animal contact point such as a water bowl, or stanchion. Moisten the area under the contact probe to ensure good contact. Good contact can be verified by repeating the reading with a second bridging resistor plugged in on top of the first. If there is no significant change in the reading, good contact has been made.

1.3 Locate the area in the barn where the highest reading exists under normal load.

1.4 Monitor the AC and DC voltage while the farm service entrance load is varied from full load to no load. Record the results.

1.5 If the value of voltage measured (no-load or full-load) is greater than or equal to 5.0 volts, contact your LDC.

1.6 If the highest AC voltage measured in 1.5 does not exceed 1.0 V, this does not guarantee that the event will not occur at a later date because T.V. can be transient. There can be a daily change or the change can be erratic.

Interpretation:

Appendix 1 is a simplified schematic of a typical farm electrical system. Referring to Appendix 1, the first livestock contact point is the metal stanchion, the second is the concrete floor under the animal's back feet.

Acceptable T.V. levels are 1.0 V AC or DC between animal contact points. Voltages measured during off peak hours will be substantially less than those during the peak period, which in a dairy operation, is during milking. Therefore, the full load test should simulate the milking operation loading.

A.1.2.2 Customer Barn Grounding System Resistance Test

Objective: To measure the resistance of the barn grounding system

Procedure:

Method 1

2.1 Open the service entrance breaker at the barn.

2.2 Remove the secondary service supply neutral.

2.3 Using the method associated with the earth megger, measure the barn grounding resistance. If an Earth Megger is not available, go to Method 2. This level should be 10 Ω or less in accordance with Rule 10-704 of the Electrical Safety Code. Values of 5 Ω or less are readily attainable in most installations.

2.4 If in 2.3, 10 Ω is exceeded, refer to method 2 interpretation.

2.5 If 10 Ω is not exceeded restore the secondary supply neutral.

Method 2

2.2.1 Remove the connection from the neutral bar to the T.V.F. Insert a 0-25 Ω (3 watts) variable resistor (rheostat) between the neutral bar and the grounding strip in the service box.
2.2.2 Set the variable resistor to zero ohms. Note the reading on the multimeter.
2.2.3 Measure the voltage between the grounding strip and the barn floor as shown in Appendix 7. Note, this will be the voltage the animals are exposed to in the barn, with all the metal structures properly bonded.
2.2.4 Increase the resistance of the variable resistor until the voltage decreases to one half of the value noted in item 2.2.3 above.
2.2.5 Measure the voltage between the neutral bar and the grounding strip.
2.2.6 The voltage measured in 2.2.5 should be the same as the voltage measured in 2.2.4
2.2.7 If the two voltages are unequal adjust the rheostat until they are equal.
2.2.8 Disconnect the variable resistor being careful not to alter the setting
2.2.9 Measure the resistance value of the variable resistor with the multimeter. This value is the value of the barn grounding system resistance. For proper operation of the filter, it is recommended that this value be reduced to 10 ohms or less.
2.2.10 Replace the connection from the neutral bar to the T.V.F.

Interpretation:

A primary and secondary grounded neutral system is shown in Appendix A.

Reduction in the "on-the-farm" or, in particular, the barn grounding resistance, reduces the level of T.V. However, there is a point where this approach is no longer cost-effective. OESC Rule 10-702 outlines the requirements of installation for artificial electrodes.

The most common cause of a high ground resistance is a corroded or defective ground rod clamp and/or deterioration of the rod electrode due to corrosion. Insuring that all connections from the service panel to its associated ground rod electrode is "clean", that the barn service entrance neutral is bonded to the water system and all metal in the barn, such as the stanchions will usually decrease the barn grounding resistance and to ensure that all metallic structures are at equipotential.

If high ground resistance prevails (a) adding additional ground rods, separated by at least three times the length of the rod being added, for maximum effect, (b) bonding to a well casing with #6 conductor, (c) driving deeper ground rods (e.g. stack 2 or 3 rods on top of each other and bond them together) and/or (d) placing #6 copper conductor at least 2 feet under the soil, around the barn in a circular or rectangular pattern, should reduce the ground resistance to an acceptable value.

A.1.2.3 Bonding Test

Objective: To determine if all metal parts in the barn have a low resistance path to the service entrance ground as required by the Electrical Safety Code, Rule 10-406 (5).

Procedure:

3.1 Open the barn service entrance main breaker or switch.
3.2 Select the 200 Ω range on the multimeter.
3.3 Using a long test lead, connect one terminal of the multimeter to the service entrance ground. Connect the other terminal to a sharp probe.
3.4 Touch the sharp probe to the service entrance ground to determine the lead resistance. This should be less than five ohms.
3.5 Move around the barn and contact each metal part with the sharp probe.
3.6 Record as improperly bonded, any metal part that has a reading 1 Ω higher than the lead resistance measured in 3.4.

Interpretation

The equipment bonding conductor provides a low resistance path to open a fuse or operate a circuit breaker if the phase or "hot" conductor comes in contact with the enclosure. Bonding all metal parts provides the same protection against frayed extension cords or defective power cords on portable equipment which might contact the metal structure. Bonding these parts also helps to eliminate any induced T.V.

A.2 Detailed Installation Instructions For The Tingle Voltage Filter

A.2.1 Application

The T.V.F. is for use on livestock barn services to eliminate the effects of T.V. on livestock and is not applicable for residential applications. These instructions are based on the assumption that one of the causes of T.V. in the barn is due to voltages up to 100 Volts on the primary neutral.

A.2.2 General

1. The device is installed in series with the grounding conductor between the neutral block and the grounding system, at the main service entrance.
2. In order for the device to function, the only grounding connection to the neutral at the barn service entrance is through the filter. Any other contact between neutral and ground will "bypass" the filter and thereby defeat its action.
3. As with any electrical installation, electrical inspection is a requirement.

A.2.3 Filter Rating

1. The filter rating must be at least equal in rating to the main overcurrent device. The filter is marked with a maximum ampere rating e.g., 200 A.
2. A paralleling kit and instructions are available from Hammond Manufacturing. For larger services (600 A and larger) the T.V.F. cannot be used.

A.2.4 Service Arrangement

1. There must be one main overcurrent device at the service in question (ie., fuses, circuit breakers or equivalent).
2. The incoming neutral must be insulated if installed in a metallic conduit. If a bare neutral has been used in a non-metallic raceway the neutral conductor must not touch grounded metal parts. In the service equipment tape or sleeving over the bare neutral conductor should be applied.
3. The service equipment must be approved for the service entrance.
4. The distribution panel must have provisions for terminating branch circuit bonding conductors.
5. The existing service and distribution equipment must be in good condition and meet the requirements of items 1, 2, 3 and 4 above otherwise the equipment should be replaced.
6. If there is more than one electrical service on the building in question a T.V.F must be installed on each service unless the two services are completely isolated from each other such that a "Bypass" is impossible.

A.2.5 Service Preparation

1. De-energize the electrical service to the building and remove covers from service equipment. If an additional means of isolation is available, such as a pole top transfer

switch or a farm service switch it should also be opened for added safety. ESA does not recommend working on the main breaker of a service panel while it is energized.

2.Check with a voltmeter to ensure that all circuits are de-energized.
3.Remove the incoming neutral conductor from the neutral block.
4.Remove the grounding conductor from the neutral block.
5.Remove the neutral block bonding screw or bonding strap, that bonds the neutral block to the service entrance enclosure.
6.Remove the metal service raceway bonding jumper, water system bonding conductor, stanchion bonding conductor and any other bonding conductor attached to the neutral block. These bonding conductors should then be connected to the service box enclosure with the grounding strip supplied with the filter. The strip is to be mounted inside the service entrance enclosure (see Appendices 2 & 3).

Whenever major wiring alterations are being made in a barn, or when a new barn is being wired it is a requirement of the Ontario Electrical Safety Code that all stanchions, metal stalls and structural steel, be bonded together with #6 A.W.G. copper conductor to the service equipment enclosure. When a T.V.F. is installed the bonding at the service equipment enclosure is made with the grounding strip installed in Item 6 above, and should be verified using the Bonding Test outlines in Section A.1.2.3.

A 2.6 <u>Recommended Pre Installation Test</u>

Testing the barn wiring with a 500 V megger will check for bypasses in the barn wiring system and by achieving reasonable high insulation levels, the continued proper operation of the filter can be expected.

Measure the insulation resistance value of the barn neutral system as detailed on Appendix 5, Insulation Test Method 1.

A good installation is expected to have an insulation resistance in excess of 50,000 Ω . If the resistance is less than 5000 Ω it is recommended that the poor circuits be identified and improved.

If the resistance is less than 1500 Ω it is likely that the filter will not function properly. Refer to Section A.2.9 Trouble Shooting.

A.2.7 <u>Installation</u>

1. Mount the T.V.F. as near as practicable to the main service equipment (not to be located more than 3 metres from the main service).
2. Connect the service neutral block to the neutral terminal of the T.V.F. with a white insulated conductor sized according to Table 17 of the OESC. This conductor

must be run in non-metallic raceway unless the neutral and ground are run in the same cable assembly or raceway (see Appendices 2 & 3).

3. Connect the ground terminal of the T.V.F. to the grounding electrode and to the service entrance enclosure with a grounding conductor selected according to Table 17 of the Ontario Electrical Safety Code. (See Appendices 3 & 4).
4. Reconnect the incoming neutral conductor to the main service neutral block.
5. Check all work and replace covers.
6. Re-energize the service, close the service switch, and any other isolation switches previously opened.
7. Close all branch circuit breakers and/or replace all branch circuit fuses.

A.2.8 Final Tests

In order to verify that the T.V.F. is working, take voltage readings as follows:

1. Short out the filter with a wire jumper or clip cord by connecting the "Ground" and "Neutral" terminals together
2. Measure the T.V. between animal contact points in the barn. Turn on various loads in the barn to obtain the highest reading. Note this value.
3. While monitoring the T.V., remove the clip cord installed in 1 above. The voltage should decrease by a ratio of 10:1 and should not be greater than 1 volt.
4. If the value of voltage measured in 2 above is greater than or equal to 5 volts, contact your LDC..
5. If the ratio in 3 above is less than 10:1 refer to Section A.2.9 Trouble Shooting and make repairs as necessary.

A.2.9 Trouble Shooting

If the final tests indicate a voltage ratio of less than 10 the filter is not working properly. The following checks and tests will help in determining the cause. These checks are listed in order of probability and simplicity.

A.2.9.1 Visual Checks

Most common problem is a "bypass" circuit which is a connection between neutral and ground which may be caused by:

(a) All bonding screws and/or straps not being removed from sub panels and disconnects.
(b) Wiring errors – neutral and ground connections interchanged.

(c) Poor workmanship – bared neutral conductor touching enclosures.
(d) High leakage currents due to deteriorated insulation in equipment such as watering bowls, where insulation resistance is less than 1500 ohms.
(e) A metallic water pipe running from the barn to another building which contains a service. This will bypass the filter and a length of non-metallic pipe must be installed in the water line. (See Appendix 4).
(f) Neutral of overhead triplex cable touching the metallic service mast or steel frame or siding of the barn (failed spool insulators have been found).
(g) A meter base, if located on the barn service can be a potential bypass as the neutral block in the meter base is grounded. In this situation the neutral must be insulated from the meter base enclosure and if the service conduit is non-metallic the socket enclosure must be bonded to the service box enclosure with a copper bonding cable, sized as per Table 17 of the Ontario Electrical Safety Code (#6 for 100A, #3 for 200 A).
(h) If a circuit (such as yard lights) runs from building to building the identified conductor (neutral) of the circuit must not contact the neutral of any service other than for the one where it originates.
(i) If the circuit originates in another building the neutral of this circuit must be contact any portion of the grounding in the barn where the light or equipment is installed.
(j) If the barn has a telephone fed by an underground cable, the grounded cable sheath of the telephone cable will "bypass" the filter, if the telephone cable sheath is left connected to the barn ground system. To eliminate the possibility of a "bypass"", the telephone ground must be reconnected to the neutral at the service and <u>communication company must be contacted for assistance and/or authorization prior to disconnection or reconnection.</u> (See Appendices 2 & 3). A continuous (splice free) minimum 12 AWG, insulated, copper conductor must be run from the telephone protector to the neutral bar. A box connector must be used where this conductor enters the enclosure. Additional insulation must be applied to the conductor at the box connector to prevent insulation damage.
(k) If there is a bar neutral in the metal service entrance conduit, this will "by-pass" the filter. This neutral must be insulated.
(l) The only connection between neutral and ground must be through the filter so all other mechanical and/or electrical connections must be removed.
(m) Two services into the same barn must be electrically and mechanically isolated or a filter must be installed on each service.

A.2.9.2 Test Checks

If visual checks do not isolate the problem the following tests will help to identify issues.

(a) Insulation Tests: Make certain that all power is off. Refer to Appendix 6 and follow to procedure for checking each branch circuit for poor insulation resistance. Any circuits less than 1500 ohms are to be upgraded.

(b) Bypass External to the Barn: This type of Bypass can be detected by referring to Appendix 7 and following this test.

(i) Disconnect the neutral from the T.V.F. at the Filter.
(ii) Disconnect the incoming neutral at the service switch.
(iii) Using a suitable length of insulated wire (minimum gauge #18) as a test lead (A.1.1.4) and a voltmeter (A.1.1.1) as described under Section A.1.1, "Test Equipment", measure the voltage between the barn floor and the grounding strip installed and record the reading. Ensure that the incoming neutral is not connected to the neutral block for this test (see Appendix 7). If this voltage is 50mV (1/20th volt) or less than there are no bypass connections between other service neutrals and the barn grounding. If the voltage is over 50mV there is a probability of external bypasses as shown in Appendix 4 and these must be cleared.

Temporarily re-connect the incoming neutral conductor to the neutral block .Measure the voltage as in (iii) above and record. If the voltage is higher than 50mV then there are still neutral to ground faults in the barn wiring and they must be cleared, return to step (iii) above.

(c) Ground Resistance

The ground system resistance for the service entrance must be 10 ohms or less.

(Refer to section A.1.2.2 for procedure).

In most cases where the plumbing, stanchions, structural steel and ground rods are all bonded together the ground resistance will be less than 10 Ω.

(d) DC Current

There exists a very remote chance that a DC current could be present on the neutral. If a DC current saturates the filter it will not function.

This condition can be tested as follows:

(i) Turn off the power.
(ii) Disconnect the incoming neutral.
(iii) Connect a 1 ohm resistor between the incoming neutral and the neutral block.
(iv) Use a D.C. voltmeter and measure the D.C. voltage across the 1 ohm resistor. The volt meter used must be capable of measuring voltages between 10 and 50mV (1mV equals 1/1000 volt).
(v) If the measured voltage is over 30mV (30/1000 volts) reconnect the neutral to the neutral block. Contact your Local LDC.

A.3 Tingle Voltage Indicator

A tingle voltage indicator (T.V.I.), developed by Hammond Manufacturing, is now available to be used in conjunction with the T.V.F. or on its own. This unit will indicate the presence or absence of T.V; the reoccurrence of T.V. after a long period of time and has a memory function when and if T.V. exceeds 1.0V.

For more information on the T.V.I., contact any Hammond Distributor and/or Hammond Manufacturing.

B.1 Installation Instructions For the Equipotential Grids

B.1.1 Function

To isolate the affected area from "off-the-farm" sources of T.V. This solution is now mandatory for new barns which are to be equipped with milking parlours. It is also worthy of consideration for new tie stall barns depending on the size of the barn as dictated by installation costs..

B.1.2 Installation

The details of the installation are shown on sheets 1 through 3 Appendix 9.

Use of accelerators in the cement (rapid curing agents) is not recommended. These agents contain chloride which will accelerate corrosion of the steel wire mesh. If the installation of the grid is during the winter months and accelerators are a must, the amount of accelerator added to the concrete mix should not exceed 2.5% by weight.

All electrical connections between the steel wire mesh, the grounding conductor and the metal stanchions should be brazed. The brazing rod used for this process must be of an alloy suitable for connecting the two metals involved, eg. Connection of the ground wire to the steel mesh will require an alloy suitable for a copper/steel connection.

Refer to sheet 1 of 3 of Appendix 9, note that it is not necessary to run the #6 copper ground wire the length of the milking parlor, in order to bond the exit and entrance areas together when the steel wire mesh is continuous within the milking parlour. In this situation, it is sufficient to bond sections together using a minimum length of copper ground wire. All sections or discontinuities in the steel wire mesh should be bonded together at a minimum of four places. This can be accomplished by welding one section directly to the other, or by using a piece of the #6 copper ground wire as a "jumper" connecting the two sections. Each end of the jumper should be welded to a section.

B.1.3 Electrical Tests

Adequate operating performance of the equipotential grid may be verified by taking two simultaneous voltage readings. The first reading is taken between any bonded metal part in the milking parlour and a remote ground rod placed at least 15 metres from the barn. This reading measures the total N-E-V voltage. The second reading is taken between animal contact points in the milking parlous. This reading measures the total T.V. The second reading should be repeated at several locations in the parlour to determine the highest reading. The ratio of the first reading to the second should be 50 to 1 or greater.

B.2 Installation Instructions For the Isolation Transformer

B.2.1 Function

To isolate the affected area from "off the farm" sources of N-E-V voltage. Normally, this means installing the transformer ahead of the barn service entrance equipment in order to isolate the barn.

B.2.2 Pre-Installation Tests

In order to ensure that the source of the T.V. is "off the farm", the Insulation Test (Appendix 6), Customer Barn Grounding System Resistance Test (Section A.1.2.2) and Bonding Test (A.1.2.3) should be performed. If the wiring in the barn has not been upgraded for a number of years, a general electrical inspection by ESA is recommended subject to a nominal fee.

B.2.3 Instruction to the Electrical Contractor

2.3.1 Bypass Problems

The isolation transformer basically opens the mechanical connected tie between the LDC primary neutral and the customer's secondary neutral. Anything that re-establishes this tie will make the transformer ineffective as a solution. The most common by-pass is an underground service such as the communication(telephone) underground cable when there is a phone in the barn. The cable sheath on the underground cable is usually tied to the LDC primary neutral. If this is connected to the ground electrode in the barn, the isolation transformer will be by-passed. This problem can be eliminated by requesting the communication company to connect their cable sheath to the enclosure of the isolation transformer which is connected to the neutral conductor from the supply transformer. Another alternative is to have the communication company install a separate ground electrode for their cable sheath. The second ground electrode must be a minimum of 2 meters from any other electrodes as required by Rule 10-702 of the Ontario Electrical Safety Code.

Another common by-pass is the farm water system. It is a requirement of the Ontario Electrical Safety Code to connect the secondary neutral to the water system at any service box. If there is a metallic connection from the house to the barn, or any other electrical service entrance to the barn, the transformer will be by-passed. This problem is easily resolved by inserting a 0.5 m length of non-conducting pipe in the water system entering or leaving the barn.

2.3.2 Transformer Size

The transformer must be sized to supply the peak load of the service entrance being isolated. Some additional capacity should be allowed for load growth. It is expected the transformer will be a dry-core type transformer. It should be noted that dry-core type transformers have virtually no overload capabilities.

2.3.3 Availability

Several companies manufacture dry-core type transformers of a suitable size. These should be available through any electrical wholesale distributor.

2.3.4 Means of Isolation

The transformer is connected between the supply transformer and the barn service entrance equipment. In accordance with the

Ontario Electrical Safety Code Rule 26-250, a disconnect must be installed in the primary circuit of the isolating transformer.

2.3.5 Transformer Location and Mounting

The Ontario Electrical Safety Code Rule 26-248, specifies these requirements.

Note

A dangerous voltage can develop between the primary neutral and the customer's ground electrode under fault conditions. In order to reduce this risk, it is recommended that the transformer be mounted external to the barn or allow two meters in distance between equipment connected to the two ground electrodes.

2.3.6 Overcurrent Protection

The Ontario Electrical Safety Code Rule 26-256 specifies overcurrent requirements.

2.3.7 Conductor Size

The Ontario Electrical Safety Code Rule 26-256 specifies the ampacity of the conductors on the primary and secondary of the transformer. It states that the ampacity of both the primary and secondary conductors must have a rating not less than 125% of the rated current of the transformer.

2.3.8 Lightning Protection

Lightning protection is recommended although not mandatory. Ontario Electrical Safety Code Rules 26-500 to 26-512 cover the installation of lightning protection.

2.3.9 Electrical Connections to the Transformer

All conductors from the supply or circuit breaker shall terminate at a fused disconnect switch. From the fused disconnect switch, the phase conductors L1 and L2 will terminate on the primary of the isolation transformer; the neutral conductor will terminate on the enclosure of the isolation transformer. Any internal shield in the isolation transformer will be connected to the enclosure. The secondary neutral conductor from the isolation transformer to the service box must not be connected to the case of the transformer. All three secondary conductors (L1, L2 and N) terminate in the barn service box. If a bare secondary neutral conductor is used, it must be insulated in areas where it could touch the enclosure of the isolation transformer or any other metal part. If the secondary neutral makes contact with the case, the isolation transformer becomes bypassed.

2.3.10 <u>Customer Grounding</u>

With installation of the isolation transformer, low resistance customer grounding at the barn is essential as the customer ground electrode it is electrically separated from the LDC grounding system. Therefore, the requirements of the Ontario Electrical Safety Code Rule 10-701 is critical. . Rule 10-704 stipulates, where practicable, the barn grounding system must have a ground resistance of no great than 10 ohms.

B.2.4 <u>Electrical Tests</u>

Following the installation of the transformer the following tests are recommended:

1. Open all branch circuit overcurrent devices in the barn. Close the supply switch or circuit breaker to the transformer and measure the voltage L1 – L2, L1 – N, L2- N, at the distribution panel to insure normal voltage levels.
2. Measure the N-E-V voltage on the primary and secondary of the transformer. A voltage in excess of 0.1 VAC on the secondary indicates the transformer is being by-passed. This by-pass must be eliminated.
3. Close all branch circuit overcurrent devices in the barn panel. Energize the barn loads. Measure the highest T.V. between animal contact points. This voltage should not exceed 0.1 VAC. If it does, further investigation for faults or wiring deficiencies is required.

<u>NOTE:</u> RESEARCH IS STILL BEING CONDUCTED INTO IMPROVING EQUIPOTENTIAL GRID INSTALLATIONS. THEREFORE, CONTRACTORS WHO WILL BE IMPLEMENTING THIS SOLUTION SHOULD ENSURE THAT THE GRID INSALLATION INSTRUCTIONS ARE THE MOST CURRENT. SIGNIFICANT CHANGES ARE NOT EXCEPTED HOWEVER ANY CHANGES COULD MAKE THE INSTALLATION SIMPLER AND/OR MORE ECONOMICAL.

YOUR LOCAL LDC COULD VERIFY THE AVAILABILY OF ANY NEW GRID INSTALLATION INFORMATION.

C.1 <u>Terminology</u>

Numerous terms are used to describe an electrical voltage that directly affects animals. Usually this voltage can be measured between metal equipment and the earth or between two points on the earth. The voltage can be transient. There can be a daily change or the change can be erratic.

C.1.1 <u>Neutral-to-earth voltage</u>

N-E-V is the voltage measured between the earth and the neutral conductor in either the customer's or the utility's electrical distribution system.

C.1.2 <u>Transient Voltage</u>

Is a voltage that is not constant. It can be a sudden voltage spike or a gradual rise and fall of the voltage.

C.1.3 <u>Tingle Voltage (T.V.)</u>

Is the portion of the N-E-V which appears on a metallic part of a farm structure or piece of equipment and which may affect the well-being of an animal which contacts them. T.V. is the voltage measured between animal contact points and is sometimes called neutral-to-earth voltage, transient voltage, stray voltage or stray current.

C.1.4 <u>Line Voltage</u>

Is a term understood to mean the actual voltage of a current, such as 120 or 240 volts.

The maximum N-E-V allowed on LDC's distribution system is 10 volts. This voltage is measured between a remote ground electrode (located at least 15 meters from the customer's existing transformer ground electrode or buried metal which is connected to the neutral) and the bare conductor connecting the primary neutral to the transformer ground electrode at the customer's supply transformer.

C.2 <u>Voltage Levels That Affect Animals</u>

The following guideline is applicable to persons working with T.V. problems:

volt ac and above may affect some animals under wet conditions. (8)

50 to 110 volts probably fatal. (9)

0.10 to 1.00 volt dc has not been determined to affect animals at the present time. (7)

C.3 Tingle Voltage Symptoms with Dairy Cattle

Animal reactions will vary depending on the severity of the problem .The following symptoms are commonly associated with T.V. problems in dairy operations according to Research by R.J. Gustafson at the University of Minnesota. (1)

C.3.1 Uneven milk out

The mechanism of how this occurs is not fully understood. However, when milk out is uneven, more machine stripping may be required and longer milking time may become necessary.

C.3.2 Cattle extremely nervous while in the parlour

This trait often is characterized by cattle dancing or stepping around almost continuously while in the parlour stall. However, dairymen are reminded that cattle may become nervous for other reasons, such as malfunctioning milking equipment or rough handling by the operator.

C.3.3 Cattle reluctant to enter the parlour

When cattle are subjected to T.V. in the parlour stalls, they soon become reluctant to enter the parlour. In extreme cases, nearly all the cattle have had to be driven into the parlour and there was a tendency to "stampede" out of the parlour upon release. But again, this symptom is not specific since cattle may be trained to expect the parlour operator to chase them into the milking stalls.

C.3.4 Increased mastitis

When milk out is incomplete, more mastitis (inflammation of the udder) is likely to occur. As white blood cells rush to fight the infections and are discarded in the milk, an increased somatic cell count may result.

C.3.5 Reduced feed intake in the parlour

If cattle detect T.V. while eating from the grain feeders, a reluctance to eat and reduce feed intake may occur.

C.3.6 Reluctance to drink water

T.V. may reach the cattle in stall barns through the water supply or metal drinking bowls. Thus, cattle may become reluctant to drink.

C.3.7 Decreased manure deposition in the parlour

It is common for operators to report a drastic reduction in manure deposited in the parlour following the solution of a T.V. problem.

C.3.8 Intermittent periods of poor 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 may result.

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 either symptoms. A careful analysis of all possible causes is necessary if the proper corrective procedure is to be found.

C.4 Sources of Tingle Voltage

These sources can be broken up into "on the farm", "off the farm" and "direct current".

C.4.1 On the farm sources

A major problem with T.V. on farms is that it may arise from several sources simultaneously. The voltage is often transient. The transient effect may vary predictably throughout the day or it may vary completely without pattern. The source may originate "on the farm" or "off the farm". Particular sources are more common in some locations than others.

On the farm T.V. may originate from the following sources:

a) Ground faults on the farm, either neutral or line faults.
b) Voltage gradients across the ground or floor arising from wires faulted in the earth.
c) Electric fencer wires shorting direct to equipment or inducing a charge in pipes and equipment.

d) Grounding conductor intentionally used as a neutral and a neutral used as a grounding conductor.

e) Voltage drop on the secondary service neutrals.

C.4.1.1 Ground Faults in Equipment

Voltage is produced at a farm by the LDC transformer. The flow of current originates at a transformer and tries to return to the transformer. Current can escape from the hot wire and return to the transformer through an alternate path such as the earth. If a grounding conductor is provided, such as wire or the metal raceway, sufficient current will usually flow when the fault occurs to open the fuse or trip the circuit breaker. In the case where adequate grounding is not provided, current must take a high resistance path through the earth. Usually sufficient current will not flow to open the overcurrent device. The result is a voltage between the shorted equipment and the earth. An animal or human may come in contact with the voltage between equipment and earth, or between points on the earth or floor that are at different voltages.

Ground faults can arise from numerous types of problems in wiring and equipment. Breakdown of insulation in equipment, or a loose connection can short to the metal frame. Wire may be damaged during installation, or insulation may wear thin due to excessive vibration or inadequate protection. These tend to be metal to metal faults which clear an overcurrent device if properly grounded. An improperly made splice in wire or dirt accumulation inside equipment may become conductive in damp or wet weather. These are generally high resistance faults which cause current leakage, but do not necessarily clear the overcurrent device.

C.4.1.2 Voltage Gradients

Voltage gradients through the earth or across a floor will occur when an underground wire faults to earth. This situation is really another form of ground fault. The insulation on an underground conductor may become damaged particularly if it is not buried at the proper depth (minimum 600 mm), or provided with mechanical protection.

Frequently current flow through the earth is not sufficient to clear the over-current device. The animal is therefore, subjected to a high voltage gradient between the front and rear hooves. Many animals have been killed due to voltage gradients created by faults in underground wires. If the wire is placed to a sufficient depth (minimum 600 mm or mechanically protected) into the earth, there is less chance a fatal voltage will occur at the surface.

C.4.1.3 Electric Fencers

Electric fence wires run through buildings can cause problems of T.V. Insulation breakdown may cause a fault to ground from an insulated electric fence wire to metal equipment inside a barn.

Another source of T.V., may be capacitive charge on sections of piping running parallel to an electric fence wire, such as with cow trainers. If a charge builds up in the pipe, the first cow to make contact may feel a shock as the charge is discharged to ground.

C.4.1.4 Grounding Conductor and Neutral Interconnections

An intentionally grounded conductor such as the neutral and the grounding conductor are only permitted to be directly connected at the service box to a building. These conductors are required to be kept separated for all feeders and branch circuits panels and equipment supplied by the service entrance. This is a requirement of the Ontario Electrical Safety Code.

The most common violations of the Ontario Electrical Safety Code rules on grounding are (1) using the grounded circuit conductor; (2) using the grounding conductor as a neutral, and (3) not grounding equipment. All three violations induce tingle voltages.

C.4.1.5 Voltage Drop on Secondary Service Neutral

Voltage drop in some situations on the neutral conductor of feeders supplying farm buildings can create a voltage between metal equipment and the earth or floor. The cause is too much neutral current flowing through an excessive neutral resistance. The load may be too high due to imbalancing the 120 volt loads in the building. High neutral resistance may be the result of a loose or oxidized connection, or it may simply be a case of an inadequately sized feeder for the load and length of run.

C.4.2 Off Farm Sources

The secondary service neutral conductor on the farm is generally connected to the utility primary neutral. This bond is provided to insure maximum safety to the customer particularly from lightning damage. This primary to secondary neutral bond can, however, introduce off-farm sources of T.V. Off-farm sources to T.V. have been traced to:

a) Voltage drop on primary neutral conductor.
b) Ground fault at neighbour's property
c) Fault in primary equipment or problem with primary grounding.

C.4.2.1 <u>Voltage Drop on the Primary Neutral Conductor</u>

A single-phase primary distribution line may consist of only two conductors. One of the conductors is grounded. Voltage drop will be experienced on the primary wires. If a large load is served, the voltage drop may become significant, thus producing an objectionable neutral to earth potential.

C.4.2.2 <u>Ground Faults at Neighbour's Property</u>

Current leaking into the ground from an energized conductor tries to find a path back to the grounded terminal of the transformer. The bond connections between the primary and secondary neutrals at each transformer may permit the fault current to find a path to the source transformer via the grounding electrodes at a neighbouring farm.

C.4.2.3 <u>Fault in Primary Equipment or Problem with Primary Grounding</u>

Breakdown of electrical components on the primary distribution system occurs infrequently. However, lightning may cause a problem at a transformer, regulator, capacitor bank or circuit recloser.

**Note: Customer owned primary neutral integrity and grounding must also be checked to insure it is adequate.

C.4.3 <u>Direct Current Sources</u>

Direct current sources can originate on as well as off the farm.

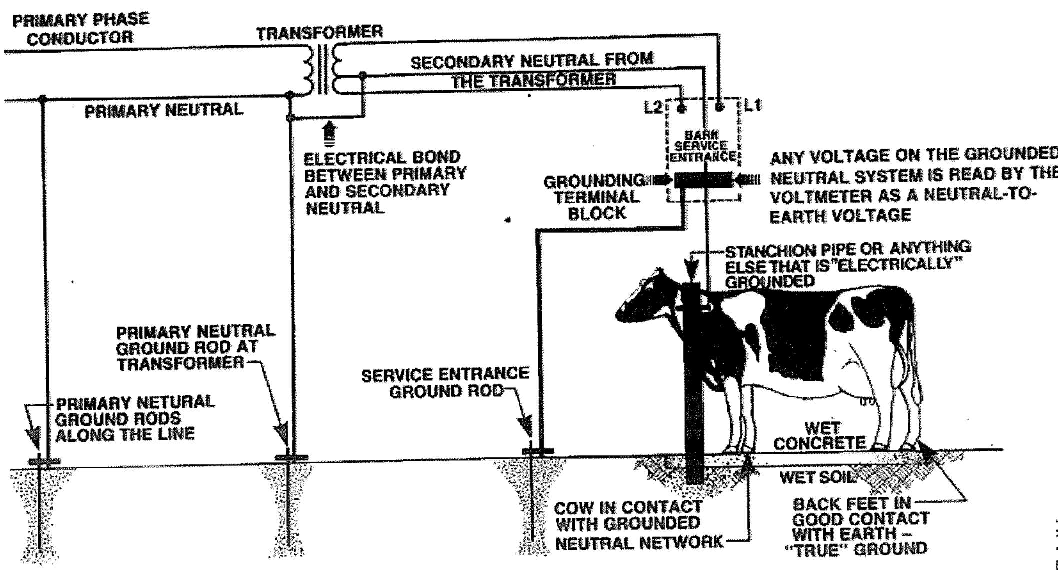
Care must be taken to make sure a dc source is real. It is suggested that a load resistor of about 10,000 ohms be connected across the source of the dc voltage to determine if the voltage remains. If a reading is obtained with a load resistor in place, then the source should be of concern.

The dc source of T.V. may originate off the farm from a telephone system or corrosion protection rectifiers on an underground utility piping system. Direct current sources occur infrequently; however, they have been reported to be a problem. Less is known about the sources of dc T.V. and solution techniques than about ac sources.

C.5 References

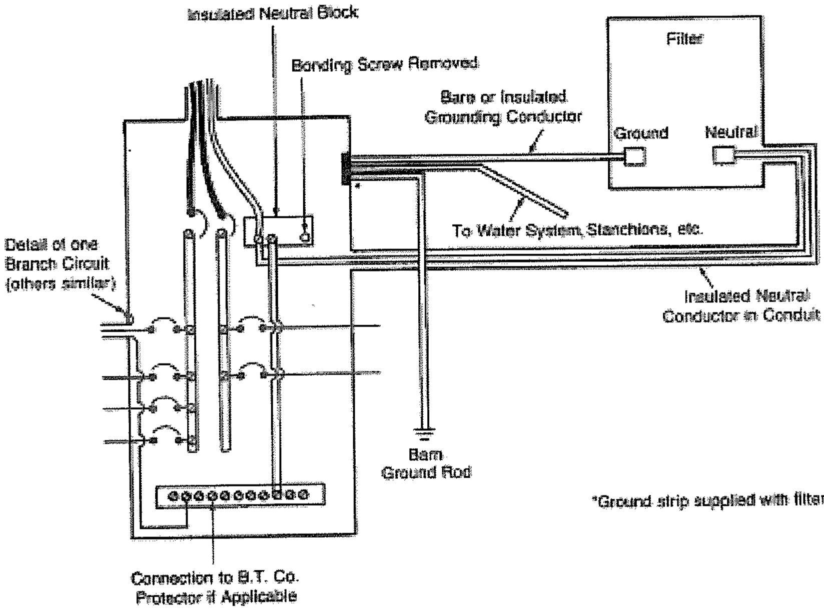
1) Stray Voltage Problems with Dairy Cows. H.A. Cloud, R.D. Appleman, and R.J. Gustafson. 1980.
2) Electronic Grounding System Reduces Stray Voltages or NE/P in Animal Confinement Structures. W.K. Dick, ITT Blackburn. 1983.
3) Effects of Stray Voltage on Animals. R. Gorewit, Cornell University. 1983.
4) Workshop on Stray Voltages in Agriculture. 1983.
5) Understanding and Dealing with Stray Voltage Problem. R.J. Gustafson, H.A. Cloud, and R.D. Appleman. 1982.
6) Stray Voltage: Detection and Diagnostic Procedures Guide for Rural Electric Systems. R.J. Gustafson, University of Minnesota. 1983.
7) Stray Voltage on Farms. T.C. Surbrook and N.D. Reese. 1981.
8) Letter from the Ontario Ministry of Agriculture and Food, March 1982.
9) Rural Neutral Potentials. J.H. Waghorne. 1950.

A DAIRY COW SUBJECTED TO A NEUTRAL-TO-EARTH(N-E) VOLTAGE



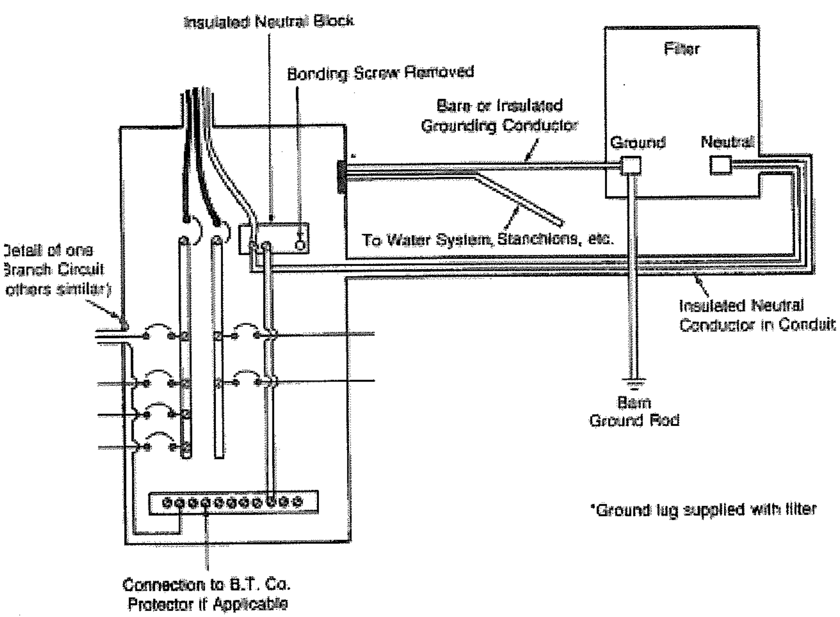
APPENDIX 1

Tingle Voltage Filter Installation

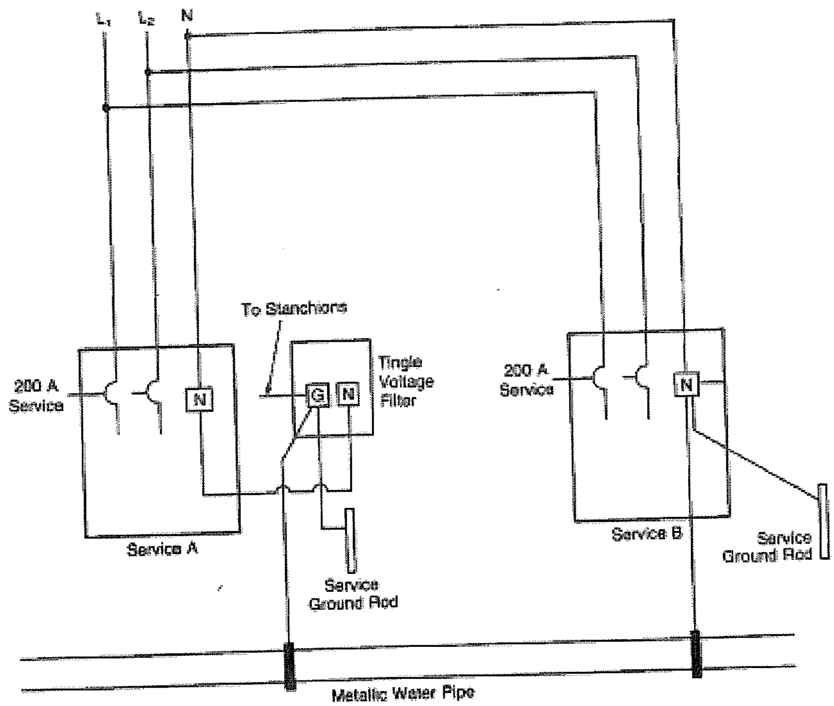


*Ground strip supplied with filter.

Tingle Voltage Filter Installation
Alternate Grounding
(Preferred for Overhead Service)

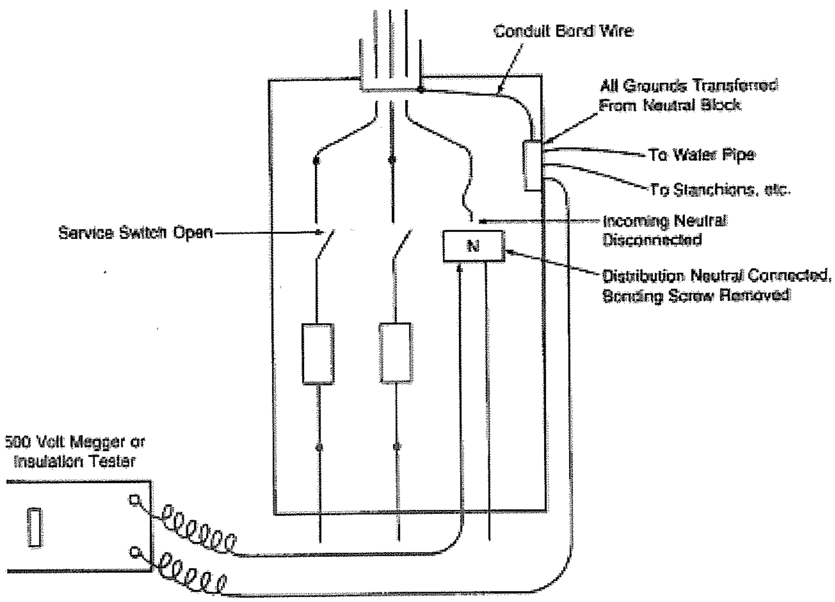


Bypass Circuit for Two Services



Metallic water pipe will bypass the filter in this situation; insertion of a length of non-conductive pipe is required.

Insulation Test – Method 1
(Megger Test of Barn Service Neutrals)



1.0 Open main switch.

2.0 Check with a voltmeter to ensure all circuits are dead.

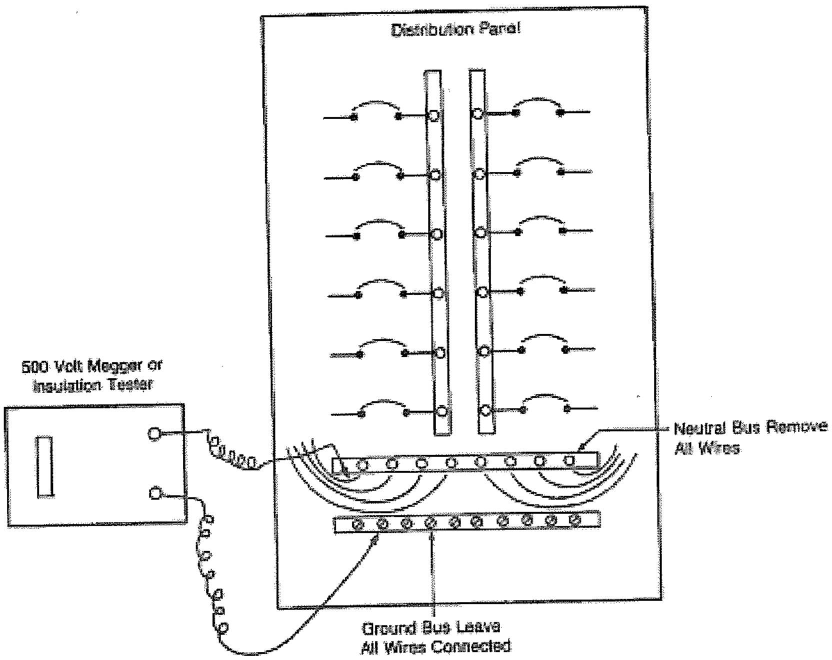
3.0 Remove incoming neutral from neutral block.

4.0 Turn all switches on at the equipment. This includes light switches, milking equipment switches, etc.
Any magnetic contactors should be mechanically blocked closed.

5.0 Megger between neutral block and ground strip.

6.0 If readings are not 50,000 Ohms or higher then go to Method 2

Insulation Test – Method 2
(Megger Test of Branch Circuit Neutrals)



1.0 Open all branch circuit breakers or remove all fuses.

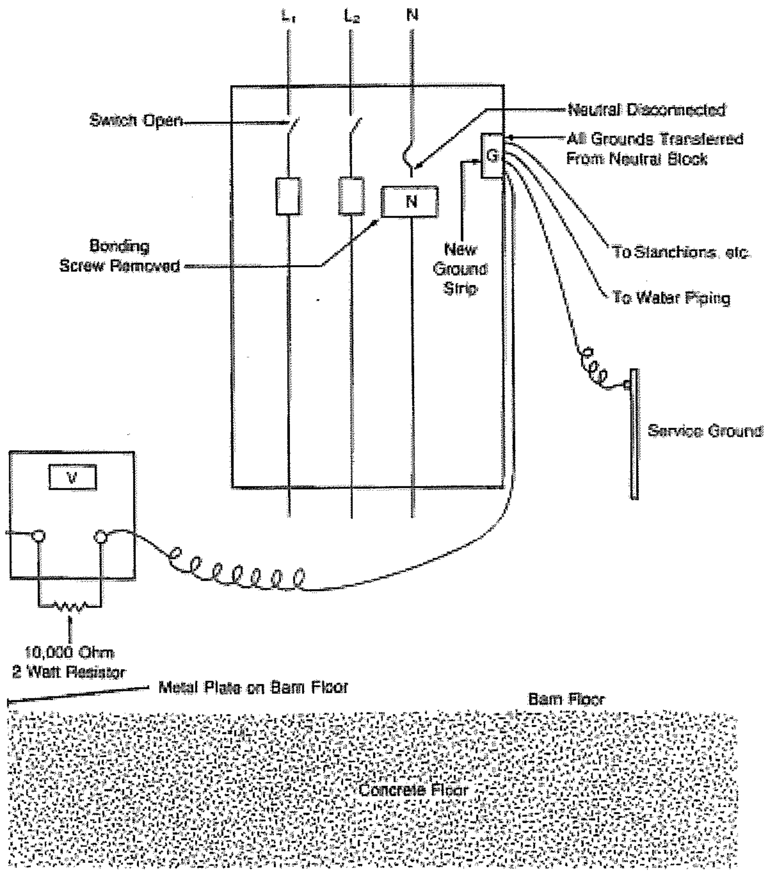
2.0 Remove a branch circuit neutral conductor from neutral bus.
Do not remove the branch circuit ground or bonding conductor.

3.0 Check each neutral with an insulation testor as shown.
Good circuits will read 100,000 Ohms or more.
Bad circuits are tagged and then repaired.

4.0 Reassemble when complete. Remove any blocking materials placed in the magnetic contactors installed as per Method 1-4.

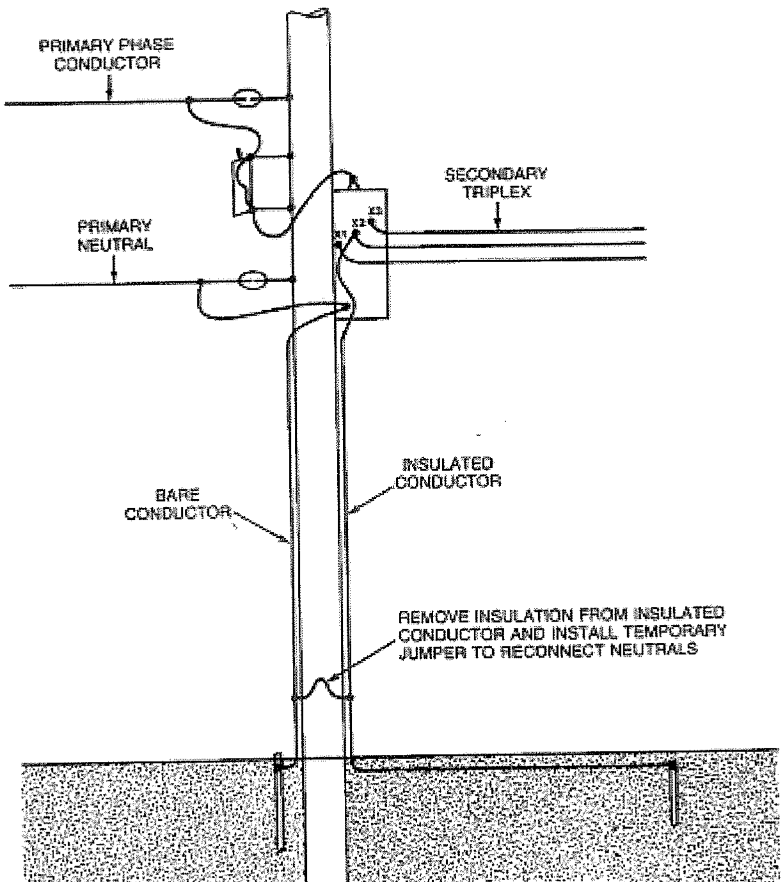
Note: *It is usually faster to remove all neutral conductors from the neutral bus, perform the test, then restore all the conductors.*

Testing for Bypass Circuits External to the Barn



If Voltage measured is over 50 millivolts (1/20th of a volt) then there must be external "Bypasses".

INSTRUCTION (NEUTRALS SEPARATED)

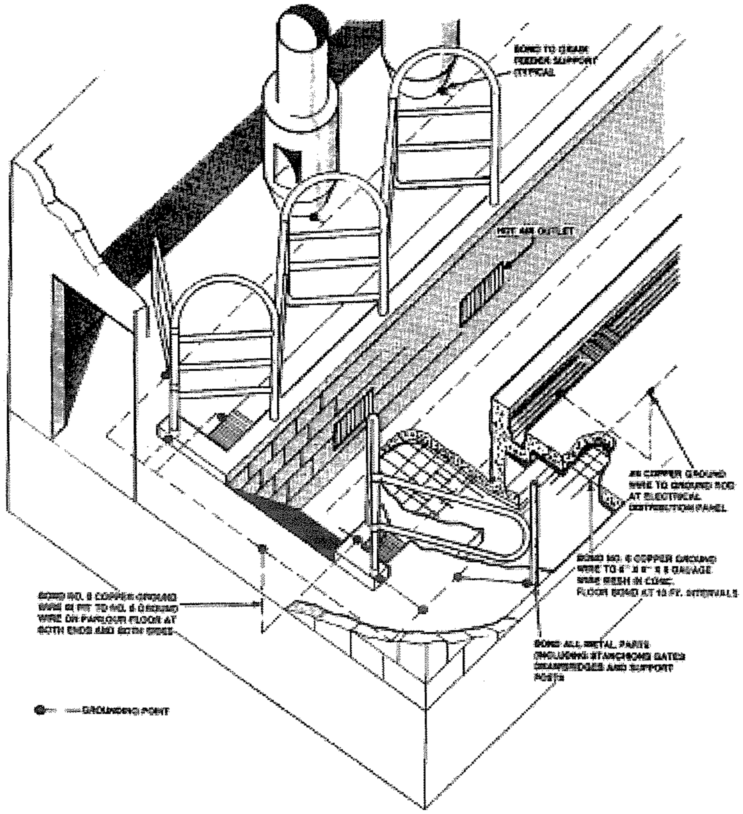


BEFORE STARTING THE INSTALLATION THE PRIMARY NEUTRAL AND SECONDARY NEUTRAL MUST BE RECONNECTED

WHEN THE INSTALLATION HAS PASSED ALL TESTS THE JUMPER INSTALLED IN THE ABOVE MAY BE LEFT INSTALLED OR REMOVED AT THE DISCRETION OF THE INSTALLER . AFTER THE INSPECTION IS COMPLETE THE INSPECTOR WILL ISSUE A CONNECTION AUTHORIZATION TO HAVE THE PRIMARY AND SECONDARY NEUTRALS PERMANENTLY RECONNECTED

APPENDIX 9

ONTARIO HYDRO – RURAL SERVICE DEPT.
GROUNDING FOR MILKING PARLOUR

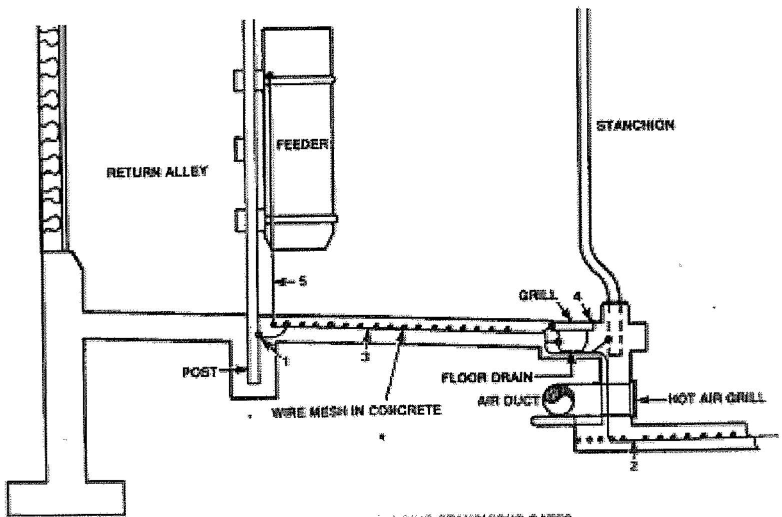


NOTES:

1. MINIMUM SIZE OF GROUND WIRE TO BE NO. 6 COPPER
2. WIRE MESH TO BE 6" X 6" X 9 GAUGE.
3. WIRE MESH TO BE BONDED TO GROUND WIRE AT MAX. INTERVALS OF 10 FT.
4. ALL STEEL POSTS, GATE POSTS, SUPPORT POSTS, FEEDER BRACKETS ETC. TO BE BONDED TO GROUND WIRE.
5. ANGLE IRON GRATE SUPPORTS FOR FLOOR DRAINS TO BE BONDED AT BOTH ENDS OF PARLOUR & BOTH SIDES OF GRATE.
6. GROUND LOOP ON FLOOR OF PIT TO BE CONNECTED TO GROUND LOOP ON FLOOR PARLOUR AT BOTH ENDS AND BOTH SIDES.
7. GROUNDING CONDUCTOR SIZE IS GIVEN IN AMERICAN WIRE GAUGE
8. FOR NEW & RECONDITIONED EXISTING PARLOURS WIRE MESH TO HAVE CONCRETE COVER OF 3"

· ONTARIO HYDRO – RURAL SERVICE DEPT.

CROSS SECTION-MILKING PARLOUR GROUNDING



1 BOND ALL METAL PARTS (INCLUDING STANCHIONS GATES DRAWBRIDGES AND SUPPORT POSTS)

2 BOND NO. 6 COPPER WIRE IN PARLOUR FLOOR TO NO. 6 COPPER WIRE IN PIT AT BOTH ENDS AND BOTH SIDES.

3 BOND NO. 6 COPPER GROUND WIRE TO 6" X 6" X 9 GAUAGE WIRE MESH IN CONC. FLOOR AT 10 FT. INTERVALS.

4 ANGLE IRON GRATE SUPPORTS FOR FLOOR DRAINS TO BE BONDED AT BOTH ENDS OF PARLOUR & BOTH SIDES OF GRATE.

5 (SEE DETAIL 1).

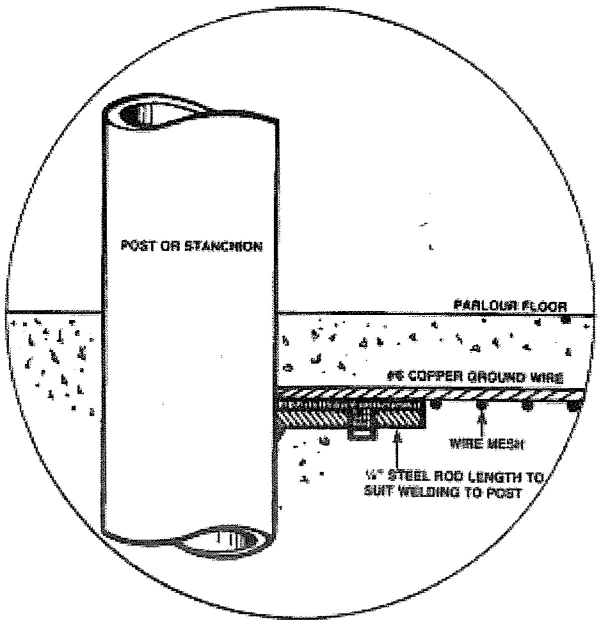
6 FOR NEW & RECONDITIONED EXISTING PARLOURS WIRE MESH TO HAVE A CONC. COVER OF 3".

GROUNDING FOR MILKING PARLOUR

APPENDIX 9

ONTARIO HYDRO – RURAL SERVICE DEPT.

DETAIL 1



WIRE MESH, GROUND WIRE & ¼" STEEL ROD ALL WELDED TO ENSURE CIRCUIT CONTINUITY

¼" ROUND STEEL ROD WELDED TO FEEDER – DOWN TO MESH
WELD ¼" ROD, MESH & NO. 6 COPPER GROUND WIRE TOGETHER
2 PER SIDE

GROUNDING FOR MILKING PARLOUR