Protocols and Practices for Stray Voltage Testing

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An important objective of a protocol for investigating neutral-to-earth voltage on a farm is to determine at which locations livestock may be exposed to stray voltage so that their body will become a part of an electrical pathway. The nature of the stray voltage needs to be determined such as the magnitude, and whether it is a steady value, periodic, or intermittent. It also needs to be determined whether the wiring of the farm or the utility system serving the farm has a condition that results in an elevated level of stray voltage. Specific conditions that result in elevated levels of stray voltage can be identified by tests that isolate those conditions. An investigation to determine the source or sources of stray voltage needs to be an organized step-by-step procedure with the investigator understanding the purpose of each test. This paper describes a set of step-by-step procedures that can be used to uncover the most probable sources of 60 hertz steady state neutral-to-earth voltage.

Measurements made during a stray voltage evaluation need to be for a specific purpose. It is important not to make measurements for which the investigator does not understand the purpose of the tests. This paper provides a set of procedures and data recording sheets for conducting a neutral-to-earth voltage evaluation. Each investigation must be complete, or if terminated, an explanation provided for not completing all of the tests. Organizations that provide a stray voltage evaluation service must have an established procedure that is documented and followed by all personnel conducting evaluations.

Organizations conducting evaluations should have a prescribed set of actions that are taken based upon the results of the evaluation. For example, in Michigan the Michigan Department of Agriculture dairy field inspectors conduct electrical screening measurements for a two month period approximately once every 1 to 1½ years. They are provided approved equipment and a specific measurement procedure that is appropriate for their training. A voltage level was established for that test above which action is to be taken. Either the field inspector or the producer calls the utility number provided to arrange a thorough evaluation that is conducted at no cost to the producer. The point is that the measurement is not taken to generate a number, but to determine if further action is recommended. Based upon the voltages determined as a result of a follow-up evaluation, corrective action may be taken on the utility system or on the farm electrical system. Levels of voltage measured for a specific test during the detailed evaluation trigger follow-up tests on specific portions of a wiring system. These voltage levels are not necessarily constants, but may be site specific. A problem is that conditions generally worsen gradually that lead to elevated levels of neutral-to-earth voltage, and it is not an easy task in some situations to determine when further action is required. These decisions become easier with experience. Those organizations who have little opportunity to gain this experience need to establish links with other organizations also conducting neutral-to-earth voltage investigations.

Probable Stray Voltage Sources

The most probable sources of neutral-to-earth voltage that result in levels at contact points where a livestock effect may be observed are the result of conditions that develop in an electrical system and equipment. Good design at the time of installation and continued maintenance are key at minimizing sources of neutral-to-earth voltage. Wiring system conditions can occur on the utility system as well as on the farm electrical system. The two major sources of neutral-to-earth voltage are voltage drop on neutral conductors and ground faults in equipment that is not properly grounded.

The voltage drop on neutral conductors is caused by excessive resistance along with current flow. The excessive resistance can be the result of a loose or corroded connector or termination. Joining copper and aluminum conductors together where they are exposed to the weather often results in corrosion. Another cause of excessive resistance is a conductor that is too small for the length of run and load to be carried. Balancing the 120 volt loads on a set of conductors supplying a building will minimize the current on the neutral conductor which will minimize the neutral-to-earth voltage.

A way to test for excessive resistance in a farm neutral conductor is to apply a known burden load. A voltmeter is connected neutral-to-earth at the building end of the conductor. According to Ohm s law current times resistance will result in voltage drop. If there is excessive resistance at some point along the neutral conductor, the voltmeter will register a significant change in the level of neutral-to-earth voltage when the burden load is applied. This is a standard test included in the following set of procedures.

A burden test can also be applied to a utility primary distribution system neutral. A common means of distributing electrical power to customers is with a multi-grounded distribution system. There can be up to three ungrounded conductors along with one common neutral conductor. This neutral conductor is grounded to the earth at the substation that supplies power to the line and at locations along the line. The earth is a part of the distribution circuit and can carry some neutral current. To test the level of resistance of the primary neutral circuit a burden load needs to be applied that is not likely to cause neutral-to-earth voltage by some other means. It is possible to load the primary neutral conductor by turning on 240 volt loads on the farm. These 240 volt loads such as a vacuum pump, milk tank cooling compressor, silo unloaders and similar equipment do not use the on-farm neutral conductors, and thus will not cause neutral-to-earth voltage because of resistance in the farm neutrals. It is possible there may be a fault in one of the circuits that will cause neutral-to-earth voltage, but not all of the circuits. When the 240 volt loads are turned on, they cause current to flow on the primary distribution neutral. If the resistance of the primary neutral circuit is high, this burden load will usually result in a significant increase in neutral-to-earth voltage at the farm. The purpose of turning on several large 240 volt loads on the farm is to test the utility neutral.

The level of current applied to the primary neutral circuit by an on-farm 240 volt burden load can easily be estimated. Assume each horsepower of load is equivalent to about one kilowatt. This is about 4 amperes per kilowatt on the farm. If the burden load operated during a test is 15 horsepower, then the burden load is about 60 amperes. The current on the primary side of the transformer is much less because the voltage is higher. The current applied to the primary neutral is the farm current divided by the ratio of primary to secondary voltage. For a distribution line operating at 7200 volts, the voltage ratio is 7200 divided by 240 volts or 30 to 1. This means it takes 30 amperes flowing on the farm wiring to cause 1 ampere to flow on the primary line neutral. In this case of the 60 ampere farm load example, the approximate current applied to the primary neutral by the on-farm burden load is 60 divided by 30, or 2 amperes.

A ground fault on the farm can be continuous or intermittent. If some piece of equipment on the farm is faulting and causing neutral-to-earth voltage, then the equipment is allowing current to flow into the earth. Look for some piece of equipment that is making contact with the earth. This is likely to be a livestock waterer, a sump pump, manure pump, water pump, or similar equipment. Identify all potential equipment that is making contact with the earth and operate the equipment to see if a change in neutral-to-earth voltage is observed. Generally an equipment fault will cause neutral-to-earth voltage to be measured at numerous locations around the farm. If a steady value is observed, then turn off services on the farm to see if the neutral-to-earth voltage can be reduced. The results of a ground fault evaluation can be recorded on Form 6 Neutral and Ground Fault Evaluation.

Electric fences and cow trainers can be a source of stray voltage. If this equipment is used on a farm, then it should be examined during the evaluation. Space is provided on Form 3 Electrical and Utility System Information to make a note of electric fencers and animal trainers. Proper grounding of these devices is important. When electric fencers make contact with vegetation they put current into the earth every time they energize the fence. If the electric fence charger is grounded to the electrical system ground, or if the electric fence charger ground is close to metal equipment, a circuit can be created that exposes livestock to a significant voltage caused by current returning from the earth to the charger. Proper installation of fence chargers and animal trainers is important to prevent livestock exposure to significant levels of stray voltage. Proper installation of an electric fence system to prevent stray voltage is described in the bulletin, Safe and Effective Electric Fences by Fick and Surbrook.

Shunt Resistor Use:

When used, a shunt resistor is placed across the input terminals of a voltmeter as shown in the right hand meter of Figure 2. The primary purpose of using a shunt resistor is to place a resistance in the livestock measurement path that is of the general order of magnitude of the body resistance of an animal in wet conditions. A commonly used value of resistance for this purpose is 500 ohms. There is more resistance in a path through an animal than just the animal body resistance. There is resistance from the feet into the earth. There is contact resistance as the animal touches the metal object with the voltage present. There may also be other significant resistance in the circuit through the animal. By placing a resistor across the terminals of a voltmeter, a small current will flow. This current flow will result in a voltage drop across every resistance in the circuit. This test provides a means of evaluating the general magnitude of the other resistance in the livestock path other than the resistance of the animal body. A measurement taken with a shunt resistor should also be compared with an open circuit voltage at the same location where a resistor is not place across the voltmeter terminals. This is why a switch is shown in the resistor circuit of Figure 2. On Form 4 Neutral-to-Earth Voltage Evaluation, livestock contact voltage measurements without (open) a resistor and with (shunt) a resistor are specified. The voltage reading with the shunt resistor will generally be less than the open circuit voltage taken at the same location.

When making a measurement to the earth or floor with a shunt resistor placed across the input of the voltmeter, proper contact to the floor or earth is necessary. A metal plate with an area of 12 in^2 to 16 in^2 is required to make a voltage measurement to the floor with a shunt resistor. The surface of the floor should be wet with some type of material between the floor and the metal plate that will ensure even contact. Salt added to the water will ensure high conductivity. An electrode gel used in the medical field can also be used to make a high conductivity bond between the metal plate and the floor. Adequate weight must be applied to make sure a firm contact between the metal plate and floor is maintained.

Evaluation Equipment:

The materials and instruments described are intended to be used to conduct an evaluation of the sources of neutral-to-earth voltage associated with voltage drop and ground faults on-the-farm as well as off-the-farm. An effective evaluation can be conducted with other equipment, but this equipment results in effective measurements in a timely manner.

- reference ground
- 120 volt hair dryer
- 4 in. diameter or 4 in. square metal plate
- resistor, approximately 500 ohms, on a double banana plug with a switch if possible
- four digital voltmeters
- one rms clamp-around ammeter that will measure accurately to 0.001 ampere.
- low voltage gloves
- 15 amp, 125 volt receptacle with alligator clamps on leads
- Assorted electrical tools
- Assortment of short leads with banana terminals.
- Reel of 2-wire cable (size 18 AWG copper, SP-1 lamp cord, 250 ft)
- four reels of 1-wire cable (size 16 AWG, copper MTW, 200 ft)

Inexpensive wire reels can be made up to make long distance connections on the farm for the evaluation. Since digital voltmeters have high input impedance, they draw an insignificant amount of current. Voltage drop on the long leads is insignificant. The wire on the reels needs to be a small size to limit weight and the insulation needs to be flexible. Double wire leads can be constructed using size 18 AWG copper lamp cord. The single conductor reels can be constructed using size 16 AWG copper MTW wire. Put a banana connector on the leads and a recessed banana jack in the reel connected to the other end of the cable.

Preparing for the Evaluation

A farm operator who suspects problems on the farm may be caused by stray voltage most likely has been searching for a cause for some time. The farm operator may be growing impatient with the inability to identify a cause. Be patient with the farm operator and do not jump to conclusions and do not ask questions that may be interpreted as looking for a non-electrical solution. If an electrical evaluation is being conducted, only gather electrical information that is necessary to conduct the evaluation. Only gather information that has a specific purpose in the evaluation. At the end of this paper are several forms that can be used to conduct a neutral-to-earth voltage evaluation of a farm. All questions have a relevant purpose in the evaluation. The following is a suggested procedure for conducting a neutral-to-earth voltage evaluation with references made to specific forms for recording information. Be thorough and complete with the evaluation.

1. Talk with farm operator about specific concerns. If information was not written down during telephone contact, then record the specific concerns of the farm operator at the onset of the evaluation, use Form 1 Stray Voltage Concerns. If there were no specific concerns, but a precautionary evaluation was requested, then note that information. If there is a specific concern, then it may be advisable to have the farm operator point out the area of concern before starting the evaluation.
2. Ask if there are any equipotential planes installed at the farm. Explain that this is metal that was installed in the floor of animal areas to prevent livestock from being exposed to neutral-to-earth voltage. The level of neutral-to-earth voltage at a location will be affected if there is an equipotential plane in the floor.
3. Explain that during the testing it will be necessary to turn off all farm power for a few minutes, and to operate large 240-volt motors. It may be necessary to enter different buildings to operate a 120-volt test load. Check to see if a temporary power interruption will cause any problems. Ask if the farm operator desires to be present to operate test loads during the evaluation.
4. Examine wiring at the farm transformer and the meter pole. Look at grounds and neutrals. It will be necessary to connect leads later so be sure the grounds have been identified. Look at neutral and ground splices on the pole. Look for any damaged equipment. It may be desirable to make a diagram of the grounding and neutral conductors at these locations. Indicate on the data forms if the neutrals are separated at the transformer.
5. Examine the wiring supplying the building of primary concern or of major animal contact. Also examine the service entrance to that building. Determine if there is more than one electrical service to that building. Determine if the neutral and equipment grounds have been separated at that building. Examine the grounding at that building.
6. Do an overview examination of the wiring to the various buildings. Either now or later sketch the building layout and the wiring and grounding to the buildings. Form 2 Farm Sketch is provided to make a drawing of the layout of the buildings and note the overhead and underground wiring between buildings as well as grounding.
7. Conduct a survey of the electrical system on the farm as well as the utility electrical system serving the farm. Make a note of other utility providers at that location. Form 3 Electrical and Utility Systems Information, is provided to help record information and to make certain important data is recorded.
8. Conduct a complete survey of the farm to find all possible contact locations where livestock

may be exposed to stray voltage through contact with metal equipment that may have a voltage from the farm neutral or grounding system. Mark all livestock contact locations on Form 2 Farm Sketch. Record all voltage measurements on Form 4 Neutral-to-Earth Voltage Evaluation. Make sure livestock location voltage measurements on Form 4 can be identified on Form 2. Obtain permission from the farm operator before going into livestock areas. Ask if there are any locations where there are dangerous livestock. Wear either disposable foot wear or have washing equipment present to thoroughly clean boots before leaving the farm.

9. Choose a location for the reference ground away from power lines and any building or underground water pipes. If possible locate this reference ground at least 100 feet from any building or known underground metal that may affect the reference ground. As shown in Figure 1, run a single lead from the reference ground to the transformer pole.

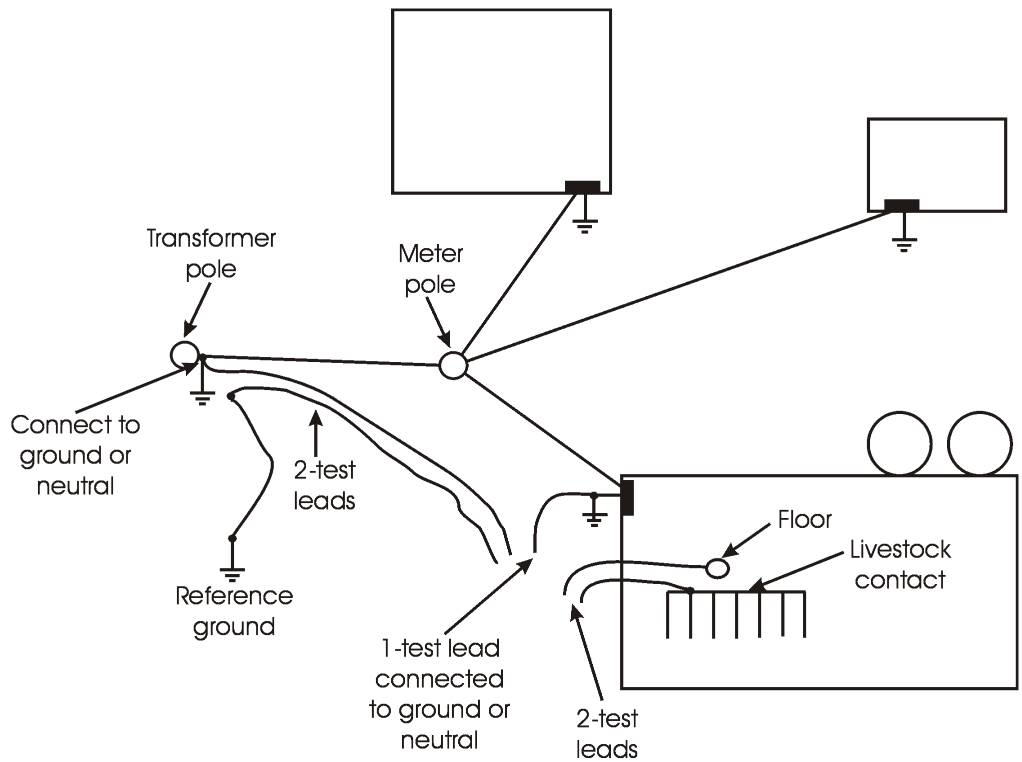


Figure 1 Lead wires on reels can be used to extend several measurement points to one convenient location.

10. Run two lead wires from the transformer pole to the electrical service entrance location of the building of primary interest. This is shown in Figure 1. One lead is connected to the reference ground lead and the other lead is connected to the ground or neutral wire at the transformer pole. If utility personnel are not present to make this ground connection, then move to the meter pole location to make the neutral connection. If the utility primary and farm secondary neutral conductors have been separated, it may be desirable to run three lead wires from the transformer pole to the building of primary interest. Test lead reals are described later in this paper.
11. Determine the best location to make a livestock contact voltage measurement. This may

be a location designated by the farm operator as a place where abnormal livestock behavior is observed or where a voltage sensation was felt by personnel. Consider all locations where livestock were exposed to a voltage. It must be a practical location where lead wires will not be disturbed during the evaluation. When the location is selected, extend a lead from the contact point and from the floor to the measurement location. Making proper contact to the floor will be discussed later in this paper.

12. Make a connection to the building of interest service ground wire or neutral wire. This is the service panel that supplies electrical power to the area where the livestock contact voltage measurement will be taken. The metal equipment to which livestock can make contact is connected to the grounding terminal of this service panel. Extend one lead to the location where voltmeters will be connected for the evaluation. This wire is shown in Figure 1.
13. Verify the accuracy of the voltmeters at the beginning of the evaluation. Connect all voltmeters to be used for the evaluation to the same voltage source to determine if they register the same reading. Make sure all voltmeters are accurate to at least one decimal place.
14. It is recommended that several voltmeters be used to take simultaneous measurements during the evaluation. Figure 2 illustrates the connection of voltmeters for making simultaneous measurements. Recommended voltage measurements are as follows:
    a. Neutral at the transformer location to reference ground.
    b. Neutral at the building of primary concern to reference ground.
    c. Neutral at the transformer location to neutral at the building of primary concern.
    d. Livestock contact voltage.

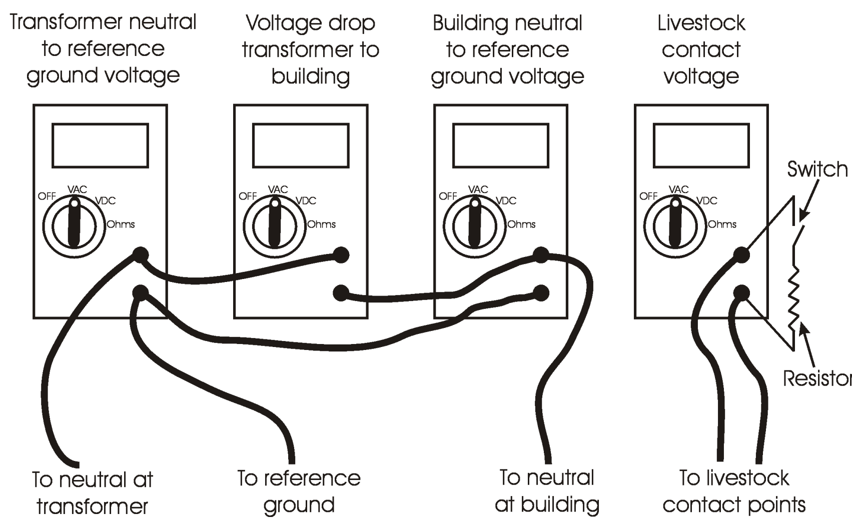


Figure 2 With the lead wires as shown in Figure 1 extended to one location, voltmeters can be connected to make simultaneous measurements during the evaluation.

15. A 120 volt burden load of about 10 amperes will be applied to each ungrounded conductor at the service panel in the building of interest. It is best to conduct this test with the circuits turned off at the building. A burden load with alligator connecting leads or a plug on the end of a short cord with alligator leads is a convenient means of connecting the burden load while the circuits in the building are disconnected. This procedure should only be conducted by trained personnel using proper safety equipment.
16. Determine in advance how a 240 volt load will be applied for a burden test of the primary distribution system. A load box specifically designed for the purpose can be connected at the main farm disconnect. An alternate method is to turn on large 240 volt loads such a the vacuum pump, milk tank compressor, or silo unloaders.

Suggested Procedure for Conducting an NEV Evaluation

A farm evaluation must include tests to determine the level at which a utility neutral conductor and a farm neutral conductors are contributing to neutral-to-earth voltage. Some utility distribution systems are ungrounded and do not have a neutral conductor that contributes to neutral-to-earth voltage. If there is reason to believe a ground fault may be contributing to voltage levels measured, then an additional test will be necessary to identify the source.

High resistance conditions of the utility and farm neutral systems are generally slow to change and if a high resistance exists, it will most likely be present at the time of the evaluation. Ground fault conditions may be intermittent. If a ground fault is expected, all suspect circuits and equipment should be operated during the evaluation. If a ground fault condition cannot be found at the time of the evaluation, it may be necessary to set a recording voltmeter for several days to determine if a voltage condition occurs. Pen and paper recorders work well for this purpose. Be careful when setting up recorders with electronic storage to make sure they will store transient events that have a duration as short as only a few 60 hertz cycles. Make sure there is some way of identifying time of day when using a recording voltmeters.

To conduct the basic evaluation use Form 4 Neutral-to-Earth Voltage Evaluation. For this set of test measurements, points similar to those shown in Figure 1 have been selected with test wires run to a convenient location. It is suggested voltmeters be connected similar to shown in Figure 2. To avoid errors, arrange the voltmeters in the same order they will be recorded on the data sheet (Form 4). Form 4 is a multipurpose data sheet. Cross out data rows that are not appropriate for the evaluation being conducted. If the voltmeters are set up as shown in Figure 1 and Figure 2, then the points being measured are the primary neutral conductor at the transformer to the reference ground (N_PEV), the voltage drop from the transformer pole to the barn (N_PN_B), the barn panel neutral to reference ground (N_BEV), and the livestock contact voltage. Identify the specific livestock contact location used. Also record the value of shunt resistor used for this evaluation. When the tests are being conducted, count the number of kWh meter disc revolutions during a set time period such as 30 seconds and record this information on Form 5.

It is recommended the tests shown on Form 4 be conducted in as short a time interval as practical to avoid major changes in system loading during the evaluation. It may be necessary to repeat this sequence of test if a major change during the evaluation is suspected. At least record the starting and ending time of the sequence of tests. Also note if the evaluation is being conducted with the farm and utility neutrals bonded or separated. When the electrical system neutrals are separated, a bypass can be created by communications cables, and metal piping systems such as natural gas. If practical, record the livestock contact location voltages without (open) and with (shunt) a shunt resistor. The following tests can usually be completed in under 5 minutes.

1. Determine the load on the farm from the kWh meter and record the value on all voltmeters.
2. Disconnect all power to the farm and record the value on the voltmeters.
3. Reconnect power to the farm, determine the load from the kWh meter and record the value on all voltmeters. The load should be approximately the same and the voltmeter readings should be approximately the same as they were just prior to disconnecting power. If not, repeat the previous sequence of tests. If consistent results cannot be obtained, then make a note of the reverse side of Form 4 of your observations.
4. Turn on the 240 volt burden load, determine the total load applied at the kWh meter, and record the values on the voltmeters.
5. Turn off the 240 volt burden load and note if the voltage readings return to approximately their previous value.
6. Next disconnect power to the circuits in the building of interest. In most cases this is done by opening the main circuit breaker to the service panel. For this test, leg A is the left ungrounded conductor connected to the panel and leg B is the right hand conductor. Turn on the 120 volt burden load and record the value at the top of Form 4. Record the values on the voltmeters first with the 120 volt burden load off and then with the load operating.

When the load is turned off, the value of the voltmeters should return to approximately the previous value with the load off. If not, repeat the test until consistent results are obtained. Connect the 120 volt burden load test for both service panel legs A and B.

Interpreting Test Results

The following is a common interpretation of the results of the test conducted and recorded on Form 4 - Neutral-to Earth Voltage Evaluation. These are the common but not the only conclusions that can be drawn from the results of the evaluation. Experience conducting evaluations will help to improve identification skills.

The second column of data on Form 4 is with all farm power disconnected. With all farm power disconnected, there are no sources for neutral-to-earth voltage to be produced on the farm. The voltages measured at all locations should be approximately the same. There may be a difference of a few tenths of a volt in some situations. Assuming the utility and farm neutral conductors are bonded at the transformer, the voltage measured with the power off at the farm is most likely due to an off-farm source. The source may be voltage drop on the primary neutral, or it can be a ground fault at a neighboring property in the area.

If a farm is supplied with a single-phase multi-grounded utility distribution line, the 240 volt load test of column 4 of Form 4 should result in at least a slight increase in voltage when the load is applied. A large increase in neutral-to-earth voltage during the 240 volt load test would indicate the primary neutral circuit resistance may need to be reduced. When the farm is supplied from a multi-phase grounded distribution line, the neutral-to-earth voltage may increase or it may decrease when load is applied. If equipment on the farm such as a vacuum pump is used as the 240 volt load during this test, it is possible that a condition in the circuit may be the cause of the neutral-to-earth voltage change. If several loads each cause an incremental change in the neutral-to-earth voltage, it is most likely the cause of the change is voltage drop along the primary neutral conductor and not a condition on the farm.

The 120 volt test in the last two columns of Form 4 are testing the condition of the neutral conductors between the transformer pole and the building of interest. The results from the Leg A and Leg B test should be the same unless the conductors supplying the building of interest also supply other buildings where power is still being used during the testing. A large increase in the neutral-to-earth voltage at the building of interest panel indicates there is an abnormal resistance in the neutral supplying the building. The resistance of the neutral conductor between the transformer and the building of interest can be determined using the formula on Form 5. It is possible there is no problem with the neutral conductor to the building except it is too small for the length of run and the load to be supplied. The actual voltage drop along this conductor is measured. If there is an excessive resistance in the neutral conductor, then check all connections between the building and the transformer.

It is possible that a high resistance in a neutral conductor to another building is causing the neutral-to-earth voltage measured at the building of interest. Form 6 can be used to evaluate every neutral conductor supplying buildings on the farm. Before going to the trouble of taking test leads to every building, it is advisable to take the burden load to each building while leaving the voltmeters set up at the building of interest. Operate the 120 volt burden load at all buildings to see if a change in voltage is observed at the building of interest. This test will require at least two persons. If the test personnel are using a wireless communications device, make sure the devices are not held near the voltmeters. The signal from a communications device can affect the readings of digital voltmeters at close range. If a particular set of supply conductors is suspected as a cause of neutral-to-earth voltage, a more thorough test of that set of conductors can be conducted using the formula on Form 5 and the procedure described on Form 6.

It is possible that a level of neutral-to-earth voltage persists during the testing and does not seem to be affected by the various tests. This tends to indicate a ground fault on the farm. A ground fault tends to cause a neutral-to-earth voltage at several locations. With the voltmeters connected as in the previous tests, go to the various buildings and turn off power to see if there will be a change in the voltage level. The data for this test can be recorded on Form 6 Neutral and Ground Fault Evaluation. If there is a ground fault on the farm, the source will eventually be found when one of the service panels is disconnected from power. When the service panel is identified, then proceed to identify the suspect circuit from the panel. Ground faults can be intermittent, and it may be necessary to operate suspect equipment in order to identify the circuit causing the neutral-to-earth voltage. The notation titles non-return current on Form 6 refers to current that is finding an alternate path back to the supply panel. If an ammeter is clamped around a cable carrying current the meter should read zero. If the circuit is functioning properly, all the circuit current will be present in the cable and the ammeter reading will be zero. When there is a reading of several amperes, for example, on an ammeter clamped around a cable, then some current is finding an alternate path back to the panel. This is called non-return current and it may be the cause of neutral-to-earth voltage. In any case, this condition should not exist and the cause should be identified.

Evaluation Forms

The following is a set of six neutral-to-earth voltage evaluation forms that can be used to conduct an evaluation or they can be incorporated into the evaluation procedures of any organization. These forms are offered for use by any party who desires to conduct a neutral-to-earth voltage evaluation. These forms can be used for several types of testing. For example, Form 4 can be used to conduct a complete evaluation at a farm. It can also be used to do a quick test of the effectiveness of neutral separation at a transformer. Make sure the purpose of the test is noted on the form. It is a good idea to cross out those items on the form that are not appropriate to the test being conducted.

References:

Fick, R.J. and T.C. Surbrook, 1999. Safe and Effective Electric Fences, Michigan State University Extension bulletin E-2706.

Gustafson, R.J. 1983. Stray voltage detection and diagnostic procedures guide for rural electric systems, NRECA Research Project 80-1.

Schrandt, J.M. and T.C. Surbrook, 1993. Understanding neutral-to-earth and stray voltage, Consumers Energy, 212 W. Michigan Ave., Jackson, MI 49201.

Surbrook, T.C., N.D. Reese, and Changming Li, 1989. Trouble-shooting earth to neutral voltage, IEEE-IAS San Diego.

Form 1 Stray Voltage Concerns

Farm Name: ____ Date: __________

Address:____ Telephone: (____)________

Has a person felt a shock or tingling sensation when touching pipes or equipment: Yes No

If so, list location: ____

When did this first occur? ____

Time of day most noticeable? ____

Do animals avoid certain areas or equipment? Yes No

If so, list areas or equipment: ____

When did this first occur? ____

Time of day most noticeable? ____

Do animals show abnormal behavior at certain times and places? Yes No

If so, please list location: ____

When did this first occur? ____

Time of day most noticeable? ____

Please explain concerns of farm operator:

Do lights get bright or dim when electric loads are changed? Yes No

If so, where? ______________________________

What happened at same time? ______________________________

When motors start, do lights dim and stay dim? Yes No

When motors start, does the yard light go off? Yes No

Do fuses blow or circuit breakers trip frequently? Yes No

If so, please explain: ______________________________

Do motors or other equipment start or run improperly: Yes No

If so, please explain: ______________________________

Please list any other equipment or wiring concerns:

Has a stray voltage evaluation been conducted by anyone prior to this date? Yes No

If so, any details that can be provided may be helpful:

Have any changes been made to the farm or other electrical system or equipment? Yes No
If so, any details that can be provided may be helpful:

Have any new buildings or equipment been added recently? Yes No

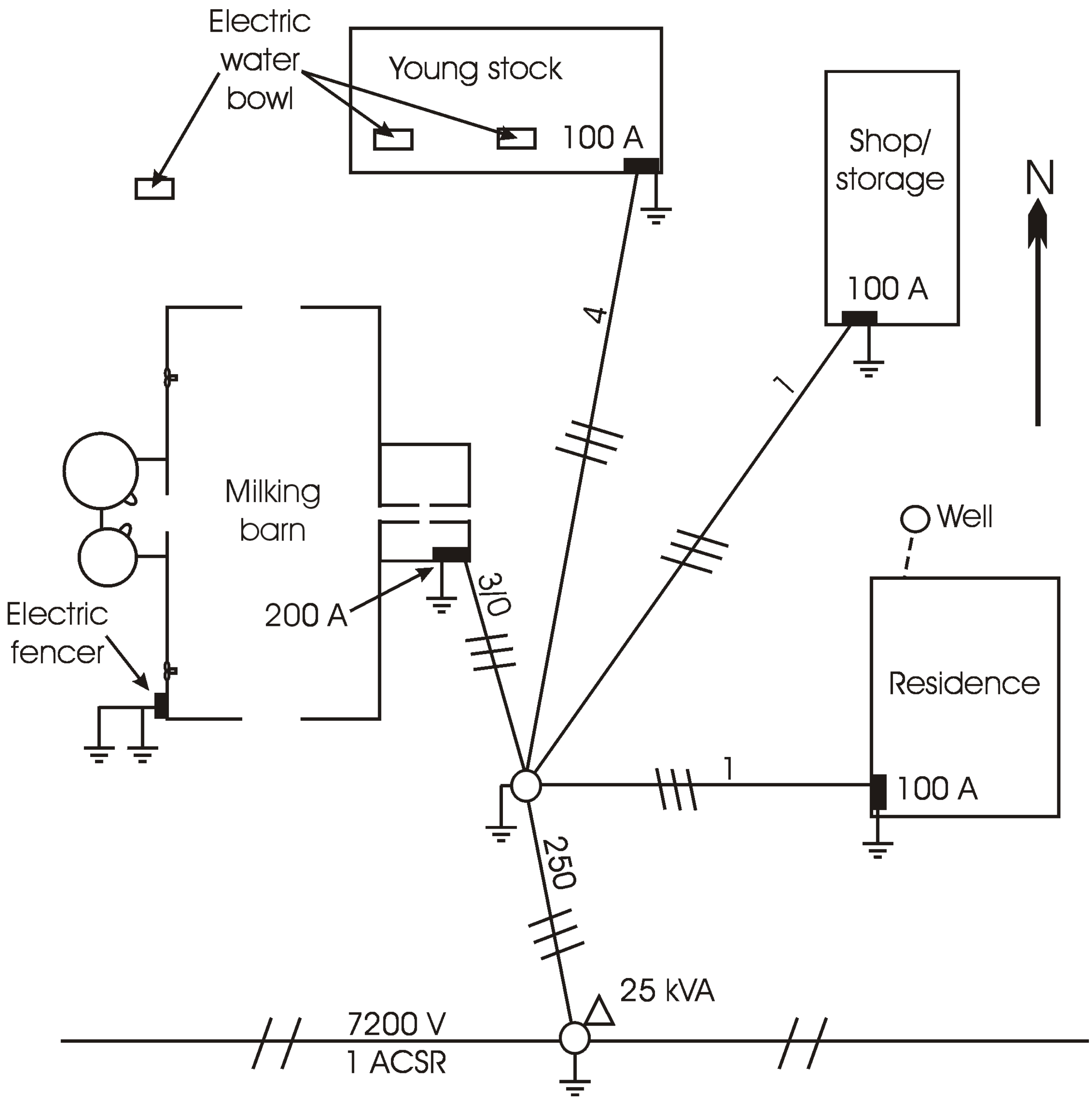
If so, any details that can be provided may be helpful:

Form 2 Farm Sketch

Farm Name: ____ Date: ____________

County: _____________ Township: ____________ Number & Street: _______________________

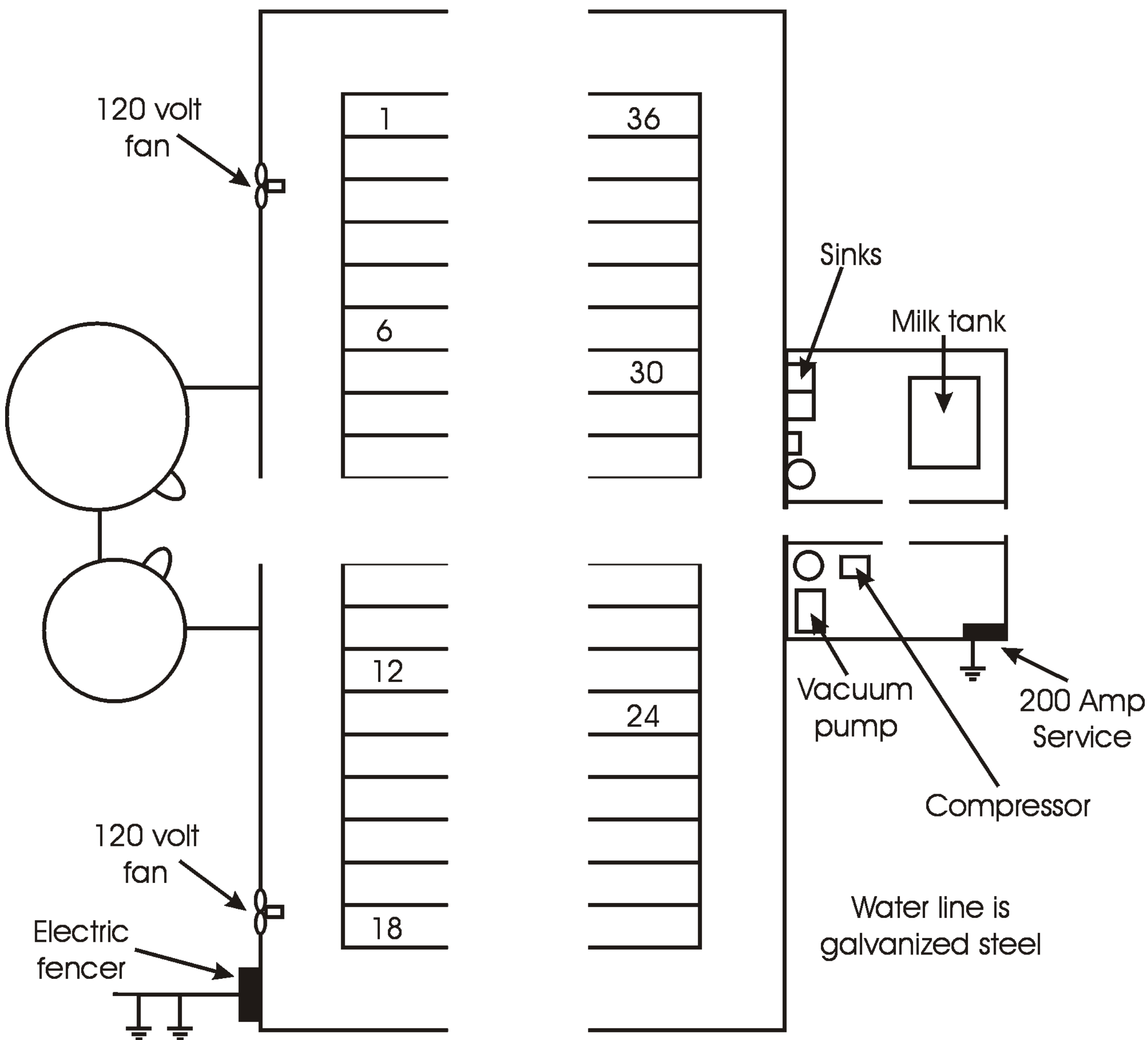
InIn addition to sketching buildings indicateIn addition to sketching buildings indicate theIn addition to sketching buildings indicate the overhead and unde undergroundunderground wires and solid lines for overhead wires. As much asunderground wires and solid lines for overhead wires. As much as possib possiblepossible indicate approximate lengths of conductors and wire sizes. It is understood thatpossible indicate approximate lengths of conductors and w not be known. Please indicate the locations of the mainnot be known. Please indicate the locations of the main service road and what direction isnot be to show detailed drawings such as individual building details.



Farm Name:______________________________ Date: ____________

Address: ______________________________ Telephone: ____________

Notes or additional sketches:



Form 3 Electrical and Utility System Information

Farm Name: ____ Date: _____________

Address: ____

Telephone: (_____) _______________ Fax:(_____) ____________ e-mail: ______________

Electric Power Supplier Name: ____

Telephone provider: ____

CATV provider: _______________________ Natural Gas provider: _______________________

Type of farm enterprise: (if livestock list types and approximate numbers)

Farm Electrical Service Data: (if more than one service describe each)

Type of power: 1-phase 3-phase 3-wire 4-wire Operating voltages ________ / _________

Transformer:_________kVA Service drop or lateral: OVH URD Aluminum Copper

Direct metered CT metered Conductor size: _________________

Drop or lateral length: _________________

Check condition of grounds: Transformer ground: Yes No If measured ________

Meter location ground: Yes No If measured ________

Note any damaged or missing equipment observed at transformer or meter location:

Telephone drop or lateral to farm: (if more than one please note) OVH URD

Main street telephone cable: OVH URD

Is farm served by a community water system?

Underground water pipes: Metal Nonmetallic (if both please describe)

Primary distribution system: **(record following information if known)**

Grounded distribution system: Yes No Number of phase conductors: ___________

Primary phase-to-phase voltage:__________ Primary phase to neutral voltage:____________

Primary phase conductor type: _______________ size: ________________

Primary neutral conductor type if known: __________________ size if known: ____________________

Note other primary information in space:

Neutral Separation: (If applicable)

Are electrical system neutrals separated at the transformer? Yes No

If neutrals are separated and telephone is underground is sheath ground disconnected? Yes No

If served with CATV has a cable isolator been installed? Yes No

Has gas pipe insulator been installed? (If pipes are underground and metal) Yes No

Has water pipe insulating section been installed? (If metal pipe and community system) Yes No

---

Electric Fencers and Animal Trainers: (note information for each which is in use)

Animal Trainer: Yes No Type: Battery 120 V plug-in

Is charger rated as animal trainer type or is it a fence type?

Does charger have it s own ground separated from other grounds or metal?
(describe ground)

Electric Fence: Yes No Type: Battery 120 V plug-in

Is charger rated as animal trainer type or is it a fence type?

Does charger have it s own ground separated from other grounds or metal?
(describe ground)

Form 4 Neutral-to-Earth Voltage Evaluation

Farm Name: ______________________________ Date: ____________

Address: ______________________________ Evaluator ____________

Shunt: ________ Light Load: ________ kW 240 V Load: ________ kW 120 V Load: ________ A

NEV Test: & location	Bond/Sep Light load	Bond/Sep Power off	Bond/Sep Light load	Bond/Sep 240 V load	Bond/Sep 120 V load Leg A	Leg B
Time:	____	____	____	____	____	____
Transformer:					(Off/On)	(Off/On)
N_PEV	____	____	____	____	____	____
N_PN_S	____	____	____	____	____	____
N_SEV	____	____	____	____	____	____
Central Distribution Point:						
$N_{CPD}EV$	____	____	____	____	____	____
Voltage Drop: Transformer to building ____________						
N_PN_B	____	____	____	____	____	____
Building: ____________						
N_BEV	____	____	____	____	____	____
Livestock Contact		Open/Shunt	Open/Shunt	Open/Shunt	Open/Shunt	Open/Shunt
____	____	____	____	____	____	____

N_PEV	Voltage from primary neutral at the transformer to a reference ground
N_PN_S	Voltage from the primary neutral to the secondary neutral at the transformer
N_SEV	Voltage from the secondary neutral at the transformer to a reference ground
$N_{CPD}EV$	Voltage from the neutral at the center distribution point to a reference ground
N_PN_B	Voltage drop from the primary neutral at the transformer to the neutral of the service panel at the building of interest
N_BEV	Voltage from the neutral at the service panel at the building of interest to a reference ground

Farm Name: ____ Date: __________

NEV Test: & location	Time:	Bond/Sep Power off	Bond/Sep Light load	Bond/Sep 240 V load	Bond/Sep 120 V load Leg A	Leg B
		Open/Shunt	Open/Shunt	Open/Shunt	Open/Shunt	Open/Shunt
__________	_____		________			
__________	_____		________			
__________	_____		________			
__________	_____		________			
__________	_____		________			
__________	_____		________			
__________	_____		________			
__________	_____		________			
__________	_____		________			
__________	_____		________			
__________	_____		________			
__________	_____		________			

Notes:

Form 5 Formulas & Calculations

Determine load draw on farm: It is helpful to know the farm load when measurements are being taken. This is an easy calculation for determining the approximate farm load by counting the kWh meter disc revolutions in a given length of time. The K_h factor will be printed on the face of the meter. If current transformer metering is in use, there will be a multiplier marked on the face of the kWh meter.

$$\frac{(\text{Number of Meter Revolutions}) \times K_h \times 3.6}{\text{Seconds}} = \text{kW}$$

Time of test	Load condition	Meter revolutions	×	K_h factor	×	3.6	÷	Seconds	=	Load kW
______	________	________	×	_______	×	3.6	÷	______	=	_______ kW
______	________	________	×	_______	×	3.6	÷	______	=	_______ kW
______	________	________	×	_______	×	3.6	÷	______	=	_______ kW

Grounding electrode resistance: Approximate resistance of a grounding electrode can be calculated by measuring the neutral-to-earth voltage at the grounding electrode and the current flowing to the grounding electrode. This method requires a current reading that is accurate to at least the nearest milliampere (0.001 ampere).

Measure the NEV at the grounding electrode _________ V

Measure the current flowing to the grounding electrode _________ A

$$\frac{\text{Grounding electrode NEV}}{\text{Grounding electrode current (A)}} = \text{Grounding electrode resistance}$$ _________

Building	NEV	÷	Ground Wire Amps	=	Electrode Resistance
_____________	________V	÷	____________A	=	____________
_____________	________V	÷	____________A	=	____________
_____________	________V	÷	____________A	=	____________
_____________	________V	÷	____________A	=	____________

Farm Name: ____ Date: __________

Determine neutral wire resistance between buildings per 100 feet: The resistance of the neutral conductor supplying a building is needed to determine if the voltage drop measured during a test can be attributed to the resistance of the conductor or is it partially due to abnormal resistance such as a corroded connection. This procedure provides the resistance of the neutral conductor circuit on a 100 ft basis for comparison with the value in Table 1. If the value calculated is larger than the value from Table 1, then there is abnormal resistance in the neutral circuit.

Measure or pace off the distance in ft and divide by 100 ________ft / 100 = _______ (hundreds of ft)

$$\frac{\text{Voltage drop between buildings}}{\text{Neutral current (A)} \times \text{Length in hundreds of ft.}} = \text{Neutral resistance per 100 ft. \_\_\_\_\_\_\_\_\_}$$

Table 1 Resistance of conductors at a temperature of approximately 120°F.

Wire size (AWG or kcmil)	Aluminum (ohms per 100 ft)	Copper (ohms per 100 ft)
12	0.257	0.159
10	0.162	0.100
8	0.102	0.064
6	0.064	0.040
4	0.040	0.025
2	0.026	0.016
1/0	0.016	0.010
2/0	0.013	0.008
3/0	0.010	0.006
4/0	0.008	0.005
250 kcmil	0.007	0.004
350 kcmil	0.005	0.003
500 kcmil	0.003	0.002

Building	Voltage Drop	÷	[Neutral Amps	×	Length in hundreds of ft]	=	Resistance	
_______	_______V	÷	[_______A	×	_______]	=	_______	/100 ft
_______	_______V	÷	[_______A	×	_______]	=	_______	/100 ft
_______	_______V	÷	[_______A	×	_______]	=	_______	/100 ft
_______	_______V	÷	[_______A	×	_______]	=	_______	/100 ft

Form 6 Neutral & Ground Fault Evaluation

Farm Name: ______________________________ Date: __________

Evaluator: ________________ 120 V Load: ______A Page ____ of ____

Building: ____________ Source: ____________ Distance: ____________ft.

Neutral Size: ________ (Al-Cu) Neutral resistance per 100 ft. ________ Neutrals: Bonded/Sep.

	Time	Load Off $_{(A)}$	Load On$_{(A)}$	Load Off$_{(B)}$	Load ON$_{(B)}$
Panel NEV	____	______V	______V	______V	______V
Source NEV	____	______V	______V	______V	______V
Panel to Source V	____	______V	______V	______V	______V

Panel grounding description: ____________________ Resistance if determined: ________

Conductor to building: OVH URD 3-wire 4-wire Services to building: 1 2 3

Building supply conductor non-return current: ________A (Clamp ammeter around all conductors)

Notes:

Building: ____________ Source: ____________ Distance: ____________ft.

Neutral Size: ________ (Al-Cu) Neutral resistance per 100 ft. ________ Neutrals: Bonded/Sep.

	Time	Load Off $_{(A)}$	Load On$_{(A)}$	Load Off$_{(B)}$	Load ON$_{(B)}$
Panel NEV	____	______V	______V	______V	______V
Source NEV	____	______V	______V	______V	______V
Panel to Source V	____	______V	______V	______V	______V

Panel grounding description: ____________________ Resistance if determined: ________

Conductor to building: OVH URD 3-wire 4-wire Services to building: 1 2 3

Building supply conductor non-return current: ________A (Clamp ammeter around all conductors)

Notes:

Farm Name: ______________________________ Date: ____________

Ground Fault Evaluation:

Record the following measurements as the power is turned on and off at each building service. Keep the time as short as possible between the on and off measurements. Indicate if a shunt resistor is used when making animal contact voltage measurements.

*☐Shunt used

Building service	Time	Service? power	N_PEV	$N_{CPD}EV$	N_BEV	Animal contact	Non-return current
______	____	On	____	____	____	____	____
	____	Off	____	____	____	____	____
______	____	On	____	____	____	____	____
	____	Off	____	____	____	____	____
______	____	On	____	____	____	____	____
	____	Off	____	____	____	____	____
______	____	On	____	____	____	____	____
	____	Off	____	____	____	____	____
______	____	On	____	____	____	____	____
	____	Off	____	____	____	____	____
______	____	On	____	____	____	____	____
	____	Off	____	____	____	____	____
______	____	On	____	____	____	____	____
	____	Off	____	____	____	____	____