EQB

September 13, 1993

To: Roberta LeFleur
Legislative Reference Library

From: George Durfee
Environmental Quality Board

Subject: Contract Number 30000-18797-01: Test to Investigate Primary Neutral Grounding Practices and the Effects of Such Practices on Dairy Herd Health and Production. (General Topic for Filing - Stray Voltage)

The above referenced contract to investigate the effects of primary-neutral grounding practices on dairy herd health and production has been completed. The product of the investigation is data that will be used by the Environmental Quality Board's Stray Voltage Steering Committee to seek solutions to stray voltage problems. The Steering Committee includes representatives from several state agencies, The Electromagnetic Research Institute (TERF), an organization representing dairy farmers, and the electric utilities.

The investigation was conducted on a dairy farm near Miltona in Douglas County. Detailed measurements were made over a four week period of the farm's electrical environment and also of indicators of dairy herd health, production, and behavior. Attached to this memo is a copy of the test protocol and a list of the available data.

The complete data set consists of approximately 1,700 pages of paper records, 13 high density computer disks, and six video tapes and is on file and available for public inspection at the Environmental Quality Board office.

Please direct any questions and requests to view the data to George Durfee, Environmental Quality Board, 300 Centennial Office Building, 658 Cedar Street, St. Paul MN 55155. Telephone (612) 296-2878.

TDD 612 297-5353, OR 1-800-627-3529

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Test Protocol

To Investigate Primary Neutral Grounding Practices And the Effects of Such Practices On Dairy Herd Health and Production

By:

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Introduction

The Minnesota Environmental Quality Board Stray Voltage Steering Committee requested the development of a test protocol to examine the effects, if any, of primary neutral grounding practices of rural distribution systems on dairy herd health and production. Initiation of protocol development was in response to reports from dairy operators from both Wisconsin and Minnesota that disconnecting grounds on the primary neutral has had immediate and significant positive effects on production and the health of their dairy cattle.

The test as here designed is limited in that measurements will be made at just one farm over a relatively short time period. Extrapolation of conclusions to other farms may be problematic, considering the variability of electrical installations and other factors among farms. The test has been carefully designed to include the issue of quality control. The measurement strategy has been reduced to a set of relatively simple, specific, appropriate and easily documented observations which can serve as indicators of the effect, should it exist on the test farm.

This test requires a temporary disconnection of the primary neutral ground wire at the transformer pole serving the test farm and one adjacent pole ground. The disconnection of the grounds for this purpose will be done only under the testing provisions of the National Electric Safety Code.

A. Objective

Relate electrical grounding on and off a test farm to currents and voltages on the farm and specific selected indicators of herd health and production.

B. Possible Mechanism as a Working Hypothesis

Electrical grounding on and off the farm results in ground currents which are picked up by conducting elements in the barn and show up as ac and dc currents which access the cow in some way.

C. Test Site and Schedule

Criteria for selection of a test site were:

1) The test farm will be one on which the farmer believes a stray voltage problem exists.
2) The test farm will be one acceptable to all parties involved in the test.

Selected Site: David Lusty Farm, Miltona MN, served by Otter Tail Power.

Schedule: Test starts on March 1, 1993 and ends on March 29, 1993.

D. Measurement Strategy

Measurements and observations will be made during periods in which the primary neutral grounds at the transformer pole and at the next grounded pole are alternately connected and not connected. This will be a blind experiment; only the test supervisor will know the status of the ground connections. Duration of the test will be four weeks. Blind switching of the ground connections will be made at approximately weekly intervals.

Measurements and observations will be made to address the following general areas of interest:

1) Herd health, behavior and production to be measured by the dairy operator in conjunction with a veterinarian.

2) Electrical quantities pertinent to the secondary electrical system to be measured and recorded digitally using a data acquisition system. Appropriate signal conditioning modules will be used where necessary.

3) Electrical quantities pertinent to the distribution line and primary neutral-to-ground connections to be measured and recorded continuously and digitally using a second data acquisition system. Appropriate signal conditioning modules will be used where necessary.

4) Transient event measurements using a separate recording instrument(s) (BMI power quality monitor or equivalent with low voltage input module).

5) Distribution system operating data supplied by utility serving the test farm and monitored by an acceptable engineer.

All electrical quantities in D.2 and D.3 above will be measured once per second by the data loggers. The one-second data will be averaged each minute and stored as one-minute data with the following exception: For a period lasting from five minutes before changing the primary ground to five minutes after, data will be recorded as one-second data to provide greater time resolution of changes in the measured quantities.

E. Quantities to be Measured

1) Herd Health, Behavior and Production. The following information will be documented:

a) Stress as measured by blood tests (identical to those done at Dave Lusty's farm by Dan Hartzell, DVM) administered by the veterinarian to all cows in the herd once per week. Additionally, a blood test will be performed one week prior to start of the test and another will be administered one week after completion of the test. Blood test analysis will emphasize acute parameters including stress and CPK.

b) Daily herd water intake as measured by water meter. The model number, specifications, and accuracy range of the water meter will be documented, and further testing may be requested by either party.

c) Appearance of animals as evaluated daily by veterinarian and dairy operator. The name(s) of the dairy operator making the evaluation will be indicated after each milking period.

d) Cow behavior as evaluated by dairy operator and veterinarian; documented with video camera. Video recordings will be initiated by the test supervisor at his discretion. However, a minimum of 4 milking periods per week will be recorded.

e) Daily herd milk production.

f) Health records of cattle on the farm will be maintained before, during and after the test.

g) Feed analysis performed coincident with each blood test. Feed samples will be divided in three portions; one will be submitted for analysis by the veterinarian. The other two will be made available to the TERF representative and to the utility representative for analysis at their discretion.

h) The status of all cow trainers and fencers will be detailed prior to and during the test. The test supervisor will diagram the electrical connections of these devices.

i) DHIA results from samples taken during test period and results from samples immediately before and after the test period.

j) Animal turnover during test period.

k) Somatic cell count information before, during and after test period.

l) Record of all milk "dumped" during test period, and reasons.

m) Amount of time cows spend outside of barn for each day during test.

2) Cow contact potentials and secondary electrical system quantities. Quantities E.2.a - E.2.h to be recorded by data acquisition system #1 equipped with 8 differential DC analog inputs. Quantity E.2.i to be recorded on strip chart alone. Current measurements (items E.2.f and E.2.h) will also be recorded on strip charts to capture fast events. The TERF equipment being used in E.2.f and E.2.h must be tested for accuracy as per described by the MEQB Stray Voltage Steering

Committee prior to use. It will be acceptable for the TERF equipment to be tested immediately after the MEQB test if it cannot be completed prior to the test. The results will be submitted to all parties.

a) AC volts - watering cup to floor, open circuit. Use true rms AC to DC converter. Periodically measure across a 300 ohm resistor during quality control checks.
b) DC volts - watering cup to floor, open circuit to half-cells. Periodically measure across a 300 ohm resistor during quality control checks.
c) AC volts - front to back hoof across 300 ohm. Use true rms AC to DC converter. Remove 300 ohm periodically at the discretion of the test supervisor.
d) DC volts - front to back hoof across 300 ohm. Remove 300 ohm periodically at the discretion of the test supervisor.
e) AC volts - secondary neutral to remote ground. Use true rms AC to DC converter. (Note: The EGS ground will not be used as a reference rod for the test but may periodically be used by the test supervisor for spot measurements in the test protocol for comparison purposes.)
f) AC current - secondary neutral to remote ground. See E.2.e Note). Or between two other points such as the gutter chain, water pipes or stall dividers. Use shunt with ac-to-dc converter. Independently, measure the same current using a clamp recorded on a strip chart.
g) AC magnetic field - center of a stall at floor level. Coil orientation will be selected to maximize the reading. Provides integrated measure of AC currents in cow's immediate environment. Use milligauss meter with recorder output. Additionally once during each of the one-week periods the AC magnetic field will be mapped throughout the barn by measuring the total AC magnetic field at the center of each stall at floor level and at 1 m above the floor. Compare total AC magnetic field measurements obtained with a three-dimensional Field Star meter with those obtained by calculating the resultant of three one dimensional readings.
h) DC current between two points in the barn. Use dc clamp.
i) DC magnetic field - center of a stall at floor level. Sensor orientation will be selected to minimize the reading. Provides integrated measure of DC currents in cow's immediate environment. Use DC gauss meter with recorder output. TERF will provide meter output specifications to the utilities prior to the beginning of test.
j) The total farm load will be recorded with an appropriate instrument to measure KW load, power factor, voltage, and current.

3) Primary system electrical quantities. Quantities E.3.a - E.3.h to be recorded by data acquisition system #2 equipped with 8 differential analog inputs. Current measurements (items E.3.b, E.3.d, E.3.f, E.3.g and E.2.h) will also be recorded on strip charts or a Waverider system to capture fast events. Quantity E.3.i to be recorded in stand-alone mode. All clamp on type CT's

(current transformers) for measuring current levels less than 1 amp in magnitude must have an accuracy range of +/- 1 milli-amp. Any meters that do not meet the specification must have their accuracy clearly noted in the report.

a) AC volts - primary neutral to remote ground. (See E.2.e Note). Use true rms AC to DC converter.
b) AC current - primary neutral to transformer pole ground when connected. Use clamp.
c) AC current - phase conductor. Use clamp.
d) AC current - neutral conductor. Use clamp.
e) DC volts - primary neutral to remote ground (half cell).
f) DC current - primary neutral to ground at transformer pole when connected. Use dc clamp.
g) AC current - primary neutral to ground at one adjacent pole. Use clamp.
h) (item omitted)
i) Time-of-use energy. Use energy meter with recorder output (see E.2.j).
j) Primary system impedance. On the last day of the test utility personnel will temporarily bypass the isolator and make measurements necessary for the test supervisor to determine the primary system impedance.

4) Measurements will be made to detect transient voltages between two pairs of cow contact points: (Water line to front hooves) and (Front to rear hooves).

Use one multichannel power quality monitor such as BMI or equivalent with low voltage input modules. Measure across 300 ohm or open circuit alternately at the discretion of the test supervisor. Proper training by Ottertail Power Employee, Harvey McMahan or other experienced personnel, will be conducted as required.

5) Distribution system operating data. The utilities will keep track of the following information on the distribution system in a monitored region which is six miles in radius centered on the Dave Lusty farm:

a) Substation outage.
b) Change in neutral isolation of any distribution transformer.
c) Changes in either the transmission or distribution system that would constitute a change from the normal feed of electricity in the area.
d) If any substation or section of line is intentionally disconnected and for what reason.

Each utility will designate a contact person (and backup) to whom the MEQB test supervisor may contact at any time to request an update or inquire as to any specific time something may have occurred. A summary report should be available from each utility to the MEQB test supervisor at the end of the test period. For Runestone Electric Association this would include the Belle River and Carlos Substations. No other utilities have been requested to provide information.

Runestone and Otter Tail Power will provide the 15 minute average data for the substations in the monitoring area. These are Belle River and Carlos for Runestone and Parkers Prairie and Carlos for OTP. OTP will supply current monitoring readings on the feeders out of their Carlos and Parkers substations that serve distribution in the direction of the Dave Lusty farm. Current monitoring of the neutral conductors at the three phase junction pole 1 mile west of the Dave Lusty farm will be provided by OTP phase current monitors.

OTP will supply a diagram showing the 41.6 kv transmission lines from their respective sources to the point where they meet near Carlos. This will be the 41.6 kv lines from the Alexandria, Henning and Brandon bulk power subs. Fifteen minute (if available) or hourly load data at the source of each of these lines will be provided to the test supervisor at the end of the test period. No other transmission lines are included in this test.

The test supervisor will take spot harmonic levels of the secondary phase voltages twice a day and periodically through the test period these harmonic measurements should be taken with no load on the farm. OTP will provide one day of BMI training to the test supervisor.

6) Weather data. Summary weather records will be maintained on a daily basis during the test and will include: temperature (min/max), dew point, barometric pressure, precipitation and wind speed/direction.

F. Quality Control

The test supervisor will be responsible for obtaining a high quality multimeter capable of measuring all quantities in items E.2 and E.3 above. This multimeter will be submitted to an independent laboratory for testing and calibration before and after the test. During the test the supervisor will audit all data inputs on a daily basis to determine that the quantities being measured and recorded by the data acquisition systems are accurate to within some predetermined amount. Audit data will also be applied to the resulting data base as used for analysis after the test is ended.

Utility and TERF representatives will be present on the test farm only at the request of the test supervisor and then only when the test supervisor is present. The test supervisor will insure that an opportunity for equal representation is provided to both groups during each visit.

G. Peer Review

Peer review of this protocol will be used to assess the validity of the test. The protocol will be submitted to a reviewer selected by dairy farmers and a reviewer selected by the utilities. A two-week deadline will be imposed to expedite the review process. Reviews will be sent to the Stray Voltage Steering Committee for evaluation.

H. Data Analysis

Data analysis will be performed by the MEQB staff as follows:

1) Herd health, behavior and production.

a) Stress indicator(s) plotted graphically vs time.
b) Daily herd water intake plotted graphically vs time.
c) Appearance of animal presented as text provided by veterinarian and dairy operator.
d) Animal behavior presented as text provided by dairy operator and veterinarian with reference to video tape index of each observation.
e) Daily milk production plotted graphically vs time.
f) Written record of health of animals.

2) Electrical quantities pertinent to secondary system plotted as one-minute averages graphically vs time (or one-second averages when primary ground is changed). A summary of strip chart data (current measurements) will be presented as text with an example of each record. The complete strip chart record will be available for examination by interested parties and as a special order appendix.

3) Electrical quantities pertinent to primary system plotted as one-minute averages graphically vs time (or one-second averages when primary ground is changed). A summary of strip chart data (current measurements) will be presented as text with an example of each record. The complete strip chart record will be available for examination by interested parties and as a special order appendix.

4) Transient voltages as available. Some measure of power quality plotted vs time (e.g., impulse/minute).

5) Distribution system operating data (as available) plotted vs time.

6) Daily weather data presented in a table.

I. Data Interpretation

The data as described in Section H will be provided by the MEQB staff to the representatives of the dairy farmers and the utilities for their interpretations.

J. Data Reporting

Interpretations including recommendations will be provided by the representatives of the dairy farmers and the utilities to the MEQB staff. Staff will submit these interpretations and their own interpretation in a report to the MEQB via the Stray Voltage Steering Committee.

K. Project Personnel

The test supervisor will be Riley Hendrickson.

A veterinarian will be selected as follows: The Minnesota Department of Agriculture will request that the President of the Minnesota Milk Producers' Association recommend two veterinarians in the Alexandria/Miltona area who have strong dairy experience. Protocol authors will vote on final choice.

L. Equipment List

Item	Provided By
-all veterinarian supplies	veterinarian
-water meter	dairy operator
-video camera	
-milk measurement equipment	dairy operator
-data logger system in barn	RC Hendrickson
-data logger system for distribution system at transformer pole:	
-AT computer	utility
-A/D board, cable, assembly	purchase(?)
-(4) true rms-to-dc converters	RC Hendrickson
-ac magnetic field meter w/rec output	RC Hendrickson
-dc magnetic field meter w/rec output	D Dahlberg
-(1) ac current clamp w/rec out	D Dahlberg
-(1) dc current clamp w/rec out	D Dahlberg
-phase wire current measuring equipment	utility
-(3) ac current clamp w/rec out	rent
-(1) dc current clamp w/rec out	rent
-audit multimeter w/ac & dc current clamps & hv probe	RC Hendrickson
-2 power quality monitors w/low voltage input module	utility
-ground rod(s), wire, cable	RCH, utility
-survey instruments for mapping test farm	RC Hendrickson
-(4 channels) strip chart recorders for secondary system measurements	MEQB
-(5 channels) strip chart recorders for -primary system measurements	utility-(Waverider)
-half cell	RC Hendrickson
-half cell	utility
-energy meter	utility
-weather instruments	RC Hendrickson
-oscilloscope (battery-powered)	D Dahlberg
-trailer (heated)	utility or RCH

Signed (see the following):

Signature List, Test Protocol - 1/29/93.

Signed letter of agreement of 2/18/93 on changes and clarifications to the Test Protocol of 1/29/93 from Dan Mairs to Duane Dahlberg, Riley Hendrickson and George Durfee.

PRIMARY NEUTRAL GROUNDING TEST
INFORMATION LIST

001		DAILY TEST SCHEDULE
002	E.1)a,b,c,d,e,g,k	BEEHLER REPORT - TEXT AND TABLES; GRAPHS; (TWO PARTS)
003	E.1)c,d,e	OBSERVATIONS BY DAVE AND SUE LUSTY
004	E.1)b,e,i,k	MISC - DHIA MAY; HERD PARAMETERS;
005	E.1)d	VIDEO OF COW BEHAVIOR (6 TAPES)
006	E.1)f	VET MEDICAL HISTORY REPORT
007	E.2)a,b,c,d,e,f	BARN DATA LOGGER - DATA FILES DISK (6 DISKS)
008*	E.2)a,b,c,d,e,f	BARN DATA LOGGER - GRAPHS
009	E.2)a,b,c,d,e,f	BARN DATA LOGGER SWITCHING - BSTCH FILES (1/2 DISK)
010	E.2)a,b,c,d,e,f	BARN DATA LOGGER SWITCHING - GRAPHS
011	E.2)i,f	DC MAGNETIC FIELD AND AC CURRENT WP TO GC CHART PAPER (2 PARTS)
012	E.2)j	MAX DAILY DEMAND, KW, TIME AND POWER FACTOR; DAILY ENERGY, KWHr
013	E.2)j	KW DEMAND AND POWER FACTOR, 15 MINUTE INTERVALS
014	E.3)a,b,e,f	DISTRIBUTION POLE DATA LOGGER - DATA FILES DISK (2 DISKS)
015	E.3)a,b,e,f	DISTRIBUTION POLE DATA LOGGER - GRAPHS
016	E.3)a,b,e,f	DISTRIBUTION POLE SWITCHING - DATA FILES DISK (1/2 DISK)
017	E.3)a,b,e,f	DISTRIBUTION POLE SWITCHING - GRAPHS
018	E.3)b,	DISTRIBUTION PRIMARY TO XFORMER POLE GROUND CHART PAPER (2 PARTS)
019	E.3)c,d	LUSTY DATA FILES - DATA FILES DISK (1/2 DISK)
020	E.4)	4800 - WL TO RH HOURLY REPORTS IMPULSES >5 VOLTS
021	E.4)	4800 - WL TO RH IMPULSES >5 VOLTS (10 PARTS)
022	E.4)	4800 - HOURLY SUMMARIES; WL TO RH; FH TO RH; RMS V AND HIGH FREQ. NOISE
023	E.5)	OTP PARKERS PRAIRIE SUB REPAIR AND MAINTAINENCE
024	E.5)	OTP CARLOS SUB REPAIR AND MAINTAINENCE
025	E.5)	OTP CARLOS SUB 15 MINUTE KW, KVAR DATA (2 PARTS)
026	E.5)	OTP PARKERS PRAIRIE SUB 15 MINUTE KW, KVAR DATA (2 PARTS)
027	E.5)	RUNESTONE CARLOS SUB 15 MINUTE KW, KVAR DATA
028	E.5)	RUNESTONE BELLE RIVER 15 MINUTE KW, KVAR DATA
029	E.5)	CARLOS SUB 3 PHASE AND NEUTRAL CURRENTS - CSUB FILES (1/2 DISK)
030*	E.5)	CARLOS SUB 3 PHASE AND NEUTRAL CURRENTS - GRAPHS
031	E.5)	PARKERS PRAIRIE SUB 3 PHASE AND NEUTRAL CURRENTS - PPSUB FILES (1/2 DISK)
032*	E.5)	PARKERS PRAIRIE SUB 3 PHASE AND NEUTRAL CURRENTS - GRAPHS
033	E.5)	NEUTRAL CURRENTS PP, CARLOS, MILTONA - NEU FILES (1/2 DISK)
034	E.5)	OTP SYSTEM DIAGRAMS
035*	E.5)	OTP 41.6 KV TRANSMISSION LOAD DATA

036	E.5)	8800 IMPULSES >20 VOLTS - GRAPHS - FARMPRI FILE (1/4 DISK)
037	E.5)	8800 FARM PRIMARY TO NEUTRAL >20 VOLT IMPULSES (4 PARTS)
038	E.5)	8800 P1,P2,& N TO EARTH GROUND; VOLTAGE, HIGH FREQ. NOISE, FREQ, IMPULSES
039	E.5)	8800 HARMONIC, HIGH FREQ., AND SNAPSHOT REPORTS
040	E.5)	8800 SPEC HARMONIC REPT, FARM POWER ON/OFF, SNAPSHOTS, V SPECTRUM
041	E.5)	8800 HARMONIC REPT, SNAPSHOTS AND VOLTAGE SPECTRUM (2 PARTS)
042		8800 SPECIAL TESTS: FARM PRIMARY TO NEUTRAL, >20 VOLT IMPULSES
043		HENDRICKSON DRAFT REPORT ON MATERIALS AND METHODS, 8/25/93
044		DATA FILES ON DISK
~~045~~		~~MISC~~

H.1)a,b,c,d,e,f	PROVIDED ABOVE
H.2)	PROVIDED ABOVE
H.3)	PROVIDED ABOVE
H.4)	PROVIDED ABOVE
H.5)	PROVIDED ABOVE
H.6)	NOT DONE - INFO PROVIDED ABOVE IN # 001

INFO TO BE PROVIDED

F.	QUALITY CONTROL
	MISC