Preface – Prelude – Prologue

(Take your pick)
to the Institute of Electrical and Electronic Engineers' (IEEE) paper

EQUIPOTENTIAL PLANES, A FIGMENT OF THE IMAGINATION

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Mr. Donald W. Zipse offered a very controversial technical paper on equipotential planes stating that the National Electrical Code Sections 547 on Agriculture Buildings and 680 Swimming Pools were INCORRECT when they state that equipotential planes " . . . prevent a difference in voltage from developing within the plane." In addition, Mr. Zipse also states in his paper that four agriculture professors were incorrect in their three papers published in the early 1980s. They did not understand the difference between IEEE Standard 80 Substation Grounding and Step-Touch potentials based on high levels of fault current for extremely short time and steady state continuous flowing stray current of very low magnitude.

The IEEE's Industrial and Commercial Power Systems Committee at first rejected Mr. Zipse's paper offering. However, cooler heads prevailed stating that the IEEE was the place for new ideas and discussion. The I&CPS Committee went out to 23 persons who were opponents in court cases or were utility employees or agriculture professors requesting that they rebut Mr. Zipse's paper.

Three papers were submitted in rebuttal. The first was authored by one of the original professors, Robert J. Gustafson and co-author LaVerne E. Stetson. The other time slot had two papers by employees of Alabama Power, Keith Wallace and Don Parker. The Alabama papers were no more than regurgitation of the Agriculture Red book, Document 696 and should be totally disregarded.

Dr. Gustafson completely disregards the multigrounded neutral electrical distribution system circuit that connects the primary neutral with solid copper conductors to the equipotential plane. It is this circuit that supplies approximately 50 percent of the stray current flowing in swimming pools and dairy farms. Note that EPRI, the Electrical Power Research Institute, the utilities brain trust, state that 60 percent of the return neutral current on multigrounded neutral electrical distribution system circuits returns over the earth. Only 40 percent returns over the neutral conductor.

Between the draft of Zipse's paper and the presentation Mr. Zipse suggested to Mr. Neubauer, Master Electrician who makes all the electrical measurements, to switch to iron rebar wire which was used for the test conductors and iron plates for contact with the floor, thus eliminating any suggestion of galvanic cell generating the direct current. The section on direct current was inserted to show that three actions were taking place simultaneously, galvanic cell action and rectification of the ac by rebar in concrete as noted in IEEE Standard 80 and the flow of harmful alternating current in the equipotential plane.

What Dr. Gustafson completely ignores is the alternating current measurements that were recorded that harm dairy cows causing decreased milk production, injury, and death to the cows. What is not in the paper is last week we disconnected the phase and neutral and the telephone grounds to a dairy, and still had current flowing over earth and into the equipotential plane and into the cow proving stray current flows over and through the earth and equipotential plane in sufficient magnitude to harm a cow or human. Tests at the Allen Dairy and court records also confirm the flow of uncontrolled current in earth.

EQUIPOTENTIAL PLANES, A FIGMENT OF THE IMAGINATION

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Abstract – This paper challenges conventional established practice and presently accepted standards concerning equipotential planes. The concepts, ideas and recommendations contained within this paper are the opinions of the author.

It is the opinion of the author that it is unfortunate that in the United States the vast majority of utilities use the hazardous multigrounded neutral electrical distribution system.[1] This type of electrical distribution system uses the earth for a partial electrical neutral return path for the dangerous high voltage distribution current. The correct term for this uncontrolled current is "stray current" as opposed to the incorrect term, stray voltage, commonly used [2]

Robert Gustafson was editor of Chapter 4, Mitigation, in the document titled, "USDA Agriculture Handbook No. 696, Effects of Electrical Voltage/Current on Farm Animals" known as the Agriculture Red Book, [3] where he presents "various solutions to stray or neutral-to-earth voltage problems." One of his major suggestions is the installation of an equipotential plane. This paper will relate testing that suggests that such a solution is harmful not only to animals such as cows and pigs, but also to humans.

With the flow of stray neutral distribution current over and through the earth, one must consider the effects that this dangerous stray neutral distribution current will have on an equipotential plane. According to the National Fire Protection Association's (NFPA) Standard 70, the National Electrical Code (NEC) Articles 547 and 680, equipotential planes " . . . prevent a difference in voltage from developing within the plane." This paper will discuss the contradictions, inconsistencies and incompatibilities of equipotential planes, Ohms Law and the NEC.

For years it has been opined that with detailed understanding, and the correct application of Ohms Law, one would come to the conclusion that the concept of equipotential planes was not only potentially dangerous, but also blatantly false. In December 2004, tests were conducted that finally confirmed that the concept of equipotential planes is a figment of the imagination.

Index Terms - equipotential plane(s), multigrounded neutral electrical distribution system(s)

Definition of Terms:

The definitions, which follow, are predominately those used in the United States unless otherwise noted.

Equipotential: In the early 1980s: "The definition of the equipotential plane is derived from two words. Equipotential means having the same electrical potential throughout; plane means a flat or level surface, together they form a level surface having the same electrical potential throughout." [3]

Equipotential: (Dictionary) **1.** Having equal potential. **2.** *Physics*. Having the same electric potential at every point.[1]

equipotential as used in the power industry: (conductor stringing equipment) (power line maintenance) An identical state of electrical potential for two or more items. (PE/T&D) 1048-1990, 516-1995, 524-1992, 524a-1993

equipotential plane as constructed: An area where wire mesh or other conductive elements are embedded in or placed under concrete, bonded to all metal structures and fixed nonelectrical equipment that may become energized, and connected to the electrical grounding system to prevent a difference in voltage from developing within the plane. NEC 2005, Section 547.2.

Equipotential Bonding:

"(A) Performance. The equipotential bonding required by this section shall be installed to eliminate voltage gradients in the pool area as prescribed." NEC 680.26

Metallic Structural Components. "All metallic parts of the pool structure, including the reinforcing metal of the pool shell, coping stones, and deck, shall be bonded. The usual steel tie wires shall be considered suitable for bonding the reinforcing steel together, and welding or special clamping shall not be required. These tie wires shall be made tight. If reinforcing steel is effectively insulated by an encapsulating nonconductive compound at the time of manufacture and installation, it shall not be required to be bonded. Where reinforcing steel of the pool shell or the reinforcing steel of coping stones and deck is encapsulated with a nonconductive compound or another conductive material is not available, provisions shall be made for an alternative means to eliminate voltage gradients that would

[1]Excerpted from *American Heritage Talking Dictionary*. Copyright © 1997 The Learning Company, Inc. All Rights Reserved.

otherwise be provided by unencapsulated, bonded reinforcing steel." NEC 680.26 (B) (1).

I. INTRODUCTION

This paper discussion is limited to the application of the equipotential planes to agriculture buildings and swimming pools, hot tubs and similar applications.

In 1962, the first study of stray voltage and cows was published in New Zealand. About the early 1980s Robert J. Gustafson, T. Surbrook, N. Reese, H. Cloud wrote about equipotential planes.[4] [5] [6] In each of the documents the incorrect term, "Stray Voltage" appears. The preeminent professor Charles F. Dalziel in 1946 states, "Perhaps the most serious misconception concerns the effects of voltage versus the effects of current. Current and *not* voltage is the proper criterion of shock intensity." [7] It is opined that the U.S. Department of Agriculture, the American Society of Agriculture Engineers and others who coined and use the term "stray voltage" in the late 1970s failed to do adequate research on the subject.

In the early 1980s, three papers on equipotential planes and dairies were written based on, it is opined, a misunderstanding. Robert J. Gustafson, T. Surbrook, N. Reese, H. Cloud wrote about and coined the term equipotential planes. [4] [5] [6] In the author's opinion in each of the documents the incorrect term, "Stray Voltage" appears and unfortunately, the introduction of equipotential planes appeared. It is this author's opinion that confusion and misunderstanding existed in their interpretation of the Institute of Electrical and Electronic Engineers' (IEEE) Standard 80, "Guide for Safety in AC Substation Grounding" where step – touch potentials are covered, the NEC Article 250 where "bonding" is covered and the desire to protect cows from electric shocks.

In 1985, the Ad Hoc Subcommittee on Electrical Grounding of Agriculture Buildings submitted proposal # 19-16, Log # 1363, which can be found in the 1985 ROP for the 1987 NEC. The proposal was to modify the 1986 Edition of the NEC, Article 547, Agriculture Buildings. This proposal put forth the idea of equipotential planes based on the above equipotential plane papers by Gustafson, et al. Since the proposal came from a subcommittee, it was adopted by Panel 19 "Unanimously Affirmative".

It has been opined that the lack of understanding of 1) Ohms Law and 2) the concept of step-touch potential and 3) misunderstanding of the concept of bonding has lead unfortunately to the universal acceptance without question of the validity, of equipotential planes.

Mr. Lawrence C. Neubauer in December 2004 came up with the concept and devised a means of testing that has proven the principle of equipotential planes to be blatantly false. The use of equipotential planes leads to conditions that are hazardous to the health of humans and animals such as cows and pigs.

This paper will discuss the current flow through equipotential planes from the utility's primary neutral to secondary neutral connection, and the multigrounded neutral distribution system's neutral to earth connections. The paper will not discuss the normal electrical phase to earth faults, lightning discharge or geomagnetic induced currents. The paper will be limited to the first two items, which it is opined, are the major concerns.

II. IS IT STRAY VOLTAGE OR STRAY CURRENT?

It has been reported by Edward Owen, IEEE Fellow, a student of the preeminent Professor Charles F. Dalziel, University of California, that Professor Dalziel "required" his students to participate in experiments to measure the human animal's response to voltage and current by placing their feet into a bucket of salt water and holding onto a conductor. Professor Dalziel then applied varying amounts of current and measured their response. As recalled by the author from presentations by William B. Kouwenhoven, Professor of Electrical Engineering, Johns Hopkins University, he used fresh cadavers to measure electric current necessary to revive the heart in order to develop the defibrillator.

These experiments and others produced Table 1.

It has been shown that it takes approximately 35 volts across dead dry skin to force electricity into the male human body. Less voltage or electrical pressure is required for a woman's dead dry skin. The vast majority of the resistance is in the first layer of dead dry skin. This high resistance vanishes when the skin is cut or the person or animal is immersed in conductive liquid such as water or manure.

For a 60 Hertz alternating current (ac) at 0.4 milliamps (mA) or 0.0004 Amps (A) a human male animal will feel a slight sensation on the hand. For a woman it only takes 0.3 mA. A painful shock requires 9 mA for a man and for a woman 6 mA. One must note these low values.

Time plays a function in the equation of electrical current and injury. The longer a person or animal is subjected to an electrical current flowing through the body, the more likely an injury will occur.

"The most damaging path for electrical current is through the chest cavity. In short, any prolonged exposure to 60 Hz current of 20 mA or more may be fatal. Fatal ventricular fibrillation of the heart (stopping of rhythmic pumping action) can be initiated by a current flow of as little as several milliamperes. These injuries can cause fatalities resulting from either direct paralysis of the respiratory system, failure of the rhythmic heart pumping action, or immediate heart stoppage." [8]

Comparison of the human animal with the cow shows many similar conditions. Both are mammals with a blood system and both have an electrical communication system, nerves. In fact, the internal resistances of both are approximately 500 Ohms

It is clear that it is the current that causes a reaction in humans, not the voltage. The voltage is the driving force and there is a threshold below which there is an inability to drive any current through the human body or animal.

III. PROLIFERATION OF THE TERM STRAY VOLTAGE

From personal experience back 50 years, a clamp-on ammeter was very costly. In fact, at first this author as an electrician had only a 100-watt lamp in a rubber molded medium base lamp socket with two insulated wire pigtails. This was the poor man's voltage tester. It was close to 10 years before an ammeter was owned.

To make it perfectly clear, the following is the opinion of the author. If a person did have an ammeter, the jaws would not be large enough to place the ammeter around a cow or other large object. Therefore, a voltmeter was substituted. With the proliferation of the dangerous multigrounded neutral electrical distribution system using the earth as a path for return neutral distribution current to flow back to the source substation, anyone placing the two voltmeter probes into the earth could get a voltage reading. Since the operator of the voltmeter was straying all over and getting voltage readings, the term "stray voltage" was coined, it is opined, without doing adequate research in fields other than agriculture and cows.

The IEEE Standard Dictionary of Electrical and Electronics Terms, Sixth Edition, does not contain any entry for stray voltage. However, there are entries for stray current.

Voltage does not stray since voltage is a function of the current times the resistance; Ohms Law. Overlooked was this simple fact that it was the current that flowed uncontrolled through the earth. It is a fact that with the multigrounded neutral distribution system there is no way the stray current could be limited in magnitude or where in the earth the stray current flowed. Therefore, when the word "uncontrolled" is used it is applied to both the magnitude and location of flow of the current.

As a side comment Edison did not call his type of electrical distribution system Direct Voltage, but Direct Current. Likewise, Nikola Tesla and George Westinghouse called their type of electrical system Alternating Current, not Alternating Voltage.

With the advent of ever-increasing electrical load, the neutral distribution current flows through the earth in ever increasing amounts. It is a fact that the Electric Power Research Institute (EPRI) states that 40 to 60 percent of the neutral return current from a multigrounded neutral electrical distribution system returns to the source substation through and/or over the earth (page 1-5).[1] Testing by Mr. Neubauer has revealed higher percentage. In one case up to 81 percent of the stray neutral distribution current was returning uncontrolled through the earth to the source substation. The above was entered into court records. [9]

Cows can receive an electrical shock from stray neutral distribution current flowing through and/or in the earth when trying to drink; they jerk their head out of the water and refuse to drink. With lower water intake, a cow's milk production decreases. When the cow is shocked in the milking parlor, she will not drop her milk and again reduced milk production results. It is a fact that both of the above conditions can lead to mastitis and the health of the cow deteriorates along with income from milk production.

Thus, with good intentions the schools of agriculture entered the electrical arena seeking a solution. Robert J. Gustafson, et al., sold the industry and the NEC, it is opined and will be proven later, a flawed concept of the equipotential planes as a solution to stray neutral distribution current shocking cows and reducing milk output.

Unfortunately, the NEC also adopted this flawed concept for swimming pools.

IV. EQUIPOTENTIAL PLANES AND THE NATIONAL ELECTRICAL CODE

The 2005 Edition of the National Fire Protection Association's National Electrical Code contains the following requirements for agriculture buildings:

547.2 Definitions.

"Equipotential plane. An area where wire mesh or other conductive elements are embedded in or placed under concrete, bonded to all metal structures and fixed nonelectrical equipment that may become energized, and connected to the electrical grounding system to prevent a difference in voltage from developing within the plane."

The requirements for swimming pools are:

680.26 Equipotential Bonding.

"(A) Performance. The equipotential bonding required by this section shall be installed to eliminate voltage gradients in the pool area as prescribed."

The key words for agriculture buildings are, "to prevent a difference in voltage from developing within the plane" and in the case of swimming pools, "equipotential bonding required by this section shall be installed to eliminate voltage gradients in the pool area".

As will be shown, one cannot prevent voltage gradients in an equipotential plane.

V. IEEE STANDARD 80, SUBSTATION GROUNDING

It is opined that Gustafson, et al and the NEC Making Panels did not take into consideration the purpose of the IEEE Standard 80, "Guide for Safety in AC Substation Grounding".

IEEE Standard 80 states:

"1.2 Purpose

"The intent of this guide is to provide guidance and information pertinent to safe grounding practices in ac substation design.

"The specific proposes of this guide are to

a) Establish, as a basis for design, the **safe limits of potential differences** that can exist in a substation **under fault conditions** (Author's emphases) between points that can be contacted by the human body.
b) Review substation grounding practices with special reference to safety, and develop criteria for a safe design.
c) Provide a procedure for the design of practical grounding systems, based on these criteria.
d) Develop analytical methods as an aid in the understanding and solution of typical gradient problems."

It is a fact and is very clear that Clause 1.2 a) states that IEEE Standard 80 is under **fault conditions.** Stray current or if one insists, stray voltage, exists under normal continuous flow of neutral distribution current, under continuous utility operating conditions, not fault conditions.

Professor Robert J. Gustafson wrote, "Gradient control is used by the electrical industry to minimize the risk of hazardous step (foot-to-foot) and touch (hand-to-foot) potentials **under fault conditions** (emphases by author) at substations and around electrical equipment. In addition to protecting people, animals, and equipment **under fault or lightning conditions**, proper

equipotential systems in livestock facilities can solve stray voltage/current problems."[3]

It is opined by this author, that from the above that it is clearly evident that this is an enormous mis-application of an electrical principle.

VI. DEFINING "FAULT"

To clarify this situation of what is a "fault", the IEEE compendium of terms, the Dictionary, Standard 100 states, "(protective grounding of power lines) (current). A current that flows from one conductor to ground or to another conductor owing to an abnormal connection (including an arc) between the two. (PE/T&D) 1048-1990". In layman's terms, a short circuit to ground.

One could argue that stray neutral distribution current is a fault. Unfortunately, the utilities and the National Electrical Safety Code define multigrounded neutral electrical distribution system as a normal method of electrical distribution, even though it is in this author's opinion a dangerous and hazardous electrical distribution system and this has been stated in court testimony and documents. In fact these thoughts are expressed in great detail in the IEEE – PCIC paper titled, "The Hazardous Multigrounded Neutral Distribution System And Dangerous Stray Currents". [10] [2] Thus, stray uncontrolled neutral distribution current emanating from a multigrounded neutral electrical distribution system is not a fault current as referred to in the IEEE Standard 80, but it is a continuous flow of neutral return current flowing back to the source substation with 40 to 60 percent of the return neutral distribution current flowing uncontrolled over and through the earth.

VII. MAGNITUDE OF CURRENT

The enormity of the amount of fault current that can flow within a high voltage substation dwarfs the infinitesimal, yet hazardous stray neutral distribution current flowing over the earth from the multigrounded neutral electrical distribution system. Faults at high voltage substations are thousands of amperes with driving voltages of 35 000 volts and higher.

For cow contact voltages, the Agriculture Red Book, Cornel Studies, states that the level is below 10 volts, in the area of 0.5 to 4.0 or 8.0 volts. However, the work of Dr. Gorewit has been challenged by Dr. Michael Behr as being incorrect and the resulting lawsuit has been settled in favor of Dr. Behr. It is opined that this action places the Agriculture Red Book in question as to its accuracy. The above statement is based on court cases where testimony has been given.

The current level is measured in milliamperes. With humans, concern begins at the Ground Fault Circuit Interrupter (GFCI) operating level of 6 milliamperes. Even at that, low-level humans will react with pain. See Table 1.

This author along with Mr. Neubauer have measured stray neutral distribution currents ranging from 5 amperes to 20 amperes or more that are flowing over the earth from individual multigrounded neutral electrical distribution systems circuits and not contained within the neutral conductor. The return neutral distribution current is dispersed over and through the earth. The study of the multigrounded neutral electrical distribution system of the New Jersey Stray Voltage Investigation conducted by VitaTech Engineering, LLC of the "JCP&L's Herbertsville – Neutral-to-Earth (NEV) Investigation" revealed a neutral distribution current of 5.5 amperes flowing over the earth returning to the substation in a residential area.

With the dead dry skin resistance of human body eliminated by immersion in water, these lower levels of current have proven capable of causing internal body functions to fail or to cause death.

A. Method Used to Determine the Amount of Electric Current Returning Over the Earth – Single Phase

The method used to determine the amount of electric current returning over the earth for the single-phase case is as follows. Assume a single-phase circuit extends beyond a dairy farm or a home with a swimming pool, for approximately 20 km (12 miles). In this distance, there are other dairy farms and homes. The first measurement is to measure the current on the phase conductor. In the case that comes to mind, the outgoing single-phase current measured 18.5 amperes maximum. Another recording ammeter was placed on the multigrounded neutral of the multigrounded neutral distribution system. The neutral current corresponding to the maximum is noted and in the case at hand was 3.5 amperes.

The instrument used is a data recorder recording the time, current and frame number. The measurement was based on a 24-hour period.

If there is 18.5 amperes flowing out to the outer farms and only 3.5 amperes coming back on the neutral conductor, the only conclusion is the difference is returning to the substation through the earth. Thus, in the case at hand, 15 amperes was missing and has to be flowing over and through the earth. A 1.22 km (4000 ft.) loop of bare copper conductor was laid on the surface surrounding the dairy and this loop picked up sufficient current to light a miniature lamp.

B. Method Used to Determine the Amount of Electric Current Returning through the Earth – Three-Phase

In this example, assume a three-phase multigrounded neutral distribution system runs past a dairy farm. A three-phase tap extends up the lane to the pole mounted open delta transformer bank. A three-phase open delta transformer bank produces unbalanced phase currents, which results in additional neutral currents flowing over the earth.

The data recorders in this case must record not only the time and current, but will have to record the power factor. Where as in the single-phase case a minimum of two data recorders is required, in the case of the three-phase tap a total of twelve data recorders are required.

The substation side of the tap will require three data reorders for the three phase conductors and another data recorder for the neutral. Likewise, four will be required for the tap and four more for the multigrounded neutral distribution system on the far side of the tap, away from the substation. With this amount of instrumentation installed, the current flowing up to the tap from the substation can be recorded. The three phases feeding the dairy along with the neutral current can also be recorded. Finally, the amount of electricity flowing past the dairy can be documented. Unfortunately, the calculations are not as simple as the single-phase case.

C. Harm To the Dairy Herd Caused By the Multigrounded Neutral Distribution System

In the review of this paper, the statement was made that the paper implies, "that the gradients in agricultural applications can be enough to drive currents through cows that are enough to discourage them from giving milk, but you don't suggest that currents and voltages are fatal to cows." The comment is very legitimate.

A cow consumes 30 or more gallons of water per day in order to produce 80 to 90 or more pounds of milk per day. With stray current invading the dairy, the cow when she goes to drink normally sticks her mouth down into the water and sucks the liquid up like a vacuum.

However, when she goes to drink and she receives an electric shock from the stray current, she often jerks her head out of the water. Her thirst drives her to only lap at the water. The lack of water intake results in production and health problems, the inflammation of the breast or udder. Mastitis could be compared to a cold. Like a cold, it leads to other complications.

In addition, to receiving an electric shock at the waterers, when the cow goes into the milking parlor and touches the stanchions while standing on the equipotential plane, she receives more electric shocks. Now she will not let her milk down and if the cow is not milked out completely, she can get mastitis.

In the center of the hoof is a soft flesh. Evidently, when electric current flows through the hoof the center of the hoof gets inflamed and the joints become swollen, preventing the cow from walking.

The poor dairy farmer is now faced with milk production at 40 to 50 pounds per day when approximately 50 pound per day is the economical breakeven point.

On one dairy farm, it was reported that out of a herd of 3000 cows, approximately five cows per day were dying. This death rate lasted for over a year before the dairy found out the problem was stray current.

While we are on cows, the insertion of a neutral blocker (a form of a lightning arrester) between the primary neutral and the secondary neutral reduces the amount of stray current by 40 to 60 percent. Usually, as soon as a neutral blocker is installed or better yet a transformer that isolates the primary neutral from the secondary neutral is installed, the milk production increases and the health of new, fresh cows does not deteriorate. Once a cow is damaged from the flow of stray current she remains damaged and usually does not return to a healthy state.

It is opined that humans have died from stray current. Several cases of drowning included reports of person's muscles freezing when entering or exiting a pool. When a member of the Delaware Medical Examiners office was asked how would they tell if a person died of a heart attack or was electrocuted if found in a shower? The answer was we would look for the entrance and exit wounds. When it was pointed out that there would be no entrance or exit wounds because the body would have been wet and the major part of the human resistance is contained on the surface of dead dry skin. The reply was, "We would not be able to tell."

In a case involving a KOA campground the lawyer for the campground owner was approached and suggested the utility be sued also. This was based on reports of a boy's muscles froze when exiting the pool. This happened after all the electricity was turned off to the pool. However, the equipment grounding conductor and the neutral were still connected. Explanation is contained later. Also, see figure 3. The lawyer declined based on his lack of knowledge of electrocutions. The insurance company lawyer was also contacted and his reply was to the effect that the insurance company has lots of money.

Presently the author is involved in a case where stray current has disabled a person, while in the water from his waist down. The person has medical problems with his stomach being upset all the time and medicine does not settle it. His bowels feel like he has to go all the time. He had for three years erectile dysfunction along with other medical problems.

VIII. REJECTION OF THEORY ONLY

While waiting for a flight from San Francisco, a chance encounter back in the mid 1960s, with an electrical engineer working on the other side of the decimal point, a computer chip designer, changed this author's thinking on bonding. The other engineer related the problem he had in where to place electrical connections of transistors, resistors, capacitors, etc onto a copper surface no larger than a person's fingernail. His problem was the voltage difference across the minute copper substrate.

If two points are bonded together or on the same conductive surface, it was explained to this then young electrical engineer (author), then no difference in voltage could possibly exist.

The above is correct if, and this is the BIG IF, if there is no current flow across the surface. It is the opinion of the author that it is amazing how misconceptions are produced by the mind rather than understanding of the principles.

The principle here is to understand Ohms Law, which states that current times the resistance will equal the voltage produced. The reinforcing iron bar buried in concrete has resistance, be it ever so small. Thus, it is a fact that any stray neutral distribution current traveling through the concrete will develop a voltage. This is just a simple application of Ohms Law. However, it remained until Mr. Neubauer's testing to show and prove once and for all that equipotential planes do not prevent a voltage gradient.

A. How did the misunderstanding occur?

How did the misunderstanding of equipotential planes and bonding occur? In addition to the above dissertation, it is opined that the accuracy of analog voltmeters was insufficient to detect an existing low voltage gradient. Sensitive ammeters were available only in the laboratory, not in the field. Finally, few if any persons questioned the dangers and hazards associated with the multigrounded neutral electrical distribution system with its associated uncontrolled flow of current over and through the earth.

B. Bonding and Ohms Law Explored.

The key to understanding bonding and equipotential planes is Ohms Law. In order to understand Ohms Law and eliminate the misunderstanding is to realize that Ohms Law can be thought of having two states. The assumption that has to be made in this example is that there is a resistance value.

The value of resistance is not zero. After all, everything has resistance unless the object is at absolute zero, which is not the case on a dairy farm or at a swimming pool.

Is there a current flow or not? With Ohms Law if the current value is zero, the voltage is also zero. However, if there is a current flow, no matter how small, there will be a voltage. Therefore, since an equipotential plane's concrete and reinforcing bars both have resistance any current flow across or through the concrete containing bare steel reinforcing bars will have a voltage across the area.

C. Voltage Drop

If we were to take a number 12 AWG copper conductor of 304.8 m (1000 feet), which has a resistance of 2.01 Ohms, and apply a current of 16 amperes, the resultant voltage drop would be 32.16 volts.

Should we cut the copper conductor in half the voltage drop would likewise drop in half or to 16.08 volts. We still have a voltage gradient as long as there is a current flow in the copper conductor. No matter how small a section of copper conductor, with a current flowing through the copper conductor, there will be a voltage drop. A copper conductor of a centimeter length would have a voltage gradient of 0.001055 volts.

Therefore, if we take a piece of copper conductor and bond two electrical points together to form an electrical bond and there is a current flow across that electrical bond, there will be a voltage difference between the two points. If there is no current flow, then and only then will the two points be at the same voltage. The problem is most people do not ask the question when dealing with an electrical bond, is there a current flow across the bond?

Now let us imagine the copper conductor is as malleable as gold and with a hammer press we flatten the center section of the 304.8 m long copper conductor until it is as wide as milking parlor or a swimming pool. With the same current flowing through the copper conductor, round at both ends and flat as a slab of steel plate in the middle, would not the same voltage drop occur?

Now in your mind, replace the flat center section of the copper conductor with the so-called equipotential plane consisting of concrete and reinforcing bar, which also has resistance, but of a different value. The same current is flowing through the copper conductor and now also the equipotential plane. Unless there is something magic about an equipotential plane, there would be a voltage drop, voltage gradient, across the so-called equipotential plane.

IX. MR. NEUBAUER'S TEST

Mr. Neubauer is a Master Electrician of unequal talents. The question that Mr. Neubauer resolved was how to put an end to any doubt, question or uncertainty that equipotential planes do have a harmful and dangerous voltage gradient across them.

A. Test Setup Number 1.

The entrance to most milking parlors consist of a large concrete pad reinforced with re-bars, forming a grounded, so-called equipotential plane either square or rectangular of dimensions approximately 6 to 15 meters per side. The size is dependant on the milking parlor capacity.

In the middle of the equipotential plane, Mr. Neubauer placed a large plastic bucket of approximately 50 cm in diameter and 40 cm high. Using a length of insulated conductor, number 14 AWG with the end stripped, the bare section is coiled and placed under the plastic bucket in intimate contact with the wet and urine soaked concrete. Mr. Neubauer filled the plastic bucket with water. (See Appendix for drawing.)

The insulated end of the conductor was connected to the instrumentation. Next another length of conductor was partially stripped, and the bare section coiled and placed in the bottom of the plastic bucket. The insulated end was connected to the other end of the instrumentation terminal.

Mr. Neubauer obtained a video splitter allowing a standard computer/video display screen to have four inputs. (See Video Capture) This allowed the recording of four different video cameras at one time and to be displayed on the same screen, one in each quadrant. With video cameras set to record the instrumentation and the plastic bucket, we sat back and waited for the cows to try to drink.

B. Curious Critters.

Cows are cautious and yet curious animals. They immediately notice something different and stood back eyeing the situation. Finally, one cow approached, with curiosity, yet hesitated. Then with caution, she placed her mouth into the water.

Immediately the dc milliammeter needle moved showing current was flowing through the cow and current can only flow if there is a potential forcing, driving the current. Later both ac and dc ammeters were used. The person familiar with galvanic action would reply it is a galvanic cell. The first response of any utility person is, "We do not produce direct current. We distribute 60 Hertz alternating current that has a sine wave associated with it. That direct current must be coming from somewhere else such as a direct current impressed on a pipeline to prevent corrosion."

C. Recognizing Galvanic Action

"Galvanic" means relating to direct-current electricity, especially when produced chemically. A galvanic cell is also called a voltaic cell. The spontaneous reactions in it provide electric energy or current in the form of direct current. An electrolytic cell is used for electrolysis. In this case, electric energy is used to force nonspontaneous chemical reactions, the opposite of a galvanic cell. [11]

The maximum voltage that can be produced by a half-cell is comprised of Litthium at –3.04 volts and Iron at + 2.87 volts for a total of a constant output of 6.93 volts. This combination is not available in a normal dairy or swimming pool setting. What is available in a dairy would be using a copper

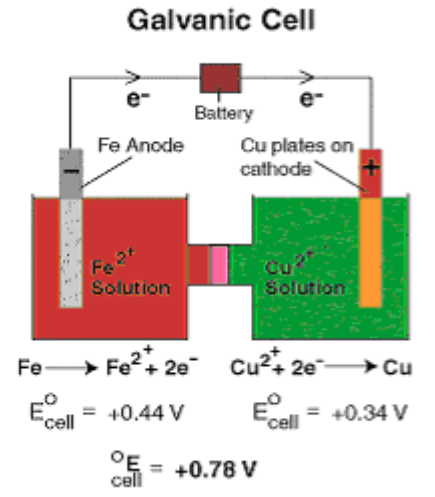

Figure 1. Galvanic or Voltaic Cell [12]

conductor and the iron in the concrete, which will produce a constant +0.34 volts for the copper and the iron at –0.44, or a paltry sum of 0.78 constant dc volts maximum.

"The nature of concrete corrosion is an exchange of energy within different sections of the reinforcing steel. At the anode, corrosion occurs and iron ions are released into the electrolyte. The relative energy levels can be determined in relation to a reference electrode with a stable electrochemical potential. A high impedance voltmeter is connected between the reinforcing steel and a reference electrode placed on the surface of the concrete. The resulting potential reading on the voltmeter is an indication of the energy levels (corrosion activity) of the steel in the vicinity of the reference cell." [13]

D. Concrete Encased Reinforcing Bar Rectification

The 60-Hertz Alternating Current flowing through the concrete with the reinforcing bar is rectified within the concrete producing an alternating current wave that has a dc offset [14]

What happens is as the stray current flows through the concrete some, a very small amount of the alternating current, ac, is changed, rectified into direct current. This injection of a direct current offsets the alternating sine wave. This is very common for anyone with a Lionel old three-rail train set. In order to blow the whistle or bell a low dc voltage is injected into the ac sine wave. The dc activates the relay that blows the whistle. This is not a new concept since the dc operated whistle blowing mechanism has been around since the author's childhood, the 1940s and is still available.

One of the many unsatisfactory solutions offered is to drive copper grounding rods next to the water tanks to "ground" the water tank. When this is done, immediately milk production drops by approximately 10 pounds per cow in 3 to 4 days. However, the water tank is on an equipotential plane.

Are equipotential planes effective with only ac and not for dc? Do equipotential planes maintain no potential gradient for only 60 Hz and not galvanic, voltaic cell currents?

E. The Path of the Current.

The stray neutral distribution current direction of flow is arbitrarily taken, for ease of understanding, to flow up the legs of the cow, through the body to the neck and down to the mouth. The current continued from the mouth, the tongue, into the water, through the water to the coil of bare copper conductor in the bottom of the plastic bucket and through the insulated portion of the copper conductor to the terminal on the milliammeter. (See Figure 2)

The current exited the ammeter into the insulated portion of the other length of copper conductor to the bare coiled section of the same copper conductor, which was in intimate contact with the wet, urine soaked floor, thus completing a portion of the circuit from approximately 4 feet away on the concrete floor.

The complete circuit is described in the Petroleum and Chemical Industry Committee's technical paper titled, "The Hazardous Multigrounded Neutral Distribution System and the Dangerous Stray Currents" [10][2]. Briefly, the circuit begins at the substation supplying the distribution circuit. The current leaves the substation flowing on the phase conductor to the transformers on the line. The stray current enters the earth by two paths. (See figure 3)

The first path is what the author considers aberrant inappropriate inferior connection first made in 1932 between the neutral of the primary and the neutral of the secondary allowing primary neutral return current to enter the service of the residence and or dairy farm. Since there are multiple connections from the secondary neutral to the earth made by both the utility and at the service entrance, primary neutral distribution current can enter the earth. In addition, at the service entrance the neutral is connected to the green insulated equipment-grounding conductor, which is connected to earth at many locations affording the path to earth for the primary return neutral distribution current. (See figure 4)

The other path into the earth for the primary neutral return current is the requirement for the primary neutral conductor to be connected to earth at every transformer and at least four times per mile. Thus, there are multiple paths for the primary neutral distribution current to enter the earth uncontrolled on its way back to the substation. (See figure 5)

F. Test Setup Number 2

Mr. Neubauer devised a test to replicate cow contact. Cow contact is a test using a voltmeter placed between any two places that a cow could contact at the same time. Such an example would be a stanchion as one point that a cow could contact and the floor.

A plastic container with plastic hooks that fitted around the horizontal metal railing was secured. An insulated copper conductor was stripped for about 45 cm (18 inches) and the bare copper conductor was coiled and placed in the bottom of the plastic container. The plastic container was filled with crushed corn and wetted to make it conductive. The end was connected to the instrumentation.

Another copper conductor was clamped to the stanchion and connected to the instrumentation. This was a dry surface-to-surface connection.

The circuit this time ran from the stanchion to the instrumentation and then to the bottom of the plastic

container. When a cow approached to eat, the circuit was from the stanchion to the instrumentation to the plastic container to the cow's mouth that was immersed in the wetted cracked corn, through the cow and out her feet, thus completing that portion of the circuit.

X. TEST DATA RESULTS

The data was collected by Mr. Neubauer. The electronic copy contains 40 some pages of data from various dairies in the United States. Data is from states such as Wisconsin, Minnesota, Michigan, Idaho, California and even Hawaii. Data from utilities with open delta (data page 33) is included. The open delta produces unbalanced primary current, which escalates the stray current and increases the harm to the dairy herd and humans. In California where the hazardous stray current does not exist in the dairy areas since only phase-to-phase transformers are used, problems can occur with nearby electrical installations.

Both ac and dc voltage and current waveforms were recorded. Pages 46 and 47 show a maximum of 1.8 mA flowing through the cow from the water tank. The circuit is from the water tank to the conductive feed container through the cow to earth.

Page 39 shows the ac voltage and another plot on the same page and made at the same time of the dc voltage, parlor steel to floor, open circuit. The interesting thing about these two plots is the fact that when the ac voltage dips, the dc voltage spikes. The two waves are the inverse of each other. There are no external influences on the voltaic cell such as copper plates. The potential exists even when Mr. Neubauer leaves that area with his instrumentation.

The "old fashion" way of taking into account the cow by the paralleling a 470 ohm resistor, the closest readily available to the supposedly 500 ohm cow, is shown on page 29

Page 20 shows 1.566 ac rms voltage flowing across equipotential plane. This was measured using for the cow a 470-ohm resistor proving that electricity does flow through the earth.

XI. EQUIPOTENTIAL PLANES AS USED IN THE DAIRY INDUSTRY AND SWIMMING POOLS ARE DANGEROUS

It is presumed and opined, that the massive collection of concrete encased reinforcing bars contained within the concrete, which are grounded and bonded to the electrical system act as an "electrical sink". This electrical sink draws stray neutral distribution current to the equipotential plane since the equipotential plane is in intimate contact with the earth and has a very low impedance, resistance to the earth. The stray current could be flowing either into or out of the equipotential plane.

Concrete encased re-bar is accepted as an earthing electrode. Ralph H. Lee, IEEE Fellow and Eugene J. Fagan, IEEE Life Fellow wrote a classic technical paper titled, "The Use of Concrete- Encased Reinforcing Rods as Grounding Electrodes," [15]

The NEC Article 250, NEC Making Panel 5 accepted their work. It appears today as, "Concrete-Encased Electrode. An electrode encased by at least 50 mm (2 in.) of concrete, located within and near the bottom of a concrete foundation or footing that is in direct contact with the earth, consisting of at least 6.0 m (20 ft) of one or more bare or zinc galvanized or other electrically conductive coated steel reinforcing bars or rods of not less than 13 mm (½ in.) in diameter, or consisting of at least 6.0 m (20 ft) of bare copper conductor not smaller than 4 AWG. Reinforcing bars shall be permitted to be bonded together by the usual steel tie wires or other effective means."

It has been shown that a concrete pad with re-bar installed on the earth's surface such as an equipotential plane, acts in the same way as an earthing electrode contained within a buried foundation.

This author has designed and has overseen the construction of re-bar reinforced concrete slabs used as an earth electrode for placement of transformers, switchgear and motor control centers. The design was identical to the design for equipotential planes. It is opined that one could suppose the electrons would know the difference between an earth electrode and an equipotential plane.

A. Utilities' Corrupted Transformer Connection

Transformers were failing In Chicago in 1932 because the high resistance of the earth connection for the lightning arrester. The Utilities Research Commission of Chicago and the Engineering Experimental Station at Purdue University conducted an investigation of surge protection of the distribution circuits as to why transformers were failing. The conclusions reached were, "Measurements of the voltage between primary phase c lead and secondary neutral have shown that the *interconnection of the secondary neutral with the lightning arrester ground is, in general, beneficial to the transformer.* In particular, with a low resistance secondary neutral ground and a high resistance lightning arrester ground, the interconnection reduced the above voltage by 30 to 50 per cent." [16]

Instead of lowering the lightning arrester's resistance to earth by installing additional ground rods or other methods, at additional costs to the utilities, the utilities elected to save the additional cost by using the customers' connections to earth. The NEC was requiring grounding of the neutral in the electric service to homes. The earthing connection was made to the metallic water lines and a ground rod.

This practice placed the homeowners and the farmers in danger from excessive lightning current flow over the neutral conductor and the ground conductor in their facilities and the potential of high voltages during the lightning arresters' operations.

In addition, this primary neutral to secondary neutral connection permitted the hazardous electrical current from the operation of the lightning arrester to flow into the customers' homes, into the homeowner's ground rod, through the metallic water piping without their knowledge or consent which benefited the utility without proper approval or compensation of the owner of the secondary wiring system.

The extension of this invasion of the customers' wiring systems was when the utilities connected the primary neutral to the secondary neutral at the transformer. This allowed primary neutral current to flow unimpeded into and over the customers' homes, into the homeowner's ground rod, through the metallic water piping into their showers, hot tubs and bathtubs and into the industrial facility without the owners' knowledge or consent.

It is a fact that since 1932, the majority of utilities in North America have made standard a corrupted connection between the primary neutral and the secondary neutral. This electrical path allows primary neutral distribution current to flow unimpeded directly into not only your own home, but into dairies and onto the so-called equipotential plane, which now acts as an earthing electrode. This is in addition to the lightning current.

The electrical load is ever increasing. Equipotential planes will be carrying ever larger amounts of continuously flowing neutral distribution current into or out of the earth resulting in ever increasing potential for electric shocks to users of swimming pools, hot tubs, showers, bath tubs, metallic play swings and dairies.

B. Utilities Failure to Install Neutral Blocker Correctly

The neutral blocker was mentioned above. There are three manufacturers of neutral blockers. Two manufacturers sell a lightning type of neutral blocker. The third manufacturer sells an electronic type. When the author last looked at the installation instructions, approximately 10 years ago and recently at the actual installations as reported by Mr. Neubauer, the installation calls for the primary neutral to be grounded to a ground rod on one side of the pole with the secondary connected to a ground rod on the opposite side of the pole. In other cases, the specified distance is only a minimum of 1.83 m (minimum 6 feet) apart.

Anyone familiar with the IEEE Standard 142, "Recommended Practice for Grounding of Industrial and Commercial Power Systems", will know that to separate two ground rods by just 40 cm (16 inches) is the same as connecting the two ground rods together. Connecting the two ground rods together negates the neutral blocker's operation and allows primary neutral current to continue to flow directly into the dairy or home. The distance should be the depth of rod # 1 plus the depth of rod # 2. If using an 2.4 m (8 foot) and a 3 m (10 foot) rods the distance apart should be 2.4 plus 3 or 5.4 m apart. Most persons will multiply the result by 10 percent and separate the two rods by 5.9 m (19.8 feet)

XII. ACTION THAT SHOULD BE TAKEN

The NEC needs to remove the sections in Articles 547 and 680 referring to equipotential planes. The Wisconsin Code Section 16.42 (2) removed the requirement for equipotential planes in April 1, 1994. The knowledgeable dairymen realized that equipotential planes were hazardous to their dairy cows.

It is opined that the NEC Making Panels need to re-think grounding and bonding of swimming pools and dairies. With respect to dairies, the NEC should revert back to the normal grounding requirements as found in Article 250, that is equipment grounding connections to metallic outlet boxes. If plastic boxes were used, the metallic structure would not be connected to the equipment grounding conductor. In addition, with respect to swimming pools it is the author's opinion that all grounding/bonding connections and equipment grounding conductors that originate from the service entrance panel should be eliminated from the pool. This would include the prohibition of any underwater luminaries, (light fixtures) from being installed in the pool, as the luminarie frame would be connected to the electrical system equipment-grounding conductor. The equipment-grounding conductor is directly connected back to the transformer primary neutral to secondary connection, allowing the direct flow of high voltage primary neutral distribution current into the pool, resulting in electrical shocking conditions within the pool.

In addition, it is the author's opinion that the NEC Making Panel 5 needs to recognize the dangers and hazards associated with the multigrounded neutral electrical distribution system and to remove the acceptance of this electrical distribution system from the NEC.

The above action will reduce the potential for electric shocks emanating from multigrounded neutral electrical distribution systems, but will not remove them. Only by the elimination over a period of years of the multigrounded neutral electrical distribution system will North America become safe from stray neutral distribution current and the shock consequence of uncontrolled flow of stray current over the earth.

It is the author's opinion that the cost to remove the dangerous multigrounded neutral electrical distribution systems can be minimized by changing from the multigrounded neutral electrical distribution system to any of the other types of electrical distribution system that do not produce stray neutral distribution current. This can be accomplished over a period of years as was accomplished with the requirement for the installation of three pole, terminal receptacles. The other types of electrical distribution systems that do not produce stray current are detailed in the references [10][2].

XIII. CONCLUSION

It is opined that the equipotential plane is no more than an earth electrode, which lacks any ability to maintain or to have zero voltage gradient across it when any amount of electrical current flows over, across or through the equipotential plane. As an electrode-earthing element, the equipotential plane has the potential for uncontrolled stray current from the multigrounded neutral electrical distribution system to flow across the equipotential plane generating a dangerous and hazardous voltage to drive the stray current into and through humans and cows and pigs with devastating results.

It is opined that the mis-guided agriculture personnel and the NEC Making Panels failed to recognize the three difference conditions between 1) momentary flow of fault current and 2) the continuous flow from stray current emanating from the multigrounded neutral electrical distribution system and 3) the condition where there is no current flow across the equipotential plane.

It is a fact that there are two methods that stray current enters the so-called equipotential plane. One is the direct primary neutral to secondary neutral connection at the vast majority of utility transformers in North America that has a solid electrical connection between the primary neutral to the equipment grounding conductor and thus to the equipotential plane. The other source of stray current is the multiple connections, at least 4 per mile, connecting the primary neutral to earth allowing additional stray current to flow uncontrolled over and through the earth.

Mr. Neubauer's test proved conclusively, that the equipotential plane was just a figment of the imagination by using an instrumented plastic water bucket and plastic feed

container and cows, leaving no doubt in the opinion of this author that the so called equipotential plane does not prevent a voltage gradient as proclaimed by the agriculture personnel and the NEC.

XIV. ACKNOWLEDGMENT

The paper was written by Mr. Zipse, while Mr. Neubauer performed the testing and supplied the data.

Mr. Lawrence C. Neubauer, is continuously seeking new ways to measure the amount of stray neutral distribution current flowing through cows. He devised the concept of the testing of cows drinking out of a plastic bucket on an equipotential plane and eating out of a plastic container that revealed the fallacy of the equipotential plane concept by testing. Mr. Neubauer has been invaluable to the author. Mr. Neubauer is an outstanding Master Electrician with exceptional practical knowledge.

The author is indebted also to Messrs William J. Moylan, Louie Powell and Carey Cook for their help, guidance and patience in the preparation of this controversial paper.

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XVI. DISCUSSION

One of the reviewers developed several significant comments. “You refer to EPRI's conclusion that ‘40 to 60% of the neutral return current - - - returns through earth’. This statement requires considerable expansion and explanation. Doesn't this conflict with Kaufmann's empirical work that demonstrated that the vast majority of current returns over the neutral? Doesn't it also conflict with the fundamental physical understanding that current favors the path of lowest impedance, and since the neutral conductor tends to be physically closer to the outgoing conductor than the equivalent earth return path, then the impedance through the earth is much higher than the impedance of the return path through the neutral? And where is this current being measured? Is this amazingly large current being measured at the remote end of the circuit, where an "equipotential plane" might reasonably be expected to be applied, or is it at the source end of the circuit?”

Mr. R. H. Kaufmann’s work was with fault currents, not low level stray continuous flowing steady state current. The title of his paper was, “Let’s Be More Specific About Equipment Grounding”. It was published by General Electric, GER-1974 and was reprinted from the American Power Conference, 1962. His set up was comparing various sizes of metallic conduit containing an outgoing conductor and an internal ground conductor. At the end of the conduit, the metallic conduit was connected to the internal conductor. When fault current of “current magnitudes of 20 times continuous rating or more” was applied, approximately the majority of the return current flowed back over the conductor closest to the outgoing conductor. Thus, the internal conductor carried as the author recalled, 90 % of the return and the remaining 10 % over the metallic conduit. Note that there was a division of current. In fact as I recall, there were three return paths, 1st an insulated conductor inside the conduit, 2nd the conduit and 3rd the return conductor strapped to the outside of the conduit.

Mr. Kaufmann’s next experiment was with an external return conductor strapped to the conduit and the metallic conduit. Again, the conductor closest to the outgoing conductor, which in this case was the metallic conduit, carried

the majority of the return current. He also set up an experiment with an external conductor strapped to the metallic conduit and a second return conductor several inches away from the metallic conduit. Again, the majority of the current return over the closest path to the outgoing phase conductor, which was the conductor strapped to the conduit and not the conductor several inched away from the conduit.

One of Mr. Kauffmann's objects was to determine the external potential gradients in order to determine safe touch potentials. In his conclusions, Mr. Kaufmann states that he was testing "insulation failure from one phase conductor to the grounding conductor." "For the purpose of resolving the problem of electric shock hazard due to potential differences in the equipment grounding system, the first step concerns evaluation of the magnitude of voltage drop along the electric circuit grounding conductor." Mr. Kaufmann's conclusions contradict the equipotential plane theory that there is no voltage potential across an equipotential plane.

Now what is overlooked is the fact that under a fault condition there is a large magnetic field component. It is the interaction of the magnetic field that controls the division among the various paths of return current. It should be evident that with a total of from 5 to 20 or more amperes flowing over a dispersed area there would be little effect from any magnetic field.

As an experiment, the author conducted an electrical and magnetic field measurements at the Allen Dairy using an instrument that measures the natural magnetic field, the distance, the electric field, the magnetic field, the time and frame of data. The magnetic field fell away from the overhead line in the case of the 18.5 amperes on the phase conductor within 12 m (40 feet). A buried loop picked up some of the current flowing through the earth, which was in the milliamperes range as recalled.

As for the remote end of the line, would you consider a tap of 400 m (0.25 mile) the end of the line? On that dairy, the multigrounded neutral distribution system extended for 6.4 km (4 miles) beyond the dairy. Even after the installation of transformers to isolate the primary neutral from the secondary neutral, there was still sufficient amount of stray current to prevent the dairy from reaching full production.

Yet, the dairy across the road was not bothered by stray current. There is a page in the attached data file showing a dairy at the end of the distribution circuit where there is no stray current over the earth recorded.

The reviewer asks, "Doesn't the . . . current favors the path of lowest impedance". One must remember that the flow of electric current takes all paths, not just the path of lowest impedance. The individual flows are based on the inverse of the impedance of the path.

The reviewer asks, "You mention that ground fault circuit interrupters have a trip threshold of 6 ma. Doesn't the NEC require GFCI's in both agricultural "equipotential plane" and swimming pool applications? Why do these not provide adequate people protection?

The answer to the above comment can be found in the reference paper titled, "The Hazardous Multigrounded Neutral Distribution System and the Dangerous Stray Currents". [10] [2] The PCIC version is unedited, whereas the IAS Transactions is. You must realize that this current is flowing on the equipment-grounding conductor and through the earth. The GFCI does not protect that portion of the circuit. The GFCI measures the outgoing phase current and compares it against the neutral return current and trips if not within the 5 mA. In the appendix is figure 3 from the above-cited paper, which should answer your comment.

Referring to the figure 3 in the appendix, the GFCI protects Line 1 on the secondary side and the neutral or line 2 and the neutral, but not the equipment-grounding conductor. The major problem is the equipment grounding conductor is connected to the equipotential planes in dairies, swimming pools, in pool luminarie fixture frames, etc., allowing the stray current to flow from the primary neutral directly to the above mentioned objects.

The reviewer asks, "You mention that you and Mr. Neubauer have measured stray currents of 5 to 20 amperes or more. Where were these currents measured? You mentioned that in the New Jersey example, the 5.5 amperes of neutral current was "returning to the substation" – which implies that this was the total current in the circuit. Doesn't Kirchhoff's Law apply to the phenomena involved in practical "equipotential plane" physics? If so, the actual current that could be forced to flow through the body of an animal in contact with the grid will be less than this total. Do you have any actual numerical examples that show what the body currents are likely to be? Can you provide some numerical examples, preferably taken from actual applications, that support your assertions that the potential gradients that can exist on practical "equipotential planes" are sufficient to drive dangerously high currents through the bodies of animals in contact with those grids?"

Addressing your last comment first, to hurt a cow does not take "high currents" To hurt a human it takes less than what a GFCI will let through, 5 mA. The author has testified that 0.00025 amps, one-quarter of a milliampere will continue to harm a cow with inflamed hoofs. Questionable data used by the other side in court cases use I.0 mA as dangerous to the health of a cow. Would you want to have 1.0 mA of either ac or dc flowing through your body continuously?

The "current of 5.5 amperes flowing over the earth" was the current that was not flowing on the neutral conductor of the multigrounded neutral distribution system. In figure 3, the current was measured between the ground rod at the substation and point "D". The study, VitaTech Engineering, LLC of the "JCP&L's Herbertsville – Neutral-to-Earth (NEV) Investigation" was well done. The phase currents were measured along with the neutral conductor currents and the currents flowing over the earth. The 5.5 amperes was measured at the substation on the transformers neutral connection to earth. In other words, the current was flowing back to the substation over the earth and going up the ground rod to the transformer's Xo connection. The reader should go onto the web and study this report for the reader will see the potential dangers to your home. Contact www.bpu.state.ni.us and ask for a copy of the VitaTech Engineering, LLC of the "JCP&L's Herbertsville – Neutral-to-Earth (NEV) Investigation"

The paper presented at the 1999 I&CPS titled, "Are the National Electrical Code and the National Electrical Safety Code Hazardous to Your Health?" subtitled The Shocking Swimming Pool details the stray current found during testing from 11 am to 1 pm. Persons were getting shocked at 6 to 7 pm, when the electrical load was peaking resulting in

increased amounts of stray current flowing uncontrolled over the earth and through the swimming pool.

The reviewer asks, “You note that the "equipotential planes" described in IEEE 80 are intended to address potential gradients associated with ground faults currents, but you don't challenge the conclusions and recommendations contained in that standard. Fault currents typically are larger than load currents by at least an order of magnitude. If your conclusion that "equipotential planes" are dangerous is correct, then does that also not suggest that the fundamental premise of IEEE 80 that ground grids can be designed to limit step and reach potentials to "safe" levels is not also flawed?

IEEE Standard 80, “Guide for Safety in AC Substation Grounding” does not define the grid as an equipotential plane. Equipotential plane was defined by agriculture professors in the early 1980. Again to speak of IEEE 80 and equipotential planes in the same breath neglects the fact that IEEE 80 is step – touch potential protection under fault conditions and has nothing to do with equipotential planes with continuous flow of current of low magnitude. The resultant design using IEEE Standard 80 results in a step-touch potential of less than 30 to 35 volts, which is not an equipotential plane. The misunderstanding is the fact that IEEE Standard 80 does not eliminate step-touch potential, but lowers the step-touch potential to an acceptable level.

The author accepts IEEE Standard 80 as effective, feasible and workable. He does not accept the concept of Equipotential Planes as the concept is flawed and is actually an oxymoron, being a contradiction of terms, incompatible.

Equipotential planes operate under continuous current flow, not fault current flow. Fault current is not the same as continuous current flow from stray current. It is impossible to have a current flow through a resistance and yet, have zero voltage in a dairy or any other situation, excluding an absolute zero temperature condition.

	Std. 80	Equipotential Plane
Object	Protection Step-Touch	No Voltage Gradient
Current Condition	Fault	Continuous Flow
Available Amperes	$> 10^{3}$	$< 10^{-2}$
Voltage	< 35 V	0.0 V

Table 2 Comparison of IEEE Standard 80 and Equipotential Planes

XVII. VITA

Donald W. Zipse (S'58-M'62-SM'89-F’94-LF’97) graduated from the Williamson Free School of Mechanical Trades with honors where he gained practical experience in electrical construction and in power plant operation. He received his electrical engineering degree from the University of Delaware and went to work for Cutler-Hammer as an area sales engineer. He spent 16 years with ICI America, Inc in their Central Engineering Department as a company wide electrical specialist.

For the next 14 years, he was with the FMC Corporation in their Engineering Service organization, functioning as an Electrical Engineering Consultant, responsible for providing electrical design of new facilities and consulting service to the total corporation, both chemical and mechanical groups.

He is a registered Professional Engineer. He represents the IEEE on the National Electrical Code Making Panel #14, Hazardous Locations as well as the Lightning Standard NFPA 780 and is a member of the International Association of Electrical Inspectors. He serves on the National Electrical Safety Code Grounding Subcommittee.

He has served on many IEEE committees, participated in the color books (IEEE Recommended Practice), and standards groups, including the Standards Board and the Standards Board’s Review Committee. He is a member of the IEEE COMAR, Committee on Man and Radiation and Standards Correlating Committee #28, International Committee on Electromagnetic Safety (ICES). Mr. Zipse received the Standards Medallion for his work in and promoting standards.

He has published countless technical papers on such diverse and controversial subjects as Unity Plus Motors, Computers, Neutral to Ground Faults, NEC Wire Tables, Health Effects of Electrical and Magnetic Fields, Measuring Electrical and Magnetic Fields, Lightning Protection Systems: Advantages and Disadvantages, the NESC and the NEC: Are Dangerous to Your Health? Electrical Shock Hazard Due To Stray Current and has participated on National Electrical Code panels and in teaching the Code.

For the last twelve years, he has was President of Zipse Electrical Engineering, Inc., an electrical forensic engineering consulting firm. The past eleven years, he has been primarily involved as a forensic engineer and expert witness in cases resulting from electrical accidents and electrocutions and for the last five years he has been involved in legal cases concerning stray current involving humans and dairy cows. He is now President of Electrical Forensics, LLC.

Lawrence C. Neubauer, Master Electrician, has been testing dairy farms for stray current since 1993 with over 600 dairies as clients. He holds a Master Electrician license in the states of Wisconsin, North Dakota and South Dakota.

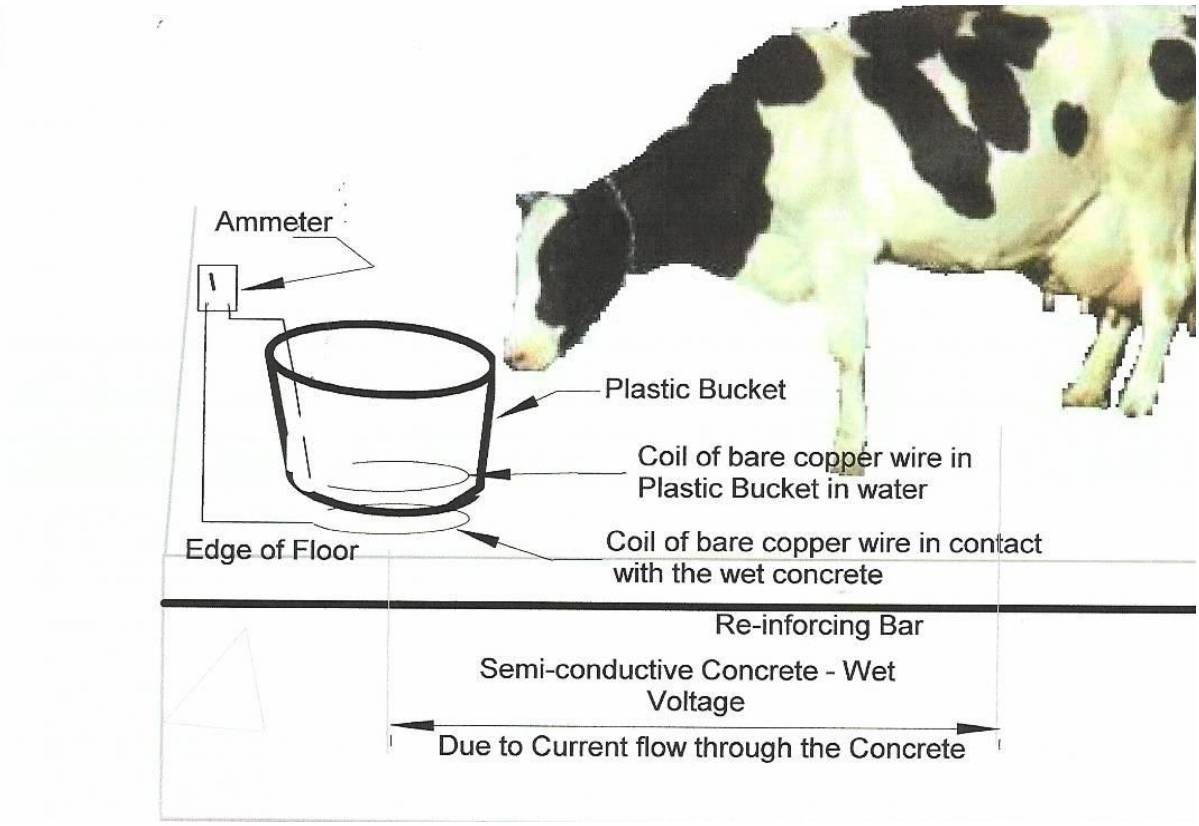
He graduated from Winneconne High School, WI in 1978. Mr. Neubauer has attended Fox Valley Technical College from 1978 to 1980.

Mr. Neubauer served a 4-year indentured Electrical Apprenticeship, from 1982 to 1986. He worked as a Journeyman wireman AFL-CIO I.B.E.W. # 577 from 1986 to 1995. As a journeyman electrician, he worked on projects involving power quality, instrumentation and basic circuit installation. He worked at Quad Graphics as Project

Foremen, Kimberly Clark Paper Industry, research and development for American National Can and Kerwin Paper, Inc.

In 1988 to 1993 Mr. Neubauer was foeman for Valley Electric where he was primarily involved in installing and maintaining machine operations and controls, frequency drive and process controls. His duties also included power quality, high and medium voltage work on power distribution systems.

In 1993, Mr. Neubauer set up Concept Electric, Inc. The company is involved with all aspects of electrical installations and commercial wiring projects. He specializes in removal of electrical leakage issues and corrective action concerning dairies.



Drawn by Stringfellow

Figure 2. Test Setup Number 1

	Direct Current		Alternating Current			
			60 Hz		10 kHz	
	Men	Women	Men	Women	Men	Women
Slight sensation on hand	1.	0.6	0.4	0.3	7	5
Perception “let go” threshold median	6.2	3.5	1.1	0.7	12	8
Shock – not painful and NO loss of muscular	9.	6.	1.8	1.2	17	11
Painful shock – muscular control loss	62.	41.	9.	6.	55	37
Painful and severe shock breathing difficult	90.	60.	23.	15.	94	63

Table 1. Sensitivity of Humans to Electric Current in Milliamperes

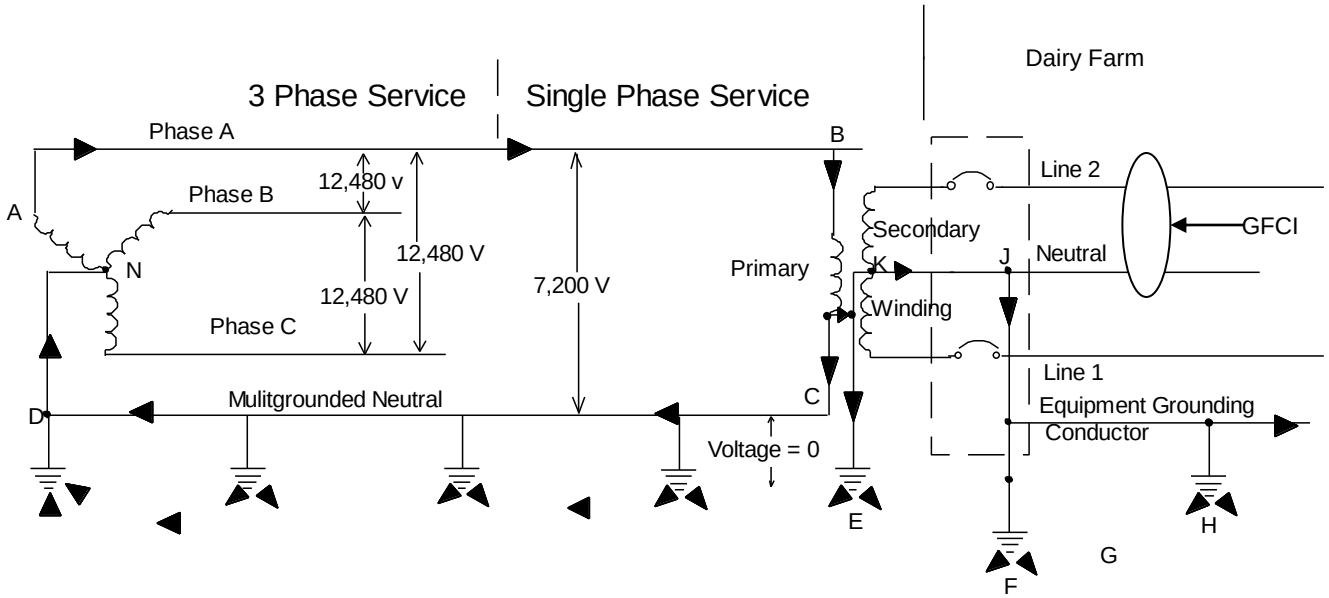
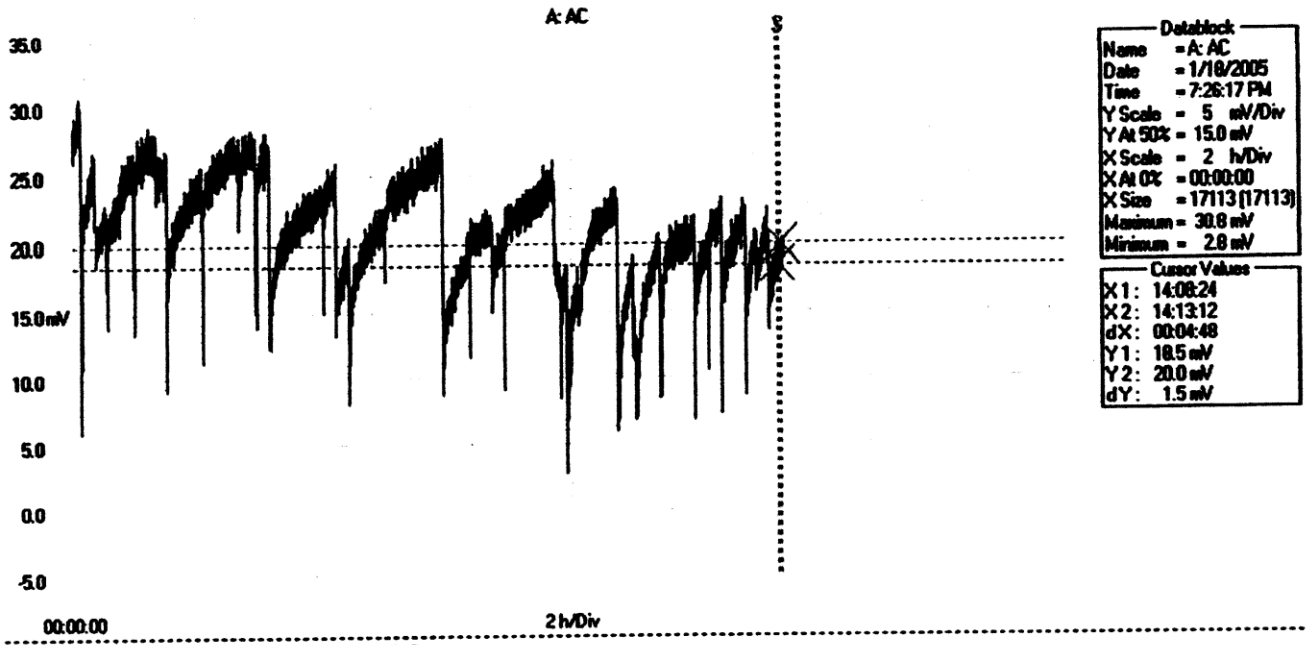
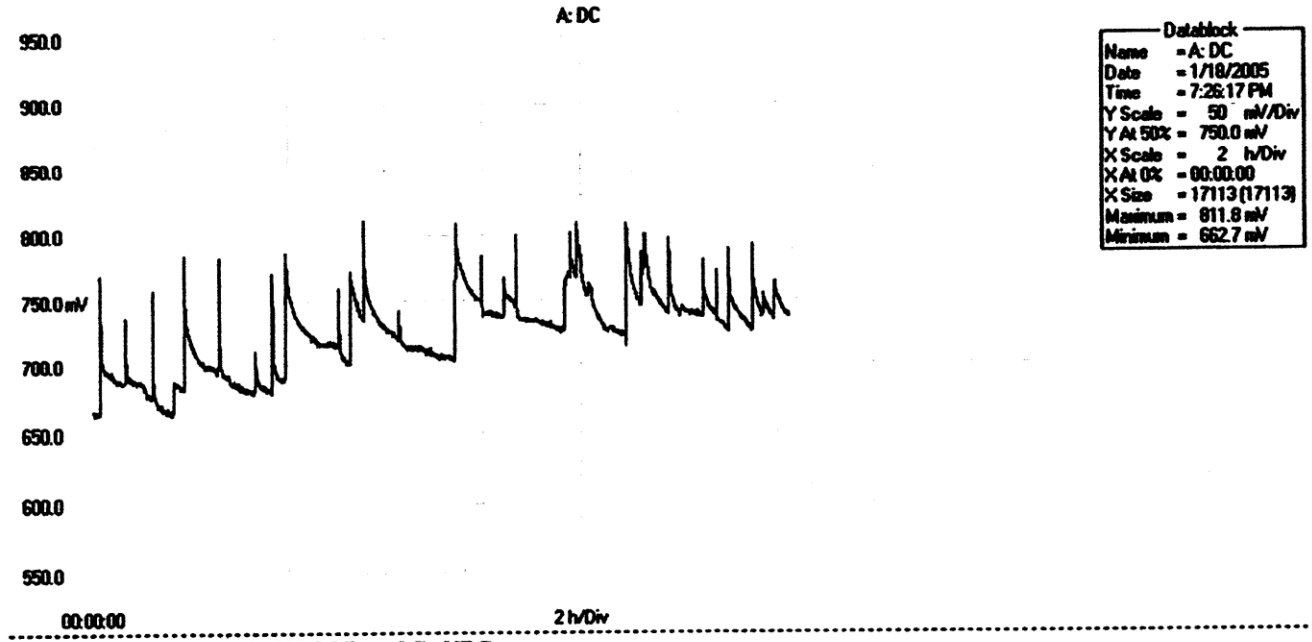


Figure 3. Wye Connected Electrical System Multigrounded Neutral with Primary Neutral to Secondary Neutral Electrical Service Connection Showing the Hazardous Stray Uncontrolled Primary Current Flow over Dairy’s Facility

Each of the black triangles at the lower portion of the figure indicate stray current entering and flowing over the earth and returning to the substation’s earth connection ground rod and up to point labeled “D”, and on to the substation’s Xo, neutral terminal, labeled “N”.



PARLOR STEEL TO FLOOR ,OC,



PARLOR STEEL TO FLOOR -OC-VDC

Chart 1. The above plots are preliminary and greater study is required. However, it is believed the following is occurring. Both plots are voltage measurements, open circuit measurements. The measurements are being taken in the milking parlor from the metal to the floor. The upper plot is ac voltage while the lower plot is dc voltage. The cow is drinking. The dc is galvanic action from copper and steel and the rectified dc. The maximum galvanic voltage is approximately 0.79 volts dc. Note that as the ac voltage decreases the dc voltage increases. It is opined that the rectified voltage is in opposite polarity to the galvanic cell in this case.

Video Capture 1. The above image has been captured from videotape made during testing of a dairy. There are inputs from four cameras. The upper left quadrant shows the cow eating from a plastic bucket. The bucket is filled with grain, which is wetted in order to make it conductive. The measuring circuit is from one end of a copper conductor connection to the metal stanchion. The other end of the conductor is connected to the measuring equipment, such as ammeters and/or voltmeters. From the other side of the measuring equipment a copper conductor is placed in the bottom of the plastic feed bucket. About 305 mm (12 inches) of the insulated copper conductor is stripped, coiled and placed in the bottom of the plastic bucket.

This test is referred to as cow contact, cc. Cow contact is defined as any two places that a cow can come into contact with and receive an electric shock. Before Mr. Neubauer's water bucket and plastic feed container tests, just a voltmeter was used between the two cow contact points and a resistor of 470 ohms placed across the voltmeter. The 470 ohm resistor was the most readily available value and closest to the supposedly internal resistance of a cow, 500 ohms. These tests use the actual cow to determine the actual electrical current flowing through the cow.

The measuring circuit is similar to that shown for the water bucket as shown in Figure 2. Please note that the measuring circuit is only part of the complete electrical circuit that starts at the substation as is shown in figure 3.

The upper right quadrant can capture an ac ammeter or voltmeter. The lower left quadrant shows the milliampere meter. The lower right quadrant is available for another camera input.

The four-quadrant video is captured on tape and or feed into one of seven computers in the data collection trailer. Each measuring device can and usually is captured by its self in one of the seven computers. Data can be transferred to CD.

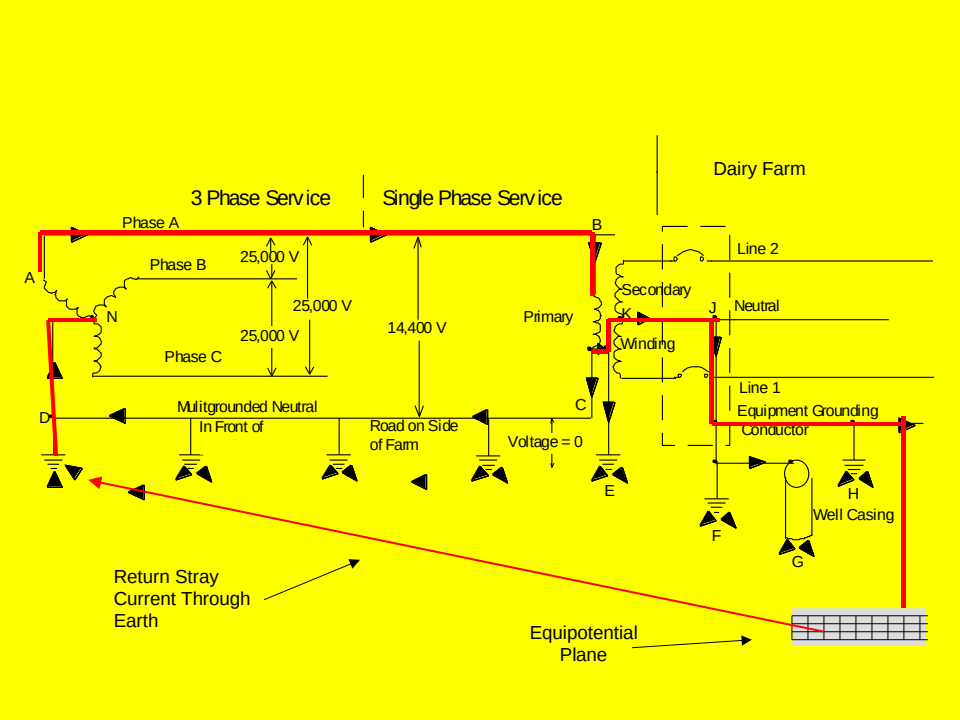


Figure 4. Stray Current Flow Directly Connected To Equipotential Plane

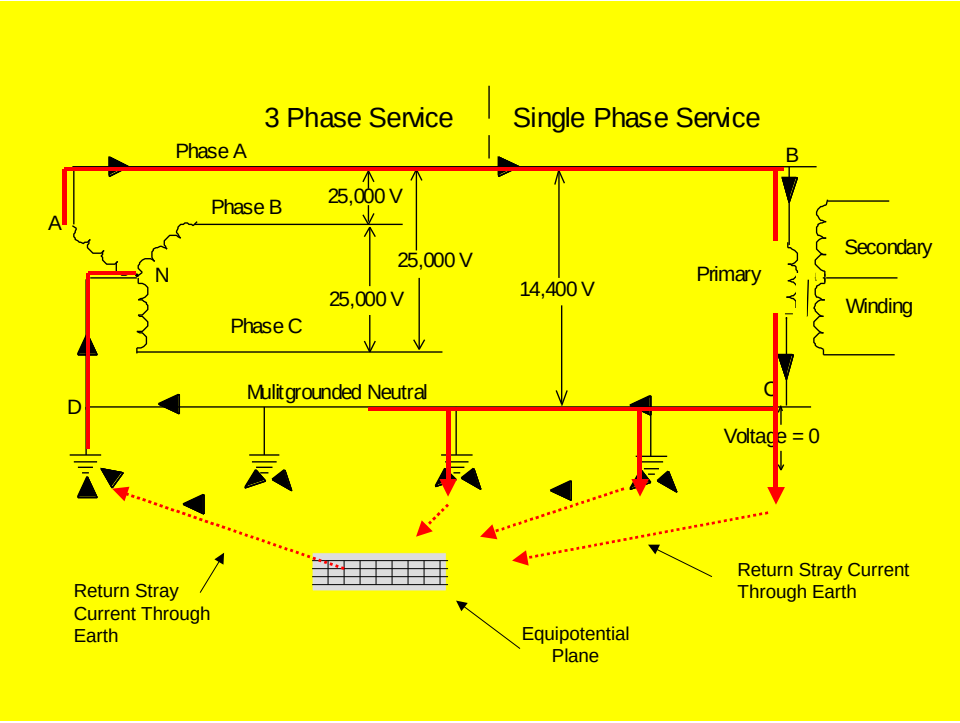


Figure 5. Stray Current Flowing through the Earth and Through the Equipotential Plane.