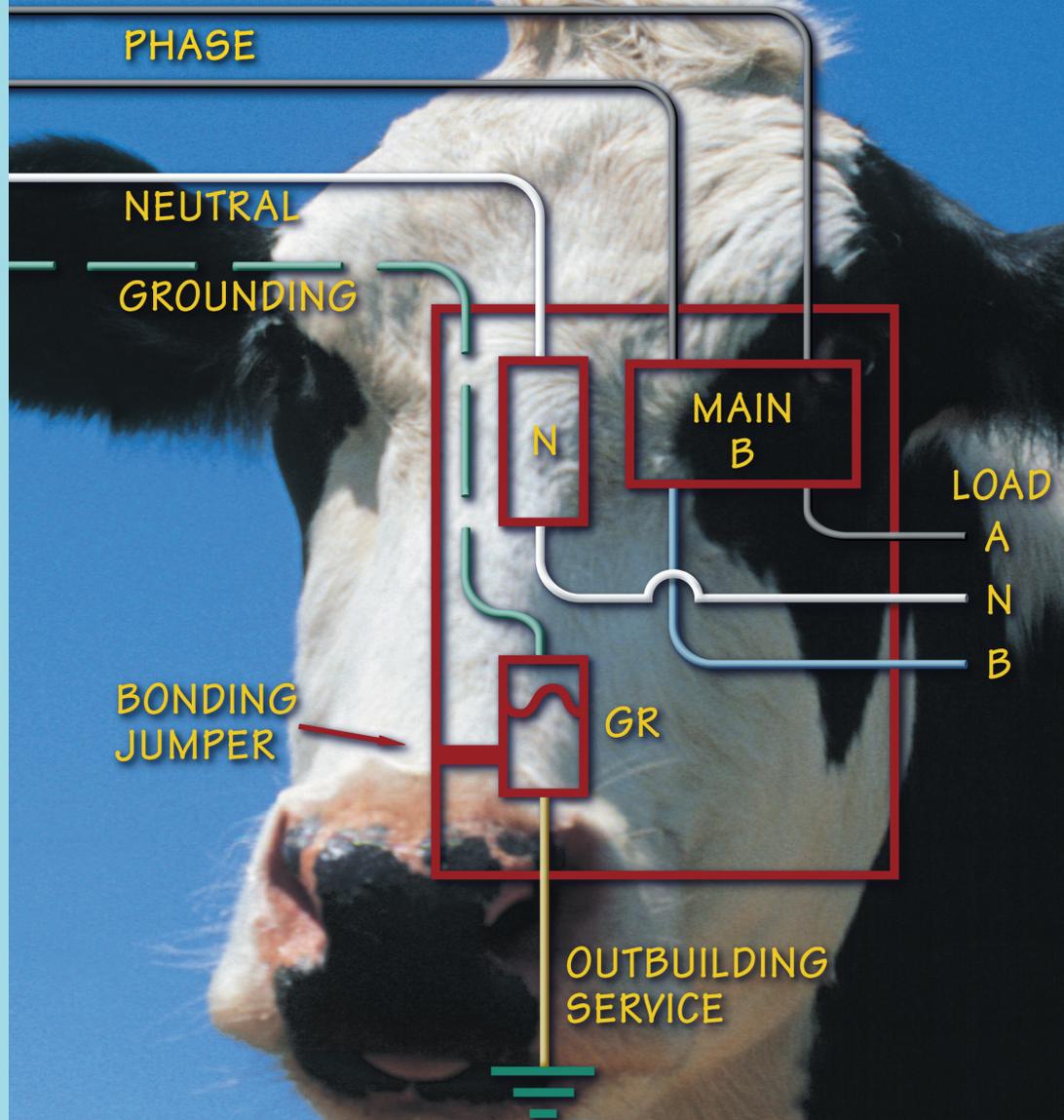


# ANSWERS TO YOUR STRAY VOLTAGE QUESTIONS: BACKED BY RESEARCH



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## OFFICIAL DEFINITIONS OF STRAY VOLTAGE

**USDA:** “Stray voltage is a small voltage (less than 10 volts) measured between two points that can be simultaneously contacted by an animal. Because animals respond to the current produced by a voltage and not to the voltage directly, the source of the voltage must be able to produce current flow greater than the threshold current needed to elicit a response from an animal when an animal, or an equivalent load, contacts both points.”

**Public Service Commission of Wisconsin (PSCW):** “Stray voltages are low-level voltages present across points (for example, drinking cup to rear hooves) in which a current flow is produced when an animal simultaneously comes into contact with them.”

## ELECTRICAL TERMS YOU SHOULD KNOW IN ORDER TO UNDERSTAND THE EFFECTS OF STRAY VOLTAGE

- **Hertz (Hz):** A unit of frequency equal to one cycle per second. Example: Many research studies used generators that produce a 60 Hz current.
- **Milliampere (mA):** 1/1000 of an amp. Example: Studies found that no water/feed consumption changes were found up to the 4 mA level.
- **Volt (V):** a unit of electrical potential difference and electromotive force. Example: *A generator might produce 4V, but it is the current generated from the 4 V that livestock respond to.*

## STRAY VOLTAGE IS NO MYSTERY

The stray voltage phenomenon has been studied for the last 30 years. Research funded by federal and state agencies, electric utilities, private consultants and others has a common goal: to determine the effect stray voltage has on livestock and farm operations.

Before research on stray voltage began, there were no clear answers for farmers who wanted to know: How does stray voltage affect livestock? What causes stray voltage? Is there a way to prevent it?

Today there are answers, but too often those answers fall short of reaching everyone. To many farmers, stray voltage is still an unknown. The intent of this booklet is to offer research findings to farmers—the people who need answers.

One thing is certain: if you go looking for stray voltage on your farm, chances are good that you’ll find it. The key is understanding what level of stray voltage does and does not impact your operation.

This summary of up-to-date research findings by U.S. government agencies and major universities provides clear, objective answers to questions about stray voltage.

## WHAT IS STRAY VOLTAGE?

Stray voltage is a natural phenomenon that can be found at low levels between two contact points at any property where electricity is grounded.<sup>1</sup>

Electrical systems—farm systems and utility distribution systems—are grounded to the earth to ensure safety and reliability. This includes water lines and metalwork on your farm. Inevitably, some current flows through the earth at each point where the electrical system is grounded and a small voltage develops. This voltage is called neutral-to-earth voltage (NEV). *When NEV is found at animal contact points, it is frequently called stray voltage.*

In other words, stray voltage is this small voltage that is measured between two points that livestock can simultaneously touch. If these points are simultaneously contacted by an animal, a current will flow through the animal.<sup>2</sup>

Although it may seem unacceptable that small amounts of current can flow through an animal when two contact points are touched simultaneously, most research points to the fact that stray voltage is a natural phenomenon on farms powered by electricity. According to a report by the Public Service Commission of Wisconsin, “The occurrence of neutral-to-earth voltage and current flow on neutral and grounding conductors are unavoidable consequences of the use of electrical power. Complete elimination of these phenomena is an unreasonable and costly goal.”<sup>3</sup>

If a farmer tests for stray voltage, he should expect to find low levels of voltage throughout his property.

# THE IMPORTANCE OF TESTING FOR STRAY VOLTAGE

Herd problems often can be difficult to diagnose. There are many factors to consider, such as the herd's environment, diet and health. Often, stray voltage is considered a last resort when other potential causes have been eliminated.

If stray voltage becomes the suspect, the only way to know if it is a problem is to have the farm tested. "It is not possible to tell with any accuracy if a farm has stray voltage or not without appropriate electrical testing," according to John Roberts, D.V.M., of the Wisconsin Department of Agriculture, Trade and Consumer Protection.<sup>4</sup>

But it's important for farmers to know that research repeatedly states this: if a stray voltage test is conducted on a property, some stray voltage will almost always be found. That's why it's important to understand what levels of stray voltage do and do not affect an operation.

## HOW MUCH STRAY VOLTAGE DOES IT TAKE TO AFFECT AN OPERATION?

The mere presence of stray voltage does not necessarily affect livestock. What is important is the *level* of stray voltage present between two livestock contact points.

Much research has been done to determine the level of stray voltage needed to affect dairy cattle in different ways. Following are the key findings:

### WHEN AWARENESS AND PERCEPTION ARE EVIDENT

The USDA has found that the level of electric current that elicits the first signs of awareness by livestock is 1 to 3 milliamps (mA), with no milk production loss in this range.<sup>5</sup>

Other studies have found the USDA response levels to be conservative and claim that perception at 1 to 3 mA will occur only for a small percentage of cows.<sup>6</sup>

### WHEN STRAY VOLTAGE CAUSES BEHAVIORAL CHANGES

Moderate behavioral changes in livestock are expected in the range of 3 to 6 mA (at a frequency of 60 hertz).<sup>7</sup> An animal may be more difficult to manage when the current exceeds 4 mA.<sup>8</sup>

## COMMON LIVESTOCK REACTIONS TO STRAY VOLTAGE IN ORDER FROM LEAST EFFECT TO MOST EFFECT

- 1. Basic perception/awareness (1-3 mA)<sup>9</sup>:** Cows first show signs that they are aware of the presence of stray voltage. Indications could include leg lifting, performing a specific task that they have been trained to do in response to a stimulus, flinching, weight shifting and eye blinking.<sup>10</sup>
- 2. Behavioral responses (4-6 mA)<sup>11</sup>:** Normally involves some type of avoidance by animals and can be indicated by a delay to drink water or by flinching.
- 3. Production loss (>6 mA)<sup>12</sup>:** Over a sustained period of time, water and feed intake is reduced, resulting in lower milk production.

## HOW UTILITIES MUST RESPOND TO THE PSCW'S DEFINITION OF STRAY VOLTAGE

The PSCW defines the "level of concern" of stray voltage as a measurement of 2 mA of steady state current flowing in a cow contact area (Docket 05-EI-115). The level of concern is the point at which action should be taken to reduce cow contact currents. If a stray voltage investigation reveals that there is more than 2 mA between cow contact points, Wisconsin's utilities are required to take responsibility for one-half of that level and report the farm as having stray voltage—even though research has shown that only a very small percentage of cows detect 2 mA of stray voltage.<sup>13</sup>

## EACH ANIMAL REACTS DIFFERENTLY TO STRAY VOLTAGE

It's important to know that the level of cows' perception and response to an electrical current varies widely between animals.<sup>14</sup> Most studies either took into account each animal's sensitivity level or discarded the findings from the most sensitive and least sensitive cows.

## WHEN WATER/FEED INTAKE AND MILK PRODUCTION ARE AFFECTED

Many studies and field observations have noted that stray voltage can cause changes in animal behavior with no measurable decline in water/feed intake or milk production.

In fact, research has shown no significant changes in feed/water consumption or milk production for currents at or below 4 mA. One study<sup>15</sup> measured a decrease in milk production at 5 mA, but all other studies found that currents of 5 and 6 mA had no effect on long-term milk production.<sup>16</sup>

In 2009, the Journal of Dairy Science published a report of a study on medium-term effects of repeated exposure to stray voltage in 74 Holstein cows. During the study, cows were assigned to one of three treatments during two 8-week experimental periods. The treatments were permanent/constant exposure to voltage, random exposure and no exposure. Results showed slight modifications in stress physiology and activity, but all groups maintained regular milk production and water intake.<sup>17</sup>

When current levels were tested at 1.5 times the amount that caused behavioral response, a short-term reduction in water/feed intake and milk production was measured. The researchers continued to test current levels at 1.5 times the behavioral response level applied to water bowls for three weeks. Reductions in water/feed intake and milk production were measured on the first three days of exposure. From the fourth day on, cows resumed their regular feed/water intake and milk production levels for the remainder of the three-week study.<sup>18</sup>

A 305-day study was conducted to measure feed/water intake and milk production loss during very long-term exposure to stray voltage. Four groups of 10 cows were analyzed and the groups were exposed to 0, 1, 2 or 4 volts. Results showed no significant difference in milk weights, milk composition or feed/water intake between groups not exposed and those exposed to 1, 2 or 4 volts.<sup>19</sup>

## AT WHAT LEVEL CAN STRAY VOLTAGE CAUSE HERD PROBLEMS?

Since the late 1980s, the PSCW has collected data from about 1,700 Wisconsin farms at which stray voltage was suspected. Of these farms, the PSCW found that more than 90 percent had "cow contact currents"—currents flowing when a cow simultaneously contacts two conducting surfaces—less than 2 mA and more than 70 percent had currents less than 1 mA.<sup>20</sup>

*As stated above, stray voltage at 1–2 mA may cause slight behavioral changes, but research has found that feed/water intake and milk production are not affected at these levels.*

# WHERE, WHEN AND HOW STRAY VOLTAGE IS LIKELY TO OCCUR ON A FARM

## PRIMARY VS. SECONDARY DISTRIBUTION SYSTEMS

Electrical systems—both on-farm systems and utility distribution systems—are grounded to the earth. From the grounding points, some current flows through the earth and a small voltage develops.

This voltage is called neutral-to-earth voltage (NEV). When NEV is found at animal contact points, it is frequently called stray voltage.<sup>21</sup>

The NEV measured at any point on the system can come from two sources:

- *The primary system: the electric utility's distribution system.*
- *The secondary system: the farm's electric system.*

NEV can stem from either or both of these sources. If a farm has 10 service drops, then there are 10 potential secondary sources and one potential primary source.

*However, research has shown that secondary NEV is the major source of stray voltage.<sup>22</sup>*

## STEADY STATE AND TRANSIENT VOLTAGES

Voltage can be categorized as either steady or transient. Steady voltages are normally caused by current being used to operate an electrical motor and generally run at the same level for several minutes to several hours.

Transient voltages are generally caused when an improperly grounded electrical device is started or stopped or by improperly grounded devices that operate intermittently, such as a fencer. Transient voltages may occur as infrequently as once per day or as frequently as once per second.<sup>23</sup> Steady state and transient voltages have common sources that should be checked in a stray voltage investigation.

Since transient currents are more common on farms than steady currents, cows were exposed to the transient current (1 cycle, 60 Hz) whenever they attempted to drink during most of the studies reviewed above.

In practice, however, transient currents are not always present,<sup>24</sup> meaning that researchers often provide the worst-case scenario when studying the effect of stray voltage on livestock.

## STRAY VOLTAGE RESEARCH BY GOVERNMENT AGENCIES

- **The PSCW** formed the Wisconsin Stray Voltage Analysis Team (SVAT) in 1989, which collects data from its on-farm stray voltage investigations. Beginning in 1988, the PSCW ordered Wisconsin's major investor-owned utilities to record findings from their stray voltage investigations and release these findings to the PSCW.
- **The USDA.** In 1991, a group of agricultural scientists published the *USDA Agricultural Handbook 696, Effects of Electrical Voltage/Current on Farm Animals: How To Detect and Remedy Problems*. This publication is considered the standard bearer in the stray voltage research field. The purpose of the USDA handbook is:
  - *to prevent research results from being misinterpreted and misconstrued, and*
  - *to improve the understanding of causes and effects of stray voltage on farms.*
- **The Wisconsin Department of Agriculture and Consumer Protection** has a stray voltage division. It tests for stray voltage and educates farmers about such things as (a) how to reduce stray voltage if high enough levels are found and (b) how to look for other sources of herd problems if stray voltage is found not to be the problem.

## HOW IS STRAY VOLTAGE RESEARCH CONDUCTED?

The most important part of a stray voltage investigation is to determine how much electric current could flow through a cow in its normal environment.<sup>26</sup> Many researchers use a watering bowl as a cow contact point since a cow's mouth has very low resistance to electric current—this will provide the most conservative result—and a watering bowl is a common contact point for cows.<sup>27</sup>

A circuit is often hooked up using a voltage generator, two contact points (often the water bowl and the floor) and the animal. Other common cow contact areas include milking and feeding areas.

A specific current is applied for a certain duration. Behavioral effects—such as facial expressions, mouth opening, leg lifting or contact avoidance—can be measured in the short term, while overall water/feed intake and milk production measurements usually require more time to study. Both short- and long-term studies have been conducted over the past 30 years.

## COMMON MYTHS ABOUT THE CAUSE OF STRAY VOLTAGE

The PSCW and a researcher from UW–Madison joined up to publish a report in 1995 about the cause of stray voltage on farms, using findings from PSCW investigations and investigations by Wisconsin's largest investor-owned electric utilities.

*The data show that cow contact current is dependent on many physical factors stemming from both on-farm and off-farm electrical power systems. Specific measurement of (stray voltage) on each farm is required to determine the potential impact on cows on that farm. Because of the wide variation in the data, gross indicators—such as grounds per mile, secondary and primary neutral to reference voltages, etc.—are not good predictors of cow contact currents.<sup>25</sup>*

Following are some attributes of farms and electrical systems that are commonly believed to affect the level of stray voltage, along with research findings that provide answers. Data were derived by the PSCW Stray Voltage Analysis Team's database of stray voltage investigations.

### DISTANCE BETWEEN FARM AND SUBSTATION

Over the years there have been concerns that the location of the farm along the electric distribution line determines the probability that a farm is affected by stray voltage. *Research by the PSCW and the University of Wisconsin–Madison shows that there is no significant relationship between cow contact current and distance from the substation.<sup>28</sup>*

### GROUNDS PER MILE BETWEEN THE FARM AND SUBSTATION

Although circuit theory states that the primary neutral voltage will be reduced as more grounds are placed between the farm and substation, this theory is true in less than one percent of the farms studied. The researchers concluded that there are factors of far greater importance influencing cow contact currents than grounds per mile between the farm and substation.<sup>29</sup> In rural areas, new standards require each pole to be grounded when new construction takes place.

### PRIMARY NEUTRAL CONDUCTOR SIZE

Based on 1,089 sites, the primary neutral conductor size explains only one percent of the variation in cow contact currents.<sup>30</sup>

### PRIMARY LINE VOLTAGE MAGNITUDE

A trend indicates that higher primary line voltages actually produce lower cow contact current measurements, according to data from 1,089 sites.<sup>31</sup>

During the summer of 1997, a group of science advisors commissioned by the Minnesota Public Utilities Commission (PUC) conducted a field study of stray voltage on Minnesota dairy farms. Following are their three major conclusions:

- “We have not found credible scientific evidence to verify the specific claim that currents in the earth or associated electrical parameters such as voltages, magnetic fields and electric fields, are causes of poor health and milk production in dairy herds.”
- “At the present time, there is no basis for altering the PUC-approved standards by which electric utilities distribute power onto or in the vicinity of individual dairy farms.”
- “There are many well-documented non-electrical factors that are known and accepted by the scientific community, and by most farmers as well, to cause dairy cow health and production problems. Among the most noteworthy stressors are poor nutrition, poor cow comfort and hygiene, and low or no use of vaccinations and related preventive veterinary practices. Those who want to improve performance of dairy herds should always address these factors.”

## **PRIMARY TRANSFORMER KVA RATING**

The larger the herd size, the larger the transformer kilovolt ampere (kVA) rating needed to supply power to a farm. The data consists of 854 sites with transformer sizes ranging from 10 kVA to 75 kVA. This is not a good indicator of stray voltage problems.<sup>32</sup>

## **POWER PROVIDER**

Of the cases from the Stray Voltage Analysis Team (SVAT) investigations database where the *primary distribution system* contributed more than 1 mA of stray voltage, 69 percent were served by an electric cooperative and 23 percent were served by an investor-owned utility. In those cases where *on-farm sources* caused more than 1 mA of stray voltage, 62 percent of the farms were served by an investor-owned utility and 31 percent were served by an electric cooperative. In those cases where the stray voltage exceeded 1 mA and a *combination of the two sources was identified*, 69 percent were served by an electric cooperative and 25 percent were served by an investor-owned utility.<sup>33</sup>

# **COMMON CAUSES OF LOWERED MILK PRODUCTION AND LIVESTOCK BEHAVIORAL PROBLEMS**

According to a study commissioned by the Minnesota Public Utilities Commission<sup>34</sup>, some of the common herd problems that farmers mistake for stray voltage are reduced milk production, increased somatic cell counts, reduced water consumption and hocks that are swollen or have sores and abrasions.

There are known causes for these adverse health and production outcomes that are not electrical.

## **LOWERED MILK PRODUCTION**

The main risk factors for lowered milk production include:

- Poor nutrition
- High temperatures
- Infectious diseases
- Milking machine defects
- Improper handling of cows

## **REDUCED WATER INTAKE**

Water intake is primarily determined by four factors: dry matter intake, milk production, air temperature and sodium intake. According to the study, “Exceptions occur when cows are not able to swallow water because of some physical disability or when the cow cannot reach a water source. Over a period of several days, a cow must consume enough water either through drinking or in forages to maintain a balance in body constituents. A change in water intake can occur whenever one or more of the four major determinants of water needs is altered.”

## RUMEN ACIDOSIS: COMMONLY MISDIAGNOSED AS STRAY VOLTAGE

Subacute rumen acidosis is basically bovine acid indigestion. It causes lameness and lower milk production and has been misdiagnosed as stray voltage—even though acidosis is estimated to affect more than half the dairy herds in the country. Often caused by the diet fed to high-producing herds, once diagnosed acidosis is cured quite simply: alter the diet. UW–Madison School of Veterinary Medicine estimates that subacute rumen acidosis is a major health problem in five percent of herds, responsible for 20 percent of culling, and reduces a cow's milk production by 3,000 pounds a year.<sup>36</sup>

## ELEVATED SOMATIC CELL COUNT (SCC)

“An elevated SCC in milk indicates that the mammary gland has an inflammatory condition and is shedding more cells than normal in the milk. Inflammation of the mammary gland can be caused by many factors such as traumatic injury or bacteria that originate in the environment or come from another cow through contamination of milking machine equipment, defective milking equipment or improper milking techniques. Improper nutrition can also lead to deficiencies in the immune system which are often associated with high SCC. In addition, poor environmental conditions such as dirty stalls and muddy pastures can produce high levels of contamination in the teat openings,” according to the study.

## COW DISCOMFORT AND RUMEN ACIDOSIS

“A lack of cow comfort and rumen acidosis are the primary causes of swollen hocks, abscesses, sore feet and nose bleeding. Small stalls and little or no bedding commonly cause increased standing time and sore feet and swollen hocks. Rumen acidosis typically results from feeding high carbohydrate rations that, in addition to the signs listed above, increase the production of lactic acid, cause a metabolic acidosis, and reduce rumen motility, feed intake and milk production,” as stated in the Minnesota PUC study.

## CONCLUSION

As long as electricity is supplied to farms, the issue of stray voltage will exist. Although research has found that stray voltage is rarely strong enough to affect the behavior or production of dairy cattle, many farmers still consider its mere existence to cause herd problems.

Today's perception of stray voltage may be compared to the suspicion of the microwave oven when it was first introduced to consumers two decades ago. Microwave ovens were once feared for possibly transmitting dangerous waves but were deemed safe after much research was conducted and results were widely communicated. Stray voltage, too, may be better understood once more and more people learn what little effect it has on livestock today.

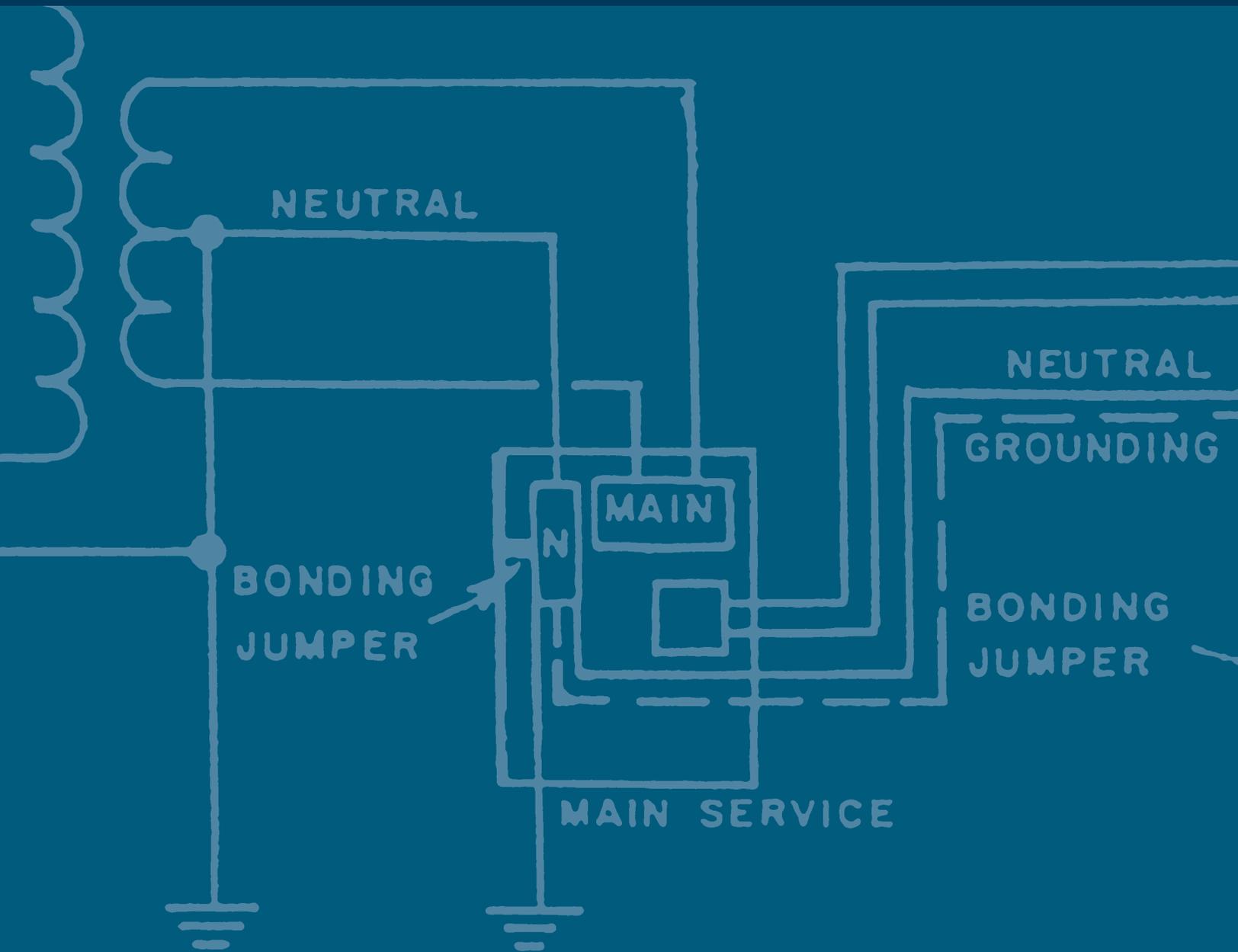
Remember, the key to ensuring that your farm is safe from the negative effects of stray voltage is to:

- *Understand what levels of stray voltage pose a threat to livestock;*
- *Have your farm tested by an expert who is trained to test cow contact areas.*

If you have further questions about stray voltage or would like Wisconsin Public Service to test your farm, you may contact the Agricultural Department at 1-877-444-0888.

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