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ELECTRICAL WIRING AND EQUIPMENT FOR SWINE FACILITIES

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ABSTRACT

Environments found in swine housing require appropriate electrical equipment and wiring methods. Recommendations are provided for selecting and locating equipment, applying wiring methods, and adding safety switches for protection of equipment and personnel. Proper grounding

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of systems and equipment and selection of overcurrent devices to facilitate fail-safe electrical systems are presented. Methods to limit voltage drop to 5% from the facility power source to the end-use equipment are offered. Since many recommendations are general, there are suggested references for further details on wiring and equipment selection.

KEYWORDS: Electric Wiring, Electrical Codes, Electric Power, Swine.

INTRODUCTION

Swine facilities and equipment are sanitized periodically with chemicals creating a wet and corrosive atmosphere. Corrosive gases, moisture, and dust are present regularly and hasten deterioration of electrical components. Proper design, selection, and installation of electrical systems for swine facilities are crucial to using electricity safely and efficiently. Inferior wiring and equipment cause hazardous conditions for humans and livestock, and often result in higher insurance premiums, increased maintenance costs and greater risk of fire. The mere fact that an electrical system "works" doesn't mean it's safe or will fail safe. The standard for electrical work in the United States is the National Electrical Code® (NEC, National Fire Protection Association 1999). The NEC is a standard for selection and safe installation of equipment and materials. Article 547 in the NEC provides additional specific requirements for wiring in swine facilities, or any damp, corrosive agricultural environment.

General requirements for swine facilities are found in other sections of the NEC. Practices, which supplement the requirements of the NEC, reduce maintenance, describe alternatives, and permit expansion, are described in other handbooks (Midwest Plan Service, 1992; National Food and Energy Council, 1996) and publications (Collins et al., 1994; Stetson, et al., 1989; Stetson and Meyer, 1999; National Food and Energy Council, 1993).

This paper describes wiring methods and materials that minimize the deterioration of electrical components, which maintain electrical safety and equipment function in swine facilities. Proper grounding of electrical systems and equipment is discussed to provide safety. Selection of appropriate sized conductors to limit voltage drop is presented.

ELECTRICAL SERVICE, SINGLE-PHASE OR THREE-PHASE

With larger swine complexes and proportionate increases in electrical loads, 120/240-volt (V) single-phase (1ϕ) service may be inadequate or unsuited. When electrical loads in a building exceed 400 amperes (A), or motors of 7.5 kW and larger will be used, the option of three-phase (3ϕ) electrical service should be investigated.

The advantages of a 3ϕ electric service are reduced costs for wiring and equipment such as motors and controllers, ability to start and operate larger motors, reduced voltage drop and availability of higher system voltages. The disadvantages are utility imposed costs to extend 3ϕ primary systems, billing rates that may be more expensive. The following is a brief discussion of the common 3ϕ systems:

A. The 120/208 V WYE system[2] serves 3ϕ loads and allows balancing 120 V loads among the three-phases. Care is needed in selecting both 3ϕ and 1ϕ motors that will operate on 208 V, and derating any 240 V heating elements. Many farm-duty-rated motors are rated at 240 V. Operating these motors at the wrong voltage will destroy the motor.

B. The 120/240 V or 240/480 V DELTA four-wire systems are frequently used as they utilize 120/240 or 480 V equipment commonly available for farm applications. These systems will operate either 1ϕ and 3ϕ 120, 240 or 1ϕ and 3ϕ 240 and 480 V motor loads depending upon

[2] Mention of trade names is for identification purposes only and is not an endorsement by the U.S. Department of Agriculture, the University of Nebraska or the University of Missouri.

the supply voltage. Avoid connecting 120 or 240 V 1ϕ loads to the high voltage or "wild" phase of the system. Proper balancing of the 3ϕ with 1ϕ loads to minimize neutral current is more difficult with either of these supply systems.

C. The 277/480 V WYE system offers reduced conductor and motor controller sizes and costs. For a required horsepower rating, the motors are physically smaller. However, dry type transformers are required to operate 120 V loads.

Determining the most appropriate electrical service to the swine facilities must be a joint effort between the operator, power supplier, equipment suppliers, and electrical contractor. Coordination is essential to provide a safe, workable electrical system whether it results in a single-phase or three-phase supply.

ELECTRIC SUPPLY SYSTEMS

The electrical service for a swine facility must be large enough to provide electrical capacity for present and future needs. Service conductors may be overhead (service drop) or underground (service lateral) and should be sized to limit voltage drop to 2% or less. The total voltage drop from the meter to any operating equipment should not exceed 5%. Therefore, if each designed segment (service, feeders and branch circuits) is 2% or less the total voltage drop will be near 5%. Use tables in the Agricultural Wiring Handbook (AWH, National Food and Energy Council 1996) for sizing service conductors based on electrical load and distance. Voltage drop exceeding 5% causes dimming of lights, a shortened life of motors, controllers and other equipment. Voltage drop is also a major source of stray voltage problems.

Most swine facilities will require a 100 A minimum electrical supply and distribution panel. Sizes of 200 and 400 A are often needed. When sufficient capacity for a swine facility cannot be provided with a single distribution panel, multiple distribution panels are required. A main disconnecting means is needed to enhance safety in case of an emergency. Each distribution panel is supplied with a four-conductor service. Interconnection of the grounding and neutral conductors at a subpanel increases the risk of stray voltage as neutral current flows on the grounding conductor and is a violation of the NEC (sections 250-24(a)(5) and 250-142). Wiring diagrams for main panels and subpanels, or any panels, showing separation of grounding and neutral (grounded) conductors are in Figure 36 of the Farm Buildings Wiring Handbook (FBWH, Midwest Plan Service, 1992).

Service conductors should enter service equipment through the side or bottom. This keeps condensation in the conduit from dripping onto the panelboard. Use electrician's putty to seal conduits at each end to minimize the migration--and condensation--of moisture. Numerous corrosion problems have been observed when service conduit enters the top of a service panel and condensation drips onto electrical contacts.

Locate the building service equipment on an interior partition or on the surface of an insulated exterior wall in the utility room or office. Never recess any panel or electrical box into an outside wall. Inadequate insulation behind the enclosure results in condensation and corrosion.

Provide at least 0.9 m of open space in front of all service equipment and distribution panels. This depth must also equal the width of the service equipment. The door or cover must be capable of being opened a full 90 degrees (NEC 110-26(a)(2)). Place distribution panels near the largest electrical load for that building or structure. This will minimize requirements for long runs of larger, more expensive conductors and reduce voltage drop. If the distribution panel must be located in a room subject to frequent washdown, use a moisture-tight nonmetallic enclosure (NEMA 4 or 4X1). The National Electrical Manufacturers Association (NEMA) has equipment enclosure ratings for the location environment of equipment. A NEMA 1 is indoor use only and is not water resistant. When a distribution panelboard is installed in an equipment room, maintain the working space needed for safely servicing the panelboard.

Each disconnecting device (e.g., switch, circuit breaker, etc.) must be clearly labeled to indicate its purpose. All panelboards should have select distribution panels or subpanels space for the needed circuits plus space for future circuits. Each circuit should be protected by a circuit breaker sized to the conductor or circuit load. Fused distribution panelboards are not common, but fused disconnects for services, feeders and branch circuits are common. Rejection-type holders for cartridge fuses are designed to match the voltage of the fuse to the supply voltage and provide overcurrent and short-current protection that can't be changed. Edison-base fuseholders do not have rejection features. Rejection-type adapters known as "Type S" provide rejection features for Edison-base fuseholders. Type S fuses with Type S adapters limit the installed fuse rating. However, supplementary short-circuit or overload protection, such as for a fan motor, in a weatherproof fusible switch (Bussman type SSN) device should be an Edison-base fuse to allow closing of the cover.

Three-wire vs. Four-wire Services

In a three-wire 120/240 V 1ϕ service, two ungrounded (phase) conductors and a grounded (neutral) conductor are supplied to the service equipment. In a four-wire service to a building, the grounded conductor is bonded to the grounding conductor in a disconnect enclosure a distance from the building. This distance may be the distribution point for the swine complex. Two ungrounded (phase) conductors, a grounded conductor, and an equipment grounding conductor are brought to the service equipment.

The four-wire system keeps neutral voltage drop on that service from appearing on the grounding circuit, which is one source of stray voltage. A four-wire service is not recommended unless all buildings and wiring on the premises are served by four-wire 1ϕ systems (Cook et al. 1995). A properly sized three-wire 1ϕ service is appropriate where other buildings, including the residence, are provided with three-wire service. A four-wire service to agriculture buildings meeting all the requirements of the 1996 NEC is difficult to achieve and in practice is rarely done correctly. The 1999 NEC 547-8 now lists three options for providing service to agricultural buildings. A four-wire feeder 547-8(b) would be a preferred way to supply a four-wire service.

Lightning (Surge) Arresters

All service equipment should have a lightning arrester (often called surge arrester). Such protection greatly reduces the risk of fire or damage from lightning or switching surges. Provide additional surge or transient voltage protection for sensitive equipment such as electronic controls, computers or data recorders. The main arrester protects any additional surge protectors from high energy spikes. Secondary protectors, such as those on power strips, have limited energy shunting capability.

Grounding

A grounding electrode is required at the service equipment for each building. Rods of 2.4 m length (minimum) are commonly used, but the NEC (250-50) permits several other methods. Resistance from one grounding electrode to surrounding soil must be 25 ohms or less (NEC 250-56). If greater than 25 ohms an additional rod or electrode must be added. Additional rods should be spaced at least twice the length of the ground rods (e.g., two 2.4 m rods should be at least 5 m apart) and interconnected with a copper conductor and ground rod clamps approved for direct burial. The 2 m rule for spacing of ground rods in the NEC is for safety. Increased spacing decreases the combined resistance of the parallel rods (IEEE 1991).

The grounded service conductor (neutral) is bonded to a properly sized grounding electrode conductor, which extends to the grounding electrode (NEC 250-24 and Table 250-66). This provides system grounding for the service. (Note: With a four-wire service, the grounding electrode conductor is attached to the grounding bus not the neutral bus in the service equipment.) The grounding electrode conductor to the grounding electrode must be protected from physical damage and must be continuous. Only nonreversible splices are permitted. Grounded conductors carry current during the normal operation of 115 V equipment. They must have white or gray identification. They also carry fault current from the supply equipment to the service transformer because of the bonding to the grounding conductors in the distribution panel (in a single-phase three-wire service).

Grounding conductors should carry large currents under fault conditions and are commonly referred to as the "grounding" wire. NEC Table 250-112 specifies the size of grounding conductors based on circuit overcurrent protection rating. The NEC requires that grounding conductors be bare or be identified with green or green with yellow stripe insulation or marking. All new wiring in swine complexes must include a copper equipment grounding conductor (NEC 547-4(f)). Equipment such as motors or electrically-heated waterers must be grounded by means of this equipment grounding conductor. Installing a ground rod at such equipment as a substitute for an equipment grounding conductor is not permitted (NEC 250-2(d)), but a ground rod may be installed as a supplement to the grounding conductor. Be cautious about adding extra ground electrodes (rods) as ground loops can result in problems with computers and electronic controls. The grounded and grounding conductors are permitted to be interconnected only at the service equipment (NEC 250-24). The FBWH has many circuit diagrams showing the proper connection and separation of the grounded and grounding conductors. Since equipment grounding conductors are connected to the grounded system and to the earth, they generally conduct some current under normal operating conditions.

To minimize danger from electrical faults, the NEC requires all metallic equipment, e.g. metallic water lines, gates, flooring materials or grates--including building components, within 2.4 m of the floor or soil surface that is likely to become energized, to be bonded together and to the electrical grounding system. Bonding can be achieved through the branch circuit equipment grounding conductor or other appropriate grounding conductors.

<u>Equipotential Planes</u>

The 1999 NEC continues to require an equipotential plane in livestock confinement areas of swine facilities, which have concrete floors. This practice has been recommended for dairy facility designs since 1979. Such an installation minimizes the problems of stray voltages in the animal confinement areas and should prevent electrocutions in the event of equipment ground faults. Some buildings or areas, which have limited or no electrical equipment in grounding contact with the floor, do not need equipotential planes (547-9(b) Ex. No.1). Details of constructing equipotential planes are found in ASAE Engineering Practice EP473 “Equipotential Plane in Animal Containment Areas” (ASAE 1998a) and in ASAE EP342 “Safety for Electrically Heated Livestock Waterers” (ASAE 1998b).

<u>Circuits</u>

Swine buildings will require both general purpose and special equipment circuits. General purpose circuits include lights and duplex convenience outlets. Special equipment circuits include those for ventilation fans, heaters, heatlamps, fixed equipment, appliances over 1,500 W, motors exceeding 0.25 kW, and other special purpose outlets such as high pressure washers.

A general purpose circuit should allow 1.5 A per fixture or receptacle outlet. Use the actual load value to size circuits that supply such loads as heat lamps, floodlights, and ventilation fans. Branch circuit conductors with only one motor should be sized for 125% of the motor full load current rating. If more than one motor will be on a feeder circuit, rate the largest motor at 125%, and add the others at 100% of full load current rating. The motor currents listed in the AWH Tables 8 and 9 or NEC Tables 430-148, 430-149 and 430-150 should be used. The 1999 NEC also permits using the motor nameplate for current ratings

Plan for dedicated circuits from the distribution panel for that area to serve computers, data logging outlets or electronic controllers such as adjustable speed fans. This will reduce power quality problems. The use of adjustable speed drives will require a filter or trap to prevent harmonics generated by these drives from affecting computers and similar equipment. These drives also need to be supplied by a dedicated circuit.

Long runs of undersized conductors result in wasted energy and reduced performance of lights and electrical equipment. Each branch and feeder circuit should be sized so voltage drop does not exceed 2%. Size all conductors based on length of run as well as connected load. Relationships between current, circuit length, voltage drop, and conductor size are in detailed tables in the AWH.

Standby Power

In most swine facilities, ventilation is critical. Response to a power outage must occur rapidly either by personnel responding or automatic starting of a standby power system. There are many types of alarms and alarm responses available to alert operators of a power failure or loss of ventilation for any reason. These alarms can also automatically start a standby power system.

In many areas, local utilities will provide rate incentives for operators to use standby power systems in times of peak power demands. This provides additional operating times for the standby power units so they are more likely to be ready to supply power. When investing in standby power, consult with the electric utility for their rules or incentives for standby power systems.

A double throw transfer switch is required either at the main farm service entrance, the swine complex, or at the specific area supplied so the standby power source is always isolated from incoming power. This transfer switch keeps generated power from feeding back into the power supply systems, and eliminates generator damage when utility power is restored. Utility workers can be electrocuted if the standby power is not isolated from the power supply.

Precise sizing of a standby power unit can be difficult. For a partial-load system, use the sum of the starting wattage of the largest motor (a table for motor starting wattages is in Section 33 FBWH), plus the running wattage of all other motors, nameplate wattage of essential equipment, and wattage of essential lights. Especially with a partial-load system, develop a procedure and identify circuits to be used with the standby generator. Post instructions or procedures near the generator. For additional details on the safe use and operation of standby power units, see Section 33 of FBWH, Section 22 of AWH, ASAE EP364 (1998c), and Benson and Stetson, 1990.

WIRING MATERIAL AND METHODS

All materials and equipment should bear a label indicating they are listed by some recognized testing agency, e.g., Underwriters' Laboratories (UL), Electrical Testing Laboratories (ETL), Factory Mutual, etc. A suggested list of equipment is included in Stetson and Meyer 1999. Some of the wiring materials may be available only from wholesale electrical supply houses.

All interior wiring should be attached to interior surfaces of the buildings and not concealed within wall cavities, ceilings, or attic spaces. In insulated buildings, surface mounting eliminates the need to make holes in the continuous vapor barrier, thus reducing the migration of moisture into wall or ceiling cavities and attics with resulting condensation. Surface mounting also reduces the risk of rodent and insect damage and facilitates inspection and repair.

Cable and Conduit

Cable is often used rather than conduit, except where subject to physical damage or where multiple circuits are needed. Type UF cable is required (NEC 547-4) because it is moisture resistant and allows use of watertight connectors and fittings at box connections. Do not use Type NM-B cable, as this cable is not rated for damp or wet locations.

Rigid nonmetallic conduit offers an effective complement or alternative to Type UF cable, especially where wiring is subject to frequent washdown, physical damage or where conduit may facilitate use of multiconductor circuits. Single conductors rather than cable are used in conduit. Select conductors with a Type W designation such as THWN. Use schedule 40 conduit for general use. Use schedule 80 (thicker-walled) and other protective methods in areas subject to physical abuse by animals or equipment.

Allow for thermal expansion and contraction in each conduit run. Couplings, e.g., 25 mm expansion, are available for expansion at boxes or panel boards. In long runs, expansion joints of

7 – 14 cm are available. Conduit mounting must allow movement as temperatures change. Install conduit to minimize entry of dust, water and vapor into enclosures. Where a conduit is exposed to different temperatures, such as where it passes through the outside wall of a heated building or between two different rooms, the inside of the conduit must be sealed using duct sealer. Silicone or similar caulking should not be used as a substitute for duct seal.

Conductor color coding requirements must be followed (NEC 310-12). Except where they are part of a cable assembly. Grounded conductors of No. 6 AWG or smaller must have white, gray or three continuous white stripe colored insulation (NEC 200-6). Phase conductors may be any color except green, gray or white. In a center-tapped DELTA 3ϕ supply system, the high voltage phase must be in the center lug of 3ϕ equipment and be orange or labeled with orange tape (NEC 215-8).

Use flexible wiring methods for fans and other equipment subject to vibration. Liquidtight flexible nonmetallic conduit wired with stranded conductors is recommended. The metal inner core of liquidtight flexible metal conduit can corrode. Flexible cords with water-and-dust proof strain-relief fittings are also appropriate. Select cords with a wet rating, such as SJW, SJTW, SJTEW, SOW, SEW, STW.

Electrical nonmetallic-tubing (ENT) is not recommended in swine complexes because of temperature limitations and snap-on fittings are not watertight. In addition, the corrugations of ENT make it difficult to sanitize. Rigid metal conduit is not recommended (except to provide required mechanical protection in very special areas). Protect nonmetallic conduit with posts, beams, etc. rather than use rigid metal conduit.

<u>Boxes and Fixtures</u>

Molded nonmetallic boxes with gasketed covers are necessary on all boxes to protect wire splices, switches, receptacles, and other electrical apparatus from exposure to moisture, corrosive gases and dust. Nonmetallic boxes with pre-punched knockouts are not designed for use in swine buildings (NEC 547-5). They are designed for residential and some commercial uses. Cast aluminum boxes in swine building interiors are not recommended, even though they are rated corrosion resistant. Experience has shown cast aluminum boxes deteriorate and delaminate when exposed to cleaning and sanitizing chemicals. Cast aluminum boxes and fixtures are suitable for outdoor use and in areas not subject to washdown.

Receptacles should be in molded nonmetallic boxes with gasketed covers. Outdoor receptacles in use for extended periods should have a special cover so the outlet is weatherproof when in use (NEC 410-57(b)). Switches must also be protected from moisture, either by means of spring-loaded covers, moisture-tight switch levers, or flexible moisture-tight covers. Most switch covers will accommodate general use switches.

Mount receptacles, switches and controls where they will be protected from animals. A rule of thumb is to place boxes and controls at least twice animal height, or at least 1.2 m above the floor unless extra protection is provided. Provide 20 cm of wire at each box to facilitate making connections and servicing switches, outlets and other devices.

<u>Lighting</u>

Lighting must be planned to minimize shadows. In general, more lower wattage fixtures are better than fewer higher wattage fixtures, despite higher costs. Incandescent, fluorescent and quartz lights are commonly used. High pressure sodium, quartz and metal halide fixtures are used in high ceiling areas or outside areas. Each has different properties of light output, color, and maintenance, which could be suitable for special tasks. All light fixtures subject to condensation or water cleansing must be watertight and made of corrosion resistant materials (NEC 547-7(c)). Light fixtures in outdoor areas only need to resist dust, moisture and corrosion (NEC 547-7(a)).

A heat-resistant globe is required for incandescent lights to cover the light bulb. Temperatures in boxes above some globed fixtures exceed 90 C. Neither Type THHN/THWN conductors, nor the conductors in Type UF cable meet these temperature requirements. Some incandescent globed fixtures are designed to allow wiring with 60 C rated conductors and are rated watertight. Check the temperature and listing instructions of the incandescent fixtures before purchase and installation.

Fluorescent fixtures cost more than incandescent but produce three to four times more light per watt. Lamp life ranges from 7,500 h for short-use cycles to 20,000 h for long-use cycles. Some fluorescent units do not perform well below 15 C but can be ordered with special ballast to allow starting under cold conditions. Other fluorescent lights are also sensitive to relative humidity higher than 65%. Check the fixture ratings. Fixtures with fiberglass enclosures and polycarbonate (Lexan®) covers have been found most serviceable. Fluorescent light fixtures made of ABS plastic and fitted with acrylic diffusers have not provided satisfactory service. Type UF cable and THHN/THWN conductors can be wired into fluorescent fixtures if the conductors are kept away from the ballast.

Quartz lights provide a high intensity light and are more efficient than incandescent lights. Bulb replacement costs are high but bulb life is long (20,000 h or more). Sharp shadowing can be a problem without careful planning. Use PAR type lamps so the outside reflector contains any internal rupture of filaments and shields. Metal halide provides white light and excellent color rendition. High-pressure sodium lamps with good color rendition can be obtained.

MOTORS AND CONTROLLERS

Fans, Pumps, Washers, Etc.

Because of dust and corrosion, use only totally-enclosed motors. Open motors are more prone to early failure and more apt to cause fire. All motors should be Farm Duty rated.

With fractional horsepower motors, or when more than one fan is included on a branch circuit, secondary overcurrent and short-circuit protection is appropriate. A fused switch or properly sized circuit breaker installed in a corrosion resistant box, and located within 3 m of each fan, is recommended for safety during cleaning and maintenance. (The NEC requires a disconnect to be within sight of and within 15 m of the motor.) Fused switches and special circuit breakers are available to meet both individual fan overcurrent and switching requirements. Size the protective device (fuse or circuit breaker) at 150% (125% for motors without thermal protection) of the motor full load current rating. For fusing, use a time delay fuse or rejection-type cartridge fuses (also time delay).

Most fans, motors, and heaters should be permanently wired. Plugs require receptacle covers to be open continuously, allowing moisture and corrosive gases to enter the wiring system. Permanent wiring maintains the integrity of the watertight electrical system. As an alternative, use waterproof plug and receptacle cord assemblies.

Switching Lights

Three-way switches for lighting are necessary so personnel can control lights from any entrance or exit. Two levels of lighting are often supplied. One low level provides lighting for feeding and general observations and maintains some light so a drastic light change does not occur each time personnel enter the unit. A second level of lighting is provided for sorting or veterinary purposes.

High Pressure Washers

Permanently mounted high pressure washers should be hard-wired into junction or switch boxes and should be ground fault circuit interrupter (GFCI) protected. On portable units a GFCI is required as part of the service cord. Even with GFCI protection, an equipment grounding conductor must be part of the wiring system to the washer.

INSPECTION

States or counties may require electrical inspection. Some power suppliers require an inspection before electrical service will be provided. Many insurance companies require inspections, while others offer reduced premium rates for buildings that are inspected and verified as meeting NEC requirements. If inspection is not required, the use of available inspection services is encouraged.

SUMMARY

Appropriate electrical wiring practices are critical when remodeling or constructing swine facilities. The wet and corrosive conditions in these buildings necessitate particular practices and materials to increase the life of the electrical system and to reduce the likelihood of loss of property, animals, and income, or personal injury caused by electrical failures. Use equipment, wiring, and installation methods, which will assure that the equipment fails safely. Equipment will fail. Provide fail-safe wiring.

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