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THINK YOU UNDERSTAND CENTER PIVOT SAFETY AND MAINTENANCE - REALLY?

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INTRODUCTION AND BACKGROUND

Center pivot irrigation systems have revolutionized irrigated production agriculture in the United States and other parts of the world since their inception in 1949. The benefits of reduced labor requirements, dependability, and increased production efficiency as compared to earlier surface flow methods have been well documented through both research and demonstration efforts for over 50 years. More recently, integrated computerization and control capabilities have allowed for increased functionality and automation of these systems. Center pivot irrigation systems have a long history of outstanding performance and reliability, more so when well maintained and managed. While typically designed for a 15-year life span, many have far exceeded that service period with proper maintenance and conversion upgrades. Maintenance of these systems primarily entails mechanical and safety related aspects.

Center pivot irrigation equipment manufacturers have done an excellent job of developing operationally versatile irrigation machines, most of which are installed correctly by qualified dealers/installers. The vast majority of center pivot systems in use today are powered by electricity, supplied entirely from an electrical grid or from on-site power generation sources. However, the maintenance of electrically powered machines has an inherent safety concern since most operate on 3-phase, 440V (or higher) power. The use of 3-phase high voltage provides added benefits of smaller wire sizing along the long lateral run and increased motor efficiency. However, the use of higher voltages present added safety concerns for operators. Moreover, the safety requirements for such systems are often not adequately understood by owners/operators, which prevents adequate inspection/maintenance to ensure safety and performance. Safety regarding these high voltage systems is far too often taken for granted, and the consequences includes both injuries and fatalities. Agricultural producers are great integrators of a multitude of diverse production system technologies, yet complacency or incorrect assumptions that safety protocols have been adequately addressed and maintained too often have catastrophic consequences.

Injuries and deaths have occurred as a result of electrical, mechanical and chemical hazards associated with center pivot irrigation systems. In 2011, a widely publicized fatal incident described how two 14-year old girls were electrocuted while detasseling corn (Giuliani, 2011). It was reported that the girls either came in contact with the center pivot irrigation equipment or received the shock through a pond of water in which the irrigation system was parked. Not unlike other agricultural accidents, others were injured trying to rescue the stricken workers. It was also noted that application of OSHA regulations and other regulations to agriculture is complicated (Steffen, 2011) and even experienced center pivot service personnel face hazards on the job (NIOSH, 2003). It is also noted that agriculture is generally exempt from many OSHA regulations; however, publicly the lack of implementation of adequate safety measures is causing concern for more regulation application to agriculture. Training, safety protocols, and lockout/tag out programs are always recommended for electrical operations.

Review studies of center-pivot irrigation systems indicate that electrical hazards due to improper wiring or inadequate grounding are common. A survey of electrically driven center pivot systems with electric pump motors showed "37 % were potentially hazardous because of the lack of a grounding conductor, and nearly 40 % did not have a grounding rod installed. More than 50 % lacked a fuse or a means of disconnection. Other hazardous situations were found, including loose connections, improper circuit and motor protection, and deteriorated insulation" (Schottman, et al., 1993). Inspections by a Nebraska state electrical inspector reported similar results. "Of 77 systems inspected at the owners' requests, 10 were classified as lethal; 38 were definitely hazardous; the remaining 29 were potentially hazardous. The 10 lethal systems had current flowing to ground at the time of the inspection or had almost killed someone shortly before the inspection. The National Electrical Code (NEC) had been violated in all 77 installations." (Schottman, et al., 1993).

Owners and operators of center pivot systems should seriously consider and implement regular inspections of their equipment. Accidents, surveys, and the risks of serious injury or death to farm workers (often including farm children), warrant appropriate inspections on a routine basis. Farmers are busy, but inspections to prevent/reduce hazards are much preferred over accident investigations.

ELECTRIFICATION AND SAFETY

Electricity must complete a circuit loop to be useful for work. In higher voltage AC circuits, such as those used on center pivot systems, there are multiple voltage level circuits within a typical control system. The control circuits are typically operated on a 120VAC level while relays (contactors with coils) engage the 480VAC motor circuits. Additionally, there are lower level voltage (transformed to DC) for the electronic circuits. In any case, all power to these circuits are derived from the main, 3 phase 480VAC infeed lines. These infeed lines also contain a ground wire configuration that may vary depending on the distribution and transformer setup. The two main types are delta and wye infeed systems. All major electrical components are manufactured to meet UL electrical safety standards. The grounding and safety circuits are governed by the National Electric Code (NEC) and are generally adhered to by manufacturers. Installation guidelines have also been developed by ASABE. In Texas and other states, agricultural installations are not required to be conducted by certified electricians as they are exempt.

Grounding for a center pivot unit is typically located at the pivot point pad and achieved with an 8 to 10 foot long copper clad grounding rod attached to a #6 bare, solid copper wire attached to the pivot point tower leg and/or the grounding lug in the pivot control panel. This is considered acceptable grounding practice for most installations and all is generally well initially. The longer-term issue occurs over time where: 1) the grounding lug screw becomes loose on the grounding rod connection or 2) the bare cooper wire reacts with the environment in many locations and the wire begins to degrade and does not make a firm connection. The rate of bare wire degradation varies with soil around the pivot pad. Commonly caliche is brought in to build up the elevation and caliche (calcium carbonate) reacts with the bare wire over time. It is not uncommon that the wire is severed at the pad through degradation corrosion. Why does this matter? In the event of a wire fray and/or "current leakage", the ground wire is designed to complete the circuit and prevent shock to operating personnel that could come in contact with the center pivot structure, frame or control panel. The ground wire is designed to have better conductivity than personnel completing the electrical circuit. When that wire circuit degrades, an individual touching the system may provide a better path of electrical current. Marek's recommended practice is to use infeed service wire that carries an extra full ground wire lead from the meter loop and to tie that ground to the ground lead of the electric service power company's utility pole. These grounded utility poles are also typically tied back to the electrical grid transformer station. With this installation set up, the grounding rod is considered redundant and the resulting grounding system is safer than the minimum requirement.

The redundancy mentioned may seem like "overkill" to some but lightning strikes have partially damaged meter loops and allowed transient voltages and high amperages to be imparted onto to the ground leg of 3 phase power systems. Marek has measured a voltage leakage of 165 VAC with over 40 amps current flow onto the ground lead. This leakage voltage was "transferred" to the entire grid coming from the power company's line transformer. What this meant in laymen's terms is each and every electrical device attached to the downstream grid (below the utility pole transformer) had 165VAC imparted onto any "grounded" metal component, conduit or case. The "amount of shock" felt by any personnel touching any metal component varied and was proportional to the conductivity of the individual to ground contact (i.e., it depended as to what kind of shoes or boots personnel were wearing at the time of contact and what the soil or pad conductivity status was: dry, moist or wet?). In any case, it was obviously a most dangerous situation. What it also meant was that the amount of voltage and amperage "leakage" was essentially trying to "heat the soil" at the point where the grounds were in contact with the soil - which in this case was for months before the leakage was identified by Marek. (Marek readily informs the reader that when one notifies the power company that they have 165VAC on their ground leg they become very excited due to the realization of liability and their response can be most rapid. The cost of the electrical leakage to the producer in the above example is virtually irrelevant in comparison to the safety consequence.)

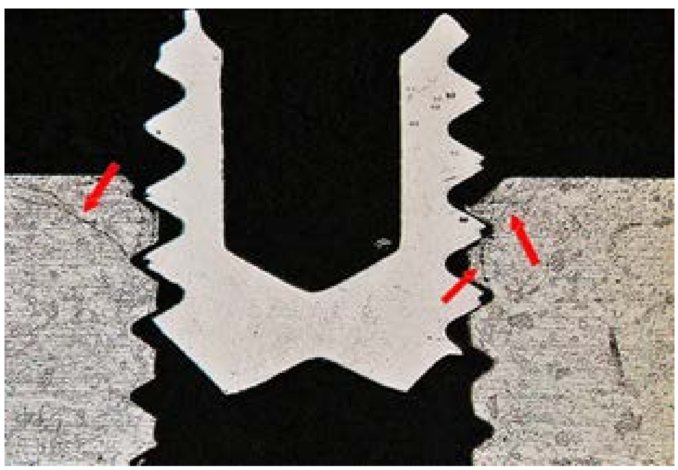
There is no higher priority than high voltage electrical safety. For the benefit of users, there are simply NO SECOND CHANCES with 3 phase, 440VAC or even 240VAC line "shorts", should good circuit contact be made. One cannot "pull away" as with a single phase 120VAC shock connection. Three phase electricity has too great a potential and one "sticks" to the contact due to the voltage level. If there is any safety doubt with such systems, simply DO NOT CHANCE IT. It is not worth the risk.

Another critical item that is routinely overlooked and not understood by electrical operators is that of terminal screw loosening. When a metal object is heated or cooled, its length changes. Why is this important and what does it really mean? It means that as temperature varies from cold to hot and vice versa, materials such as copper and aluminum wire (where allowed) contract and expand. The generalized equation that governs the linear thermal expansion of an object can be expressed generally (without units) as:

$$l = L_i * \alpha * (t_1 - t_0) \qquad \text{(eq. 1)}$$

where:
l = change in length
Li = initial length
α = linear expansion coefficient
t_0 = initial temperature
t_1 = final temperature

The torsional thermal expansion of a terminal screw is governed by the pitch of the threads of a screw connector and is depicted in the following figure. The thermal and tightening fatigue action of the screws on the terminal blocks can also be seen depicted by the arrows.



Source: met-tech.com

Figure 1. Cross sectional view of single electrical wire terminal screw and connector block.

This thermal cycling action allows screws holding wires to become loosened in terminals. In the Texas High Plains climate temperature variations and the accumulation of thermal cycling effects over an annual season can loosen screw terminals ¼ to ½ turn nominally as noted by Marek. Terminal wires have also literally fallen out of the terminal connection due to the lack of electrical tightening maintenance over longer periods, and that is particularly concerning when they can potentially come into contact with other system components. The issue is even more pronounced with stranded and multiple wires are used per terminal connector. If you were asked as to when was the last time your systems were checked regarding this maintenance task, hopefully your answer would not be when the units were installed. During this maintenance operation it is also a good time to remove dust or other foreign material that accumulates, particularly in the windy environment of the Central Great Plains region.

Proper tower and control panel grounding is a must at the pivot point and disconnect point (usually the meter loop location). The electrical ground wires between the center pivot spans at each tower should also be inspected, and any degradation or break in the wire indicates that the wire should be replaced. Most systems are usually equipped with one grounding connector; however, two grounding connectors – one on each side - is highly recommended for redundancy purposes and some safety advocates suggest using chain. However, chains are not viewed as electrically contiguous by Marek. The tightness and contact surfaces of the ground wire lug connections (bolts or screws) should also be checked. If these surfaces are rusted, they warrant replacement for firm contact. Thus, an annual inspection of screw connector tightness is strongly recommended. For older or refurbished systems, the tower boxes should also be checked for deterioration as they become soft and degraded from UV radiation and/or hail damage. This then exposes the high voltage tower motor contactors to rain, sleet and snow and birds have been known to build nests in them as well. The same is true for the collector (or pivot point rotator) cover and rotator contacts. Electrical connection blocks inside the tower boxes become brittle with time and should be checked and replaced as necessary. Also, check for weather cracks on wire insulation and motor and sensor and control wire leads, in case they have been damaged (often by rodents or birds). Coyotes also cause damage by chewing on wire insulation on the drive motors damaging it to the point of necessary replacement. When the wire insulation is damaged, the use of a Megohmmeter (sometimes referred to as a “megger”) can be used to ascertain the insulation condition. The Megohmmeter is used to determine the degree of “electrical leakage”, and acceptable resistance values vary depending on the type of wire used with the measurement being temperature calibrated. Since these meters are relatively expensive, they are primarily used by professional electrical service personnel.

MECHANICAL MAINTENANCE

While mechanical hazards of center pivot operations are generally not viewed as dangerous as the electrical risks, caution is still warranted. The obvious risks are falls from the structure (during maintenance activities), potential entanglements with moving parts, and potential for damage, injury or death associated with carelessness around these large autonomously moving machines. These can pose special risks to children (Associated Press, 2010) or livestock. Failure to adequately address mechanical maintenance can lead to operational and structural issues that can lead to additional hazards. The basic annual mechanical checklist of items should include a checking of tire inflation pressures and for wear and cracking (“checking”) of the tires, as replacement of an in-season flat or blowout can be truly troublesome. Also, check the lug bolts and nuts. Tires are directional and each pair should face each other cleat-wise. On three wheeled systems, two of the tire cleat directions should face toward the predominant direction of typical travel. Checking the drive shaft yokes and inserts is also essential, as many new yokes are made of aluminum and require more frequent inspection than those of older steel-based systems. Gearbox leakage and proper oil level should also be checked. Hydraulic driven systems should be checked for gauge damage, oil contamination, filter age, hose damage and line and valve leakage.

As with the electrical connections, structural frame connections need to be inspected. Due to the stress/strain nature and twisting action of the pivot system, bolt and nuts holding the structure together loosen and Marek has seen several major tower bolts missing after years of operation on several tower units. Replacement bolted connections should be torqued to recommended levels to assure adequate performance.

A simple checklist of mechanical issues should include:

- Tires (condition and air pressure)- (are they aged, cracked, or missing cleats?)
- Lug nuts (are they rusty, is anti-seize thread treatment used?)
- Gear boxes (oil level & seal condition)
- Drive shafts condition (bent?)
- Drive shafts u-joints condition (broken/cracked?)
- Drive shafts covers /clamps (twisted/broken/missing?)
- Motor wire leads (are they secured/strapped/damaged?)
- Structure bolts (broken/missing?)
- Tower control arms (bent?)

CONCLUDING STATEMENTS

The best designed center pivot irrigation system will not perform as expected if it is not adequately maintained. Maintenance is an essential part of any center pivot operation. Maintenance inspections are usually best conducted in the spring of each year since the summer season accounts for the majority of system use and operation. For smaller operations, maintenance issues can be readily addressed in a relative reasonable time period; however, for larger operations with tens and even hundreds of center pivot units, on-going maintenance can be a necessary and demanding aspect of the business. In these cases, dedicated personnel and service equipment should be considered to ensure the needed adequacy of address.

Unfortunately, electrocution injuries and deaths have occurred in recent years, due to inadequate safety measures and/or the lack of maintenance with center pivot systems. Proper design, installation, redundant grounding, routine inspection, care and maintenance can prevent personnel injuries and deaths associated with center pivot irrigation systems and associated equipment.

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