MIL EVALUATION OF CENTER PIVOT IRRIGATION SYSTEMS

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Introduction

The Mobile Irrigation Lab (MIL) project is an educational and technical assistance program focused on enhancing the irrigation water management practices of Kansas irrigators (Clark et. al., 2002 and Rogers et. al., 2002). The MIL has two parts: one part emphasizes irrigation software development and hands-on computer training for producers; the second part has emphasis on field activities, which has included on-farm irrigation demonstrations and center pivot performance evaluations. Center pivot nozzle package evaluations have used IrriGage catch can data to calculate a distribution uniformity coefficient. However in the Ogallala irrigated areas of western Kansas, the most commonly utilized center pivot nozzle package is an in-canopy nozzle placement, which can not be tested using the catch can procedure. The MIL team has worked on to develop an in-canopy nozzle testing procedure that can be done in a time efficient manner to help producers evaluate systems and make adjustments as needed to keep the system distributing irrigation water and chemicals effectively and allow for good irrigation water management. Both evaluation procedures are discussed and examples of test results are shown. MIL computer software programs and materials are available through your local county Research and Extension Office but can also be easily accessed via the MIL website at http://www.oznet.ksu.edu/mil/.

IrriGage Nozzle Package Testing

MIL has an emphasis on field evaluation center pivot sprinkler packages for distribution uniformity. The initial rational for testing was to make certain that water was distributed so that individual plants within a field had equal access to the water. This is particularly important when using irrigation scheduling procedures to minimize irrigation water application depth. If "just in time, just enough" water is applied, then the water must be distributed so that plants have equal access to the water to prevent over- or under-water within the field, which would have yield implications.

Center pivot systems are the dominate irrigation system type in Kansas, representing about 80 percent of the irrigated acres. The sprinkler package design is based on a number of factors with system pressure and flow rate as major considerations. Center pivot irrigation systems have been largely assumed to be properly operating if the pivot point pressure and flow rate are set at the design operating specifications. Routine evaluation of the center pivot sprinkler packages are seldom performed after installation. Testing involves placement of multiple catch containers along the lateral of the system and then measurement of each catch. The catch containers used had to be measured quickly in order to avoid measurement error that would be introduced by evaporation losses. Therefore, a number of individuals had to be present at the test site for quick measurement. Measurement required entry into a very wet field, making for difficult data collection.

Development of a more streamlined testing procedure has been made possible through the use of IrriGages. IrriGages are a non-evaporating collection device as shown in Figure 1. A series of IrriGages are placed along the center pivot or linear lateral and are normally spaced at about 80 percent of the nozzle spacing. The IrriGages are placed so that all water from a complete pass of the center pivot is collected. The data collected includes the volume of catch and the position radius of the IrriGage relative to the center pivot point or the end of the linear system. System operating and package characteristics are also recorded. The catch data is entered into a MIL uniformity evaluation program where the average depth of application and the coefficient of uniformity (CU) value is calculated. The program also plots the catch data, which helps to visually identify the location of package weakness.

Center pivot package evaluations using IrriGages are limited to sprinkler packages that are at least four feet above ground as three feet of clearance is recommended between the top of the collector and nozzle outlet. Another restriction is the need for the top of the collector to be above the crop canopy or be placed in a non-vegetated strip of a width of about three times the height differential between the collector top and the nozzle on each side of the catch container. The height restriction means many in-canopy systems can not be evaluated using IrriGages.

Test Result Examples

Field test results have found a number of center pivot nozzle packages that were not performing to expectations. Some non-uniform system results may be related to the original design where possibly the incorrect well yield and pivot pressure was provided to the designer. Some non-uniformity may be due to incorrect input pressure and flow settings due to well or pump changes or faulty gauge or meter readings. A number of systems have been found that had the package incorrectly installed, while some had performance problems related to nozzle maintenance issues.

The uniformity evaluation results for three systems using IrriGages are shown in Figures 2 through 4. Figure 2 is center pivot system equipped with rotators[1] and tested at a CU of 84 percent. The major spike in application depth in the inner part of this system was due to a leaky tower boot. This catch data for this system extended nearly to the center pivot point. The inner spans of many systems often have an application depth that is greater then the system average due to size limitations on nozzle orifices. There is also a tendency to see some choppiness in the application uniformity, which can also be due to the range of orifice size availability at the lower flow rates but also due to the nozzle spacing configuration.

The results for a new system equipped with I-Wob[1] nozzles in Figure 3 showed an increasing depth of application with increase of radius. Although the CU value is acceptable at 82 percent, the application depth was approximately one-third greater in the outer portion as compared to the inner portion. The cause of this condition is believed to be due to improper flow and pressure conditions at the pivot point. However, independent measurements were not taken at the time of the test. This system was re-tested the following season. When the pivot point pressure and flow was measured and was verified as correct, the average application depth was constant along the lateral. This illustrates the importance of making certain design operating conditions are met for proper performance.

Figure 4 shows the results from another system equipped with rotator nozzles. The CU value of this system was low at 67 percent and there was also decreasing water application depth with increasing distance from the pivot point. The design inflow rate to the nozzle package was below specifications. The field also had a considerable elevation increase at the outer edge at the test location. Some of the major spikes were noted to be several tower boot leaks, goose neck leaks and non-rotating rotators. Remediation for this system would likely be best achieved with a new package design, including consideration of pressure regulators.

While the systems evaluated to date have found many systems to be performing as designed, the evaluation program has found a number of systems not meeting performance expectations. The industry has developed a large number of nozzle options that can perform very well under a wide range of operating conditions, but only if they are properly designed, installed, and operated. The Other tests have revealed installation problems, such as missing drop nozzles and reversal of tower nozzle sequences. Poor performances have also been attributed to changes in operating conditions as compared to original design specifications. Another possible cause of low uniformity could be internal incrustation similar to the material encrusted on nozzles splash types, which would alter friction loss characteristic of the system resulting in loss of design integrity.

In-canopy Nozzle Package Testing

Unlike an above canopy nozzle package, where the uniformity of water distribution is dependent on non-interference by the crop canopy, the in-canopy nozzle package almost always has the water streams from the nozzle being intercepted and/or redirected by the crop stocks and leaves. The primary exception to this would be a LEPA system, utilizing circularly planted rows and bubble mode nozzles or drag tubes. Few of these types of system are utilized in Kansas. However, even these types of systems would have non-uniform water distribution if the design flow rate and pressure requirement were not met. As with above-canopy nozzle packages, in-canopy systems must be properly designed, installed, and operated to perform properly.

The concept of the in-canopy test was to develop a protocol to minimize data collection from a system that would still allow a determination of whether design and operating conditions matched. The intent was to take a number of pressure and flow readings from nozzles along the center pivot lateral and measure total flow and pivot point pressure and compare this information to the design sheet specifications. It was thought that eventually only readings of a few nozzles at the beginning and end of the pivot lateral would be sufficient to verify the system performance in terms of water distribution along the center pivot lateral.

Since the nozzles are near the ground and many are mounted on a flexible drop tube, the installation of a pressure shunt is generally accomplished by crimping off the water flow to an individual nozzle and installing the pressure shunt to determine the nozzle pressure. The flow rate could be determined by volume flow measurement and a stop watch. However before testing began, several small digital flow meters (F-1000-RB flow rate meters from Blue-White Industries[1]) were purchased and configured with the pressure shunt.

This procedure is only effective in determining if the design operating conditions are being met. It will not reveal installation errors, such as tower reversals or mis-sized nozzles. However, these types of problems can be much more easily

[1] No criticism or endorsement is intended by the use of commercial name. The use is only for clarity of the presentation.

detected for an in-canopy system by visual inspection and comparison to the design chart, since the nozzles are low to the ground

Most irrigation wells are metered in Kansas and flow meter readings were accepted for use in the previous above-canopy evaluations. However, several of the systems that were evaluated had poor performance ratings for no apparent reason. One reason might have been improper flow or pressure at the pivot point. However input flow and pressure readings were not initially independently verified, so this could not be proven. One of the systems was retested at a later date and the performance rating was good and both input flow and pressure were verified independently. To allow this to routinely occur, a non-intrusive flow meter was obtained.

The digital flow meters were lab tested and worked well over the specified flow range. However, during field tests, we have had some difficulty with moisture accumulation in the LED display to the degree that the display can not be read. Although the instrument specifications indicate they can be used in a wet environment, the instruments would also shut down after several readings presumably due to the moisture condensation within the body of the instrument. The instrument bodies can be opened to allow drying without apparent effect on accuracy. Several ideas to prevent condensation have been tried without much success, so this remains an issue for these particular instruments. The back up method for obtaining flow readings is the bucket and stop watch.

Test results from the first in-canopy pivot analysis are shown in Figures 5 and 6. Most of the measurements were taken adjacent to a pivot tower. The test was conducted early in the irrigation season. The center pivot was 1305 feet long and equipped with LDN[1] nozzles using concave grooved by chemigation pads with 6 and 10 psi pressure regulators. The design flow rate was 350 gpm with a top of pivot pressure of 14 psi.

Figure 5 shows the field measured pressure distribution and the design pipe pressure. The field pressures were measured at approximately the nozzle height of 3 feet from the ground. The design pipe pressure would be at an elevation of approximately 12.5 feet, for about a 4 psi pressure differential. The measured values appear to be slightly higher than the design values. However, all nozzles are pressure regulated, so much of the pressure differential would be dampened out through the regulators.

Figure 6 shows measured flow rates and design flow rates. Measured observations appeared to be slightly higher at the end of the center pivot than design values. The test was conducted before the start of the general irrigation season, which could mean the well yield was higher than what it might be after long term pumping. However flow measurements at the beginning of the pivot lateral were matched very closely to the design values. Overall, it appears this system's performance was satisfactory.

Concluding remarks

The obvious improvements needed for the in-canopy test procedure are 1) reliable measurement of the pivot point flow rate and pressure, 2) either a different nozzle flow measurement instrument or a method to better seal the existing instrument, and 3) a standardized data collection routine. The latter comes with multiple testing and analysis. Items one and two are being addressed. In addition to moisture condensation or accumulation within the instrument, the instruments also shut down completely after a number of uses. This was originally thought to be due to the moisture exposure, but an additional suggestion that exposure to cold ground water may be having an effect on the instrument. This will be tested in the lab. During the test, the instruments are not exposed to direct spray from other nozzles, but do get wet from handling.

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Rogers, D.H., G. A. Clark, M. Alam, R. Stratton, and S. Briggeman. 2002. A Mobile Irrigation Lab for Water Conservation: II Education Programs and Field Data. In proceedings of Irrigation Association International Irrigation Technical Conference, October 24-26, 2002, New Orleans, LA, available from I.A., Falls Church, VA.

Figure 1. Series of IrriGages being positioned prior to an above canopy nozzle package evaluation.

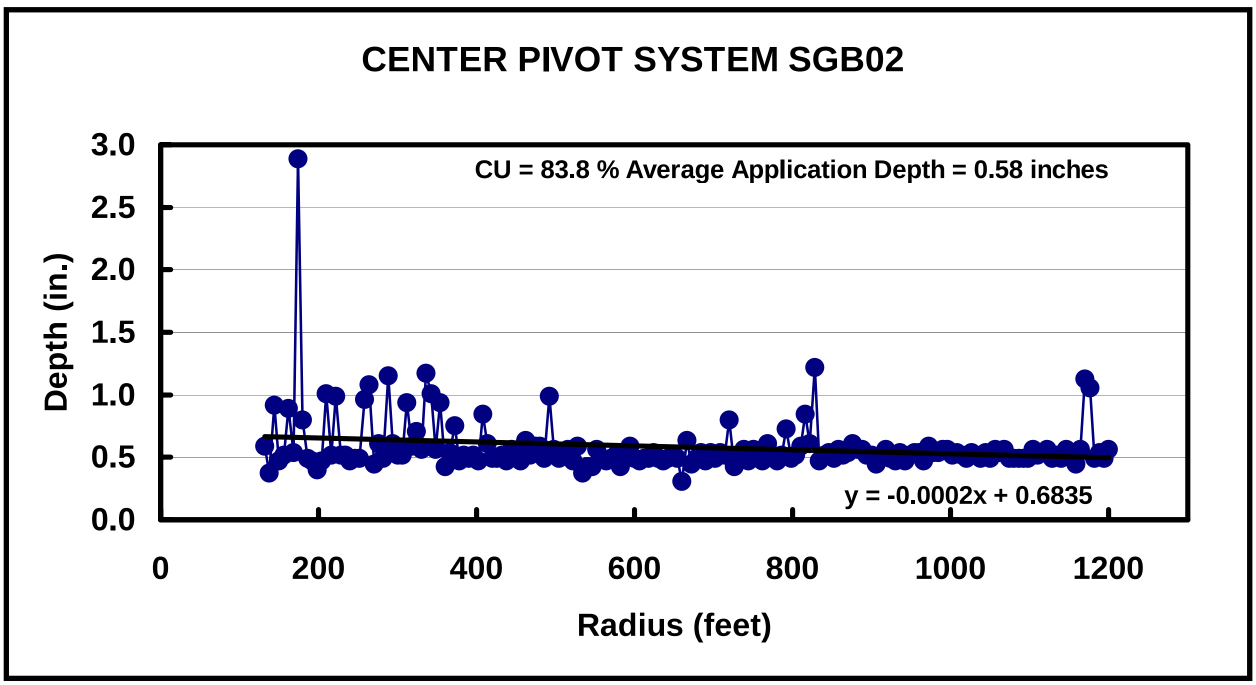

Figure 2. MIL uniformity test results for a center pivot equipped with an above canopy nozzle package of rotator nozzles.

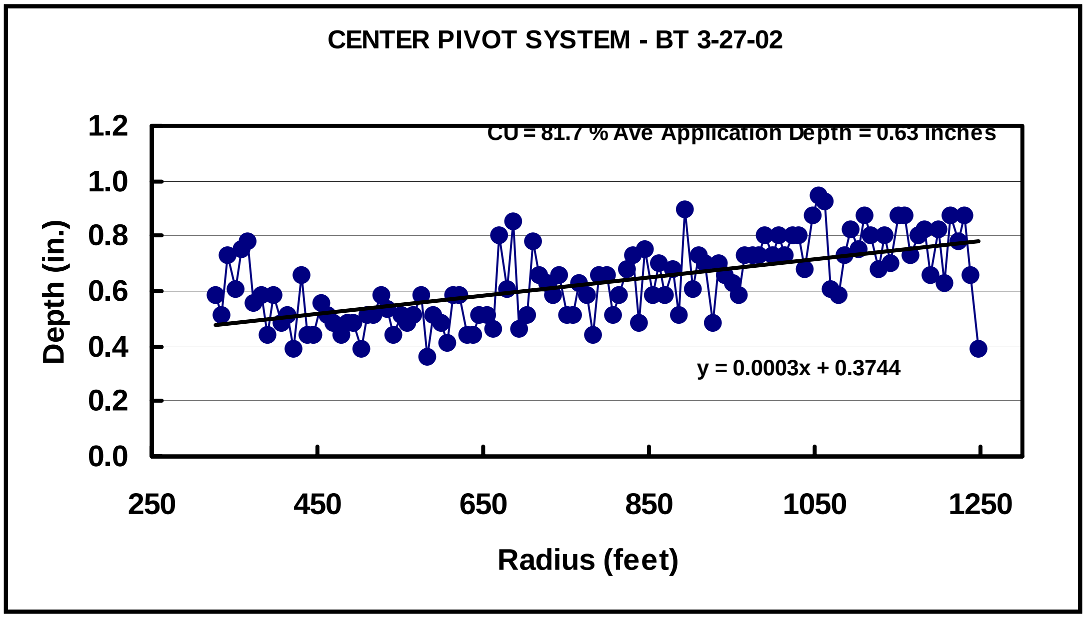

Figure 3. MIL uniformity test results for a center pivot equipped with an above canopy nozzle package of I-wob nozzles.

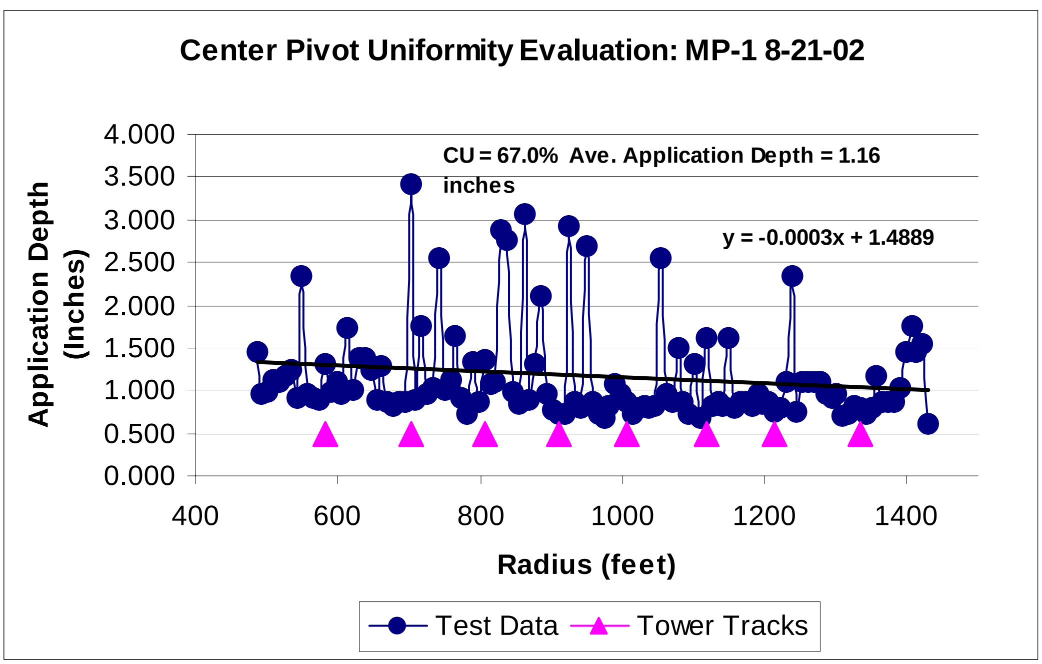

Figure 4. MIL uniformity test results for a center pivot equipped with rotator nozzles.

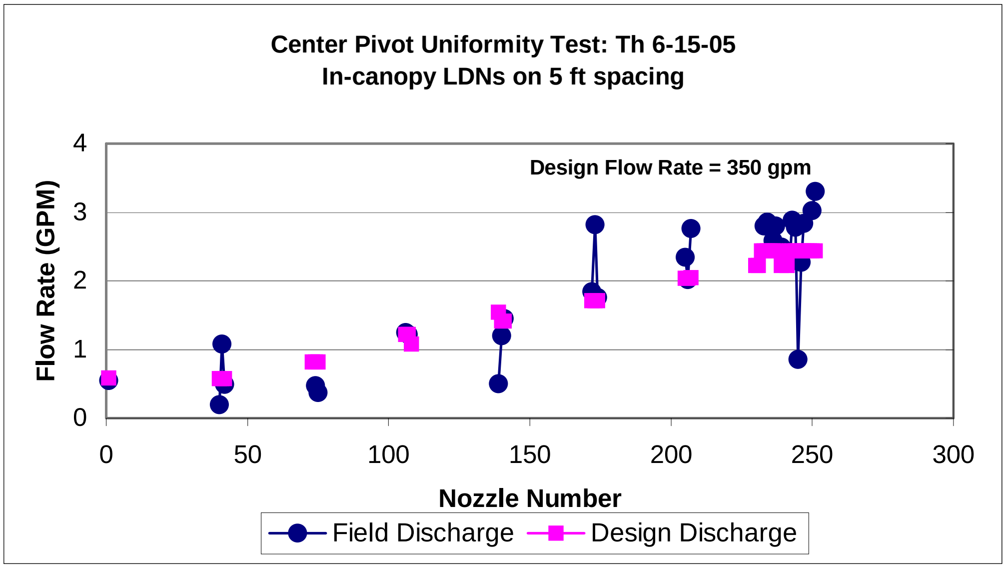

Figure 5. Field measured and design pressure versus nozzle location in-canopy center pivot evaluation.

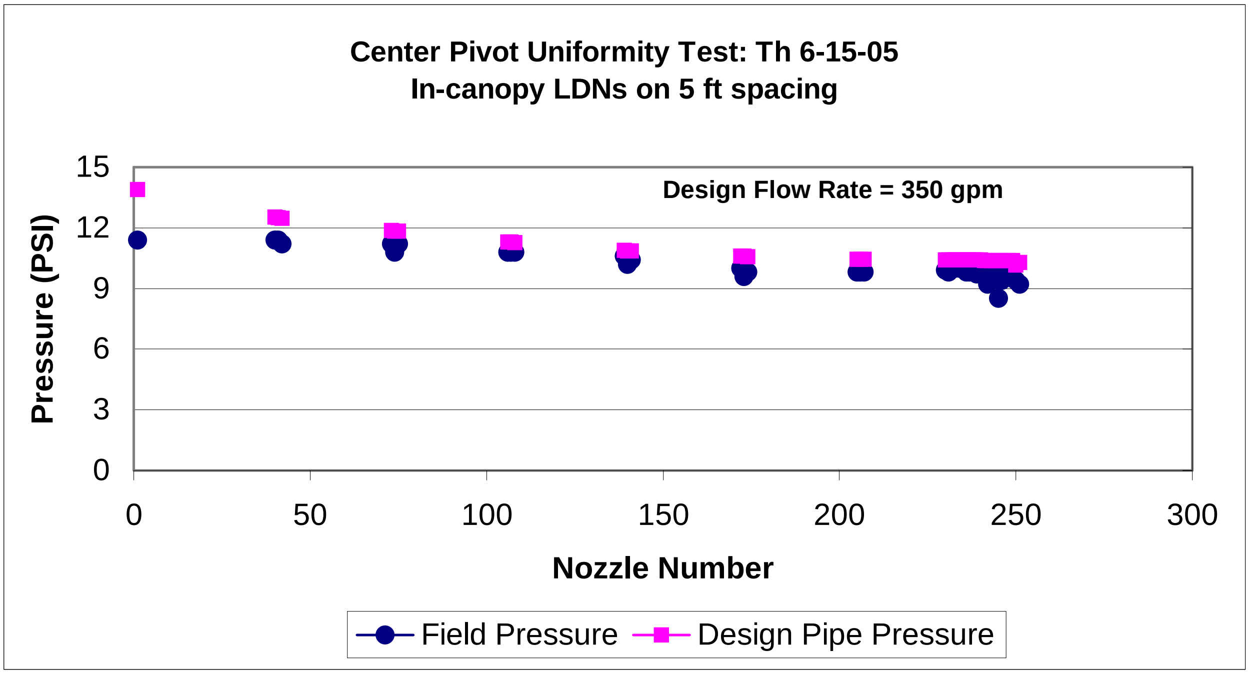

Figure 6. Field measured and design nozzle flow rates verses nozzle location on an in-canopy center pivot evaluation.