RELIABILITY TESTING OF AN ON-HARVESTER COTTON WEIGHT MEASUREMENT SYSTEM

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Abstract

A system for weighing seed cotton onboard stripper harvesters was developed and installed on several producer owned and operated machines. The weight measurement system provides critical information to producers when in the process of calibrating yield monitors or conducting on-farm research. The objective of our work was to conduct system reliability testing and obtain producer feedback on the operation and utility of the system. The system was modified from the system used in 2014 to include new hydraulic system components and a simplified user interface; all of which were added to improve accuracy, data reliability, and ease of operation. Observed accuracy was similar to that observed in 2014. Recommended practices to ensure high weight accuracy in regard to mitigating the effects of wind, vane position, and tare/weight routine operation were developed. Overall, the cooperating producers provided positive feedback on the weight measurement system. Several noted that the system was easy to use, reliable, and provided valuable information.

Introduction

The objective of this work is to develop a system used onboard a cotton harvester for obtaining seed cotton weight data. This system can be used to measure seed cotton weight on a full basket or partial basket basis, thereby enhancing the ability for a producer to conduct on-farm research to evaluate the yield influence of various treatments applied on a small-plot basis (e.g. variety, tillage, irrigation, chemical, etc.) Further, seed cotton weight data can be used to calibrate yield monitor systems on a semi-continuous basis as crop conditions or varieties change throughout a field. Work began in 2013 on the development of this system and continued in 2014 and 2015. This report details the research conducted in 2015.

Materials and Methods

The main goal of our work in 2015 was to install the weight measurement system on several producer owned and operated cotton strippers and evaluate system performance and reliability. Development work during 2013 and 2014 indicated that the system provided accurate weight measurements using a simple linear regression model based on hydraulic lift circuit pressure (figure 1). The two part model shown in figure 1 was used in 2015 and is based on hydraulic pressure measurements collected with the basket stopped at 13.7 +/- 0.2 degrees from the fully down position in the dump rotation cycle. Based on our work in 2014, industrial limit switches were installed at the rear of the cotton strippers (figure 2) in 2015 to sense the position of the basket and stop it at the specified location for reading the basket lift cylinder circuit pressure. Hydraulic pressure was measured using a pressure transducer with 0 – 2500 psi pressure range from Omega Engineering (PX409-2.5KG5V-EH, error specification +/- 0.05% FS = +/- 1.25 psi).

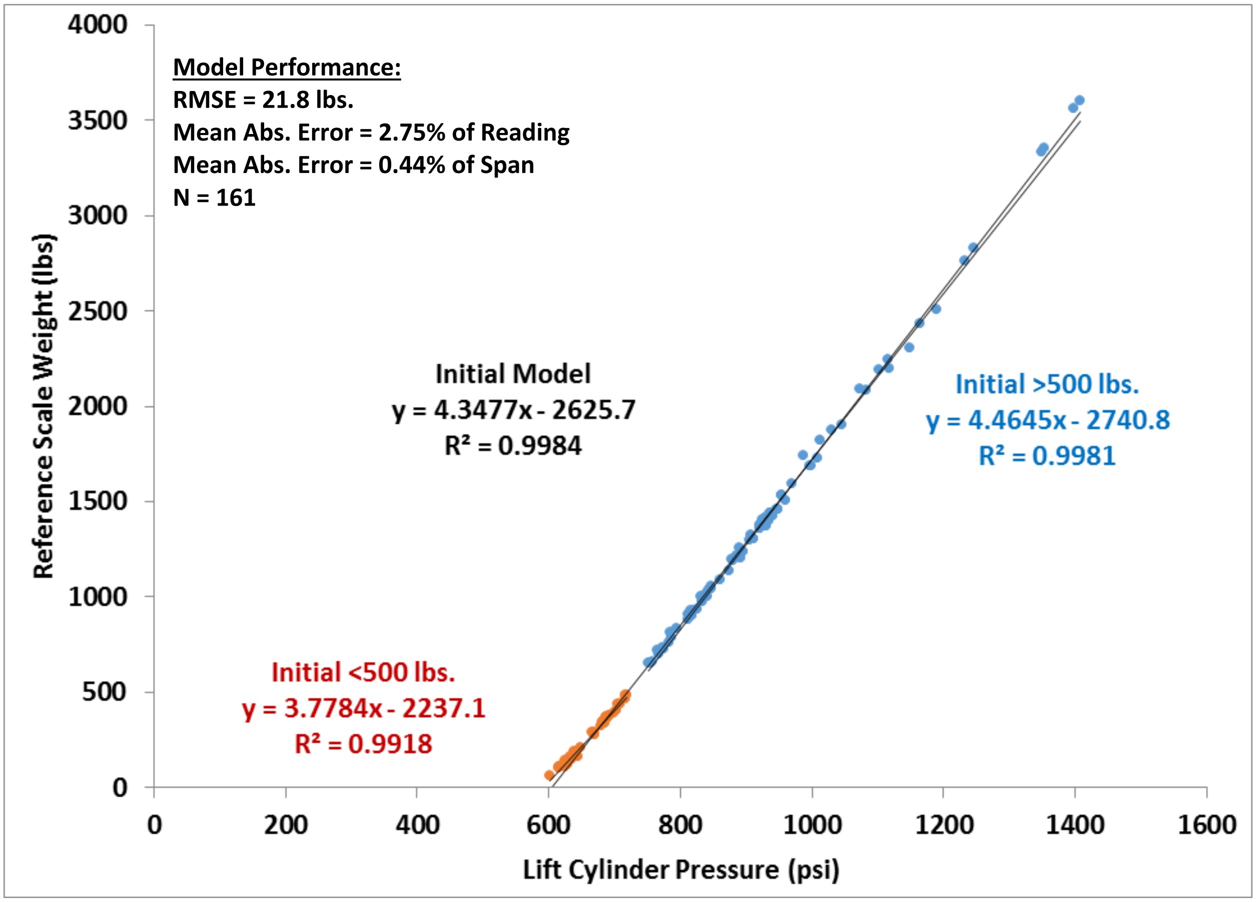

Figure 1. Two part model for cotton load weight as a function of lift cylinder hydraulic pressure.

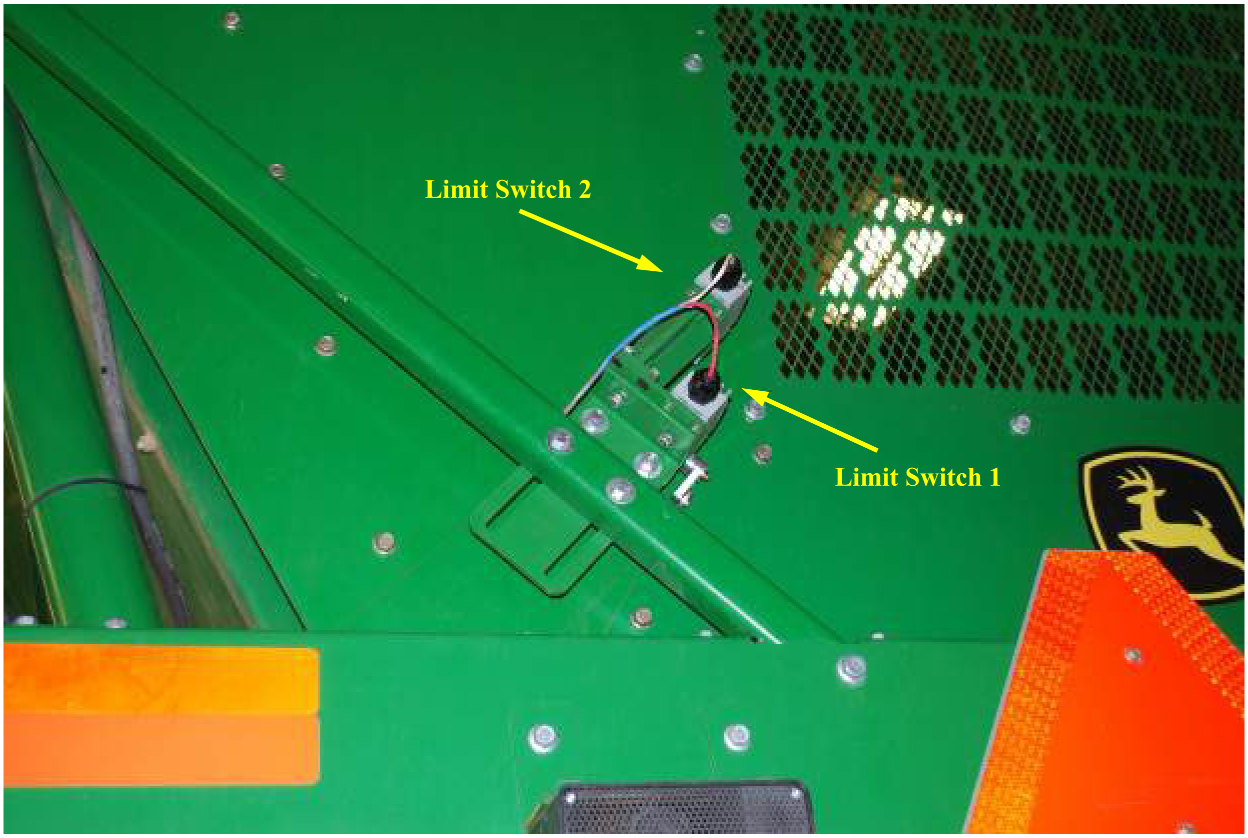

Figure 2. Limit switches mounted at the rear of the basket used to slow and stop the movement of the basket.

A microcontroller on the chassis mounted data acquisition (DAQ) board was used with a proportional directional control valve (DCV) to automate the basket positioning cycle (figure 3). When commanded to move the basket into position by the cab mounted PC, the microcontroller sends a pulse width modulated (PWM) current signal to the proportional DCV hydraulic valve that sends pressurized fluid to the lift cylinder circuit (figure 4). The microcontroller senses the position of the two limit switches mounted on the rear of the machine to sense the presence/position of the basket. The two switches are offset such that when switch one actuates, the microcontroller reduces the duty cycle of the PWM signal, effectively slowing the basket movement. When switch 2 actuates, the microcontroller stops the PWM signal and basket movement. Once the basket stops after switch 2 actuates, the system delays for 0.5 s before closing two hydraulic isolation valves that block flow to and from the top and bottom ports on the lift cylinders. The delay allows any pressure on the top side of the cylinders resulting from the basket movement to dissipate, thus reducing pressure measurement error caused by trapped pressure at the rod end of the cylinders. After the delay, the microcontroller begins reading the voltage signals from the hydraulic pressure transducer. The pressure transducer is read for a preset period that is specified by the user. A filtering scheme is used to reduce weight error caused by hydraulic “noise” induced by stopping the basket, wind, and other sources. The filtering scheme disregards the first third of the data read from the transducer over the reading duration and calculates and records the average of the last third of the data as long as the difference in hydraulic pressure between the average of the middle third and last third of collected data is not greater than the hydraulic pressure threshold set during installation. A reading period of 8 to 12 seconds was used in 2015 with a hydraulic stability threshold of 5 psi.

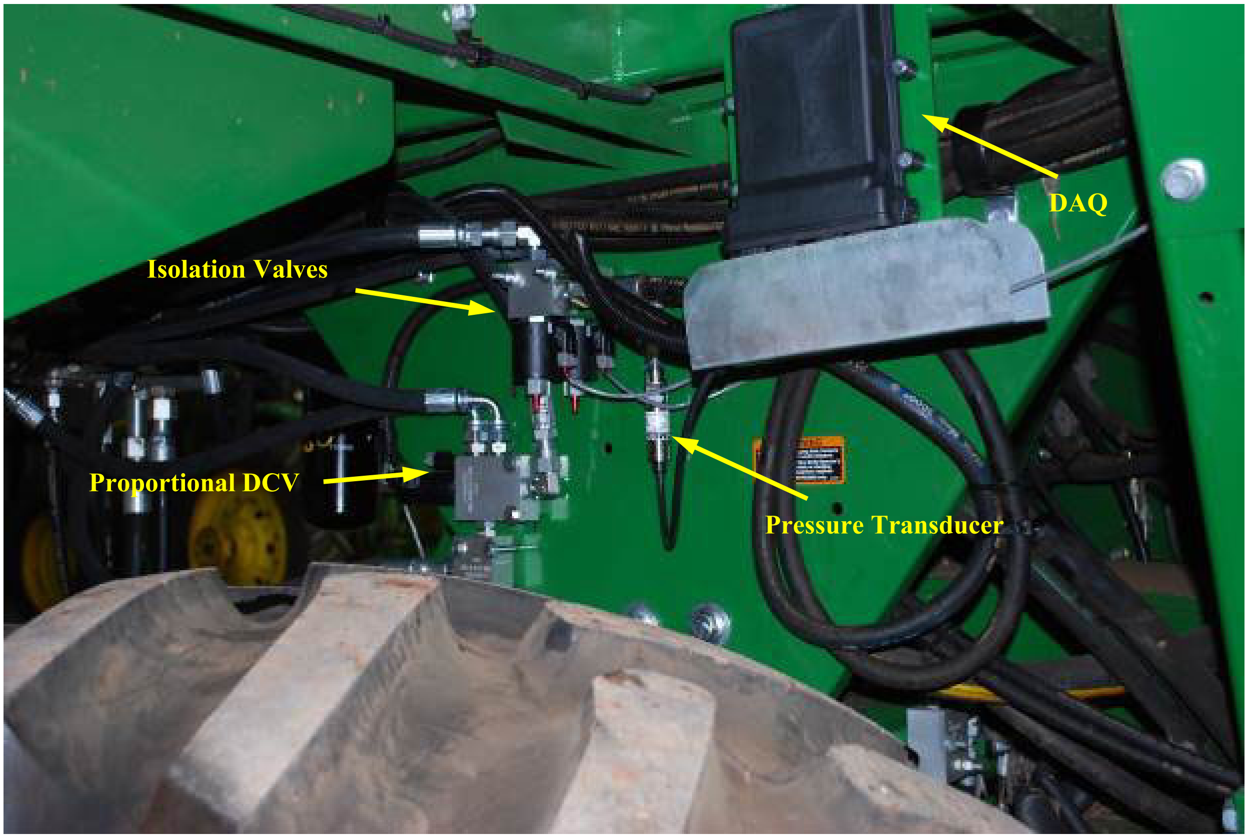

Figure 3. Hydraulic valves, pressure transducer, and DAQ board (inside the black box) used to control basket position and measure basket hydraulic pressure.

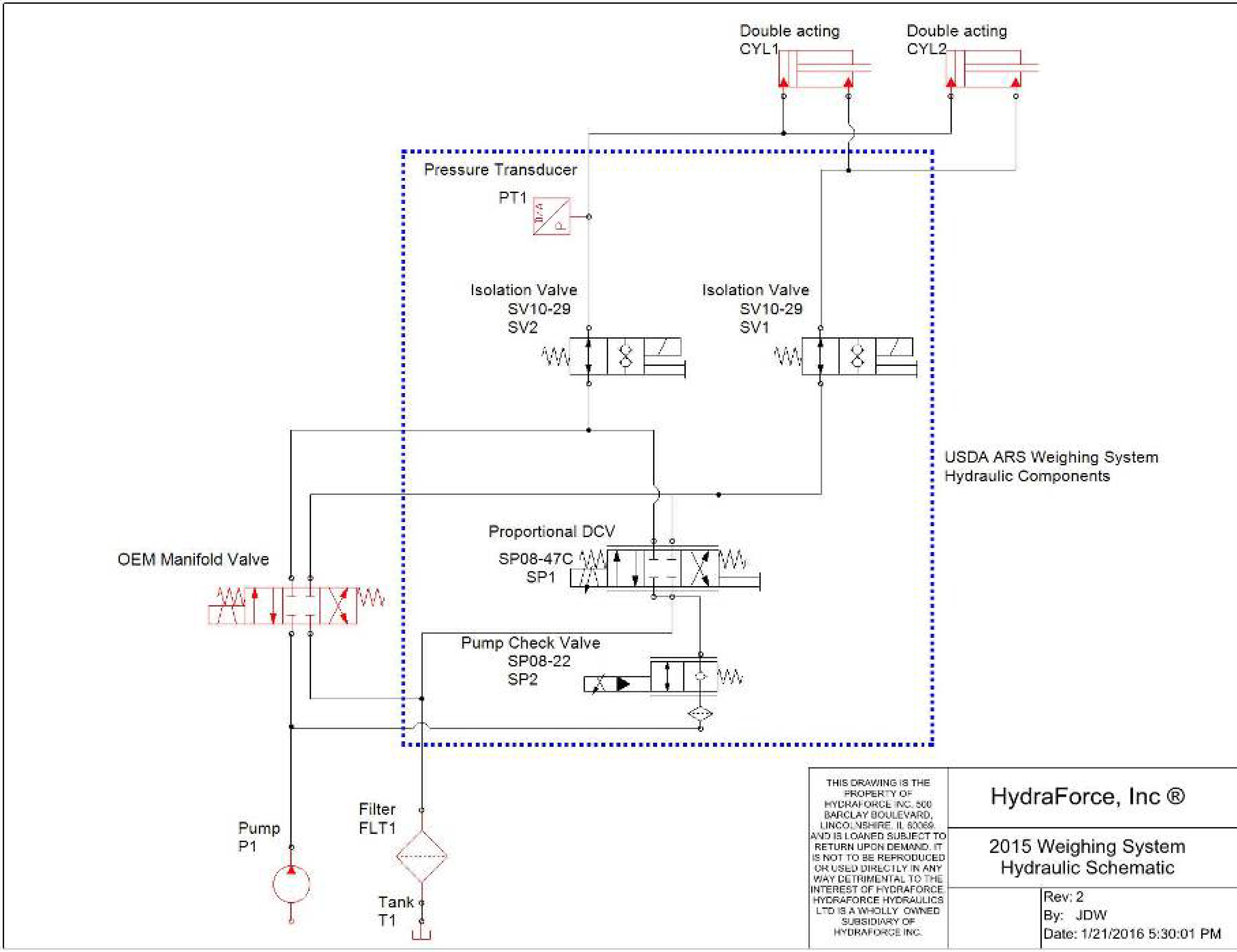

Figure 4. Schematic of hydraulic components used in the weight measurement system in 2015.

A touch screen display and mobile PC mounted in the cab (figure 5) was used with custom written software to control the weight measurement system and record system data from the DAQ board. The DAQ board communicates with the PC via serial communication. In 2015, the DAQ board and PC were configured to power up when the operator switched the ignition key to the run position. The computer was configured to automatically initialize the weight measurement system software upon boot-up. Once initialized, the software opens up to the "Setup" page (figure 6) where the operator populates the client, farm, and field text boxes and selects the radio button corresponding to the current wind conditions – calm (0 – 10 mph), normal (10 – 15 mph), or windy (>15 mph). The operator also inputs values for the header width (number of row units) and row spacing (row unit width, in) on the "Setup" page before pressing "OK" to proceed to the main "Run" page.

Figure 5. Weighing system touch screen display (right) and John Deere 2630 yield monitor display mounted in the cab of a John Deere 7460 cotton stripper.

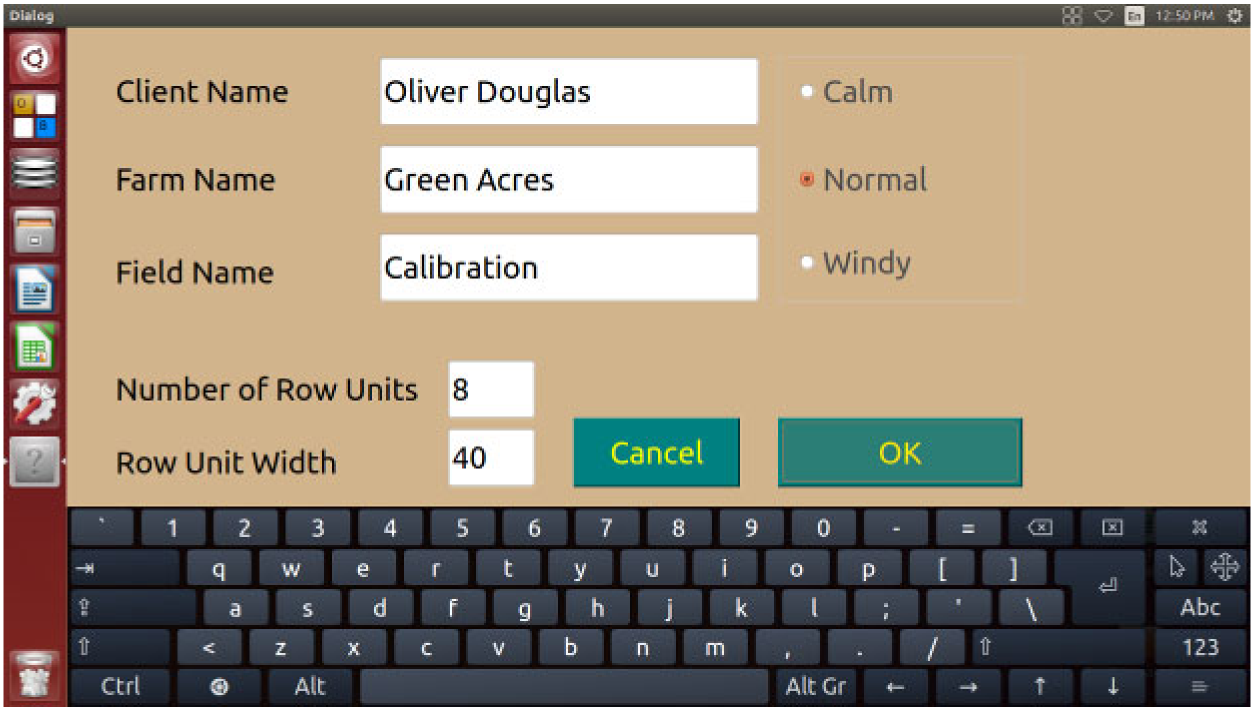

Figure 6 – “Setup” page of weight measurement system software.

The main “Run” page (figure 7) displays the current farm and field entered by the operator and provides an indication for when the system is properly communicating with the GPS receiver and the DAQ board. Prior to harvesting cotton, the system tare function is used to adjust the calculated weights for the empty basket weight including any accumulation of cotton not cleaned from the basket. To perform the tare function, the operator presses the “Tare” button and the system initiates the basket auto-positioning cycle and measures the empty basket weight. The basket tare weight is saved by the system and used to adjust all subsequent basket weights until the tare function is performed again. When the operator is ready to begin harvesting a plot, the harvester is moved to the beginning of the plot and the operator presses the green “area start” button and begins harvesting. With the “area start” button pressed, the system continuously updates and displays the total distance traveled and area harvested (based on distance and header width) until the operator presses the red “area stop” button [at the end of the plot]. With the machine on level ground, the operator presses the blue “weigh basket” button to begin the automatic basket positioning cycle and measure the weight of the cotton in the basket. Once the weight has been determined, the system displays the load number, area harvested, basket weight (lb), and calculated yield (lb/acre). The load number assigned to each basket weight is a sequential number that never repeats even if the machine and weighing system are shut down. The data displayed on the screen for each load number is saved in a comma delimited text file along with the “setup” page data and values for hydraulic stability, measured lift cylinder pressure, GPS coordinates and UTC time where the “area start” and “area stop” buttons were pressed.

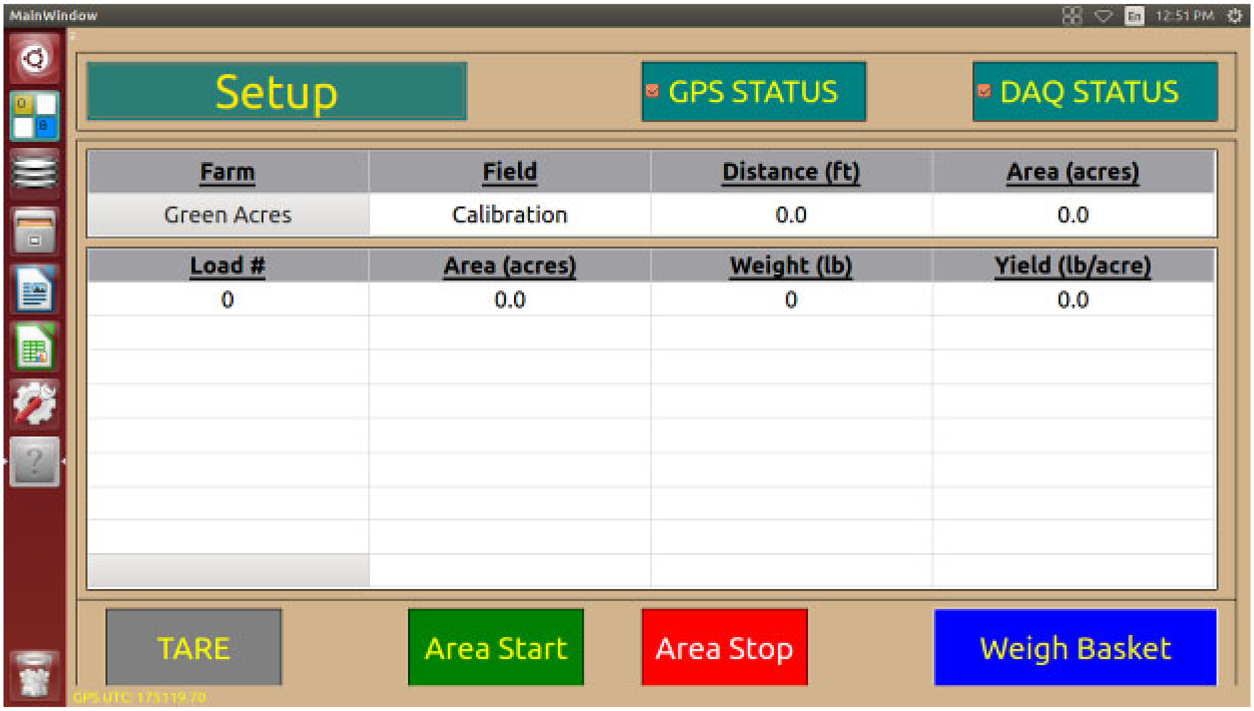

Figure 7. Main "Run" page of weight measurement system software.

In 2015, weight measurement systems were installed on four cotton strippers: a 2014 model JD 7460 owned by Danny Davis, Elk City, OK (Elk City stripper); a 2011 model JD 7460 owned by USDA ARS, Lubbock, TX (USDA stripper); a 2005 model JD 7460 owned by Mark and David Appling, Crosbyton, TX (Crosbyton #1 stripper); and a 2004 model JD 7460 owned by Mark and David Appling, Crosbyton, TX (Crosbyton #2 stripper). Although the amount of weight data collected with each machine varied, a minimum of about 40 loads were harvested using each machine for which corresponding reference weights were also measured using a set of mobile scales. Operators differed in regard to personality and the amount of attention paid to ensure that the system was operated to achieve high accuracy. An operator's manual was developed for the weight measurement system and provided to each operator prior to the beginning of harvest in 2015.

Results and Discussion

2015 System Performance

After installation of each system, the weight system calibration was verified using a reference scale and approximately five baskets of cotton ranging in weight from about 500 to 2500 lbs. The weights reported by the harvester based system agreed well with the reference scale weights for each installation. Differences in the initial tare values measured for the clean/empty basket weights were observed and were attributed to slight differences in year model. Regardless, the tare function was able to adjust for these differences allowing the system to report accurate weights.

Harvester weight system and reference scale cotton weights are plotted for the systems installed on the Crosbyton #1, USDA, and Elk City strippers in figures 8, 9, and 10, respectively. Data for the system installed on the Crosbyton #2 stripper is under analysis and will be reported in later publications. The slopes of the regression lines of the data shown in figures 8, 9, and 10 are close to 1.0 indicating a consistent dynamic system response relative to the reference scale over the range of weights tested. The intercepts of the regression lines varied between datasets for a particular stripper (see figures 8 and 9) and also between strippers. The intercepts of the regression lines are influenced by the tare value obtained on the stripper prior to the harvest of each field trial. Moreover, differences in the influence of wind on reference scale weights and weights determined by the harvester weight system are manifest in differences in the regression line intercepts. RMSE values indicating the error in weight measurement of each system over the range of values shown in figures 8, 9, and 10 were 61.7, 28.9, and 35.6 lb for the Crosbyton #1, USDA, and Elk City strippers, respectively. The data presented in figure 8 was collected on two days, each with a different tare value and range in measured weights. The RMSE value for the Day 1 data was 32.6 lb and increased to 88.4 lb for the Day 2 data. RMSE expressed as a percentage of span was 2.3%, 2.07, and 1.7% for the Crosbyton #1, USDA, and Elk City strippers, respectively.

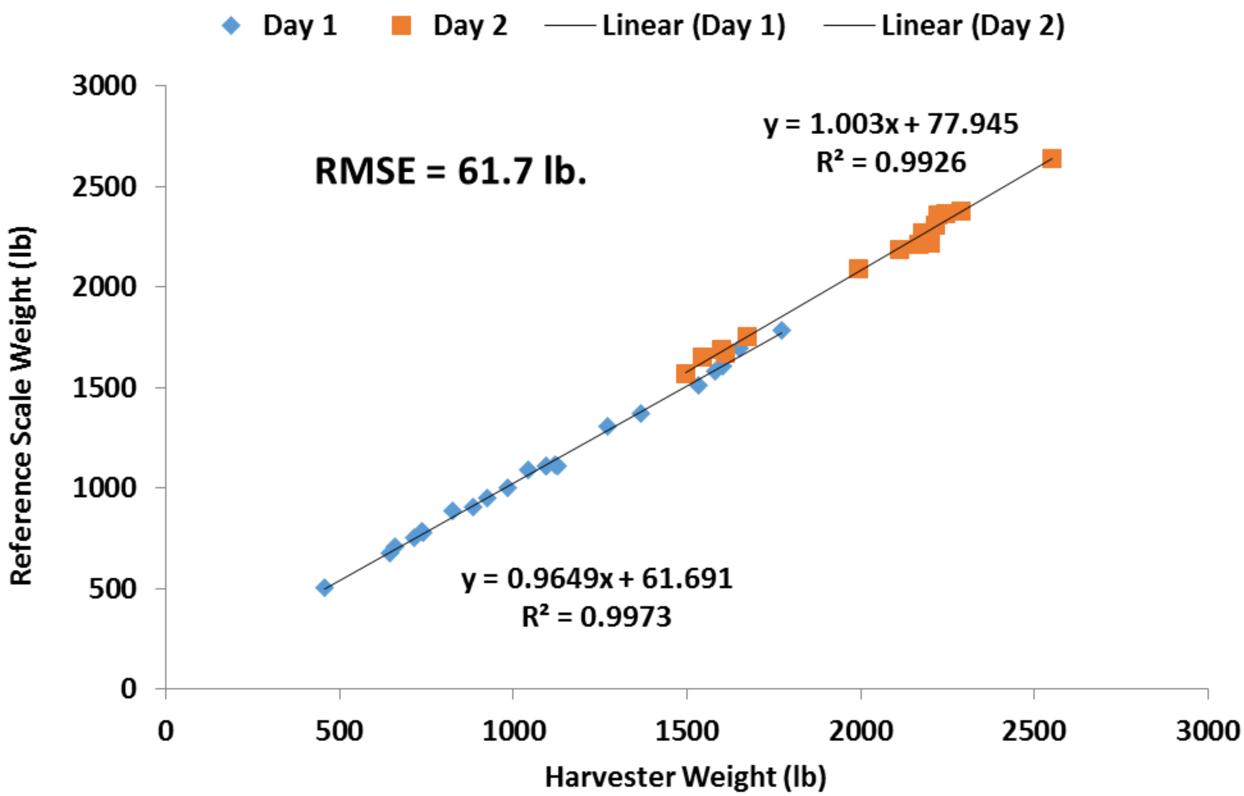

Figure 8. Harvester weight system and reference scale weights for the Crosbyton #1 stripper.

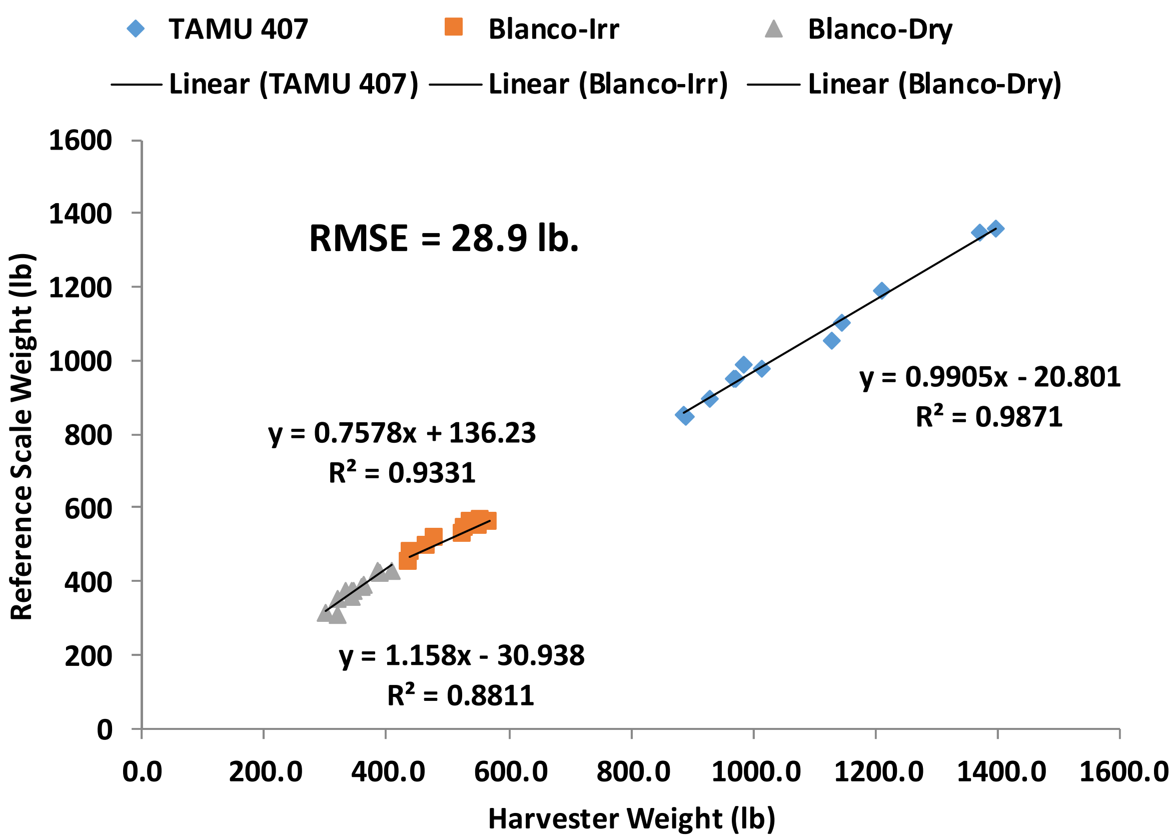

Figure 9. Harvester weight system and reference scale weights for the USDA stripper.

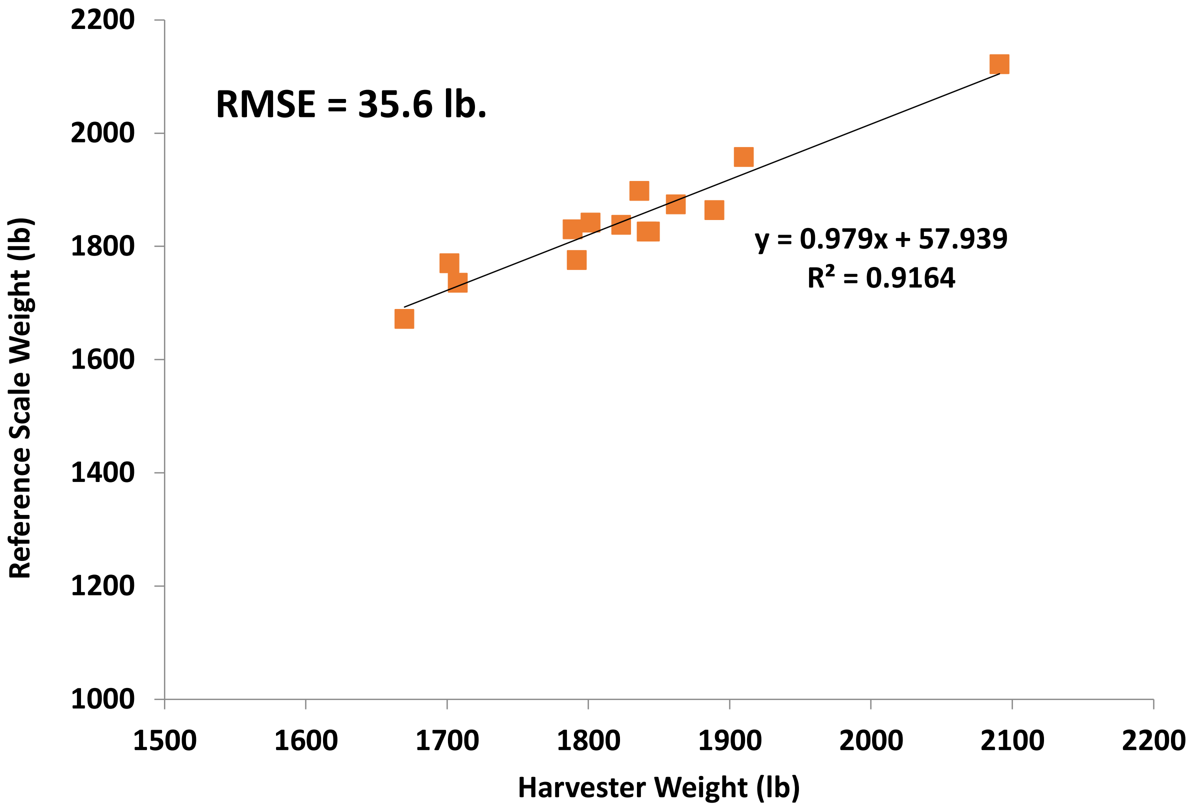

Figure 10. Harvester weight system and reference scale weights for the Elk City stripper.

Operation of the tare function was investigated on the Elk City stripper during harvest of a replicated variety test. In concept, the tare function is considered to be a tool which should be used frequently to improve weight measurement accuracy. Thus, the system was operated for the first 10 loads by performing an initial tare prior to initiation of harvest and then conducting a tare operation after each basket load of cotton was dumped. This practice in combination with varying winds produced poor weight accuracy as illustrated in figure 11. Subsequently, a single tare operation performed prior to the beginning of harvest of a particular field test was recommended to prevent the inclusion of additional error resulting from erratic tare weights. This single tare operation was used to collect the data presented in figures 8, 9, and 10.

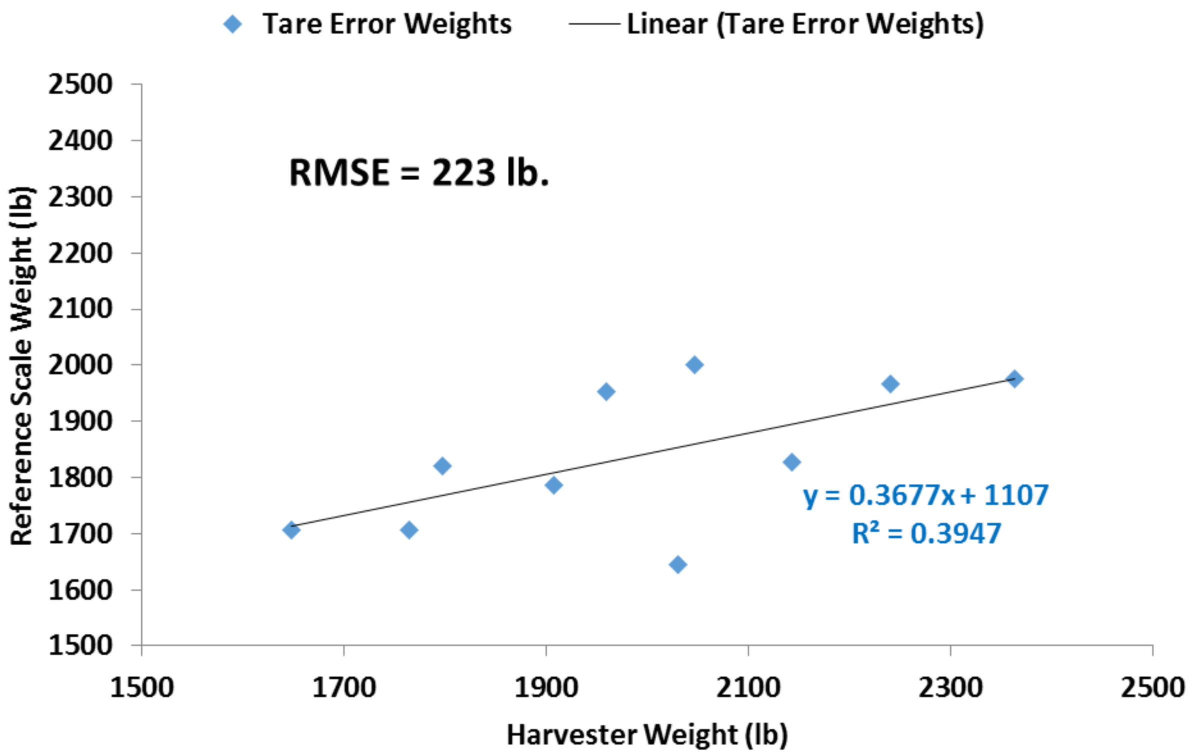

Figure 11. Harvester weight system and reference scale weights for the Elk City stripper when performing the tare function after each basket load of cotton was dumped.

2015 Field Observations and Operator Feedback

Field observations of system performance lead to the following best operating practices:

- All weight and tare functions should be performed with the compactor vanes held in the same position each time. A weight difference of about 100 lbs results from weighing the basket with the vanes in the left vs. right position. Our preference is to position the vanes fully left when operating the weight measurement system.
- All weight and tare functions should be performed with the harvester on level ground and with the machine operating in the same state (i.e. with the header off, field cleaner on, fan on, engine at full throttle).
- Perform the tare routine multiple times (one right after another) at the beginning of a test prior to running any weigh routines so that the system will cycle warm hydraulic fluid through the valves. Perform at least 4 to 6 tare routines so that the tare weight stabilizes and the most recent 3 tare values are within 10 lb of one another. The system will store only the last tare value determined.
- Perform all tare routines with the harvester heading in the same direction as you plan to conduct each basket weigh routine.
- Perform all basket weigh routines in the same direction each time.
- Weight measurement repeatability was good with the standard deviation of 3 repeated measures on one basket load of cotton less than 10 lb. To obtain higher reliability in weight measurements, it is advisable to conduct several (3 – 5) weigh routines on each basket load of cotton.
- If using a weigh wagon or mobile scale system, make sure to conduct all tare and weigh routines with the harvester oriented with the wind in the same way as the reference scale basket. For example, with an east wind (wind blowing from the east) orient the reference scale basket so that it dumps cotton with the wind and also orient the harvester such that it dumps with the wind with the header to the north.
- Operators must be attentive to the system to make sure that the correct load numbers are associated with the corresponding treatment information (e.g. plot number, rep number, or other plot identification information). Additionally, operators must be attentive to input the appropriate client, farm, and field information as needed.

In general, the operators were pleased with the performance of the system over the harvest season. Few issues in regard to the reliability of system components were observed. One system experienced a software issue in which the database/software communication failed. This was remedied by reinstalling a fresh version of the software. Three of the four strippers experienced a serial communication failure between the PC and the GPS receiver. The cause of this failure was traced to a loose USB port connection on the PC and the problem was remedied by adding additional support to the connections (e.g. properly placed tape). Two of the strippers experienced minor hydraulic leaks caused by poorly crimped hose connections. The hoses were replaced to fix the leaks. No failures were experienced with any of the main system components including hydraulic valves, limit switches, pressure transducers, DAQ board electrical circuits, computers or touch panel displays. Suggested improvements to the system for future installations should consider moving away from USB communication ports to better supported DB9 serial ports (vibration caused connection issues); improve the display and computer mount to reduce vibration; a hydraulic system design which incorporates the valves into a single piece manifold block to reduce hose requirements; and a cover for the limit switch bracket which helps keep cotton from falling on the limit switches.

Summary

The harvester weight measurement system was installed on four cotton strippers in 2015 to evaluate system performance and reliability. The system developed in 2014 was used in 2015 with slight modifications to the hydraulic system and software to improve weight accuracy and ease of use. The system performed as expected with weight measurement errors about equal to that observed in 2014. Although operation of the system was simplified through the new software interface, an attentive operator remains an absolutely necessary part of the system to ensure high weight measurement accuracy and data quality. Recommended operating practices to mitigate the effects of wind were developed. Over the 2015 harvest season, few minor system component failures were experienced and were quickly remedied. The weight measurement system is capable of measuring accurate load weights and is a useful tool in conducting on-farm research and in the calibration of cotton yield monitors.

Acknowledgements

Thank you to the cooperating producers for allowing us to install the systems on their harvesters and collect data during harvest. They invested a significant amount of time and effort in working with us and learning to use the system. The authors gratefully acknowledge the financial support of Cotton Incorporated in this research.