# THE AG LEADER TECHNOLOGY COTTON YIELD MONITOR SYSTEM

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## Abstract

The Ag Leader Technology cotton yield monitor system utilizes multiple optical sensors to measure cotton volumetric flow rate in the chutes which convey cotton from the picking rotors to the basket of a cotton picker. Volumetric flow rates from at least two rows of the cotton picker are measured and are communicated to a PF3000 yield monitor unit in the cab of the picker over a serial communication bus. The PF3000 stores accumulated cotton volume for both fields and individual loads within fields, and combines these volumetric values with accumulated harvest areas, weight calibration values, and estimated percent lint turnout, to calculate total weights and average yields for fields and loads. When coupled to a GPS receiver, the PF3000 can also record data on a PCMCIA memory card for producing yield maps with desktop PC software.

## Introduction

The Ag Leader Technology cotton yield monitor system is the result of joint development efforts between the University of Tennessee Agricultural Engineering Department, Case IH and Ag Leader Technology. The original concept of optically sensing the volumetric flow rate of cotton in the chutes of a cotton picker was generated by the University of Tennessee in 1993, and a concept development project was subsequently funded by Case IH. U.S. patent number 5,920,108 has issued protecting the design of the cotton flow sensors that were developed by the University of Tennessee.

Ag Leader Technology entered the cooperative development efforts in 1997 to develop commercial versions of the cotton flow sensors and to help integrate the sensors into complete yield monitoring and yield mapping systems. The Ag Leader Technology cotton yield monitor system has undergone four harvest seasons of field testing, two in the United States and two in Australia, and will be initially offered for sale as a field retrofit kit for Case IH cotton pickers for the 2000 Australian and U.S. cotton harvest.

## Discussion

The cotton yield monitor utilizes multiple pairs of optical emitter/detector units to measure the volumetric flow of cotton in the chutes which convey picked cotton from the picking rotors to the basket of a cotton picker. Figure 1 shows a detector unit at the left and an emitter unit at the right.

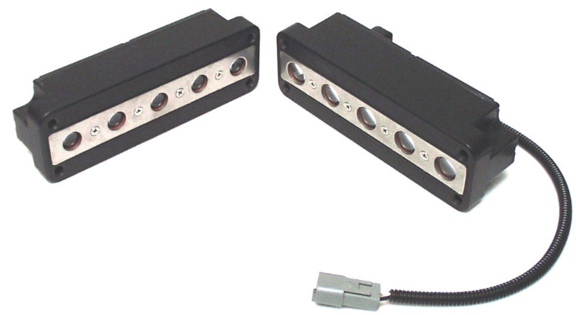

Figure 1. Cotton flow sensor detector unit (left) and emitter unit (right).

The sealed plastic housing of the emitter unit contains a circuit board on which (5) infrared Light Emitting Diodes (LED's) are mounted. The LED's are precisely positioned behind lenses which convert the LED point light sources into cylindrical parallel beams of light. The emitter unit is mounted on the front of a chute so that the beams of light pass transversely through the chute from the front to the rear of the chute.

The detector unit is mounted on the rear of the chute directly opposite the emitter unit. The detector unit contains (5) lenses which focus the cylindrical beams of light from the emitter unit onto individual light sensors which are mounted on a circuit board inside the sealed plastic detector housing. As cotton passes through the light beams, the intensity of the light detected by the light sensors is reduced proportional to the amount of cotton which partially interrupts the light beams. The detector unit contains a microprocessor which reads the output of each light sensor hundreds of times per second, performs calculations on the varying signals, and transmits its readings to the yield monitor's display and data recording device in the picker cab, once per second, over an RS-485 serial communication bus.

Figure 2 shows two emitter units mounted on the front of a double-width chute on a Case IH cotton picker. The corresponding detector units are mounted on the back of the chute, where they cannot be seen in this photograph. Two pairs of emitter/detector units are used on the double-wide chutes which transport cotton from both picking rotors of a row unit, while a single pair of emitter/detector units can be used on single-width chutes which transport cotton from only one picking rotor. For aftermarket retrofit onto existing cotton pickers, the emitter and detector units are mounted on a chute adapter which is provided as part of the yield monitor

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installation kit. The lower portion of the picker's original upper chute is cut off and is replaced by the chute adapter, which has openings for mounting the emitter and detector units.

Figure 2. Two emitter units mounted on the front of a double-width chute on a Case IH cotton picker.

Both the emitter units and detector units are mounted on identical metal mounting plates which pivot on quick-release mechanisms, and are retained to the chute by two captive knurled nuts which engage studs mounted in the chute adapter. Figure 3 shows the mounting plate for one emitter unit, rotated 90 degrees downward to allow inspection of the lens covers of both the emitter unit and the detector unit. One of the detector units which is mounted on the back of the chute adapter can be seen through the opening in the chute adapter. If it is desired to completely remove either the emitter or detector unit from the chute, the mounting plate can simply be lifted from its mounting bracket after tilting the mounting plate out just enough to clear the studs which mate with the captive knurled nuts.

The clear circles seen in Figure 3 are not the focusing lenses of the emitter and detector units, but are lens covers made of translucent plastic sheets, which are embossed so that their exposed surface is approximately flush with the inside edge of the mounting plate. The lens covers protect the focusing lenses from contamination and wear that could be caused by particles in the high velocity air stream. The lens covers are made from a fluoropolymer material which has very good non-stick characteristics, to prevent adhesion of moist soil or plant material. A soft gasket is clamped between the lens cover and the emitter or detector block to keep dust and moisture out of the space between the lenses and the lens covers.

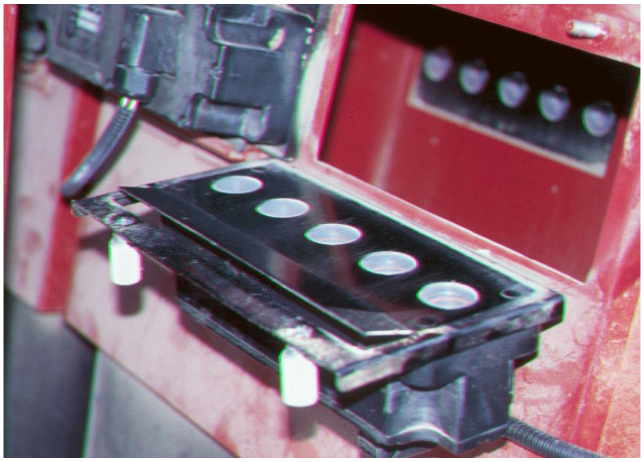

Figure 3. Emitter unit with mounting plate opened to allow inspection of lens covers.

Figure 4 shows the yield monitor display and data collection unit mounted on the right-front corner post of the picker cab. The unit shown is the PF3000 monitor, which has been widely used by Ag Leader Technology for grain yield monitoring on combines since 1998. This monitor reads the output of all of the detector units mounted on the picker over the RS-485 serial bus, plus a ground speed sensor, a row unit height sensor and a fan speed sensor, and once per second, computes updated values for the yield-related parameters shown in Table 1.

Table 1. Yield related parameters calculated by the PF3000 yield monitor

| Parameter | Imperial | Metric |
|---|---|---|
| Instantaneous seed cotton flow rate | Lb/Hr | Kg/Hr |
| Load or field total weight of seed cotton | Lb | Kg |
| Load or field total weight of lint cotton | Lb | Kg |
| Load or field total volume of lint cotton | Bale | Bale |
| Instantaneous ground speed | Mi/Hr | Km/Hr |
| Instantaneous harvesting rate | Ac/Hr | Ha/Hr |
| Load or field total distance traveled | Feet | Meters |
| Load or field total area harvested | Acres | Hectares |
| Seed cotton yield | Lb/Ac | Kg/Ha |
| Lint cotton yield | Bales/Ac | Bales/Ha |

The accumulated values for fields and loads are stored in the internal memory of the PF3000 monitor and can be viewed at any later time, or can be transferred to a desktop computer on a PCMCIA memory card.

The PF3000 can also record instantaneous yield values, simultaneously with GPS-determined location coordinates, for use in making yield maps on a desktop computer. The PF3000 can receive GPS coordinates from an external GPS receiver through an RS-232 serial port, or it can be mated directly to Ag Leader Technology's GPS3000, GPS3050 or GPS3100 Add-on GPS receivers, which mount directly to the back of the PF3000 monitor. An ATA type Flash Memory

Card is used in the card slot of the PF3000 to record instantaneous data as cotton is harvested.


Figure 4. PF3000 yield monitor mounted in cab of Case IH cotton picker

Figure 5 shows a close-up view of the screen of the PF3000 monitor. The small text at the top of the screen identifies the field number (F3 indicates Field number 3), field name (LARRY'S), load number (L13 indicates Load number 13), load name (DPL), GPS status (DG indicates that both GPS and Differential Correction signals are being received) and card status (the card icon indicates that a card is inserted and has been recognized by the monitor). Also, when the monitor is logging to the card, an arrow is displayed to the right of "DG", pointing to the card, indicating that instantaneous yield and position data are being logged to the card.

The small text at the bottom of the screen indicates the cotton variety (COTTON1), which refers to a specific set of calibration numbers used for calculating the seed cotton weight and lint yield of loads which are set to this cotton variety. The blocks with "FIELD" and "LOAD" in inverse text indicate the keys below the screen which should be pressed to select viewing of either field or load total and average values. The text "AREA ON" indicates that the row units are lowered to picking position and that the monitor will count the area being covered as the picker travels.

The four lines of text in the center of the screen show accumulated field totals or averages for harvest data which is of interest to the picker operator as cotton is harvested. In this photograph, the PF3000 monitor is displaying average seed cotton yield in pounds/acre, total load weight in pounds, total load area in acres and total load lint cotton yield in bales. By pressing any of the keys just to the right of the display, a menu of all the parameters which can be displayed appears at the bottom of the screen. In this manner, the picker operator can customize the display to show any available parameter at any position on the screen.

Pressing the key to the left of the screen changes the two lines of text at the bottom of the screen from "FIELD LOAD" to "SUMMARY CAL SETUP DIAG". Pressing the key below SUMMARY allows selecting summaries of either all of the fields stored in the monitor or all of the loads in a selected field. Pressing the key below CAL allows selecting screens for calibrating load weights, field areas, distance, and row unit height at which area counting is stopped. Pressing the key under SETUP allows selecting screens for entering setup values for the monitor, picker configuration and cotton varieties. Any number of cotton varieties can be set up and named, and each can be set to have its own bale size and lint percentage. Pressing the key under DIAG allows selecting several screens which can be used for troubleshooting system operation.


Figure 5. Display screen of PF3000 monitor.

As is required with grain yield monitors, obtaining accurate measurement of cotton yield requires calibrating the measured weight of one or more loads that are recorded in the yield monitor against actual scales weights corresponding to those loads. These weights can be obtained by unloading the picker basket into a boll buggy that is equipped with scales on its axles and hitch, by weighing a wagon that has been filled by one picker only, or by weighing a module that has been picked by one picker only. The picker can continue harvesting other loads or fields before these actual weights are entered into the monitor. When the actual weights are available at a later time, they can be entered into the monitor for the corresponding loads, and the monitor can recalibrate previously recorded data to obtain the best match between the monitor's estimated weights and the actual scales weights.

The PF3000 monitor allows individual loads recorded in the monitor to be set as any number of different cotton varieties which can each be calibrated individually. Although it is desirable for a cotton grower to be able to harvest an entire cotton crop with only one calibration, this is often not possible, due to agronomic or environmental factors which require different calibrations to obtain good yield accuracy. For example, varieties with significantly different seed or staple characteristics may require different calibrations for optimum accuracy. Although the default names for the cotton varieties are COTTON1, COTTON2, etc, the monitor allows the operator to enter an actual name for each variety. The actual or estimated lint percentage can also be set individually for each cotton variety.

Figure 6 shows a yield map of a 108 acre field that was harvested in Mississippi in October 1999, over a period of two days, with three Case IH 4-row pickers equipped with yield monitors. The blank strip in the field is a field road that contained no crop. The strip of indicated low yield that is approximately perpendicular to the blank strip is also a field road. Yield readings with low values were recorded over this second road because the pickers crossed this road without stopping while picking, thus recording yield values over the area of the road. The low yielding areas at the left of the field are in a lower elevation portion of the field, where the maturity of the crop lagged that of the rest of the field. The three strips of low yield in the short rows at the bottom of the map are strips which had previously been picked with a picker which did not have a yield monitor.

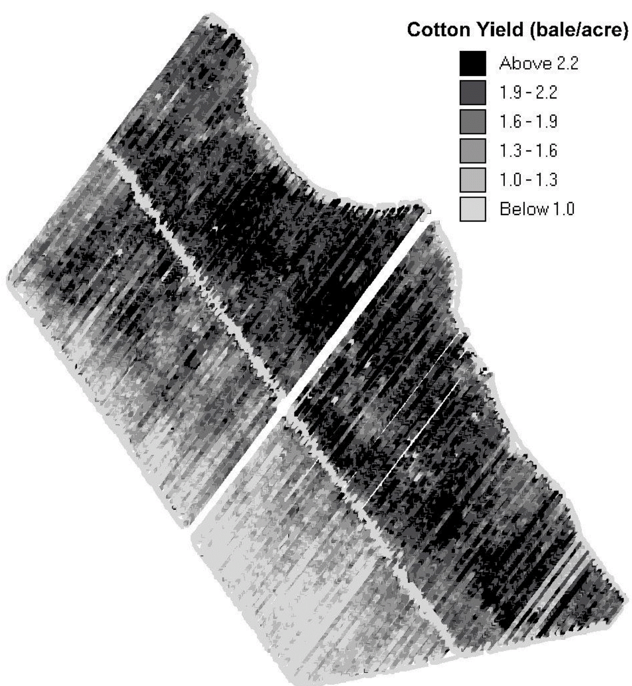


Figure 6. Yield map of 108 acre Mississippi cotton field harvested in two days with three cotton pickers.

During the harvesting of this field, plus another field harvested just before this field, a boll buggy with axle/hitch scales was used to calibrate the yield monitors of all three pickers and to evaluate the load accuracy of the yield monitors. A total of (39) load weights, varying in size from 2000 to 6000 pounds, were obtained on these two days. After calibrating each yield monitor using all of the actual weights obtained on these two days, the accuracy of predicting load weight for each the three yield monitors was as shown in Table 1.

Table 1. Calibration results for three cotton yield monitors over three consecutive days of picking.

| Picker number | 1 | 2 | 3 |
|---|---|---|---|
| Number of load weights | 8 | 21 | 10 |
| Average load weight | 5063 Lb | 2932 Lb | 2858 Lb |
| Maximum positive error | +5.9% | +8.4% | +13.5% |
| Maximum negative error | -7.1% | -8.6% | -7.7% |
| Average absolute error | 4.9% | 4.9% | 6.8% |

These weight checks were made without causing any interruption in the normal harvesting routine of the grower's harvesting operation. Although not quantified, there are believed to be components of the errors shown in Table 1 due to differing amounts of cotton remaining in the picker baskets after unloading into the boll buggy. It was observed that differing amounts of cotton remained trapped around and above the compactor augers of the picker basket on different loads. In one instance, this remaining cotton was manually removed and added to the cotton in the boll buggy, adding about 150 pounds of weight to the cotton that had been unloaded into the boll buggy. This weight of cotton represents about 2.5% of a full picker basket weight of about 6000 pounds.

The University of Tennessee also conducted tests with an Ag Leader Technology yield monitor system on a Case IH 4-row cotton picker during the 1999 cotton harvest season in the more controlled environment of a university test field. Their test personnel obtained weights on (100) small loads ranging in weight from 605 to 2830 pounds scales weight. The yield monitor was calibrated three times during the harvest season. It was calibrated at the start of the season, after a yield monitor firmware upgrade and after a variety change. Each calibration was based on four consecutive loads. The average absolute error was 3.83% with a maximum error of 16.7%. However, the maximum error on load weights over 1500 pounds was 5%.

During the 1999 U.S. cotton harvest, a total of (13) Case-IH cotton pickers were field tested with the Ag Leader Technology cotton yield monitor system. Field testing occurred with commercial cotton growers in Mississippi, Tennessee and Arizona, plus at the University of Tennessee. Although the lens covers of the emitter and detector units were inspected frequently by field test personnel, cleaning of the lens covers was never required on any of these machines.

Of the (13) cotton pickers, three were equipped with cotton flow sensors on all rows of the picker and ran with two to four other pickers that were equipped with sensors on only two rows of the picker. No observable difference in yield measurement accuracy was observed between the partially versus fully monitored pickers. Therefore, to keep the yield monitor system cost effective, the system will be offered with sensors for two rows of 4-row or 5-row Case IH cotton pickers.

Although the cotton growers commented that a cotton moisture sensor on the picker would be a very useful feature in itself, the current yield monitor does not incorporate a moisture sensor. It is believed that the primary impact of cotton moisture is to affect load weights obtained from scales, rather than to affect the actual lint volume measured by the cotton flow sensors.

Although the cotton growers were primarily interested in obtaining yield information to fine-tune their management practices, the picker operators found significant usefulness in the information available to them from the display of the monitor. By starting a new load after unloading the picker basket, they could use the load weight display to tell them whether they could go another round in the field without filling the picker basket. By communicating with the other picker drivers over two-way radios, they could decide which picker had the right amount of cotton to finish out a module that was nearly complete or a trailer that was nearly full. By observing the average yield display, they could decide whether to continue second-picking operations without having to harvest several acres to determine the scrap yield. Of course, this also benefited the growers by increasing the efficiency of their harvest operations.

## Summary

The Ag Leader Technology cotton yield monitor system will offer cotton growers a tool which has benefits both in terms of optimizing real-time harvesting activities in the field and in terms of providing valuable management information through accurate characterization of yield variations within fields.

This yield monitor system has demonstrated that it requires no cleaning of the optical sensors in normal cotton harvesting conditions.

This yield monitor system has demonstrated that when calibrated against scales weights, it is capable of measuring load weights within about +/- 5% average error, with nearly all errors contained within +/- 10%, while measuring cotton flow on only two rows of 4-row or 5-row pickers.

This yield monitor has demonstrated that it is capable of generating accurate yield maps from data gathered by multiple pickers operating in the same field.

## References

Wilkerson, J. and F. Moody. 2000. Tennessee Cotton Yield Measurement System – Field Evaluation. 2000 Beltwide Cotton Conferences.