# IN-GIN MASS FLOW MEASUREMENT OF SEED COTTON

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## Abstract

The mass flow rate of pneumatically conveyed seed cotton is a real-time variable required by gin automation devices. Two systems developed to measure mass flow were tested in a commercial gin to determine durability and accuracy. After a two-day calibration period, the instrument-based estimate of mass flow was compared to the mass flow calculated on a bale-by-bale basis. One system failed because of trash particle fouling. The other system provided a mass flow signal that had an 88% correlation to the bale-by-bale calculation after one month of ginning. Analysis is preliminary, but low initial and installation costs coupled with long expected life favor the latter system.

## Introduction

Cotton gins are increasingly using automation to improve fiber quality and reduce operating costs. Systems to measure the real-time mass flow rate of seed cotton were explored previously to support these automation goals (Funk et al, 2000a, b). The most promising systems were based on air pressure differential in a vertical pipe and air velocity after the suction fan. To facilitate commercialization of mass flow instrumentation for cotton gins, the technology previously tested in the USDA-ARS SW Cotton Ginning Research Laboratory was moved to a commercial gin. At the end of one ginning season, the systems will be evaluated based on accuracy and durability.

## Objective

The objective of this investigation was to find a reliable device that can quantify the mass flow rate of pneumatically conveyed seed cotton in real time. Mass flow estimates from two experimental systems were compared to bale weight and turnout to determine which system estimated mass flow throughout a ginning season most consistently and accurately.

## Approach

A change in elevation of a mass results in a change in potential energy. When the elevation change is brought about by pneumatic conveying there is a difference in static pressure between the two elevations. This pressure differential correlates to the rate of change in potential energy and hence to the mass flow rate. The first system evaluated for this study was based on the pressure differential measured in six feet of vertical pipe. The other system monitored changes in the velocity of the conveying air. Potential energy changes resulting from pneumatically conveyed mass flow cause changes in velocity of the conveying air. As more cotton mass flows upward, more fan power is required to move cotton and less is available for moving air. A constant speed fan is expected to pull less air volume because it is working against a greater pressure drop; consequently air velocity is inversely proportional to mass flow.

## Materials and Methods

A commercial gin cooperated with the study by making both the gin and bale records available to us. The vertical duct leading from pre-cleaning equipment (tower dryers, cylinder cleaner and stick machine) to a valve switching between the saw and roller gin distributor conveyors was modified as follows (Figure 1): Two static rings consisting of six interconnected pressure taps (quarter inch diameter holes) spaced equally around the duct were added, one six feet above the other. The static rings were connected to air tanks of approximately one-gallon volume to dampen fluctuations in the pressure. The tanks were plumbed to either side of a Dwyer 607-21 differential pressure transducer (0.5 inch WG, ±0.25% full scale). Special care was taken to smooth the inside of the duct after drilling, to prevent formation of 'tags'.

For the velocity pressure system, an S-type Pitot tube was installed in the conveying air duct after the seed cotton separator and suction fan. It was connected to a Dwyer 607-71 differential pressure transducer (5 inch WG, ±0.25% full scale). Both systems' transducers were connected to a Hewlett Packard 34970A data acquisition/switch unit. Air temperature measured at the S-type Pitot tube and bale press turns (totalizer count) were also monitored. Raw signal values were recorded every ten seconds for 24 hours and retrieved for analysis while the gin was shut down for cleaning. Data were taken from the beginning of October through mid December.

## Actual Mass Flow

For every day for which a detailed analysis was performed, approximately 8640 lines of data were read to find each press turn signal. The time between press turn signals was assumed to correspond to the time spent conveying the quantity of seed cotton in question. The mass of that seed cotton was calculated by dividing the weight of each individual bale (less bagging and ties) by gin turnout for the trailer or module from which the bale was produced. Dividing the seed cotton mass by time yields an average mass flow rate for each bale. This bale-by-bale mass flow served as a standard of comparison by which the accuracy of the other systems could be determined.

## Estimated Mass Flow

For two days, early in the ginning season, data from both Pima and Upland cotton were available (production changeover took place mid-shift). Those two days were used to calibrate the experimental systems. Each bale-derived mass flow calculated (above) was plotted against the average pressure transducer signal for the time interval corresponding to that bale. Linear regression techniques provided a correlation equation relating the pressure transducer signal to the bale-by-bale mass flow (Figure 2). On subsequent days, that correlation equation was used to calculate instrument-estimated mass flow. The instrument estimate was compared to the bale-by-bale mass flow standard to determine system stability and accuracy.

## Results- Air Velocity System

The air velocity system failed within two weeks of installation. The Pitot tube became plugged with airborne particles. Frequently disconnecting the pressure transducer and blowing clean air through the Pitot tube could address the problem. However, asking the ginner to add another maintenance task is a step in the wrong direction. Because durability was an important criterion of this investigation, the air velocity system was not considered further.

## Results- Differential Pressure System

The differential pressure system functioned without maintenance for the entire ginning season, passing the durability test. The accuracy test is still being analyzed. The bale-by-bale mass flow standard had several sources of intrinsic uncertainty. Because bale formation takes place downstream of the gin stand and lint cleaners, there is a delay between seed cotton handling and corresponding press turn signals. Turnout (lint weight divided by seed cotton weight) is calculated for each customer (several trailers or modules), but it can vary within a module or trailer. Further, turnout

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includes trash that is removed in the pre-cleaning line. As the pre- cleaning line was located before the experimental instrumentation, differences in trash content would tend to skew the instrument estimate. Finally, turnout includes varying amounts of moisture added at the lint slide. Therefore the standard could be sensitive to cotton moisture content and dew point.

Bale weight based mass flow (the standard) and differential pressure transducer signal based estimate corresponding to the same time period were plotted for a representative day (December 4th) as presented in Figure 3. Two months of ginning had transpired since installation and one month since calibration of the differential pressure system. After removing three bale values deemed outliers (formed over lunch breaks or at startup) there were 99 observations (bales). Linear regression analysis indicated an $R^2$ of 0.882. Analysis of the remaining data set is planned for the near future.

## Conclusions

The vertical pipe differential pressure system has several advantages: 1) it is low in capital cost, 2) it can be installed in an existing gin easily and 3) it requires no maintenance during the ginning season. All this makes it an attractive technology supporting gin automation. If satisfactory accuracy can be demonstrated, differential pressure instrumentation will be recommended for sensing mass flow in pneumatically conveyed process streams in cotton gins.

## References


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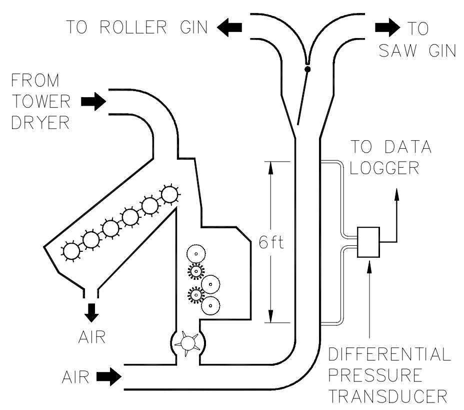


Figure 1. Location of differential pressure system in the gin.

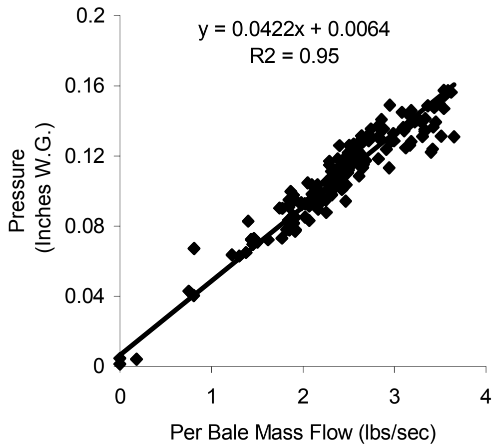


Figure 2. Linear regression of bale weight based calculation of mass flow plotted against the pressure transducer's signal. Data from two days (October 31st and November 3rd) running 135 bales of Pima and Upland.

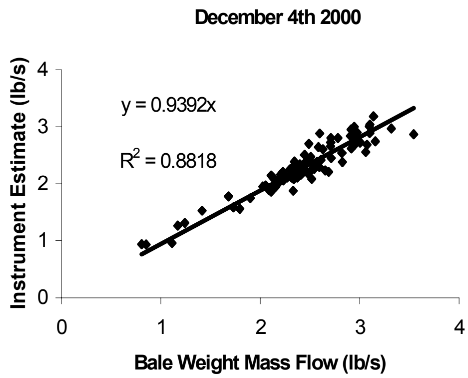


Figure 3. Comparison between bale weight-based calculation of mass flow and differential pressure system estimate after two months operation. Ninety-nine bales were processed.