CONTINENTAL EAGLE'S
VERTICAL FLOW DRIER

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Abstract

This paper describes the Vertical Flow Drier and compares it to the widely used tower driers as related to five controllable drying variables. Actual drying data show that as much as 9% moisture was removed on average in the first stage drying alone while maintaining acceptable ginning rates on single line Continental Eagle 120 inch pre-cleaning and overhead equipment.

Introduction

This paper is a continuation to the paper that Jonathan Hackett presented at the 1999 Beltwide Conference titled, "Continental's Vertical Flow Drier and Replaceable Insert Rib." This paper gives the history of Continental Eagle's Vertical Flow Drier and describes the driers construction and operation. Also discussed are five controllable variables associated with drying seed cotton and the relationship of the variables with the Vertical Flow Drier and the widely used tower drier. The five controllable variables are as follows: 1) Exposure time, 2) Volume of air, 3) Slip or Slippage, 4) Fiber exposure to the heated air, 5) Air temperature. Actual cotton sample moisture before and after the drier is also discussed.

History of the Vertical Flow Drier

The Vertical Flow Drier was built using the 1956 Continental Counterflow Drier as the base machine. The Counterflow Drier was limited to 5 or 6 bales per hour capacity. A possible reason for this limited capacity may be the fact that the air flowed in the opposite direction to the cotton. A separator and vacuum was required on the Counterflow Drier at the top because the air conveying the cotton to the drier and the heated air was provided by two separate fans. Actually, the Counterflow Drier was a lot more than just a cotton drier; it was also a cleaner. An incline cleaner and vacuum was used at the bottom of the drier which required a trash system. The Counterflow Drier was a great idea in the 1950's. However, it might have been a bit too complicated and expensive for only 5 or 6 bales per hour capacity. As much as people in this industry have talked about "slippage" of air over seed cotton in drying, what better way to maximize "slip" than for the heated air and seed cotton to be traveling in opposite directions. There is one thing for certain; the Counterflow Drier maximized "slippage".

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Based on the old adage, "keep it simple", the Vertical Flow Drier was developed from the Counterflow Drier by removing the separator, vacuum, and bottom cleaner and directing the air flow and cotton in the same direction. The Vertical Flow Drier is almost as simple as a tower drier, but has more benefits.

Flow of Cotton in the Vertical Flow Drier

The Vertical Flow Drier is 120 inches wide and stands approximately 16 feet high. Heated air and wet, matted, trashy seed cotton enters the drier at the top of the machine (see Figure 1). The seed cotton is spread across the full width of the 120 inches of the drier and splattered across the back wall, where it them falls on one of the seven directional rollers. Once the cotton hits the directional roller, it is directed upward to the start of the first finger assembly. The cotton then slides down the first finger assembly onto the next directional roller. The directional roller directs that seed cotton upward to the start of the next finger assembly, where the process is repeated. A 10 HP motor drives the directional rollers.

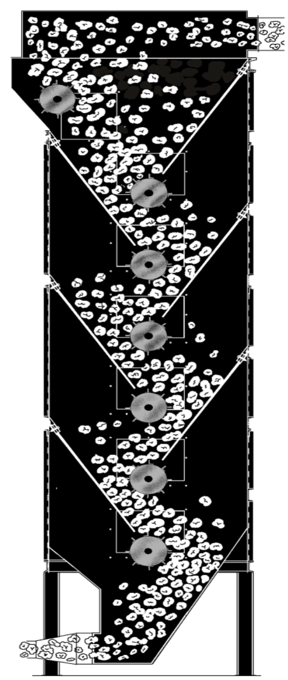

Figure 1. Cross Section of the Vertical Flow Drier

The seed cotton and air exit the bottom of the drier then goes to the incline or other air/cotton separator. Rectangular ducting is used where possible from the drier to the incline to keep the cotton spread apart for further drying in the rectangular ducting and incline. Chokes at the incline are reduced to almost zero when rectangular ducting is used because the cotton is evenly spread over the full width of the machine.

Discussion of Drying Variables

We know that "For rapid drying processes it is necessary to impose and maintain conditions that produce a high vapor pressure gradient between the cotton and its environment" (Laird and Barker, 1995). Over the years, different theories have emerged about drying cotton at the gin. For the most part the theories have been proven mathematically, through testing, or they are just "common sense". These different drying theories can be summarized into five different controllable variables. The variables are as follows: 1) exposure time, 2) volume of air per pound of seed cotton, 3) slip or slippage, 4) amount of cotton fibers exposure to the heated air, 5) air temperature. Any of these variables can be varied and drying will be affected. Varying only two of the five controllable variables listed can alter the gradient in the vapor pressures between the heated air and the cotton. They are: air temperature and volume of air per pound of seed cotton. It has been shown mathematically that the equilibrium moisture content of cotton lint and vapor pressure are functions of temperature and relative humidity (Laird and Barker, 1995). It is known from psychrometric data that air at a given relative humidity and temperature is capable of holding a certain amount of water vapor. It is also known if the temperature is increased, the water holding capability increases. If the ratio of the volume of air to cotton mass is increased (often called an air-to-cotton ratio), then the surrounding air can absorb more water, thus improving the drying ability of system air. The good drying system would maximize all of these variables, but cost or consequence must be considered. When a gin cannot dry the cotton, ginning rates and cotton grades are sacrificed. At some point economics, cost to benefit ratio must be considered.

The typical tower drier currently being used in gins adds exposure time to the seed cotton while being conveyed down the shelves of the drier. As with the tower drier, the Vertical Flow Drier adds exposure time to the wet seed cotton as the cotton zigzags down six fingered assemblies. Additional exposure time is gained once the cotton hits the directional rollers and is directed upward to the start of the next fingered assembly. Exposure time could also be increased by using long runs of piping from the cotton pick-up point to the incline. By increasing the exposure time, more moisture in the lint can reach equilibrium with the surrounding heated air.

Increasing the volume of air in CFM per pound of seed cotton improves drying. The recommended CFM per pound of seed cotton ranges from 20 to 50 for tower and towerless systems, respectively (USDA Cotton Ginners Handbook, 1994). Higher air volumes (CFM) increase the amount of moisture that the air can absorb at the same temperature. The Vertical Flow Drier supports the principle that applying high volumes of air per pound of seed cotton enhances the drying of the seed cotton at lower, less damaging temperatures (Hackett, 1999). The Counterflow Drier can handle air volumes in excess of 32,000 CFM without the use of skimmers or complicated valves at ginning rates of 50 bales/hour. Some examples of the CFM per pound of seed cotton that the Vertical Flow Drier can handle have been calculated using the assumption that it takes 1500 pounds of picker seed cotton to make a 500 pound bale of lint. The values are:

CFM	Gin Rate	CFM/lb. Cotton Ratio
16000	30	21.3
16000	50	12.8
32000	30	42.7
32000	50	25.6

The Vertical Flow Drier can handle a wide range of volumes of air. However, the most desirable drying system would use the highest CFM per pound of seed cotton ratio to optimize the amount of moisture that the air can hold. The drawback to using large volumes of air in a drying system is that fans and horsepower required for the higher volumes are expensive. However, the pressure drop across the Vertical Flow Drier has been measured to be 1" water column at 16,000 CFM. The pressure loss in a short five-shelf tower drier is five times that amount using the same 16,000 CFM. Therefore, larger volumes of air can be put through the Vertical Flow, and the pressure loss through the drier will be much less than a typical tower drier. Less pressure drop simply means less fan horsepower and less cost to run that fan and drying system.

"Slip" or "slippage" occurs when the heated air flows past the seed cotton. In piping and tower driers, slip occurs when the seed cotton is being conveyed. Since cotton is heavier than air, naturally there will be some slippage of the air past the cotton fiber that aids in removing the moisture from the cotton. In the tower drier, "slip" or "slippage" occurs when there is a change in direction of the seed cotton as it zigzags down the shelves of the tower drier. In the vertical flow drier, the cotton zigzags down the six fingered assemblies. At the end of each of the fingered assemblies, the directional rollers throw the cotton in the opposite direction of the airflow, increasing "slippage". Additional slippage occurs when air flows through the fingered assemblies, while the seed cotton follows the fingered assemblies. The Vertical Flow Drier enhances "slippage" to a much greater degree than does the tower drier.

The amount of cotton fiber exposed to the heated air depends on how well the seed cotton is single locked in the air stream. With the Vertical Flow Drier being almost two times the width of the typical tower drier, it is much easier to single lock the cotton over 120 inches versus 72 inches. Additionally, the seven directional rollers help spread the cotton over the full width of the machine and break up any wads, thus improving air exposure to more of the cotton fiber as it is single locked. How well the individual locks of seed cotton are exposed to the heated air directly impacts the drying of the cotton fiber. Wet cotton wads are not broken up in tower or towerless drying systems, creating choke problems at the incline cleaner. Because of the chokes, ginners will reduce the ginning rate to a point where chokes are not a problem.

We know from USDA testing that fiber is damaged at high drying temperatures. In fact, the maximum temperature recommended is 350 ˚F (USDA Cotton Ginners Handbook, 1994). So ideally, a drying system would dry cotton at lower temperatures to preserve the fiber quality and to reduce fuel cost. The Vertical Flow Drier increases the exposure time of the cotton in the heated air over the towerless drying systems, allows for increased ratios of air CFM per pounds of seed cotton, and dramatically increases slippage and cotton fiber exposure by single locking. After optimizing the four variables just mentioned, drying seed cotton using the Vertical Flow Drier can be done with lower temperatures. This improves fiber quility without decreasing ginning rates. Or the approach could be taken that you could use the full range of drying temperatures up to the maximum of 350 ˚F and take advantage of faster ginning rates while ginning wet cotton.

Moisture Samples

Drying data was obtained at Mobley Gin in Doerun, Georgia and at Screvin Gin in Sylvania, Georgia during the 1999 ginning season. Because of the dry year that Georgia experienced, finding wet moduled cotton was difficult. Moisture values calculated on the samples taken at Mobley gin were disregarded because the sample cans were not properly sealed which resulted in erroneous moisture values. However, cotton samples were taken at Screvin Gin on three separate modules. Five samples were taken of each module at the module feeder after the disperser cylinders and after the incline cleaner vacuum. After one sample was pulled at the module feeder, approximately 15 seconds later, a corresponding sample was then pulled at the hopper between the incline vacuum and stick machine. The reason for the 15-second interval between sampling was to try to get samples of the cotton from the same part of the module.

Screvin Gin has a total of three gin stands. The pre-cleaning system is comprised of 120-inch inclines over the Super III Stick Machine. The overhead cleaning system is also a single line of 120-inch incline and impact.

Moisture was determined as directed in ASTM Test Method D 2495 – 87, Moisture in Cotton By Oven-Drying. As depicted in Table 1, Moisture Content of Samples at Screvin Gin - 12/21/99, the cotton moisture was reduced by over 4% at 36 bales per hour and over 9% at 27 and 28 bales per hour with the mixpoint temperature at approximately 250 ˚F and 370 ˚F, respectively. Note that the moisture of the five samples from each module was averaged at the sample points. It is quite apparent from the moisture data that the modules of cotton were not the same moisture throughout the length of the module.

Summary

The Vertical Flow Drier is an example of how Continental Eagle is using “old technology” differently for a simple and effective drier. The Vertical Flow Drier is a new innovation using old technology. The Vertical Flow Drier improves drying of seed cotton in a gin by optimizing the controllable variables for an efficient drying system. The variables optimized by the Vertical Flow Drier are:

1. the design allows for more exposure time
2. allows for high air CFM per pound of seed cotton ratio
3. maximizes slip or slippage
4. alloes greater cotton fiber exposure or single locking of the cotton
5. utilizes lower drying temperatures

Initial drying rates look promising from the cotton samples that were taken at Screvin Gin during the 1999 ginning season with removing as much as 9% moisture on average in the first stage drying alone while maintaining acceptable ginning rates on single line Continental 120 inch pre-cleaning and overhead equipment.

References

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Table 1. Moisture Content of Samples at Screvin Gin - 12/21/99

Moisture @ Module	Mix Point Temperature	Moisture After 1st Stage Drying	Air Temperature At Incline
Module #1- 36 BPH			
11.38%	245˚F	10.30%	116˚F
10.57%	252˚F	8.68%	116˚F
16.74%	249˚F	8.61%	113˚F
14.19%	253˚F	8.39%	121˚F
13.06%	255˚F	8.57%	120˚F
Average: 13.19%	251˚F	8.91%	117˚F
Module #2- 28 BPH			
12.35%	370˚F	7.61%	104˚F
19.73%	375˚F	8.80%	106˚F
25.10%	368˚F	9.93%	109˚F
20.34%	365˚F	8.96%	105˚F
16.81%	371˚F	9.59%	109˚F
Average: 18.87%	370˚F	8.98%	107˚F
Module #3- 27 BPH			
17.97%	368˚F	9.38%	111˚F
18.86%	355˚F	11.07%	121˚F
22.33%	363˚F	8.96%	107˚F
16.35%	361˚F	7.47%	115˚F
17.36%	371˚F	8.44%	107˚F
17.78%	375˚F	7.72%	105˚F
Average: 18.44%	365.5˚F	8.84%	111˚F

Conditions of Test:

1. 14451 CFM through Vertical Flow Drier
2. Temperature Dry Bulb = 52.5˚F
3. Temperature Wet Bulb = 52.1 ˚F
4. Temperature Dew Point = 51.6 ˚F
5. Relative Humidity = 99.9%