THE TURBULENT FLOW HOT SHELF DRYING SYSTEM

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Abstract

Larger volummes of air are being unnessarily used in many of today's drying systems to try and keep the temperature up for longer periods of exposure time, thus reducing the temperature loss towards the end of the drying cycle caused by the evaporation of moisture. These larger volummes add substantially to energy costs as well as emission control costs. With the Turbulent Flow Hot Shelf Drying System, much smaller volummes of air are used with much lower power requirements, because the temperature drop is avoided through-out the system. This is accomplished through an arrangement of heat chambers *between the shelves*, from which heat is transferred to the shelves conveying the cotton. This same air used for the heat chambers is either re-circulated through the system on a continuous basis, or put back into, and combined with the primary air line to pick up the cotton at the mix point and convey it to the tower.

Introduction

Two years ago at this conference in San Diego, I presented a quite thorough paper on my experiences in the area of seed cotton conditioning, or drying. I was quite perturbed that a manufacturer of drying equipment was making statements in their literature that basically said, Tower Drying Systems do not dry, that there is no moisture transfer in either the pipes or in the tower. This conclusion had come directly from earlier tests run in California to determine the drying efficiency of Tower Drying Systems. As I pointed out, these tests were flawed, produced results that were not valid, and the use of these results as a promotional tool for towerless systems, did the industry a great disservice.

I have been involved in the area of research and development related to moisture removal from cotton for over 35 years. During this time, I always used a "hands-on" approach in developing my theories. These systems were all generally successful, but the results not widely known outside the private gin organizations for which they were developed. There was little or no effort to make the trade aware of them. All these years of research have allowed me to develop many systems on which I have patents, or patents pending, but my favorite is the *Turbulent Flow Hot Shelf Drying System*. I feel it is the most cost effective and efficient system available to the industry today, but previously, has had little exposure to the public. The word is now getting out, and for good reason. This system will remove up to 10 percentage points of moisture by using lower volummes of air over a short exposure period. One of the secrets to the system is the heat chambers and the turbulent flow action, which keep the temperature of the conveying air up through-out the entire drying cycle, allowing the cotton to exit the system at temperatures of 200 degrees, and enter the cleaners hot.

Description Of The System

The 6' X 12' X 16' Tower has 9 shelves with 12" spacings. We like to maintain at least a 2000' per minute shelf velocity, so for the 72" by 12" deep shelf spacing, a minimum of 12,000 CFM of primary air is required to convey the cotton through the tower. This can be accomplished by either a push-pull, or straight pull arrangement, although with straight pull arrangements, leakage in the cleaners can be a problem.

There are 7 heat chambers with 12" spacings *between the shelves* that convey the cotton. The air is supplied to these heat chambers by elbows on each side of the tower. These elbows alternate from side to side on each side and move the heated air from heat chamber to heat chamber. As air is initially introduced in the heat chamber series, it splits, goes both ways into the elbows and collides in the middle of the heat chamber, before moving on to the next set of elbows, where the same process takes place. This collision of air in the middle of the heat chamber is the basis for the name *turbulent flow*. The turbulence created by this collision creates a more ideal environment for heat transfer to the cotton shelves, than just a parallel flow of air through the heat chambers.

There seems to be considerable skepticism about how much this turbulent flow can aid in heat transfer. It is in direct proportion to the intensity of the collision, and temperature of the air. With the 8,000 CFM we recommend, approximately 700,000 BTU's can ultimately be added to the primary air as this turbulent flow occurs through the 7 heat chambers. This can result in drier exit temperatures being about 50 degrees higher than they normally would, raising the exit temperature to the 200 degree area. This is very significant, as discussed later.

The preferred arrangement is shown in Figure 1. This version requires a separate fan and heater for the heat chamber air.

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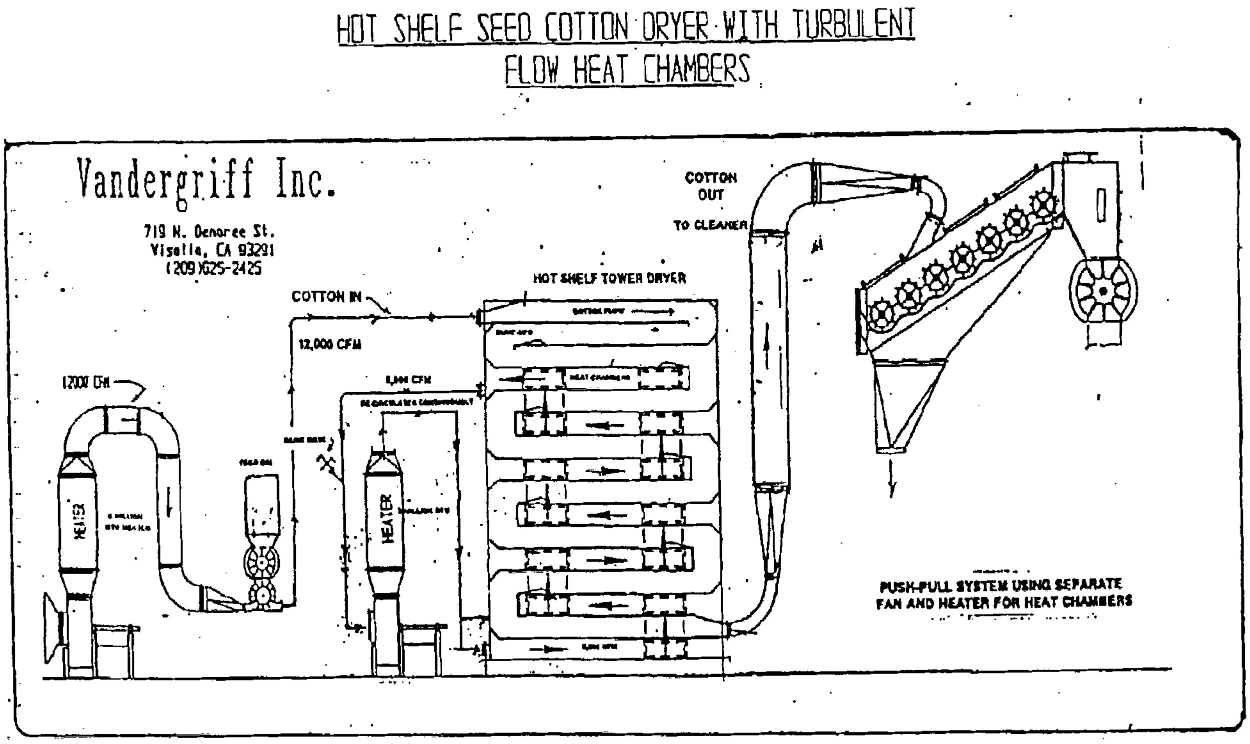

Figure 1

The fan would require a 20-30 HP motor, along with 3 million BTU heater. This arrangement will re-circulate 8,000 CFM of air continuously. A small amount of air would have to be bled off from a 10" pipe tapped into one of the lower cotton shelves, and replaced ahead of the heater to provide fresh air for combustion. One might ask, "why a separate fan and heater for the heat chamber air?" You have more flexibility in dealing with varying moisture conditions you may face. In very dry, low moisture situations, the 3 million BTU heater for the heat shelves would provide all the heat needed in the tower, allowing you to keep your 6 million BTU heater for your primary air, off. But more importantly, when faced with high moisture cotton, the 6 million BTU heater could be turned on your primary air, allowing you to easily go up to 350 degrees at the mix point. This allows the high moisture cotton to enter the tower in the range of 200 degrees. At the same time, your shelves would be plenty hot (350 degrees) due to the turbulent flow action of the heated air circulating through them. This will allow the cotton to enter the tower hot, and remain hot until it exits.

An alternate arrangement is shown if Figure 2. This method does not use a separate fan and heater for the heat shelves. The main source of air and heat is provided by a high efficiency air foil blower with a 40 HP motor to generate the required 12,000 CFM of air, along with a 6 million BTU heater as the heat source. 4,000 CFM is bled off, leaving 8,000 CFM to continue on to the heat chambers. This 8,000 CFM circulates through the elbows, into the heat chambers where the turbulent flow process takes place to transfer heat to the cotton shelves, and exits, where it meets up with the 4,000 CFM that was initially bled off into the cotton line. This provides for a total of 12,000 CFM of heated air available to pick up the cotton, and convey it through the tower.

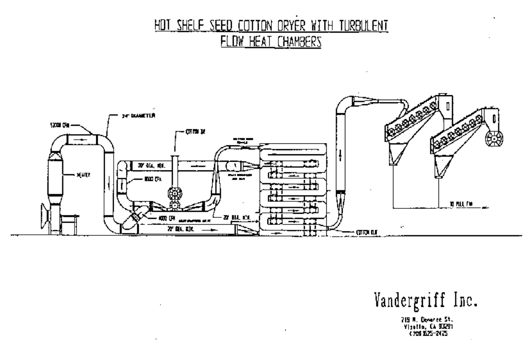

Figure 2

There is interest in pull through systems because of the convenience of picking up the cotton from a module feeder belt. Because of the high negative pressure in the system when only a pull is used vs. a push-pull, this arrangement is not the most efficient. There is an added 6,000 to 8,000 CFM to be handled by the pull fans and the dust control system. Even with a push-pull arrangement, all of the leakage is not avoided. However, it seems to be common practice to use 100 HP motors on the pull fans with pull systems, and the Hot Shelf System will operate on a push-pull with about the same amount of power. But, there may be a problem of getting the cotton from the belt into the hot air line.

A straight pull system can be successfully used, but we are proposing a booster fan in the system, preferably in the cotton line ahead of the cleaner. A skimmer separates the cotton from the air centrifugally, with some of the air going to the fan, the discharge of which joins the main stream going to pick up the cotton to the cleaner. The power required for the pull fan on the cleaner can be reduced by more than enough to off set the power used by the booster fan, and leakage is significantly reduced.

Air Volume And Temperatures

It was suggested that air volummes and temperature be discussed. I am aware that drying systems are being tested and have had limited use, with large volummes of drying air. I hear talk of 25 to 50 CFM per pound of cotton. At 40 bales per hour, this would mean volummes of air up to 50,000 CFM. Referring to my paper presented to this conference two years ago, it will be seen that I successfully used such volummes twenty five years ago. This was part of my learning process. With such volummes, it is desirable to recirculate some of the air due to the dust control costs, and the heat loss in discharging this large volume to the atmosphere. I worked with my friend, Sam Jackson, during this time on methods of recirculating some of the air. Also, in the paper mentioned above, I discussed a successful system of recirculating the drying air based on its moisture content, or dew point in this case.

My patent, Number 3,069,730, filed in 1959 and issued in 1962 discloses the earliest attempt I know of to recirculate a part of the drying air. The cotton and part of the air was skimmed off from the main stream and went to the separating cleaner, while the remaining air was passed through a fan and rejoined the primary drying air going into the tower dryer. For thirty-five years ago, this was a very large volume of drying air, using about 24,000 CFM. This method of separating the cotton and part of the air from the main flow is now quite commonly used.

During this learning process, I concluded that there were two reasons for use of a large volume of air in a drying system: *1.) There is better fiber exposure to the drying air. 2.) The large volume of air contains a lot more BTU's of heat, providing less temperature drop through the system.* During this learning process, I found that there were other ways to obtain the necessary "slippage" for moisture transfer, and to maintain a good temperature through-out the system, without using extreme volummes of air. The Hot Shelf System only uses a volume of air sufficient for conveying the cotton through the tower. However, I have never used air volume as a measure of its conveying ability. Air weight is a better measure, and I have generally used one pound of air per pound of lint. In this case, 12,000 CFM would convey 900 pounds of seed cotton per minute. Anyone who can read a psychometric chart, (they are not easy) can see that a large volume of air is not needed to evaporate a large amount of moisture, *if the temperature is kept up to the recommended level of 200 degrees through-out the drying cycle.* At this temperature, a pound of standard air will easily hold at least .10 pounds of water before reaching saturation. With 12,000 CFM of air weighing 900 pounds, .10 pounds per pound of air would be 90 pounds of water per minute. But ten percentage points from 40 bales of lint per hour is only 33.3 pounds of water, or .037 pounds of water per pound of air. This is far below its moisture absorbing capacity at 200 degrees. The air would still have a relative humidity of only about 4 1/2% at 200 degrees. Of course the key element in this system is the ability to keep the temperature up through the system when needed. *Increasing the temperature only a few degrees to offset the effect of the falling rate of drying toward the end of the system adds very significantly to the drying efficiency.*

As previously mentioned, there is considerable skepticism about the heat transfer caused by the turbulent flow hot air in the heat chambers between the shelves, to the shelves over which the cotton is conveyed. Experience has shown the discharge temperature of air leaving the tower can be increased by 40 to 50 degrees through heat transfer to the air traveling over the surfaces of the heat chambers. This would correlate fairly with the assumption that there would be about 6 BTU's per square foot through the shelf surface, with 150 degree difference across the surface, and 900 square feet of heated surface. 6 X 150 X 900 = 810,000 BTU's. This added to 12,000 CFM provides a temperature rise of about 60 degrees! Of course, conditions have to be ideal for this kind of heat transfer, but we can count on the 40 to 50 degree heat transfer at the specified temperatures - 350 degrees at the mixpoint, 350 degrees entering the heat chambers and a minimum of 8,000 CFM through the heat chambers.

It is obvious that the larger volummes of air are not needed to evaporate the moisture if the temperature is maintained at a good drying level through-out the system. Only the Hot Shelf Drying System can and does accomplish this effectively.