AIR TEMPERATURE DISTRIBUTION IN SEED COTTON DRYING SYSTEMS

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Abstract

Ten tests were conducted in the fall of 2007, to measure air temperature variation within various heated air seed cotton drying systems with the purpose of: checking validation of recommendations by a professional engineering society and measuring air temperature variation across the airflow ductwork preceding the mixpoint of heated air seed cotton drying systems with the purpose of checking for large temperature differences that may exist. The cooperating gins were located in west Texas, the San Joaquin Valley, California, and other locations in the western U.S. Drying systems tested include: pipe-fed tower, pipe, crossflow blow-box, hi-slip, fountain – collider type, and jet systems. Regarding air temperature variation along the conveying length of he seed cotton drying systems, all but one of the ten systems had the largest temperature drop in the first 6.5 feet (2 m) after the mixpoint. For all systems, the temperature drop in the first 6.5 feet (2 m) after the mixpoint was significant enough that locating a temperature control sensor at that location would achieve satisfactory control. The recommendations that were being checked appear to be satisfactory, but can be improved upon. Regarding air temperature variation across the airflow ductwork preceding the mixpoint of heated air seed cotton drying systems, three of the ten systems tested had significant variation in air temperature, ranging up to a temperature difference of 120 ^{o}F (67 ^{o}C) among the four locations tested. Drying systems which dispersed the drying air across large widths (up to 8 feet or 2.5 m), such as the crossflow blow-box and the hi-slip drying systems, were more likely to have a large variation than were systems which kept the drying air concentrated, such as the pipe, jet, and pipe-fed tower drying systems. Further testing should be done that would investigate methods of reducing the temperature variation from drying systems with problems in that area.

Introduction

A number of systems have been developed for removing moisture from seed cotton using heated air as the cotton is conveyed through the seed cotton cleaning equipment. Mayfield (1997) provides a review of many of these systems. The purpose of these systems is to remove moisture so that seed cotton cleaning can be more effective, while at the same time avoiding an adverse effect on the fiber and seed quality and minimizing the amount of additional energy required for operating the gin.

Heated air drying systems operate by supplying heated air (usually with a fan and a gas burner) and mixing it with a stream of seed cotton on a continuous-flow basis. The seed cotton is often added to the flowing air stream using an air lock feeder, although some systems have been developed that do not require this (such as the fountain dryer and the hi-slip dryer). As the heated air and the seed cotton are mixed, the heated air temperature drops significantly due to sensible heat transfer from the air to the seed cotton (the seed cotton warms as the air cools) and due to latent heat transfer (moisture is evaporated from the seed cotton causing it to dry and the air to cool). As the seed cotton and air continue to flow through the length of drying system, the heated air temperature will continue to drop due to continued drying as well as heat transfer from the walls of the drying system (Hughs, et al., 1994).

The American Society of Agricultural and Biological Engineers (ASABE) has developed a standard regarding placement and temperature settings for the heater controls for seed cotton drying systems (ASABE, 2007). This standard recommends the use of two temperature controls for the heater, a primary sensor located in the airstream after the seed cotton and heated air have mixed, referred to as the mixpoint, and a maximum temperature control sensor located before the mixpoint. The standard also categorizes seed cotton drying systems into four types, including: 1) tower drying systems; 2) mechanical transport drying systems; 3) blow-box or towerless drying systems; and 4) fountain or other short residence-time drying systems.

Although not stated in the standard, the purpose of the primary sensor is to allow the system to respond to changes in the amount of seed cotton flow and to changes in the moisture content of the seed cotton (Hughs, et al, 1994). For example, if one of the gin stands is not working, then the temperature after the mixpoint would rise unless the primary sensor is in place to keep the temperature more constant. This prevents overdrying of and damage to the cotton fiber. The standard allows the gin personnel to set the desired temperature for the primary sensor control at whatever level is necessary, while the recommended location of the primary sensor depends upon which of the previously mentioned four types that particular drying system is.

The maximum temperature control is necessary to limit the temperature of the heated air and thus avoid the possibility of scorching or igniting the seed cotton in the system (Griffin, 1977). The standard states that the maximum temperature sensor control be set at 350 ^{o}F (177 ^{o}C) or lower, and that the location of the maximum temperature sensor be 10 feet (3 meters) or less ahead of the mixpoint.

The objectives of this study were to measure air temperature variation along various heated air seed cotton drying systems with the purpose of checking validation of recommendations in ASABE standard S530.1, *Temperature Sensor Locations for Seed-Cotton Drying Systems* and to measure air temperature variation across the airflow ductwork preceding the mixpoint of heated air seed cotton drying systems with the purpose of checking for large temperature differences that may exist.

Materials and Methods

With the assistance of the Texas Cotton Ginners Association and the California Cotton Growers and Ginners Association, cooperating gins were located in the West Texas and San Joaquin Valley, California, and other western U.S. locations. The gins were selected on willingness to cooperate and on type of drying system, so that most drying system types could be tested. The drying systems tested are listed in Table 1. Arrangements had been made to test nearly all dryer types, but some were not available for testing on the day we were able to visit the site.

Table 1. Drying systems tested in the fall 2007 gin dryer study.

System type	Dryer type, number tested, and general location
Tower	Standard (1 – other), Hot shelf (0), High volume (0)
Mechanical transport	Belt dryer (0), Big reel dryer (0)
Blow-box or towerless	Pipe dryer (1–Texas), Crossflow blow-box dryer (3–Calif.), Hi-slip dryer (1–Texas, 2–Calif.), Hot-box (0)
Short residence-time	Fountain dryer (1 collider– Texas, 0 bottom-feed), Jet dryer (1– Texas)

At each gin, Type T (copper-constantan) thermocouples were installed to measure air temperature at various locations in the drying system as well as the ambient air temperature. Four thermocouples were installed in the airstream before the mixpoint and no more than 10 feet (3 m) from the mixpoint. After the mixpoint, one thermocouple was installed every 6.5 feet (2 m), if possible, depending upon the type of drying system. For the purposes of this study, the mixpoint was defined as the midpoint of the conveyance length over which the cotton was added to the airstream.

A typical test lasted for two hours. Temperatures were recorded every minute with a Hewlett-Packard 34970A data acquisition system. Thermocouple junctions in the airstream that was conveying seed cotton were somewhat likely to break, so temperatures were manually monitored during the test as well, and broken thermocouple junctions were repaired, if accessible. Seed cotton samples for oven moisture determination were collected every 15 minutes during the test. Each time, one sample was collected as close as possible before the dryer and one sample was collected as close as possible after the dryer. Since we were working in an operating gin, often the first sample would be from the module or module feeder belt, and the second sample would be from a gin stand or the overflow feeder for the gin stands. Seed cotton samples that were collected were weighed in the evening of the day they were collected, then were stored and shipped to the Southwestern Cotton Ginning Research Laboratory in Mesilla Park, New Mexico, where they were oven dried using a modified Shepard method.

Airflow through the drying system was determined either from measurements made by the gin before the current ginning season or by a Pitot tube traverse. Lint turnout was obtained from the gin records. The ginning rate (bales per hour) was determined from the gin records as well. Airflow, lint turnout, and ginning rate were used to calculate the volume of conveying air to seed cotton ratio (cubic feet of air per pound of seed cotton) using the equation:

Air to seed cotton ratio (ft^3/lb) = Airflow (cfm) x Turnout (%) / Ginning rate (bales/hr) / 833.3

Results and Discussion

Ten dryers were tested in west Texas, the San Joaquin Valley of California, and other western U.S. locations. One gin had a hi-slip dryer and a jet dryer positioned in tandem with one control system for both dryers; therefore the ten dryers are categorized as nine drying systems. Results for temperature change after the mixpoint and along the length of the conveying path have been analyzed and will be presented later in this section. Results for temperature differences across the heated air stream just ahead of the mixpoint have also been analyzed and will be presented later in this section. A summary of supporting data including airflow rate, ginning rate, turnout, air to seed cotton ratio, seed cotton moisture before and after drying, and temperature control information are listed in Table 2. Of interest to note for this study was that seven of the nine separate drying systems only used one temperature control sensor, either before or after the mixpoint, instead of the recommended two temperature control sensors. The remaining supporting data that are listed in the table were values that are typical of what would be expected.

Table 2. Supporting data for drying systems tested in the fall 2007 gin dryer study.

System type	Airflow (cfm)	Gin. Rate (bale/hr)	Turnout (%)	Airflow (ft^3/lb)	Seed cotton m.c. before (% w.b.)	end (% w.b.)	change (% pt.)	Primary control used?	Max. temp. control used?
Tower	12,500	25	34	20	10.7	9.1	1.6	Yes	No
Pipe	20,000	26.5	32	29	7.4	6.4	1.0	No	Yes
CF blow-box 1	15,000	20	35.5	32	8.6	7.7	0.9	No	Yes
CF blow-box 2	12,000	20	35.5	26	8.6	7.7	0.9	No	Yes
CF blow-box 3	11,800	21	37	25	9.0	6.3	2.7	No	Yes
Hi-slip 2	13,500	26	34.5	22	10.9	9.1	1.8	Yes	Yes
Hi-slip 3	16,000	26	37.5	28	7.1	5.3	1.8	Yes	Yes
Fountain-coll.	30,000	35	32.5	33	7.9	7.0	0.9	No	Yes
Hi-slip 1/Jet	15,000	24	32	24	7.5	6.3	1.2	Yes	No

Temperature change after the mixpoint

Tower drying system: A tower drying system was tested in a saw gin on 12/20/2007. At the time of the test, the tower drying system was the only system in use at the gin, and was located ahead of any seed cotton cleaning equipment. A vacuum dropper was used to place the seed cotton into the heated air stream. Approximately 24 feet (7.5 m) of conveying pipe preceded the tower dryer and the conveying path in the dryer was approximately an additional 50 feet (15 m). Thermocouples were installed every 6.5 feet (2 m) along the conveying path up to a total of 79 feet (24 m). The first three thermocouples were in the pipe preceding the tower, followed by eight thermocouples in the tower, and one more thermocouple in the conveying pipe after the tower. The heater was controlled by a single sensor installed after the mixpoint approximately 20 feet (6 m). Seed cotton samples were taken from the belt conveyor output of the module feeder and from the feeder apron of one gin stand.

A portion of the data for this test was lost during the process of transferring data from the RAM of the data acquisition system to the hard drive of the laptop computer. The data available was from 80 minutes to 120 minutes of elapsed time for the test. For this drying system, the combination of the control system and the burner in use resulted in very dramatic cycling of the burner and associated drying air temperature (Figure 1). This cycling most likely was not associated with the location of the control sensor. Even with the cycling, the largest temperature drop was in the first 6.5 feet (2 m) of the conveying pipe. Temperature continued to drop significantly up through 26 feet (8 m) where it had entered the tower dryer. Once in the tower, the thermal mass of the insulated dryer evened out the temperature fluctuations.

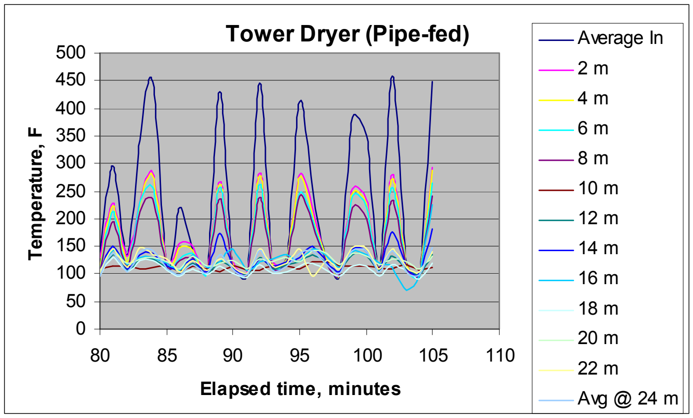

Figure 1. Temperature variation along the conveying length of the tower drying system.

Pipe drying system: A pipe drying system was tested in a saw gin in west Texas, on 10/30/2007. At the time of the test, the pipe drying system was the only system in use at the gin, and was located ahead of any seed cotton cleaning equipment. A vacuum dropper was used to place the seed cotton into the heated air stream, and the pipe system was approximately 160 feet (49 m) long. Thermocouples were installed every 6.5 feet (2 m) along the conveying path up to a total of 79 feet (24 m), plus an additional thermocouple was installed at 98 feet (30 m). The heater was controlled by a single sensor installed before the mixpoint approximately 10 feet (3 m). The setpoint of this sensor was adjusted based upon moisture content of the module, as measured with a module probe and hand-held electronic meter. Seed cotton samples were taken from the module (by removing the outer 6 inches or 15 cm of seed cotton and then hand grabbing the sample) and after the separator on the pipe drying system.

Data for 4 of the measuring locations (at 39, 52, 59, and 65 feet or 12, 16, 18, and 20 m) was lost due to broken thermocouple junctions that were not noticed during the test. For the pipe drying system, the largest temperature drop (25 ^{o}F or 14 ^{o}C averaged over time) was in the first 6.5 feet (2 m) of the conveying pipe (Figure 2). Temperature continued to drop slightly 20 feet or 6 m. Between this point and the next (26 feet or 8 m) the conveying pipe transitioned from horizontal to vertical and there was another significant temperature drop averaging 15 ^{o}F (8 ^{o}C) over time. The temperature continued to drop gradually over the remainder of the conveying length. Fluctuations in the drying air temperature for this system were primarily due to changes in seed cotton flow rate due to operational problems that occurred in the gin. The large mass that is necessary to have a durable sensor for the control system does not respond to changes as quickly as the small mass of the thermocouples that we installed.

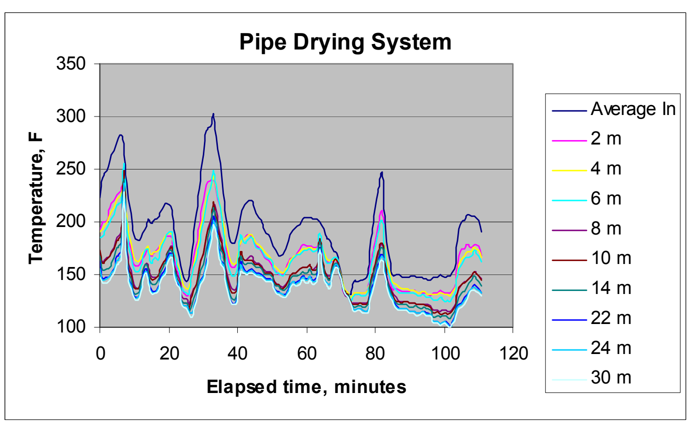

Figure 2. Temperature variation along the conveying length of the pipe drying system.

Crossflow blow-box drying systems: Three crossflow blow-box (CFBB) drying systems were tested, all in the San Joaquin Valley, California. The first two CFBB dryers (manufactured by Eckley Engineering, Fresno, California) were tested on 12/11/2007, and were the stage 2 and stage 3 dryers at the same roller gin. At the time of the test, a pipe drying system was in use as the stage 1 drying system. All drying was located ahead of any seed cotton cleaning equipment. Separate vacuum droppers were used to place the seed cotton into the top of the CFBB where it mixed with the heated air stream. The pipe system following the CFBB was approximately 50 feet (15 m) long for CFBB drying system 1 (stage 2 drying) and was approximately 80 feet (24 m) long for CFBB drying system 2 (stage 3 drying). For each system, thermocouples were installed every 6.5 feet (2 m) along the conveying path up to a total of 20 feet (6 m) at which point the conveying pipe became inaccessible with the equipment on hand. Both heaters were controlled by one sensor each that was installed before the mixpoint of each system approximately 10 feet (3 m). The setpoint of this sensor was set at 350 ^{o}F (177 ^{o}C) for both systems. Seed cotton samples were taken from the module (by removing the outer 6 inches or 15 cm of seed cotton and then hand grabbing the sample) and from the overflow feeder for the gin stands.

For the CFBB drying system 1, the largest temperature drop (50 ^{o}F or 28 ^{o}C averaged over time) was in the first 6.5 feet (2 m) of the conveying pipe (Figure 3). Temperature continued to drop another 22 ^{o}F (12 ^{o}C) in the next 6.5 feet (2 m), but only an insignificant drop occurred in the last 6.5 feet (2 m) that were measured. The drying temperature was fairly constant over time for this system, but was below the setpoint of 350 ^{o}F (177 ^{o}C), most likely due to insufficient heat output from the burner. The heat output of the burner was not sufficient enough to heat the air as much as desired.

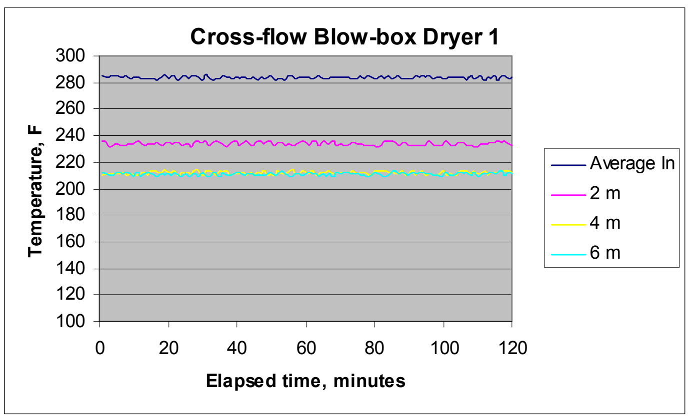

Figure 3. Temperature variation along the conveying length of the crossflow blow-box drying system 1.

For CFBB drying system 2, a portion of the data for this test was lost during the process of transferring data from the RAM of the data acquisition system to the hard drive of the laptop computer. The data available was from 100 minutes to 120 minutes of elapsed time for the test. Results from the data available for the CFBB drying system 2 were similar to those from the CFBB drying system 1 in regards to the relative temperature drop along all measuring locations.

The CFBB drying system 3 had been self-manufactured and had a wider thickness of the air duct than the system manufactured by Eckley Engineering. It was tested on 12/11/2007, and was the stage 1 drying system at the roller gin in which it was installed. This gin had a hi-slip drying system as its stage 2 dryer and a similar CFBB drying system as its stage 3 dryer, which were both operating at the time of the test. A vacuum dropper was used to place the seed cotton into the top of the CFBB where it mixed with the heated air stream. The pipe system following the CFBB was approximately 25 feet (7.5 m) long for CFBB drying system 3 (stage 1 drying). Thermocouples were installed every 6.5 feet (2 m) along the conveying path up to a total of 20 feet (6 m) at which point the conveying pipe became inaccessible with the equipment on hand. The heater was controlled by a single sensor installed before the mixpoint approximately 10 feet (3 m). The setpoint of this sensor was set at 450 ^{o}F (232 ^{o}C). Seed cotton samples were taken from the module (by removing the outer 6 inches or 15 cm of seed cotton and then hand grabbing the sample) and from the overflow feeder for the gin stands. The length of this test was only 30 minutes, because the gin shut down for a long lunch break at this time (which we were not expecting).

For the CFBB drying system 3, the largest temperature drop (105 °F or 58 °C averaged over time) was in the first 6.5 feet (2 m) of the conveying pipe (Figure 4). Temperature remained nearly constant over the remaining 13 feet (4 m) of the conveying pipe. The drying temperature was fairly constant over time for this system. The spike and drop at the end of the test occurred as the seed cotton flow rate was slowed out of the steady-flow feeder and the heater was shut down.

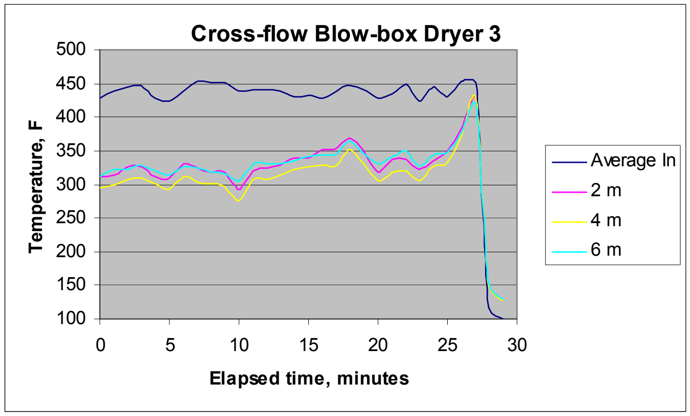

Figure 4. Temperature variation along the conveying length of the crossflow blow-box drying system 3.

Hi-slip drying systems: Three hi-slip drying systems were tested, one in west Texas, and two in the San Joaquin Valley, California. The first hi-slip dryer that was tested had been manufactured on site by Cap Rock Machinery, Cap Rock, Texas, when it was installed. It was located in a gin in west Texas, was tested on 11/2/2007, and was the stage 2 dryer in the saw gin. The hi-slip dryer fed directly into a jet dryer. No additional heat was added between the hi-slip dryer and the jet dryer. At the time of the test, other drying systems in the gin were not in use. All drying was located ahead of any seed cotton cleaning equipment. A vacuum dropper was used to place the seed cotton into the top of the hi-slip dryer where the seed cotton flow was retarded by a rotating agitator as the seed cotton mixed with the heated air stream. The pipe system following the hi-slip dryer was approximately 13 feet (4 m) long before it ended at the entrance to the jet dryer. For this dryer, thermocouples were installed every 6.5 feet (2 m) along the conveying path up to a total of 13 feet (4 m). The heater was controlled by a single sensor installed after the jet dryer approximately 46 feet (14 m) downstream of the hi-slip dryer. The setpoint of this sensor was initially set at 120 °F (49 °C), but was lowered to 85 °F (30 °C) after 38 minutes of testing due to excessive static electricity. Seed cotton samples were taken from the belt conveyor output of the module feeder and from the feeder apron of one gin stand.

A portion of the data at the beginning as well as at the end of this test was lost during the process of transferring data from the RAM of the data acquisition system to the hard drive of the laptop computer. The data available was from 25 minutes to 80 minutes of elapsed time for the test. For the hi-slip drying system 1, the largest temperature drop (40 °F or 22 °C averaged over time) was in the first 6.5 feet (2 m) of the conveying pipe (Figure 5). The temperature dropped another 7.5 °F (4 °C) in the next 6.5 feet (2 m) before the seed cotton and conveying air entered the jet dryer. The drying temperature was fairly constant over the two segments of this test, and responded quickly to the change of the control sensor setpoint. Two spikes in the air temperature ahead of the mixpoint are shown in the figure, but the reason for these spikes is unknown. Since the spikes are an average of four thermoucouple readings and all four thermocouples increased almost equally in temperature, the spikes are likely true and not anomalous readings.

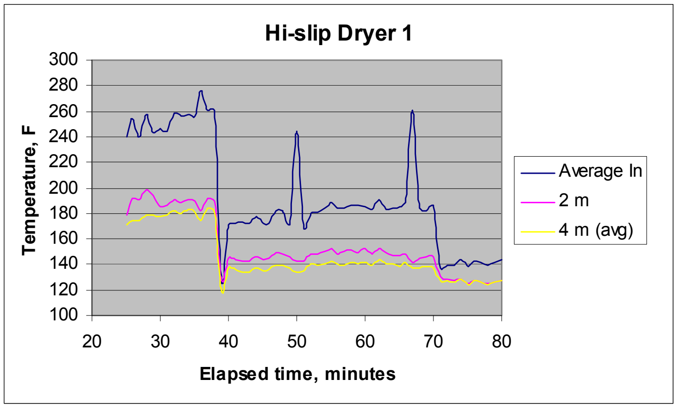

Figure 5. Temperature variation along the conveying length of the hi-slip drying system 1.

The second hi-slip dryer that was tested was referred to as a Big J dryer. It was located in a saw gin in the San Joaquin Valley, California, was tested on 12/11/2007, and was the stage 1 dryer in that gin. The hi-slip dryer fed directly into an impact cleaner. At the time of the test, a pipe drying system was operating as the stage 2 dryer and a crossflow blow-box drying system was operating as the stage 3 dryer. A vacuum dropper was used to place the seed cotton into the top of the hi-slip dryer where the seed cotton flow was retarded by a rotating agitator as the seed cotton mixed with the heated air stream. The pipe system following the hi-slip dryer was approximately 26 feet (8 m) long before it ended at the impact cleaner. For this dryer, thermocouples were installed every 6.5 feet (2 m) along the conveying path up to a total of 26 feet (8 m). The heater was controlled by a primary sensor installed after the mixpoint approximately 26 feet (8 m) and by a maximum temperature sensor located 10 feet (3 m) ahead of the mixpoint. The setpoints of these sensors were not recorded. Seed cotton samples were taken from random locations of the exposed interior of the module (a telescoping suction feeder was in use) and from the feeder apron of one gin stand.

For the hi-slip drying system 2, the largest temperature drop (190 ^{o}F or 106 ^{o}C averaged over time) was in the first 6.5 feet (2 m) of the conveying pipe (Figure 6). The temperature drop for the remaining 20 feet (6 m) of the drying system was insignificant. The drying temperature was fairly constant over the duration of this test.

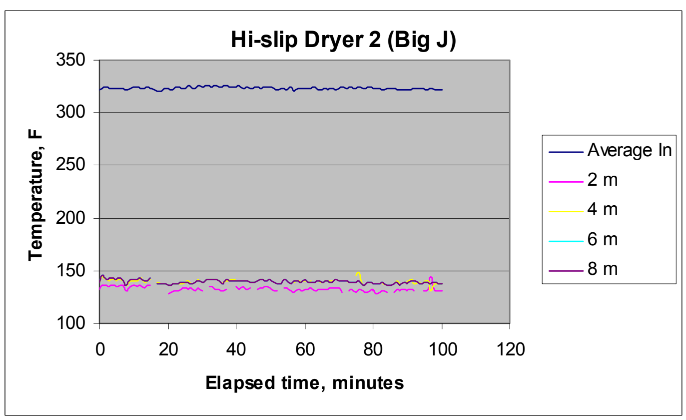

Figure 6. Temperature variation along the conveying length of the hi-slip drying system 2.

The third hi-slip dryer that was tested was also referred to as a Big J dryer. It was located in a roller gin in the San Joaquin Valley, California, was tested on 12/12/2007, and was the stage 1 dryer in that gin. The hi-slip dryer fed directly into an impact cleaner. At the time of the test, two other hi-slip drying systems were in use in the gin. Seed cotton was fed directly from the module feeder into the hi-slip dryer (without a vacuum feeder), where the seed cotton flow was retarded by a rotating agitator as the seed cotton mixed with the heated air stream. The pipe system following the hi-slip dryer was approximately 46 feet (14 m) long before it ended at the impact cleaner. For this dryer, thermocouples were installed every 6.5 feet (2 m) along the conveying path up to a total of 26 feet (8 m), at which point the ductwork became inaccessible with the equipment on hand. The heater was controlled by a primary sensor installed after the mixpoint approximately 26 feet (8 m) and by a maximum temperature sensor located 10 feet (3 m) ahead of the mixpoint. The setpoint for the primary sensor was 180 ^{o}F (82 ^{o}C) and for the maximum temperature sensor was 215 ^{o}F (102 ^{o}C). Seed cotton samples were taken from the module (by removing the outer 6 inches or 15 cm of seed cotton and then hand grabbing the sample) and from the overflow feeder for the gin stands.

For the hi-slip drying system 3, the largest temperature drop (100 ^{o}F or 55 ^{o}C averaged over time) was in the first 6.5 feet (2 m) of the conveying pipe (Figure 7). The temperature drop for the next 13 feet (2 m) of the drying system was 16 ^{o}F (9 ^{o}C) averaged over time. The temperature drop for the remaining 13 feet (4 m) of the drying system was insignificant. The drying temperature after the mix point was fairly constant over the duration of this test. The drying temperature ahead of the mixpoint showed fluctuations that are typical of the heater being controlled by the primary sensor rather than the maximum temperature sensor

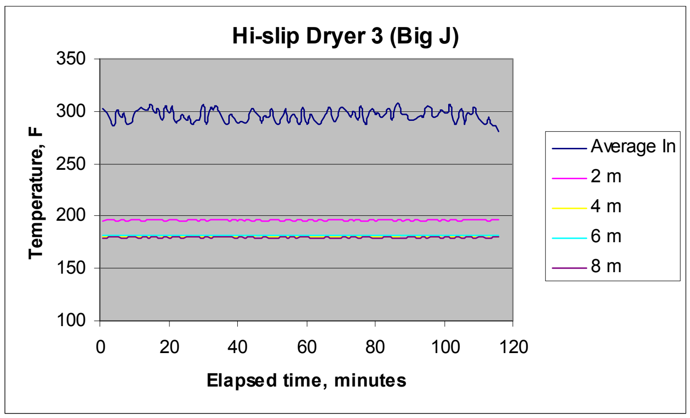

Figure 7. Temperature variation along the conveying length of the hi-slip drying system 3.

Fountain drying system – collider type: The fountain dryer that was tested had been manufactured by Samuel Jackson, Inc., Lubbock, Texas. It was located in a saw gin in west Texas, was tested on 11/2/2007, and was the stage 2 dryer in the gin. A hot-box dryer was in use as the stage 1 dryer for this gin. The conveying air with seed cottn from the hot-box dryer was fed into the fountain dryer in such a way that it collided with an additional flow of heated air at the top of the dryer. The flow path from the top of the fountain dryer to the bottom was approximately 20 feet (6 m). The seed cotton conveying pipe system following the dryer was approximately 55 feet (17 m) long before it ended at the cylinder cleaner. For this dryer, thermocouples were installed every 6.5 feet (2 m) along the conveying path (once out of the dryer) from 20 feet (6 m) to 40 feet (12 m) past the mixpoint at the top of the dryer. Another thermocouple was installed at 80 feet (24 m) past the mixpoint Temperature control information for this dryer was not recorded. Seed cotton samples were taken from the belt conveyor output of the module feeder and from the feeder apron of one gin stand.

The seed cotton for this test was initially fairly dry, averaging 7.9 % in the module; therefore, temperature settings for the dryer were low. Temperature data after the dryer showed insignificant temperature change along the conveying pipe, indicating that most of the drying occurred within the enclosure of the fountain dryer (Figure 8).

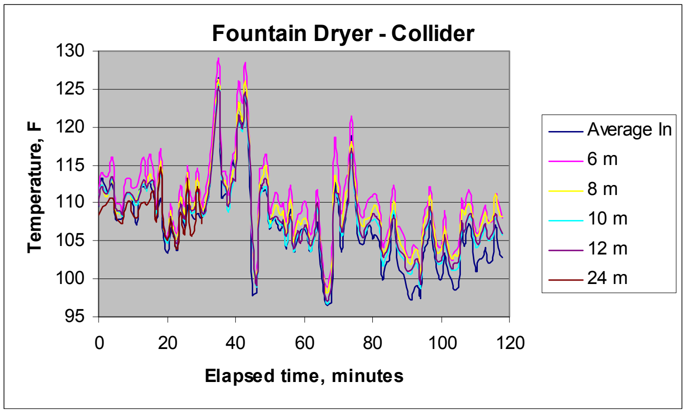

Figure 8. Temperature variation along the conveying length of the fountain drying system – collider type.

Jet drying system: The jet dryer that was tested was located in a saw gin in west Texas, was tested on 11/2/2007, and was part of the stage 2 drying system in that saw gin. A hi-slip dryer fed directly into the jet dryer. No additional heat was added between the hi-slip dryer and the jet dryer. At the time of the test, other drying systems in the gin were not in use. All drying was located ahead of any seed cotton cleaning equipment. The jet dryer was fed directly from the hi-slip dryer, a compact way to increase contact time and slip between the drying air and the seed cotton. The pipe system following the jet dryer was approximately 33 feet (10 m) long before it ended at the cylinder cleaner. For this dryer, thermocouples were installed every 6.5 feet (2 m) along the conveying path up to a total of 33 feet (10 m). The heater was controlled by a single sensor installed after the jet dryer approximately 33 feet (10 m) downstream. The setpoint of this sensor was initially set at 120 ^{o}F (49 ^{o}C), but was lowered to 85 ^{o}F (30 ^{o}C) after 38 minutes of testing due to excessive static electricity. Seed cotton samples were taken from the belt conveyor output of the module feeder and from the feeder apron of one gin stand.

A portion of the data at the beginning as well as at the end of this test was lost during the process of transferring data from the RAM of the data acquisition system to the hard drive of the laptop computer. The data available was from 25 minutes to 80 minutes of elapsed time for the test. For the jet drying system, air temperature into the system was low, averaging 146 ^{o}F (63 ^{o}C). The temperature drop in the first 6.5 feet (2 m) of the conveying pipe was 6.5 ^{o}F or 3.5 ^{o}C averaged over time (Figure 9). The temperature dropped another 11 ^{o}F (6 ^{o}C) in the next 6.5 feet (2 m). before the seed cotton and conveying air entered the jet dryer. The temperature drop for the remaining 20 feet (6 m) of the drying system was insignificant. The drying temperature was fairly constant over the two segments of this test, and responded quickly to the change of the control sensor setpoint.

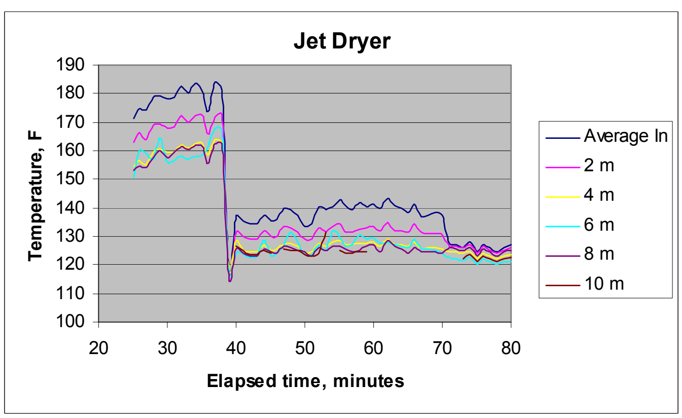

Figure 9. Temperature variation along the conveying length of the jet drying system.

Temperature variation preceding the mixpoint

Tower drying system: : The tower drying system had little temperature variation among the four temperatures that were recorded approximately 10 feet (3 m) ahead of the mixpoint. Average temperatures for the individual locations were all less than 3 ^{o}F (2 ^{o}C) above or below the overall average (Figure 10). This tower drying system was pipe-fed, and kept the airflow concentrated within the small area of the duct, which was helpful in reducing the temperature variation.

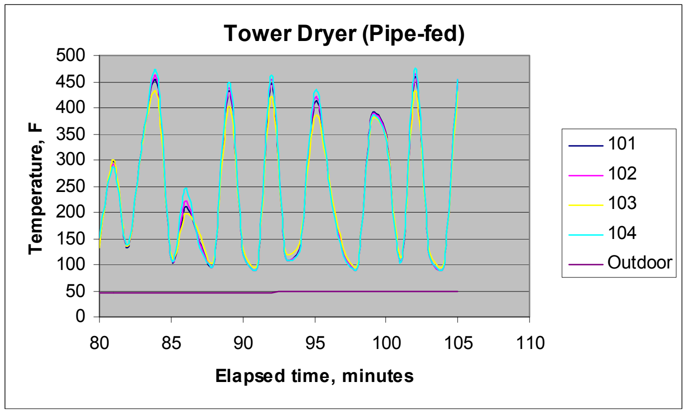

Figure 10. Temperature variation 10 feet (3 m) preceding the mixpoint of the tower drying system. The numbers 101, 102, 103, and 104 refer to the code numbers for the thermocouples as recorded by the data acquisition system.

Pipe drying system: The pipe drying system had little temperature variation among the four temperatures that were recorded approximately 10 feet (3 m) ahead of the mixpoint. Average temperatures for the individual locations were all less than 2 ^{o}F (1 ^{o}C) above or below the overall average (Figure 11). The pipe drying system used a high volume of air and kept the airflow concentrated within the small area of the duct. Both of these factors are helpful in reducing the temperature variation.

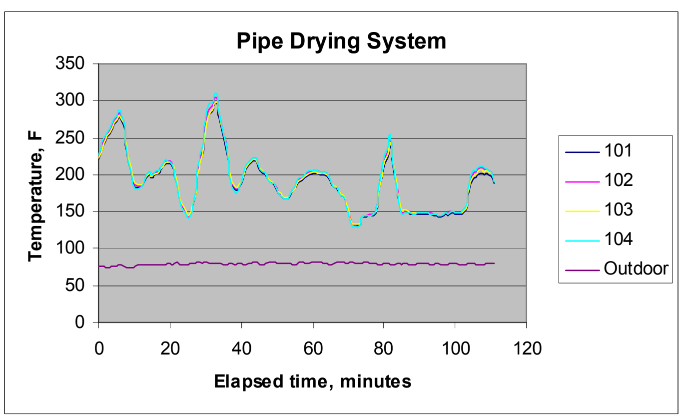

Figure 11. Temperature variation 10 feet (3 m) preceding the mixpoint of the pipe drying system. The numbers 101, 102, 103, and 104 refer to the code numbers for the thermocouples as recorded by the data acquisition system.

Crossflow blow-box drying systems: The crossflow blow-box (CFBB) drying system 1 had little temperature variation among the four temperatures that were recorded approximately 10 feet (3 m) ahead of the mixpoint. Average temperatures for the individual locations were all less than 5 ^{o}F (3 ^{o}C) above or below the overall average

(Figure 12). Unfortunately, the temperature measurements were taken in the round airflow duct instead of after the air had dispersed the 8 feet (2.5 m) across the width of the inlet side of the CFBB dryer. The CFBB dryer 2 had a similar thermocouple installation and similar results.

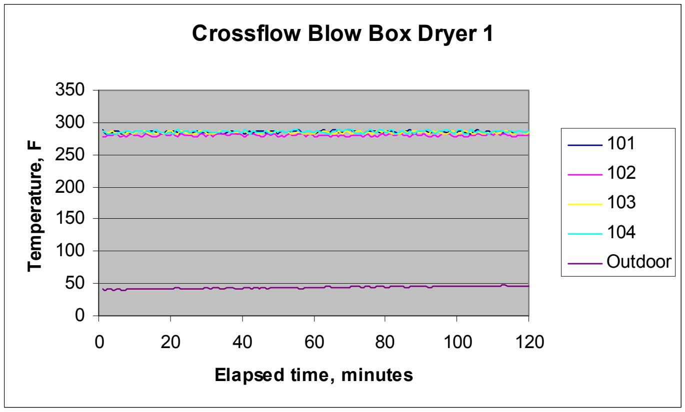

Figure 12. Temperature variation 10 feet (3 m) preceding the mixpoint of the crossflow blow-box drying system 1. The numbers 101, 102, 103, and 104 refer to the code numbers for the thermocouples as recorded by the data acquisition system.

The crossflow blow-box (CFBB) drying system 3 had significant temperature variation among the four temperatures that were recorded approximately 10 feet (3 m) ahead of the mixpoint, with average temperatures for the four locations ranging from 360 to 480 ^{o}F or 182 to 249 ^{o}C (Figure 13). For this system, the thermocouples were installed in the CFBB dryer, after the air had dispersed the 8 feet (2.5 m) across the width of the inlet side of the dryer. Temperature location 102 (Figure 13) had the lowest temperature, and surprisingly, was in the interior of the dryer. Temperature locations 101 and 104 were closest to the outside of the dryer.

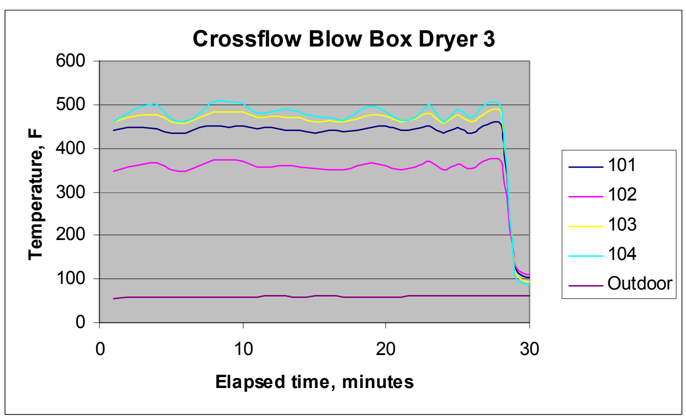

Figure 13. Temperature variation 10 feet (3 m) preceding the mixpoint of the crossflow blow-box drying system 3. The numbers 101, 102, 103, and 104 refer to the code numbers for the thermocouples as recorded by the data acquisition system.

Hi-slip drying systems: The hi-slip drying system 1 had little temperature variation among the four temperatures that were recorded approximately 10 feet (3 m) ahead of the mixpoint. Average temperatures for the individual locations were all less than 5 ^{o}F (3 ^{o}C) above or below the overall average (Figure 14). Unfortunately, the temperature measurements were taken in the round airflow duct instead of after the air had dispersed the 8 feet (2.5 m) across the width of the inlet side of the hi-slip dryer.

Figure 14. Temperature variation 10 feet (3 m) preceding the mixpoint of the hi-slip blow-box drying system 1. The numbers 101, 102, 103, and 104 refer to the code numbers for the thermocouples as recorded by the data acquisition system.

The hi-slip drying system 2 had significant temperature variation among the four temperatures that were recorded approximately 10 feet (3 m) ahead of the mixpoint, with average temperatures for the four locations ranging from 286 to 344 ^{o}F or 141 to 173 ^{o}C (Figure 15). For this system, the thermocouples were installed after the air had dispersed the 8 feet (2.5 m) across the width of the inlet side of the dryer. Temperature location 101 (Figure 15), which had the lowest temperature was near the exterior of the dryer.

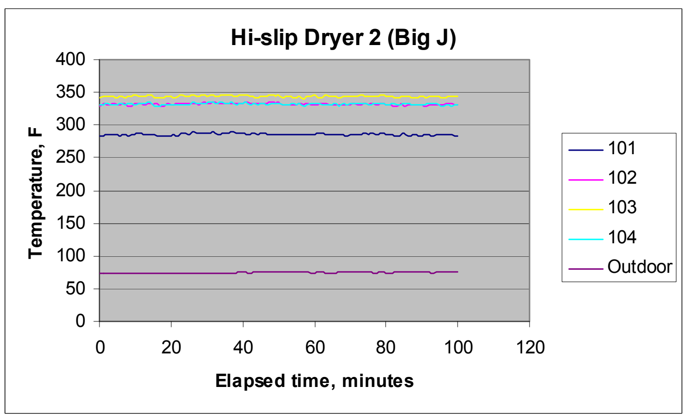

Figure 15. Temperature variation 10 feet (3 m) preceding the mixpoint of the hi-slip blow-box drying system 2. The numbers 101, 102, 103, and 104 refer to the code numbers for the thermocouples as recorded by the data acquisition system.

The hi-slip drying system 3 had significant temperature variation among the four temperatures that were recorded approximately 10 feet (3 m) ahead of the mixpoint, with average temperatures for the four locations ranging from 235 to 350 ^{o}F or 113 to 177 ^{o}C (Figure 16). For this system, the thermocouples were installed after the air had dispersed the 8 feet (2.5 m) across the width of the inlet side of the dryer. Temperature location 101 (Figure 15), which had the lowest temperature was near the exterior of the dryer, as was temperature location 104, which had the second lowest temperature.

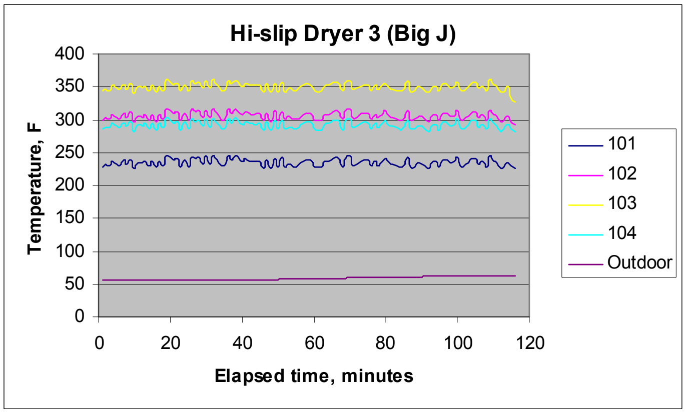

Figure 16. Temperature variation 10 feet (3 m) preceding the mixpoint of the hi-slip blow-box drying system 3. The numbers 101, 102, 103, and 104 refer to the code numbers for the thermocouples as recorded by the data acquisition system.

Fountain drying system – collider type: Three of the four thermocouples that were installed before the mixpoint had junctions that were broken before data acquisition could begin. Repairing these thermocouples during the test was not possible; therefore, information about the temperature variation preceding the mixpoint for the fountain dryer is not available.

Jet drying system: The jet drying system had little temperature variation among the four temperatures that were recorded approximately 10 feet (3 m) ahead of the mixpoint. Average temperatures for the individual locations were all less than 9 ^{o}F (5 ^{o}C) above or below the overall average (Figure 17). As with the pipe drying system, the jet drying system used a high volume of air and kept the airflow concentrated within the small area of the duct. Both of these factors are helpful in reducing the temperature variation.

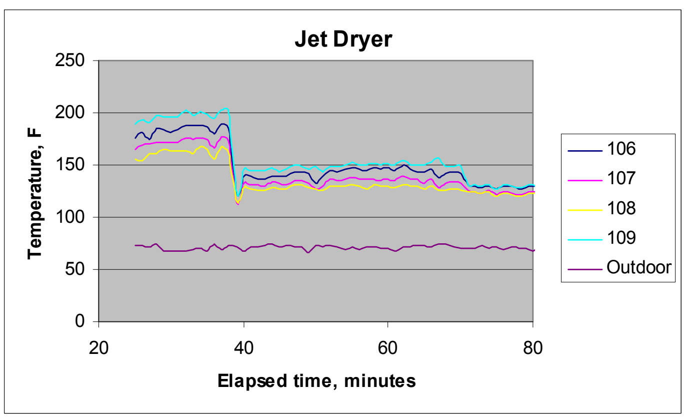

Figure 17. Temperature variation 10 feet (3 m) preceding the mixpoint of the jet drying system. The numbers 101, 102, 103, and 104 refer to the code numbers for the thermocouples as recorded by the data acquisition system.

Summary and Conclusions

Ten tests were conducted in the fall of 2007, to measure air temperature variation along various heated air seed cotton drying systems with the purpose of checking validation of recommendations in ASABE standard S530.1, *Temperature Sensor Locations for Seed-Cotton Drying Systems* and to measure air temperature variation across the airflow ductwork preceding the mixpoint of heated air seed cotton drying systems with the purpose of checking for large temperature differences that may exist. The cooperating gins were located in the West Texas and San Joaquin

Valley, California, and other locations in the western U.S. Drying systems tested include: pipe-fed tower, pipe, crossflow blow-box, hi-slip, fountain – collider type, and jet systems.

Regarding air temperature variation along the seed cotton drying systems, all but one of the ten systems had the largest temperature drop in the first 6.5 feet (2 m) after the mixpoint. For all systems, the temperature drop in the first 6.5 feet (2 m) after the mixpoint was significant enough that locating a temperature control sensor at that location would achieve satisfactory control. The recommendations in ASABE standard S530.1, *Temperature Sensor Locations for Seed-Cotton Drying Systems,* appear to be satisfactory, but may be improved upon. Further testing should be done, so that dryer types not tested this year could be studied, and so that additional data would be available for such an important recommendation.

Regarding air temperature variation across the airflow ductwork preceding the mixpoint of heated air seed cotton drying systems, three of the ten systems tested had significant variation in air temperature, ranging up to a temperature difference of 120 ^{o}F (67 ^{o}C) among the four locations tested. Drying systems which dispersed the drying air across large widths (up to 8 feet or 2.5 m), such as the crossflow blow-box and the hi-slip drying systems, were more likely to have a large variation than were systems which kept the drying air concentrated, such as the pipe, jet, and pipe-fed tower drying systems. Further testing should be done that would investigate methods of reducing the temperature variation from drying systems with problems in that area.

The data also indicate that more education is needed for gin managers and operators, so that existing recommendations concerning location of temperature control sensors and maximum drying air temperatures are more closely followed.

Disclaimer

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U. S. Department of Agriculture.

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