San Joaquin Valley
Unified Air Pollution Control District

Best Performance Standard (BPS) x.x.xx

Date: May 14, 2012

Class	**Dryers and Dehydrators**
Category	**Cotton Gin Dryer**
Best Performance Standard	• **Premium-efficiency electric motors on all dryer fans,** **And** • **Insulation of ducting from the burner to the dryer inlet as follows:** – **on the first drying stage for cotton gin drying operations designed with one or two drying stages, or** – **on the first two drying stages for cotton gin drying operations designed with three or more drying stages,** **And** • **Utilization of dryer controls and temperature sensors.**
Percentage Achieved GHG Emission Reduction Relative to Baseline Emissions	**4.9%**

District Project Number	C-1100390
Evaluating Engineer	Derek Fukuda
Lead Engineer	Joven Refuerzo
Public Notice: Start Date	April 13, 2012
Public Notice: End Date	May 11, 2012
Determination Effective Date	May 14 2012

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I. Best Performance Standard (BPS) Determination Introduction

A. Purpose

To assist permit applicants, project proponents, and interested parties in assessing and reducing the impacts of project specific greenhouse gas emissions (GHG) on global climate change from stationary source projects, the San Joaquin Valley Air Pollution Control District (District) has adopted the policy: *District Policy – Addressing GHG Emission Impacts for Stationary Source Projects Under CEQA When Serving as the Lead Agency.* This policy applies to projects for which the District has discretionary approval authority over the project and the District serves as the lead agency for CEQA purposes. Nonetheless, land use agencies can refer to it as guidance for projects that include stationary sources of emissions. The policy relies on the use of performance based standards, otherwise known as Best Performance Standards (BPS) to assess significance of project specific greenhouse gas emissions on global climate change during the environmental review process, as required by CEQA. Use of BPS is a method of streamlining the CEQA process of determining significance and is not a required emission reduction measure. Projects implementing BPS would be determined to have a less than cumulatively significant impact. Otherwise, demonstration of a 29 percent reduction in GHG emissions, from business-as-usual, is required to determine that a project would have a less than cumulatively significant impact.

B. Definitions

Best Performance Standard for Stationary Source Projects for a specific Class and Category is the most effective, District approved, Achieved-in-Practice means of reducing or limiting GHG emissions from a GHG emissions source, that is also economically feasible per the definition of Achieved-in-Practice. BPS includes equipment type, equipment design, and operational and maintenance practices for the identified service, operation, or emissions unit class and category.

Business-as-Usual is - the emissions for a type of equipment or operation within an identified class and category projected for the year 2020, assuming no change in GHG emissions per unit of activity as established for the baseline period, 2002-2004. To relate BAU to an emissions generating activity, the District proposes to establish emission factors per unit of activity, for each class and category, using the 2002-2004 baseline period as the reference.

Category is - a District approved subdivision within a “class” as identified by unique operational or technical aspects.

Class is - the broadest District approved division of stationary GHG sources based on fundamental type of equipment or industrial classification of the source operation.

C. Determining Project Significance Using BPS

Use of BPS is a method of determining significance of project specific GHG emission impacts using established specifications. BPS is not a required mitigation of project related impacts. Use of BPS would streamline the significance determination process by pre-quantifying the emission reductions that would be achieved by a specific GHG emission reduction measure and pre-approving the use of such a measure to reduce project-related GHG emissions.

GHG emissions can be directly emitted from stationary sources of air pollution requiring operating permits from the District, or they may be emitted indirectly, as a result of increased electrical power usage, for instance. For traditional stationary source projects, BPS includes equipment type, equipment design, and operational and maintenance practices for the identified service, operation, or emissions unit class and category.

II. Summary of BPS Determination Process

The District has established cotton gin dryers as a separate class and category which requires implementation of a Best Performance Standard (BPS) pursuant to the District's Climate Change Action Plan (CCAP). The District's determination of the BPS for this class and category has been made using the BPS development process established in the District's Final Staff Report, *Addressing Greenhouse Gas Emissions under the California Environmental Quality Act.* A summary of the specific implementation of the phased BPS development process for this specific determination is as follows:

Table 1 BPS Development Process Phases for Cotton Gin Dryers			
Phase	**Description**	**Date**	**Description**
1	Public Notice of Intent	11/3/10	The District's intent notice is attached as Appendix 5
2	BPS Development	7/28/11	See evaluation document.
3	Public Participation: Public Notice Start Date	4/13/12	A Draft BPS evaluation was provided for public comment. The District's notification is attached as Appendix 7.
4	Public Comments	5/11/12	No public comments were received during the commenting period.
5	Finalization	5/14/12	The BPS established in this evaluation document is effective on the date of finalization.

III. Class and Category

Dryers and dehydrators are units used to drive free water from products like fruits, vegetables, and nuts, at an accelerated rate without damage to the product, and devices in which material is dried or cured in direct contact with the products of combustion. Since cotton is dried in direct contact with the products of combustion in cotton gin dryers, they are included in the dryers and dehydrators class.

Cotton gin dryers are designed to reduce the cotton moisture to between 6 and 8 percent to facilitate cleaning and fiber seed separation. The moisture content of the cotton processed in a gin is very important to the quality of the final product and therefore the cotton gin dryer is a significant piece if equipment in the cotton ginning process. When the moisture content of the cotton is too high, it is harder to separate the trash from the lint; however when the moisture content to too low, the cotton fiber loses strength and the final product is lower grade. The delicate nature of drying cotton fiber requires very specialized drying equipment and quality control measures; therefore cotton gin dryers should be classified as a separate category.

IV Public Notice of Intent

Prior to developing the development of BPS for this class and category, the District published a Notice of Intent. Public notification of the District's intent to develop BPS for this class and category was sent on November 3, 2010 to individuals registered with the CCAP list server. The District's notification is attached as Appendix 5.

After the Notice of Intent was published the District received comments from the California Cotton Ginners and Growers Association (CCGGA). These comments are presented in Appendix 6.

The CCGGA stated that the District's intent to require insulation on the ducting in all the dryer stages of a cotton gin drying operation would be inefficient at reducing the energy consumed in the drying operation since the temperature of the air in the later drying stages is significantly lower than in the first drying stage. Since the temperature of the drying air is lower, the energy savings from the installation of insulation would be minimal.

The District took this suggestion into consideration when establishing BPS for cotton gin dryers. After further evaluation of cotton drying operations, and based on the CCGGA's suggestion, the District's initial plan was modified from requiring insulation on ducting in <u>all</u> drying stages to insulation on the ducting in the <u>first two</u> stages of a three or more stage dryer, or on the ducting in the <u>first</u> stage only of a one or two stage dryer.

These comments have been used in the development of this BPS as presented below.

V. BPS Development

STEP 1. Establish Baseline Emissions Factor for Class and Category

The Baseline Emission Factor (BEF) is defined as the three-year average (2002-2004) of GHG emissions for a particular class and category of equipment in the San Joaquin Valley (SJV), expressed as annual GHG emissions per unit of activity. The Baseline Emission Factor is calculated by first defining an operation which is representative of the average population of units of this type in the SJV during the Baseline Period and then determining the specific emissions per unit throughput for the representative unit.

A. Representative Baseline Operation

For cotton gin dryers, the representative baseline operation has been determined to be a natural gas-fired dryer with burners with temperature control monitoring system, and standard efficiency fans and electric motors. This determination is based on conversations with representatives in the cotton ginning industry.

B. Basis and Assumptions

- All direct GHG emissions are produced due to combustion of LPG in this unit.
- GHG emissions are stated as "CO_2 equivalent" (CO_2e) which includes the global warming potential of methane and nitrous oxide emissions associated with gaseous fuel combustion.
- Fuel consumption for a representative unit is 0.33 MMBtu (NG)/500-lb bale. This number is based on emission inventory results from the baseline period for natural gas-fired cotton gin dryers.
- The GHG emission factor for natural gas combustion is 116 lb-CO_2e/MMBtu per CCAR document.
- Indirect emissions for a representative unit are produced due to operation of the push-pull fans on the drying system. The drying system consists of two 100 horsepower drying stages. The fans require a combined 200 horsepower.
- The hourly bale throughput rate for a representative unit is 38 bales per hour. This value was determined by taking the average bale throughput limits on cotton gin operations during the baseline period.
- Electric motor efficiency is estimated at 90% for a conventional electric motor.
- Indirect emissions from electric power consumption are calculated based on the current PG&E electric power generation factor of 0.524 lb- CO_2e per kWh.

C. Unit of Activity

To relate Business-as-Usual to an emissions generating activity, it is necessary to establish an emission factor per unit of activity, for the established class and category, using the 2002-2004 baseline period as the reference.

The resulting emissions factor is the combination of
GHG emission reductions achieved through technology, and
GHG emission reductions achieved through changes in activity efficiencies.

For cotton gin dryers, the GHG emission factor will be based on the amount of GHG emitted per 500-lb bale of cotton produced. This emission factor takes into account any GHG reductions associated with modifications to the cotton gin dryer as well as any GHG reductions associated with modifications to the cotton gin that would increase the amount of bales produced by the cotton gin.

D. Calculations

Direct GHG Emissions:

Direct GHG emissions are based on the amount of natural gas used by the cotton gin dryer to produce one bale of cotton. The calculation for these emissions is shown below:

Direct GHG Emissions = 0.33 MMBtu/bale x 116 lb-CO_2e/MMBtu
= 38.3 lb-CO_2e/bale

Indirect GHG Emissions:

Indirect GHG emissions are based on the electric motor horsepower of the cotton gin dryer fans and the amount of cotton that can be processed by the cotton gin. The calculation incorporates the electric motor horsepower efficiency of a conventional electric motor (90%). The calculation for these emissions is shown below.

Specific electricity consumption for the dryer fans are:

200 hp-hr ÷ 38 bales/hr x 0.7457 kW/hp x (1/90%) = 4.36 kWh/bale

Indirect GHG Emissions = 4.36 kWh/bale x 0.524 lb-CO_2e per kWh
= 2.3 lb-CO_2e/bale

Total GHG Emissions per Unit of Activity:

The Baseline Emission Factor is the sum of the direct and the indirect emissions:

BEF = 38.3 + 2.3 = 40.6 lb-CO_2e/bale

STEP 2. List Technologically Feasible GHG Emission Control Measures

A. Analysis of Potential Control Measures

The following findings and/or considerations are applicable to this class and category:

Use of Premium Efficiency Motors:

An electric motor efficiency standard is published by the National Electrical Manufacturers Association (NEMA) which is identified as the "NEMA Premium Efficiency Electric Motors Program". For large motors, the NEMA premium efficiency motor provides a gain of approximately 5-8 percentage points in motor efficiency when compared to a standard efficiency motor. The NEMA specification covers motors up to 500 horsepower and motors meeting this specification are in common use and are available from most major electric motor manufacturers.

Use of Speed Control on Fans:

Control of a fan operation by use of a variable speed electric motor provide substantial energy savings when compared to a fan which is operated at a fixed speed and controlled by throttling the discharge flow. The most common and economical variable speed drive is the variable frequency drive (VFD) which has become commonly available in the last decade and is becoming typical for new asphalt applications. The VFD provides especially significant energy savings when a fan is operated at substantial turndown ratios which can result in throttling away more than half the rated energy output of the motor.

However, industry has noted that the use of VFD's on cotton gins would result in severe air volume changes and drastically increase the potential for the gin to fail. Therefore, the use of a VFD to control the speed of the fans will not be used as a potential GHG emissions control measure.

Heat Recovery:

A heat recovery system would use the exhaust air from the dryer to heat the inlet air of the dryer. The heated incoming air would be introduced to the dryer at a higher temperature and therefore less fuel would need to be used to obtain the target air stream temperature. A heat recovery system would require a heat exchanger and additional ducting and fans to rout the heated air through the heat exchanger and back to the inlet of the dryer.

There are complex air flow and potential engineering hurdles of designing a heat exchanger and required increase in power requirements to overcome the pressure drop, none of which is currently available for the cotton ginning industry. When dealing with the quantities of air involved in conveying seed cotton, to recapture or reuse the energy (heated air) in the long run does not increase the overall efficiency. The vapor pressure gradient experienced, due to the high moisture laden air reentering the process, does not increase the overall efficiency. In addition, additional fans will be required to move the air, increasing the electric motor horsepower of the drying system. Therefore, heat recovery will not be used as a potential GHG emissions control measure.

Insulation of the Dryer Walls and Dryer Ducting:

To prevent heat loss through the walls of the dryer and the dryer ducting, insulation can be added to these systems. By adding insulation to the walls of the dryer and the ducting that carries the heated air throughout the drying system, the drying air retains its temperature for a longer time and therefore less fuel is need to be combusted to maintain the target drying temperature throughout the drying system.

Dryer Controls:

The control of the temperature of the air in a cotton gin dryer is very important since cotton fibers can be irreversibly damaged if they are exposed to temperatures above 350° F. Dryer controls utilize temperature sensors place in the drying air stream to control the firing rate of the dryer burners. By controlling the temperature of the air steam to a target temperature, the dryer burner can be operated according to the batch of cotton being processed resulting the reduction of fuel used. Dryer controls are almost universally incorporated on all cotton gin dryers.

Alternative Dryer Designs:

In a recent document titled "Retrospective View of Cotton Gin Dryers", The National Cotton Ginners Association (Memphis, TN) (see Appendix 3) discussed the various dryer systems that are currently being used in industry. Their discussions centered on physical descriptions of the different dryers; however in the summary of this document the writers concluded that "There is no best drying system for all gins. A best dryer design is the one that will meet the demands for that gin plant." The opinion that there is no best dryer design for all cotton gin drying operations has also been reiterated by other members of the cotton ginning community. Therefore, specifying a specific cotton gin dryer design will not be used as a potential GHG emissions control measure.

B. Listing of Technologically Feasible Control Measures

For the specific equipment or operation being proposed, all technologically feasible GHG emissions reduction measures are listed, including equipment selection, design elements and best management practices, that do not result in an increase in criteria pollutant emissions compared to the proposed equipment or operation.

Table 2
Technologically Feasible GHG Control Measures for Cotton Gin Dryers

GHG Control Measures	Qualifications
Electric motors driving dryer fans shall have an efficiency meeting the standards of the National Electrical Manufacturer's Association (NEMA) for "premium efficiency" motors.	Use of premium efficiency motors on all fans significantly reduces electric power consumption by the drying operation.
Insulation of ducting from the burner to the dryer inlet.	The insulation of the ducting from the burner to the dryer inlet reduces the heat loss of the drying air in the drying system which results in less fuel needing to be combusted to heat the drying air.
Insulation of the cotton dryer.	The insulation of the cotton dryer reduces the heat loss of the drying air in the dryer which results in less fuel needing to be combusted to heat the drying air.
Dryer controls and temperature sensors.	Most cotton gins in operation utilize a dryer control system with temperature sensors.
• Premium-efficiency electric motors on all dryer fans, and • Insulation of ducting from the burner to the dryer inlet, and • Utilization of dryer controls and temperature sensors.	The qualifications for this combined control measure are listed above in this table.

All of the GHG emissions control measures identified above are equipped with control equipment for criteria pollutants which meets current regulatory requirements. None of the identified GHG emission control measures would result in an increase in emissions of criteria pollutants.

STEP 3. Identify all Achieved-in-Practice GHG Emission Control Measures

For all technologically feasible GHG emission reduction measures, all GHG reduction measures determined to be Achieved-in-Practice are identified. Achieved-in-Practice is defined as any equipment, technology, practice or operation available in the United States that has been installed and operated or used at a commercial or stationary source site for a reasonable period of time sufficient to demonstrate that the equipment, the technology, the practice or the operation is reliable when operated in a manner that is typical for the process. In determining whether equipment, technology, practice or operation is Achieved-in-Practice, the District will consider the extent to which grants, incentives or other financial subsidies influence the economic feasibility of its use.

The following findings or considerations are applicable to this class and category:

- Premium efficiency electric motors are readily available and currently operating at many facilities.

- Insulating of the dryer walls and dryer ducting is not a common practice; however based on conversations with members in industry, insulated dryer walls and ducting have been installed at several cotton gins in the United States. In a conversation with the USDA, it was stated that when insulation is installed at a cotton gin, it is usually just on the ducting from the burner to the cotton pickup point and from the pickup point to the dryer. Insulation in these sections of the drying system will provide the largest energy savings due to the air in these sections of the drying system having the highest temperature. Once the air and cotton is introduced into the dryer, the temperature of the mixture is significantly reduced and the energy savings due to the installation of insulation is also reduced.

  In addition, the number of drying stages in a cotton gin's drying system varies from cotton gin to cotton gin. Most cotton gins are equipped with either two or three drying stages, and based on comments received from CCGGA and further evaluation by the District, the majority of moisture in the cotton is removed in the first stages of the drying system. The final stage in the cotton drying operation is commonly operated with ambient temperature air or with low heat from burners. Since the temperature of the air used in the last stage of drying systems is usually low, insulation of the ducting in this stage of the drying system will not result in a significant reduction in fuel consumption. Therefore, insulation of the ducting in the final stage of the drying operation will not be considered a practical and efficient measure to improve the overall energy efficiency of the cotton gin's drying system.

Since the insulation of the cotton gin dryer walls is not commonly installed and is not expected to provide significant reduction in fuel consumption, the insulation of the dryer walls will not be considered achieved in practice. However, the insulation of the ducting from the burner to the dryer inlet is more common at cotton gins and is expected to significantly reduce fuel consumption. Therefore, the insulation of the ducting from the burner to the dryer inlet is considered achieved in practice.

- Dryer controls and temperature sensors were being utilized my most cotton gin dryers during the baseline period. Since the GHG emissions reductions from this technology were already taken into account during the calculation of the baseline emissions, the GHG emissions reductions associated with this GHG emissions control measure will not be calculated. However, this GHG emissions control measure will be combined with all the other GHG emissions control measures to ensure cotton gin dryers are operating with this equipment.

Based on a review of available technology and with consideration of input from industry, manufacturers and other members of the public, the GHG emission control measures in the following table are determined to be the Achieved-in-Practice (AIP) for this class and category. In addition, all the AIP control measures listed above can be implemented independently of each other or concurrently with each other. Therefore, individual, as well as combined, GHG emission control measures are listed in the table below.

<table>
<tr><th colspan="2">Table 3
Achieved-in-Practice GHG Control Measures for Cotton Gin Dryers</th></tr>
<tr><th>GHG Control Measures</th><th>Achieved-Qualifications</th></tr>
<tr><td>• Premium-efficiency electric motors on all dryer fans, and
• Utilization of dryer controls and temperature sensors.</td><td>High-efficiency fans and premium efficiency electric motors are commonly available and used in multiple industries to reduce electric power consumption. Dryer controls and temperature sensors are almost universally incorporated on all cotton gin dryers.</td></tr>
<tr><td>• Insulation of ducting from the burner to the dryer inlet as follows:
– on the first drying stage for cotton gin drying operations designed with one or two drying stages, or
– on the first two drying stages for cotton gin drying operations designed with three or more drying stages,
And
• Utilization of dryer controls and temperature sensors.</td><td>Insulated ducting is in place at several cotton gins in the United States. Dryer controls and temperature sensors are almost universally incorporated on all cotton gin dryers.</td></tr>
<tr><td>• Premium-efficiency electric motors on all dryer fans,
And
• Insulation of ducting from the burner to the dryer inlet as follows:
– on the first drying stage for cotton gin drying operations designed with one or two drying stages, or
– on the first two drying stages for cotton gin drying operations designed with three or more drying stages,
And
• Utilization of dryer controls and temperature sensors.</td><td>As discussed in this table, all of these GHG control measures are achieved in practice.</td></tr>
</table>

STEP 4. Quantify the Potential GHG Emission and Percent Reduction for Each Identified Achieved-in-Practice GHG Emission Control Measure

For each Achieved-in-Practice GHG emission reduction measure identified:

a. Quantify the potential GHG emissions per unit of activity (G_a)
b. Express the potential GHG emission reduction as a percent (G_p) of Baseline GHG emissions factor per unit of activity (BEF)

Premium-Efficiency Electric Motors, and Utilization of Dryer Controls and Temperature Sensors

A. Basis and Assumptions:

- All direct GHG emissions are produced due to combustion of natural gas in this unit.
- Fuel consumption for a representative unit is 0.33 MMBtu (NG)/500-lb bale. This number is based on emission inventory results from the baseline period for natural gas-fired cotton gin dryers.
- The GHG emission factor for natural gas combustion is 116 lb-CO_2e/MMBtu per CCAR document.
- Indirect emissions for a representative unit are produced due to operation of the push-pull fans on the drying system. The drying system consists of two 100 horsepower drying stages. The fans require a combined 200 horsepower.
- The hourly bale throughput rate for a representative unit is 38 bales per hour. This value was determined by taking the average bale throughput limits on cotton gin operations during the baseline period.
- Electric motor efficiency is 95%.
- Indirect emissions from electric power consumption are calculated based on the current PG&E electric power generation factor of 0.524 lb-CO_2e per kWh

B. Calculation of Potential GHG Emissions per Unit of Activity (G_a):

Direct GHG Emissions:

Direct GHG Emissions = 0.33 MMBtu/bale x 116 lb-CO_2e/MMBtu
= 38.3 lb-CO_2e/bale

Indirect GHG Emissions:

Indirect GHG emissions are based on the electric motor horsepower of the cotton gin dryer fans and the amount of cotton that can be processed by the cotton gin. The calculation incorporates the reduction in electric motor horsepower caused by the use of premium efficiency electric motors (95%). The calculation for these emissions is shown below.

Specific electricity consumption for the dryer fans are:

200 hp-hr ÷ 38 bales/hr x 0.7457 kW/hp x (1/95%) = 4.1 kWh/bale

Indirect GHG Emissions = 4.1 kWh/bale x 0.524 lb-CO_2e per kWh
= 2.2 lb-CO_2e/bale

<u>Total GHG Emissions per Unit of Activity:</u>

The Baseline Emission Factor is the sum of the direct and the indirect emissions:

G_a = 38.3 + 2.2 = 40.5 lb-CO_2e/bale

C. Calculation of Potential GHG Emission Reduction as a Percentage of the Baseline Emission Factor (G_p):

G_p = (BEF - G_a) / BEF = (40.6 – 40.5)/40.6 = 0.2%

<u>Insulation of ducting from the burner to the dryer inlet on the first drying stage (if the cotton drying operation is designed with one or two drying stages) or the first two drying stages (if the cotton drying operation is designed with three or more drying stages), and Utilization of Dryer Controls and Temperature Sensors</u>

Two studies on the fuel savings from the insulation of cotton gin ducting and the dryer were performed in the late 1970's (Appendix 4). These two studies concluded that insulating the dryer ducting and dryer walls could result in fuel savings of 21 to 28 percent. However, a USDA representative stated that since these studies were performed on gins operating in the 1970's, the gins would have lacked some of the technological advances commonly equipped on modern gins. These include cotton modules in the harvesting process, larger diameter ducting to handle higher quantities of cotton and air, and better burner and burner controls. With these advances in gin technology, the fuel savings from insulation would be significantly lower. Since there have not been any current studies of fuel savings due to the installation of insulation on cotton gin ducting, the District will conservatively assume fuel savings of 5% (20% of the 1970's median test value of 25%) over the baseline until additional data can be collected.

A. Basis and Assumptions:

- All direct GHG emissions are produced due to combustion of natural gas in this unit.
- Fuel consumption for a representative unit is 0.33 MMBtu (NG)/500-lb bale. This number is based on emission inventory results from the baseline period for natural gas-fired cotton gin dryers.
- The GHG emission factor for natural gas combustion is 116 lb-CO_2e/MMBtu per CCAR document.
- Indirect emissions for a representative unit are produced due to operation of the push-pull fans on the drying system. The drying system consists of two 100 horsepower drying stages. The fans require a combined 200 horsepower.
- The hourly bale throughput rate for a representative unit is 38 bales per hour. This value was determined by taking the average bale throughput limits on cotton gin operations during the baseline period.
- A 5% reduction in fuel usage is expected from the insulation of the ducting from the burner to the dryer inlet.
- Electric motor efficiency is estimated at 90% for a conventional electric motor.
- Indirect emissions from electric power consumption are calculated based on the current PG&E electric power generation factor of 0.524 lb-CO_2e per kWh

B. Calculation of Potential GHG Emissions per Unit of Activity (G_a):

Direct GHG Emissions:

Direct GHG emissions are based on the amount of natural gas used by the cotton gin dryer to produce one bale of cotton. The insulation of the ducting from the burner to the dryer inlet is expected to decrease the fuel usage by 5%. The calculation for these emissions is shown below:

$$\text{Direct GHG Emissions} = 0.33 \text{ MMBtu/bale} \times 116 \text{ lb-}CO_2\text{e/MMBtu} \times (1 - 0.05)$$
$$= 36.4 \text{ lb-}CO_2\text{e/bale}$$

Indirect GHG Emissions:

Indirect GHG emissions are based on the electric motor horsepower of the cotton gin dryer fans and the amount of cotton that can be processed by the cotton gin. The calculation incorporates the reduction in electric motor horsepower caused by the use of premium efficiency electric motors (95%). The calculation for these emissions is shown below.

Specific electricity consumption for the dryer fans are:

200 hp-hr ÷ 38 bales/hr x 0.7457 kW/hp x (1/90%) = 4.4 kWh/bale

Indirect GHG Emissions = 4.4 kWh/bale x 0.524 lb-CO_2e per kWh
= 2.3 lb-CO_2e/bale

Total GHG Emissions per Unit of Activity:

The Baseline Emission Factor is the sum of the direct and the indirect emissions:

G_a = 36.4 + 2.3 = 38.7 lb-CO_2e/bale

C. Calculation of Potential GHG Emission Reduction as a Percentage of the Baseline Emission Factor (G_p):

G_p = (BEF - G_a) / BEF = (40.6 – 38.7)/40.6 = 4.7%

Premium-Efficiency Electric Motors, and Insulation of ducting from the burner to the dryer inlet on the first drying stage (if the cotton drying operation is designed with one or two drying stages) or the first two drying stages (if the cotton drying operation is designed with three or more drying stages), and Utilization of Dryer Controls and Temperature Sensors

A. Basis and Assumptions:

- All direct GHG emissions are produced due to combustion of natural gas in this unit.
- Fuel consumption for a representative unit is 0.33 MMBtu (NG)/500-lb bale. This number is based on emission inventory results from the baseline period for natural gas-fired cotton gin dryers.
- The GHG emission factor for natural gas combustion is 116 lb-CO_2e/MMBtu per CCAR document.
- Indirect emissions for a representative unit are produced due to operation of the push-pull fans on the drying system. The drying system consists of two 100 horsepower drying stages. The fans require a combined 200 horsepower.
- The hourly bale throughput rate for a representative unit is 38 bales per hour. This value was determined by taking the average bale throughput limits on cotton gin operations during the baseline period.
- A 5% reduction in fuel usage is expected from the insulation of the ducting from the burner to the dryer inlet.

- Electric motor efficiency is 95%.
- Indirect emissions from electric power consumption are calculated based on the current PG&E electric power generation factor of 0.524 lb-CO_2e per kWh

B. Calculation of Potential GHG Emissions per Unit of Activity (G_a):

Direct GHG Emissions:

Direct GHG emissions are based on the amount of natural gas used by the cotton gin dryer to produce one bale of cotton. The insulation of the ducting from the burner to the dryer inlet is expected to decrease the fuel usage by 5%. The calculation for these emissions is shown below:

Direct GHG Emissions = 0.33 MMBtu/bale x 116 lb-CO_2e/MMBtu x (1 – 0.05)
= 36.4 lb-CO_2e/bale

Indirect GHG Emissions:

Indirect GHG emissions are based on the electric motor horsepower of the cotton gin dryer fans and the amount of cotton that can be processed by the cotton gin. The calculation incorporates the reduction in electric motor horsepower caused by the use of premium efficiency electric motors (95%). The calculation for these emissions is shown below.

Specific electricity consumption for the dryer fans are:

200 hp-hr ÷ 38 bales/hr x 0.7457 kW/hp x (1/95%) = 4.1 kWh/bale

Indirect GHG Emissions = 4.1 kWh/bale x 0.524 lb-CO_2e per kWh
= 2.2 lb-CO_2e/bale

Total GHG Emissions per Unit of Activity:

The Baseline Emission Factor is the sum of the direct and the indirect emissions:

G_a = 36.4 + 2.2 = 38.6 lb-CO_2e/bale

C. Calculation of Potential GHG Emission Reduction as a Percentage of the Baseline Emission Factor (G_p):

G_p = (BEF - G_a) / BEF = (40.6 – 38.6)/40.6 = 4.9%

STEP 5. Rank all Achieved-in-Practice GHG emission reduction measures by order of % GHG emissions reduction

Based on the calculations presented in Section II.4 above, the Achieved-in Practice GHG emission reduction measures are ranked in the table below:

Table 4 **Ranking of Achieved-in-Practice GHG Emission Control Measures**			
Rank	**GHG Control Measures**	**Potential GHG Emission per Unit of Activity (G_a) (lb-CO_2e/bale)**	**Potential GHG Emission Reduction as a Percentage of the Baseline Emission Factor (G_p)**
1	• Premium-efficiency electric motors on all dryer fans, **And** • Insulation of ducting from the burner to the dryer inlet as follows: – on the first drying stage for cotton gin drying operations designed with one or two drying stages, **or** – on the first two drying stages for cotton gin drying operations designed with three or more drying stages, **And** • Utilization of dryer controls and temperature sensors.	38.6	4.9%
2	• Insulation of ducting from the burner to the dryer inlet as follows: – on the first drying stage for cotton gin drying operations designed with one or two drying stages, **or** – on the first two drying stages for cotton gin drying operations designed with three or more drying stages, **And** • Utilization of dryer controls and temperature sensors.	38.7	4.7%
3	• Premium-efficiency electric motors on all dryer fans, **And** • Utilization of dryer controls and temperature sensors.	40.5	0.2%

STEP 6. Establish the Best Performance Standard (BPS) for this Class and Category

For Stationary Source Projects for which the District must issue permits, Best Performance Standard is – "For a specific Class and Category, the most effective, District approved, Achieved-In-Practice means of reducing or limiting GHG emissions from a GHG emissions source, that is also economically feasible per the definition of achieved-in-practice. BPS includes equipment type, equipment design, and operational and maintenance practices for the identified service, operation, or emissions unit class and category".

Based on the definition above and the ranking of evaluated technologies, Best Performance Standard (BPS) for this class and category is determined as:

<u>**Best Performance Standard for Cotton Gin Dryers**</u>

- **Premium-efficiency electric motors on all dryer fans,**

And

- **Insulation of ducting from the burner to the dryer inlet as follows:**
  - **on the first drying stage for cotton gin drying operations designed with one or two drying stages, or**
  - **on the first two drying stages for cotton gin drying operations designed with three or more drying stages,**

And

- **Utilization of dryer controls and temperature sensors.**

STEP 7. Eliminate All Other Achieved-in-Practice Options from Consideration as Best Performance Standard

The following Achieved-in-Practice GHG control measures identified and ranked in the table above are eliminated from consideration as Best Performance Standard since they have GHG control efficiencies which are less than that of the selected Best Performance Standard as stated in Step 6 of this evaluation:

- Insulation of ducting from the burner to the dryer inlet as follows:
  - on the first drying stage for cotton gin drying operations designed with one or two drying stages, **or**
  - on the first two drying stages for cotton gin drying operations designed with three or more drying stages,

- Premium-efficiency electric motors on all dryer fans, and utilization of dryer controls and temperature sensors.

VI. Public Participation

A Draft BPS evaluation was provided for public comment. Public notification was sent on 4/13/12 to individuals registered with the CCAP list server. The District's notification is attached as Appendix 7. No comments were received during the public notification period

VIII. Appendices

Appendix 1:	Baseline Units - Emissions Inventory
Appendix 2:	Baseline Units - Permitted Throughput Limits
Appendix 3:	Retrospective View of Cotton Gin Dryers
Appendix 4:	Cotton Gin Insulation Articles
Appendix 5:	Public Notice of Intent: Notice
Appendix 6:	Comments Received During the Public Notice of Intent
Appendix 7:	Public Participation Process: Public Notice

Appendix 1

Baseline Units – Emissions Inventory

Cotton Gin Dryers Emissions Inventory Baseline Years (2002 - 2004)			
Gin	**Year**	**LPG Fired Units (MMBtu/Bale)**	**NG Fired Units (MMBtu/Bale)**
1	2002		0.632911392
	2004		0.675675676
2	2002		0.274725275
	2003		0.303030303
	2004		0.333333333
3	2002	0.526103956	
	2003	0.4411552	
	2004	0.438996306	
4	2004	0.439861552	
5	2003		0.294117647
			0.152905199
	2004		0.255102041
			0.204081633
6	2002		0.215517241
	2003		0.24691358
	2004		0.27027027
7	2002		0.4
	2003		0.694444444
8	2002		0.104166667
			0.549450549
	2003		0.340136054
			0.641025641
	2004		0.395256917
			0.787401575
9	2002		0.126903553
	2003		0.197628458
10	2002		0.125
			0.101936799
	2003		0.085689803
			0.087032202
11	2002		0.216450216
	2004		0.21978022
12	2002	0.138000724	
	2003	0.186742316	
	2004	0.195129233	
13	2002	0.080179462	
	2003	0.190672668	
	2004	0.153830635	
14	2002		0.299401198
	2003		0.326797386
	2004		0.248756219

15	2002		0.354609929
	2003		0.320512821
	2004		0.321543408
16	2002		0.24691358
	2003		0.340136054
	2004		0.272479564
17	2004		0.632911392
18	2003		0.4048583

Average (MMBtu/bale)	**0.279067205**	**0.325636065**
Average (lb-CO2e/bale)	**38.51432422**	**47.87696812**

Appendix 2

Baseline Units – Permitted Throughput Limits

Cotton Gin Daily Bale Throughput Permitted Limits

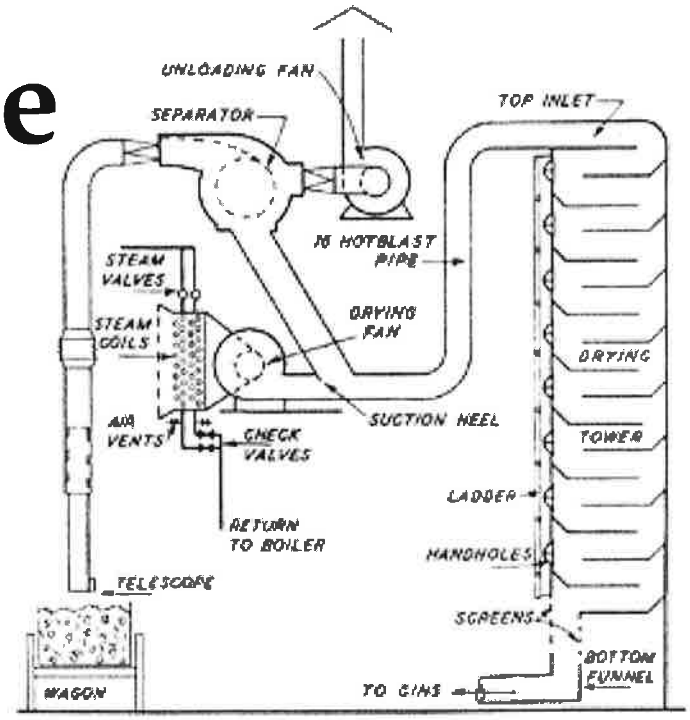
		Daily Bale Throughput Limit
Gin #	1	1200
Gin #	2	720
Gin #	3	720
Gin #	4	360
Gin #	5	840
Gin #	6	672
Gin #	7	5664
Gin #	8	782
Gin #	9	600
Gin #	10	720
Gin #	11	400
Gin #	12	1025
Gin #	13	900
Gin #	14	360
Gin #	15	576
Gin #	16	1008
Gin #	17	600
Gin #	18	700
Gin #	19	600
Gin #	20	550
Gin #	21	1163
Gin #	22	1052
Gin #	23	980
Gin #	24	768
Gin #	25	126

923.4	**Average Daily Bale Throughput Limit**
38.5	**Average Hourly Bale Throughput Limit**

Appendix 3

Retrospective View of Cotton Gin Dryers

Retrospective View of Cotton Gin Dryers



Gino J. Mangialardi, Jr.

and

W. Stanley Anthony

Published by
The National Cotton
Ginners Association
Memphis, TN

RETROSPECTIVE VIEW OF COTTON GIN DRYERS[1]

Gino J. Mangialardi, Jr.
and
W. Stanley Anthony[2]

ABSTRACT

This paper reviews gin dryer designs and compiles most of the significant research conducted on the drying of seed cotton at cotton gins since about 1929. It describes the operation of various types of dryers and gives a critical appraisal of dryer designs that may be useful at current cotton gins. The compiled information and recommendations should prove useful to scientists planning future gin drying studies, and to engineers selecting dryer designs for commercial gins.

Keywords: cotton ginning, drying systems, gin drying, seed cotton drying.

INTRODUCTION

The first seed-cotton dryers appeared in cotton gins during the late 1920s. The United States Department of Agriculture (USDA) began to study artificial seed cotton drying procedures in 1926. It established the U.S. Cotton Ginning Laboratory at Stoneville, MS, in 1930 to investigate drying and ginning problems. In 1931 only about 15 gins in the U.S. were equipped with dryers (Gerdes et al., 1941).

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[1]For publication by The Cotton Foundation, Memphis, TN.

[2]Agricultural Engineer (Retired) and Supervisory Agricultural Engineer, respectively, U.S. Cotton Ginning Laboratory, Agricultural Research Service, USDA, Stoneville, MS. 38776.

Some of the dryers developed for gins included a horizontal zigzag belt dryer supported on rollers (1924); a chemical, calcium-chloride heatless dryer (1926); and a horizontal distributor-dryer (1928). Types of drying apparatus built and tested by engineers of the USDA from 1926-1930 included the horizontal and vertical tray-type dryers, and the horizontal and vertical drag-type dryers. In the horizontal drag type dryer, skeleton conveyers dragged seed cotton along four or six sheet-metal floors through which heated air flowed (Bennett, 1962).

The tray and drag-type dryers were superseded by the USDA developed vertical dryer, which was used on the 1932 crop. It became well known as the "Government Tower-Drier". The vertical dryer contained "floors" or shelves over which a continuous current of hot air transported the seed cotton (Bennett and Gerdes, 1936).

Other seed-cotton dryers used at cotton gins during the 1930's included an improved design roller dryer (1930); vertical, conceal drier, with heater (1931); twin rotary tubular units (1932); unit distributor (1932); feeder-extractor-cleaner (1934); and the Continental conveyer-distributor (1934). Dryers developed or in operation in 1936 were a stub tower, cleaner, and feeders, two stage drying; three types with hot air in cleaner, and a fourth type with stub tower and cleaner; a 16-cylinder spider-arm cleaner with concurrent hot air flows; and a thermo-cleaner dryer, also combined with one or two Government Tower units for multi-stage drying. The Big-Reel cleaner drier was introduced in 1937; as was the multiunit Tower Dryer, upper section with plain shelves and lower section with beaters. In 1938, several manufacturers began building various type of Government tower dryers (Bennett, 1962).

OBJECTIVE

This paper reviews and compiles most of the significant research conducted on the drying of seed cotton since about 1929. It describes the operation of various types of dryers and gives a critical appraisal of dryer designs that may be useful at current cotton gins. Materials from the review are arranged chronologically into two sections, Gin – Dryer Research and Cotton Gin Dryers. The compiled information and recommendations should prove useful to scientists planning future gin drying studies, and to engineers selecting dryer designs for commercial gins. It also provides some guidance for gin owners in balancing the cost of a drying system against the needs of the gin.

GIN – DRYER RESEARCH

Background Information

Cotton Quality

A study was conducted at the U.S. Cotton Ginning Research Laboratory (USCGL), ARS, USDA, Stoneville, MS, to determine the effect of fiber moisture content on breaking strength of individual cotton fibers. The results showed that cotton fibers are weaker at lower moisture content than at higher moisture levels. Therefore, cotton ginned at low moisture levels is certain to contain more broken fibers than cotton ginned at higher moisture levels. It was recommended that gin dryers should be adjusted to produce lint at the gin stand with moisture content at about seven percent. It was also suggested that moisture might be added to seed cotton of less than six percent fiber moisture before it reaches the fiber-separation process in order to improve the ginning quality of the cotton. Ginning with fiber moisture content above eight percent is expected to give operating difficulties and rough preparation (Moore and Griffin, 1964).

Basics of Drying

The mechanisms involved in the removal of moisture from seed cotton are described by researchers in the vapor pressure theory of drying. As the temperature of the seed cotton increases the vapor pressure inside the seed-cotton components increases, and there is a flow of moisture from points of high to points of low vapor pressure. The amount of flow is approximately proportional to the vapor pressure differences between the cotton and surrounding atmosphere (Hall, 1957).

Cotton dries at a falling rate, which is why the drying rate is highest at the beginning of the drying period and decreases as the cotton is dried. At a temperature of about 250° F or higher, the cotton surface moisture is removed during the first three seconds of drying. The airflow should be sufficient to carry off the evaporated moisture so that a low relative humidity can be maintained in the heated air stream (Griffin and Mangialardi, 1961; Leonard, 1964).

The four basic factors that determine the effectiveness of seed cotton drying systems are drying air temperature, air volume, time of exposure, and the relative speed of the air and the cotton (slip). Various gin cotton drying systems offer varying levels of these basic factors. There are many combinations of these factors, which will satisfactorily dry cotton (Mayfield, 1996).

Design Concepts

Parallel-Flow Dryer

Most cotton gins still dry seed cotton utilizing the shelf-type tower dryer. The dryer operates on the parallel-flow principle where the drying air is also the conveying medium. Current tower dryers contain 16-24 shelves and conveying air velocities through the shelves are generally in the 1,000 to 2,000-ft/min range. Two centrifugal fans in a push-pull fan arrangement provide hot conveying air through the serpentine passageways (shelves) in the tower dryer. Conveyed seed cotton impacts the dryer walls as it changes direction between each shelf. This action improves the drying process by agitating the seed cotton, forcing the hot air to pass through the cotton, and helps to lengthen the exposure period. Seed cotton may be in a dryer up to about 12 seconds. For wet seed cotton, it is usually necessary to employ two stages of tower dryers for adequate moisture control. Traditional tower dryers use about 20 cubic feet of hot air per pound of seed cotton (Baker and Griffin, 1983).

Multiple-Path Drying

A 1959 experiment at the USDA Stoneville Laboratory with a 300-foot pipe drying system revealed that moisture evaporation is very rapid for 2 or 3 seconds. These data indicated that the drying curve breaks sharply when the cotton surface moisture has been removed. The pipe-drying and other research led to the design and construction of a multiple-path tower dryer capable of path selection (Franks and Shaw, 1962).

The multiple-path drying system consisted of a conventional 24-shelf tower dryer, modified to provide three drying paths (Figure 1). Cotton could be fed into the dryer at the top for 24 shelves of drying, into the center of dryer for 13 shelves, or at the bottom of the tower for 1 shelf of drying. In a 1960 experiment, using a temperature of 250° F at the mixpoint the multiple-path dryer reduced seed cotton moisture content from 12.6 percent at the wagon to 11.0, 10.5, and 10.1 percent at the feeder apron after the cotton passed through the short, middle, and long paths, respectively.

Monoflow System

The Monoflow cotton ginning system was developed at the USDA Southwestern Cotton Ginning Research Laboratory, Mesilla Park, NM about 1963. There are two air streams in the monoflow system, although only one enters and leaves the gin building. The entering air stream is the seed-cotton handling air. It enters the wagon suction pipe and conveys the seed cotton to the wagon separator. This air is cleaned, and then reused and recleaned after passage through each seed-cotton cleaning separator. After the final seed-cotton separator, this air stream is exhausted to the outside. The air must be moisture conditioned one or more times during cleanings. It is heated if the cotton is to be dried, or humidified if moisture is to be added or restored to the cotton. An inline air filter was used in the air stream ahead of every direct-fired burner (Leonard and Gillum, 1968).

The second air stream is used to convey the lint from the gin stands to the lint cleaners, and thence to the press condenser. This second air stream is pulled from the gin room and recirculated within the gin building; it may be cleaned and moisture removed or added.

In a later experiment, with natural gas as the fuel, the monoflow air system was successfully used with two stages of seed-cotton drying. The monoflow operational mode used 20-percent less total fuel than the conventional two-tower mode, and there were no differences between the modes in seed-cotton drying. In the monoflow mode heat recovery was achieved by feeding the warm exhaust air from the first stage of drying to the intake of the second stage (Leonard et al., 1979).

Moving Bed Dryer

A moving bed wire belt dryer was designed and constructed at the USDA Cotton Ginning Research Laboratory, Stoneville, MS, in 1963. Airflow was arranged so there was virtually no temperature gradient from cotton inlet to cotton outlet. The drying factors air-to-cotton mass ratio, temperature, and exposure period were studied. Comparison experiments showed the moving bed dryer to be less efficient in moisture removal than the two-tower drying system. Both procedures utilized 20 seconds of exposure. The principal conclusion drawn from the experiments was that some agitation--tumbling or stirring--of a seed-cotton mass during drying provides more rapid and more uniform drying than that provided by heated air moving through an unagitated bed of cotton where new surfaces are not continuously exposed by the tumbling action (Mangialardi and Griffin, 1968). This reinforces the contribution of "slippage" as one of the four basic factors of drying (Mayfield, 1996).

Vacuum Drying

A continuous-flow vacuum dryer was constructed and tested at the USCGL, ARS, USDA, Stoneville, MS, in 1968-69. A lobe-type rotary blower produced a vacuum pressure of approximately eight inches of mercury within a chamber through which three flexible steel conveyor belts transported a batt of seed cotton. Exposure time in the partial-vacuum chamber was controlled by the speed of the conveyor belts. The average seed-cotton moisture content decreased from 11.4 to 9.5 percent in one test series after four minutes of drying, and from 7.8 to 6.3 percent in a second series after eight minutes of drying. It was determined that the procedure is too slow to be practicable in ginneries (Mangialardi and Griffin, 1974). Vacuum drying at gins might become feasible if the ginning system is redesigned to allow longer drying periods, and more individual cotton locks are exposed by greater agitation of the seed-cotton batt. Vacuum plus heated air might have some merit as vacuum would lower the "boiling point" of the moisture.

Belt Dryer

A workable belt dryer was developed in Texas about 1983. The equipment used consisted of a 50 foot long by two-foot wide flat wire mesh belt conveyor with air plenums enclosing the areas above and below the belt. In experiments a drying front was forced through an 18-inch depth of cotton in about 65 seconds with downward aeration of 50 cubic feet of air per minute per square foot of belt surface. Aeration downwards through the cotton was nearly twice as effective in reducing moisture content as aeration upward. Heat utilization efficiency for the belt dryer was approximately twice that reported for a tower dryer system (Laird and Smith, 1992).

Counter-Flow Drying

An experimental counter-flow dryer was built and tested at the USDA Southwestern Cotton Ginning Research Laboratory, Mesilla Park, NM, about 1985. The counter-flow dryer used rotating spiked cylinder cleaner type cylinders to convey seed cotton 20 feet against a counter flowing heated air stream. Seed cotton had a dryer residency time of approximately 14 seconds. Using an air temperature of 200° F and seed cotton of 13 to 17-percent moisture content, the experimental dryer could dry the lint fraction of the seed cotton down to an average of 7.4

percent. Possible advantages to the industry could be conveying, drying, and cleaning in one compact operation; or a reduction in horsepower required for present systems (Hughs et al., 1986).

Cross-Flow Dryer

A cross-flow dryer-belt transport system was tested in New Mexico about 1985. In addition to drying, the belt-conveyor procedure moved cotton from the module into the gin. Packing density of machine-stripped cotton on the belt was approximately two pounds per cubic foot, and air velocity through the batt was about 50 feet per minute. Results showed that about 48 seconds gave adequate drying for depths of 12 to 14 inches of seed cotton on the belts, and approximately 60 seconds would be needed for 18 inches of depth. In one experiment a 60-second pass over the belt at 300 degrees F with 15 bales of 20.2-percent moisture content seed cotton resulted in trouble-free ginning (Hughs et al., 1986).

Drying System Improvements

Automatic Control

Automatic control of seed-cotton drying at cotton gins was demonstrated at Stoneville in 1960. A moisture detector measured the electrical resistance of seed cotton passing between two rotating electrodes as an index to fiber moisture content. Based on the measured moisture content, the detector changed the drying exposure period by throwing directional valves in a three-path (multipath) dryer. The moisture detector used a servomotor to position a recording pen, then through cams and snap-action switches, energized solenoids that activated pneumatic cylinders to operate the 3-path dryer directing valves. The automatic system caused dry cotton to bypass the dryer (1 shelf), damp cotton to bypass half of the dryer (13 shelves), and damper cotton to bypass none of the dryer (24 shelves) (Griffin and Mangialardi, 1961).

This automatic drying procedure was expanded into a complete moisture control system in 1967 by integrating moisture restoration. In addition to drying damp seed cotton in the three-path dryer, the detector activated a moisture restoration unit when dry cotton was processed and introduced humid air at about 85-percent relative humidity into the seed-cotton batt between conveyor distributor and extractor feeder. Thus, the moisture content of dry cotton (below 5-percent) was increased before fiber-seed separation in the gin stand (Griffin and Mangialardi, 1967).

Airflow Rates

A cotton-handling pipe system of eight-inch diameter was designed and installed at the USCGL, ARS, USDA, Stoneville, MS, in 1972 to ascertain the minimum air velocities and air-to-cotton ratios that would be sufficient to convey seed cotton at the range of moisture levels encountered at gins. Seed cotton was conveyed through the pipe by suction. Results showed that at a seed-cotton moisture content of about 10 percent, average air velocities of 900 or 1,000 ft/min at the center of the pipe were inadequate to convey seed cotton in mass and moved only a few cotton locks a few feet. Air velocity appeared to be more important than the air-to-cotton ratio (ft^3 air/lb seed cotton) in maintenance of normal cotton flow. With an average air velocity of 2,550 ft/min at an air-to-cotton ratio of 9.3 seed cotton of 22.2-percent moisture content flowed normally (Mangialardi, 1977).

Further experiments in 1978-79 showed that the minimum quantity of conveying air at 230 - 240° F would also be sufficient for adequate moisture removal in shelf drying systems. Two 24-shelf dryers were used in the study. Seed cotton was transported through each dryer by two fans in a push-pull arrangement. The study showed that the minimum air velocity in the shelf dryer, measured under standard air conditions, should be about 1,200 ft/min for seed cotton at 18-percent moisture and about 1,000 ft/min for cotton at 10-percent moisture. These velocities would be used with air-to-cotton ratios of 11 to 13 ft^3 air/lb seed cotton. It was indicated that problems with cotton flow could be expected at velocities below 900 ft/min and air-to-cotton ratios below about 9.7 ft^3/lb (Mangialardi, 1986).

Equilibrium Moisture

A part of the ginning research program at the U.S. Cotton Ginning Research Laboratory, USDA, Stoneville, MS, involved determining the equilibrium moisture content of cotton approaching equilibrium from very dry and very wet initial conditions. In the experiment, lint ginned from newly harvested samples was preconditioned dry (1.3 percent) or wet (19.5 percent) and then exposed to atmosphere covering a range of relative humidities. After being subjected to atmosphere of 12, 33, 53, 75, and 94 percent relative humidity, the preconditioned dry samples averaged 2.4, 4.4, 6.2, 8.8, and 15.2 percent moisture content, respectively. Corresponding lint moisture contents for the preconditioned wet samples were 3.8, 6.3, 8.1, 10.6, and 16.3 percent (Griffin, 1974).

Later work at the Cropping Systems Laboratory, Cotton Production and Processing Research Unit, USDA, Lubbock, TX, demonstrated the effect of drying temperature on the equilibrium moisture contents for raw cotton. Satisfactory lint cotton absorption equilibrium data was obtained for four temperature ranges. Results showed that as temperature increases, the equilibrium moisture content of the lint decreases for constant values of relative humidity up to 85%. For temperatures greater than 47° C and relative humidities above 85%, the moisture content increased with increasing temperature (Barker, 1992).

Heat Recovery

A heat-recovery incineration system performed well in tests at Stoneville, MS, in 1975. The heat exchanger, as designed by the USDA Cotton Ginning Research Laboratory, was capable of recovering and delivering to the gin drying system about 31 percent of the available heat from combustion. The recovered heat is equivalent to 2,100 Btu/lb of gin trash burned (McCaskill et al., 1977).

The system was composed of a continuous trash feeder, two burning chambers, a heat exchanger in the stack, a modulating hot-air mixing value, and a conventional gin drying system. The multichamber incinerator was a Consumat Model C-125 rated at 470 lb/hr of type "O" waste. Particulate emission from the system was calculated to be 0.36 grain per dry standard cubic foot, corrected to 12-percent CO_2. No conclusions were reached pertaining to the expected life of the system, nor had it undergone the prolonged operation that would be encountered at a commercial cotton gin.

Insulating Dryers

Investigations in 1977 and 1978 with a 24-shelf tower dryer showed that the rate of heat loss from an uninsulated drying system may be reduced 24 to 28 percent by using Thermal Insulating Wool type II in thickness of 1.5 and 3.0 inches, respectively. It was determined that with insulation, more of the heat supplied to gin dryers would be available for evaporating moisture from damp cotton than would be available without insulation. This allows using lower set-point temperatures and, thus, less fuel would be required for drying cotton in an insulated dryer than in an uninsulated dryer (Griffin, 1979).

Heat Recapture

Five commercial cotton gins in Texas were surveyed during the 1979 ginning season to obtain information on the temperature profiles within gin buildings and to estimate the heat recovery potential. It was found that a large pool of hot air collected in the upper part of the buildings, and that reclaiming the hot air might provide up to 30 percent of the heat needed for the gins drying systems. Results at one gin showed that the heat saving accomplished over an extended period through heat recovery with upper level air intake, averaged 16.7 percent compared to outside air intake. The heat saving above floor level intake within the building averaged 6.4 percent. It was recommended that heat recovery be considered in designing a new gin plant or when rearranging an existing plant (Laird and Baker, 1983).

Energy Used

A survey was conducted during the 1987 season to determine the fuel energy used at gins for drying. Fuel requirements averaged 2.33 gallons of LP gas or 247.8 cubic feet of natural gas per bale. Costs associated in 1987 with these fuel requirements were $1.17 and $1.16, respectively, for LP gas and natural gas (Anthony, 1988).

Variable costs from 221 gins for the 1997 crop were determined by survey and grouped according to four cotton production regions and three cotton ginning capacities. For the four regions representing the Mid-South, Southeast, Southwest and California, dryer fuel costs averaged \$1.22, \$1.09, \$0.96 and \$0.77/bale, respectively. When the gins were grouped into three capacities of 15 bale/hr or less, 16-24 bale/hr and 25 bale/hr and up, the corresponding fuel costs averaged \$1.09, \$1.03 and \$0.93/bale. Dryer fuel types were LP or natural gas (Mayfield, et al., 1999).

Comparison Tests

The conventional tower, blow box, and Fountain dryer systems were evaluated in field trials in California and New Mexico about 1988. Neither the blow box system nor the Fountain dryer was as effective as the tower dryer based on the testing criteria used. For the three systems tested, the tower dryer appeared to have the best potential for low temperature drying. The blow box system tested required excessive temperature to dry modestly wet seed cotton and, therefore, may be incapable of drying very wet seed cotton. The Fountain system required less air power than the blow box and three tower systems, but a two-tower system would have been comparable. The blow box system used about 1.5 times as much air power as the other two systems (Abernathy et al., 1989a). Certain aspects of the testing criteria were a controversial issue and entered into several debates and industry panel discussions at the time.

Computer Control

A computer-based dryer control was developed and tested in two cotton gins in Mississippi during the 1990 ginning season. The drying temperature setpoint was adjusted based on the seed cotton moisture content before and after drying as measured by infrared moisture meters. The control system adjusted the air temperature by opening and closing the modulator valve on the gas line feeding the burner. About 60 hours of testing of the control system in a commercial gin indicated good reliability of the system. In the study the seed cotton moisture content was rarely as much as 0.5 percent wet basis from the setpoint (Byler and Anthony, 1992).

Dryer Control

Cotton should be dried in the gin at the lowest temperature that will allow satisfactory gin operation. Laboratory tests have shown that fibers will scorch at 450-500 °F, ignite at 450 °F, and flash at 550-600 °F. In no case should the temperature in any portion of the drying system exceed 350 °F. Fiber exposure to temperatures above 350 °F causes irreversible fiber damage (Grant, et al., 1962; Hughs, et al., 1994; Anthony and Griffin, 2001).

The typical source of heat for drying cotton is a burner flame in the stream of drying air. The burner's maximum output must be adequate for the system used. The ratio of fuel flow rate at maximum burner output to the fuel flow rate that provides the lowest dependable flame is referred to as the "turndown ratio". This ratio is highly important in drying cotton. If the burner will not turn down to a low flame, the result will be overdried cotton or intermittently dried cotton as the burner flame blows out and reignites. A good drying burner will have a guaranteed turndown ratio of at least 15:1, but the ratio can be as high as 35:1, depending on the manufacturer.

Although a cotton gin burner may have been designed and built with an excellent turndown ratio, these ratios are calculated with laminar air flow characteristics around the burner head. If the burner is placed in the direct blast of a push fan (a common scenario), the turndown ratio suffers tremendously. It is not uncommon to see a turndown ratio of 35:1 reduced to an effective ratio of 3 or 2:1, or even less in cases where the air blast is extreme. A ginner should consult with the relevant burner manufacturer for solutions to avoid this problem so common to cotton gins.

The location of temperature control sensors is important. These sensors modulate the gas valve on the heater to control the burner's flames and thus the drying temperature. It is preferable to use dual sensors to prevent scorching and excessive damage to the cotton. One sensor should be a high-limit temperature controller (set for 350 °F) located ahead of the heated air and seed-cotton mixpoint. This should be an analog type of temperature control to permit temperatures to be maintained very close to the limit without nuisance shutdowns. The second sensor would be the primary control sensor and should be located downstream of the mixpoint. At this location the second sensor will allow the heaters controller to respond to the amount and wetness of the cotton. In tower dryer systems a recommended practice is to locate the control sensor at the top of the dryer (American Society of Agricultural Engineers, 2000).

Related Drying

Closed-Boll Drying

A two-year study, 1980-81, was conducted at the USCGL, Stoneville, MS, to develop temperature and time parameters for drying of closed green bolls. The objectives were related to preserving the fiber and cottonseed quality during gin processing, and reducing the incidence of byssinosis among workers handling cotton. Closed green cotton bolls were dried in an electric laboratory oven for six hours at temperatures ranging from 100° to 260° F (Mangialardi, 1984).

The more mature bolls began to open after 0.5 hour but only about 20 percent of the bolls had opened after two hours. The amount of moisture evaporated from the bolls in six hours was 30 percent of the boll weight as harvested. Results showed that bolls might be safely dried for six hours at temperatures up to 150° F without lint discoloration and up to 110° F without harm to seed germination potential. There were indications that mature bolls harvested and heated-air dried at 140° F for six hours would open sufficiently for dehulling by conventional ginning machinery.

Cottonseed Drying

A cottonseed drying project conducted from 1947 to 1958 at the USCGL, ARS, USDA, Stoneville, MS, indicated that seed containing 16 percent moisture could be sufficiently dried to store for planting when necessary. However, the use of high temperatures can kill viability in cottonseed. Tests proved that the viability of the seed may be endangered within four minutes exposure at internal seed temperatures above 140° F, and that the mortality rate increases with increases of internal seed temperature above 140° F. When seed having a moisture content of 17 to 20 percent was heated to a temperature of 180° F, the germination of the seed was completely destroyed. Considerably higher temperatures were required to kill viability of low-moisture content seed than in high-moisture content seed. Therefore, a seed temperature of 140° F was established as the crucial temperature level (Shaw and Franks, 1962).

The cottonseed drying project involved the drying of ginned seed for several minutes. These results would probably not relate to cotton gin drying. At the gin the seed in seed cotton form is exposed to the hot drying air for only 10 to 30 seconds.

COTTON GIN DRYERS

Earlier Systems

Government Tower Dryer

A USDA developed vertical dryer was used on the 1932 crop (Figure 2). It became known as the "Government Tower-Dryer". The vertical dryer had no moving parts, and passing cotton through the dryer a second time could dry very wet cotton. A tower dryer contained 13-20 "floors" or shelves through which a continuous current of hot air transported the seed cotton. This hot air traveled through the drying tower at approximately 800 to 1,200 linear feet per minute. The locks of cotton impinged upon the hot sheet-metal walls of the tower at each reversal of direction from floor to floor which caused the drying air to pass through the cotton. The temperature of the drying air ranged from 150° to 200° F. Steam coils provided heat to the dryer. A tower could be placed either within the gin building or out of doors (Bennett and Gerdes, 1936).

The Government vertical dryer was designed for the 1932 average battery of four 80- saw gin stands. This gin plant handled about 100 pounds of seed cotton per minute. Damp seed cotton was treated with a continuous current of hot air at the rate of from 40 to 100 cubic feet of hot air for each pound. Tower shelf dimensions were 5.25 ft (length) by 4 ft (width) with 15-inch spacing between shelves. From the bottom floor of the tower, the dried cotton was thrown against a cleaning screen where some of the foreign matter was cast out.

Boardman Vertical Cotton Dryer

The Boardman Vertical Cotton Dryer used the principles and features discovered by the USCGL, ARS, USDA, Stoneville, MS, in its development of the "Government Process" vertical tower dryer (Figure 3). This is probably the first tower-type dryer to be manufactured commercially. It dried damp, handpicked seed cotton before processing the cotton through the extractor-feeder and gin stand. Cotton from the dryer generally went to the overflow telescope. (Boardman Co., 1932).

Continental Conveyor Distributor Dryer

The Continental Conveyor Cotton Dryer consisted of two or four trough sections (Figure 4). A double unit (four-trough) installation was made by placing two single (two-trough) units beside each other and connecting the discharge opening of the first unit to the intake opening of the second unit. Screw conveyors of special design handled the seed cotton when the cotton traveled through the units. This dryer was first used across the cotton belt about 1934 (Continental Gin Company, 1960b).

In a typical single two-trough section dryer, hot air from the heater was drawn through a pipe into one side of a trough section. Seed cotton was deposited into the same trough from above through a separator. The seed cotton and hot air were drawn from the side of the second trough section through a pipe to a second separator over the gin system. A gin system consisted of a seed-cotton cylinder cleaner followed by the gin stands, since only minimum seed-cotton cleaning was needed in the early installations. Moisture-laden air left the separator through a pipe and was discharged from the gin building.

Lummus Thermo Cleaner

The Thermo Cleaner came into use about 1936. It was developed mainly for handling rough harvested cotton (Figure 5). It could be equipped with a moisturizer to obtain either drying or humidifying or for killing static electicity. High-speed paddles broke open wads while conveying the cotton from the inlet to the discharge end. Rod type grids removed sand and fine trash. The Thermo Cleaner was available in single units with two cylinders and dual units with four cylinders. (Lummus Cotton Gin Co., 1942).

Murray Reel-Type Dryer

The Murray Reel-Type Dryer machine combines both cleaning and drying where needed, or it can be operated as a cleaner only (Figure 6). It came into use about 1937. A grid cylinder in this dryer removes sticks and both large and fine trash. This cotton dryer contains a large 84-inch diameter grid cylinder, which is mounted on a steel frame and revolves within an insulated jacket (Murray Company of Texas, Inc., 1957).

Pressure is maintained within the hot air manifold and feeds heated air through a narrow air nozzle, which extends through the side of the dryer to a point close to the reel-cleaning cylinder. Heat penetrates the locks of seed cotton many times as the cotton is slowly carried through the reel-cleaning cylinder. As seed cotton is conveyed through the reel, it turns upward as it passes the hot air nozzle on the manifold side of the dryer. The force of the hot air blasts against the cotton, carrying it across to the opposite side of the cylinder. This helps to separate the small light trash which falls through the cylinder.

The larger foreign matter is sifted out by the trembling motion of the cotton. A conveyor in the bottom of the dryer discharges the dirt and trash to a trash fan.

Stacy Cotton Cleaning System with Drying Attachments

In the Stacy Cleaner and Dryer, hot air from a manifold is blown downward through the cotton by means of nozzles extending across the cleaner (Figure 6). Nozzles are located between each cleaning cylinder, similar to the nozzles on airblast gins. This blast of hot air dries the cotton, and also increases the cleaning by forcing the dirt, leaf trash, and stems through a screen. The moist air does not follow the cotton. Sometimes, the wire screen is replaced by grid bars to allow removal of larger trash. Each drying unit is made with six or eight cleaning cylinders. Two stages of drying and 16 cylinders of cleaning can be obtained by putting two single units in series. A separator directs the seed cotton onto the first cleaning cylinder. Stacy cleaner/dryers were built from about 1940 to 1965 (Stacy Company, Inc., 1949).

Cen-Tennial Tower Drying

The Cen-tennial Cotton Gin Co. used an 18-shelf government-type tower dryer ahead of an eight-cylinder seed cotton cleaner in the late 1940s. The cylinder cleaner was mounted above the conveyer distributor and gin stands. Later, Cen-tennial used two tower dryers in its Thinstream Ginning System. The first tower dryer used 23 shelves and the second tower dryer had 18 shelves (Cen-tennial Cotton Gin Co., 1950).

Continental Vertical Counterflow Dryer

The Continental Counterflow Dryer uses the principle of passing the cotton and warm air in opposite directions through the vertical dryer casing (Figure 8). The counterflow dryer was designed to require only 2,000 ft^3/min of heated air for efficient drying, compared to about 6,000 ft^3/min for conventional tower dryers. Thus, the fuel consumed by the heater and the power required to drive the fan is reduced more than half (Continental Gin Company, 1960a).

As seed cotton leaves the dryer separator it falls onto a directing cylinder which breaks up wads and throws the loosened cotton across the casing in a broad stream. The cotton slides down several sections made of long thin-fingered baffles and directing cylinders, where the opening actions are repeated. Warm dry air enters at the lower end of the dryer casing, passes upwardly through the falling stream of cotton, and is exhausted through an air port in the top of the casing. Since the hot air does not follow the cotton through the dryer, removed moisture cannot be redeposited in the cotton. A 3-cylinder cleaner section at the lower end of the dryer removes some loose trash between smooth, round grid bars.

A Single Drum Vertical Counterflow Dryer was designed for special applications (Figure 9). It operates on the same principle as the full-size machine. However, it is several feet shorter than the full-size machine and thus can be used above overhead cleaners or automatic suction control bins.

Hinckley Dryer-Cleaner

The 72-C Hinckley Dryer-Cleaner is sometimes referred to as the Neverchoke or Fan Drum Dryer-Cleaner (Figure 10). By featuring feeder control and fan drum preparation, the unit regulates the flow of cotton through itself and subsequent machines in the cotton process. From hot air chambers, heated air is directed into rotating fan drums which blow fine pin trash out of the flowing seed cotton and through lower cleaning screens. Moist air and trash exits to the dirt fan. Cotton travel reduces cotton machining between cylinders, and can reduce horsepower (Hinckley Gin Supply Co., 1952).

Lummus Super Volume Cotton Conditioner

The Super Volume Cotton Conditioner is designed to operate as a single drying and conditioning unit, or in combination with other conditioning equipment (Figure 11). Damp cotton passes through the Super Volume Conditioner slowly, being exposed to about four times the amount of heated air normally used in a tower dryer at a given throughput capacity. Two cleaners with reclaimer units separate trash from the cotton by the sling-off method. Reclaimer units return clean cotton to the system. Large passages allow the cotton to flow freely, and early removal of large pieces of trash helps improve the efficiency of subsequent cleaning machinery in the ginning system. The Super Volume Cotton Conditioner is also designed to be economical to operate. About three-fourths of the heated air is recirculated, reducing fuel cost (Lummus Cotton Gin Co., 1960b).

Tower Dryer Attachments

The Hardwicke-Etter Company manufactured a Fluff-and-Clean Attachment for use with its tower dryers (Figure 12). The attachment with its two cleaning cylinders opens up and fluffs the cotton; and removes some burs, dirt, trash, sticks, and leaves. Its intent was to enhance drying and ease the job of other components in the ginning system (Hardwicke-Etter Company, 1975).

Lummus Cotton Gin Co. designed the Tower-Dryer Opener Cleaner (T-Doc) Attachment for use with its tower dryer (Figure 13). Seed cotton, moving through the tower, flows into the T-Doc where it is opened, fluffed, and cleaned by one cleaning cylinder. Two of these one-cylinder T-Doc attachments are used on a tower dryer, one in the upper section and the second near the center of the tower (Lummus Cotton Gin Co., 1960a).

Gentle Giant Drying System

A "Gentle Giant" moving bed dryer, manufactured by the Samuel Jackson Mfg. Corp., was installed in a California and Alabama gin about 1965 (Figure 14). In this system as soon as seed cotton enters the gin plant, it is dropped into the Gentle Giant where it forms a slowly moving bed. Warm air is blown upward through the bed of cotton. Moving the drying air upward is designed to loosen and expand the bed of seed cotton so a large air volume can be used with little power consumption (Samuel Jackson Mfg. Corp., 1965).

The Gentle Giant dryer itself is 30 feet long, six feet wide, and 12 feet high. A 25 hp vaneaxial fan pushes about 24,000 ft^3/min of air through the dryer. An independent thermostat prevents the entering air temperature from exceeding 200 °F.

A principal fault in this method is the drying front, which advances through the bed during the drying process. Behind this front, the cotton is very dry. Ahead of the front, the cotton can be wetted by the drying process. Thus, belt speed and bed depth must be carefully monitored (Samuel Jackson, Inc., 2000).

Fountain Dryer

The Samuel Jackson Fountain dryer is designed to replace the shelf-type tower dryer. It was introduced about 1988. A Fountain dryer does not have shelves. It floats the seed cotton in the hot air within the dryer and then re-accelerates the cotton (Figure 17). Its main drying effect takes place, not in the dryer, but at its exit. The Fountain dryer uses high air volumes (50 cu. ft./lb of seed cotton). It achieves a high air/cotton ratio by use of a skimmer. It takes a stream of air at the end of the drying process, and by centrifugal force, diverts all of the seed cotton and about half the air to the first-stage incline cleaner. The remainder of the air is used to pick up the cotton under the first-stage stick machine to go to the second-stage cleaners. Since this dryer creates less static pressure than traditional tower dryers, only pull fans are used rather than the push/pull fans needed on most tower dryers (Jackson, 1996).

Current Systems

Twenty-Four Shelf Tower Dryer

Several manufacturers build tower dryers. They are generally built in sturdy steel sections and are completely self-supporting.

Continental/Murray's tower dryers are available in two models. One model is six feet wide and six feet long (Figure 16), and the second is six feet wide and 11 feet long. Their sectional design provides any number of shelves, from 11 to 24. Alternate outlet openings permit even or odd shelf installation allowing selective piping arrangements (Continental Murray Ginning Systems, 1988).

Continental/Murray also builds a tower dryer that has 12-inch shelf spacing. It is 6 feet wide and 11 feet long and features 19 or 20 shelves. This tower was built for use with high volumes of air (10,000 - 12,000 ft^3/min) and controlled low temperatures.

Blow Box

A high-speed blow-box dryer was tested in California about 1988 (Figure 17). It was intended that the new blow-box system would replace the traditional tower dryer at gins. The blow-box principle involves a jet of high-speed air, in excess of 10,000 fpm, directed horizontally, transverse to the width of a feed controller, causing seed cotton to open as it is suddenly accelerated down a rectangular duct. The rationale was that the high-velocity (jetted) hot air in the blow box opens and removes moisture from damp cotton more rapidly than the lower-velocity and somewhat lower temperature in the shelf-type dryer. Tests showed that the high-velocity blow box system required more air horsepower than uniform-velocity ones (fountain or shelf-type). To improve blow-box dryers it was suggested that a spiked-beater wheel could help to break up clumps, and designing the box with negative static pressure at the pickup point would allow omission of the vacuum dropper wheel (Abernathy et al., 1989b).

Hot Shelf Dryer

The Turbulent Flow Hot Shelf drying system uses smaller volumes of air than some drying systems, because the temperature drop throughout the system is avoided (Figure 18). This is accomplished through an arrangement of heat chambers between the shelves, from which heat is transferred to the shelves conveying the cotton. The tower has nine shelves with 12-inch spacings. Seed cotton enters at the top of the tower and exits at the bottom of the dryer. Generally, heated air enters at the bottom of dryer and exits near the top of the tower. However, this heated air used for the heat chambers can be re-circulated through the system on a continuous basis, or combined with the primary air line to pick up the cotton at the mixpoint and convey it to the tower (Vandergriff, 1996).

Kimbell Belt Dryer

Operation of a belt dryer in a commercial gin in Virginia in 1995 helped refine the technology for this system (Figure 19). The design was based on the dryer developed in Texas (Laird and Smith, 1992). It was found that installing a metal-flighted doffing roller with the flights approximately one inch from the belt helped break up wads of damp seed cotton and spread the discharge flow more uniformly. The open half by half-modified flat wire belt allowed dirt and fine pin trash to drop from the cotton through the belt as the conveyor undulated over the support grid work. It was indicated that a belt dryer would run horizontal or inclined up to 20 degrees with a maximum incline of 25 degrees. The best location for a belt dryer in an existing gin is probably overhead (Gray, 1996).

High-Volume Tower Dryer

The Lummus High Volume Tower drying system uses six shelves of 27-inch spacing and the inlet transition acts as the seventh shelf (Figure 20). This allows using a pull-through fan system, eliminating the need for a push fan and reducing dust in the gin plant. In the first stage, an air velocity of 2,000 ft per minute is used with about 25 cubic feet of drying air per pound of seed cotton. A Turbulent Dryer Trap is located ahead of the dryer to provide initial turbulent drying and to remove green bolls, rocks, etc. The secondary air needed to operate the Turbulent Dryer Trap allows the burner control to be more responsive to moisture changes in the cotton. Two stages of drying are recommended with the heated air temperature and volume reduced somewhat in the second stage. The Turbulent Dryer Trap is not used in the second stage (Van Doorn, 1996).

Two sizes of the high-volume tower dryer are manufactured. One tower dryer is 48-in. wide with a 40-in. turbulent dryer trap on the inlet, and the second tower dryer is 72-in. wide with a 60-in. wide turbulent trap on the inlet. Air volumes are 18,000 and 27,000 cfm in the 4 ft and 6 ft tower dryers, respectively (Lummus Corporation, 2001).

Rules of thumb for the Lummus systems in humid areas with machine-picked cotton are that the first-stage drying system should have at least 4 million Btu's of heat and 9,000 cfm of air at

2,000 fpm in the dryer for every 15 bales per hour. The second-stage drying system may have the heat and air capacity reduced to 2 million Btu's and 6,000 cfm per 15 bales per hour. Air velocities of approximately 1,500-2,000 fpm can be used in the second-stage drying system.

Hi-Slip Dryer

The Belt Wide Hi Slip drying machine uses the principle that turbulence and high velocities between the cotton and drying air increase the drying rate (Figure 21). A spike or lugged cylinder retards the cotton flow, but allows heated air to pass through the cotton, creating a high slip rate. According to its operation, the venturi effect created by the nozzle, which injects the hot air into the lugged cylinder, allows the cotton to be mixed into the airstream without a vacuum wheel or rotary air lock (Mayfield, 1996).

Collider Dryer

The Samuel Jackson Collider Dryer is a modification of the Fountain Dryer (Figure 22). It is a negative pressure (pull-through) dryer that seeks to take advantage of hot air and seed cotton mixing with a maximum amount of turbulence. Suction brings cotton and hot air from the module feeder into an upper chamber where a direct collision with additional drying air takes place. Following this point of turbulence, the seed cotton and hot air mixture is divided and taken through a second collision just above the outlet to the skimmer. The pressure drop is somewhat higher in the Collider Dryer than in the traditional Fountain, but the design is to magnify the drying effect because of multiple collisions and turbulence (Samuel Jackson, Inc., 2000).

Vertical Flow Dryer

Seed cotton enters the top of the Continental Vertical Flow Dryer with the drying air (Figure 23). As the seed cotton enters, it falls onto a directional cylinder arranged to break up wads and create a loosened stream of seed cotton. The loosened seed cotton slides down baffles made of long thin fingers, with air spacing between each finger. This cotton falls to another cylinder which throws the seed cotton in another direction. This alternating action is repeated five more times (Continental Eagle Corporation, 2000).

There are no shelves, screens or grids in the dryer. The opening and fluffing by the directional cylinders causes the locks of seed cotton to open to increase the drying action of the dryer. After passing downward through the dryer with the seed cotton, the drying air transports the cotton to the next process.

Even Heat Tower Dryer

The Vandergriff Even Heat Tower Dryer, manufactured by the Consolidated Cotton Gin Co., Inc., was used in several cotton gins in 2000 (Figure 24). It is built in four widths--three, four, five, and seven feet, and the shelves are eight feet long (Consolidated Cotton Gin Co., Inc., 2001).

In the Even Heat Tower Dryer there are seven progressive-spaced deep shelves, with a heat jacket for hot air injection at three points. The operating principle is to add heat downstream in the tower to maintain a drying temperature throughout the drying cycle.

In the drying stage, air from the heater is split into two streams. A portion of the air picks up the seed cotton and conveys it to the top shelf of the Even Heat Dryer. The other portion is injected at the ends of the second, fourth, and sixth shelves, providing multiple mix-points. Heated air is injected with nozzles at a velocity of 4,000 ft/min. Shelf spacing increases as the total air increases to maintain a desired 2,000 - 2,500 ft/min. conveying velocity in the tower. There are vanes and bump-ups on the floor of the tower shelves to increase drying capabilities. The drying air then conveys the seed cotton from the bottom of the Even Heat Tower Dryer to an inclined cleaner for air and cotton separation.

SUMMATION

Many dryer designs have been used to dry seed cotton at cotton gins since the late 1920s. These various gin-drying systems offer varying levels of the four basic factors that determine the effectiveness of seed-cotton dryers. The four basic factors are drying air temperature, air volume, time of exposure, and the relative speed of the air and the cotton (slip). There are many combinations of these factors, which will satisfactorily dry cotton.

Research results show that cotton fibers are weaker at lower moisture content than at higher moisture levels. Therefore, cotton ginned at low moisture levels is certain to contain more broken fibers than cotton ginned at higher moisture levels. It is recommended that gin dryers be adjusted to produce lint at the gin stand with moisture content at about seven percent.

For quality preservation, cotton should be dried at the lowest temperature that will allow satisfactory gin operation. In no case should the temperature in any portion of the drying system exceed 350 °F. Cotton is irreversibly damaged at temperatures above 300 °F. Some drying is obtained when conveying seed cotton with low relative humidity ambient air.

It can be argued that the four basic factors of drying are embodied in the 24-shelf tower dryer system. The tower dryer was developed in 1931. In this system hot air conveys seed cotton through the shelves, with seed cotton impacting the dryer walls and changing direction between each shelf. This action helps to open the cotton and provide slippage between cotton and air. Each stage of drying requires two centrifugal fans in a push/pull arrangement to handle the created static pressure. Two stages of tower dryers are usually adequate to dry wet seed cotton.

Several types of dryer designs are used in gins. Most other designs create less static pressure than tower dryers, and so only require one centrifugal pull fan to operate. These generally use higher air volumes and expose the seed cotton to hot air for shorter periods than a tower dryer system. The negative pressure (one fan) systems would be expected to require less investment, use less fan horsepower, and maintain a cleaner gin building. However, there have been indications that some of the systems that don't properly open the cotton or use adequate exposure periods may experience problems in handling very damp cotton.

Drying systems used in most newer gin installations (1990-present) include the High Volume Tower Dryer, high-speed blow boxes, Fountain and Collider dryers, Belt dryer, Hi-Slip dryer, Turbulent-Flow Hot-Shelf Tower Dryer, Even Heat Tower Dryer, and Vertical Flow Dryer.

Today most growers harvest and store seed cotton in modules for later ginning. If this cotton is harvested when its fiber moisture content is at about eight percent and the cottonseed moisture content does not exceed 10 percent, minimum drying at the cotton gin would be needed. One of the lower cost dryer designs giving minimum exposure to the drying air would be adequate for proper moisture removal. A more elaborate design would be required to handle the damper cottons.

There is no best drying system for all gins. A best dryer design is the one that will meet the demands for that gin plant. Two concerns in selecting a dryer type will be the location of the gin and the condition of the seed cotton to be processed. A gin plant located in a humid area and ginning damp cotton will require a more demanding and elaborate dryer system than a plant ginning relatively dry modules in arid regions.

The cost of a drying system must be balanced against the needs of the gin. A selected system must use sufficient low temperature drying air to evaporate adequate moisture, a procedure for opening and exposing seed cotton locks, adequate exposure time for moisture to migrate from within the fiber, and a high rate of slip between the cotton and the drying air.

DISCLAIMER

Mention of a trade name, proprietary product or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not imply approval of a product to the exclusion of others that may be suitable.

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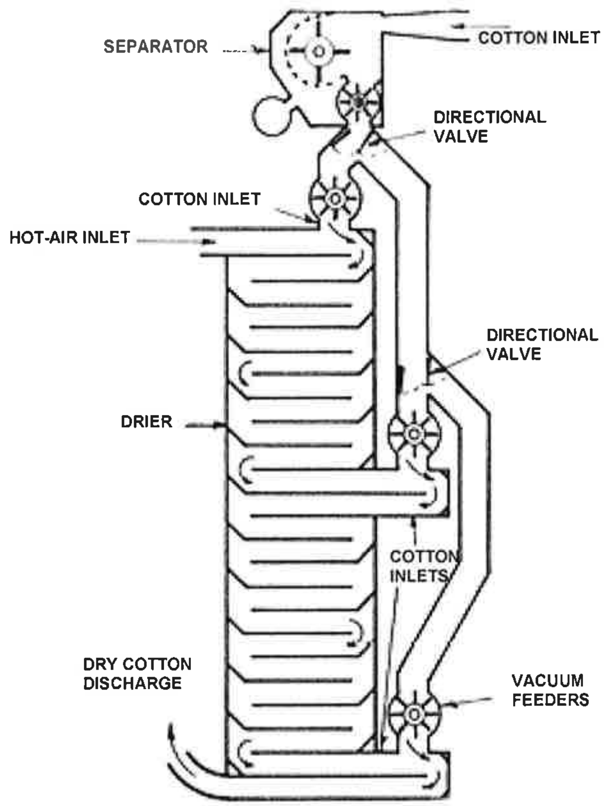

Figure 1. Multi-path Tower Dryer.

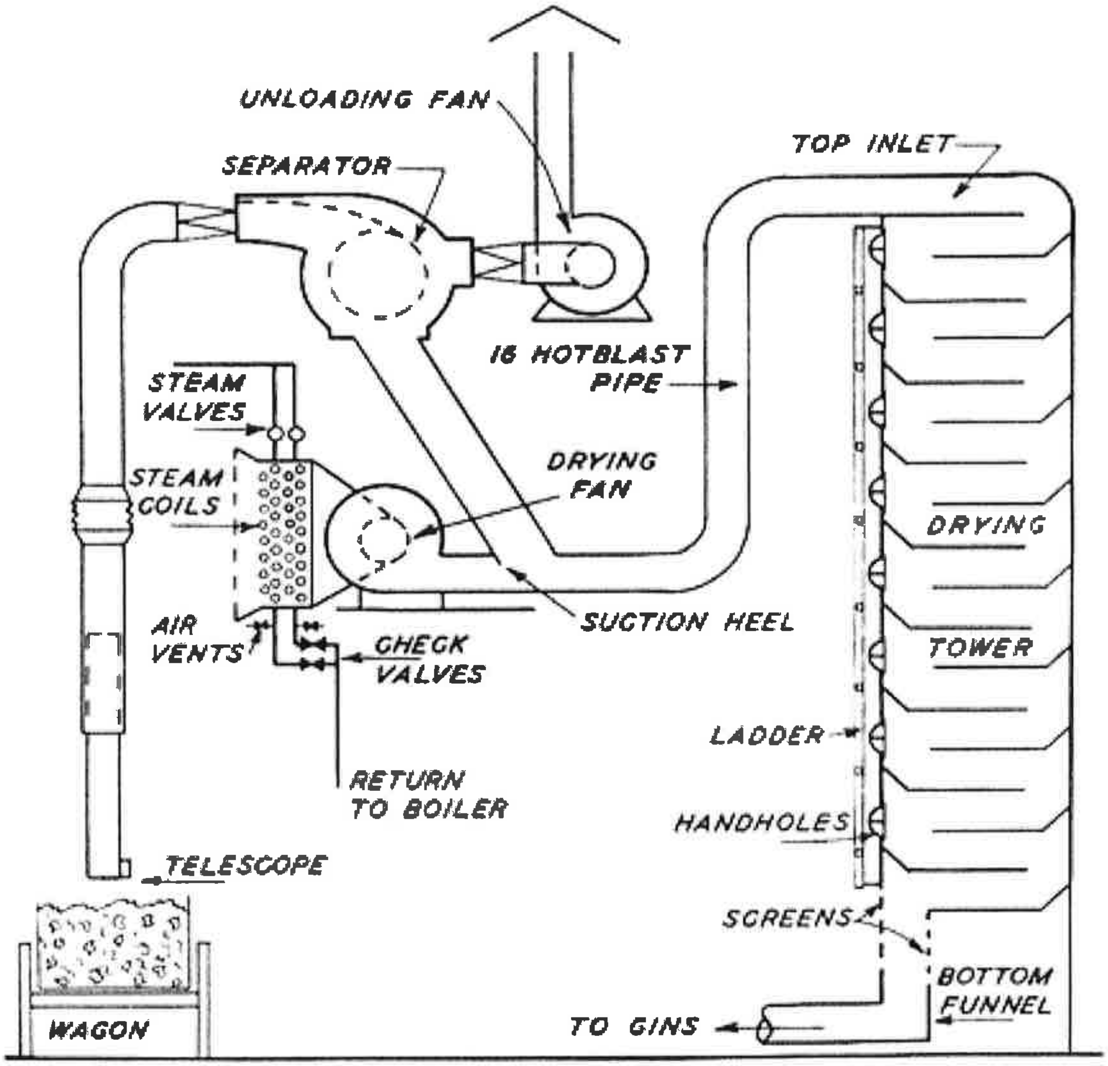

Figure 2. Government Tower Dryer.

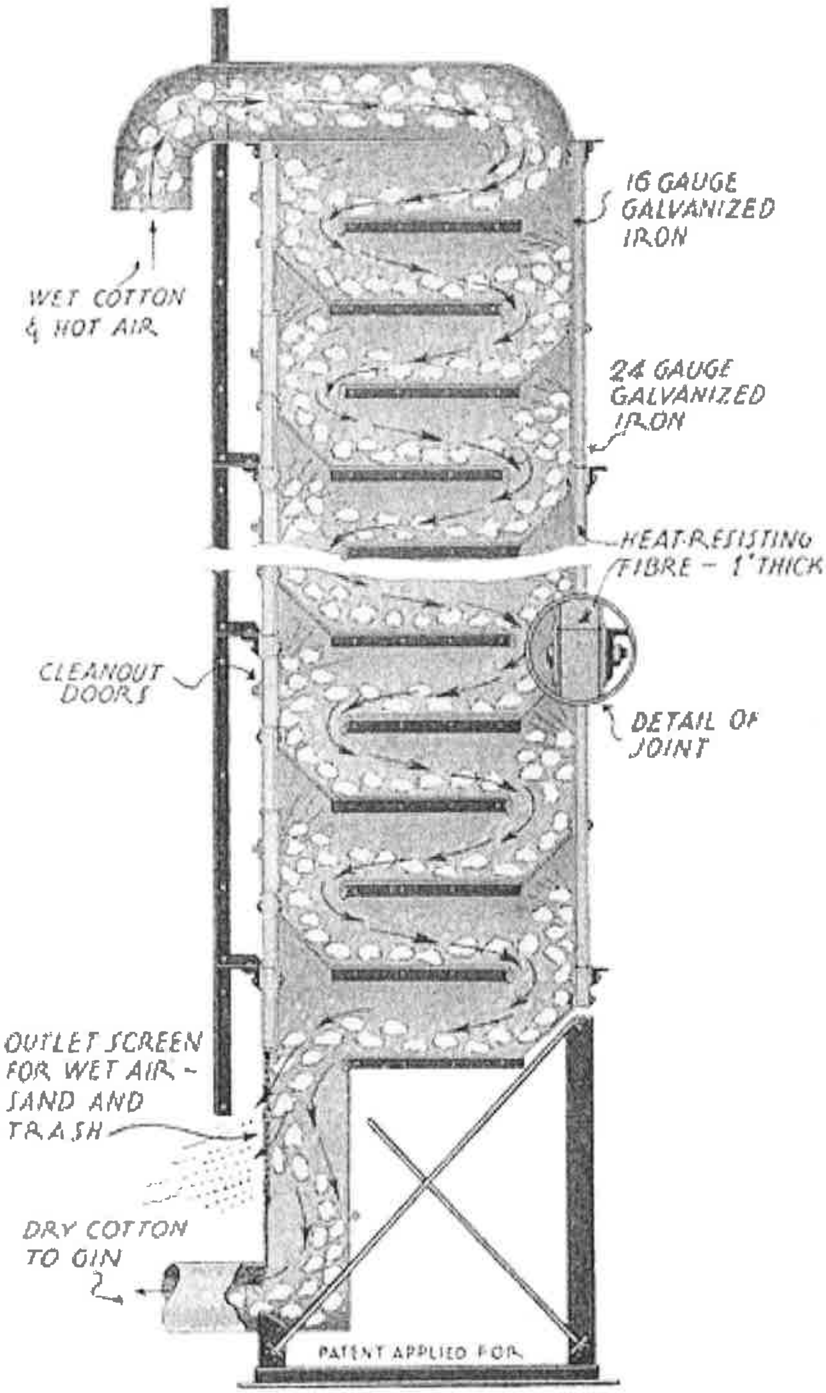

Figure 3. Boardman Vertical Dryer.

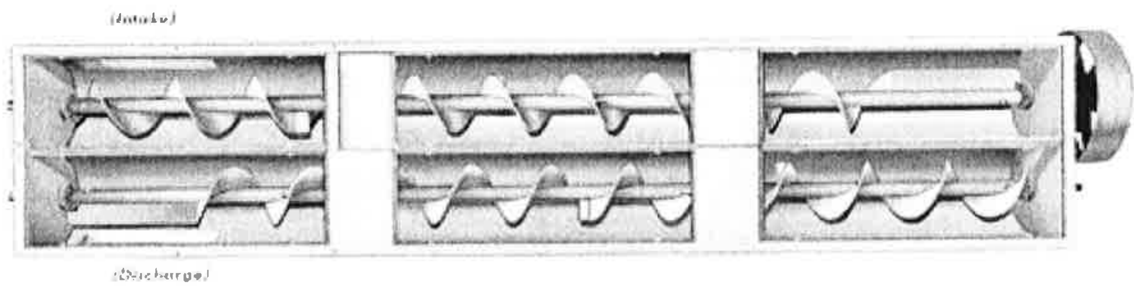

Figure 4. Continental Conveyor Distributor Single Unit (two-through) Dryer.

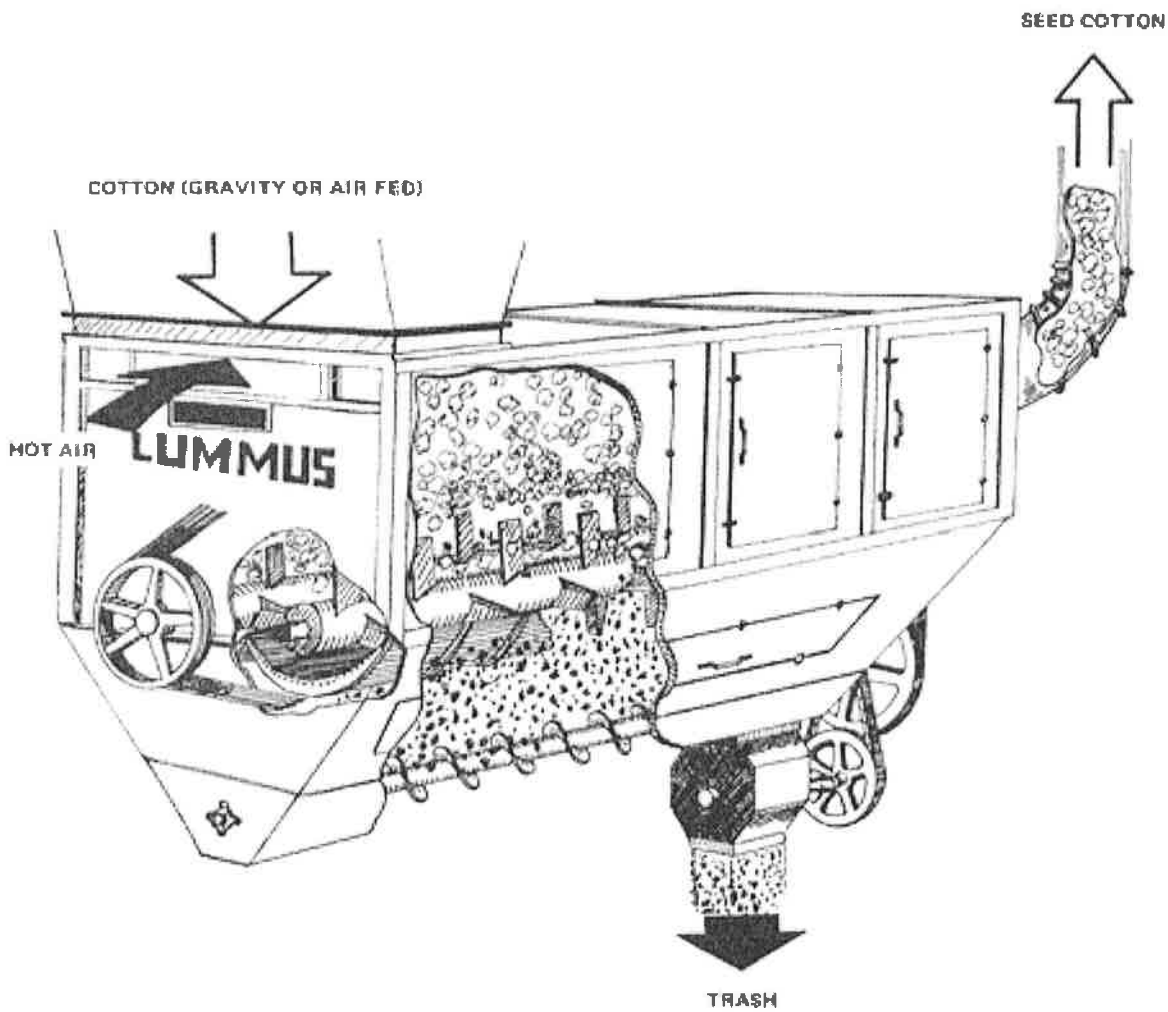

Figure 5. Lummus Thermo Cleaner.

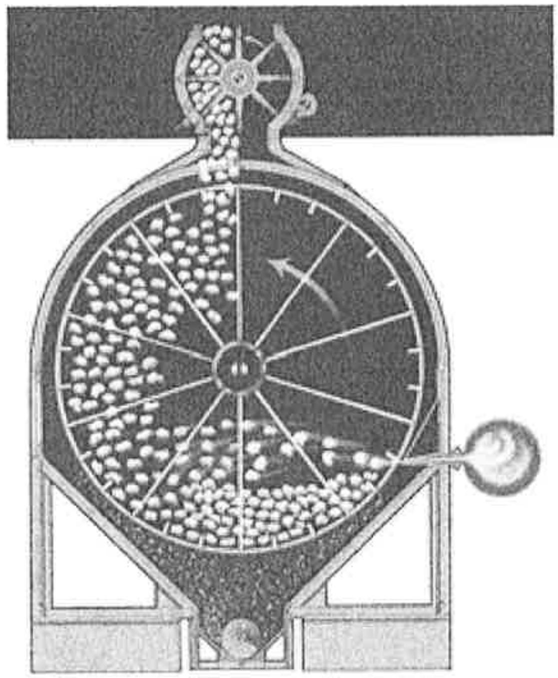

Figure 6. Murray Reel Type Dryer.

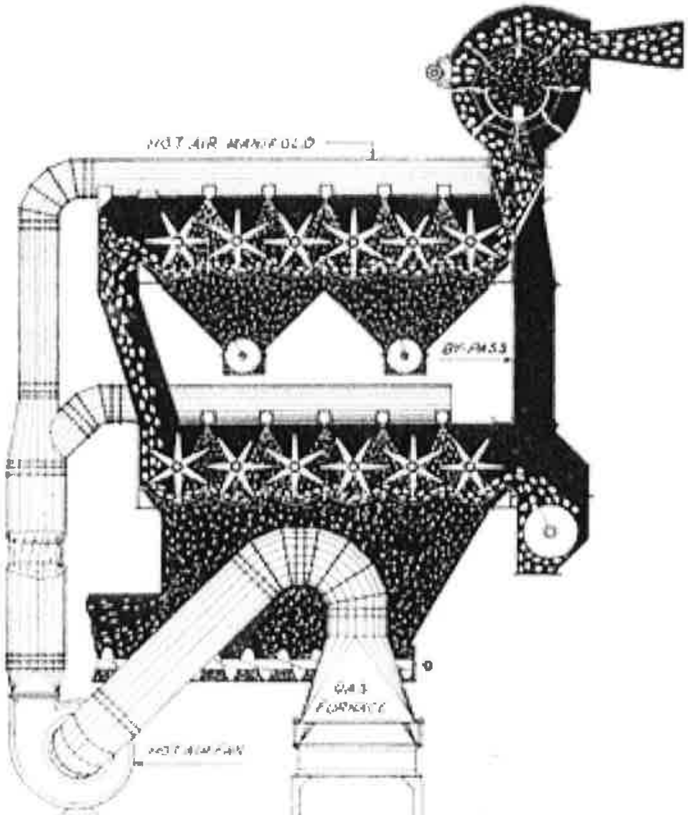

Figure 7. Stacy Cotton Cleaner and Dryer.

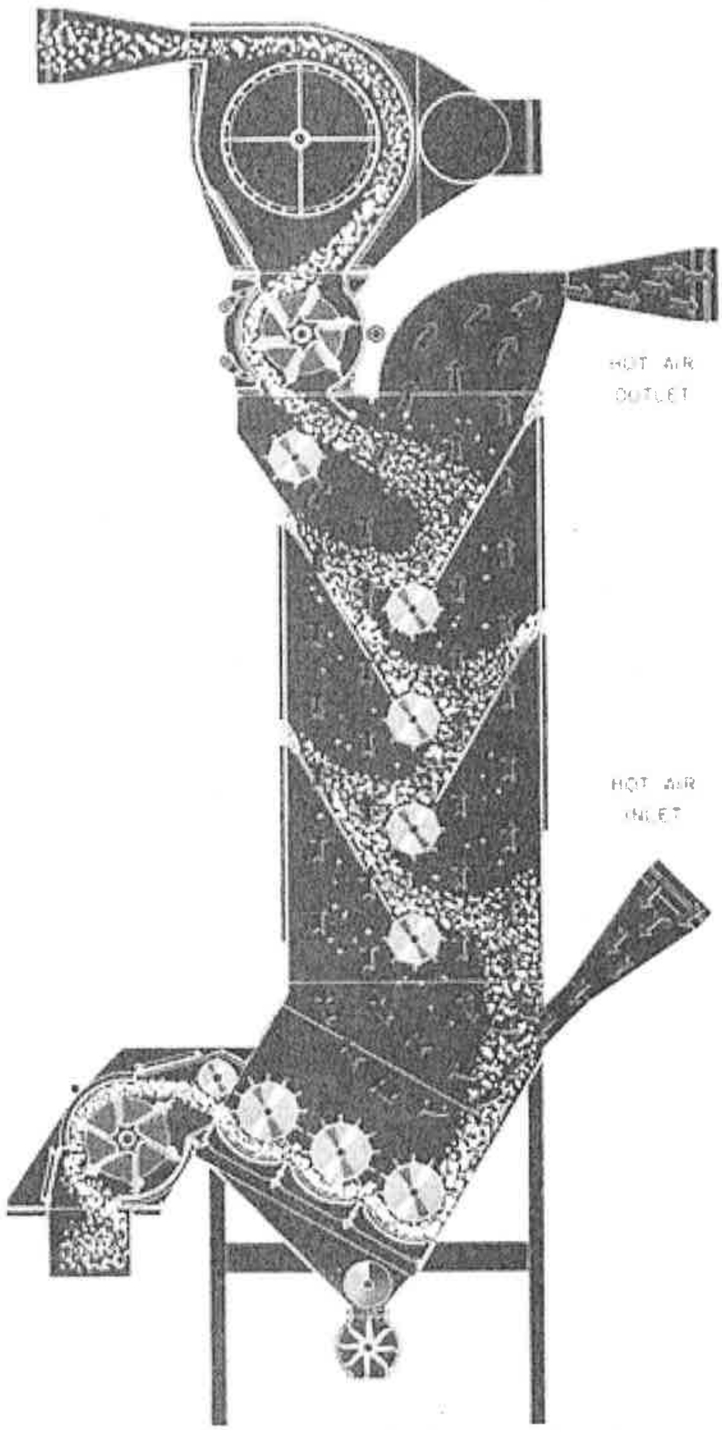

Figure 8. Continental Vertical Counterflow Dryer.

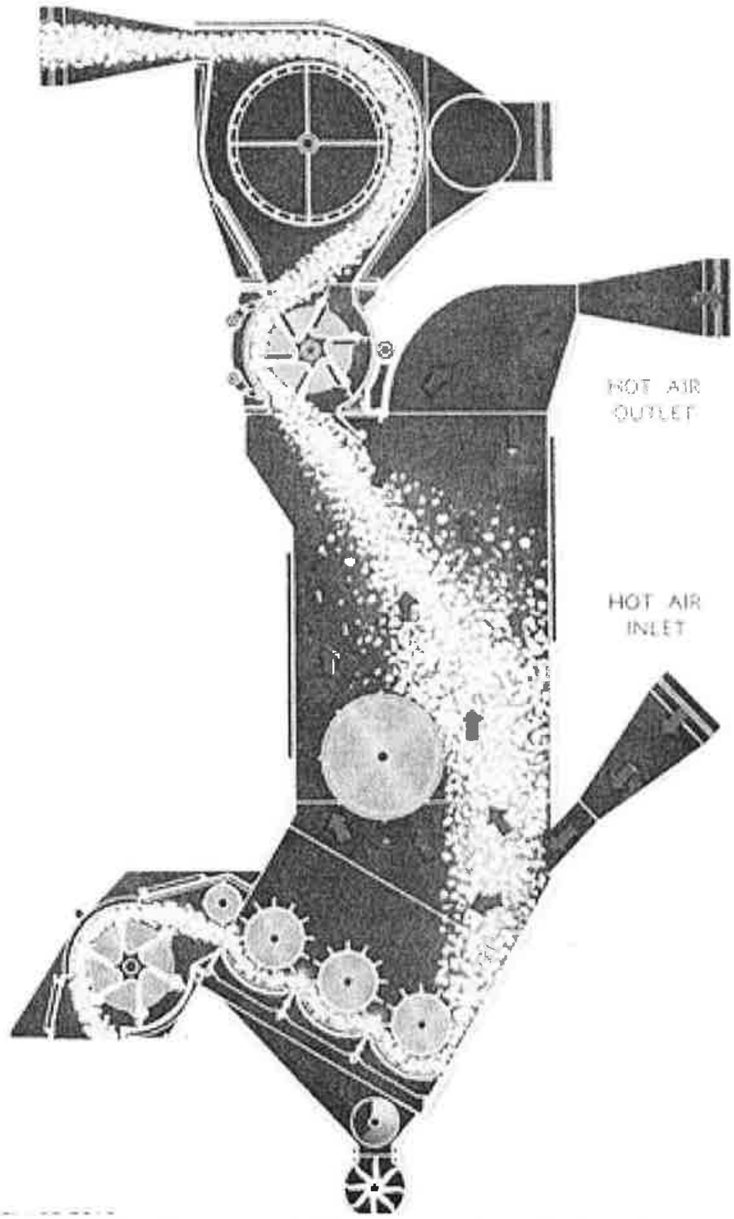

Figure 9. Continental Single Drum Counterflow Dryer.

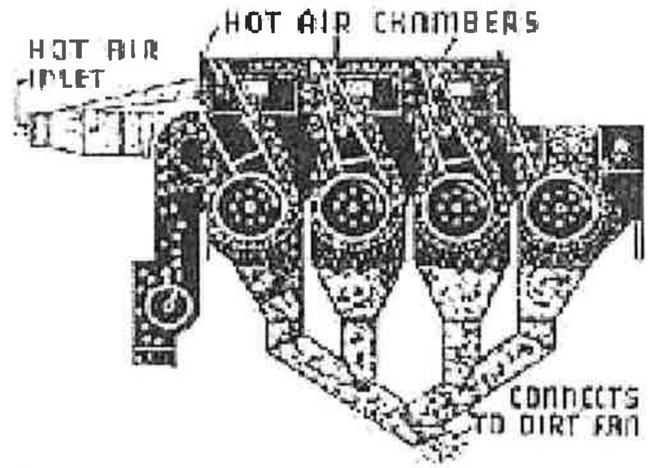

Figure 10. 72-C Hinckley Drier-Cleaner.

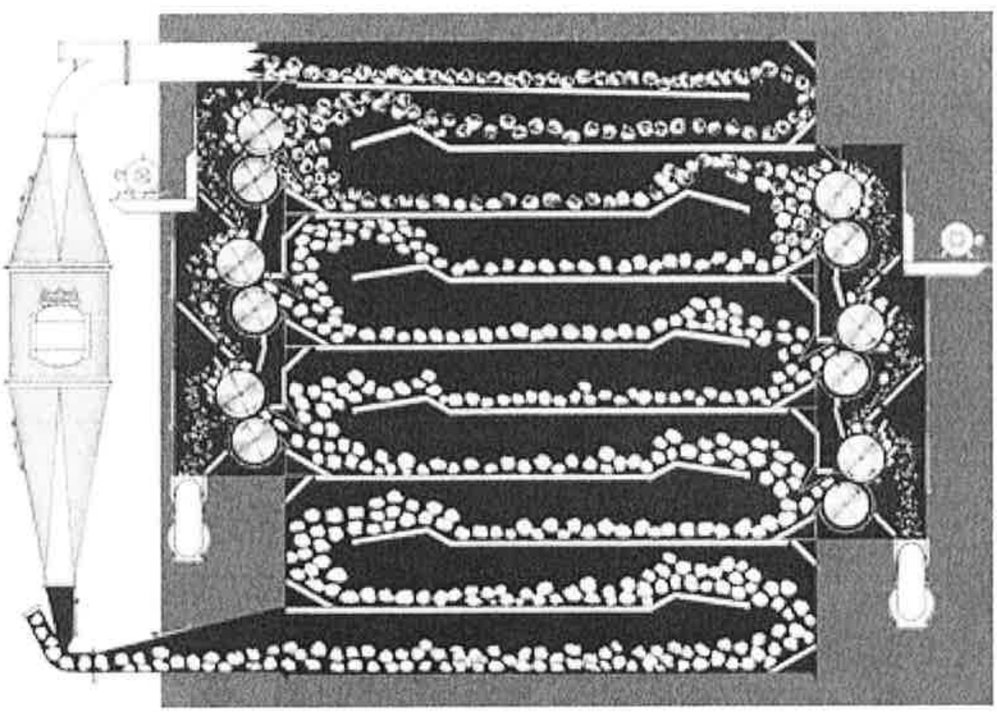

Figure 11. Lummus Super Volume Cotton Conditioner.

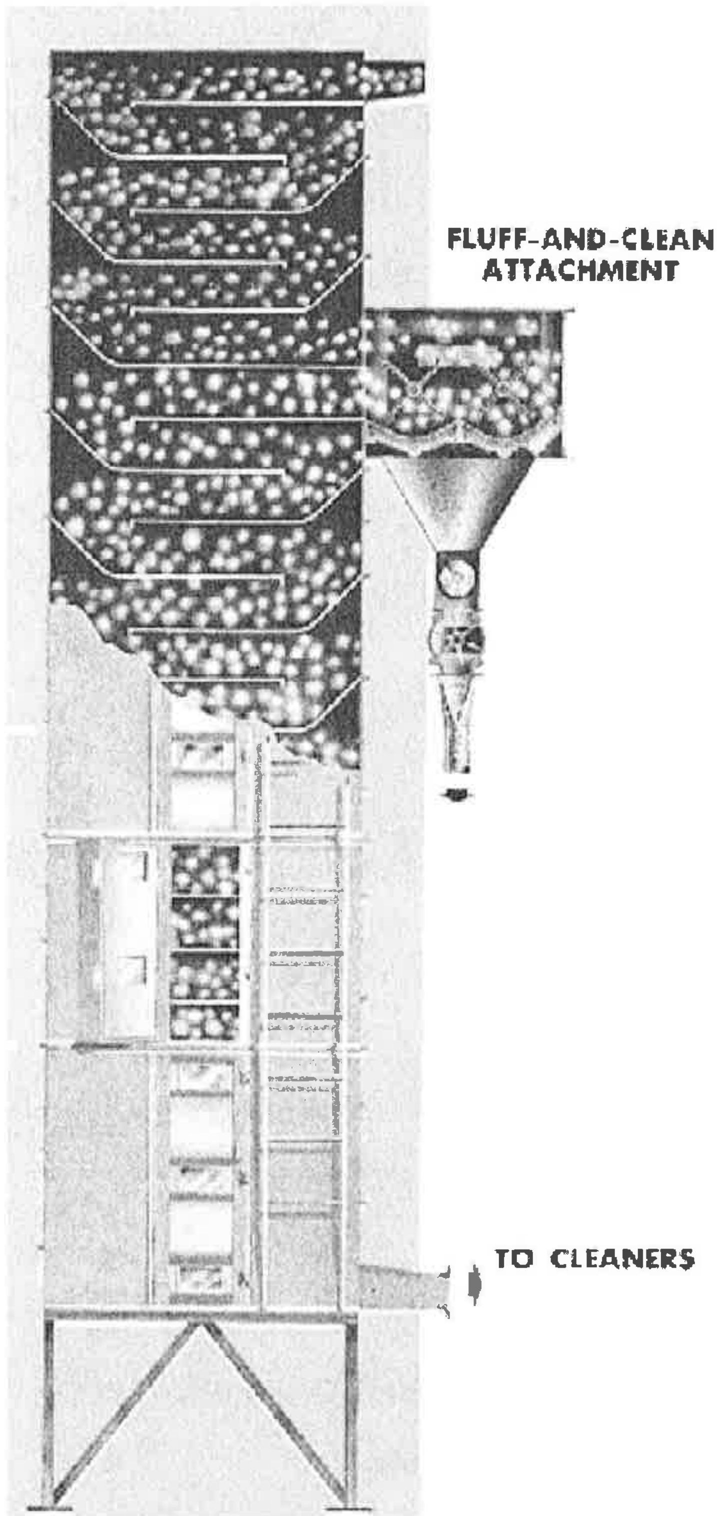

Figure 12. Hardwicke-Etter Tower Dryer with Fluff-and-Clean Attachment.

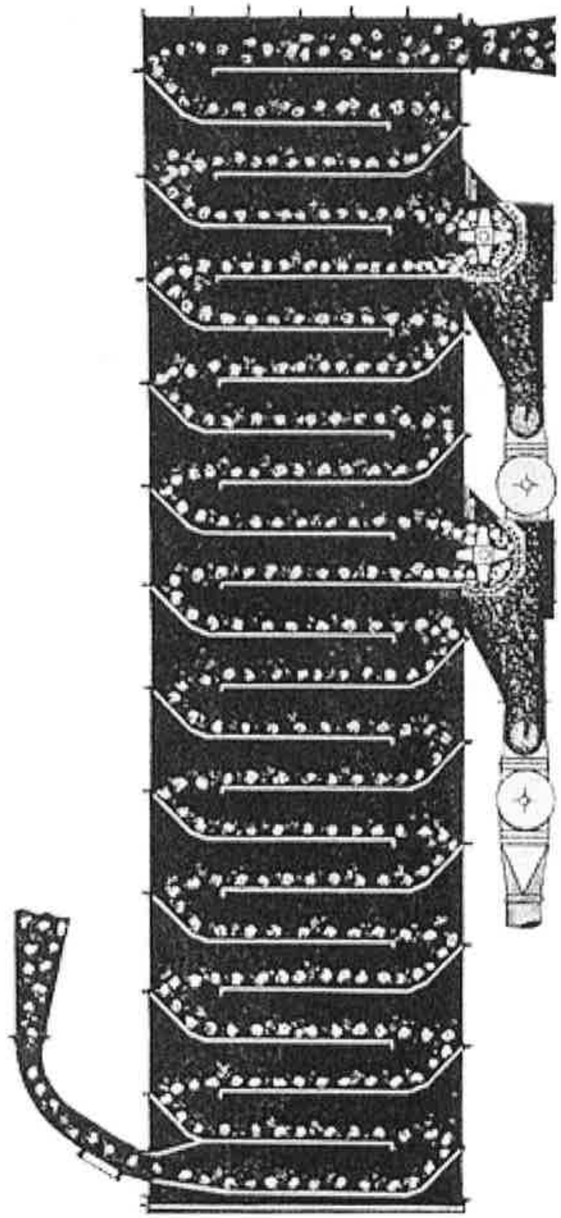

Figure 13. Lummus Tower Dryer with T-Doc Attachments.

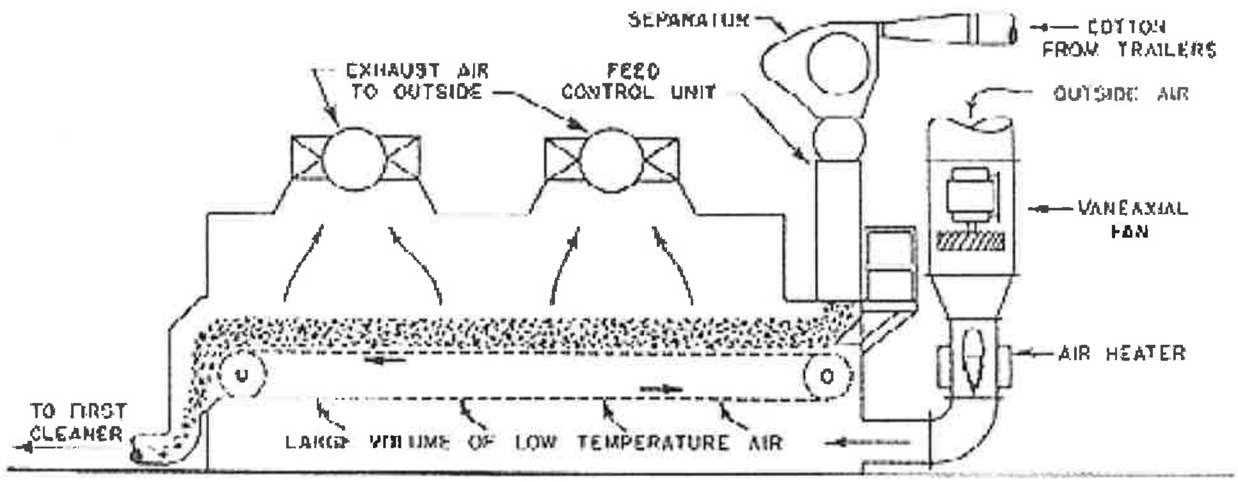

Figure 14. Samuel Jackson Gentle Giant Drying System.

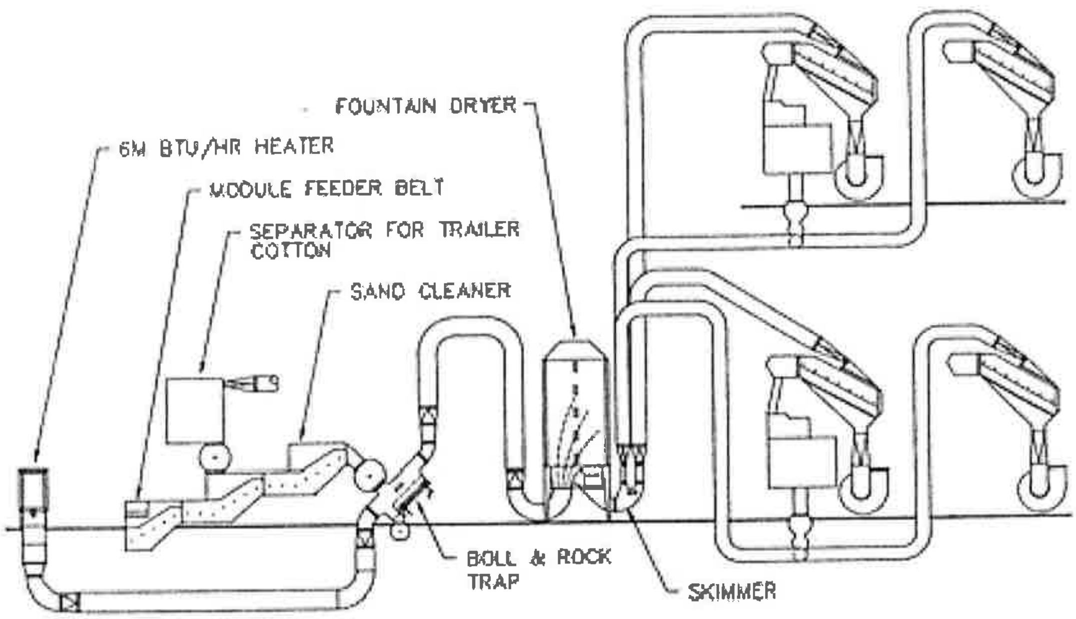

Figure 15. Fountain Cotton Drying System.

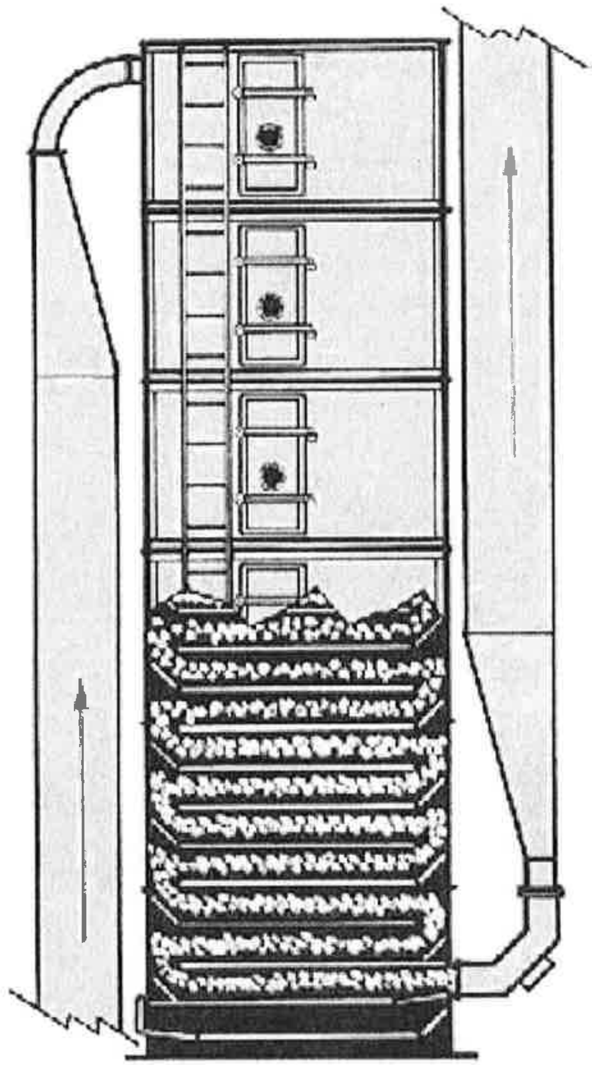

Figure 16. Continental/Murray Twenty-Four Shelf Tower Dryer.

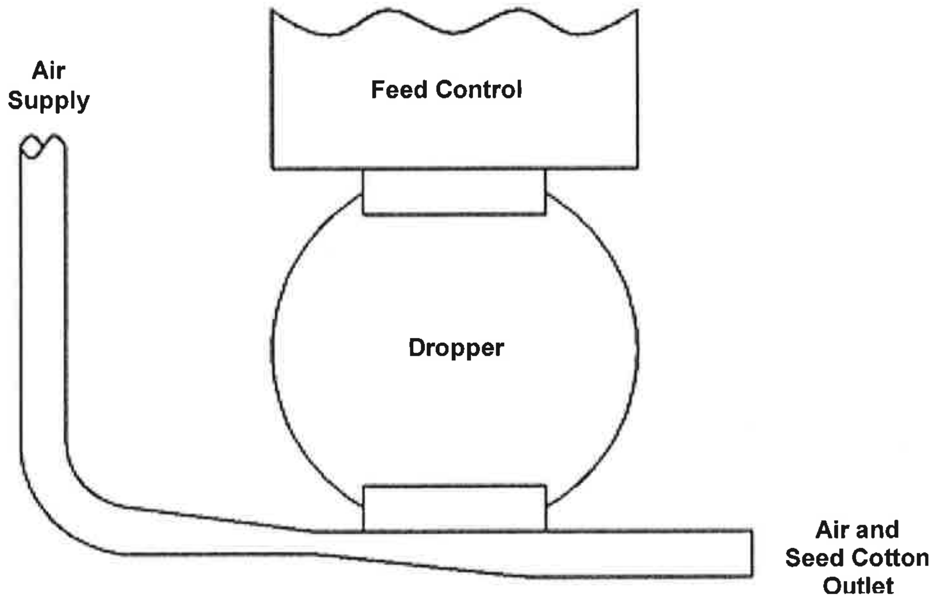

Figure 17. Schematic sketch of one High Velocity Blow Box that was evaluated.

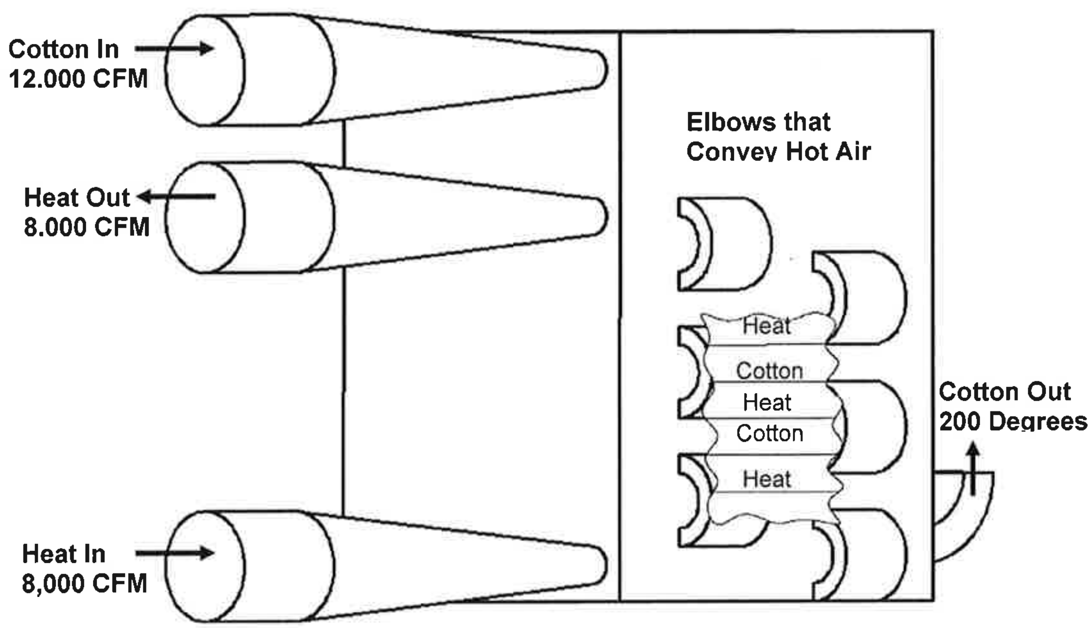

Figure 18. Turbulent Flow, Hot Shelf Tower Dryer.

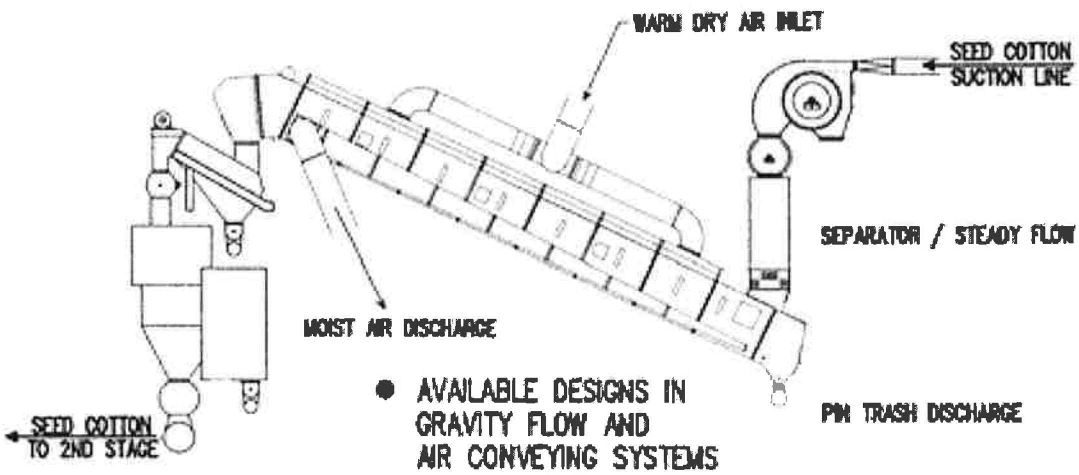

Figure 19. Kimbell Belt Dryer.

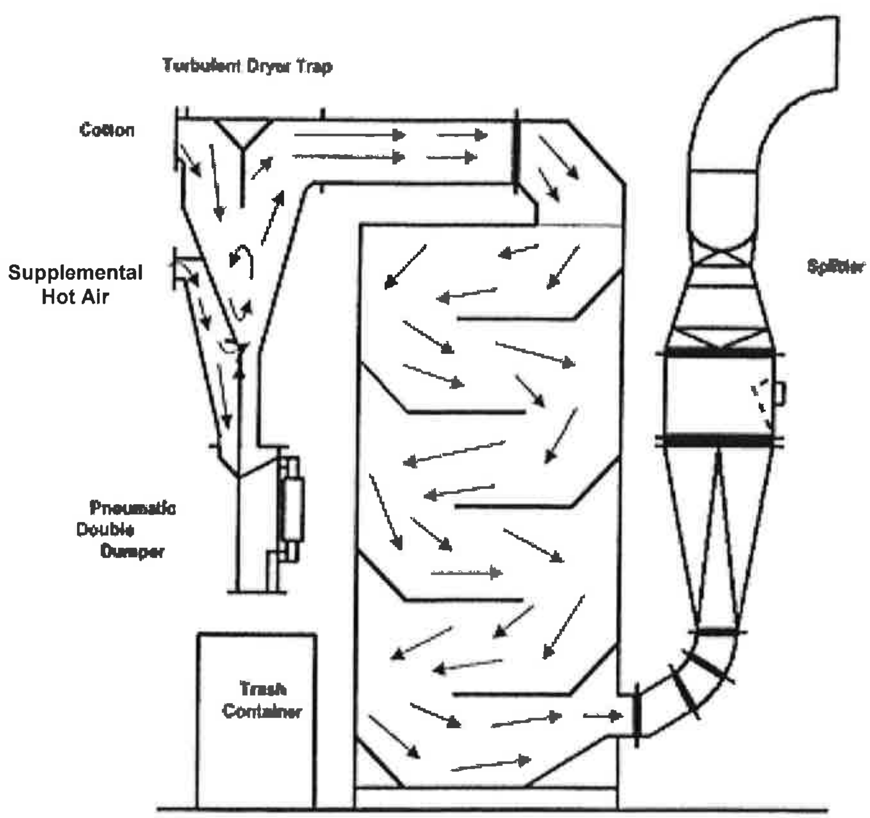

Figure 20. Lummus High Volume Tower Dryer

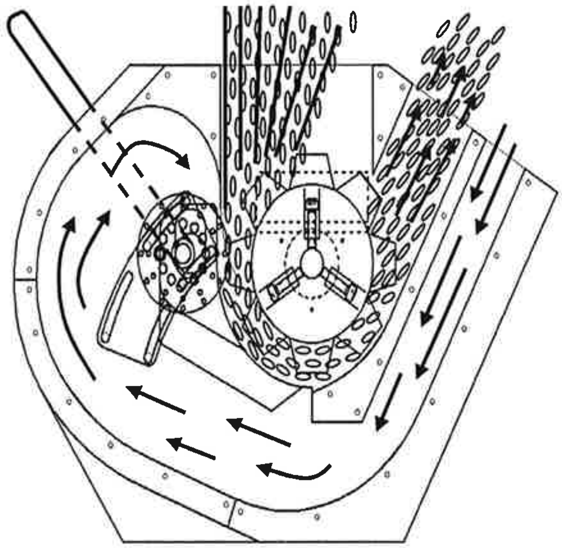

Figure 21. Hi-Slip Dryer.

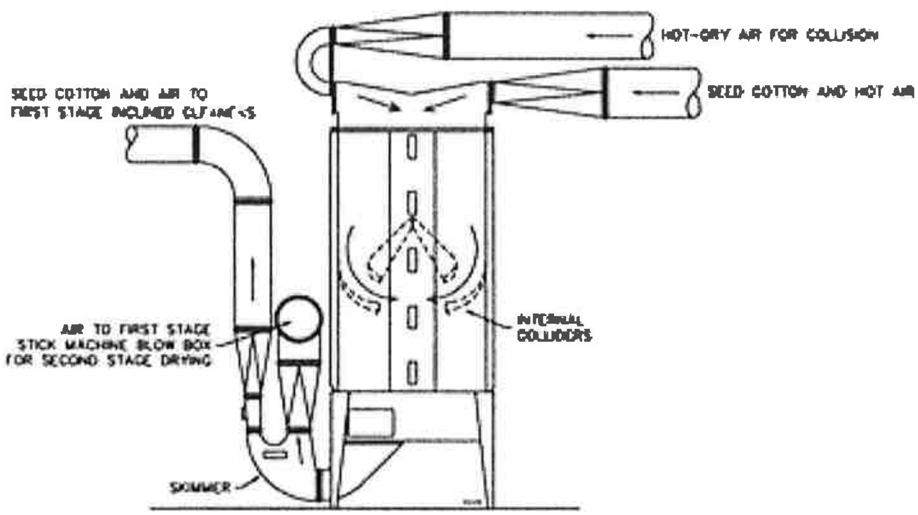

Figure 22. Collider Dryer.

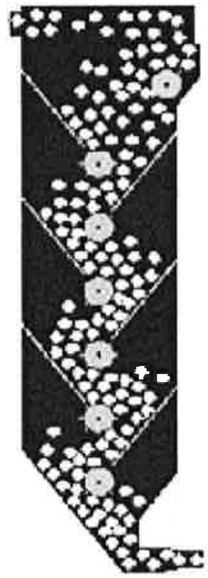

Figure 23. Continental Eagle Vertical Flow Dryer.

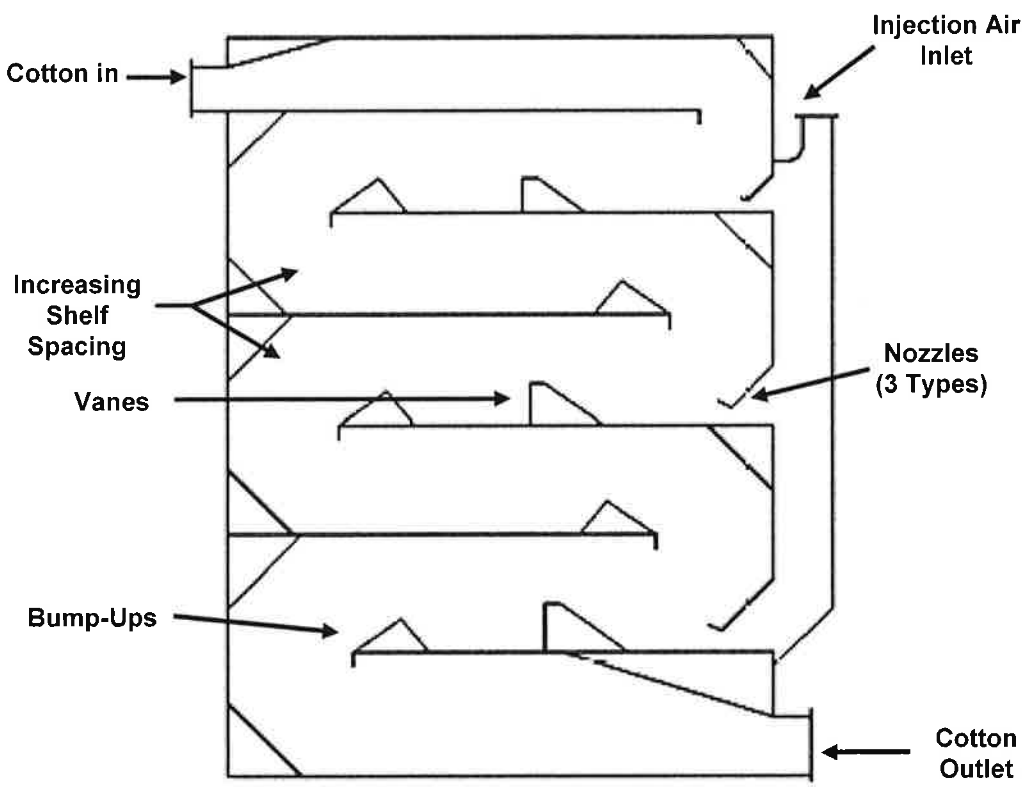

Figure 24. Even Heat Tower Dryer.

Appendix 4

Cotton Gin Insulation Articles

Insulating Driers in Cotton Gins[1]

BY A. C. GRIFFIN, JR.[2]

THE SHELF-TYPE tower drier for drying seed cotton at gins was patented in 1932 by C. A. Bennett of the U.S. Department of Agriculture. This drier was initially designed as a wooden structure, and the drying air was heated by steam coils. Another early model was constructed of metal and covered with a layer of insulating board to prevent undesirable cooling from the initial heated air temperature of 200° F. or less.

These driers were eminently successful in their missions of (1) improving the income of cotton farmers by improving lint preparation, and (2) making possible the ginning of damp cotton that theretofore required drying at the farm before it was brought to a gin.

The commercial version of Mr. Bennett's drier is of steel construction and heat is supplied to the air stream by direct-fired oil or gas burners. The mechanical harvesting of cotton that mushroomed after World War II increased the need for gin driers, and, in 1957, there were more than 6,800 ginning batteries in the United States of which more than 5,800 had one or more driers for seed cotton, although not all were made of steel, and none has been equipped with insulation because the fuel for them has been so inexpensive.

A typical gin drying system consists of air fans, a burner, a galvanized metal transport pipe that is 14-19 in. in diameter, and the drier. The system is arranged as illustrated in figure 1.

Cotton is dropped into the hot air line at the air/cotton mixpoint and remains in the heated air stream until the air and cotton are separated in a sealed-wheel separator, or as shown here, in a cylinder cleaner that also functions as a separator. In our gin the overall distance from burner to separation point is 296 ft. The distance from the pickup point to separation point is 248 ft: At an air volume of about 6,000 ft^3/min, the air transit time from mixpoint to separation point is 5.7 seconds. The velocity of cotton in an airstream is dependent upon its aerodynamic characteristics. Damp cotton travels slower than fluffed dry cotton; in our drier an average cotton lock transit time would be in the 10- to 15-second range. This is also the interval during which cotton is in contact with the heated air for drying. High air velocities are used to prevent the system from becoming clogged by partially opened cotton, hulls, soil, and other foreign matter.

In keeping with the present national policy of energy conservation and as a means of reducing the cost of ginning, the U.S. Cotton Ginning Research Laboratory at Stoneville, Miss., is actively seeking practical means of reducing the consumption of electricity and fossil fuel by gins. The purpose of this paper is to report our work directed toward reducing heat losses caused by radiation and convection in gin drying systems.

Methodology

The data reported here were collected with no cotton in the system as we were interested in external heat loses only.

The data collecting system was comprised of an automatic scanner/recorder that received temperature signals from type K thermocouples at the burner, cotton pickup point, drier inlet, drier outlet, and air/cotton separation point. Air velocity and volume information were calculated from velocity pressure data read from a pitot tube and water gauge manometer. Fuel flow data were obtained by timing the turns of a 10 ft^3/ revolution dial on a gas meter; gas pressure at the meter was 5 psig.

All data reported herein were based on real observations except those for the temperature of air leaving the burner. We found that the air leaving the burner was in laminar flow, and the temperature indicated by our single-point thermocouple did not represent that of the entire cross-section. The temperature of air leaving the burner was calculated by the use of the following equations:

$$H = 1384\ G, \qquad (1)$$

where H = heat content of fuel, Btu
1384 = Btu/ft^3 gas at 5 psig
G = fuel flow rate, ft^3/min at 5 psig;

$$Q = 0.242\ M_1 + 0.45(M_2 + 0.132\ G), \qquad (2)$$

where Q = heat capacity of the air-water vapor mixture, Btu/°F
M_1 = mass of ambient dry air flowing, lb/min
M_2 = mass of ambient water vapor flowing, lb/min.
0.242 = average specific heat of dry air, Btu/lb/°F
0.45 = average specific heat of water vapor, Btu/lb/°F
0.132 = combustion production factor, lb water vapor/ft^3 of gas at 5 psig;

$$\Delta t = H/Q, \qquad (3)$$

where Δt = temperature rise due to combustion, °F; and

$$t_1 = t_0 + \Delta t, \qquad (4)$$

where t_1 = temperature of air-water vapor mixture leaving burner, °F
where t_0 = temperature observed at burner with fans on but no fuel consumed.

The heat content of the air at the five points already indicated was calculated from observed mass flow rates of dry air and water vapor and from heat content data from enthalpy tables by Zimmerman and Lavine.[3]

The conversion efficiency of the burner was assumed to be 100 percent since combustion occurred in the air stream and the combustion products remained in the air stream. The insulation was installed by, first, simply covering the pipe and drier with a single layer of Thermal Insulating Wool (TIW) type II. This was a fiber-glass material. It had a nominal thickness of 1½ in. and was held in place by sisal wrapping twine. Then after the 1½ in. TIW tests were completed, a second layer of TIW was applied and the tests were repeated with the system covered with 3 in. of TIW.

The tests were conducted using airflow rates of 4,500 and 6,000 ft^3/min. Data for only 6,000 ft^3/min are reported here because of the data for 4,500 ft^3/min did

1 For publication in Cotton Gin and Oil Mill Press.

2 Research Physicist, U.S. Cotton Ginning Research Laboratory, Agricultural Research, Science and Education Administration, U.S. Department of Agriculture, Stoneville, Miss., in cooperation with State Experiment Stations.

3 Zimmerman, O. T., and Lavine, I. Phychrometric Tables and Charts. Industrial Service, Dover, New Hampshire. 1945.

TABLE 1.--Temperature, heat-content, and heat-loss data for a gin drying system operated at 6,000 ft^3/min airflow with no insulation and with 1 1/2 and 3 in. of thermal insulating wool (TIW), type II 1/

Gas valve position 2/	Burner		Pickup		Separation		Loss	
	°F	Btu X 10^3	°F	Btu X 10^3	°F	Btu X 10^3	Btu X 10^3	Btu/°F
				No insulation				
1	188	22.3	161	19.4	138	16.9	5.4	51
2	277	33.6	232	28.8	184	23.6	10.0	52
3	395	48.1	326	40.6	244	31.5	16.6	53
								52.0 av
				1 1/2-in. TIW insulation				
1	185	21.0	164	18.7	141	16.3	4.7	43
2	270	31.6	242	28.4	205	24.4	7.2	37
3	393	47.0	346	41.7	286	35.1	11.9	38
								39.3 av
				3-in. TIW insulation				
1	199	23.8	175	21.3	152	18.7	5.1	40
2	279	33.8	246	30.1	213	26.5	7.3	36
3	399	48.5	347	42.7	297	37.1	11.4	36
								37.3 av

1/ All values are means of four replicated tests except those for 1 1/2-in. TIW, which are means of five replicated tests.

2/ Positions 1, 2, and 3 indicate increasing rates of gas flow.

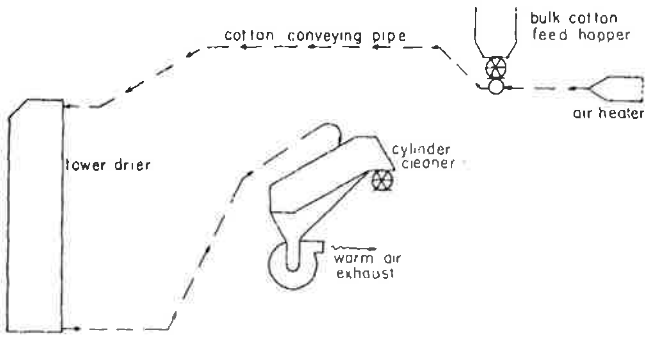

Fig. 1—Typical gin drying system in the U.S. cotton gin.

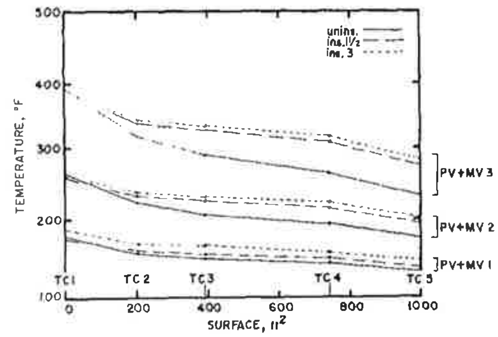

Fig. 2—Temperature profiles for a gin drying system without insulation and with 1½ and 3 in. of Thermal Insulating Wool, type II. Thermocouple locations are: TC 1—burner; TC 2—pickup point; TC 3—drier inlet; TC 4—drier outlet; and TC 5—separation point.

PV+MV1=pilot valve plus main valve in position 1.

PV+MV2=pilot valve plus main valve in position 2.

PV+MV3=pilot valve plus main valve in position 3.

not affect the conclusions drawn from the experiment.

The three fuel flow rates were controlled by bolting the main gas valve in preselected positions. Each airflow and fuel flow rate combination was allowed to continue until the system reached temperature equilibrium. The system was considered to be in temperature equilibrium when the temperature at the farthest location from the burner was changing at a rate slower than 1°F per min. The usual time required to reach equilibrium was from 25 to 45 min.

The data for the uninsulated drier were collected in the spring of 1977, and for the insulated drier, in the spring of 1978.

Results and Discussion

The temperature profiles of the sys- at the three gas valve positions are shown in figue 2. The effects of the TIW blankets are quite apparent.

The data in table 1 were based on an airflow of 6,000 ft³/min of ambient air for 1 min. The temperatures resulting from the valve positions are not uncommon in U.S. gins. The loss figures are based directly on the difference between the heat content of the air at the burner and that at the separation point. No heat was used for evaporating moisture as no cotton was in the system. The loss data expressed in Btu, only, changed with changes in the ambient atmosphere. For greater usefulness, therefore, the loss data were expressed additionally, in Btu/°F. The temperature value used as a divisor was the difference between the temperature of the air leaving the burner and the average temperature of ambient air in the vicinity of the drying system. These data indicate that the heat loss in the drier insulated with the 1½-in. layer of TIW was about 24 percent lower than that in the uninsulated drier, and when the drier was insulated with a 3-in. layer of TIW, its heat loss was about 28 percent lower than that of the uninsulated drier.

The cost of TIW type II insulation in 4′ x 100′ rolls is about $12 per 100 ft² at this time. Our commercial-type seed-cotton drying system has a total surface of about 1,000 ft², and would, therefore, require about $144 worth of insulation for a single, 1½-in. layer, allowing for 20 percent waste. The covering of two drying systems with 3 in. of TIW type II would require an expenditure of about $576. The material can be installed in 3 days with gin labor. Thus, for an insulation cost of about $1,000, radiation and convection losses should be reduced about 25 percent in an average gin. Ginners who insulate their drying systems should be especially observant during the first few days of operation to establish new, reduced operating set-point temperatures.

Summary and Conclusions

Tests in 1977 and 1978 with a full-scale gin showed that the rate of heat loss from an uninsulated drying system may be reduced 24 and 28 percent by using Thermal Insulating Wool, type II in thickness of 1½ and 3 in., respectively. With insulation, more of the heat supplied to gin driers would be available for evaporating moisture from damp cotton than would be available without insulation. Lower set-point temperatures may be used and, thus, less fuel would be required for drying cotton in an insulated drier than in an uninsulated drier, even if only one layer of insulation is used.

DISCLAIMER: Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not imply approval of a product to the exclusion of others that may be suitable.

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INSULATED DRYING SYSTEM: KEY TO CONSERVING FUEL

An ARS Engineer Cut Drying Costs Up To 14 Cents Per Bale

By Roy Childers

Introduction

In stripper-harvesting areas, almost all gins are equipped with at least one stage of seed-cotton drying (1)[1]. Many gins use two stages of drying, and some even require three stages to reduce the moisture in cotton to the proper level for optimum cleaning and ginning. Several years ago the commercial manufacturing and marketing of an insulated drying system was attempted. However, due to relatively low costs for fuel at that time, the system was not economically justifiable and therefore was unsuccessful.

The rapid rise in the cost of fuel for drying cotton over the past few years has led ginners and producers to become increasingly interested in methods for conserving energy. Also, with limited fuel supplies and with the possibility of curtailment during critical harvesting-ginning operations, the need for efficient use of available fuel increases. In studies at the USDA South Plains Ginning Research Laboratory, Lubbock, Texas, for the past 4 years an approach to energy conservation has been investigated that has the potential of significantly reducing fuel consumption. The objectives for the test reported herein were to compare the fuel consumption of an insulated drying system with that of an uninsulated system and to determine the potential fuel savings at equal levels of moisture removal.

Equipment and Procedures

The laboratory gin, equipped with two stages of drying, was used for this study. Each drying system consisted of a 3-million Btu burner, a push-pull pneumatic conveying system, a 24-shelf, 52- X 56-in. drier, and about 90 ft. of 16-in-diam pipe. In the number 1 drying system, all pipes were covered with 1-in-thick fiberglass batt, and the tower drier was covered with 1-in-thick rigid fiberglass board. The rate of airflow through the two systems was adjusted such that it would be equal for both systems.

The insulation was attached to the pipe and drier with the materials shown in Fig. 1. This system consisted of nylon "stuk-up" clips glued to the metal surface and metal washers that held the insulation in place. The batt insulation was 12 in. longer than the pipe circumference so it could overlap sufficiently at the clips (Fig. 2). Table 1 gives the recommended lengths for the insulation and the linear footage covered by standard 75-ft (2-in.) and 100 ft (1.5-in. thick) rolls of insulation for pipes 12 to 24 in. in diameter.

Before bur cotton was ginned, it was loaded from the trailer into a blender-feeder. It was loaded in horizontal layers and unloaded vertically so differences in moisture content between treatments would be minimized. Cotton was fed out of the blender into the suction line at a rate of about 8 bales per hour.

The following machinery sequence was used: airline cleaner, steady-flow feeder, tower drier, inclined cleaner, bur machine, inclined cleaner, stick machine, feeder, gin stand, and two stages of lint cleaning.

The two systems were operated alternately at air set-point temperatures (controlled at the air/cotton mix-point) of 150°, 175°, 200°, and 225°F. Temperatures were measured with thermocouples in the center of the air conduit at the fresh air inlet, 3 feet below the burner, at the mix-point, at the drier inlet, and at the drier outlet. Moisture content of the cotton was measured before and after the cotton passed through the drying system and was expressed as percentage of dry material.

Table 1. — Length of pipe covered by standard rolls of 1.5- and 2-in-thick batt insulation.

Pipe diameter, in.	Length of insulation for one wrap, in.	Length of pipe covered by standard roll, ft. 2-in. thickness (75-ft roll)	1.5-in. thickness (100-ft roll)
12	50	72	96
14	56	64	84
16	62	56	76
18	67	62	68
20	75	48	64
22	81	44	56
24	88	40	52

Roy Childers is an Agricultural Engineer at the South Plains Cotton Ginning Research Laboratory operated by USDA's Agricultural Research Service and formerly was Extension Ginning Specialist for the Texas High Plains.

Results

Table 2 contains a summary of the temperatures taken at the various locations in the system. For a given mix-point temperature, the uninsulated system operated at a higher burner temperature than the insulated system, and its total temperature drop (burner temperature minus temperature at drier outlet) was from one and a half to two times greater than that of the insulated system.

Due to differences in the operating characteristics of the two drying systems, a direct comparison based upon mix-point temperatures would not be valid. Therefore, the relationship

Figure 1. — Materials used for attaching insulation to the drying system.

Mention of a trade name or a proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

between mix-point temperature and moisture removal and burner temperature was used for determination of the fuel savings.

A linear regression of mix-point temperature vs. percentage of moisture removed was calculated for each system. Then a regression of mix-point temperature vs. burner temperature was calculated. From these regressions, the mix-point temperature and corresponding burner temperature for each system were calculated (Table 3) for moisture removal rates of 1.0, 1.25, and 1.5 percentage points.

Assuming a constant airflow rate and ambient air conditions, the heat content of the air necessary for removal of these amounts of moisture was calculated for various locations in the system. The total heat reduction and potential fuel savings that would result from insulating the drier were then determined from the expression:

$$\text{Savings (Percent)} = 100\,(U-I)/U$$

where U is total heat added to uninsulated drying system and I is total heat added to insulated drying system.

The total heat added was based on the burner temperature. For determination of the fuel savings resulting from insulation between the mix-point and the tower drier outlet, the heat content of the air

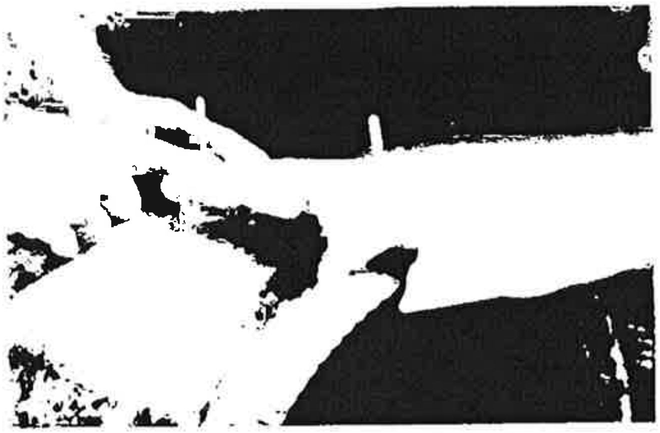

Figure 2a. — Attachment of insulation to pipe.

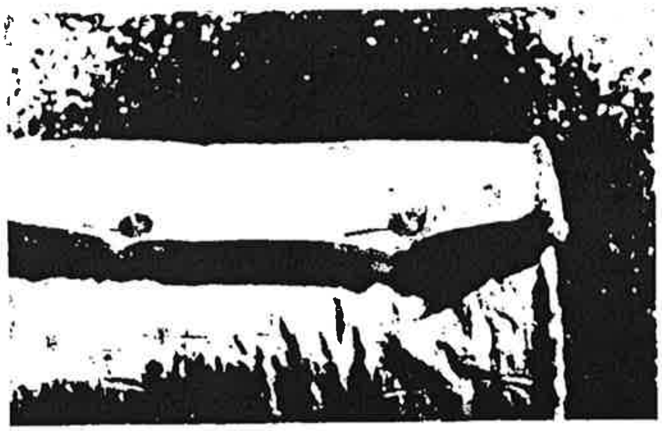

Figure 2b. — Insulation installed on pipe.

at the mix-point was substituted for total heat in the above equation. The fuel saving resulting from the insulation between the burner and mix-point is the difference between the total savings and the amount saved between the mix-point and the drier outlet.

Table 3 presents the fuel savings that would result from using an insulated drier for removal of 1.0, 1.25, and 1.50 percentage points of moisture with one stage of drying. The insulated system reduced total fuel consumption 21 to 27 percent. The total amount of fuel saved decreased as the drying temperature was increased. As operating temperatures increased the savings between the burner and mix point tended to increase, but the trend was variable. However, in the tower, fuel savings were definitely reduced as the temperature was increased. This result implied that, for higher temperatures, the use of insulation of a greater thickness than was used in this test would be beneficial, particularly for the drier.

Since the burner controller in most commercial gins is near the bottom of the drier, some modification would be necessary in the drying system if insulation should be installed. As indicated in Table 2, the insulated system has a lower mix point temperature than the uninsulated system at the same drier-outlet temperature and would, therefore, do less drying. With an increase of about 30° F in the outlet temperature, the insulated system would yield about the same amount of drying and still give a 20-25 percent reduction in fuel use.

Cost Analysis

Material as listed in Table 4 was required for the insulation of one drying system.

The labor for installing the insulation required a three-man crew working 24 hours. At $4.00 per hour, the total labor cost was $288 and the total cost for materials and labor was $517.

For optimum fuel savings at the higher operating temperatures, 2-in-thick insulation should be used throughout the system. The material and labor required and associated costs for insulating a typical gin with two stages of drying were calculated as follows: Assuming the use of 200 ft of 16-in. pipe, 56 feet of pipe can be covered with each roll of 2-in-thick insulation, for a total of four rolls.

Each drier requires 54 sheets of rigid insulation board or a total of 108 sheets. The material is packaged eight sheets per carton, making the requirement a total of 14 cartons of rigid insulation board.

Nylon clips are packaged 1,000 per carton, and one carton is sufficient for the insulation of most gins. For estimating, allow one clip per foot of pipe and six clips per sheet of rigid board. Additionally, two quarts of adhesive will be needed per 1,000 clips. The cost for materials would be about $720 and the cost for labor about $640, or a total cost of $1360 for the insulation of two drying systems.

Averaged across the season, the drying of one bale of cotton requires about 400 ft^3 of natural gas (2). At a cost of $1.40 per 1,000 ft^3 of natural gas, the cost of the drying fuel would be $0.56 per bale. A 25 percent reduction in fuel consumption would result in a saving of $0.14 per bale. Dividing the cost of installation by that value would result in a break-even point of about 9,700 bales. In areas that use higher-than-average amounts of drying, the break-even point would be lower. In areas that use minimal drying, the time required to save enough fuel to offset the cost of installation, would be longer than in areas that use more drying. If you know the actual fuel cost per bale for your gin, you could use that cost to more accurately estimate the break-even point for your gin.

References

1. U.S. Dept. of Agric. 1976. Cotton gin equipment. U.S. Dept. of Agric., Consumer and Mark. Service Release. July 27, Memphis, Tennessee.

2. Coble, C. G. and W. A. LePori. Energy for Texas Agriculture. Report SID-12. Special project B. Governor's Energy Advisory Council. December 1974.

Set 1/ Point, °F	Burner °F	Mix Point °F	Drier Inlet °F	Drier Outlet °F	Total Temp. Drop, °F 2/
Insulated System					
150	154	170	156	109	75
175	229	208	176	124	111
200	276	241	200	136	140
225	307	264	211	148	159
Uninsulated System					
150	260	206	156	104	156
175	283	246	182	114	169
200	345	272	199	117	228
225	377	298	214	130	247

1/ Controlled at mix point.

2/ Burner temperature minus temperature at drier outlet.

Table 2. — Temperature profiles of insulated and uninsulated drying systems.

Table 3. — Potential fuel savings for an insulated drying system.

Moisture removed, percentage points, dry basis	Burner temperature, °F		Mix-point temperature, °F		Potential fuel savings, pct.		
	Insulated system	Uninsulated system	Insulated system	Uninsulated system	Burner to mix point	In tower	Total
1.0	211	274	192	238	3.7	23.3	27
1.25	260	337	230	271	8.3	17.7	26
1.50	310	381	268	304	7.4	13.6	21

Summary

In an insulated drying system, fuel use was 21 to 27 percent lower than in an uninsulated system. The percentage of savings decreased as drying temperature increased, indicating than an insulation thickness greater than the 1 in. tested would be beneficial. A cost analysis indicated that about $0.14 per bale could be saved with a break-even point for material and labor of about 9,700 bales.

Table 4. — Cost Estimate format

Material	Quantity	Cost
1-in. batt insulation	100 ft roll	$ 38.00
1-in. rigid insulation board	448 ft^2 (seven cartons)	116.00
Stuk-ups w/washers	1,000 (one carton)	71.00
Adhesive	1 quart	4.00
	Total	$229.00

Reprinted from 1978 *Ginners' Journal & Yearbook*

Appendix 5

Public Notice of Intent: Notice

San Joaquin Valley
AIR POLLUTION CONTROL DISTRICT

HEALTHY AIR LIVING

NOTICE OF DEVELOPMENT of

Best Performance Standards

NOTICE IS HEREBY GIVEN that the San Joaquin Valley Air Pollution Control District solicits public comment on development of Best Performance Standards for the following Stationary Source class and category of greenhouse gas emissions:

Dryers and Dehydrators – Cotton Gin Dryers

The District is soliciting public input on the following topics for the subject Class and Category of greenhouse gas emission source:

- Recommendations regarding the scope of the proposed Class and Category, (Stationary GHG sources group based on fundamental type of equipment or industrial classification of the source operation),
- Recommendations regarding processes or operational activities the District should consider when establishing Baseline Emissions for the subject Class and Category. Baseline Emissions for this Best Performance Standard are the average GHG emissions emitted by a standard cotton gin dryer during the 2002 – 2004 seasons,
- Recommendations regarding processes or operational activities the District should consider when converting Baseline Emissions into emissions per unit of activity (i.e. emissions per bale of cotton produced), and
- Recommendations regarding technologies to be evaluated by the District, when establishing Best Performance Standards for the subject Class and Category.

Information regarding development of the proposed Best Performance Standard can be obtained from the District's website at http://www.valleyair.org/Programs/CCAP/CCAP_menu.htm.

Written comments regarding the proposed Best Performance Standard should be addressed to Derek Fukuda by email, derek.fukuda@valleyair.org, or by mail at SJVUAPCD, 1990 E. Gettysburg Avenue, Fresno, CA 93726 and must be received by **November 23, 2010**. For additional information, please contact Derek Fukuda at derek.fukuda@valleyair.org or by phone at (559) 230-5917.

Information regarding the District's Climate Action Plan and how to address GHG emissions impacts under CEQA, can be obtained from the District's website at http://www.valleyair.org/Programs/CCAP/CCAP_idx.htm.

Appendix 6

Comments Received During the Public Notice of Intent

California Cotton Ginners Association

1785 N. Fine Avenue
Fresno, CA 93727
Telephone: 559 / 252-0684
Fax: 559 / 252-0551

Mr. Derek Fukuda
SJV Air Pollution Control District
1990 E. Gettysburg Avenue
Fresno, CA 93726

November 23, 2010

Dear Mr. Fukuda:

The California Cotton Ginners Association appreciates the opportunity to comment on the development of the Cotton Gin Best Performance Standard being developed by the Air District. The California Cotton Ginners Association represents all 21 cotton ginning companies within the SJV Air District's boundaries and has been actively involved in the development of the Climate Change Action Plan and the BPS process.

GHG Inventory

The California Air Resources Board has recently updated their emissions projections for the Business as Usual forecast for 2020. The District used this projection as the baseline for creating the 29% reduction target for BPS overall and project specific reductions for projects that do not wish to use BPS. Based upon the updated inventory projections, the new reduction target should be 16%.

SJV Carbon Exchange

An important component of the Climate Change Action Plan was the development of a carbon exchange. This exchange would help simplify many applications by providing GHG emission offsets to satisfy CEQA requirements. For smaller projects, using the exchange would be a simpler process for some operations.

Cotton Gin Dryer BPS

The BPS process was envisioned as a streamlined approach for satisfying greenhouse gas emissions under the CEQA process. This may be true for large sources of emissions, but smaller sources have been brought into a process that can be lengthy because of the complexity of the many different facilities operating in the SJV Air District. The Air District needs to keep in mind the difficulty of fitting industries into a one-size-fits-all category. The drying of cotton in the San Joaquin Valley is an example of the difficulty a one-size-fits all approach.

The use of Dryers in cotton gins is very important in the ginning process. Dryers are used in the cotton ginning process to optimize cleaning efficiency of the incoming seed cotton; furthermore to optimize lint separation from the seed, the cotton must be dried to the optimum moisture content. Too much heat or too little heat can have many adverse effects on the quality of the cotton and the efficiency of the gin operation. A high moisture content in the cotton can lead choking and the complete shutdown of the ginning operation. It can also lead to damaging the gin machinery and static electricity buildup. Low moisture content can have damaging effects to the quality and present problems with bale uniformity.

There is no best drying design for all gins and no dryer design has been proven to be more efficient than the other in all situations. Each gin needs to be able to choose the best design for their particular gin, considering all factors that will dry and clean the cotton specific to their members.

Technologies

Standard Efficiency Fans

Most ginning operations use standard efficiency centrifugal electrical fans to push and pull the cotton through the dryer. Recently a gin has installed a premium efficiency fan during an upgrade to the gin. The gin was able to lower the horsepower required from 100 hp to 75 hp and this allowed the premium efficiency fan to be cost effective over the standard efficiency fan. This may not be cost effective in gin operations that are not able to reduce horsepower.

Use of Recycled Equipment

The decrease of the number of cotton ginning operations in California has resulted in a number of pieces of equipment being available for those wishing to replace or expand their operations. The difference in cost between purchasing new and using equipment that was previously installed in a gin that has since been closed can be significant. Gins need the ability to purchase used equipment instead of being forced to purchase brand new equipment.

In closing, we appreciate the opportunity to provide comments on the BPS process. The issue is of utmost importance to the ginning industry in California as we fight to remain competitive in the world marketplace. If you have any questions or need additional information, please contact Roger Isom or myself at (559) 252-0684.

Sincerely,

Casey Creamer
Vice President

cc: Dave Warner, SJVAPCD
Rick McVaigh, SJVAPCD

CALIFORNIA COTTON GINNERS AND GROWERS ASSOCIATIONS

1785 N. Fine Avenue
Fresno, CA 93727
Telephone: 559 / 252-0684
Fax: 559 / 252-0551

Mr. Derek Fukuda
SJV Air Pollution Control District
1990 E. Gettysburg Avenue
Fresno, CA 93726

October 17, 2011

Dear Mr. Fukuda:

The California Cotton Ginners Association appreciates the opportunity to comment on the Draft Cotton Gin Dryer Best Performance Standard being developed by the Air District. The Association represents all 21 cotton ginning companies within the SJV Air District's boundaries and has been actively involved in the development of the BPS process. We have two main concerns with the Draft dated September 13, 2011.

Insulation

The Draft Cotton Gin Dryer BPS does not differentiate between the various stages of drying that would need to have insulation. We understand this to mean that all stages of drying would need to insulate ducting from the burner to the dryer inlet. There can be one to three drying stages and the most efficiency gains are made by insulating the 1st stage of drying. The 2nd and 3rd stages are commonly turned to a lower heat level than the 1st stage and sometimes are not even in use depending on the conditions of the cotton. We do not believe that insulating beyond the 1st stage of drying is cost effective nor is it a common practice in the ginning industry.

GHG Emission Averages

In the Draft BPS, the District uses an "averages" of bales per hour and emissions per bale. We understand that the District needs to use some average to come up with emission estimates for the baseline period and potential reductions. However, we feel that it also needs to be noted that these "averages" should not be used for any regulatory purpose or for efficiency comparisons between gins. As we have noted in previous comments, the amount of fuel use can drastically change from year to year based on the conditions of the crop. Weather, harvest conditions, and cotton varieties are all factors for the need for more or less drying in any particular year. The "average" the District uses must have caveats attached if it is a necessity that they be included in the Draft BPS. We would caveat the averages with the following;

"The averages used were collected from limited emission data from the 2002 to 2004 baseline years. Cotton gin dryer fuel usage can vary greatly from year to year due to variations in seasonal crop conditions, cotton variety, storage conditions, etc. and the averages used here for BPS development should not be used for any regulatory purpose."

In closing, we appreciate the opportunity to provide comments on the Cotton Gin Dryer Best Performance Standard. The BPS is of utmost importance to the ginning industry in California. If you have any questions or need additional information, please contact me at (559) 252-0684.

Sincerely,

Casey Creamer
Vice President

cc: Dave Warner, SJVAPCD
Rick McVaigh, SJVAPCD

Appendix 7

Public Participation Process: Public Notice

Derek Fukuda

From: dryers_bps@lists.valleyair.org
Sent: Monday, April 16, 2012 2:58 PM
To: Derek Fukuda
Subject: [Dryers_BPS] SJVAPCD - Cotton Dryers Draft Best Performance Standard
Attachments: ATT00001.txt

The San Joaquin Valley Air Pollution Control District is soliciting public comments on the development of Best Performance Standards (BPS). This email is to advise you the proposed Draft BPS documents for Dryers & Dehydrators – Cotton Dryers is available by clicking here .

Written comments regarding the subject Best Performance Standard should be addressed to Derek Fukuda by email, Derek.Fukuda@valleyair.org, or by mail at SJVAPCD, 1990 E. Gettysburg, Fresno, CA 93726 and must be received by **May 11, 2012**. For additional information, please contact Derek Fukuda by e-mail or by phone at (559) 230-5917.