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ENGINEERING AND GINNING

Third Stage Seed-Cotton Cleaning System Total Particulate Emission Factors and Rates for Cotton Gins: Method 17

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ABSTRACT

This report is part of a project to characterize cotton gin emissions from the standpoint of stack sampling. The impetus behind this project was the urgent need to collect additional cotton gin emissions data to address current regulatory issues. A key component of this study was focused on Environmental Protection Agency (EPA) total particulate emission factors. EPA AP-42 emission factors generally are assigned a rating, from A (excellent) to E (poor), to assess the quality of the data being referenced. Current EPA total particulate emission factor ratings for cotton gins are extremely low. Cotton gin data received these low ratings because the data were collected almost exclusively from a single geographical region. The objective of this study was to collect additional total particulate emission factor data for 3rd stage seed-cotton cleaning systems from cotton gins located in regions across the cotton belt using EPA-approved stack sampling methodology. The project plan included sampling seven cotton gins. Key factors for selecting specific cotton gins included: 1) facility location, 2) production capacity, 3) processing systems, and 4) abatement technologies. Two gins with 3rd stage seed-cotton cleaning system exhausts were sampled. The average production rate during testing for the two gins was 21.0 bales/h. The average 3rd stage seed-cotton cleaning system total particulate emission factor based on two tests (six total test runs) was 0.023 kg/227-kg bale (0.052 lb/500-lb bale). This average total particulate emission factor was less than that currently published in 1996 EPA AP-42, which was 0.043 kg/bale (0.095 lb/bale). The 3rd stage seed-cotton cleaning system test average emission rates ranged from 0.27 to 0.75 kg/h (0.59-1.66 lb/h).

U.S. Environmental Protection Agency (EPA) emission factors published in EPA's Compilation of Air Pollution Emission Factors, AP-42 (EPA, 1996b) are assigned a rating that is used to assess the quality of the data being referenced. Ratings can range from A (excellent) to E (poor). Current EPA emission factor quality ratings for total particulate from cotton gins are extremely low. Cotton gin data received these low ratings because they were collected almost exclusively from a single geographical region, far western U.S. (EPA, 1996a). Cotton ginners' associations across the cotton belt, including the National, Texas, Southern, Southeastern, and California associations, agreed that there was an urgent need to collect additional cotton gin emissions data to address current regulatory issues. Working with the cotton ginning associations across the country, state and federal regulatory agencies, Oklahoma State University, and USDA-Agricultural Research Service (ARS) researchers developed a proposal and sampling plan that was initiated in 2008 to address this need for additional data. This report is part of a series that details cotton gin emissions measured by stack sampling. Each manuscript in the series addresses a specific cotton ginning system. The systems covered in the series include: unloading, 1st stage seed-cotton cleaning, 2nd stage seed-cotton cleaning, 3rd stage seed-cotton cleaning, overflow, 1st stage lint cleaning, 2nd stage lint cleaning, combined lint cleaning, cyclone robber, 1st stage mote, 2nd stage mote, combined mote, mote cyclone robber, mote cleaner, mote trash, battery condenser, and master trash. This report focuses on total particulate emissions from 3rd stage seed-cotton cleaning systems.

The 1996 EPA AP-42 average total particulate emission factor for the No. 3 dryer and cleaner was 0.043 kg (0.095 lb) per 217-kg [480-lb] equivalent bale with a range of 0.041 to 0.045 kg (0.091-0.099 lb) per bale (EPA, 1996a, b). This average and range

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was based on two tests conducted in one geographical location. The EPA emission factor quality rating was D, which is the second lowest possible rating (EPA, 1996a).

Seed-cotton is a perishable commodity that has no real value until the fiber and seed are separated (Wakelyn et al., 2005). Cotton must first be processed or ginned at the cotton gin to separate the fiber and seed, producing 227-kg (500-lb) bales of marketable cotton fiber. Cotton ginning is considered an agricultural process and an extension of the harvest by several federal and state agencies (Wakelyn et al., 2005). Although the main function of the cotton gin is to remove the lint fiber from the seed, many other processes also occur during ginning, such as cleaning, drying, and packaging the lint. Pneumatic conveying systems are the primary method of material handling in the cotton gin. As material reaches a processing point, the conveying air is separated and emitted outside the gin through a pollution control device. The amount of dust emitted by a system varies with the process and the condition of the material in the process.

Cotton ginning is a seasonal industry lasting from 75 to 120 days, depending on the size and condition of the crop. Although the trend for U.S. cotton production remained generally flat at approximately 17 million bales per year during the last 20 years, annual production varied greatly for various reasons, including climate and market pressure (Fig. 1). The number of active gins in the U.S. has not remained constant, steadily declining to fewer than 700 in 2011. Consequently, the average volume of cotton handled by each gin has risen and gin capacity has increased to an average of approximately 25 bales per hour across the U.S. cotton belt (Valco et al., 2003, 2006, 2009, 2012).

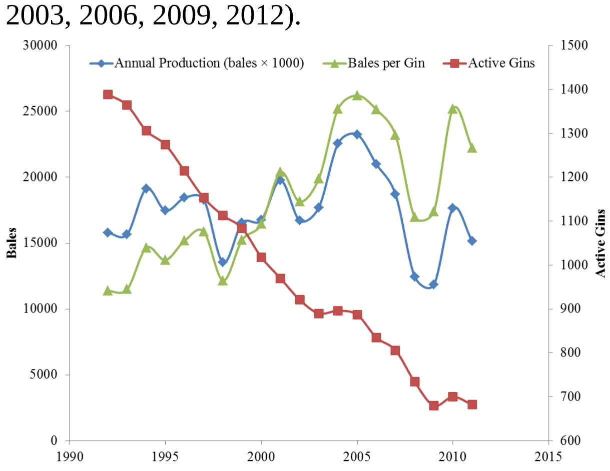

Figure 1. Annual U.S. cotton production, active U.S. gins, and average ginning volume (bales per gin) (NASS, 1993-2012).

The typical cotton gin facility includes: unloading system, dryers, seed-cotton cleaners, gin stands, overflow collector, lint cleaners, battery condenser, bale packaging system, and trash handling systems (Fig. 2); however, the number and type of machines and processes varies. Each of these systems serves a unique function with the ultimate goal of "ginning" the cotton to produce a marketable product. Raw seed-cotton harvested from the field is compacted into large units called "modules" for delivery to the gin. The unloading system removes seed-cotton either mechanically or pneumatically from the module feed system and conveys the seed-cotton to the seed-cotton cleaning systems. Seed-cotton cleaning systems dry the seed-cotton and remove foreign matter prior to ginning. Ginning systems also remove foreign matter and separate the cotton fiber from the seed. Lint cleaning systems further clean the cotton lint after ginning. The battery condenser and packaging systems combine lint from the lint cleaning systems and compress the lint into dense bales for easy transport. Gin systems produce some type of by-product or trash, such as rocks, soil, sticks, hulls, leaf material, and short or tangled immature fiber (motes), as a result of processing the seed-cotton or lint. These streams of by-products must be removed from the machinery and handled by trash collection systems. These trash systems typically further process the by-products (e.g., mote cleaners) and/or consolidate the trash from the gin systems into a hopper or pile for subsequent removal.

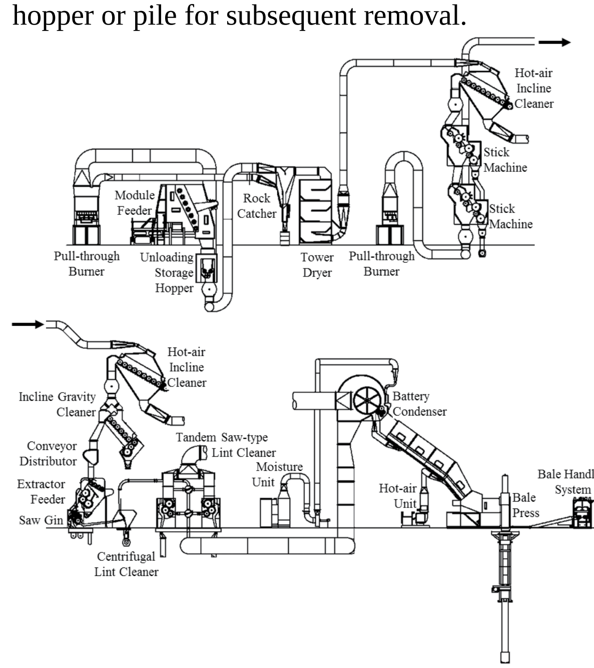

Figure 2. Typical modern cotton gin layout (Courtesy Lummus Corporation, Savannah, GA).

Seed-cotton is cleaned and dried in the seed-cotton cleaning systems. In the typical 3rd stage seed-cotton cleaning system (Fig. 3), seed-cotton drops from the 2nd stage seed-cotton cleaning system machinery into the hot air pneumatic conveying system of the 3rd stage seed-cotton cleaning system via a rotary airlock and blowbox. The seed-cotton is pulled directly into the cleaning machinery and separated from the conveying airstream by the cleaning mechanism (called a "hot-air" cleaner) or separated from the conveying air via a screened separator and dropped into the cleaning machinery. Seed-cotton cleaning machinery includes cleaners or extractors. This system removes foreign matter that includes rocks, soil, sticks, hulls, and leaf material. The airstream from the 3rd stage seed-cotton cleaning system continues through a centrifugal fan to an abatement system; generally one or more cyclones. This cleaning system may use air heated to 117°C (350°F) at the seed-cotton and air mixing point to accomplish drying during transport (ASABE, 2007). Based on system configuration, the airstream temperature at the abatement device could range from ambient to approximately 50% of the mixing-point temperature. The material handled by the abatement system is typically the same as that removed by the seed-cotton cleaning machinery (rocks, soil, sticks, hulls, and leaf material) and lint extracted with the trash (Fig. 4).

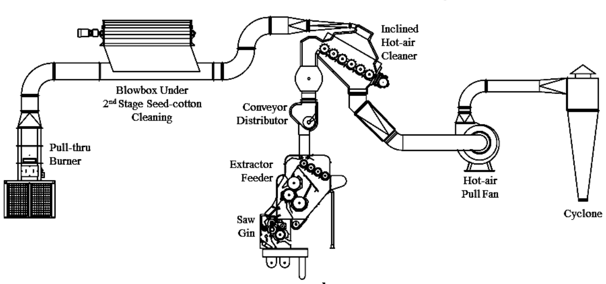

Figure 3. Typical cotton gin 3rd stage seed-cotton cleaning system layout (Courtesy Lummus Corporation, Savannah, GA).

Cyclones are the most common particulate matter (PM) abatement devices used at cotton gins. Standard cyclone designs used at cotton ginning facilities are the 2D2D and 1D3D (Whitelock, et al., 2009). The first D in the designation indicates the length of the cyclone barrel relative to the cyclone barrel diameter and the second D indicates the length of the cyclone cone relative to the cyclone barrel diameter. A standard 2D2D cyclone (Fig. 5) has an inlet height of D/2 and width of D/4 and design inlet velocity of 15.2 ± 2 m/s (3000 ± 400 fpm). The standard 1D3D cyclone (Fig. 5) has the same inlet dimensions as the 2D2D or might have the original 1D3D inlet with height of D and width D/8. Also, it has a design inlet velocity of 16.3 ± 2 m/s (3200 ± 400 fpm).

Figure 4. Photograph of typical trash captured by the 3rd stage seed-cotton cleaning system cyclones.

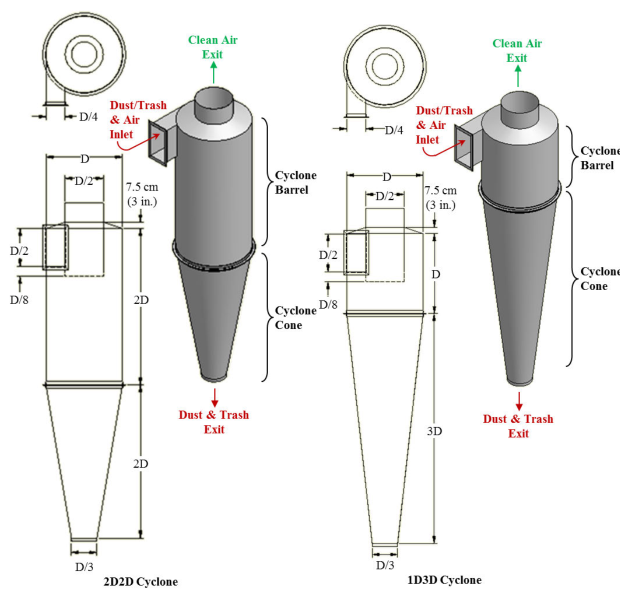

Figure 5. 2D2D and 1D3D cyclone schematics.

The objective of this study was to collect additional total particulate emission factor data for 3rd stage seed-cotton cleaning systems with cyclones for emissions control at cotton gins located in regions across the cotton belt based on EPA-approved stack sampling methodologies.

METHODS

Two advisory groups were established for this project. The industry group consisted of cotton ginning industry leaders and university and government researchers. The air quality group included members from state and federal regulatory agencies, and university and government researchers. Both groups were formed to aid in project planning, gin selection, data analyses, and reporting. The project plan was described in detail by Buser et al. (2012).

Seven cotton gins were sampled across the cotton belt. Key factors for selecting specific cotton gins included: 1) facility location, 2) production capacity, 3) processing systems, and 4) abatement technologies. Operating permits, site plans, and aerial photographs were reviewed to evaluate potential sites. On-site visits were conducted on all candidate gins to evaluate the process systems and gather information including system condition, layout, capacities, and standard operation. Using this information, several gins from each selected geographical region were selected and prioritized based on industry advisory group discussions. Final gin selection from the prioritized list was influenced by crop limitations and adverse weather events in the region.

Based on air quality advisory group consensus, EPA Method 17 (CFR, 1978) was used to sample the 3rd stage seed-cotton cleaning system at each gin. Method 17 was selected over Method 5 (CFR, 1987) because of the relatively low stack temperatures found at cotton gins. Method 5 requires a heated glass probe and filter holder to maintain the sampled gas temperature of 120°C (248°F). Key benefits of using Method 17 over Method 5 are where particulate concentrations are independent of temperature and the sampled gas contains no liquid droplets or is not saturated with water vapor, the heating systems can be eliminated and sampling can occur at stack temperature with an in-stack filter. Methodology for sampling total particulate called for withdrawing particulate-laden stack gas isokinetically (the velocity of the gas entering the sampler was equal to the velocity of the gas in the stack) through a button-hook nozzle and then collecting particles on an in-stack filter (Fig. 6). The methods for retrieving the filter and conducting acetone washes of the sampling nozzle are described in Method 17 (CFR, 1978). The mass of particulate on the filter and in the nozzle wash was determined by gravimetric analyses. The total particulate mass was determined by summing the mass of particulates on the filter and the front half wash. Stack gas temperature and moisture content were also measured using EPA Method 17.

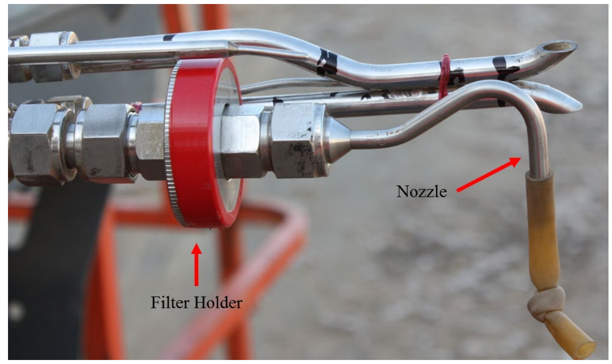

Figure 6. EPA Method 17 total particulate button-hook nozzle and in-stack filter holder photograph.

Only one stack from each 3rd stage seed-cotton cleaning system was tested. For systems with multiple stacks, it was assumed that emissions from each stack of the system were equivalent. The total particulate emissions for the system were calculated by multiplying the measured emission rates by the total number of cyclones used to control the process tested (EPA, 1996a). To obtain reliable results, the same technician from the same certified stack sampling company (Reliable Emissions Measurements, Auberry, CA), trained and experienced in stack sampling cotton gins, conducted all the tests at all the cotton gins.

All stack sampling equipment was purchased from Apex Instruments (Fuquay-Varina, NC) and met Method 17 specifications. The sampling media were 47-mm Zefluor filters (Pall Corporation, Port Washington, NY) and the sample recovery and analytical reagent was American Chemical Society certified acetone (A18-4, Fisher Chemical, Pittsburgh, PA; assay ≥ 99.5%). Filters, wash tubs, and lids were prelabeled and preweighed and stored in sealed containers at the USDA-ARS Air Quality Lab (AQL) in Lubbock, TX, and then transported to each test site. Prior to testing, the technician calibrated all sampling equipment according to EPA Method 17.

Each cyclone selected for testing was fitted with a cyclone stack extension that incorporated two sampling ports (90° apart) and airflow straightening vanes to eliminate the cyclonic flow of the air exiting the cyclone (Fig. 7). The extensions were designed to meet EPA criteria (EPA, 1989) with an overall length of 3 m (10 ft) and sampling ports 1.2-m (48-in) downstream from the straightening vanes and 0.9-m (36-in) upstream from the extension exit.

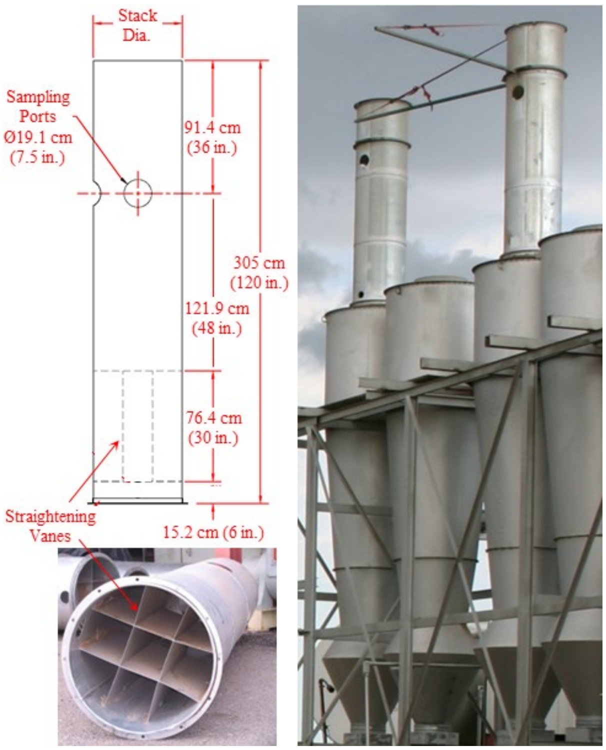

Figure 7. Schematic and photographs of stack extensions with sampling port and staightening vanes (rail attached to extension above sampling port, at right, supports sampling probe during testing traverse).

The tests were conducted by the technician in an enclosed sampling trailer at the base of the cyclone bank (Fig. 8). Sample retrieval, including filters and nozzle acetone washes, was conducted according to Method 17. After retrieval, filters were sealed in individual Petri dishes and acetone washes were dried on-site in a conduction oven at 49°C (120°F) and then sealed with preweighed lids and placed in individual plastic bags for transport to the AQL in Lubbock, TX for gravimetric analyses. During testing, bale data (ID number, weight, and date/time of bale pressing) were either manually recorded by the bale press operator or captured electronically by the gin's computer system for use in calculating emission factors in terms of kg/227-kg bale (lb/500-lb bale). Emission factors and rates were calculated in accordance with Method 17 and ASAE Standard S582 (ASABE, 2005).

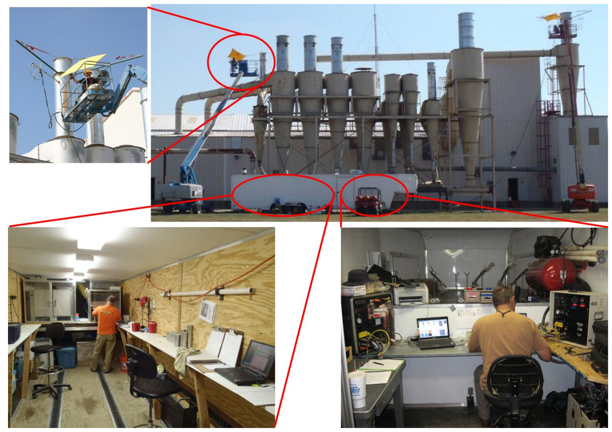

Figure 8. Clockwise from top right: cotton gin stack sampling with air quality lab trailer and technicians on lifts; certified stack sampling technician in the trailer control room conducting tests; sample recovery in trailer clean room; technician operating the probe at stack level.

All laboratory analyses were conducted at the AQL. All filters were conditioned in an environmental chamber (21 ± 2°C [70 ± 3.6°F]; 35 ± 5% RH) for 48 h prior to gravimetric analyses. Filters were weighed in the environmental chamber on a Mettler MX-5 microbalance (Mettler-Toledo Inc., Columbus, OH; 1 µg readability and 0.9 µg repeatability) after being passed through an antistatic device. The MX-5 microbalance was leveled on a marble table and housed inside an acrylic box to minimize the effects of air currents and vibrations. To reduce recording errors, weights were electronically transferred from the microbalance directly to a spreadsheet. Technicians wore latex gloves and a particulate respirator mask to avoid contamination. AQL procedures required that each sample be weighed three times. If the standard deviation of the weights for a given sample exceeded 10 µg, the sample was reweighed. Gravimetric procedures for the acetone wash tubs were the same as those used for filters.

In addition to gravimetric analyses, each sample was visually inspected for unusual characteristics, such as cotton lint content or extraneous material. Digital pictures were taken of all filters and washes for documentation purposes. After the laboratory analyses were completed all stack sampling, cotton gin production, and laboratory data were merged.

Two of the seven gins (A and C) were equipped with 3rd stage seed-cotton cleaning systems. The 3rd stage seed-cotton cleaning systems sampled were typical for the industry. The 3rd stage seed-cotton cleaning systems at gin A utilized two, separate and parallel, systems (Fig. 9). In each of these parallel systems, the seed-cotton material was pneumatically conveyed from the 2nd stage seed-cotton cleaning system with heated air through a dryer to a seed-cotton cleaner. The material was separated from the airstream by the cleaner. The air from each of the parallel 3rd stage seed-cotton cleaning systems then passed through separate fans and exhausted through separate cyclones. Gin C also utilized two, parallel 3rd stage seed-cotton cleaning systems with single cleaners, except there were no dryers before the cleaners (Fig. 10).

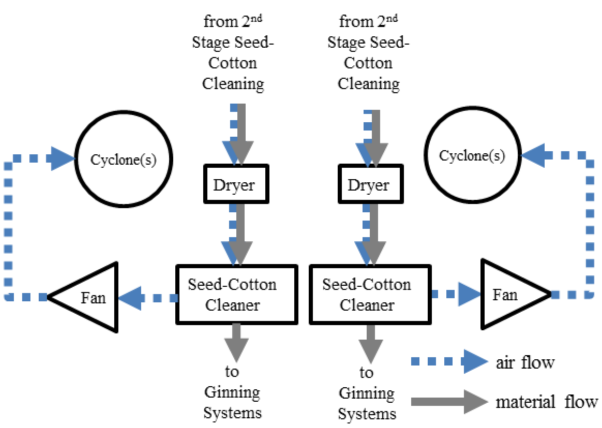

Figure 9. Schematic of split stream, single cleaner 3rd stage seed-cotton cleaning system with dryer (gin A).

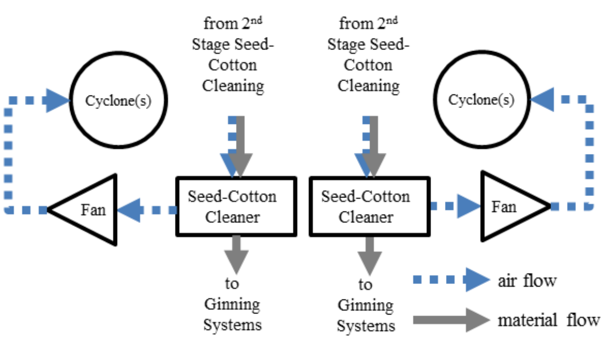

Figure 10. Schematic of split stream, single cleaner 3rd stage seed-cotton cleaning system without dryer (gin C).

Both 3rd stage seed-cotton cleaning systems sampled utilized 1D3D cyclones to control emissions (Fig. 5), but there were some cyclone design variations among the gins (Table 1 and Fig. 11). Gin C split the system exhaust flow between two cyclones in a dual configuration (side by side as opposed to one behind another). The system airstream for gin A was exhausted through a single cyclone. Inlets on the gin A and C 3rd stage seed-cotton cleaning cyclones were inverted 1D3D and 2D2D inlets, respectively. Expansion chambers were present on 3rd stage seed-cotton cleaning cyclones at both gins. All of the cyclone variations outlined above, if properly designed and maintained, are recommended for controlling cotton gin emissions (Whitelock et al., 2009).

Figure 11. Cyclone design variations for the tested systems (left to right): dual configuration that splits flow between identical 1D3D cyclones with 2D2D inlets; 1D3D cyclone with an inverted 1D3D inlet; and 1D3D cyclone with 2D2D inlet and expansion chamber on the cone.

Table 1. Abatement device configuration[z] for 3rd stage seed-cotton cleaning systems tested.

Gin	Cyclone Type	Inlet Design[y]	Systems per Gin	Cyclones per Gin	Configuration	Cone Design	Trash Exits[x]
A	1D3D	inverted 1D3D	2	2	single	expansion chamber	hopper
C	1D3D	2D2D	2	4	dual	expansion chamber	hopper

[z] Figures 5 and 11

[y] Inverted 1D3D inlet has duct in line with the bottom of the inlet

[x] Systems to remove material from cyclone trash exits: hopper = large storage container directly under cyclone trash exit

RESULTS

Table 2 shows the test parameters for each Method 17 test run for the 3rd stage seed-cotton cleaning systems sampled at the two gins. The average ginning rate was 21.0 bales/h and the test average ginning rate at each gin ranged from 19.2 to 22.8 bales/h (based on 227-kg [500-lb] equivalent bales). The 1D3D cyclones were all operated with inlet velocities within design criteria, 16.3 ± 2 m/s (3200 ± 400 fpm), except run two for gin A was outside the design range due to limitations in available system adjustments.

There are criteria specified in EPA Method 17 for test runs to be valid for total particulate measurements (CFR, 1978). Isokinetic sampling must fall within the EPA defined range of 100 ± 10%. All tests met the isokinetic criteria (Table 2). The stack gas temperatures ranged from 13 to 48°C (55-119°F) and moisture content ranged from 0.3 to 1.9% w.b.

Total particulate emissions data (emission rates and corresponding emission factors) for the 3rd seed-cotton cleaning systems are shown in Table 3. The system average emission factor for the two gins was 0.023 kg/bale (0.052 lb/bale). The test average emission factors ranged from 0.014 to 0.033 kg (0.031-0.073 lb) per bale. The average 3rd seed-cotton cleaning system total particulate emission factor for this project was approximately 54% of that published in the current 1996 EPA AP-42 for the No. 3 dryer and cleaner (0.043 kg/bale [0.095 lb/bale]) (EPA, 1996a, b), which is an equivalent system to the 3rd stage seed-cotton cleaning system. The range of test average total particulate emission factors determined for this project was lower than the AP-42 emission factor data range. The test average emission rates ranged from 0.27 to 0.75 kg/h (0.59-1.66 lb/h).

Table 2. Cotton gin production data and stack sampling performance metrics for the 3rd stage seed-cotton cleaning systems.

Gin	Test Run	Ginning Rate bales/h[z]	Cyclone Inlet Velocity		Isokinetic Sampling %	Stack Gas		
						Moisture Content % w.b.	Temperature	
			m/s	fpm			°C	°F
A	1	19.7	17.4	3427	101	0.7	13	55
	2	17.9	19.1	3759	104	0.3	36	97
	3	20.1	18.0	3535	103	1.2	30	86
Test Average		19.2	18.2	3574				
C	1	22.9	17.0	3339	96	0.8	43	110
	2	22.2	17.0	3341	98	1.8	45	114
	3	23.2	17.9	3533	93	1.9	48	119
Test Average		22.8	17.3	3404				
System Average		21.0	17.7	3489				

[z] 227 kg (500 lb) equivalent bales

Table 3. Total particulate emissions data for the 3rd stage seed-cotton cleaning systems.

Gin	Test Run	Emission Rate		Emission Factor	
		kg/h	lb/h	kg/bale[z]	lb/bale[z]
A	1	0.44	0.97	0.022	0.049
	2	0.18	0.40	0.010	0.023
	3	0.18	0.40	0.0089	0.020
Test Average (n=3)		0.27	0.59	0.014	0.031
C	1	0.71	1.57	0.031	0.069
	2	0.78	1.72	0.035	0.078
	3	0.76	1.67	0.033	0.072
Test Average (n=3)		0.75	1.66	0.033	0.073
System Average (n=2)				0.023	0.052

[z] 227 kg (500 lb) equivalent bales

Figure 12 shows an example of samples recovered from a typical 3rd stage seed-cotton cleaning system test run. Often, there were cotton lint fibers in the cotton gin cyclone exhausts. Therefore, it was not unusual to find lint fiber on the Method 17 filter or in the front half wash (Fig. 13), which was included in the total particulate emissions.

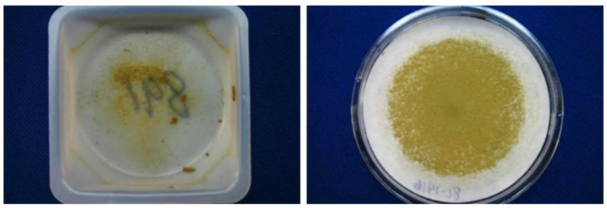

Figure 12. Typical EPA Method 17 filter and sampler head acetone wash from the 3rd stage seed-cotton cleaning system. From left to right: front half wash and filter.

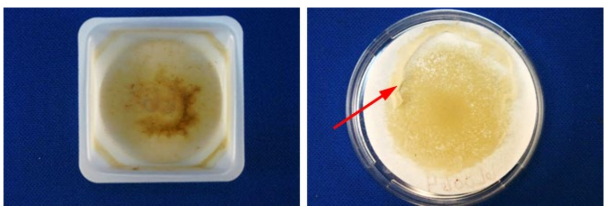

Figure 13. EPA Method 17 filter and sampler head acetone wash from the 3rd stage seed-cotton cleaning system with lint (indicated by arrows) on the filter. From left to right: front half wash and filter.

SUMMARY

Two cotton gins with 3rd stage seed-cotton cleaning systems were sampled using EPA Method 17 to collect additional data to improve the EPA AP-42 total particulate emission factor quality ratings for cotton gins. The tested systems were similar in design and typical of the ginning industry. Both system exhausts were equipped with 1D3D cyclones for emissions control with some variations in inlet and cone design. The average production rate during testing for the two gins was 21.0 bales/h. The average 3rd stage seed-cotton cleaning system total particulate emission factor based on two tests (6 total test runs) was 0.023 kg/227-kg bale (0.052 lb/500-lb bale). The average 3rd stage seed-cotton cleaning system total particulate emission factor for this project was approximately 54% of that currently published in the 1996 EPA AP-42, which is 0.043 kg/bale (0.095 lb/bale) (EPA, 1996 a, b).The gin test average emission rates ranged from 0.27 to 0.75 kg/h (0.59-1.66 lb/h).

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DISCLAIMER

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