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ENGINEERING AND GINNING

Combined Lint Cleaning System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones

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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 EPA emission factors for particulate matter with a particle diameter nominally less than or equal to 10 µm (PM_{10}). The 1996 EPA AP-42 emission factors were assigned quality ratings, from A (Excellent) to E (Poor), to assess the quality of the data being referenced. Emission factor quality ratings for cotton gins were extremely low. Cotton gin data received these low ratings because they were collected almost exclusively from a single geographical region. The objective of this study was to collect additional PM_{10} emission factor data for combined lint cleaning systems at cotton gins located in regions across the cotton belt based on EPA-approved stack sampling methodology, Method 201A. The project plan included sampling seven cotton gins 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. Three of the seven gins had 1^{st} and 2^{nd} stage lint cleaning systems where the exhaust airstreams were combined. In terms of capacity, the three gins were typical of the industry, averaging 28.0 bales/h during testing. Some test runs, included in the analyses, had cotton lint fibers that collected in the ≤ 10 µm samples. This larger lint material can affect the reported emissions data, but EPA Method 201A does not suggest methods to account for these anomalies. The combined lint cleaning system average emission factors for PM_{10} and total particulate were 0.150 kg/227-kg bale (0.332 lb/500-lb bale) and 0.293 kg/bale (0.647 lb/bale), respectively. System average PM_{10} and total particulate emission factors were higher than those currently published in EPA AP-42. The combined lint cleaning system PM_{10} emission rate test averages ranged from 1.62 to 5.19 kg/h (3.56-11.45 lb/h). The ratio of combined lint cleaning system PM_{10} to total particulate was 51.3%.

U.S. Environmental Protection Agency (EPA) emission factors published in EPA's Compilation of Air Pollution Emission Factors, AP-42 (EPA, 1996b) were 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 particulate matter with a particle diameter less than or equal to a nominal 10-µm (PM_{10}) aerodynamic equivalent diameter from cotton gins are extremely low. Cotton gin data received these low ratings because they were collected almost exclusively from a single geographical region (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 cotton ginning associations across the country and 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, 1^{st} stage seed-cotton cleaning, 2^{nd} stage seed-cotton cleaning, 3^{rd} stage seed-cotton cleaning, overflow, 1^{st} stage lint cleaning, 2^{nd} stage lint cleaning, combined

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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 PM_{10} emissions from combined lint cleaning systems.

The 1996 EPA AP-42 average PM_{10} emission factor for lint cleaners with high-efficiency cyclones (combined 1st and 2nd stage lint cleaning systems) was 0.11 kg (0.24 lb) per 217-kg (480-lb) equivalent bale with a range of 0.020 to 0.42 kg (0.043-0.93 lb) per bale (EPA, 1996a, 1996b). This average and range was based on six tests conducted in one geographical location and the EPA emission factor quality rating was D, which is the second lowest possible rating (EPA, 1996a). The AP-42 average total particulate emission factor for lint cleaners with high-efficiency cyclones was 0.26 kg (0.58 lb) per bale with a range of 0.041 to 1.0 kg (0.090-2.3 lb) per bale. This average and range was based on six tests conducted in one geographical location and the EPA emission factor quality rating was also D.

Seed cotton is a perishable commodity that has no real value until the fiber and seed are separated (Wakelyn et al., 2005). Cotton must 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 with the ginning season 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 about 17 million bales per year during the last 20 years, production from one year to the next often 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 about 25 bales per hour across the U.S. cotton belt (Valco et al., 2003, 2006, 2009, 2012).

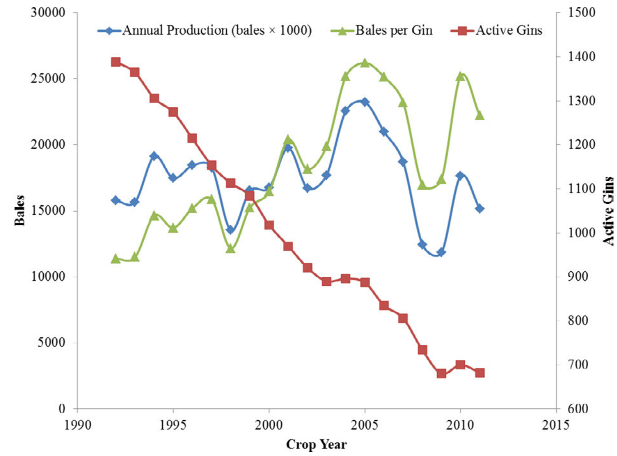

Figure 1. Annual U.S. cotton production, active U.S. gins, and average ginning volume (bales per gin) (NASS, 1993-2012).

Typical cotton gin processing systems include: 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 can vary. 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 assist with drying the seed cotton and remove foreign matter prior to ginning. Ginning systems also remove foreign matter and separate the cotton fiber from 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 efficient transport. Cotton gin systems produce some type of by-products 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.

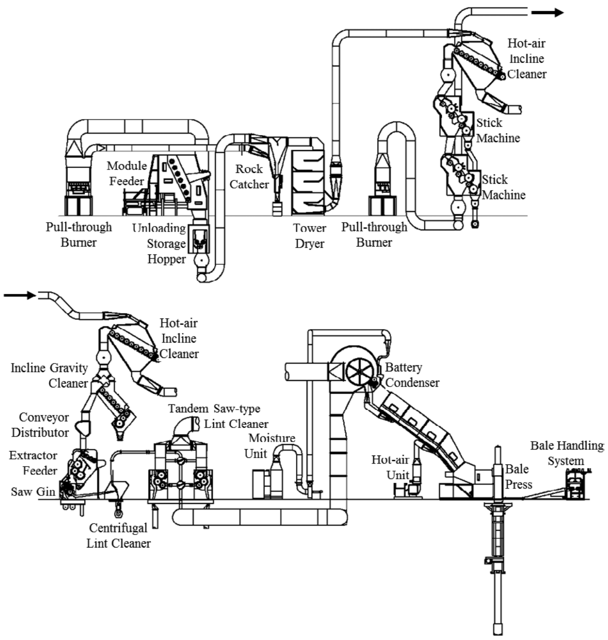

Figure 2. Typical modern cotton gin layout (Courtesy Lummus Corporation, Savannah, GA).

Cotton lint is cleaned in the lint cleaning systems (Fig. 3). In the typical combined 1st and 2nd stage lint cleaning system, cotton fiber or lint is pneumatically conveyed from the gin stands, through a centrifugal lint cleaner, to the 1st stage lint cleaners (cotton gins typically split the pre-cleaned seed-cotton among multiple, parallel gin stand/lint cleaning lines that are recombined at packaging) for further foreign matter removal. The lint is removed from the airstream with a rotating, screened separator drum and directed into the lint cleaner feed works. Lint cleaners remove fine trash, seed, and some lint. The material removed by lint cleaners is referred to as “motes”. Lint is directed from the lint cleaner to either a subsequent stage of lint cleaning or into the bale packaging system. A 2nd stage of lint cleaning is sometimes used and is essentially identical to the 1st stage. The airstream from the lint cleaner screen separators continues through a centrifugal fan to one or two particulate abatement cyclones. Some lint cleaning systems utilize a vane-axial fan, but these systems typically do not have cyclones and exhaust directly to ambient air. There are gins designed such that the exhaust of the 1st stage lint cleaning systems are completely separated from the exhaust of the 2nd stage lint cleaning systems and there are systems where the 1st and 2nd stage lint cleaning systems have a combined exhaust, sharing a fan and abatement device. The function of the 1st and 2nd stage lint cleaning systems with separate or combined exhausts is the same and it is expected that the particulate emissions from a combined exhaust system would be similar to the aggregate emissions of the 1st and 2nd stage lint cleaning systems with separate exhausts. The material handled by the lint cleaning system cyclones typically includes small trash and particulate, and lint fibers (Fig. 4).

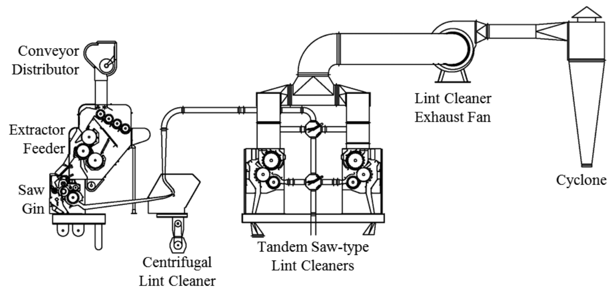

Figure 3. Typical cotton gin combined lint cleaning system layout (Courtesy Lummus Corporation, Savannah, GA).

Figure 4. Photograph of typical trash captured by the combined lint cleaning system cyclones.

Cyclones are the most common particulate matter 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 may 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).

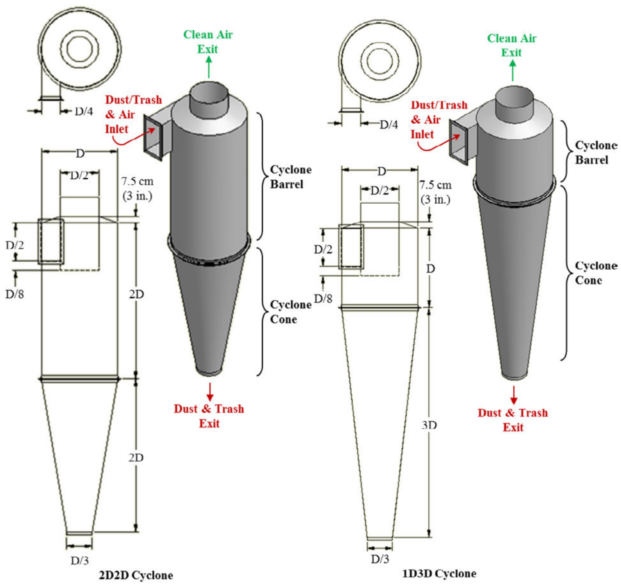

Figure 5. 2D2D and 1D3D cyclone schematics.

The objective of this study was to collect additional PM_{10} emission factor data for combined lint 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. These groups were formed to aid in project planning, gin selection, data analysis, 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 201A was used to sample the combined lint cleaning system at each gin. Method 201A was revised in 2010 to incorporate options for $PM_{2.5}$ (particulate matter with particle diameter less than or equal to a nominal 2.5-µm aerodynamic equivalent diameter) sampling (CFR, 2010); these revisions did not affect the PM_{10} stack sampling methodology used in this project. Method 201A is a constant sampling rate procedure. For the PM_{10} sampling methodology, the particulate -laden stack gas was withdrawn isokinetically (the velocity of the gas entering the sampler was equal to the velocity of the gas in the stack) through a PM_{10} sizing cyclone and then collected on an in-stack filter (Fig. 6). The methods for retrieving the filter and conducting acetone washes of the sizing cyclone are described in detail in Method 201A (CFR, 2010). The mass of each size fraction was determined by gravimetric analysis and included: > 10 µm (PM_{10} sizing cyclone catch acetone wash) and ≤ 10 µm (PM_{10} sizing cyclone exit acetone wash and filter). The PM_{10} mass was determined by adding the mass of particulates captured on the filter and the ≤ 10 µm wash. Total particulate was determined by adding the PM_{10} mass and the mass of the > 10 µm wash.

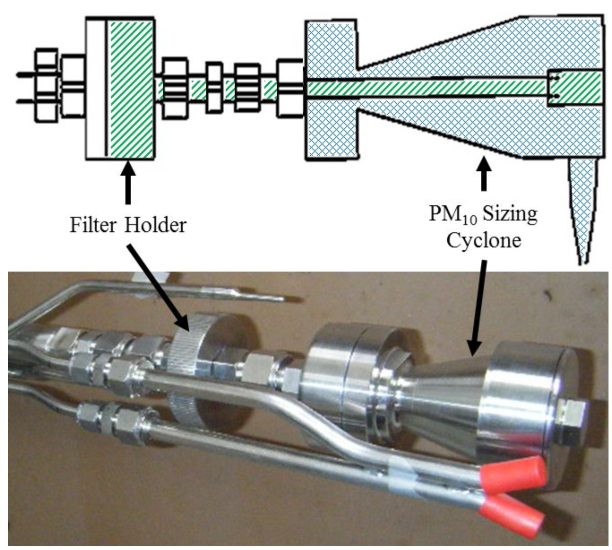

Figure 6. EPA Method 201A PM_{10} sizing cyclone and in-stack filter holder schematic (CFR, 2010) and photograph (≤ 10 µm, > 10 µm).

Figure 7 shows the performance curves for the Method 201A sizing cyclones. To measure PM_{10}, the method requires selecting a gas sampling nozzle to achieve a sampling rate that produces a cut size between 9.0 and 11.0 µm at the stack gas temperature. For this study, Method 201Awas specifically used to collect filterable PM_{10} emissions (solid particles emitted by a source at the stack and captured in the ≤ 10 µm wash and on the filter [CFR, 2010]).

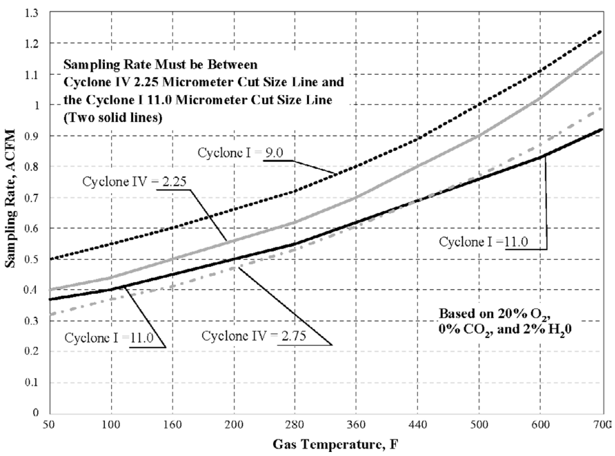

Figure 7. Acceptable sampling rate for sizing cyclones (CFR, 2010) Cyclone I = PM_{10} sizing cyclone (Gas temperatures for the combined lint cleaning systems tested ranged from 19 to 41°C [67-106°F]).

Only one stack from each combined lint cleaning system was tested. For systems with multiple stacks, it was assumed that emissions from each stack of the system were equivalent and the total emissions 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 the tests at all seven cotton gins.

All stack sampling equipment, including the sizing cyclone, was purchased from Apex Instruments (Fuquay-Varina, NC) and met specifications of Method 201A. The sampling media were 47 µm 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 and wash tubs and lids were prelabeled, pre-weighed, 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 certified stack testing technician calibrated and checked all sampling equipment according to EPA Method 201A.

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

The tests were conducted by the certified stack sampling technician in an enclosed sampling trailer at the base of the cyclone bank (Fig. 9). Sample retrieval, including filters and sampler head acetone washes, was conducted according to Method 201A. 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 pre-weighed 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 201A and ASAE Standard S582 (ASABE, 2005).

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

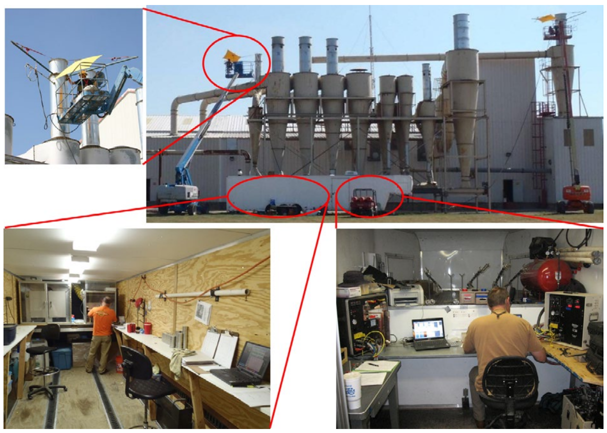

Figure 9. Clockwise from top right: cotton gin stack sampling with air quality lab trailer and technicians on lifts; certified stack sampling technician in the trailer control room conducting tests; sample recovery in trailer clean room; technician operating the probe at stack level.

MX-5 microbalance (Mettler-Toledo Inc., Columbus, OH – 1 µg readability and 0.9 µg repeatability) after being passed through an anti-static 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 prior to further analyses. After the laboratory analyses were completed all stack sampling, cotton gin production, and laboratory data were merged.

Three of the seven gins sampled were designed so that the 1st and 2nd stage lint cleaning system exhausts were combined. Gins D and G had similar systems (Fig. 10). For these systems, the cotton lint material was pneumatically conveyed from the gin stand through a centrifugal air-type lint cleaner where some larger trash was ejected. The air/material then proceeded to the 1st lint cleaner. At the lint cleaner, the lint was separated from the conveying air by a screened separator and fed into the lint cleaner. From the 1st lint cleaner, the lint was pneumatically conveyed to the 2nd lint cleaner where it was again separated from the conveying air by a screened separator and fed into the lint cleaner. The airstream from the separators at both the 1st and 2nd lint cleaners then combined and passed through a fan and exhausted through one or more cyclones. The combined 1st and 2nd stage lint cleaning systems at gin E were similar to the systems at gins D and G, except there were no centrifugal lint cleaners between the gin stands and 1st lint cleaners (Fig. 11).

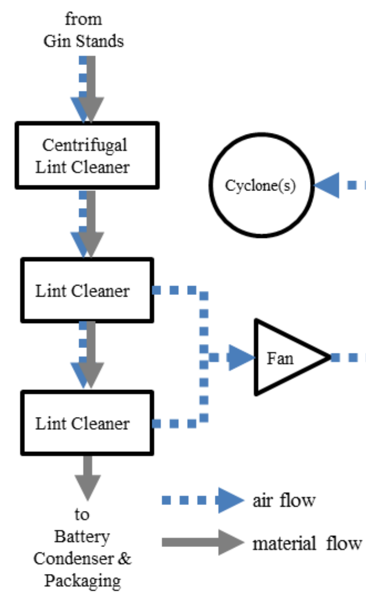

Figure 10. Schematic of combined 1st and 2nd stage lint cleaning system with centrifugal lint cleaner (gins D and G).

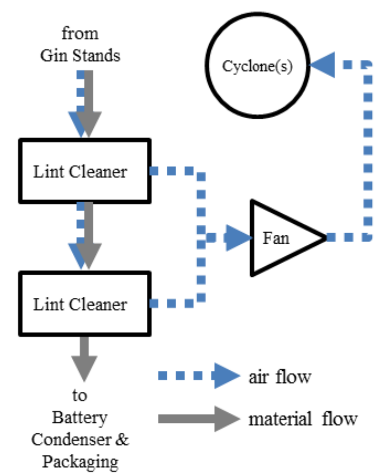

Figure 11. Schematic of combined 1st and 2nd stage lint cleaning system without centrifugal lint cleaner (gin E).

Table 1. Abatement device configuration[z] for combined lint cleaning systems tested.

Gin	Cyclone Type	Inlet Design[y]	Systems per Gin	Cyclones per Gin	Configuration	Cone Design	Trash Exits to[x]
D	1D3D	center-line 1D3D	4	8	dual	standard	robber
E	1D3D	2D2D	3	3	single	standard	auger
G	1D3D	2D2D	2	4	dual	standard	robber

[z] Figures 5 and 12

[z] Center-line 1D3D inlet has duct in line with midpoint between the top and bottom of the inlet

[y] Systems to remove material from cyclone trash exits: auger = enclosed, screw-type conveyor, robber = pneumatic suction system

All combined lint 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. 12). Gins D and G 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 E was exhausted through a single cyclone. Inlets on the combined lint cleaning system cyclones at gins E and G were 2D2D type and gin D that had center-line 1D3D inlets (inlets with the duct in line with midpoint between the top and bottom of the inlet). Standard cones were present on combined lint cleaning system cyclones at all gins. The cyclones tested at gins D and G had cyclone robber systems pulling airflow from their trash exits. This configuration helps remove lint and other trash from the cyclone that could otherwise circulate near the trash exit at the bottom of the cone for a period of time before dropping out. All of the cyclone configurations outlined above, if properly designed and maintained, are recommended for controlling cotton gin emissions (Whitelock et al., 2009).

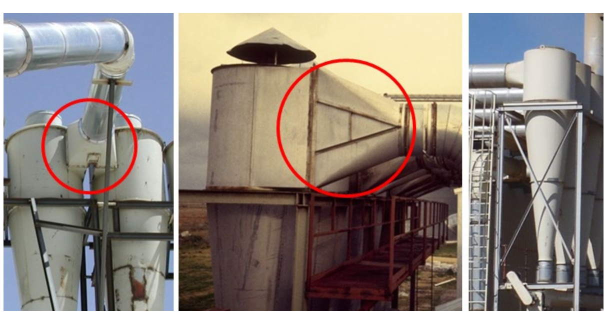

Figure 12. Cyclone design variations for the tested systems (left to right): dual configuration that splits flow between identical 1D3D cyclones with 2D2D inlets; 1D3D cyclone with an center-line 1D3D inlet; 1D3D cyclone with 2D2D inlet and standard cone.

RESULTS

Table 2 shows the test parameters for each Method 201A test run for the combined lint cleaning systems sampled at the three gins. The system average ginning rate was 28.0 bales/h and the test average ginning rates at each gin ranged from 18.7 to 33.1 bales/h (based on 227-kg [500-lb] equivalent bales). Test run two at gin D was omitted from all test averages because of inconsistent gin operation during testing. The capacity of gins sampled was representative of the industry average, approximately 25 bales/h. The 1D3D cyclones were all operated with inlet velocities within design criteria, 16.3 ± 2 m/s (3200 ± 400 fpm).

There are criteria specified in EPA Method 201A for test runs to be valid for PM_{10} or total particulate measurements (CFR, 2010). Isokinetic sampling and PM_{10} aerodynamic cut size must fall within EPA defined ranges (100 ± 20% and 10.0 ± 1.0 µm, respectively) for valid PM_{10} test runs. All tests met both criteria (Table 2). To use the method to also obtain total filterable particulate, sampling must be within 90 to 110% of isokinetic flow. All test runs met the criteria. Sampling rates ranged from 12.2 to 12.9 standard l/min (0.429-0455 standard ft^3/min). The stack gas temperatures ranged from 19 to 41°C (67-106°F).

PM_{10} emissions data (ginning and emission rates and corresponding emission factors) for the combined lint cleaning systems are shown in Table 3. The system average PM_{10} emission factor was 0.150 kg/bale (0.332 lb/bale). The test average emission factors ranged from 0.049 to 0.301 kg (0.107-0.664 lb) per bale and emission rates ranged from 1.62 to 5.19 kg/h (3.56-11.45 lb/h). Total particulate emissions data (ginning and emission rates and corresponding emission factors) for the combined lint cleaning systems are shown in Table 4. The system average total particulate emission factor was 0.293 kg/bale (0.647 lb/bale). The test average emission factors ranged from 0.066 to 0.663 kg (0.145-1.462 lb) per bale. The test average total particulate emission rates ranged from 2.18 to 11.61 kg/h (4.81-25.60 lb/h). The ratio of PM_{10} to total particulate was 51.3% (ratios calculated using tables 3 and 4 may vary slightly from those listed due to rounding).

Table 2. Cotton gin production data and stack sampling performance metrics for the combined lint cleaning systems.

Gin	Test Run	Ginning Rate, bales/h[z]	Cyclone Inlet Velocity, m/s	Cyclone Inlet Velocity, fpm	Isokinetic Sampling, %	Aerodynamic Cut Size D_{50}, PM_{10} µm	Sampling Rate[y] slpm	Sampling Rate[y] scfm	Stack Temperature °C	Stack Temperature °F
D	1	23.8	16.1	3168	100	10.0	12.4	0.439	20	69
	2[x]	4.7	16.6	3267	99	9.8	12.7	0.449	19	67
	3	13.6	16.4	3238	109	10.0	12.6	0.444	23	74
Test Average		18.7	16.3	3203						
E	1	32.8	17.4	3434	99	10.3	12.7	0.450	39	102
	2	29.9	17.2	3389	102	10.2	12.9	0.455	40	104
	3	33.8	16.9	3325	104	10.3	12.9	0.455	41	106
Test Average		32.2	17.2	3382						
G	1	32.7	14.4	2833	92	10.3	12.5	0.440	32	90
	2	32.6	14.5	2849	90	10.5	12.2	0.429	33	91
	3	34.1	14.4	2836	92	10.3	12.4	0.437	32	90
Test Average		33.1	14.4	2840						
System Average		28.0	16.0	3141						

[z] 227 kg (500 lb) equivalent bales

[y] slpm = standard l/min, scfm = standard ft^3/min

[x] Test run omitted from test averages due to inconsistent gin operation during testing

Table 3. PM_{10} emissions data for the combined lint cleaning systems.

Gin	Test Run	Emission Rate, kg/h	Emission Rate, lb/h	Emission Factor, kg/bale[z]	Emission Factor, lb/bale[z]
D	1	5.18	11.42	0.218	0.480
	2[y]	1.62	3.57	0.344	0.759
	3	5.21	11.48	0.384	0.847
Test Average (n=2)		5.19	11.45	0.301	0.664
E	1	3.20	7.05	0.098	0.215
	2	2.85	6.27	0.095	0.210
	3	3.77	8.32	0.112	0.246
Test Average (n=3)		3.27	7.22	0.101	0.224
G	1	1.53	3.36	0.047	0.103
	2	1.39	3.06	0.043	0.094
	3	1.93	4.26	0.057	0.125
Test Average (n=3)		1.62	3.56	0.049	0.107
System Average (n=3)				0.150	0.332

[z] 227 kg (500 lb) equivalent bales

[y] Test run omitted from test averages due to inconsistent gin operation during testing

Table 4. Total particulate emissions data for the combined lint cleaning systems.

Gin	Test Run	Emission Rate, kg/h	Emission Rate, lb/h	Emission Factor, kg/bale[z]	Emission Factor, lb/bale[z]
D	1	12.18	26.86	0.513	1.130
	2[y]	3.01	6.64	0.641	1.414
	3	11.04	24.33	0.814	1.794
Test Average (n=2)		11.61	25.60	0.663	1.462
E	1	4.78	10.54	0.146	0.322
	2	4.25	9.37	0.142	0.313
	3	5.59	12.33	0.165	0.365
Test Average (n=3)		4.87	10.75	0.151	0.333
G	1	2.15	4.75	0.066	0.145
	2	1.94	4.28	0.060	0.131
	3	2.45	5.39	0.072	0.158
Test Average (n=3)		2.18	4.81	0.066	0.145
System Average (n=3)				0.293	0.647

[z] 227 kg (500 lb) equivalent bales

[y] Test run omitted from test averages due to inconsistent gin operation during testing

The average combined lint cleaning system total particulate emission factor for this project was about 1.12 times of the EPA AP-42 published value for lint cleaners with high-efficiency cyclones (EPA, 1996a, 1996b), which is equivalent system to combined 1st and 2nd stage lint cleaning systems. The range of test average total particulate emission factors determined for this project fell within the AP-42 emission factor data range. The average combined lint cleaning system PM_{10} emission factor for this project was 1.38 times the EPA AP-42 published value for lint cleaners with high-efficiency cyclones. The test average PM_{10} emission factor range also fell within the AP-42 emission factor data range.

Figure 13 shows an example of samples recovered from a typical combined lint cleaning system test run. Often, there were cotton lint fibers, which have cross-sectional diameters much greater than 10 µm, in the cotton gin cyclone exhausts. Therefore, it was not unusual to find lint fiber in the > 10 µm wash from Method 201A. However, in the sample shown in Figure 14, lint fibers passed through the PM_{10} cyclone and collected on the filter. This type of material carry-over can bias the gravimetric measurements and affect reported PM_{10} emission data. EPA Method 201A does not suggest methods to account for these anomalies. Thus, no effort was made to adjust the data reported in this manuscript to account for these issues.

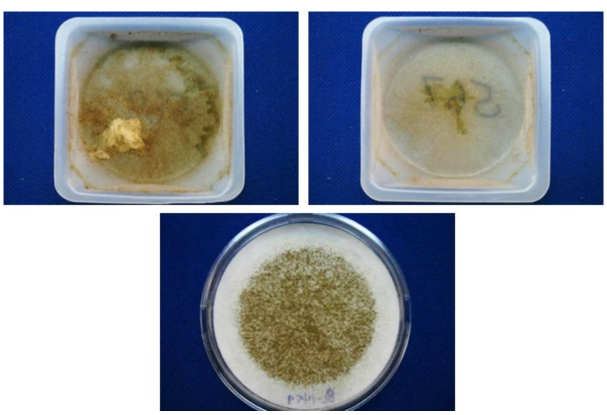

Figure 13. Typical EPA Method 201A filter and sampler head acetone washes from the combined lint cleaning system. Clockwise from top left: > 10 µm wash, ≤ 10 µm wash and filter.

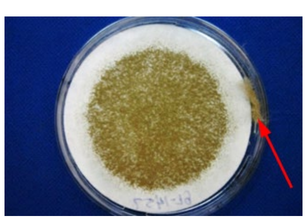

Figure 14. EPA Method 201A filter from the combined lint cleaning system with lint fiber present (indicated by arrow).

SUMMARY

Seven cotton gins across the U.S. cotton belt were sampled using EPA Method 201A to collect additional data to improve the EPA AP-42 PM_{10} emission factor quality ratings for cotton gins. Three of the seven gins had 1st and 2nd stage lint cleaning systems where the exhaust airstreams were combined. The tested systems were similar in design and typical of the ginning industry. All the systems were equipped with 1D3D cyclones for emissions control with some slight variations in inlet and cone design. In terms of capacity, the three gins were typical of the industry, averaging 28.0 bales/h during testing. Some test runs, included in the analyses, had cotton lint fibers that collected in the ≤ 10 µm samples. This larger lint material can affect the reported emissions data, but EPA Method 201A does not suggest methods to account for these anomalies. The combined lint cleaning system average emission factors for PM_{10} and total particulate were 0.150 kg/227-kg bale (0.332 lb/500-lb bale) and 0.293 kg/bale (0.647 lb/bale), respectively. System average PM10 and total particulate emission factors were higher than those currently published in EPA AP-42. The gin test average PM_{10} and total particulate emission rates ranged from 1.62 to 5.19 kg/h (3.56-11.45 lb/h) and 2.18 to 11.61 kg/h (4.81-25.60 lb/h), respectively. Based on the combined lint cleaning system average emission factors, the ratio of PM_{10} to total particulate was 51.3%.

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DISCLAIMER

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the Oklahoma State University or U.S. Department of Agriculture. Oklahoma State University and USDA are equal opportunity providers and employers.

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