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ENGINEERING AND GINNING

Mote Trash System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ 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. In 2006, the Environmental Protection Agency (EPA) finalized and published a more stringent standard for particulate matter with nominal diameter less than or equal to 2.5 µm ($PM_{2.5}$). This created an urgent need to collect additional cotton gin emissions data to address current regulatory issues, because current EPA AP-42 cotton gin $PM_{2.5}$ emission factors did not exist. The objective of this study is the development of $PM_{2.5}$ emission factors for cotton gin mote trash systems based on the EPA-approved stack sampling methodology, Method 201A. The project plan included sampling seven cotton gins across the Cotton Belt. Two of the seven gins had mote trash systems where the exhaust airstreams were not combined with other major systems. In terms of capacity, the two gins were typical of the industry, averaging 25.1 bales/h during testing. Some test runs were excluded from the test averages because they failed to meet EPA Method 201A Test criteria. Also, other test runs, included in the analyses, had cotton lint fibers that collected in the ≤ 10 µm and/or ≤ 2.5 µm samples. This larger lint material can impact the reported emissions data, but EPA Method 201A does not suggest methods to account for these anomalies. Average measured mote trash system $PM_{2.5}$ emission factor based on the two tests (six total test runs) was 0.0011 kg/227-kg bale (0.0024 lb/500-lb bale). The mote trash system emission factors for PM_{10} and total particulate were 0.0094 kg/bale (0.021 lb/bale) and 0.017 kg/bale (0.038 lb/bale), respectively. The mote trash system $PM_{2.5}$ emission rate from test averages ranged from 0.025 to 0.03 kg/h (0.055-0.066 lb/h). System average PM_{10} and total particulate emission factors were lower than those currently published in EPA AP-42. The ratios of mote trash system $PM_{2.5}$ to total particulate, $PM_{2.5}$ to PM_{10}, and PM_{10} to total particulate were 6.4, 11.7, and 54.5%, respectively.

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In 2006, the United States (U.S.) Environmental Protection Agency (EPA) finalized a more stringent standard for particulate matter with a particle diameter less than or equal to a nominal 2.5-mm ($PM_{2.5}$) aerodynamic equivalent diameter (CFR, 2006). The cotton industry's primary concern with this standard was that published cotton gin $PM_{2.5}$ emissions data did not exist. 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 $PM_{2.5}$ cotton gin emissions data to address the implementation of the $PM_{2.5}$ standards. 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, first-stage seed cotton cleaning, second- stage seed cotton cleaning, third-stage seed cotton cleaning, overflow, first-stage lint cleaning, second- stage lint cleaning, combined lint cleaning, cyclone robber, first-stage mote, second-stage mote, combined mote, mote cyclone robber, mote cleaner, mote trash, battery condenser and master trash. This report focuses on $PM_{2.5}$ emissions from mote trash systems.

There are published PM_{10} (particulate matter with a particle diameter less than or equal to a nominal 10-µm aerodynamic equivalent diameter) and total particulate emission factors for cotton gins in EPA's Compilation of Air Pollution Emission Factors, AP-42 (EPA, 1996a, 1996b); however, there are no $PM_{2.5}$ emission factors. The AP-42 average PM_{10} emission factor for the mote trash fan was 0.0095 kg (0.021 lb) per 217-kg (480-lb) equivalent bale with a range of 0.0021 to 0.018 kg (0.0046 to 0.040 lb) per bale. The AP-42 average total particulate emission factor was 0.035 kg (0.077 lb) per bale with a range of 0.025 to 0.051 kg (0.055 to 0.11 lb) per bale. These PM_{10} and total factors were both based on three tests and were assigned EPA emission factor quality ratings of D; 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 be processed 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 varies greatly for various reasons, including climate and market pressure (Fig. 1). The number of active gins in the U.S. has not remained constant, but has steadily declined to less 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).

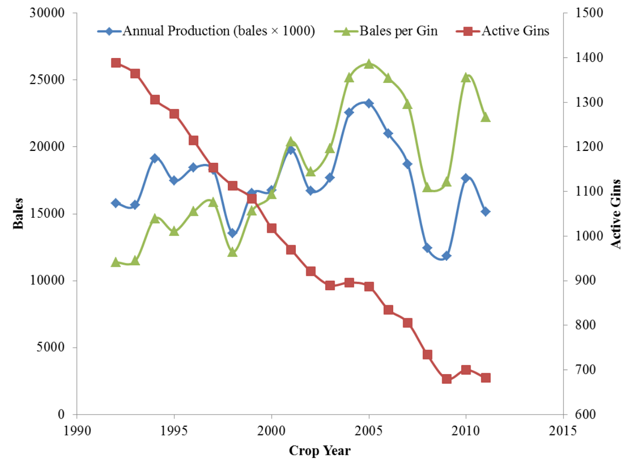

Figure 1. Annual U.S. cotton production, active U.S. gins, and average ginning volume (bales per gin) (NASS, 1993-2012).

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 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 efficient 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.

Material captured by cyclones that handle airstreams laden with greater amounts of lint (battery condenser, lint cleaning, and mote system cyclones), referred to as "motes", have considerable value, especially when cleaned further in a device that removes much of the non-lint material. The cleaned motes typically drop directly into packaging machinery and the trash removed by the cleaner must be handled and conveyed by the mote trash system (Fig. 3). The mote trash is pulled by suction from the trash exit of the mote cleaner and pneumatically conveyed through a centrifugal fan to the mote trash cyclone. The material handled by the mote trash cyclone typically includes particulate, small leaf material, and lint fibers (Fig. 4).

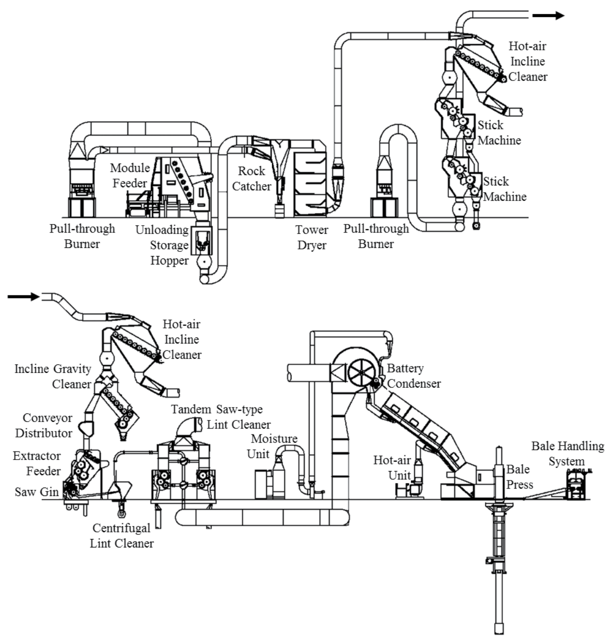

Figure 2. Typical modern cotton gin layout (Courtesy Lummus Corporation, Savannah, GA).

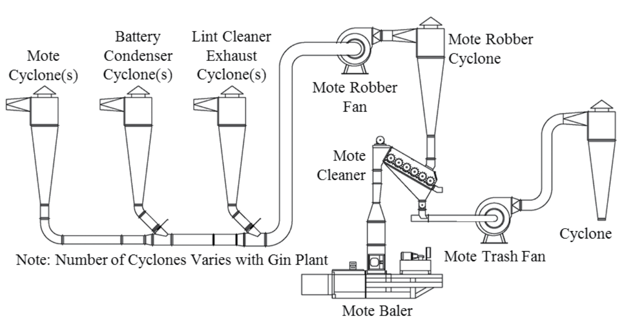

Figure 3. Typical cotton gin mote trash system layout (Courtesy Lummus Corporation, Savannah, GA).

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 ± 2m/s (3200 ± 400fpm).

Figure 4. Photograph of typical trash captured by the mote trash system cyclones.

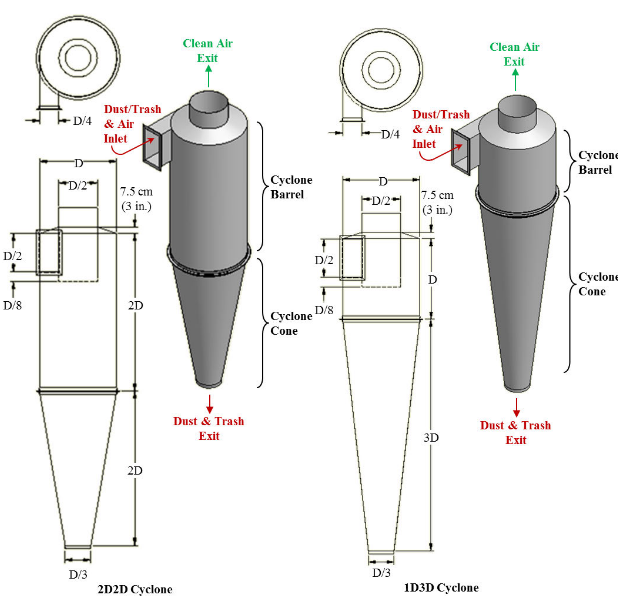

Figure 5. 2D2D and 1D3D cyclone schematics.

The objective of this study is the development of $PM_{2.5}$ emission factors for cotton gin mote trash systems with cyclones for emissions control 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 is 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 (geographically diverse), 2) industry representative production capacity, 3) typical processing systems and 4) gins equipped with properly designed and maintained 1D3D cyclones. 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 Other Test Method 27 (OTM27) was used to sample the mote trash system at each gin. When testing for this project began in 2008, OTM27 was the EPA method for determination of PM_{10} and $PM_{2.5}$ from stationary sources. In December 2010, OTM27 was replaced with a revised and finalized Method 201A (CFR, 2010). The revised Method 201A was a successor to OTM27. The two methods were similar to the point that EPA stated in an answer to a frequently asked question for Method 201A (EPA, 2010) that “If the source was using OTM 27 (and 28) for measuring either PM_{10} or $PM_{2.5}$ then using the revised reference methods Method 201A (and 202) should not be a concern and should give equivalent results.” Accordingly, OTM27 is no longer an EPA method that can be cited, and the revised Method 201A will be cited in this manuscript. Using Method 201A to sample $PM_{2.5}$, 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 a $PM_{2.5}$ 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 cyclones 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); 10 to 2.5 µm (PM_{10} sizing cyclone exit acetone wash and $PM_{2.5}$ sizing cyclone catch acetone wash); and ≤ 2.5 µm ($PM_{2.5}$ sizing cyclone exit acetone wash and filter). The $PM_{2.5}$ mass was determined by adding the mass of particulates captured on the filter and the ≤ 2.5 µm wash. The PM_{10} mass was determined by adding the $PM_{2.5}$ mass and the mass of the 10 to 2.5 µm wash. Total particulate was determined by adding the PM_{10} mass and the mass of the > 10 µm wash.

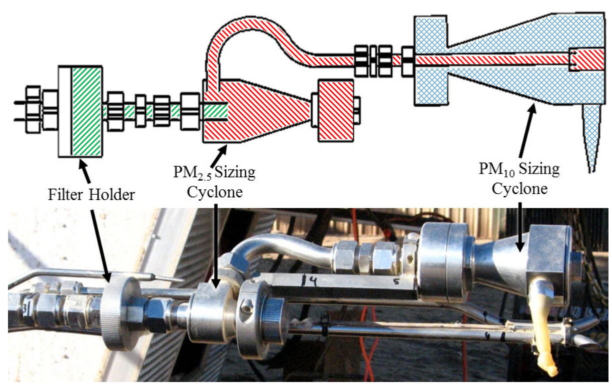

Figure 6. EPA Method 201A PM_{10} and $PM_{2.5}$ sizing cyclones and in-stack filter holder schematic (CFR, 2010) and photograph (≤ 2.5 µm, 10 to 2.5 µm, > 10 µm).

Figure 7 shows the performance curves for the PM_{10} and $PM_{2.5}$ sizing cyclones. To measure both PM_{10} and $PM_{2.5}$, Method 201A requires selecting a gas sampling rate in the middle of the overlap zone of the performance curves for both sizing cyclones. For this study, the method was specifically used to collect filterable $PM_{2.5}$ emissions (solid particles emitted by a source at the stack and captured in the ≤ 2.5 µm wash and on the filter [CFR, 2010]). The PM_{10} sizing cyclone was used to scrub larger particles from the airstream to minimize their impact on the $PM_{2.5}$ sizing cyclone. Thus, the gas-sampling rate was targeted to optimize the $PM_{2.5}$ cyclone performance.

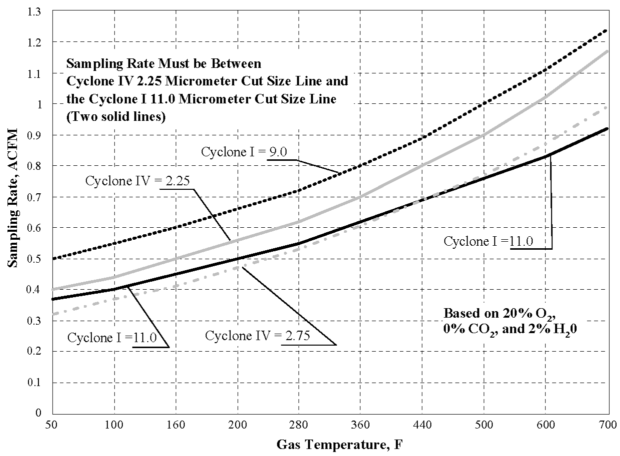

Figure 7. Acceptable sampling rate for combined cyclone heads (CFR, 2010). Cyclone I = PM_{10} sizing cyclone and Cyclone IV = $PM_{2.5}$ sizing cyclone (Gas temperatures for the mote trash systems tested ranged from 23 to 40˚C [73-104˚F]).

Only one stack from each mote trash 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 cyclones, was purchased from Apex Instruments (Fuquay-Varina, NC) and met specifications of Method 201A. 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 and wash tubs and lids were prelabeled and 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 conducted calibrations and checks on all stack sampling equipment according to EPA Method 201A.

Each cyclone tested 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.

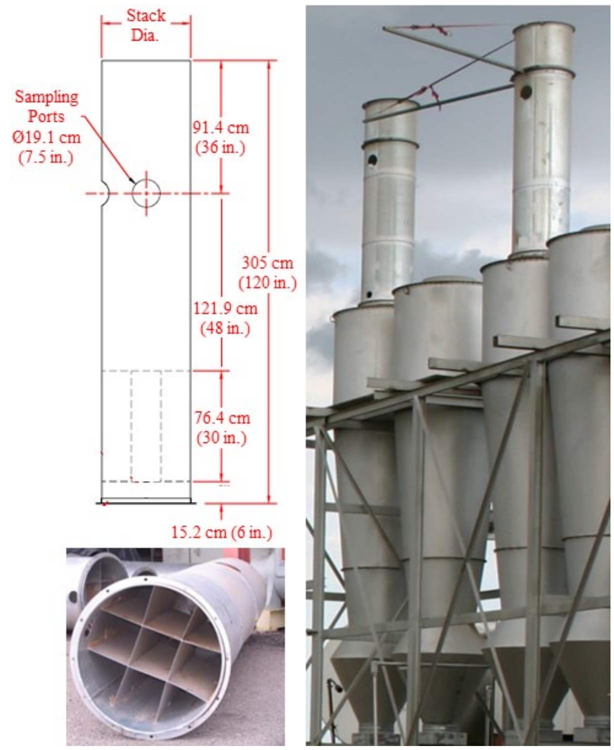

Figure 8. Schematic and photographs of stack extensions with sampling ports and staightening vanes (rail attached to extension above sampling port, at right, supports sampling probe during testing traverse).

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 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).

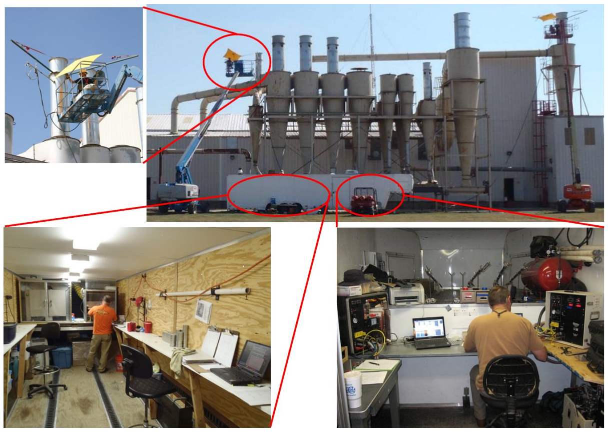

Figure 9. Clockwise from top right: cotton gin stack sampling with air quality lab trailer and technicians on lifts; certified stack sampling technician in the trailer control room conducting tests; sample recovery in trailer clean room; technician operating the probe at stack level.

All laboratory analyses were conducted at the AQL. All filters were conditioned in an environmental chamber (21 ± 2°C; 35 ± 5% RH) for 48 hours 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 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 digitally 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.

Two of the seven gins had mote trash systems where the exhaust airstreams were not combined with other major systems. The mote trash systems sampled were typical for the industry. At gin E (Fig. 10), motes from the combined mote system were dropped directly into the mote cleaner. The cleaned motes then dropped into the mote press for packaging. The trash removed from the motes by the cleaner was picked up in the mote trash system and pneumatically conveyed through a fan to the mote trash system cyclone where the trash was then combined into the master trash system. Trash from the mote cleaner was also picked up by the mote trash system at Gin B (Fig. 11) but, before the fan, the mote trash airstream was combined with a conveying airstream containing trash from the cyclones for three first-stage lint-cleaning systems. The combined airstreams then passed through a fan and were exhausted through the mote trash system cyclone.

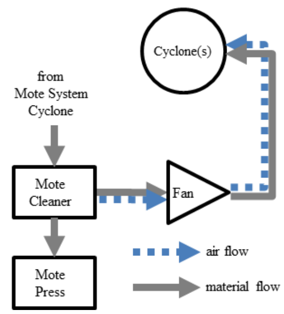

Figure 10. Schematic of mote trash system (gin E).

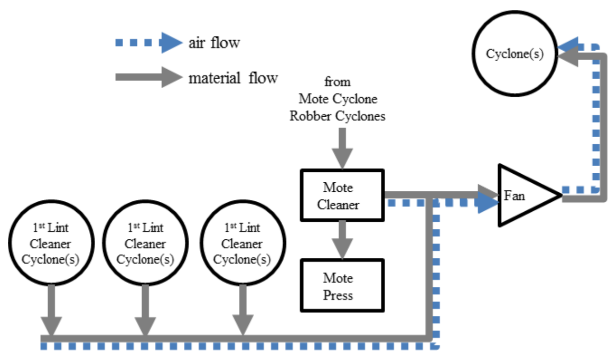

Figure 11. Schematic of mote trash system combined with airstream containing trash from the cyclones for three 1st stage lint cleaning systems (gin B).

Both mote trash systems sampled utilized 1D3D cyclones to control emissions (Fig. 5), but there were some cyclone design variations between the gins (Table 1 and Fig. 12). The mote trash systems at both gins B and E exhausted through a single cyclone. The cyclone inlet on the mote trash cyclone at Gin B was a 2D2D type and the gin E mote trash cyclone had inverted 1D3D type inlet. An expansion chamber was present on mote trash cyclone at gin B and the gin E cyclone had a standard cone. All of the cyclone variations outlined above, if properly designed and maintained, are recommended for controlling cotton gin emissions (Whitelock et al., 2009).

Table 1. Abatement device configuration[z] for mote trash systems tested.

Gin	Cyclone Type	Inlet Design[y]	Systems per Gin	Cyclones per Gin	Configuration	Cone Design	Trash exits to[x]
B	1D3D	2D2D	1	1	Single	expansion chamber	auger
E	1D3D	inverted 1D3D	1	1	Single	Standard	auger

[z] Figures 5 and 12

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

[x] Systems to remove material from cyclone trash exits: auger = enclosed, screw-type conveyor

Figure 12. Cyclone design variations for the tested systems (left to right): 1D3D cyclone with an inverted 1D3D inlet; 1D3D cyclone with 2D2D inlet and expansion chamber on the cone; 1D3D cyclone with 2D2D inlet and standard cone.

RESULTS

Table 2 shows the test parameters for each Method 201A test run for the mote trash systems sampled. The system average ginning rate was 25.1 bales/h and the test average ginning rates at each gin ranged from 24.5 to 25.8 bales/h (based on 227-kg [500-lb] equivalent bales). The capacity of gins sampled was representative of the industry average that is 25 bales/h. The 1D3D cyclone inlet velocities for the mote trash system cyclones at both gins were outside the design criteria, 16.3 ± 2 m/s (3200 ± 400 fpm), due to limitations in available system adjustments.

There are criteria specified in EPA Method 201A for test runs to be valid for $PM_{2.5}$, PM_{10}, or total particulate measurements (CFR, 2010). Isokinetic sampling must fall within EPA defined ranges (100 ± 20%) for valid $PM_{2.5}$ and PM_{10} test runs. All tests met the isokinetic criteria (Table 2). The $PM_{2.5}$ aerodynamic cut size must fall within EPA defined ranges (2.50 ± 0.25 mm) for valid $PM_{2.5}$ test runs. $PM_{2.5}$ cut size criteria was met in all tests. The PM_{10} aerodynamic cut size must fall within EPA defined ranges (10.0 ± 1.0 mm) for valid PM_{10} test runs. PM_{10} cut size criteria was not met in the first test run at gin B or the third test run at gin E; thus the data associated with these runs were omitted from the PM_{10} test averages. To use the method to also obtain total filterable particulate, sampling must be within 90 to 110% of isokinetic flow. This criterion was not met in the first test run for gin B; thus the data associated with this run were omitted from the total particulate test averages.

Table 2. Cotton gin production data and stack sampling performance metrics for the mote trash systems.

Gin	Test Run	Ginning Rate, bales/h[z]	Cyclone Inlet Velocity,		Isokinetic Sampling, %	Aerodynamic Cut Size D_{50},		Sampling Rate[y]		Stack Temperature	
			m/s	fpm		$PM_{2.5}$ μm	PM_{10} μm	slpm	scfm	°C	°F
B	1	24.3	20.0	3945	89[x]	2.48	11.2[w]	11.2	0.396	37	98
	2	25.9	20.0	3942	92	2.43	11.0	11.5	0.407	39	102
	3	27.3	20.4	4022	94	2.33	10.7	12.0	0.423	40	104
Test Average		25.8	20.2	3969							
E	1	23.9	14.0	2758	108	2.35	10.9	11.1	0.392	23	73
	2	24.7	14.2	2794	106	2.38	11.0	11.1	0.391	25	77
	3	24.7	14.2	2795	106	2.41	11.1[w]	11.1	0.391	28	82
Test Average		24.5	14.1	2783							
System Average		25.1	17.1	3376							

[z] 227 kg (500 lb) equivalent bales

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

[x] Did not meet total particulate isokinetic sampling rate criteria (100 ± 10%)

[w] Did not meet PM_{10} (10.0 ± 1.0 μm) aerodynamic cut size criteria

Sampling rates ranged from 11.1 to 12.0 standard l/min (0.391-0.423 standard ft^3/min) (Table 2). The stack gas temperatures ranged from 23 to 40°C. The sampling method documentation (CFR, 2010) warns that the acceptable gas sampling rate range is limited at the stack gas temperatures encountered during this project's testing, as indicated by the narrow difference between the solid lines in Figure 7 for the temperatures listed above. These stack gas characteristics justified targeting the $PM_{2.5}$ cut size criteria and treating the PM_{10} cut size criteria as secondary.

The $PM_{2.5}$ emissions data (ginning and emission rates and corresponding emission factors) for the mote trash systems are shown in Table 3. The system average $PM_{2.5}$ emission factor was 0.0011 kg/bale (0.0024 lb/bale). The test average emission factors at each gin ranged from 0.0010 to 0.0012 kg (0.0023-0.0026 lb) per bale and $PM_{2.5}$ emission rates ranged from 0.025 to 0.030 kg/h (0.055-0.066 lb/h). PM_{10} emissions data (ginning and emission rates and corresponding emission factors) for the mote trash systems are shown in Table 4. The system average PM_{10} emission factor was 0.0094 kg/bale (0.021 lb/bale). The test average emission factors ranged from 0.0058 to 0.013 kg (0.013 to 0.029 lb) per bale and emission rates ranged from 0.14 to 0.34 kg/h (0.31-0.75 lb/h). Total particulate emissions data (ginning and emission rates and corresponding emission factors) for the mote trash systems are shown in Table 5. The system average total particulate emission factor was 0.017 kg/bale (0.038 lb/bale). The test average emission factors ranged from 0.0088 to 0.026 kg (0.019 to 0.056 lb) per bale. Test average total particulate emission rates ranged from 0.22 to 0.68 kg/h (0.48-1.49 lb/h). The ratios of $PM_{2.5}$ to total particulate, $PM_{2.5}$ to PM_{10}, and PM_{10} to total particulate were 6.4, 11.7, and 54.5%, respectively (ratios calculated using Tables 3, 4, and 5 may vary slightly from those listed due to rounding).

The mote trash system total particulate emission factor average for this project was about 49% of the EPA AP-42 published value for the mote trash fan (EPA, 1996a, 1996b), which is an equivalent system to the mote trash system. The range of test average total particulate emission factors determined for this project and the range of AP-42 emission factor data overlapped. The mote trash system PM_{10} emission factor for this project was about 98% of the EPA AP-42 published value for the mote trash fan. The test average PM_{10} emission factor range fell within the range of the AP-42 emission factor data.

Table 3. $PM_{2.5}$ emissions data for the mote trash systems.

Gin	Test Run	Emission Rate,		Emission Factor,	
		kg/h	lb/h	kg/bale[z]	lb/bale[z]
B	1	0.032	0.070	0.0013	0.0029
	2	0.028	0.062	0.0011	0.0024
	3	0.030	0.067	0.0011	0.0024
Test Average (n=3)		0.030	0.066	0.0012	0.0026
E	1	0.033	0.072	0.0014	0.0030
	2	0.021	0.047	0.0009	0.0019
	3	0.021	0.046	0.0008	0.0019
Test Average (n=3)		0.025	0.055	0.0010	0.0023
System Average (n=2)				0.0011	0.0024

[z] 227 kg (500 lb) equivalent bales

Table 4. PM_{10} emissions data for the mote trash systems.

Gin	Test Run	Emission Rate,		Emission Factor,	
		kg/h	lb/h	kg/bale[z]	lb/bale[z]
B	1[y]	0.44	0.97	0.018	0.040
	2	0.40	0.88	0.015	0.034
	3	0.28	0.63	0.010	0.023
Test Average (n=2)		0.34	0.75	0.013	0.029
E	1	0.14	0.32	0.0060	0.013
	2	0.14	0.30	0.0055	0.012
	3[y]	0.15	0.32	0.0059	0.013
Test Average (n=2)		0.14	0.31	0.0058	0.013
System Average (n=2)				0.0094	0.021

[z] 227 kg (500 lb) equivalent bales

[y] Test run omitted from test averages because aerodynamic cut size (10.0 ± 1.0 µm) was not met

Table 5. Total particulate emissions data for the mote trash systems.

Gin	Test Run	Emission Rate,		Emission Factor,	
		kg/h	lb/h	kg/bale[z]	lb/bale[z]
B	1[y]	0.80	1.76	0.033	0.073
	2	0.72	1.59	0.028	0.062
	3	0.63	1.39	0.023	0.051
Test Average (n=2)		0.68	1.49	0.026	0.056
E	1	0.22	0.49	0.0092	0.020
	2	0.21	0.46	0.0084	0.019
	3	0.22	0.48	0.0089	0.020
Test Average (n=3)		0.22	0.48	0.0088	0.019
System Average (n=2)				0.017	0.038

[z] 227 kg (500 lb) equivalent bales

[y] Test run omitted from test averages because isokinetic sampling rate (100 ± 10%) was not met

Figure 13 shows an example of samples recovered from a typical mote trash system test run. Often, there were cotton lint fibers, which have cross-sectional diameters greater than 10 mm and much greater than 2.5 mm, 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 atypical sample shown in Figure 14, lint fibers passed through the PM_{10} cyclone and collected in the 10 to 2.5 μm wash. This type of material carryover can bias the gravimetric measurements and impact reported 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.

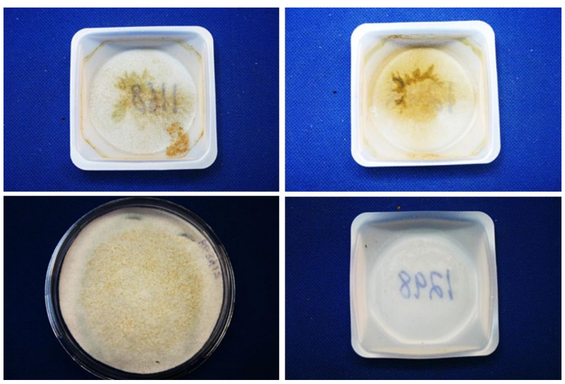

Figure 13. Typical EPA Method 201A filter and sampler head acetone washes from the mote trash systems. Clockwise from top left: > 10 μm wash, 10 to 2.5 μm wash, ≤ 2.5 μm wash, and filter.

Figure 14. Atypical EPA Method 201A filter and sampler head acetone washes from the mote trash systems with lint in the 10 to 2.5 μm wash. Clockwise from top left: > 10 μm wash, 10 to 2.5 μm wash, ≤ 2.5 μm wash, and filter.

SUMMARY

Seven cotton gins across the U.S. Cotton Belt were stack sampled using EPA Method 201A to fill the data gap that exists for $PM_{2.5}$ cotton gin emissions data. Two of the seven gins had mote trash systems where the exhaust airstreams were not combined with other major systems. 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 two gins were typical of the industry, averaging 25.1 bales/h during testing. Some test runs were excluded from the test averages because they failed to meet EPA Method 201A Test criteria. Also, other test runs, included in the analyses, had cotton lint fibers that collected in the ≤ 10 μm and/or ≤ 2.5 μm samples. This larger lint material can impact the reported emissions data, but EPA Method 201A does not suggest methods to account for these anomalies. Average measured mote trash system $PM_{2.5}$ emission factor based on the two gins tested (six total test runs) was 0.0011 kg/227-kg bale (0.0024 lb/500-lb bale). The mote trash system average PM_{10} and total particulate emission factors were 0.0094 kg/bale (0.021 lb/bale) and 0.017 kg/bale (0.038 lb/bale), respectively. The gin test average $PM_{2.5}$, PM_{10}, and total particulate emission rates ranged from 0.025 to 0.030 kg/h (0.055-0.066 lb/h), 0.14 to 0.34 kg/h (0.31-0.75 lb/h) and 0.22 to 0.68 kg/h (0.48-1.49 lb/h), respectively. System average PM_{10} and total particulate emission factors were lower than those currently published in EPA AP-42. The ratios of mote trash system $PM_{2.5}$ to total particulate, $PM_{2.5}$ to PM_{10}, and PM_{10} to total particulate were 6.4, 11.7, and 54.5%, respectively. These data are the first published data to document $PM_{2.5}$ emissions from mote trash systems at cotton gins.

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DISCLAIMER

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