

ENGINEERING AND GINNING

Combined Mote System PM₁₀ Emission Factors and Rates for Cotton Gins: Method 201A PM₁₀ 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 (PM₁₀). 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 PM₁₀ emission factor data for combined mote 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. Two of the seven gins were equipped with combined mote systems where the 1st and 2nd stage mote system exhaust airstreams were combined. In terms of capacity, the two gins were typical of the industry, averaging 35.1 bales/h during testing. The combined mote system average emis-

sion factors for PM₁₀ and total particulate were 0.098 kg/227-kg bale (0.215 lb/500-lb bale) and 0.141 kg/bale (0.310 lb/bale), respectively. System average PM₁₀ and total particulate emission factors were higher than those currently published in EPA AP-42. The combined mote system PM₁₀ emission rate test averages ranged from 2.57 to 4.28 kg/h (5.66-9.44 lb/h). The ratio of combined mote system PM₁₀ to total particulate was 69.3%.

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-mm (PM₁₀) 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, 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

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trash. This report focuses on PM₁₀ emissions from combined mote systems.

The 1996 EPA AP-42 average PM₁₀ emission factor for the mote fan (combined 1st and 2nd stage mote systems) was 0.060 kg (0.13 lb) per 217-kg (480-lb) equivalent bale with a range of 0.023 to 0.14 kg (0.050-0.30 lb) per bale (EPA, 1996a, b). This average and range was based on six tests conducted in one geographical location; 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 the mote fan was 0.13 kg (0.28 lb) per bale with a range of 0.045 to 0.47 kg (0.099-1.0 lb) per bale. This average and range was based on nine tests conducted in one geographical location. 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 approximately 25 bales per hour across the U.S. cotton belt (Valco et al., 2003, 2006, 2009, 2012).

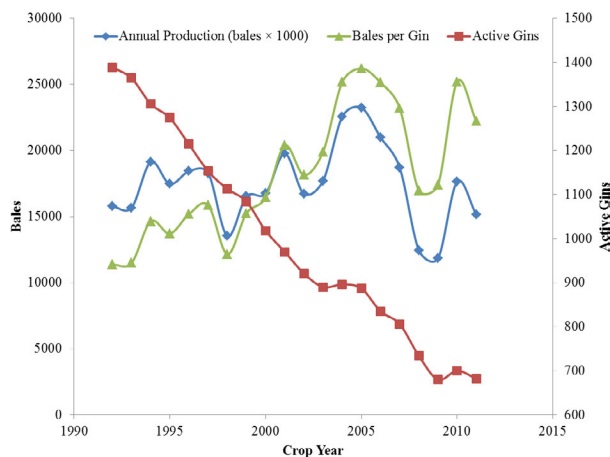


Figure 1. Annual U.S. cotton production, active U.S. gins, and average ginning volume (bales per gin) (NASS, 1993-2012).

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.

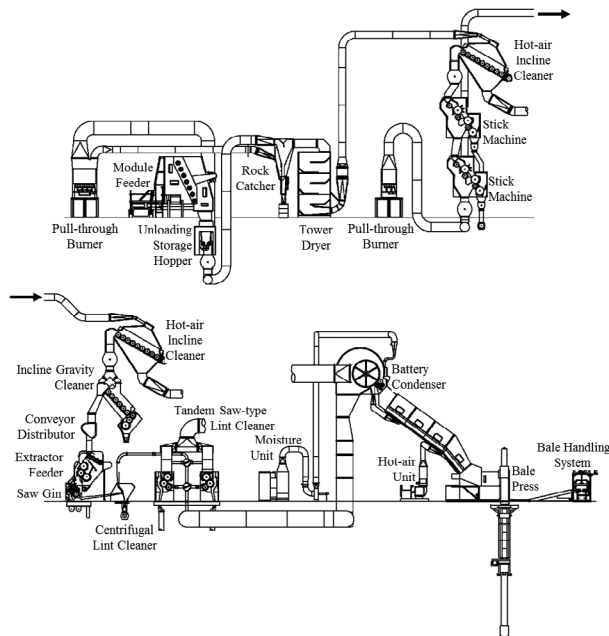


Figure 2. Typical modern cotton gin layout (Courtesy Lummus Corporation, Savannah, GA).

After the seed and lint are separated at the gin stand, the lint is cleaned by one or more stages of lint cleaners. The material removed by lint cleaners is referred to as “motes” and is handled by the mote systems (Fig. 3). Motes are pneumatically conveyed by suction away from the lint cleaners, through a centrifugal fan, to one or two particulate abatement cyclones. Depending on the gin facility, the 1st and 2nd stages of lint cleaning might be combined and share a mote system, thus sharing a fan and abatement devices, or lint-cleaning stages might have mote systems that operate independently with separate fans and cyclones. The function of the 1st and 2nd stage mote systems with separate or combined exhausts is the same and it is expected that the PM emissions from a combined exhaust system would be similar to the aggregate emissions of the 1st and 2nd stage mote systems with separate exhausts. The material handled by the mote cyclones typically includes small trash and particulate and large amounts of lint fibers (Fig. 4).

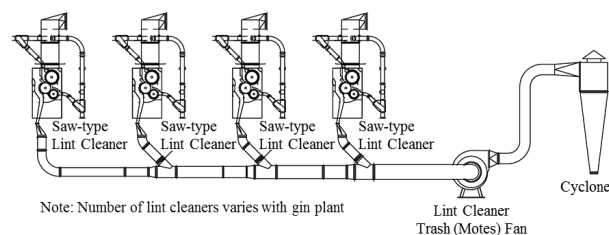


Figure 3. Typical cotton gin combined mote system layout (Courtesy Lummus Corporation, Savannah, GA).



Figure 4. Photograph of typical trash captured by the combined mote 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 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).

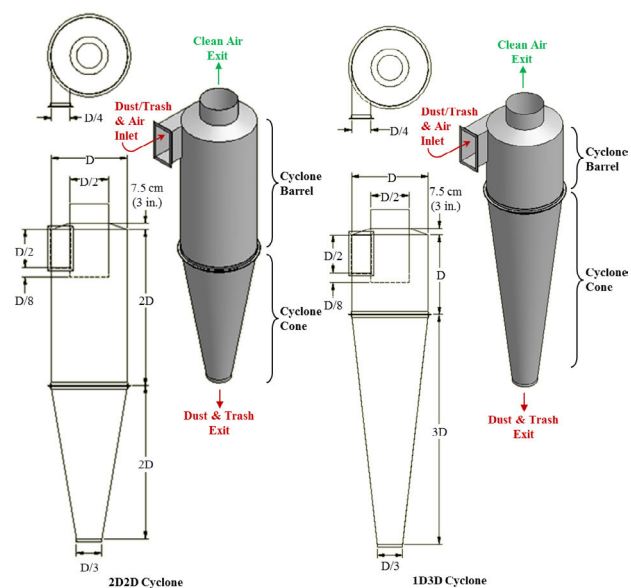


Figure 5. 2D2D and 1D3D cyclone schematics.

The objective of this study was to collect additional PM₁₀ emission factor data for combined mote 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 mote 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-mm aerodynamic equivalent diameter) sampling (CFR, 2010); these revisions did not affect the PM₁₀ stack sampling methodology used in this project. Method 201A is a constant sampling-rate procedure. For the PM₁₀ 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 PM₁₀ 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 (PM₁₀

sizing cyclone catch acetone wash) and ≤ 10 μm (PM₁₀ sizing cyclone exit acetone wash and filter). The PM₁₀ 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 PM₁₀ mass and the mass of the > 10 μm wash.

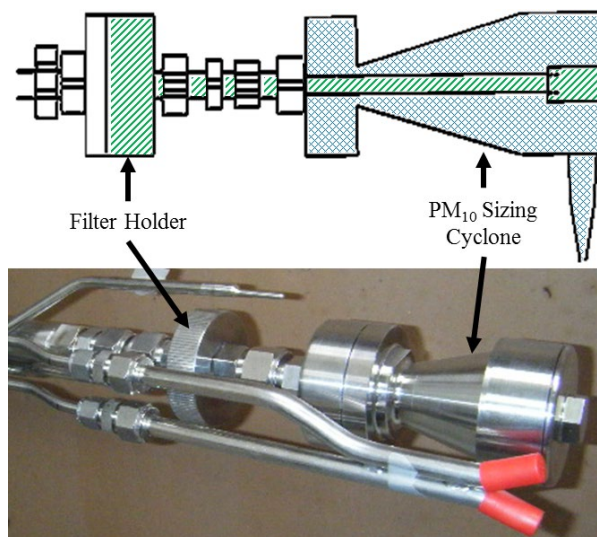


Figure 6. EPA Method 201A PM₁₀ sizing cyclone and in-stack filter holder schematic (CFR, 2010) and photograph (▨ ≤ 10 μm, ▨ > 10 μm).

Figure 7 shows the performance curves for the Method 201A sizing cyclones. To measure PM₁₀, the method requires selecting a gas sampling nozzle to achieve a sampling rate that produces a cut size between 9.0 and 11.0 mm at the stack gas temperature. For this study, Method 201A was specifically used to collect filterable PM₁₀ emissions (solid particles emitted by a source at the stack and captured in the ≤ 10 μm wash and on the filter [CFR, 2010]).

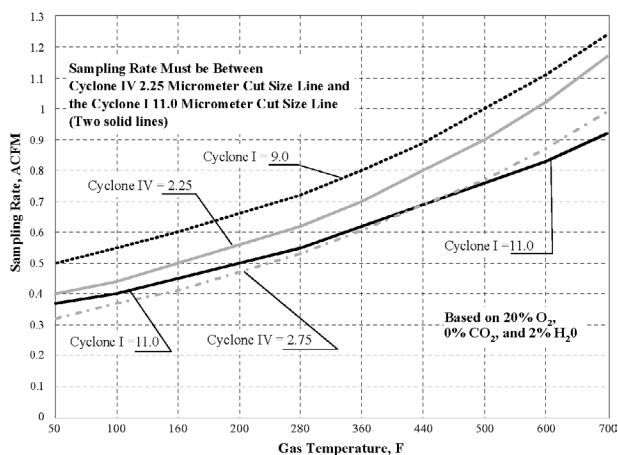


Figure 7. Acceptable sampling rate for sizing cyclones (CFR, 2010) Cyclone I = PM₁₀ sizing cyclone (gas temperatures for the combined mote systems tested ranged from 25 to 40°C [77-104°F]).

Only one stack from each combined mote 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-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 $\geq 99.5\%$). Filters and wash tubs with lids were pre-labeled, 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 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.

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 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 201A and ASAE Standard S582 (ASABE, 2005).



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

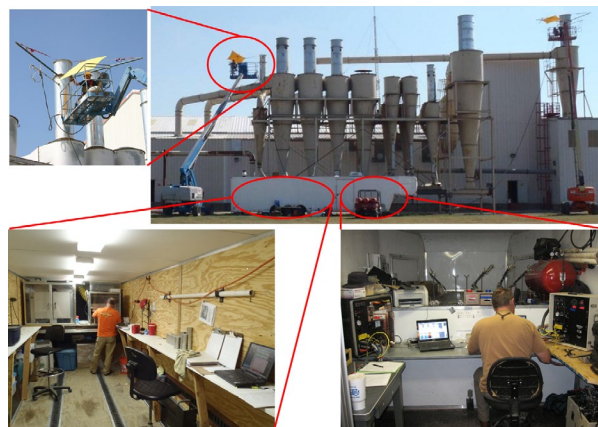


Figure 9. Clockwise from top right: cotton gin stack sampling with air quality lab trailer and technicians on lifts; certified stack sampling technician in the trailer control room conducting tests; sample recovery in trailer clean room; technician operating the probe at stack level.

All laboratory analyses were conducted at the AQL. All filters were conditioned in an environmental chamber ($21 \pm 2^\circ\text{C}$ [$70 \pm 3.6^\circ\text{F}$]; $35 \pm 5\%$ 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; $1 \mu\text{g}$ readability and $0.9 \mu\text{g}$ 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 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 were designed so that the exhaust airstreams from the 1st and 2nd stage mote systems were combined. The combined 1st and 2nd stage mote systems sampled were typical for the industry, but varied among the gins. As the cotton lint was cleaned in three 1st stage lint-cleaning systems and then three 2nd stage lint-cleaning systems at gin E, the trash removed from the lint in the six cleaners was collected in the combined mote system and pneumatically conveyed from the lint cleaners through a fan and exhausted through one or more cyclones (Fig. 10). The combined 1st and 2nd stage mote system at gin G was essentially the same, except the combined mote system pulled trash from two 1st stage lint-cleaning systems and two 2nd stage lint-cleaning systems (Fig. 11).

Both combined mote systems sampled utilized 1D3D cyclones to control emissions (Table 1 and Fig. 5). The system airstream for both gins was exhausted through a single cyclone. Inlets on the combined mote system cyclones were 2D2D type. Standard cones were present on combined mote system cy-

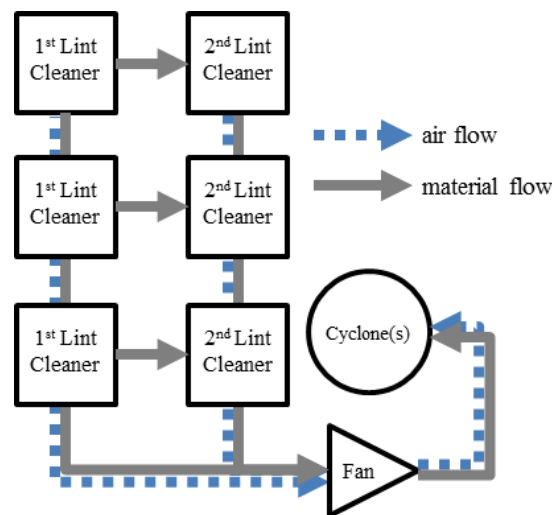


Figure 10. Schematic of combined 1st and 2nd stage mote system pulling material from three 1st and 2nd stage lint-cleaning systems (gin E).

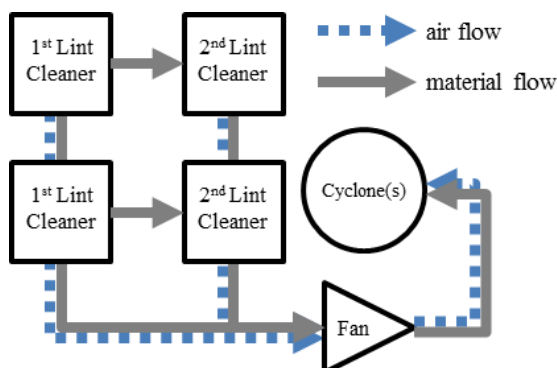


Figure 11. Schematic of combined 1st and 2nd stage mote system pulling material from two 1st and 2nd stage lint-cleaning systems (gin G).

clones at both gins. The cyclone tested at gin G had a mote cyclone robber pulling airflow from its trash exit. 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. The design characteristics for the combined mote system cyclones outline above, if properly designed and maintained, are recommended for controlling cotton gin emissions (Whitelock et al., 2009).

Table 1. Abatement device configuration^z for combined mote systems tested.

Gin	Cyclone Type	Inlet Design	Systems per Gin	Cyclones per Gin	Configuration	Cone Design	Trash Exits to ^y
E	1D3D	2D2D	1	1	single	standard	mote cleaner
G	1D3D	2D2D	1	1	Single	standard	robber

^z Figure 5

^y Systems to remove material from cyclone trash exits: mote cleaner = gin machine that further cleans fiber captured by system; robber = pneumatic suction system

RESULTS

Table 2 shows the test parameters for each Method 201A test run for the combined mote systems sampled at the two gins. The system average ginning rate was 35.1 bales/h and the test average ginning rates at each gin ranged from 34.8 to 35.4 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 test run one at gin E was outside the design range due to limitations in available system adjustments.

There are criteria specified in EPA Method 201A for test runs to be valid for PM₁₀ or total particulate measurements (CFR, 2010). Isokinetic sampling and PM₁₀ aerodynamic cut size must fall within EPA defined ranges ($100 \pm 20\%$ and 10.0 ± 1.0 μm , respectively) for valid PM₁₀ test runs. All tests met both criteria (Table 2). To use the method to obtain total filterable particulate also, sampling must be within 90 to 110% of isokinetic flow. This criterion was not met in the second test run for gin E or the first and second test runs for gin G; thus the data associated with these runs were omitted from the total particulate test averages. Sampling rates ranged from 11.6 to 14.2 standard l/min (0.409-0.503 standard ft³/min). The stack gas temperatures ranged from 25 to 40°C (77-104°F).

PM₁₀ emissions data (ginning and emission rates and corresponding emission factors) for the

combined mote systems are shown in Table 3. The system average PM₁₀ emission factor was 0.098 kg/bale (0.215 lb/bale). The test average emission factors ranged from 0.074 to 0.121 kg (0.163-0.268 lb) per bale and emission rates ranged from 2.57 to 4.28 kg/h (5.66-9.44 lb/h). Total particulate emissions data (ginning and emission rates and corresponding emission factors) for the combined mote systems are shown in Table 4. The system average total particulate emission factor was 0.141 kg/bale (0.310 lb/bale). The test average emission factors ranged from 0.104 to 0.178 kg (0.228-0.392 lb) per bale. The test average total particulate emission rates ranged from 3.74 to 6.23 kg/h (8.26 to 13.74 lb/h). The ratio of PM₁₀ to total particulate was 69.3% (ratios calculated using Tables 3 and 4 might vary slightly from those listed due to rounding).

The average combined mote system total particulate emission factor for this project was about 1.11 times the EPA AP-42 published value for the mote fan (EPA, 1996a, b), which is an equivalent system to combined 1st and 2nd stage mote systems. The range of test average total particulate emission factors determined for this project fell within the range of AP-42 emission factor data. The average combined mote system PM₁₀ emission factor for this project was 1.65 times the EPA AP-42 published value for the mote fan. The test average project PM₁₀ emission factor range also fell within the AP-42 emission factor data range.

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

Gin	Test Run	Ginning Rate	Cyclone Inlet Velocity		Isokinetic Sampling	Aerodynamic Cut Size D ₅₀	Sampling Rate ^y		Stack Temperature	
		bales/h ^z	m/s	fpm	%	PM ₁₀ μm	slpm	scfm	°C	°F
E	1	36.4	18.5	3635	104	9.9	13.4	0.475	38	101
	2	36.0	18.2	3578	112 ^x	9.5	14.2	0.503	40	103
	3	33.9	18.2	3589	102	10.1	13.0	0.460	40	104
Test Average		35.4	18.3	3601						
G	1	34.3	17.3	3405	118 ^x	10.0	12.8	0.450	26	78
	2	33.8	17.6	3469	117 ^x	9.8	12.9	0.457	25	77
	3	36.2	17.6	3468	105	10.6	11.6	0.409	25	77
Test Average		34.8	17.5	3448						
System Average		35.1	17.9	3524						

^z 227 kg (500 lb) equivalent bales

^y slpm = standard l/min, scfm = standard ft³/min

^x Did not meet total particulate isokinetic sampling rate criteria ($100 \pm 10\%$)

Table 3. PM₁₀ emissions data for the combined mote systems.

Gin	Test Run	Emission Rate		Emission Factor	
		kg/h	lb/h	kg/bale ^z	lb/bale ^z
E	1	4.02	8.87	0.111	0.244
	2	4.17	9.20	0.116	0.256
	3	4.66	10.27	0.138	0.303
Test Average (n=3)		4.28	9.44	0.121	0.268
G	1	2.28	5.02	0.066	0.146
	2	2.59	5.72	0.077	0.169
	3	2.83	6.24	0.078	0.172
Test Average (n=3)		2.57	5.66	0.074	0.163
System Average (n=2)				0.098	0.215

^z 227 kg (500 lb) equivalent bales

Table 4. Total particulate emissions data for the combined mote systems.

Gin	Test Run	Emission Rate		Emission Factor	
		kg/h	lb/h	kg/bale ^z	lb/bale ^z
E	1	6.00	13.23	0.165	0.364
	2 ^y	6.08	13.41	0.169	0.373
	3	6.46	14.25	0.191	0.421
Test Average (n=2)		6.23	13.74	0.178	0.392
G	1 ^y	2.76	6.08	0.080	0.177
	2 ^y	3.23	7.11	0.095	0.210
	3	3.74	8.26	0.104	0.228
Test Average (n=1)		3.74	8.26	0.104	0.228
System Average (n=2)				0.141	0.310

^z 227 kg (500 lb) equivalent bales

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

Figure 12 shows an example of samples recovered from a typical combined mote 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, lint fibers could pass through the PM₁₀ cyclone and collect in the ≤ 10 μm wash and on the filter. This type of material carryover can bias the gravimetric measurements and affect reported PM₁₀ 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.

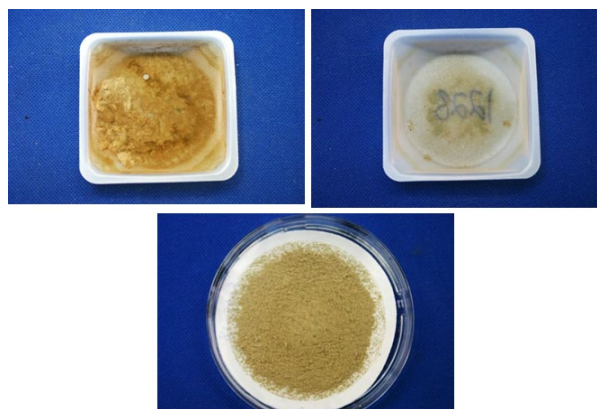


Figure 12. Typical EPA Method 201A filter and sampler head acetone washes from the combined mote system. Clockwise from top left: > 10 μm wash, ≤ 10 μm wash, and filter.

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 PM₁₀ emission factor quality ratings for cotton gins. Two of the seven gins were equipped with combined mote systems where the 1st and 2nd stage mote system exhaust airstreams were combined. The tested systems were similar in design and typical of the ginning industry. Both the systems were equipped with 1D3D cyclones for emissions control. In terms of capacity, the two gins were typical of the industry, averaging 35.1 bales/h during testing. The combined mote system average emission factors for PM₁₀ and total particulate were 0.098 kg/227-kg bale (0.215 lb/500-lb bale) and 0.141 kg/bale (0.310 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 PM₁₀ and total particulate emission rates ranged from 2.57 to 4.28 kg/h (5.66–9.44 lb/h) and 3.74 to 6.23 kg/h (8.26–13.74 lb/h), respectively. Based on the combined mote system average emission factors, the ratio of PM₁₀ to total particulate was 69.3%.

ACKNOWLEDGMENTS

The authors appreciate the cooperating gin managers and personnel who generously allowed and endured sampling at their gins. In addition, we thank California Cotton Ginners' and Growers' Association, Cotton Incorporated, San Joaquin Valleywide Air Pollution Study Agency, Southeastern Cotton Gin-

ners' Association, Southern Cotton Ginners' Association, Texas Cotton Ginners' Association, Texas State Support Committee, and The Cotton Foundation for funding this project. The authors also thank the Cotton Gin Advisory Group and Air Quality Advisory Group for their involvement and participation in planning, execution, and data analyses for this project that is essential to developing quality data that will be used by industry, regulatory agencies, and the scientific community. The advisory groups included: the funding agencies listed above, California Air Resources Board, Missouri Department of Natural Resources, National Cotton Council, National Cotton Ginners' Association, North Carolina Department of Environment and Natural Resources, San Joaquin Valley Air Pollution Control District, Texas A&M University, Texas Commission on Environmental Quality, USDA-NRCS National Air Quality and Atmospheric Change, and U.S. Environmental Protection Agency (national, Region 4 and 9).

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