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ENGINEERING AND GINNING

Battery Condenser 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 battery condenser 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. Six of the seven gins were equipped with battery condensers with cyclones on the system exhausts. In terms of capacity, the six gins were typical of the industry, averaging 31.6 bales/h during testing. The battery condenser system average emission factors for PM_{10} and total particulate were 0.017 kg/227-kg bale (0.036 lb/500-lb bale) and 0.034 kg/bale (0.075 lb/bale), respectively. System average PM_{10} and total particulate emission factors were higher than those currently published in EPA AP-42. The battery condenser system PM_{10} emission rate test averages ranged from 0.17 to 1.16 kg/h (0.37-2.57 lb/h). The ratio of battery condenser system PM_{10} to total particulate was 48.3%.

The United States (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, 1st stage seed-cotton cleaning, 2nd stage seed-cotton cleaning, 3rd stage seed-cotton cleaning, overflow, 1st stage lint cleaning, 2nd stage lint cleaning, combined lint cleaning, cyclone robber, 1st stage mote, 2nd stage mote, combined mote, mote cyclone robber, mote cleaner, mote trash, battery condenser and master trash. This report focuses on PM_{10} emissions from battery condenser systems.

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The 1996 EPA AP-42 average PM_{10} emission factor for the battery condenser with high-efficiency cyclones was 0.0064 kg (0.014 lb) per 217-kg (480-lb) equivalent bale with a range of 0.0036 to 0.011 kg (0.0079-0.025 lb) per bale (EPA, 1996a, 1996b). This average and range was based on five 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 the battery condenser with high-efficiency cyclones was 0.018 kg (0.039 lb) per bale with a range of 0.0059 to 0.037 kg (0.013-0.082 lb) per bale. This average and range was based on five 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).

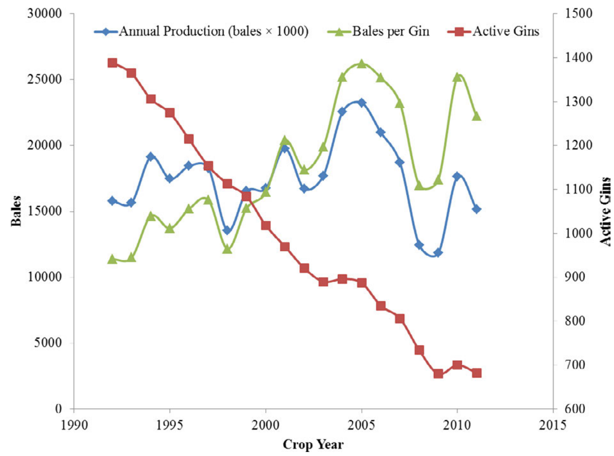

Figure 1. Annual U.S. cotton production, active U.S. gins, and average ginning volume (bales per gin) (NASS, 1993-2012).

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.

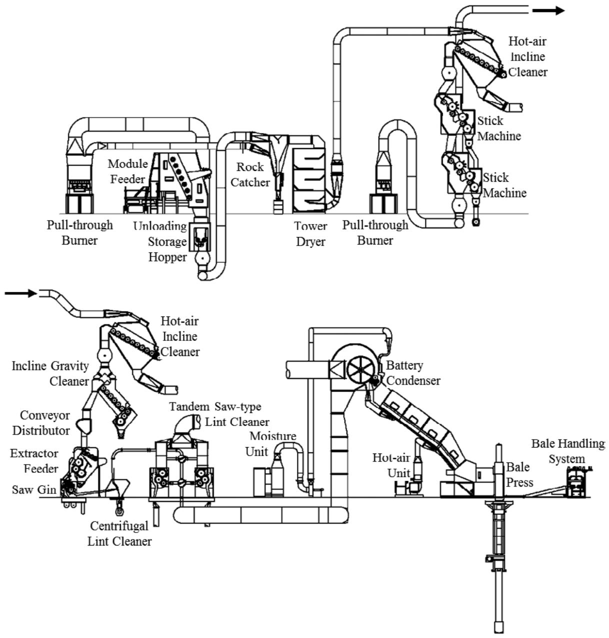

Figure 2. Typical modern cotton gin layout (Courtesy Lummus Corporation, Savannah, GA).

Lint from the final stages of lint cleaning are combined (cotton gins typically split the precleaned seedcotton among multiple, parallel gin stand/lint cleaning lines) and pneumatically conveyed to the bale packaging system via the lint flue and separated from the airstream by a large, screened, rotating drum separator called the "battery condenser". A schematic of the battery condenser system is shown in Figure 3. The battery condenser drops the lint onto the lint slide, which feeds lint into the bale press for compressing and packaging the lint into a 500 lb bale. The airstream from the battery condenser system continues through a large centrifugal fan to one to four particulate abatement cyclones. Some battery condenser systems utilize a vane-axial fan, but these systems typically do not have cyclones and exhaust directly to ambient air. The material handled by the battery condenser cyclones typically includes small trash and particulate, and lint fibers (Fig. 4).

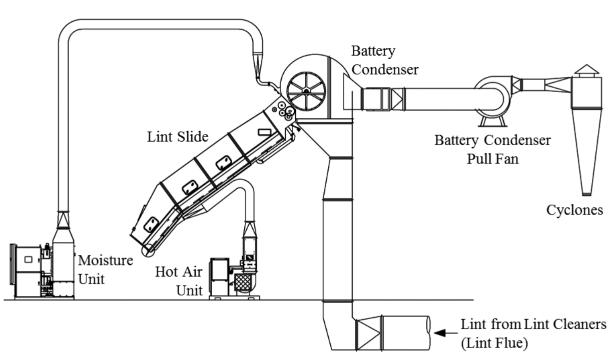

Figure 3. Typical cotton gin battery condenser system layout (Courtesy Lummus Corporation, Savannah, GA).

Figure 4. Photograph of typical trash captured by the battery condenser 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).

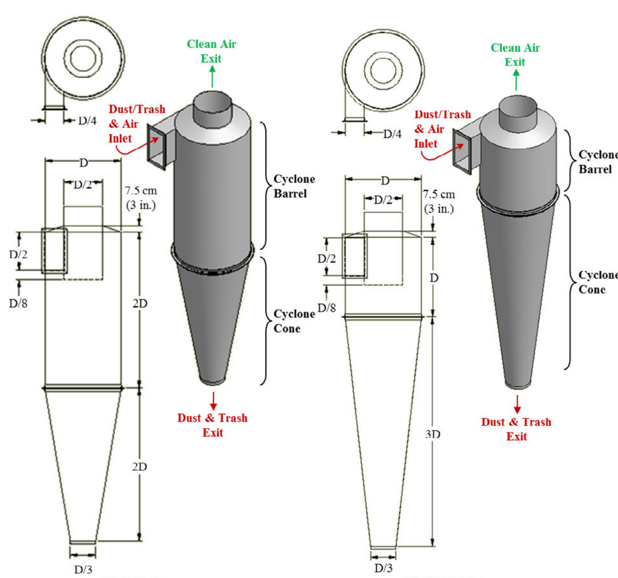

Figure 5. 2D2D and 1D3D cyclone schematics.

The objective of this study was to collect additional PM_{10} emission factor data for battery condenser 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 battery condenser 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.

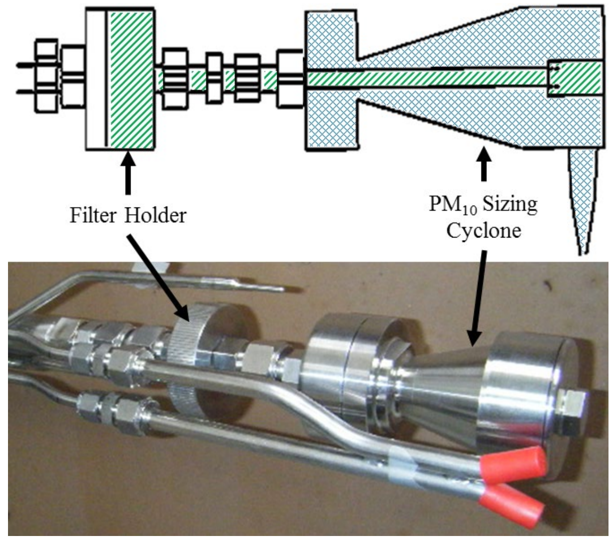

Figure 6. EPA Method 201A PM10 sizing cyclone and in-stack filter holder schematic (CFR, 2010) and photograph (≤ 10 µm, > 10 µm).

Figure 7 shows the performance curves for the Method 201A sizing cyclones. To measure 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 201A was 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]).

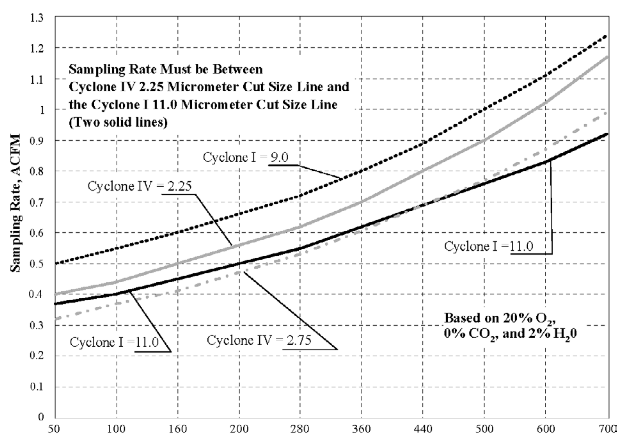

Figure 7. Acceptable sampling rate for sizing cyclones (CFR, 2010) Cyclone I = PM10 sizing cyclone (Gas temperatures for the battery condenser systems tested ranged from 20 to 37°C [67-98°F]).

Only one stack from each battery condenser 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 pre-labeled, 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.

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).

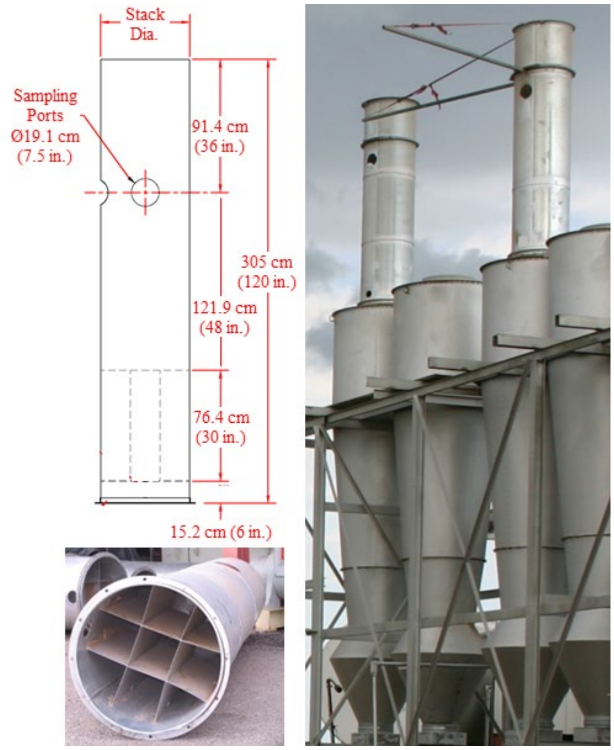

Figure 8. Schematic and photographs of stack extensions with sampling ports and staightening vanes (rail attached to extension above sampling port, at right, supports sampling probe during testing traverse).

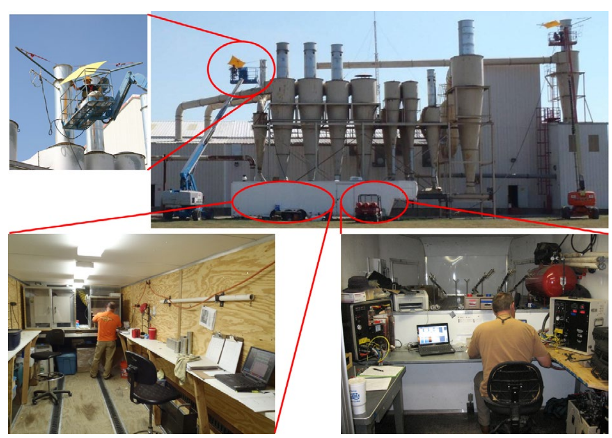

Figure 9. Clockwise from top right: cotton gin stack sampling with air quality lab trailer and technicians on lifts; certified stack sampling technician in the trailer control room conducting tests; sample recovery in trailer clean room; technician operating the probe at stack level.

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

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

Six of the seven gins had battery condenser systems with cyclones on the systems exhausts. The battery condenser systems sampled were typical for the industry, but varied among the gins. After the cotton lint was cleaned in the three 1st stage lint cleaning systems and then three 2nd stage lint cleaning systems at gins A and E, the lint was combined and pneumatically conveyed from the 2nd stage lint cleaners to the battery condenser. The battery condenser separated the lint from the conveying air and fed the lint, via the lint slide, to the bale packaging press. The air stream then passed through a fan and exhausted through one or more cyclones (Fig. 10). The battery condenser systems at gins C and G were essentially the same as those at gins A and E, except the system combined lint from two 2nd stage lint cleaning systems (Fig. 11). The battery condenser systems at gins D and F were also similar, but the systems at those gins combined lint from four 2nd stage lint cleaning systems (Fig. 12).

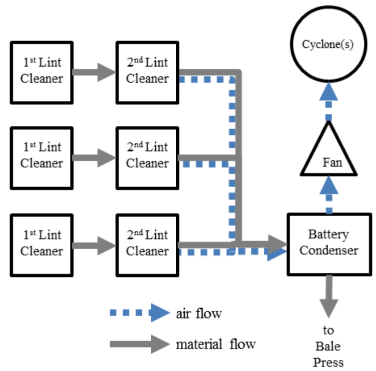

Figure 10. Schematic of battery condenser system pulling material from three 2nd stage lint cleaning systems (gins A and E).

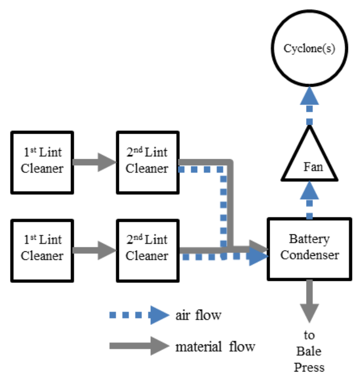

Figure 11. Schematic of battery condenser system pulling material from two 2nd stage lint cleaning systems (gins C and G).

Table 1. Abatement device configuration[z] for battery condenser systems tested.

Gin	Cyclone Type	Inlet Design[y]	Systems per Gin	Cyclones per Gin	Configuration	Cone Design	Trash Exits to[x]
A	1D3D	2D2D	1	3	triple	expansion chamber	auger
C	1D3D	inverted 1D3D	1	3	triple (tandem)	standard	robber
D	1D3D	center-line 1D3D	1	3	triple (tandem)	standard	robber
E	1D3D	2D2D	1	1	single	standard	auger
F	1D3D	2D2D	1	3	triple	standard	robber
G	1D3D	2D2D	1	3	triple	standard	robber

[z] Figures 5, 13, and 14

[y] Inverted 1D3D has duct in line with bottom of cyclone inlet, center-line 1D3D inlet has duct in line with midpoint between the top and bottom of the inlet

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

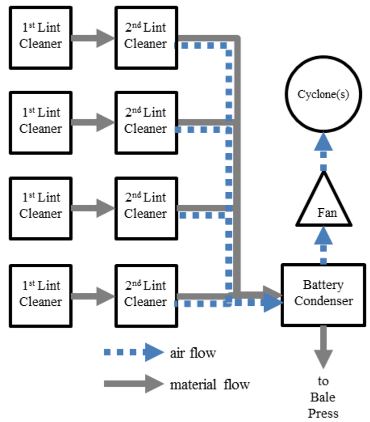

Figure 12. Schematic of battery condenser system pulling material from four 2nd stage lint cleaning systems (gins D and F).

All battery condenser systems sampled utilized 1D3D cyclones to control emissions (Fig. 5), but there were some cyclone design variations among the gins (Table 1 and Figures 13 and 14). All the gins, except gin E, split the system exhaust flow between three cyclones. Gins A, F, and G used a triple (side-by-side) cyclone configuration and gins C and D used a tandem (one-behind-another) cyclone configuration (Fig. 13). The system air stream for gin E was exhausted through a single cyclone. Inlets on all the battery condenser cyclones were 2D2D type, except gin C that had inverted 1D3D inlets and gin D that had center-line 1D3D inlets. Standard cones were present on battery condenser cyclones at all gins, except gin A that had expansion chambers. The cyclones tested at gins C, D, F, 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 13. Photographs triple cyclone conrfigurations (left to right): triple cyclone configuration with flow split among three, side-by-side, identical cyclones; triple cyclones in a tandem configuration with flow split among three, one-behind-another, identical cyclones.

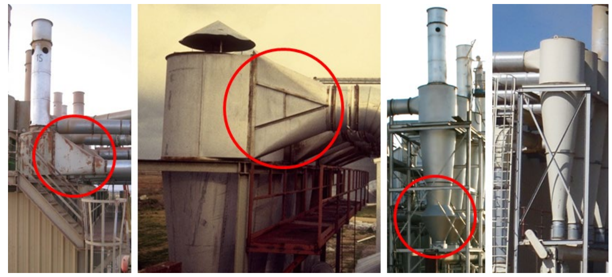

Figure 14. Cyclone design variations for the tested systems (left to right): 1D3D cyclone with an inverted 1D3D inlet; 1D3D cyclone with a center-line 1D3D inlet; 1D3D cyclone with 2D2D inlet and expansion chamber on the cone; 1D3D cyclone with 2D2D inlet and standard cone.

RESULTS

Table 2 shows the test parameters for each Method 201A test run for the battery condenser systems sampled at the six gins. The system average ginning rate was 31.6 bales/h and the test average ginning rates at each gin ranged from 17.5 to 44.7 bales/h (based on 227-kg [500-lb] equivalent bales). 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), except the test runs at gins C and E and test run one at gin F that were 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 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. This criterion was not met in the first and third test runs for gin C, the second and third test runs for gin E, the first test run for gin F, or the third test run for gin G; thus the data associated with these runs were omitted from the total particulate test averages. Sampling rates ranged from 11.9 to 13.7 standard l/min (0.420-0.484 standard ft^3/min). The stack gas temperatures ranged from 20 to 37°C (67-98°F).

PM_{10} emissions data (ginning and emission rates and corresponding emission factors) for the battery condenser systems are shown in Table 3. The system average PM_{10} emission factor was 0.017 kg/bale (0.036

lb/bale). The test average emission factors ranged from 0.0037 to 0.031 kg (0.0082-0.068 lb) per bale and emission rates ranged from 0.17 to 1.16 kg/h (0.37-2.57 lb/h). Total particulate emissions data (ginning and emission rates and corresponding emission factors) for the battery condenser systems are shown in Table 4. The system average total particulate emission factor was 0.034 kg/bale (0.075 lb/bale). The test average emission factors ranged from 0.0058 to 0.084 kg (0.013-0.185 lb) per bale. The test average total particulate emission rates ranged from 0.25 to 1.55 kg/h (0.55-3.42 lb/h). The ratio of PM_{10} to total particulate was 48.3% (ratios calculated using tables 3 and 4 may vary slightly from those listed due to rounding).

The average battery condenser system total particulate emission factor for this project was about 1.9 times the EPA AP-42 published value for the battery condenser with high-efficiency cyclones (EPA, 1996a, 1996b). The range of test average total particulate emission factors determined for this project and the AP-42 emission factor data range overlapped. The average battery condenser system PM_{10} emission factor for this project was 2.6 times the EPA AP-42 published value for the battery condenser with high-efficiency cyclones. The test average PM_{10} emission factor range also overlapped with AP-42 emission factor data range.

Table 2. Cotton gin production data and stack sampling performance metrics for the battery condenser systems.

Gin	Test Run	Ginning Rate, bales/h[z]	Cyclone Inlet Velocity,		Isokinetic Sampling, %	Aerodynamic Cut Size D_{50}, PM_{10} µm	Sampling Rate[y]		Stack Temperature	
			m/s	fpm			slpm	scfm	°C	°F
A	1	25.9	16.6	3266	107	9.9	13.1	0.461	20	68
	2	19.4	16.7	3279	103	10.2	12.6	0.445	20	68
	3	26.8	16.5	3244	109	9.9	13.2	0.466	20	67
Test Average		24.0	16.6	3263						
C	1	16.8	14.0	2758	85[x]	10.3	12.2	0.431	28	83
	2	18.5	14.1	2769	95	10.5	11.9	0.420	26	78
	3	17.4	13.8	2715	118[x]	10.3	11.9	0.421	21	70
Test Average		17.5	14.0	2747						
D	1	33.8	16.1	3170	110	9.6	13.7	0.484	33	92
	2	34.6	15.7	3094	108	10.0	13.1	0.462	34	93
	3	32.8	15.7	3096	106	10.0	12.9	0.457	34	93
Test Average		33.8	15.8	3120						
E	1	30.4	12.0	2371	106	9.9	13.1	0.461	31	88
	2	31.1	11.2	2203	119[x]	9.7	13.6	0.480	33	92
	3	33.1	11.4	2253	113[x]	10.0	13.2	0.466	36	97
Test Average		31.5	11.6	2276						
F	1	46.6	18.3	3601	89[x]	10.5	12.6	0.444	36	97
	2	44.7	17.4	3434	92	10.5	12.4	0.438	35	94
	3	42.9	17.6	3467	96	10.1	13.1	0.463	34	93
Test Average		44.7	17.8	3501						
G	1	38.2	15.0	2953	93	10.0	13.1	0.464	37	98
	2	39.1	15.0	2944	93	10.1	13.0	0.458	36	97
	3	36.1	14.8	2904	113[x]	10.0	12.9	0.457	34	93
Test Average		37.8	14.9	2934						
System Average		31.6	15.1	2973						

[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%)

Table 3. PM_{10} emissions data for the battery condenser systems.

Gin	Test Run	Emission Rate, kg/h	Emission Rate, lb/h	Emission Factor, kg/bale[z]	Emission Factor, lb/bale[z]
A	1	0.31	0.68	0.012	0.026
	2	0.34	0.74	0.017	0.038
	3	0.35	0.76	0.013	0.029
Test Average (n=3)		0.33	0.73	0.014	0.031
C	1	0.46	1.02	0.028	0.061
	2	0.38	0.84	0.021	0.046
	3	0.33	0.72	0.019	0.042
Test Average (n=3)		0.39	0.86	0.022	0.049
D	1	0.51	1.12	0.015	0.033
	2	0.63	1.38	0.018	0.040
	3	0.32	0.71	0.010	0.021
Test Average (n=3)		0.48	1.07	0.014	0.031
E	1	0.37	0.82	0.012	0.027
	2	0.40	0.88	0.013	0.028
	3	0.54	1.18	0.016	0.036
Test Average (n=3)		0.44	0.96	0.014	0.030
F	1	0.22	0.48	0.0047	0.010
	2	0.13	0.29	0.0030	0.0065
	3	0.15	0.33	0.0035	0.0077
Test Average (n=3)		0.17	0.37	0.0037	0.0082
G	1	1.17	2.58	0.031	0.067
	2	1.19	2.63	0.031	0.067
	3	1.13	2.48	0.031	0.069
Test Average (n=3)		1.16	2.57	0.031	0.068
System Average (n=6)				0.017	0.036

[z] 227 kg (500 lb) equivalent bales

Figure 15 shows an example of samples recovered from a typical battery condenser 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 PM_{10} 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 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.

Table 4. Total particulate emissions data for the battery condenser systems.

Gin	Test Run	Emission Rate, kg/h	Emission Rate, lb/h	Emission Factor, kg/bale[z]	Emission Factor, lb/bale[z]
A	1	0.57	1.25	0.022	0.048
	2	0.70	1.53	0.036	0.079
	3	0.59	1.31	0.022	0.049
Test Average (n=3)		0.62	1.36	0.027	0.059
C	1[y]	1.85	4.08	0.110	0.243
	2	1.55	3.42	0.084	0.185
	3[y]	1.65	3.63	0.095	0.209
Test Average (n=1)		1.55	3.42	0.084	0.185
D	1	1.09	2.40	0.032	0.071
	2	1.26	2.77	0.036	0.080
	3	0.75	1.66	0.023	0.050
Test Average (n=3)		1.03	2.28	0.030	0.067
E	1	0.62	1.36	0.020	0.045
	2[y]	0.72	1.58	0.023	0.051
	3[y]	0.85	1.86	0.026	0.056
Test Average (n=1)		0.62	1.36	0.020	0.045
F	1[y]	0.47	1.03	0.010	0.022
	2	0.23	0.50	0.0051	0.011
	3	0.28	0.61	0.0064	0.014
Test Average (n=2)		0.25	0.55	0.0058	0.013
G	1	1.40	3.09	0.037	0.081
	2	1.53	3.36	0.039	0.086
	3[y]	1.42	3.12	0.039	0.087
Test Average (n=2)		1.46	3.23	0.038	0.083
System Average (n=6)				0.034	0.075

[z] 227 kg (500 lb) equivalent bales

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

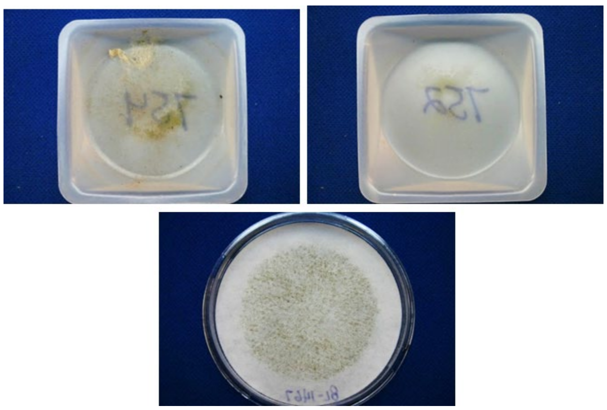

Figure 15. Typical EPA Method 201A filter and sampler head acetone washes from the battery condenser system. Clockwise from top left: > 10 µm wash, ≤ 10 µm wash, and filter.

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 PM_{10} emission factor quality ratings for cotton gins. Six of the seven gins were equipped with battery condensers that had cyclones on their exhausts. 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 six gins were typical of the industry, averaging 31.6 bales/h during testing. The battery condenser system average emission factors for PM_{10} and total particulate were 0.017 kg/227-kg bale (0.036 lb/500-lb bale) and 0.034 kg/bale (0.075 lb/bale), respectively. System average PM_{10} 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 0.17 to 1.16 kg/h (0.37-2.57 lb/h) and 0.25 to 1.55 kg/h (0.55-3.42 lb/h), respectively. Based on the battery condenser system average emission factors, the ratio of PM_{10} to total particulate was 48.3%.

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