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ENGINEERING AND GINNING

Mote Cleaner System Total Particulate Emission Factors and Rates for Cotton Gins: Method 17

Derek P. Whitelock, Michael D. Buser*, J. Clif Boykin, Gregory A. Holt

ABSTRACT

This report is part of a project to characterize cotton gin emissions from the standpoint of stack sampling. The impetus behind this project was the urgent need to collect additional cotton gin emissions data to address current regulatory issues. A key component of this study was focused on Environmental Protection Agency (EPA) total particulate emission factors. There is no total particulate emission factor published for mote cleaner systems in the 1996 EPA AP-42. The objective of this study was to collect total particulate emission factor data for mote cleaner systems from cotton gins located in regions across the cotton belt using EPA-approved stack sampling methodology. The project plan included sampling seven cotton gins. Key factors for selecting specific cotton gins included: 1) facility location, 2) production capacity, 3) processing systems and 4) abatement technologies. Two gins with mote cleaner systems were sampled. The exhaust from one of the mote cleaner systems was combined with the module feeder dust system. The average production rate during testing was 32.7 and 47.0 bales/h for the stand alone mote cleaner system and mote cleaner and module feeder dust system, respectively. The average total particulate emission factor for the mote cleaner system that was not combined with another gin system (three total test runs) was 0.105 kg/227-kg bale (0.232 lb/500-lb bale). The average emission rate for this system was 3.46 kg/h (7.63 lb/h). The average total particulate emission factor for the mote cleaner system that was combined with the module feeder dust system (three total test runs) was 0.109 kg/bale (0.239 lb/bale). The average emission rate for this system was 5.10 kg/h (11.24 lb/h).

United States (U.S.) Environmental Protection Agency (EPA) emission factors were published in EPA's Compilation of Air Pollution Emission Factors, AP-42 (EPA, 1996b). These factors were assigned a rating from A (Excellent) to E (Poor) that is used to assess the quality of the data being referenced. In the 1996 EPA AP-42, there are emission factors for total particulate listed for eleven common cotton gin systems. The EPA emission factor quality ratings for these data are extremely low. Cotton gin data received these low ratings because they were collected almost exclusively from a single geographical region, far western United States (EPA, 1996a). The AP-42 data are limited in that some systems commonly used in cotton gins are not represented or are combined with another system under a single emission factor (e.g. 1st and 2nd stage lint cleaning are represented by lint cleaners). Cotton ginners' associations across the cotton belt, including the National, Texas, Southern, Southeastern, and California associations, agreed that there was an urgent need to collect additional cotton gin emissions data to address current regulatory issues. Working with the cotton ginning associations across the country and state and federal regulatory agencies, Oklahoma State University and United States Department of Agriculture-Agricultural Research Service (USDA-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

D.P. Whitelock, USDA-AR Southwestern Cotton Ginning Research Laboratory, 300 E College Dr., P.O. Box 578, Mesilla Park, NM 88047; M.D. Buser*, Biosystems and Agricultural Engineering Oklahoma State University, 214 Agricultural Hall; Stillwater, OK 74078; J.C. Boykin, USDA-ARS Cotton Ginning Research Unit, 111 Experiment Station Road, P.O. Box 256, Stoneville, MS 38776; and G.A. Holt, USDA-ARS Cotton Production and Processing Research Unit, 1604 E FM 1294, Lubbock, TX 79403
*Corresponding autor: buser@okstate.edu

master trash. This report focuses on total particulate emissions from mote cleaner systems.

There are no 1996 EPA AP-42 average emission factors for mote cleaner systems (EPA, 1996b). Mote cleaner systems would be similar to the combined mote fan and mote trash fan listed in AP-42. The AP-42 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 (EPA, 1996a). This average and range was based on nine tests conducted in one geographical location. The AP-42 total particulate emission factor for the mote trash fan was 0.035 kg (0.077 lb) per bale with a range of 0.025 to 0.051 kg (0.055-0.11 lb) per bale and was based on three tests. The EPA total particulate emission factor quality ratings for both the mote fan and mote trash fan were D, which is the second lowest possible rating (EPA, 1996a).

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

Cotton ginning is a seasonal industry lasting from 75 to 120 days, depending on the size and condition of the crop. Although the trend for U.S. cotton production remained generally flat at about 17 million bales per year during the last 20 years, annual production varied greatly for various reasons, including climate and market pressure (Fig. 1). The number of active gins in the U.S. has not remained constant, but has steadily declined 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).

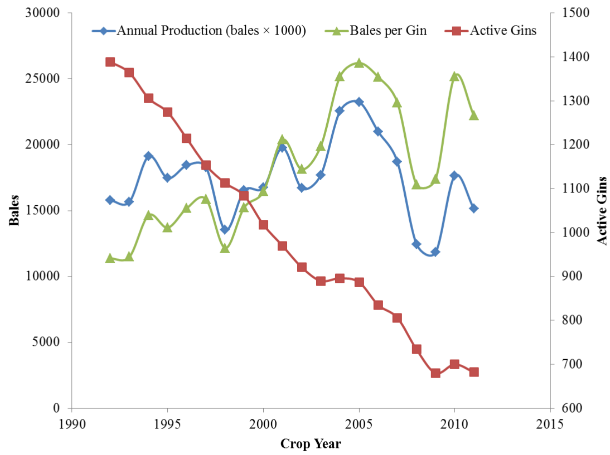

Figure 1. Annual U.S. cotton production, active U.S. gins, and average ginning volume (bales per gin) (NASS, 1993-2012).

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

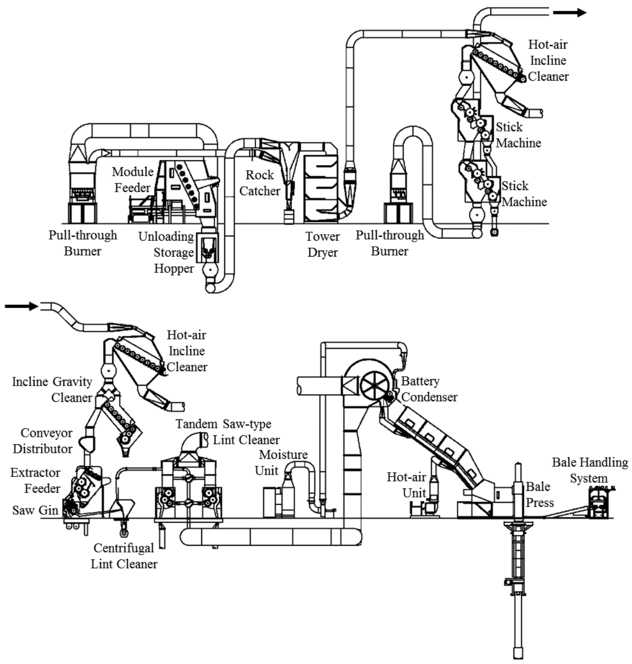

Figure 2. Typical modern cotton gin layout (Courtesy Lummus Corporation, Savannah, GA).

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, has considerable value, especially when cleaned in a device similar to a seed-cotton cleaning machine; the mote cleaner. In mote cleaner systems (Fig. 3) the material is pneumatically conveyed from the trash exit of the cyclones to a screened separator where the motes are separated from the conveying airstream and dropped into the mote cleaner. The airstream from the screened separator continues through a centrifugal fan to one or two particulate abatement cyclones. A branch of the pneumatic system between the separator and fan is often utilized to pick up, by suction, the mote trash from the mote cleaner trash exit. The material handled by the mote cleaner system cyclones typically includes small leaf trash, soil, and some lint fibers (Fig. 4).

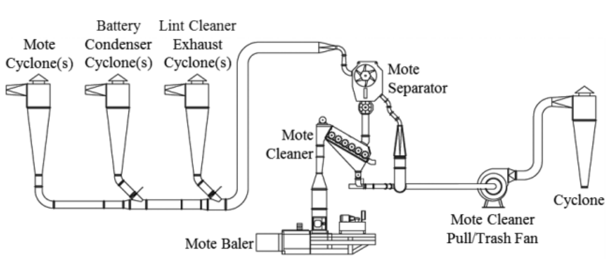

Figure 3. Typical cotton gin mote cleaner system layout (Courtesy Lummus Corporation, Savannah, GA).

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

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

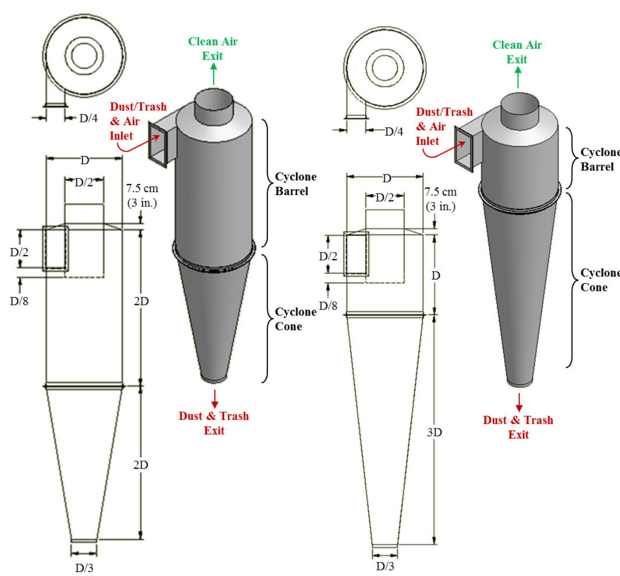

Figure 5. 2D2D and 1D3D cyclone schematics.

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

METHODS

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

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

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

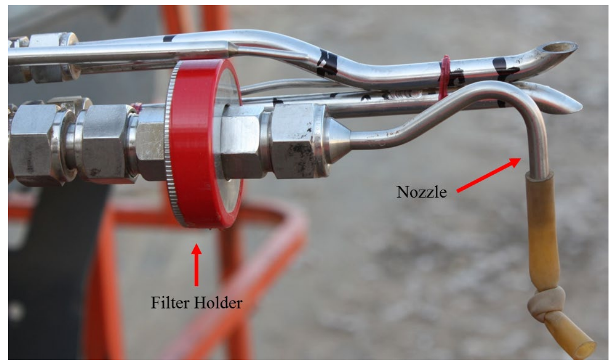

Figure 6. EPA Method 17 total particulate button nozzle and in-stack filter holder photograph.

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

All stack sampling equipment was purchased from Apex Instruments (Fuquay-Varina, NC) and met Method 17 specifications. The sampling media were 47 mm Zefluor filters (Pall Corporation, Port Washington, NY) and the sample recovery and analytical reagent was American Chemical Society certified acetone (A18-4, Fisher Chemical, Pittsburgh, PA – assay ≥ 99.5%). Filters and wash tubs and lids were pre-labeled 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 technician calibrated all sampling equipment according to EPA Method 17.

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

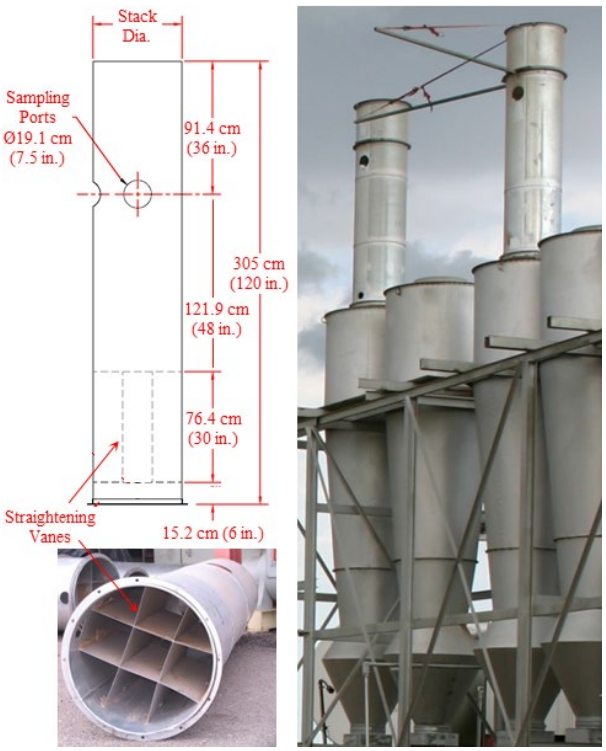

Figure 7. Schematic and photographs of stack extensions with sampling port and staightening vanes (rail attached to extension above sampling port, at right, supports sampling probe during testing traverse).

The tests were conducted by the technician in an enclosed sampling trailer at the base of the cyclone bank (Fig. 8). Sample retrieval, including filters and nozzle acetone washes, was conducted according to Method 17. After retrieval, filters were sealed in individual Petri dishes and acetone washes were dried on-site in a conduction oven at 49°C (120°F) and then sealed with 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 17 and ASAE Standard S582 (ASABE, 2005).

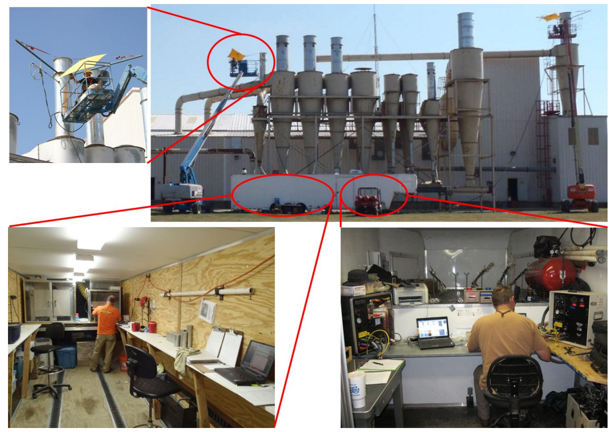

Figure 8. Clockwise from top right: cotton gin stack sampling with air quality lab trailer and technicians on lifts; certified stack sampling technician in the trailer control room conducting tests; sample recovery in trailer clean room; technician operating the probe at stack level.

All laboratory analyses were conducted at the AQL. All filters were conditioned in an environmental chamber (21 ± 2ºC [70 ± 3.6ºF]; 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 anti-static device. The MX-5 microbalance was leveled on a marble table and housed inside an acrylic box to minimize the effects of air currents and vibrations. To reduce recording errors, weights were electronically transferred from the microbalance directly to a spreadsheet. Technicians wore latex gloves and a particulate respirator mask to avoid contamination. AQL procedures required that each sample be weighed three times. If the standard deviation of the weights for a given sample exceeded 10 µg, the sample was reweighed. Gravimetric procedures for the acetone wash tubs were the same as those used for filters

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

Two of the seven gins (F and G) had mote cleaner systems. At gin G (Figure 9), the motes were pneumatically conveyed from the trash exit of the lint handling cyclones (mote, lint cleaning, and battery condenser systems) to the mote cleaner. At the mote cleaner, the motes were separated from the conveying airstream by a screened separator and dropped into the cleaner. The airstream from the screened separator continued through a centrifugal fan to a cyclone. The mote trash was picked up from the trash exit of the mote cleaner and combined with the exhaust airstream from the screened separator. The mote cleaner system at gin F was essentially the same, except a conveying airstream from a system that captured dust generated at the module feeder (module feeder dust system) was combined with the exhaust airstream before the fan (Figure 10). The addition of the module feeder dust system could significantly influence the particulate matter test results for the gin F mote cleaner system; therefore, no system averages were calculated.

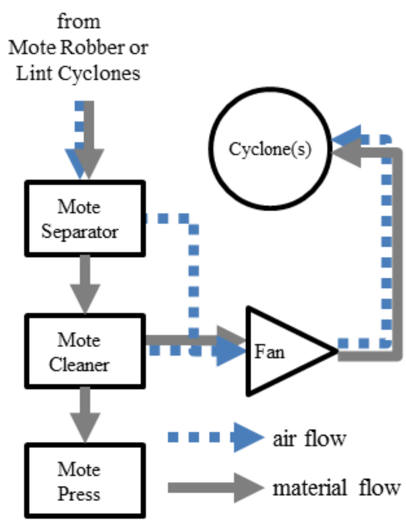

Figure 9. Schematic of mote cleaner system (gin G).

The mote cleaner systems sampled at both gins F and G utilized a single 1D3D cyclone to control emissions (Table 1). The mote cleaner cyclone design for both systems included a 2D2D inlet and standard cone. These cyclone characteristics are shown in Figure 11 and, if properly designed and maintained, are recommended or acceptable for controlling cotton gin emissions (Whitelock et al., 2009).

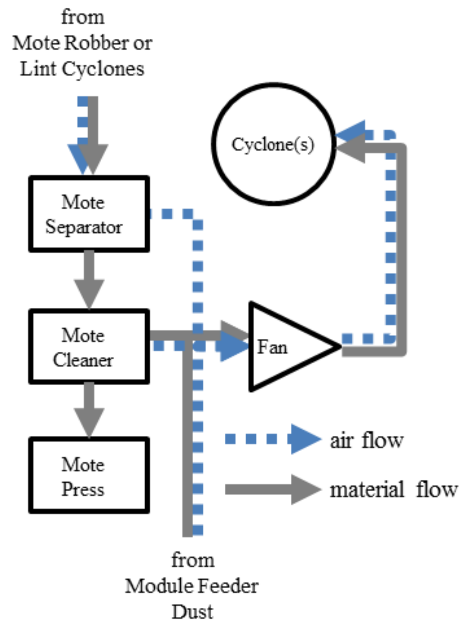

Figure 10. Schematic of mote cleaner system combined with module feeder dust system (gin F).

Figure 11. Cyclone design for the tested systems: 1D3D cyclone with 2D2D inlet and standard cone.

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

Gin	Cyclone Type	Inlet Design	Systems per Gin	Cyclones per Gin	Configuration	Cone Design	Trash Exit[y]
F	1D3D	2D2D	1	1	single	standard	auger
G	1D3D	2D2D	1	1	single	standard	auger

[z] Figures 5 and 11

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

RESULTS

Table 2 shows the test parameters for each Method 17 test run for the mote cleaner systems sampled at the two gins. The average ginning rate for the gin F mote cleaner system combined with the module feeder dust system was 47.0 bales/h and ranged from 44.9 to 49.5 bales/h (based on 227-kg [500-lb] equivalent bales). The average ginning rate for the gin G mote cleaner system was 32.7 bales/h and ranged from 30.5 to 34.0 bales/h. The 1D3D cyclone at gin F was operated with inlet velocities within design criteria, 16.3 ± 2 m/s (3200 ± 400 fpm), but the cyclone at gin G was operated outside the design range due to limitations in available system adjustments.

There are criteria specified in EPA Method 17 for test runs to be valid for total particulate measurements (CFR, 1978). Isokinetic sampling must fall within the EPA defined range of 100 ± 10%. All tests met the isokinetic criteria (Table 2). The stack gas temperature averaged 36°C (97°F) for gin F and ranged from 25 to 31°C (77-88°F) for gin G. The stack moisture content ranged from 0.7 to 1.3% w.b. and 1.3 to 2.1% w.b. for gins F and G, respectively.

No system averages for both gins were calculated because the gin F mote cleaner system was combined with a module feeder dust system that could significantly impact the mote cleaner system emissions. Total particulate emissions data (emission rates and corresponding emission factors) for the mote cleaner systems are shown in Table 3. The average emission factor based on the three test runs at gin F was 0.109 kg/bale (0.239 lb/bale) and ranged from 0.100 to 0.117 kg (0.221-0.259 lb) per bale. The system average emissions factor based on the three test runs for the stand alone mote cleaner system at gin G was 0.105 kg/bale (0.232 lb/bale) and ranged from 0.089 to 0.121 kg (0.196-0.266 lb) per bale. The mote cleaner system total particulate emission factor for this project was about 65% of that published in the current 1996 EPA AP-42 for the mote fan (0.13 kg/bale [0.28 lb/bale]) and mote trash fan (0.035 kg/bale [0.077 lb/bale]) combined (EPA, 1996a, b), which would be similar to the mote cleaner system. The total particulate emission factor determined for this project fell within the AP-42 emission factor data range for the mote fan and was higher than the data range for the mote trash fan. The emission rates ranged from 4.84 to 5.49 kg/h (10.66-12.10 lb/h) and 2.71 to 4.06 kg/h (5.96-8.94 lb/h) for gins F and G, respectively.

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

Gin	Test Run	Ginning Rate, bales/h[z]	Cyclone Inlet Velocity,		Isokinetic Sampling, %	Stack Gas		
						Moisture Content, % w.b.	Temperature,	
			m/s	fpm			°C	°F
F	1	49.5	17.7	3477	93	0.7	36	97
	2	44.9	17.8	3510	95	1.3	36	98
	3	46.8	17.4	3430	92	0.8	36	96
Test Average		47.0	17.6	3472		0.9		
G	1	33.6	20.2	3980	93	1.3	25	77
	2	30.5	20.2	3979	93	2.1	28	83
	3	34.0	20.4	4012	99	1.5	31	88
Test Average		32.7	20.3	3990		1.6		

[z] 227 kg (500 lb) equivalent bales

Table 3. Total particulate emissions data for the mote cleaner systems.

Gin	Test Run	Emission Rate,		Emission Factor,	
		kg/h	lb/h	kg/bale[z]	lb/bale[z]
F[y]	1	4.97	10.95	0.100	0.221
	2	4.84	10.66	0.108	0.237
	3	5.49	12.10	0.117	0.259
Test Average (n=3)		5.10	11.24	0.109	0.239
G	1	4.06	8.94	0.121	0.266
	2	2.71	5.96	0.089	0.196
	3	3.62	7.98	0.106	0.234
Test Average (n=3)		3.46	7.63	0.105	0.232

[z] 227 kg (500 lb) equivalent bales

[y] Mote cleaner system exhaust was combined with a module feeder dust system exhaust

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

Figure 12. Typical EPA Method 17 filter and sampler head acetone wash from the mote cleaner system with lint fiber on the filter (indicated by arrow). From left to right: front half wash and filter.

SUMMARY

Two cotton gins with mote cleaner systems were sampled using EPA Method 17 to collect additional data to improve the EPA AP-42 total particulate emission factor quality ratings for cotton gins. Each of the gins had mote cleaner system exhausts, but the exhaust from one of the mote cleaner systems was combined with the module feeder dust system. Both systems were equipped with 1D3D cyclones for emissions control. The average production rate during testing for the two gins was 32.7 and 47.0 bales/h for the stand alone mote cleaner system and the combined mote cleaner and module feeder dust system, respectively. The average total particulate emission factor for the mote cleaner system that was not combined with another gin system (3 total test runs) was 0.105 kg/227-kg bale (0.232 lb/500-lb bale). The average emission rate for this system was 3.46 kg/h (7.63 lb/h). The average total particulate emission factor for the mote cleaner system that was combined with the module feeder dust system (three total test runs) was 0.109 kg/bale (0.239 lb/bale). The average emission rate for this system was 5.10 kg/h (11.24 lb/h).

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DISCLAIMER

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The statements and conclusions in this report are those of the USDA-ARS and Oklahoma State University and not necessarily those of the California Air Resources Board, the San Joaquin Valleywide Air Pollution Study Agency, or its Policy Committee, their employees or their members. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

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