

## ENGINEERING & GINNING

### Characterization of Cotton Gin Particulate Matter Emissions—Project Plan

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#### ABSTRACT

**In 2006, the U.S. Environmental Protection Agency implemented a more stringent standard for particulate matter with an effective diameter less than or equal to 2.5 microns (PM<sub>2.5</sub>). The implementation timeline for this standard will vary by state/district regulatory agency. For example, the San Joaquin Valley Air Pollution Control District has proposed to include cotton gins in their PM<sub>2.5</sub> State Implementation Plan under the assumption that the PM<sub>2.5</sub> emissions from cotton gins are significant enough to warrant further study and possibly additional control measures above and beyond the current mandate to install enhanced “1D-3D” cyclones on all emission points. All cotton gins across the cotton belt will eventually be impacted by this standard. The primary issues surrounding particulate matter regulations for the cotton ginning industry are: 1) limited or lack of PM<sub>2.5</sub> data; 2) potential overprediction of current dispersion models; and 3) effects of sampler errors. The cotton ginners’ associations across the cotton belt, including the National, Texas, Southern, Southeastern, and California associations, have agreed that there is an urgent need to collect gin emission data to address these issues. In response to the gin association’s requests the project outlined in this paper was developed.**

**I**n 2006, the U.S. Environmental Protection Agency (EPA) implemented a more stringent standard for

particulate matter (PM) with an effective diameter less than or equal to 2.5 microns (PM<sub>2.5</sub>) (CFR, 2006). PM<sub>2.5</sub> is listed as a criteria pollutant in the National Ambient Air Quality Standards (NAAQS). The revised standards for PM<sub>2.5</sub> require that concentrations within any area must not exceed 35 micrograms per cubic meter (µg/m<sup>3</sup>), reduced from the former value of 65 µg/m<sup>3</sup>; and the annual mean PM<sub>2.5</sub> concentrations for any area must not exceed 15 µg/m<sup>3</sup>, unchanged from before 2006. All cotton gins will be impacted by this standard. The timeline by which this standard will be implemented in the individual cotton belt states will vary by state/district agency. Although California appears to be the first state to address these new federal standards, other states such as Texas are currently implementing PM<sub>2.5</sub> regulations.

In California, the San Joaquin Valley Air Pollution Control District has proposed to include cotton gins in their PM<sub>2.5</sub> State Implementation Plan (SIP) under the assumption that the PM<sub>2.5</sub> emissions from cotton gins are significant enough to warrant further study and possibly additional control measures above and beyond the current mandate to install enhanced “1D-3D” cyclones on all emission points. In the district’s candidate control measures section of the 2008 PM<sub>2.5</sub> SIP, the district considered additional control measures such as baghouses, series cyclones, and other technologies that can have substantially higher fixed and variable costs compared to current control measures. If additional control measures such as baghouses are mandated, the costs will be significant and will likely impact ginning costs.

The primary issue affecting the cotton industry across the country in regards to the implementation of the PM<sub>2.5</sub> standard is that little scientifically sound information is available on cotton gin PM<sub>2.5</sub> emissions. Some recent research indicated that current PM<sub>2.5</sub> sampling methods (developed for sources that emit PM with a relatively small particle diameter) could be overestimating cotton gin (PM with relatively larger particle diameters) PM<sub>2.5</sub> emission concentrations by 14 times (Buser et al., 2006a, 2006b, 2006c). This possibly explains why

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some reports indicated that more than 30% of total cotton gin PM emissions were  $PM_{2.5}$  and others indicated that this ratio was less than 3%.

States such as Missouri, North Carolina, South Carolina, and New Mexico are or have used dispersion modeling to estimate cotton gin boundary line  $PM_{10}$ , particulate matter less than or equal to 10 microns in diameter, concentration levels for comparison with the NAAQS. Cotton gins in states such as Missouri are finding it difficult to meet the requirements necessary to obtain air quality permits through modeling. The EPA-recommended dispersion models used by the states were not developed for low-level point sources such as cotton gins. Several studies included in the literature suggest that these models could be over-predicting cotton gin boundary line concentrations by as much as a factor of 10 (Fritz, 2002; Zwicke, 1998). These modeling errors coupled with the  $PM_{2.5}$  stack sampling errors could make it extremely difficult for cotton gins to meet  $PM_{2.5}$  modeled concentration limits set by the individual states.

In response to this issue, cotton ginners' associations across the cotton belt, including the National, Texas, Southern, Southeastern, and California associations, have agreed that there is an urgent need to begin collecting gin emissions data that might be used to refute inaccurate data used by state regulatory agencies. At the request of the ginning associations, Oklahoma State University and the USDA-ARS Ginning Laboratories at Lubbock, TX; Mesilla Park, NM; and Stoneville, MS developed a proposal for a four-year study to evaluate cotton gin PM emissions at several gins at locations across the cotton belt. The four objectives of the study were as follows:

1. Develop  $PM_{2.5}$  emission factors and verify current  $PM_{10}$  emission factors for cotton gins through stack sampling.
2. Develop a robust data set that can be used in the design, development, and evaluation of current and future air quality low-level dispersion models. This data set will consist of stack and ambient sampling data.
3. Characterize the PM emitted from cotton gins in terms of particle size distribution (PSD), particle density, and particle shape.
4. Collect field data to further quantify federal reference method (FRM) ambient and stack  $PM_{10}$  and  $PM_{2.5}$  oversampling rates.

## PROJECT PLAN

**Advisory Groups.** Two different advisory groups were formed to aid in project planning. The first advisory group, Gin Advisory Group, included persons from the National, California, Southeastern, Southern, and Texas Cotton Ginners' Associations, Texas A&M University, Cotton Incorporated, and the National Cotton Council. This group was formed to identify prospective gins for sampling and act as liaison between the gins and the research team, and to aid in securing funding for the project. The second advisory group, Air Quality Advisory Group, included persons on the Gin Advisory Group and individuals from the EPA, California Air Resources Board, San Joaquin Valley Air Pollution Control District, Texas Commission on Environmental Quality, Missouri Department of Natural Resources, and North Carolina Department of Natural Resources. This group was formed to advise on stack sampling, ambient sampling, equipment, sampler placement, sample handling and laboratory analysis, quality control and assurance protocols, and data analysis and reporting. For the project to be successful and accepted by the industry and regulatory agencies, participation of the two advisory groups was essential.

Based on Gin Advisory Group deliberation, four to seven sampling sites (based on total contributed funds) were targeted for evaluation. Plans included sampling a New Mexico gin in the fall of 2008, one South Texas gin in the summer of 2009, two California gins in fall of 2009, a West Texas and a Missouri gin in 2010, and a North Carolina gin in 2011. All gins included in the plan were saw-type gins with the exception of one roller gin in California. The identified gins and initial sampling timeline was flexible due to unforeseen weather or crop issues. The specific gins sampled were selected based on the input from the cotton gin advisory group. These gins were to be equipped with similar abatement technologies and process streams similar to: module feeder or suction, No. 1 pre-cleaning, No. 2 pre-cleaning, overflow, No. 1 lint cleaning, No. 2 lint cleaning, mote fan, mote trash fan, battery condenser, and master trash. If the selected gins were equipped with additional process streams (e.g., feeder, No. 3 pre-cleaning, No. 3 lint cleaning) then those streams would be sampled in the same manner as the 10 predefined process streams. A generalized cotton gin process stream flow diagram is shown in Fig. 1. Results from this study included replicated data for the predefined process streams from the majority of the gins and more limited data on the additional process streams.

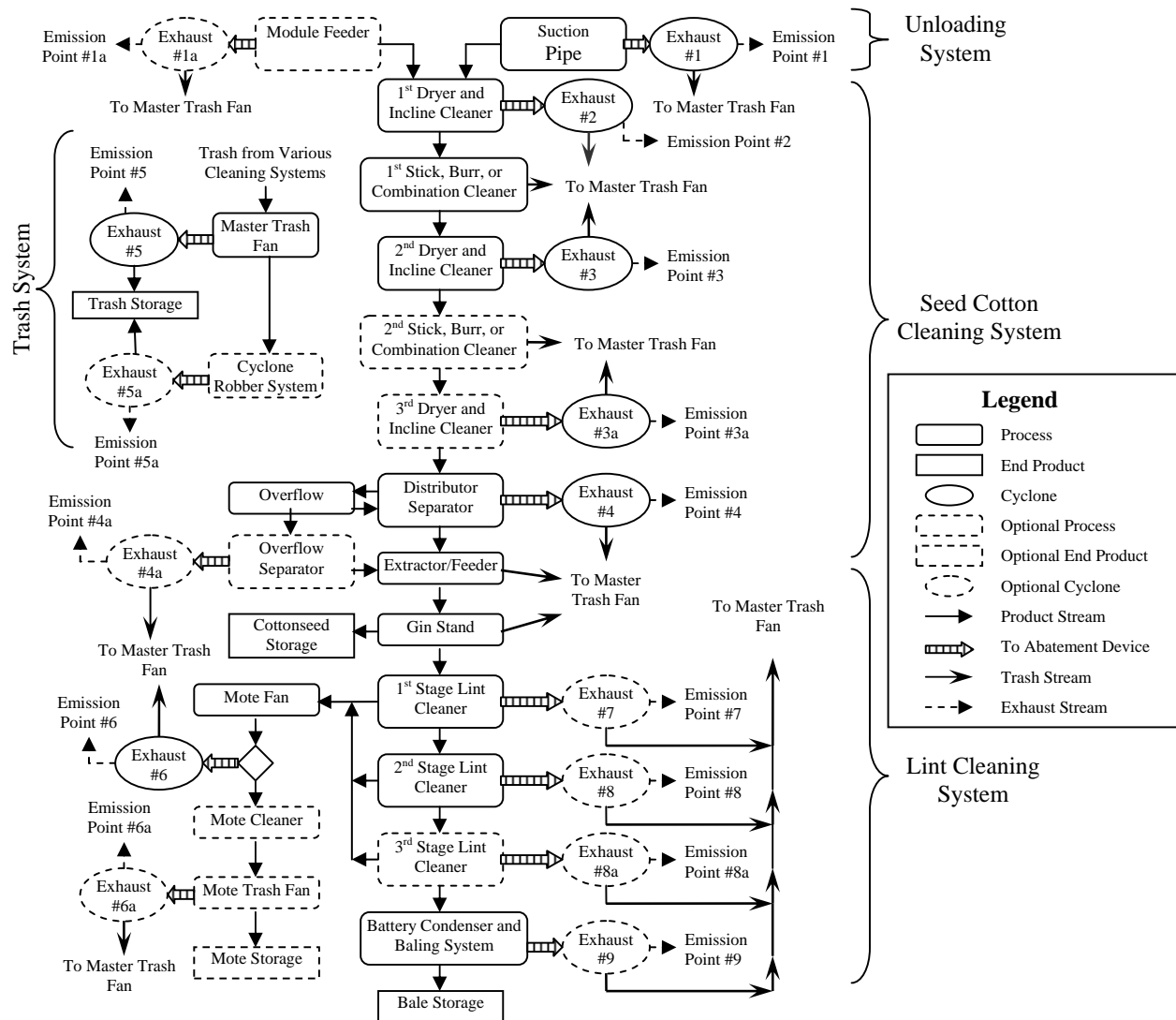


Figure 1. Generalized cotton gin process stream flow diagram (Buser, 2004).

**Stack Sampling.** Stack sampling adhered to EPA protocols and was performed by a certified stack sampling company under the supervision of the researchers. To maintain better quality control, the same certified stack sampling company was used at all sites. Stack sampling methods used with consensus of the Air Quality Advisory Group were:

1. Other Test Method 27 (OTM 27) — Determining PM<sub>10</sub> and PM<sub>2.5</sub> Emissions from Stationary Sources — the EPA method for measuring PM<sub>2.5</sub> filterable stack emissions (EPA, 2008), converted to Method 201A by the EPA Administrator on 1 Dec. 2010;
2. Method 201A — Determination of PM<sub>10</sub> Emissions (Constant Sampling Rate Procedure) — a standard EPA method for measuring PM<sub>10</sub> filterable stack emissions (CFR, 1990); and

3. Method 17 — Determination of Particulate Matter Emissions from Stationary Sources — a standard EPA method for measuring total filterable stack emissions (CFR, 1978).

The three methods are similar, but employ slightly different equipment to target different sizes of particulate. OTM 27 is a method to measure PM<sub>10</sub> and PM<sub>2.5</sub> filterable stack emissions. Particulate is withdrawn isokinetically from the stack through a PM<sub>10</sub> sizing cyclone and then a PM<sub>2.5</sub> sizing cyclone and collected on a filter (Fig. 2). Gravimetric analyses were used to determine the mass for each size fraction. To measure both PM<sub>10</sub> and PM<sub>2.5</sub> the method required selecting a gas sampling rate in the middle of the overlap zone of the performance curves for both cyclones. For this study, the method was used specifically to collect PM<sub>2.5</sub> emissions and the

gas sampling rate was targeted to optimize the PM<sub>2.5</sub> cyclone. Method 201A is a federal reference method to measure PM<sub>10</sub> filterable stack emissions. The method is similar to OTM 27, but does not employ a PM<sub>2.5</sub> sizing cyclone in the sampling train (Fig. 3). Method 17 is similar to the other two methods, but uses neither PM<sub>10</sub> nor PM<sub>2.5</sub> sizing cyclones in the sampler train. Instead, Method 17 uses a simple, total suspended particulate nozzle before the filter (Fig. 4). Figure 5 is a photo of the three different stack sampling heads.

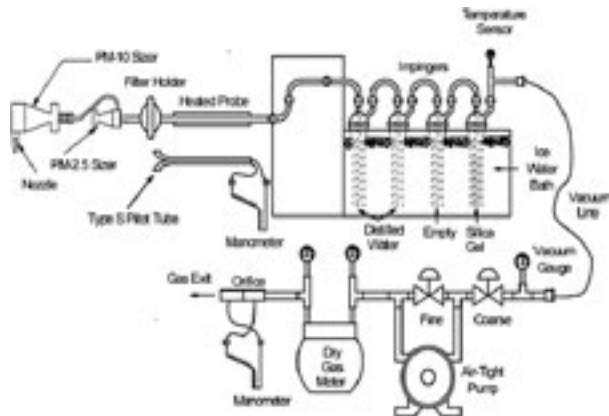


Figure 2. Environmental Protection Agency Other Test Method 27 (method for measuring PM<sub>2.5</sub> filterable stack emissions) sampling train diagram (EPA, 2008).

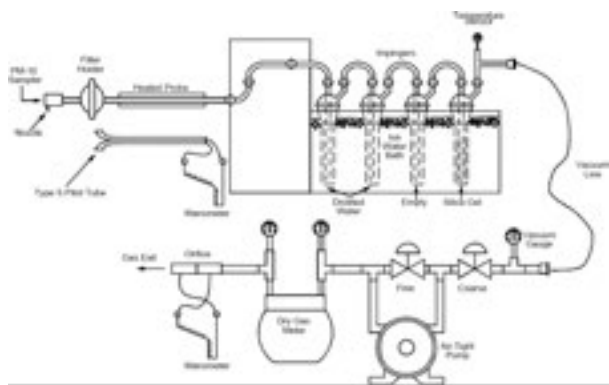


Figure 3. Environmental Protection Agency Method 201A - Determination of PM<sub>10</sub> Emissions (Constant Sampling Rate Procedure) sampling train diagram (CFR, 1990).

Cotton gin cyclones are typically source sampled via a sampling port in either a cyclone-stack extension or “candy cane”. A cyclone-stack extension (Fig. 6) is a section of duct added to the top of the cyclone exit that extends a prescribed distance upwards from the exit and contains straightening vanes (Fig. 7) to eliminate the cyclonic flow of the air exiting the cyclone (EPA, 1989). A candy cane (Fig. 8) is a section of duct that is connected to the cyclone exit which, via a 90° elbow, brings the exhaust down to near ground level for easier sampling.

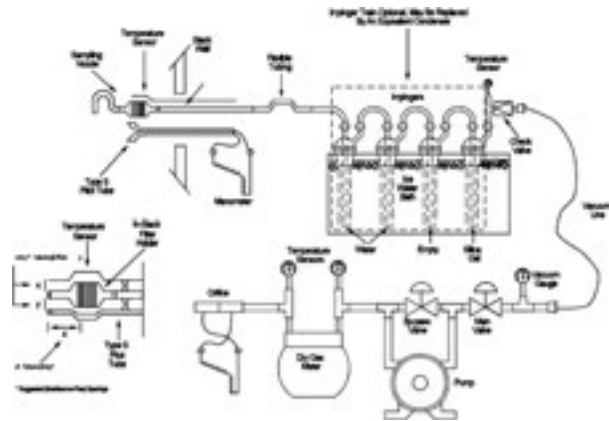


Figure 4. Environmental Protection Agency Method 17 - Determination of Particulate Matter Emissions from Stationary Sources sampler train diagram (CFR, 1978).



Figure 5. OTM 27 (top), Method 201A (middle), and Method 17 (bottom) sampler heads.



Figure 6. Stack extension installed on cyclone exhausts.



Figure 7. Stack extension with straightening vanes.



Figure 8. “Candy cane” stack extension for cyclone particulate sampling.

Based on discussions with the Air Quality Advisory Group, a cyclone-stack extension with straightening vanes was attached to each cyclone exit tube prior to the start of a sampling campaign at a particular gin. The justification for using cyclone-stack extensions instead of candy canes was as follows:

1. Less impact on ambient sampling. Three-meter tall extensions in place for the duration of the source and ambient sampling would have less impact on the ambient sampling results than candy canes that would bring the emissions for a source essentially to ground level and would change as they were moved from one source to the next.
2. Time savings. Cyclone-stack extensions could be installed on all cyclones to be tested before actual source testing began. Thus, delays to move extensions or candy canes while the certified source tester was on-site would be eliminated.
3. Cost savings. Although 10 or more extensions would be needed to source test all the stacks at a particular gin, a crane and operator would need to be on-site to install and take down the extensions for only a day or two before and after the source testing period, whereas the crane and operator would need to be on-site most days of sampling to move the candy canes from one stack to the next.

For this project the extensions were designed to meet EPA criteria (EPA, 1989) with overall length of 3 m (10 ft) and sampling port 1.2 m (48 in) above straightening vanes and 0.9 m (36 in) upstream from the extension exit (at least two times the average equivalent diameter of the vane openings downstream of the straightening vanes and at least one-half of the overall stack diameter upstream of the stack outlet) (Fig. 9).

Three replications of each sampling protocol were performed for each process stream. Forty-seven-millimeter (mm) Zefluor filters (Pall Corporation, Port Washington, NY) were used as the primary filters for all sampling methods. All filters were pre-labeled, pre-weighed, and stored in sealed containers at the USDA-ARS Air Quality Laboratory (AQL) in Lubbock, TX for shipping to the sampling site. After each test the filters and washes were retrieved in accordance to EPA respective protocol. The exposed filters were stored in individual sealed Petri dishes and packed for transportation to the AQL. Sampler heads were acetone washed according to EPA protocol into pre-weighed tubs and acetone was evaporated on-site at 49° C in a conduction oven housed in the AQL air

quality mobile unit. Dried acetone wash containers were then sealed with a pre-weighed lid and placed in individual sealed plastic bags for transportation back to the AQL. All filters and washes were analyzed by the AQL. Individual source test reports for each site were prepared by the investigators and the certified stack testing company personnel.

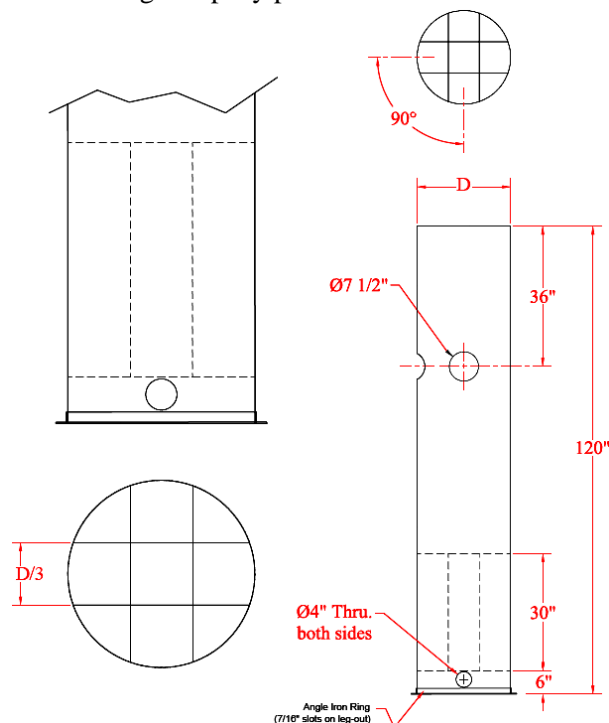


Figure 9. Stack extension with straightening vanes design.

**Ambient Sampling.** For the most robust modeling data set, the Air Quality Advisory Group determined that ambient sampling should run concurrently with the stack sampling. The target duration of ambient sampling was 15 d; therefore, ambient sampling was launched before and continued throughout the duration of the stack sampling portion of the study. A set of ambient samples were collected from the ambient sampler network once in every 24-h period. The actual sampling time was less than 24 h and depended on the time required to change out filters and prepare for the next run. Ambient air sampling was conducted by the researchers and followed AQL protocol. The equipment used in the ambient sampling network included:

1. Twelve 10-m tower samplers (Fig. 10) with (a) low-volume (16.7 liters per minute (lpm) target flow rate) Texas A&M/USDA-ARS-designed total suspended particulate (LVTSP) (Wanjura et al., 2005) sampler heads located at 1.0, 2.0, 3.0, 4.5, 7.25, and 10 m; (b) MetOne (Grants Pass, OR) 034B anemometers (wind speed and direction) located at 1.0, 2.0, 3.0,

4.5, 7.25, and 10 m; (c) ambient temperature, relative humidity, and barometric pressure collected at approximately 1 m; (d) USDA-ARS-designed flow control and data collection system electronics; (e) wind speed, ambient temperature, relative humidity, barometric pressure, and sampler flow rate; (f) data was stored on-board every 17 sec on secure digital (SD) data cards and relayed to the base station at 5-min intervals with a radio frequency modem.

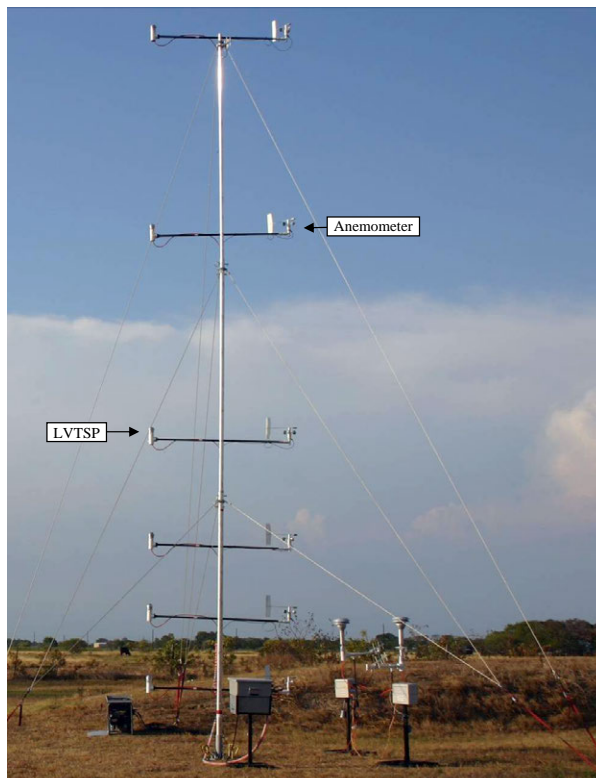


Figure 10. Ten meter tower samplers with low-volume (16.7 lpm target flow rate) equipped with a TAMU-USDA total suspended particulate (LVTSP) sampler heads and wind anemometers at 1.0, 2.0, 3.0, 4.5, 7.25, and 10 m.

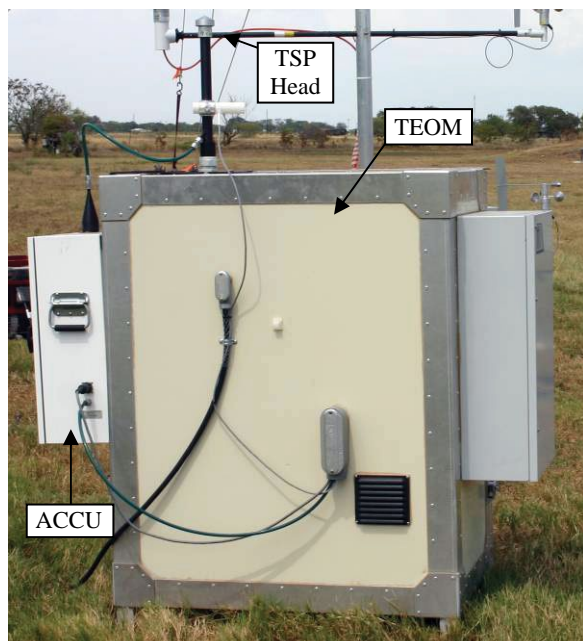
2. Forty-eight stand-alone PM samplers (Fig. 11) with (a) low-volume (16.7-lpm target flow rate) sampler heads located 2 m above the ground and equipped with TAMU-USDA LVTSP sampler head, PM<sub>10</sub> sampler head (Thermo Scientific, East Greenbush, NY), Well Impactor Ninety-Six (WINS) PM<sub>2.5</sub> sampler head (BGI Incorporated, Waltham, MA), or very sharp cut cyclone (VSCC) PM<sub>2.5</sub> sampler head (Thermo Scientific, East Greenbush, NY); (b) ambient temperature, relative humidity, and barometric pressure collected at approximately 1 m; (c) USDA-ARS-designed flow control and data collection

system electronics; (d) ambient temperature, relative humidity, barometric pressure, and sampler flow rate data collected; (e) data stored on-board every 17 sec on SD data cards and relayed to the base station at 5-min intervals with a radio frequency modem.



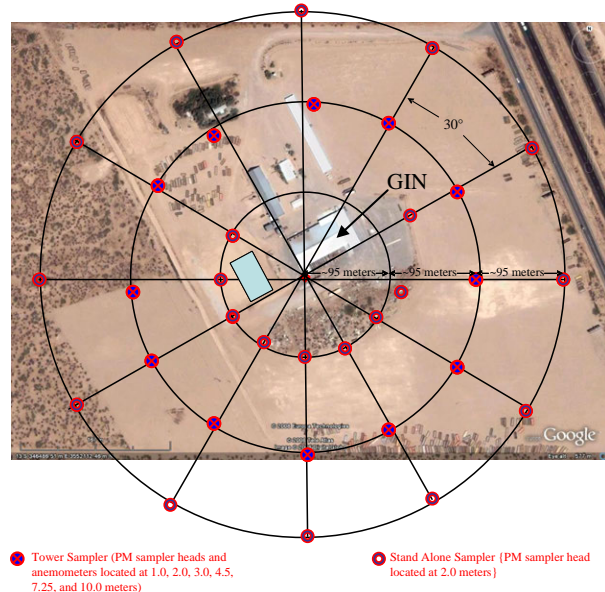
**Figure 11.** Low-volume (16.7 lpm target flow rate) stand-alone samplers equipped with a TAMU-USDA total suspended particulate (LVTSP) sampler head, a PM<sub>10</sub> sampler head, a Well Impactor Ninety-Six (WINS) PM<sub>2.5</sub> sampler head, and a very sharp cut cyclone (VSCC) PM<sub>2.5</sub> sampler head.

3. Four Thermo Scientific (East Greenbush, NY) tapered element oscillating microbalance (TEOM) PM samplers (Fig. 12) equipped with Thermo Scientific TSP heads and Thermo Scientific automatic cartridge collection units (ACCU).



**Figure 12.** Tapered element oscillating microbalance (TEOM) samplers with TSP head and automatic cartridge collection unit (ACCU).

Through discussions with the Air Quality Advisory Group, a robust uniform sampling array was developed based on the available sampling equipment to maximize data quality, while minimizing the effects of changing wind direction. The sampling array consisted of samplers located at 30° intervals encompassing the gin at three radial distances from a predetermined center point located near the gin’s main cyclone bank. The radial distances were determined by the available land area associated with each site. As each gin site was different, this sampling array allowed for flexibility in sampler location to account for site restrictions. Also, the magnitude and density of the sampling array limited the impact of necessary deletion of some sampling points altogether due to on-site restrictions, such as buildings or roads. An example of an array, with deviations, is shown in Fig. 13. The inner and outer rings were comprised of stand-alone samplers and the middle ring was comprised of tower samplers. In this example, three samplers were not deployed in the inner circle because of site restrictions (e.g., buildings) and several of the samplers on the inner and middle circles were moved to accommodate site restrictions (e.g., roadways).



**Figure 13.** Layout of ambient sampler sites.

The number and location of ambient samplers located at each site varied. As previously mentioned, stand-alone samplers with LVTSP sampler heads (Fig. 11) were deployed at each site on the inner and outer rings shown in Fig. 13. For the middle ring of 10-m tower samplers, one of six different configurations (Table 1) of samplers was located at each site. Wind

roses were generated from met data for a location near each site and tower site configurations were located based on the predominant wind direction. Configurations I and II with a tower sampler, two collocated PM<sub>10</sub> stand-alone samplers, a TEOM sampler, and two collocated PM<sub>10</sub>\VSCC-PM<sub>2.5</sub> or PM<sub>10</sub>\WINS-PM<sub>2.5</sub> samplers (Fig. 14) were sited at locations downwind from the gin cyclone bank. Configurations III and IV with a tower sampler, a PM<sub>10</sub> stand-alone sampler, a TEOM sampler, and a PM<sub>10</sub>\VSCC-PM<sub>2.5</sub> or PM<sub>10</sub>\WINS-PM<sub>2.5</sub> sampler were sited at locations upwind and opposite locations for configurations I and II, respectively. Configurations V and VI with a tower sampler, a PM<sub>10</sub> stand-alone sampler, and a PM<sub>10</sub>\VSCC-PM<sub>2.5</sub> or PM<sub>10</sub>\WINS-PM<sub>2.5</sub> sampler (Fig. 15) were then alternated around the middle ring among the remaining sites. Configurations I and II had collocated VSCC and WINS sampler heads, respectively, to provide a measure of the variability for the measurements, as recommended by the EPA participants of the Air Quality Advisory Group. Depending on the final layout, approximately 125 total ambient sampling points were deployed at each gin.

Generally, generators would be required at each sampling site to provide electrical power for the samplers. However, due to number of sampling sites, the need to conduct stack sampling and ambient sampling simultaneously, and the importance of reducing the possible impact of combustion engine emissions on the samples collected, the number of generators was minimized. Each stand-alone ambient sampler draws roughly 0.9 amps, requiring only light



Figure 14. Ambient air sampler site similar to Configuration I and II.



Figure 15. Ambient air sampler site similar to Configuration V and VI.

Table 1. Listing of ambient samplers for tower site configurations located at the middle sampler ring.

Configuration No.	Number of Sites	Samplers in Configuration				
		10 m Tower Sampler with LVTSP Heads <sup>z</sup>	PM <sub>10</sub> Head <sup>y</sup>	PM <sub>10</sub> \VSCC PM <sub>2.5</sub> combination head <sup>x</sup>	PM <sub>10</sub> \WINS PM <sub>2.5</sub> combination heads <sup>w</sup>	TEOM Sampler <sup>v</sup>
I	1	1	2	2	---	1
II	1	1	2	---	2	1
III	1	1	1	1	---	1
IV	1	1	1	---	1	1
V	4	1	1	1	---	---
VI	4	1	1	---	1	---

<sup>z</sup> LVTSP Head: Texas A&M/USDA-ARS-designed total suspended particulate sampler head.

<sup>y</sup> PM<sub>10</sub> Head: Thermo Scientific ambient PM<sub>10</sub> sampler head.

<sup>x</sup> VSCC PM<sub>2.5</sub>: Thermo Scientific very sharp cut cyclone PM<sub>2.5</sub> sampler head.

<sup>w</sup> WINS PM<sub>2.5</sub>: BGI Incorporated Well Impactor Ninety-Six PM<sub>2.5</sub> sampler head.

<sup>v</sup> TEOM: Thermo Scientific tapered element oscillating microbalance PM samplers.



gauge electrical wire to run approximately 95 m from a power source to a stand-alone sampler. Based on the pre-test site evaluation visits, on-site electrical service sites were identified and used to the full extent to reduce the number of gasoline powered generators. An example of routing the power is shown in Fig. 16. In Fig. 16, the dotted lines and stars correspond to electrical lines and power sources, respectively. All electrical lines running through the gin yard in which the integrity could be compromised by traffic or other normal activities were buried approximately 15 cm deep. The research team worked closely with the gin management to identify the most efficient means of powering the samplers, while minimizing the impact on normal gin operations.

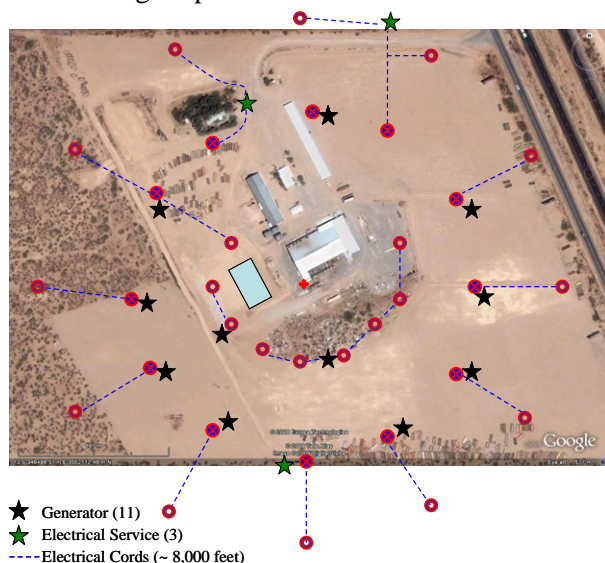


Figure 16. Sampler power distribution example.

Prior to each sampling run, pre-labeled and pre-weighed 47-mm Zefluor filters were removed from sealed Petri dishes and loaded into filter cassettes in an enclosed room in the AQL air quality mobile unit. The filter cassettes, shown in Fig. 17, were stored in air tight canisters for transportation to and from the field and were used to facilitate filter changes reducing time, errors, and possible contamination. Each deployed sampler head had two filter cassettes. In the field, exposed filters were retrieved from sampler heads, quickly placed in empty cassettes for transport back to the AQL mobile unit, and replaced by clean filters in the sampler heads. The exposed filters were extracted from the cassettes in the AQL mobile unit clean room and sealed in Petri dishes for transport to the AQL in Lubbock, TX. In general, the protocol for retrieval of exposed filters and loading of clean filters required that the sampler pumps at each

of the 36 sites all be switched off manually and the time recorded within a short timeframe. Then, the filters from 3.0-, 4.5-, 7.25-, and 10-m tower levels were changed using man-lifts. As the remaining tower sampler filters near ground level (1 and 2 m) and the stand-alone samplers at each tower site were changed, the stand-alone sampler and tower sampler pumps were restarted together and the start time recorded. This procedure was repeated for each tower sampler site.



Figure 17. Filter cassette with clean filter being deployed in an ambient air sampler.

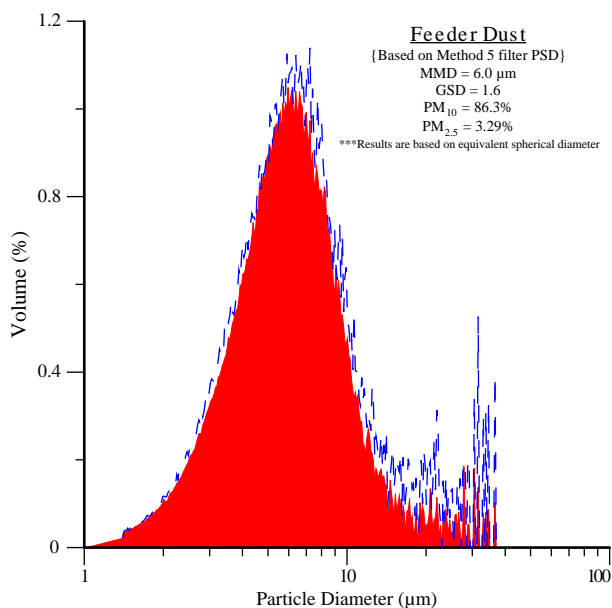
After stack testing and ambient sampling at a particular gin were completed, the SD data storage cards containing flow data were retrieved from each sampler, all exposed filters were sealed Petri dishes, all sampler head washes were sealed in containers, all samples were placed in secure enclosures and transported to the AQL in Lubbock, TX for laboratory analysis.

**Laboratory Analyses.** Pre- and post-processing of all filter and wash samples from the stack and ambient sampling were conducted at the USDA-ARS AQL in Lubbock, TX and followed AQL standard operating procedures (SOP). Depending on the type of sample, this included observational, gravimetric, particle size, and/or particle shape analysis. Each sample was visually inspected for unusual characteristics, such as high cotton lint content or extraneous material. Digital pictures were taken of all samples, filters and washes, for documentation purposes prior to further analysis.

Gravimetric analysis was conducted on all samples. All filters, clean and exposed (pre- and post-sampling), were conditioned in an environmental chamber (21 +/- 2° C; 35 +/- 5% relative humidity)

for 48 h prior to weighing. Filters were weighed in the environmental chamber on a Mettler MX-5 microbalance (Mettler-Toledo Inc., Columbus, OH) after being passed through an anti-static device. To reduce recording errors, weights were digitally transferred from the microbalance to a Microsoft Excel spreadsheet using Mettler's BalanceLink software. Technicians wore latex gloves and a particulate respirator mask covering the mouth and nose when handling samples to avoid contamination. SOP requires that samples be weighed three times each in batches of 20. If the standard deviation of the weights for a given sample exceeded 10  $\mu\text{g}$ , the sample was reweighed as part of the next batch of 20. Once the pre- and post-gravimetric analyses are completed, the data was merged and the total mass collected on each filter calculated. Gravimetric SOP for the acetone washes was similar, except a Mettler AG285 balance (Mettler-Toledo Inc., Columbus, OH) was used.

Particle size analysis was conducted on a Beckman Coulter Counter Multisizer III and/or a Beckman LS 230 laser diffraction system (Beckman Coulter, Inc., Fullerton, CA). Both systems have unique advantages and disadvantages, so both systems were used in the overall analysis to strengthen the overall data set. Sample preparation for all samples was identical and followed AQL SOP (Buser, 2004). An example of information from the particle size analysis is shown in Fig. 18.



**Figure 18.** Example of particle size analysis results (red represents the average distribution and the blue relates to the distribution standard deviation).

Particle size analyses will not be completed on all samples. USDA-ARS SOP requires that lightly loaded samples not be analyzed due to accuracy concerns. When conducting the PSD analyses with the Coulter Counter or laser diffraction system, the number of particles counted would be low and the time required to count those particles greater than 5 min for a lightly loaded filter, degrading the accuracy of the test. A sample's eligibility for particle size analysis will be determined by visual inspection and review of the gravimetric analysis results. It is expected that all filters and the majority of the acetone washes from stack sampling will be analyzed and approximately 50% of the filters from the ambient sampling will be analyzed. This percentage will be lower for samples collected on days where high wind and/or rain events occurred. It is important to note that particle size analysis is a destructive process so every effort was made to preserve as much sample as possible for additional analyses, such as particle shape analysis. Also, when possible both the Coulter Counter or laser diffraction system analyses will be conducted on a sample.

**Data Analyses.** The data from each individual gin site were merged and combined with the corresponding field data. Emission concentrations and rates were calculated for the ambient and stack data, respectively. Wind roses, snapshot wind site profiles, temperature and relative humidity profiles, and ambient concentration contour maps were developed. This information would be captured in individual sampling campaign reports and submitted to collaborators for review. After the completion of all sampling campaigns, the entire set of data would be compiled and prepared for publication.

**Reporting.** An important aspect of the project plan was reporting. Quarterly and annual reports were submitted to all contributors and participants in the project. Additionally, presentations were made at the various industry and society meetings throughout the project duration. Besides these progress type reports, the end products of the project included several peer reviewed journal manuscripts. The planned publications included coverage of the following results:

1. PM<sub>2.5</sub> emission factors — the first comprehensive set of cotton gin PM<sub>2.5</sub> emission factors published;
2. PM<sub>10</sub> emission factors — verifying and enhancing cotton gin PM<sub>10</sub> emission factors previously published;

3. Particulate characteristics — the first comprehensive set of cotton gin particulate characteristics for every unique emissions source from gin plants across the entire cotton belt;
4. Cotton gin modeling dataset — the first comprehensive set of cotton gin emissions dispersion modeling data including simultaneously collected stack emissions, ambient concentrations, onsite meteorological data, and particulate matter characteristics; and
5. FRM and TSP/PSD comparison — further documentation of the differences in concentrations measured using FRM samplers and TSP samplers with PSD analyses of the filters when sampling PM from agricultural operations.

### SUMMARY

The development of PM<sub>2.5</sub> emission factors for gins across the belt will benefit local cotton gins and state air pollution regulatory agencies by providing accurate, science based data needed to amend cotton gin air quality permits for PM<sub>2.5</sub> emissions. Because more and more states are moving towards using dispersion modeling to determine a gin's eligibility for an operating permit, the development of a high quality data set that can be used to evaluate and modify current dispersion models is critical and urgently needed. This data set could be used to develop new, more accurate models for low-level agricultural point sources, which would greatly benefit cotton gins and other agricultural processing facilities. Under current regulatory agency assumptions, cotton gins will be regulated and permitted based on PM<sub>2.5</sub> data that are likely more than 10 to 14 times higher than actual PM<sub>2.5</sub> levels. Conducting this comprehensive study and including state and federal regulatory agencies in all phases of the study will provide science-based information with which policy and regulatory issues can be addressed by state and federal agencies.

The goals of this research project were based on environmental stewardship and economic viability. From an environmental perspective: determination of scientifically sound PM<sub>2.5</sub> cotton gin emissions data. Will cotton gins meet the upcoming PM<sub>2.5</sub> regulations? Will cotton gins have problems obtaining PM<sub>2.5</sub> operating permits? From an economic viability perspective: if state regulatory agencies mandate

additional cotton gin PM<sub>2.5</sub> controls, the decisions need to be based on sound science. If substantial abatement system changes are mandated, fixed and variable costs could substantially increase and would likely be passed on to the producers. With cotton production input costs soaring, all input decisions including ginning issues need to be based on sound science. Sound science is a key to ensuring that the US cotton industry remains strong and competitive on the world market.

### ACKNOWLEDGMENTS

The authors would like to thank the cooperating gin managers and personnel who generously allowed and endured sampling at their gins. We would like to thank the Texas State Support Committee, Cotton Incorporated, Cotton Foundation, Southern Cotton Ginners Association, California Cotton Growers and Ginners Association, Texas Cotton Ginners Association, Southeastern Cotton Ginners Association, California Air Resources Board, and the San Joaquin Valley Unified Air Pollution Control District for their generous support of this project. The authors would also like to thank Texas A&M University, U.S. EPA, Texas Commission on Environmental Quality, North Carolina Department of Natural Resources, Missouri Department of Natural Resources, National Cotton Council, National Cotton Ginners Association, and USDA Natural Resources Conservation Service for serving on the advisory groups for this project.

### DISCLAIMER

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