CHARACTERIZATION OF COTTON GIN PARTICULATE MATTER EMISSIONS – SECOND YEAR

M.D. Buser
Biosystems Engineering, Oklahoma State University
Stillwater, OK
J.C. Boykin
USDA-ARS, Cotton Ginning Research Unit
Stoneville, MS
D.P. Whitelock
USDA-ARS, Southwestern Cotton Ginning Research Laboratory
Mesilla Park, NM
G.A. Holt
USDA-ARS, Cotton Production and Processing Research Unit
Lubbock, TX

Abstract

Due to EPA's implementation of more stringent standards for particulate matter (PM) with an effective diameter less than 2.5 microns ($PM_{2.5}$), the cotton ginners' associations across the cotton belt agreed that there is an urgent need to collect gin emission data. The primary issues surrounding PM regulations for the cotton ginning industry are the limited or lack of available $PM_{2.5}$ data, that current dispersion models can potentially over-predict property-line PM concentrations at cotton gins, and that federal reference method PM samplers may over-predict emissions or concentrations when sampling in agricultural environments. In response to the gin associations' requests, a cotton gin PM emissions sampling project was planned and begun in 2008. During 2010, the second year of the sampling campaign, two gins were extensively sampled in Missouri and West Texas and lab analyses were conducted on more than 4000 samples. This paper highlights the individual sampling campaigns and summarizes the information collected to date.

Introduction

Due to U.S. Environmental Protection Agency (EPA) implementation of more stringent standards for particulate matter with an effective diameter less than 2.5 microns ($PM_{2.5}$) from 65 to 35 ug/m^3 on average over a 24 hr period (CFR, 2006), the cotton ginners' associations across the cotton belt, including the National, Texas, Southern, Southeastern, and California associations, agreed that there is an urgent need to collect gin emission data. There are three main issues impacting regulation of particulate matter from cotton gins. The first is that there is very little scientifically based $PM_{2.5}$ emissions data for gins or any industry available. Second, many states, including Missouri, North Carolina, South Carolina, and New Mexico, rely on EPA recommended dispersion models to estimate property-line PM_{10} (particles less than 10 microns in diameter) concentrations and compare with National Ambient Air Quality Standards when issuing air permits for cotton gins. The EPA recommended dispersion models used by the states were not developed for low-level point sources, such as cotton gins and studies have shown that these models could be over-predicting cotton gin property-line concentrations by as much as a factor of 10 (Zwicke, 1998; Fritz, 2002). Third, some recent research shows that EPA federal reference method (FRM) samplers, used to selectively sample $PM_{2.5}$ and PM_{10}, may not performed as designed under conditions normally encountered at cotton gins, where the average particulate size is often larger than the design cut-point of the sampler and may over-estimate cotton gin $PM_{2.5}$ and PM_{10} emissions and ambient concentrations (Buser et al., 2006a; Buser et al., 2006b; Buser et al., 2006c).

In response to these issues, a four year study to evaluate cotton gin particulate matter (PM) emissions at several gins at locations across the cotton belt was planned and begun in 2008, by researchers at the USDA-ARS Ginning Laboratories at Lubbock, Texas; Mesilla Park, New Mexico; and Stoneville, Mississippi and continued in 2009 and 2010, by the Ginning Laboratories in collaboration with the Biosystems Engineering Department at Oklahoma State University in Stillwater, Oklahoma.

The four objectives of the study were:

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 consisting of combined stack and ambient sampling data.
3) Characterize the PM emitted from cotton gins in terms of particle size distributions, particle density, and particle shape.
4) Collect field data to further quantify federal reference method ambient and stack PM_{10} and $PM_{2.5}$ over-sampling rates.

This paper summarizes the project work during the second year of the study.

Project Methodology & Accomplishments

The bulk of the project planning was conducted in 2008, and was detailed by Buser et al. (2009). Two different advisory groups, Cotton Gin and Air Quality, were formed with membership consisting of people from the national and state gin associations, university researchers, industry representatives, and state and federal regulatory agencies personnel. These advisory groups were important to the planning process and essential to the success of the project, providing valuable insight in their areas of expertise and insuring industry and regulatory agency acceptance of the results.

Stack Sampling

To develop estimates of PM emissions (i.e. pounds of $PM_{2.5}$ or PM_{10} emitted per bale of cotton produced) from cotton gin process stream exhausts, seven gins from across the Cotton Belt were to be sampled (figure 1). Whitelock et al. (2010) summarized the project work during the first full year of sampling, 2009. In 2010, the second full year of the study, gins in Missouri and West Texas were sampled. Each unique process stream exhaust equipped with cyclones was fitted, prior to all testing, with an exit stack extension with straightening vanes to provide a sampling port and minimize cyclonic flow of the exiting air (figures 2 and 3) and then sampled using EPA test methods for $PM_{2.5}$ – OTM 27 (EPA, 2008), PM_{10} – Method 201A (CFR, 1990), and total suspended particulate (TSP) – Method 17 (CFR, 1978).

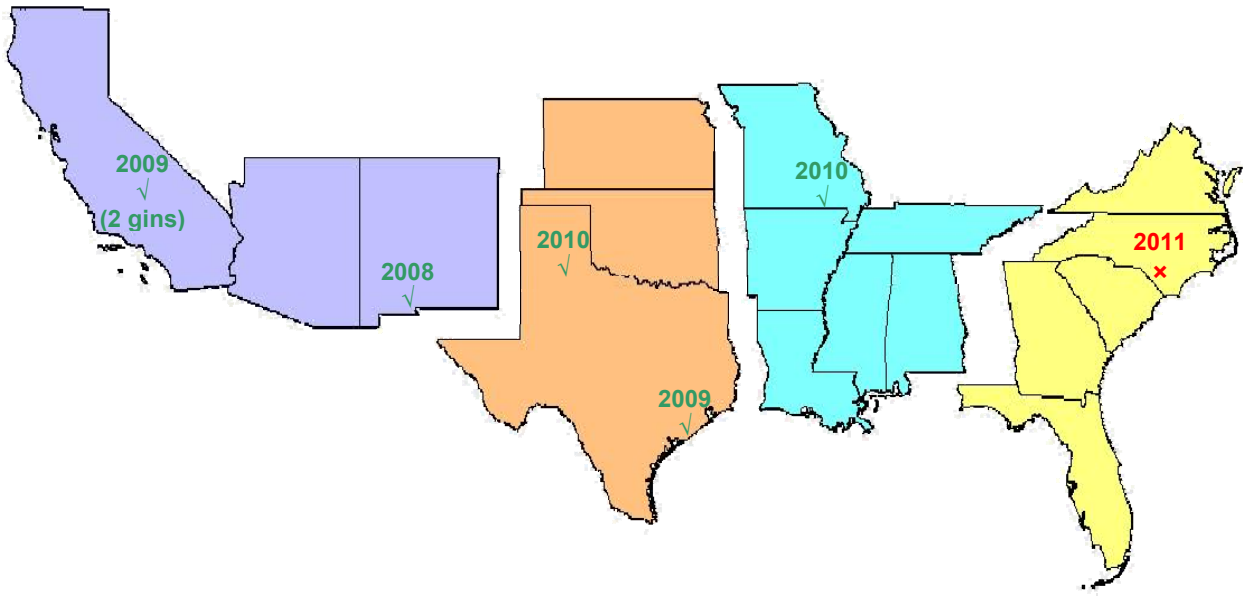

Figure 1. Completed (√) and target (×) gins.

Figure 2. Stack sampling at the Missouri cotton gin.

Figure 3. Stack sampling at the West Texas cotton gin.

Ambient Sampling

To develop a robust data set for cotton gin emissions for use in design, development, and evaluation of current and future air quality low-level dispersion models, ambient sampling was conducted concurrently with the stack sampling. A uniform sampling array of about 125 ambient samplers, located at 30^{o} intervals around the gin, at three radial distances from approximately the center point of the gin's main cyclone bank, was sited using sampling equipment to maximize data quality and minimizing the effects of changing wind direction (figures 4 and 5). This sampling array allowed for flexibility and limited the impact of deleting some of sampling points altogether to account for site restrictions. The number and order of ambient samplers located at each site varied. Single stand-alone TSP samplers were deployed at each site on the inner and outer rings (figure 6). Ten-meter tall towers with TSP sampler inlets at 1, 2, 3, 4.5, 7.25, and 10 meters were deployed at each of the middle ring sites (figure 7). In addition to the towers at the middle ring sites, six additional sampler configurations with different combinations of FRM samplers, including tapered element oscillating microbalance sampler with TSP inlet (Thermo-Scientific, East Greenbush, NY), stand-alone samplers with ambient PM_{10} sampler heads (Thermo-Scientific, East Greenbush, NY), stand-alone samplers with $PM_{2.5}$ very sharp cut cyclone heads (Thermo-Scientific, East Greenbush, NY), and stand-alone samplers with $PM_{2.5}$ WINS heads (BGI Incorporated, Waltham, MA) were used (figure 6). At the Missouri gin, ambient samplers were run each day for approximately 10 hours since the gin only operated one shift per day. The West Texas gin samplers were run for approximately 24 hours each day.

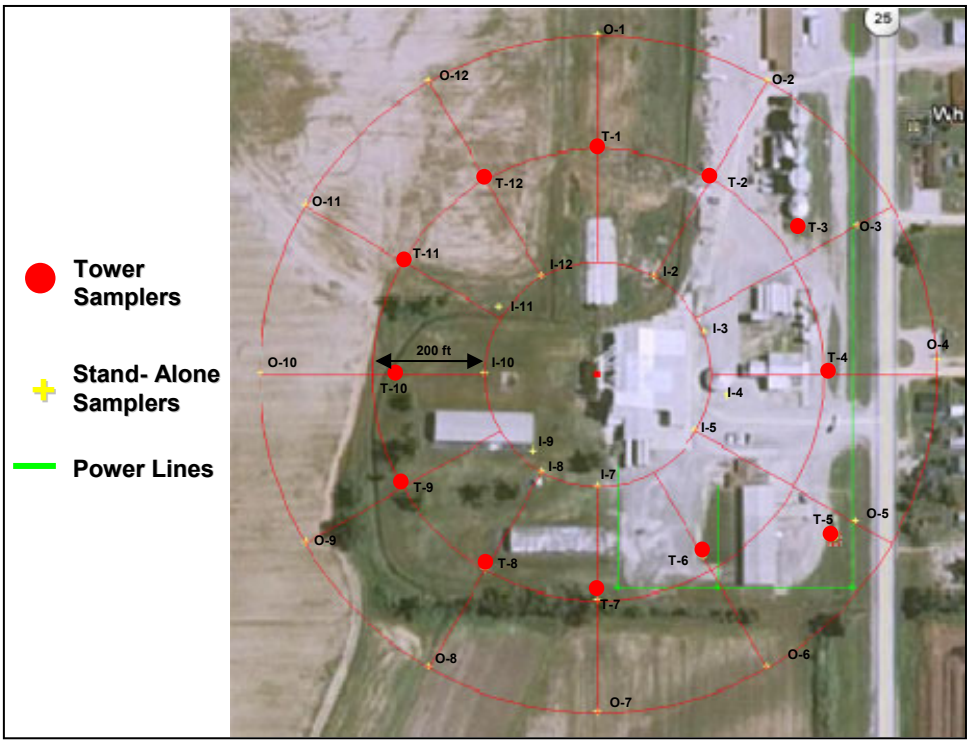

Figure 4. Layout of ambient sampler sites at the Missouri cotton gin.

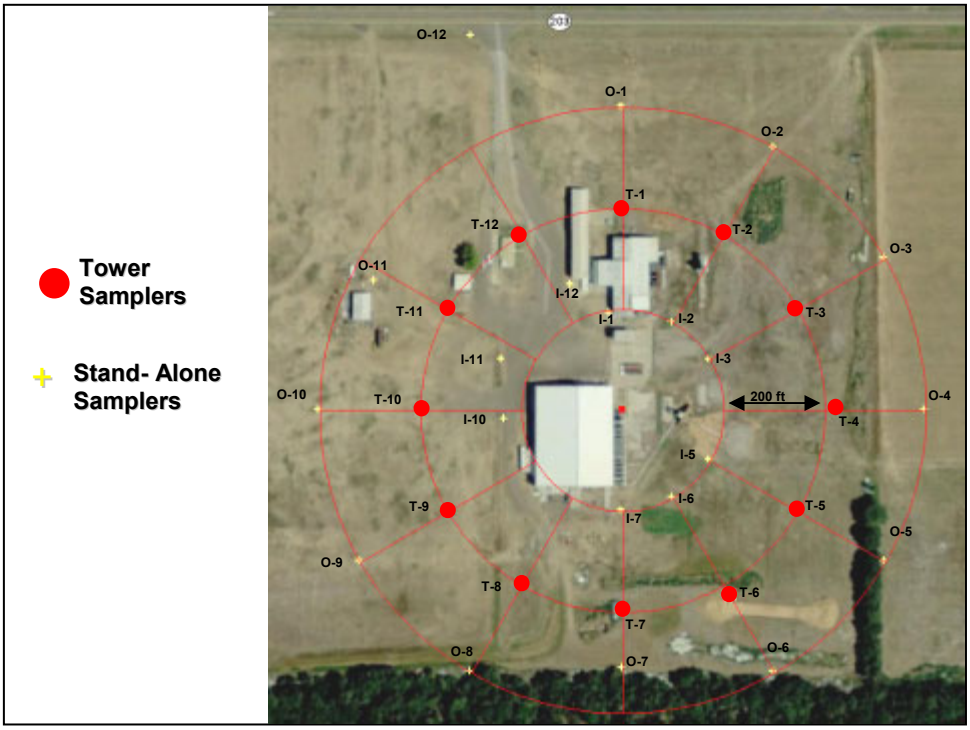

Figure 5. Layout of ambient sampler sites at the West Texas cotton gin.

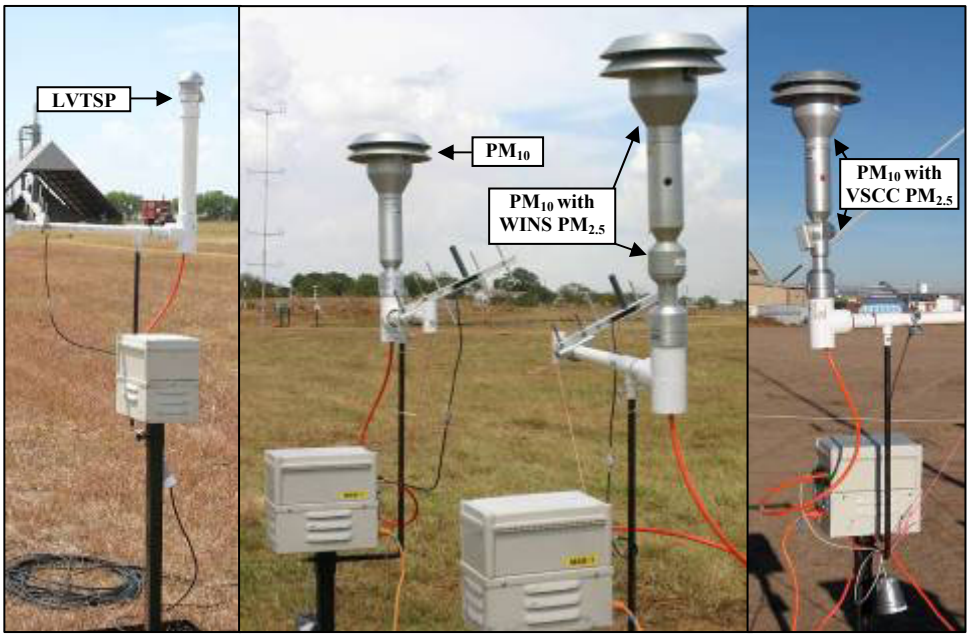

Figure 6. Single stand-alone total suspended particulate sampler (LVTSP), PM_{10} sampler, $PM_{2.5}$ very sharp cut cyclone sampler (VSCC), and $PM_{2.5}$ WINS sampler.

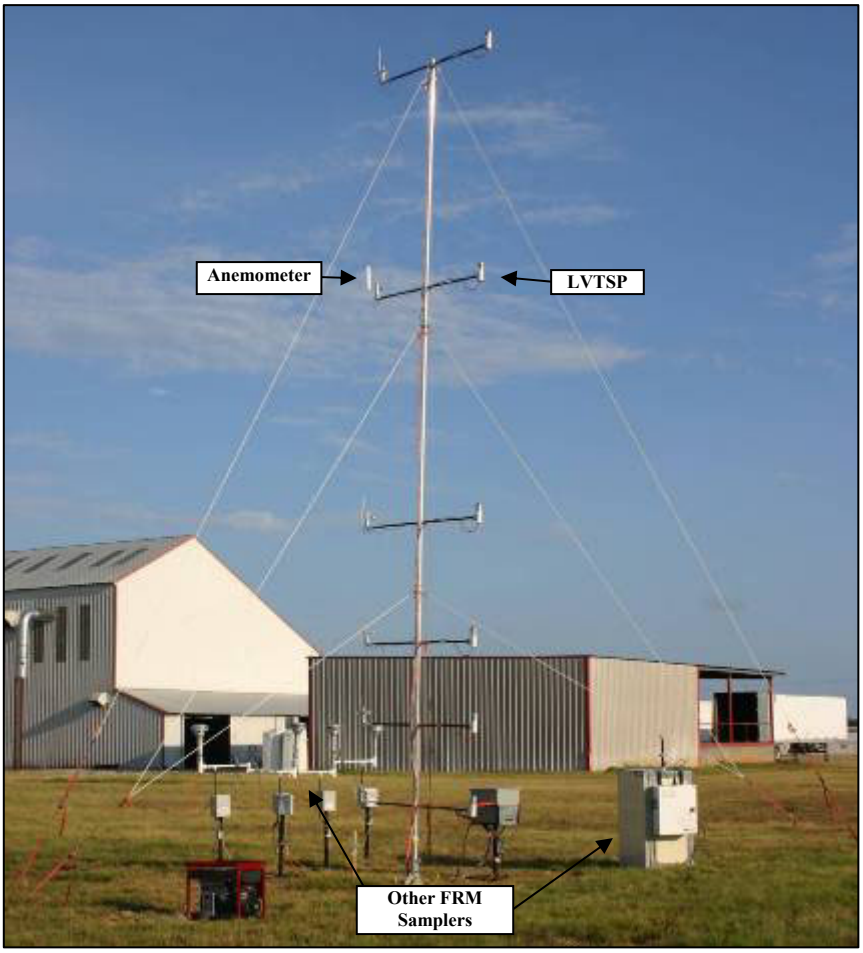

Figure 7. Configurations of ambient tower samplers with total suspended particulate sampler heads (LVTSP), wind anemometers, and additional stand-alone federal reference method samplers.

The Missouri gin was sampled in September of 2010. Nine unique systems with cyclones, including No. 1 Pull, No. 2 Pull, Lint Cleaner Condenser, Mote Cleaner, Overflow, Mote Cleaner Trash, Hulls, Battery Condenser, and Main Trash, were stack sampled with all three EPA methods (three replications per method). Ambient sampling was conducted over ten days. A total of 1520 samples were collected (81 stack sampling filters, 189 stack sampling washes, and 1250 ambient sampling filters). ARS and OSU researchers were on site for approximately 3 ½ weeks.

The West Texas gin was sampled in October of 2010. At this gin, ten unique systems, including No. 1 Pull, No. 2 Pull, No. 1 Lint Cleaner Condenser, No. 2 Lint Cleaner Condenser, No. 1 Motes, No. 2 Motes, Mote Trunk Line, Mote Cleaner, Battery Condenser, and Main Trash, were stack sampled. Ambient sampling was conducted over ten days. Samples collected included 90 stack sampling filters, 210 stack sampling washes, and 1250 ambient sampling filters. Researchers were on site for about 2 ½ weeks.

Sample Analyses

All filters and wash samples from the stack and ambient sampling were analyzed at the USDA-ARS Air Quality Laboratory (AQL) in Lubbock, Texas. These analyses included observational and photographic, gravimetric, and particle size distribution (PSD). PSD analyses were conduction on a Beckman Coulter Counter Multisizer III and/or a Beckman LS230 laser diffraction system (Beckman Coulter, Inc., Fullerton, CA).

Throughout 2010, the AQL continued to process the samples collected during the 2009 campaigns and began processing the samples collected during the 2010 campaigns. To date, all analyses of the samples from the 2008 and 2009 sampling campaigns have been completed and the gravimetric analyses of the 2010 samples have been completed (table 1).

Table 1. Summary of all samples collected and laboratory analyses to date.

			California			
	New Mexico	South Texas	Saw	Roller	Missouri	West Texas
	2008	2009	2009	2009	2010	2010
Stacks Sampled	12	9	13	13	9	10
Filters Collected	108	84	117	117	81	90
Washes Collected	252	189	273	273	189	210
Ambient Sampling	12 days	9 days	14 days		10 days	10 days
Filters Collected	1375	1125	1750		1250	1250
Total Samples Collected	1735	1398	2530		1520	1550
Lab Analyses Completed						
Gravimetric	100%	100%	100%		100%	100%
Particle Size	100%	100%	100%		---[z]	---[z]

[z] To be processed in 2011

Data Processing

Throughout the year, between gin season sampling campaigns and planning and preparation for upcoming campaigns, data processing progressed. For each stack test run and every day of ambient sampling conducted, there is corresponding data that must be complied, checked for accuracy, and analyzed. Data to process and compile from the stack sampling at the first six gins include: 597 individual test data sheets; gravimetric and PSD results for 597 filters and 1386 washes; and number and weights of bales ginned during each test. Data to be compiled, checked, and analyzed from ambient sampling at the first six gins include: 8733 individual sampler-day data-sets each containing sampler flow rate and ambient temperature and pressure (recorded every 17 seconds); filter gravimetric and PSD results; and meteorological data (recorded every 5 minutes). At the end of the project, the authors estimate that approximately 10,000 data summary sheets will be generated to document the sampling data collected.

At this time, processing of the FRM stack data for the first four gins sampled (New Mexico, South Texas, and California), less the PSD information, is nearly complete. Processing the ambient data has begun, but due to the great volume of information to processes and since the need for the stack sampling results is more immediate, progress has been less evident.

Future Work

Work for 2011, will continue in all three areas of sampling, lab analysis, and data processing. Sampling the seventh and final gin of the project is planned for the 2011-12 ginning season in North Carolina. The gin selection process, in collaboration with the Gin Advisory Group, was begun in 2010. Planning and preparations for that gin will be conducted including: system identification and selection; airflow checking and adjustment; stack extension design and fabrication; sampler and power transmission equipment siting; sampling equipment calibration; etc. Current plans are for completion of the laboratory analyses and compilation of the stack sampling data for the first six gins before the 2011 sampling campaign. Similarly, significant progress on compiling the ambient data for the first six gins is expected before the 2011 campaign.

Disclaimer

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

Acknowledgements

The authors would like to thank the cooperating gin managers and personnel who generously allowed and endured sampling at their gins. The authors would like to thank the Texas State Support Committee, Cotton Incorporated, California Air Resources Board, San Joaquin Valleywide Air Pollution Study Agency, The Cotton Foundation, California Cotton Ginners' and Growers' Association, Texas Cotton Ginners' Association, Southern Cotton Ginners' Association, and Southeastern Cotton Ginners' Association for funding this project. The authors would also like to thank the Cotton Gin Advisory Group and Air Quality Advisory Group for their involvement and participation in planning, execution, and data analysis for this project that is essential to developing quality data that will be used by industry, regulatory agencies, and the scientific community.

References

Buser, M.D. 2004. Errors associated with particulate matter measurements on rural sources: appropriate basis for regulating cotton gins. Ph.D. Dissertation. College Station, TX: Texas A&M University., Department of Agricultural and Biological Engineering.

Buser, M.D., C.B. Parnell, Jr., B.W. Shaw, and R.E. Lacey. 2006a. Particulate matter sampler errors due to the interaction of particle size and sampler performance characteristics: Background and theory. Trans. ASAE 50(1): 221-228.

Buser, M.D., C.B. Parnell, Jr., B.W. Shaw, and R.E. Lacey. 2006b. Particulate matter sampler errors due to the interaction of particle size and sampler performance characteristics: Ambient PM_{10} samplers. Trans. ASAE 50(1): 229-240.

Buser, M.D., C.B. Parnell, Jr., B.W. Shaw, and R.E. Lacey. 2006c. Particulate matter sampler errors due to the interaction of particle size and sampler performance characteristics: Ambient $PM_{2.5}$ samplers. Trans. ASAE 50(1): 241-254.

Buser, M.D., D.P. Whitelock, J.C. Boykin. 2009. Characterization of cotton gin particulate matter emissions - Project plan. In *Proc. Beltwide Cotton Conf.*, CD-ROM, 559-571. Cordova, TN: National Cotton Council of America.

CFR. 1978. Method 17— Determination of particulate matter emissions from stationary sources. 40 CFR 60 Appendix A. Available online at http://www.epa.gov/ttn/emc/promgate/m-17.pdf (verified February 2009).

CFR. 1990. Method 201A—Determination of PM_{10} emissions (Constant sampling rate procedure). 40 CFR 51 Appendix M. Available online at http://www.epa.gov/ttn/emc/promgate/m-201a.pdf (verified February 2009).

CFR. 2006. National ambient air quality standards for particulate matter; final rule. 40 CFR, Part 50. Washington, D.C.: U.S. Government Printing Office.

Fritz, B.K. 2002. Dispersion modeling of particulate emissions from low-level point sources. Ph.D. Dissertation. Agricultural Engineering Department, Texas A&M University, College Station, TX.

U.S. Environmental Protection Agency (EPA). 2008. Other test method 27 – August 11, 2008: Determination of PM_{10} and $PM_{2.5}$ emissions from stationary sources (Constant sampling rate procedure). Available online at http://www.epa.gov/ttn/emc/prelim/otm27.pdf (verified February 2009).

Whitelock, D.P., J.C. Boykin, M.D. Buser, G.A. Holt. 2010. Characterization of cotton gin particulate matter emissions - First Year. In *Proc. Beltwide Cotton Conf.*, CD-ROM, 709-718. Cordova, TN: National Cotton Council of America.

Zwicke, G.W. 1998. The dispersion modeling of particulate for point and multiple point sources in agriculture. M.S. Thesis. Agricultural Engineering Department, Texas A&M University, College Station, TX.