CHARACTERIZATION OF COTTON GIN PARTICULATE MATTER EMISSIONS – FIRST YEAR

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Abstract

Due to EPA's implementation of more stringent standards for particulate matter with an effective diameter less than 2.5 microns, 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. The primary issues surrounding particulate matter regulations for cotton ginning industry are: 1) limited or lack of PM2.5 data; 2) potential over-prediction of current dispersion models; and 3) effects of sampler errors. In response to the Gin Associations' requests, a cotton gin particulate matter emissions sampling project, "Characterization of Cotton Gin Particulate Matter Emissions", was planned by USDA-ARS researchers, the Gin Associations, and State and Federal Regulators. During 2009, the first full year of the sampling campaign, three gins were extensively sampled in Texas and California, over 5800 samples and data from four gins were processed and analyzed

Introduction

In 2006, the United State Environmental Protection Agency (EPA) implemented a more stringent standard for $PM_{2.5}$, particulate matter with an effective diameter less than 2.5 microns (CFR, 2006). All cotton gins will be impacted by this standard. The primary issue affecting the cotton industry across country in regards to the implementation of the $PM_{2.5}$ standard is the fact that very little scientifically sound information is available on cotton gin $PM_{2.5}$ emissions. Some recent research indicates that current EPA $PM_{2.5}$ sampling methods (developed for sources that emit PM with a relatively small particle diameter) could be over-estimating cotton gin (PM with relatively larger particle diameters) $PM_{2.5}$ emission concentrations by 14 times (Buser et al., 2006a; Buser et al., 2006b; Buser et al., 2006c). This may explain why some reports indicate that over 30% of total cotton gin PM emissions are $PM_{2.5}$ and others indicate that this ratio is 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} (particles less than 10 microns in diameter) concentration levels for comparison with the National Ambient Air Quality Standards. Cotton gins in states like 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, studies have shown that these models could be over-predicting cotton gin boundary line concentrations by as much as a factor of 10 (Zwicke, 1998; Fritz, 2002).

In response to these issues, a four year study to evaluate cotton gin PM emissions at several gins at locations across the cotton belt was begun by USDA-ARS Ginning Laboratories at Lubbock, Texas, Mesilla Park, New Mexico, and Stoneville, Mississippi. 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.

Project Methodology

Two different advisory groups were formed for these projects: Cotton Gin and Air Quality Advisory groups. The Cotton Gin Advisory Group was formed to act as liaison between the ginning industry and ARS personnel, identify prospective gins for sampling and to review all sampling protocols and results from an industry perspective. The Cotton Ginning Advisory Group consists of members from the following organizations: National Cotton Council, National Cotton Ginners' Association, Texas Cotton Ginners' Association, California Cotton Growers and Ginners' Association, Southern Cotton Ginners' Association, Southeastern Cotton Ginners' Association, Cotton Incorporated, and Texas A&M University. The Air Quality Advisory group was formed to review the stack and ambient sampling methodologies; sample handling and laboratory protocols and analyses, quality control and assurance, data analysis and reports from a scientific and regulatory perspective. This advisory group consists of members from: U.S. Environmental Protection Agency (EPA), California Air Resources Board, San Joaquin Valley Air Pollution Control District, Texas Commission on Environmental Quality, Missouri Department of Natural Resources, North Carolina Department of Natural Resources, USDA-NRCS, USDA-ARS, and Texas A&M University. The involvement and participation of all advisory group members is essential to developing quality datasets that will be used by industry, regulatory agencies, and the scientific community.

The purpose of these studies is to advance the current knowledge base. Currently, $PM_{2.5}$ emission factor data for the cotton ginning industry is extremely limited and no $PM_{2.5}$ data is listed for Cotton Ginning in EPA AP-42 tables. In some states, this information is required for modeling purposes during the permitting process or is used in the modeling associated with state implementation plans. The details of the experimental plan were developed by the investigators and advisory groups through a cooperative effort. Any changes to the experimental plan were or will be discussed and agreed to by the investigators and advisory groups.

Stack Sampling

Toward the goals of developing estimates of the emissions of particulate matter less than 2.5 microns (i.e. pounds of $PM_{2.5}$ emitted per bale of cotton produced) from cotton gin process stream exhausts and reducing EPA's defined uncertainty associated with cotton gin process stream exhaust PM_{10} and total particulate emission factors, three commercial cotton gins from Texas (1) and California (2) were sampled in 2009. Each unique process stream (e.g., air handling system with an air intake and exhaust) with an exhaust equipped with cyclones was sampled. Each selected cyclone exhaust was retrofitted, prior to all testing, with a cyclone exhaust exit stack extension with straightening vanes to minimize the cyclonic flow of the air exiting the cyclone (Figure 1). The $PM_{2.5}$, PM_{10}, and TSP stack sampling methodologies strictly followed U.S. EPA test methods OTM 27 – Other Test Method for measuring $PM_{2.5}$ filterable stack emissions (EPA, 2008), Method 201a for measuring PM_{10} filterable stack emissions (CFR, 1990), and Method 17 for measuring total filterable stack emissions (CFR, 1978) (Figure 2). Three replicate measures were collected for each sampling treatment. All samples were processed and will be reported in accordance with their corresponding EPA methodology to produce calculated emission factors in terms of pounds of PM per 500 pound bale of lint cotton produced. Ginning industry and air quality advisory groups formed for this project will review and provide feedback on the site specific and final reports.

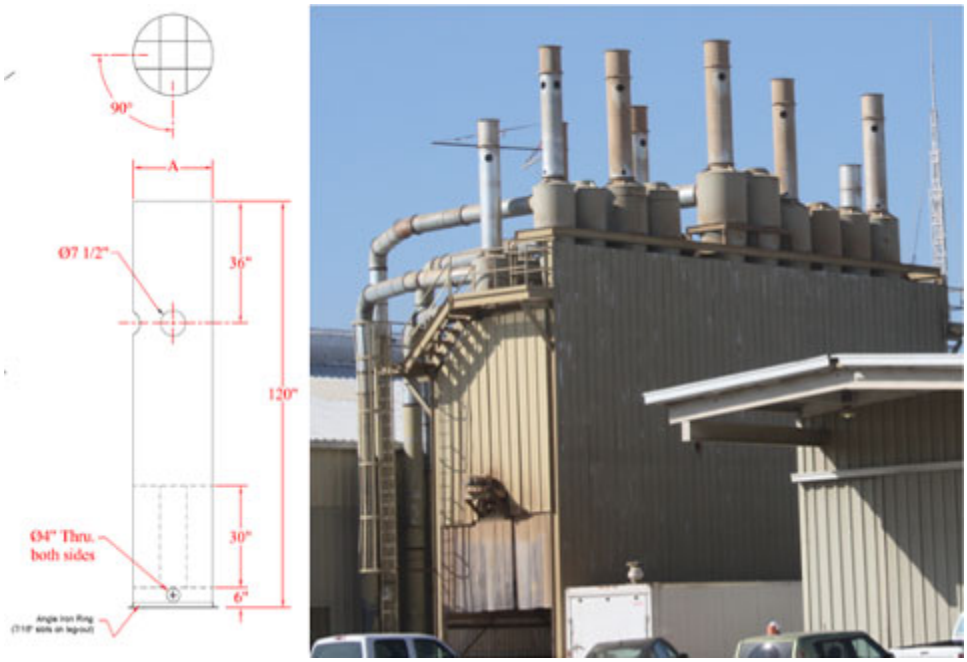


Figure 1. Cyclone exhaust stack extensions with straightening vanes.


Figure 2. OTM 27 (top), Method 201a (middle), and Method 17 (bottom) sampling heads.

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 campaigns at the Texas and California gins were conducted concurrently with the stack sampling described above. Robust uniform sampling arrays (Figure 3) of over 100 ambient samplers were sited using available sampling equipment to maximize data quality, while minimizing the effects of changing wind direction. The sampling array consisted of samplers located at 30^{o} degree intervals encompassing the gin at three radial distances from a pre-determined center point located near the gin's main

cyclone bank. As each gin site is different, the form, magnitude, and density of 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 with air inlets at 2 meters were deployed at each site on the inner and outer rings (Figure 4). Ten-meter 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 5). In addition to the towers at the middle ring sites, six additional sampler configurations that include different combinations of Thermo-Scientific (T-S) tapered element oscillating microbalance sampler with a T-S TSP inlet, stand-alone samplers with T-S ambient PM_{10} sampler heads, stand-alone samplers with T-S $PM_{2.5}$ very sharp cut cyclone heads, and stand-alone samplers with $PM_{2.5}$ BGI Incorporated Well Impactor Ninety-Six heads were used. The two gins in California, one roller gin and one saw gin, were situated side-by-side so that the ambient sampler array remained unchanged for both gins.

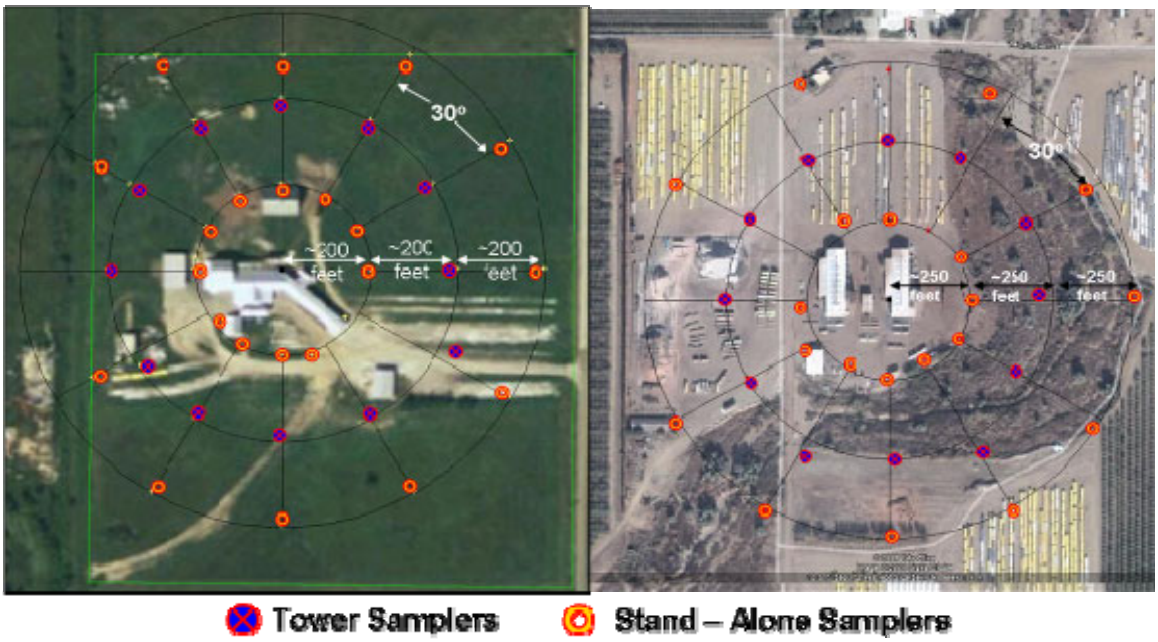


Figure 3. Layout of ambient sampler sites at the Texas Gin (left) and California Gins (right).

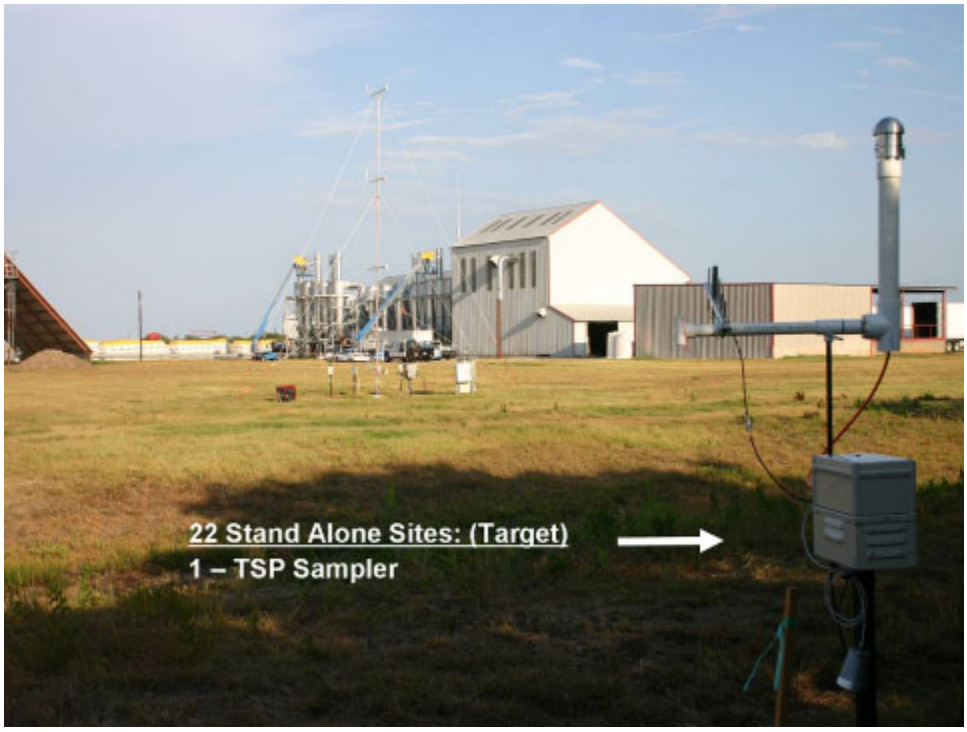


Figure 4. USDA-ARS TSP stand-alone samplers.

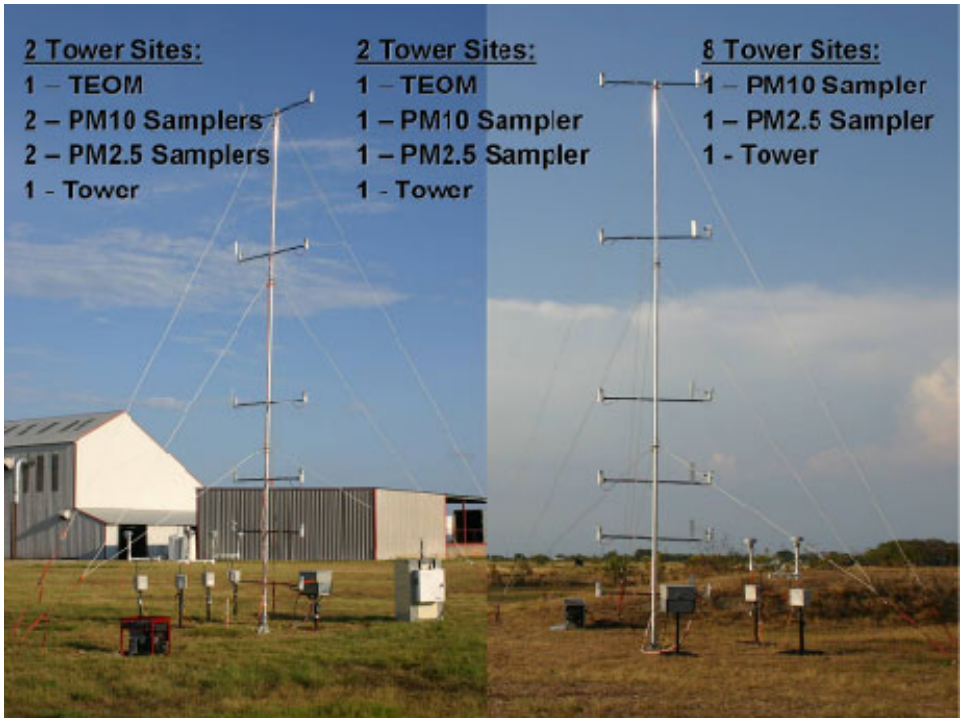


Figure 5. Configurations of ambient tower samplers.

Prior to each sampling run, pre-labeled and pre-weighed 47-mm Zefluor filters were loaded into filter cassettes, transported to the field in airtight canisters, and then loaded in the samplers (Figure 6). At the Texas gin, ambient samplers were run for approximately 12 hours since the gin only operated one shift per day. At least one of the side-by-side California gins always operated 24 hours per day, so the ambient samplers were run for approximately 24 at

that location. After each run, all the exposed filters were retrieved from the field, extracted from the cassettes in the USDA-ARS Air Quality Laboratory (AQL) mobile unit clean room and sealed in Petri dishes for transport to the AQL in Lubbock, Texas.

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

Sample Analyses

Pre- and post-processing of all filters 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 and digital pictures were taken for documentation purposes prior to further analysis. Gravimetric analysis was conducted on all samples. Once the pre- and post-gravimetric analyses were completed, the data were merged and the total mass collected on each filter calculated. Particle size analyses were not completed on all samples. USDA-ARS SOP requires that lightly loaded samples not be analyzed due to accuracy concerns. A sample's eligibility for particle size analysis was determined by visual inspection and review of the gravimetric analysis results. It was expected that all filters and the majority of the acetone washes from stack sampling would be analyzed and approximately 60% of the filters from the ambient sampling would be analyzed. This percentage would be lower for samples collected on days where high wind and/or rain events occurred.

Figure 6. Filter cassette with clean filter being deployed in an ambient air sampler.

Particle size analysis was conduction on a Beckman Coulter Counter Multisizer III and/or a Beckman LS230 laser diffraction system (Beckman Coulter, Inc., Fullerton, CA). It was expected that roughly 75% of the samples would be analyzed on the LS230 and 50% would be analyzed on both the LS230 and the Multisizer III. An example of information from the particle size analysis is shown in Figure 7. 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, at a later date.

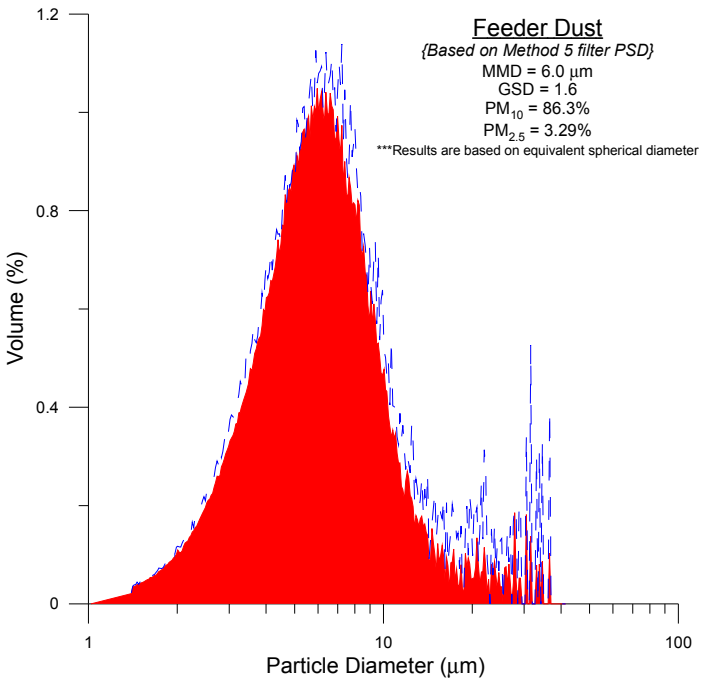


Figure 7. Example of particle size analysis results (red repsents the average distribution and the blue relates to the distribution standard deviation).

Specific 2009 Progress

Work on this project in 2009, fell mainly into three categories: 1) Planning and Preparation, 2) Sampling, and 3) Sample Analyses. The first sampling campaign at the New Mexico gin was completed at the end of 2008. All samples (~1800) for the NM gin were taken to the USDA-ARS AQL in Lubbock, TX and analyses begun in early 2009. Although processing the Mesa samples was a high priority, the primary focus was to prepare for the 2009 sampling campaigns at the Texas gin in August and the two California gins in October.

The planning and preparation process for the 2009 campaigns progressed in several different areas. The PIs made site evaluations at the gins to assess each site's potential and to lay out the pre-developed sampler arrays using GPS units. While on site, measurements and adjustments to the airflow for each gin system to be sampled were made to ensure that they were operating according to regulations. Since the California gins used their gin yard for module storage, an additional site visit to those gins was required prior to the ginning season to bury electrical lines for the samplers. The cyclone extensions with sampling ports were specified and ordered for each gin. Also, the stack sampling and ambient sampling equipment, already used at the New Mexico gin, was cleaned, calibrated, and prepared for the upcoming sampling campaigns.

Actual sampling was long and arduous for the USDA sampling crew. In August 2009, nine unique gin systems were source sampled at the Texas gin (Figure 8). Ambient samples were taken over nine days (~12 hours per day). More than 1200 ambient and stack samples (filters and wash tubs) were collected. Including equipment set-up and take-down, USDA personnel were on site for 3 ½ weeks.

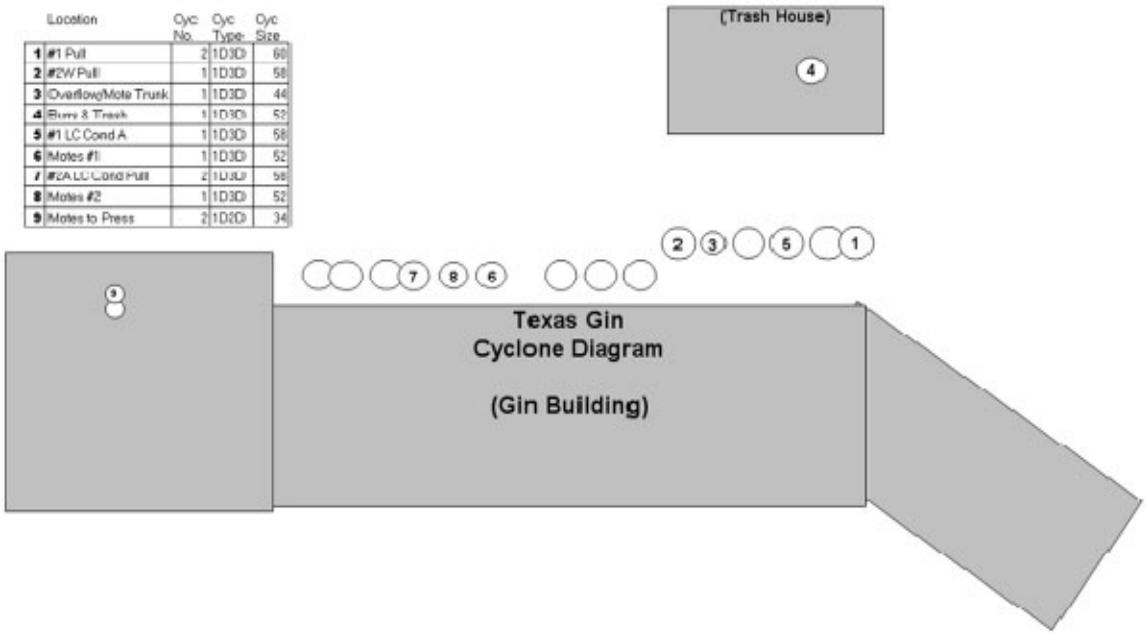
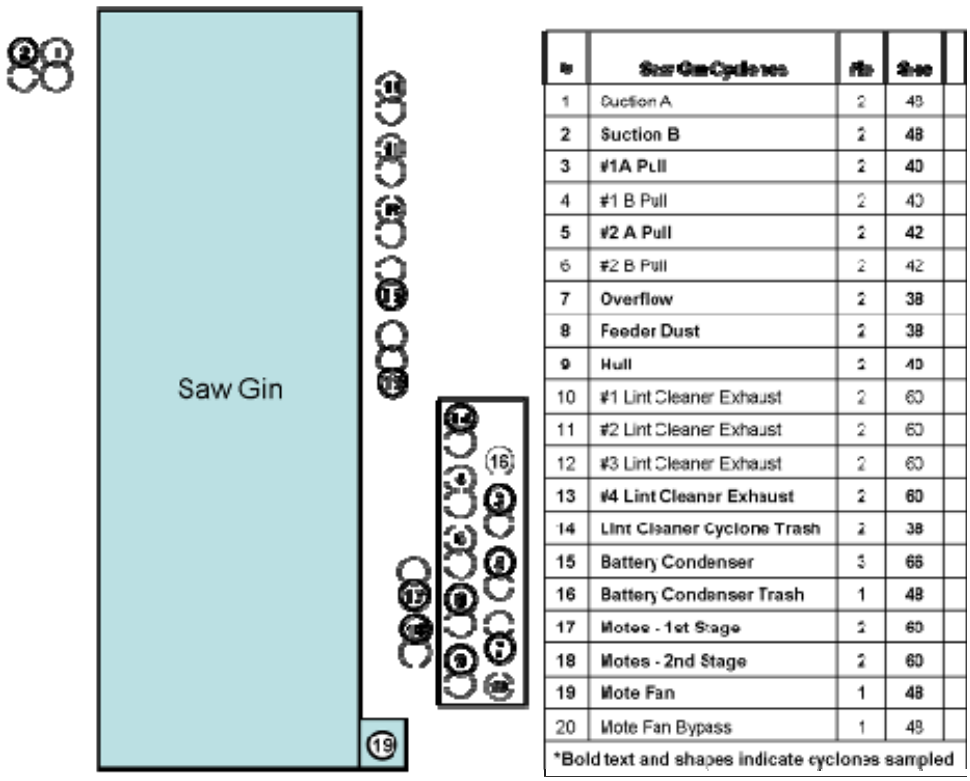


Figure 8. Texas gin systems layout and sampled.

Thirteen unique systems were source sampled at each of the California gins. Ambient sampling occurred over 14 days (~24 hours per day). Between source and ambient sampling, over 2600 samples were collected at the two gins. The USDA crew was on site at the California gins for 4 ½ weeks.



#	Saw Gin Cyclones	#'s	Size
1	Suction A	2	48
2	Suction B	2	48
3	#1A Pull	2	40
4	#1 B Pull	2	40
5	#2 A Pull	2	42
6	#2 B Pull	2	42
7	Overflow	2	38
8	Feeder Dust	2	38
9	Hull	2	40
10	#1 Lint Cleaner Exhaust	2	60
11	#2 Lint Cleaner Exhaust	2	60
12	#3 Lint Cleaner Exhaust	2	60
13	#4 Lint Cleaner Exhaust	2	60
14	Lint Cleaner Cyclone Trash	2	38
15	Battery Condenser	3	66
16	Battery Condenser Trash	1	48
17	Motes - 1st Stage	2	60
18	Motes - 2nd Stage	2	60
19	Mote Fan	1	48
20	Mote Fan Bypass	1	48

*Bold text and shapes indicate cyclones sampled

Figure 9. California saw gin systems layout and sampled.

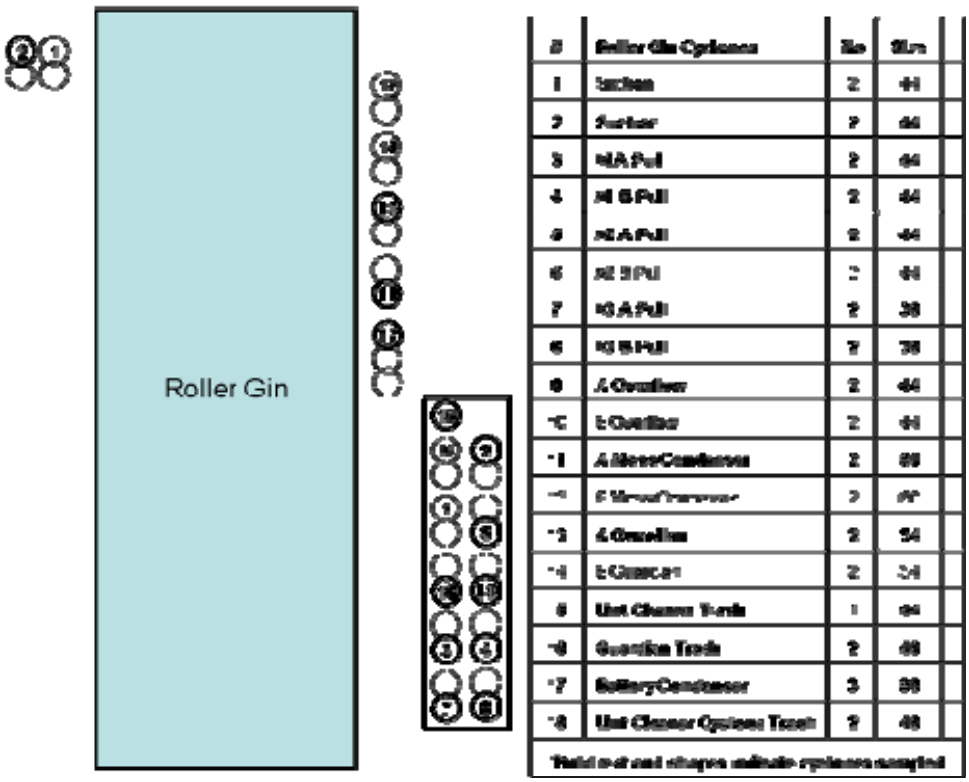


Figure 10. California roller gin systems layout and sampled.

Sample analysis at the Lubbock AQL occurred throughout the year. Between the four gins (NM, TX, & CA) sampled to date, over 5800 samples, including filters and wash tubs, have been brought back to the AQL for analysis. Photographs of every sample to document anomalies were taken in 2009. Gravimetric analyses of all the New Mexico (~1800) and Texas (~1400) samples and 40% of the 2600 California samples were completed. Particle size distribution analyses were completed on about 45% (550 of 1200) of the New Mexico samples and 60% (480 of 800) of the Texas samples.

The project will continue in 2010, with two gins to be sampled (Missouri and West Texas) and continued sample and data analyses.

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.

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