PROPOSED UPDATES FOR AP-42 COTTON GIN EMISSION FACTORS

By

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AP-42 COTTON GIN
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Abstract: A cotton ginning industry-supported project (National Study) was initiated in 2008 and completed in 2013 to collect additional particulate matter (PM) data for EPA's AP-42. PM stack emissions were collected using three EPA-approved methodologies and particle size analysis for 17 cotton gin systems. This study used the National Study and the 1996 AP-42 PM data and EPA's 2013 Emission Factor Development Procedures to develop suggested $PM_{2.5}$, PM_{10}, and total PM cotton gin emission factors, particle size distribution (PSD) characteristics, and evaluate EPA's development methodology. Unrepresentative test runs were removed from the National Study dataset for erratic gin operation, laboratory errors, or if the data was an outlier. Test runs were assign Individual Test Ratings (ITRs), ordered by descending "test" ITR for a given system, which was used to calculate Factor Quality Indices (FQI). If a "test" ITR increased the FQI, that "test" and those below it were excluded from the system emission factor calculation. Three "Test" Designs were evaluated to determine which was best for calculating emission factors and associated ratings. Test data ratings from the 1996 AP-42 were converted to ITRs and rerated with the ITR methodology to determine how that data should be handled. PSD data was evaluated for inclusion with EPA-approved emissions data. The optimal "Test" Design was determined to be one that used the average of all test runs from a single sampling method on a single system at a single facility as a "test." It was determined that the 1996 AP-42 data ratings should be rerated. PSD data should be combined with the section 9.7 emission factors. Final suggested typical gin emission factors were 0.0459 (0.1013), 0.4514 (0.9951), and 0.9404 kg/bale (2.0732 lb/bale) for $PM_{2.5}$, PM_{10}, and total PM, respectively. Final suggested typical gin PM_{10} and total PM emission factors were 22% higher and 14% lower than the 1996 AP-42 emission factors, respectively. Final suggested typical gin $PM_{2.5}$, PM_{10}, and total PM emission factors were 33, 22, and 0.81% lower than the National Study technical reports. Twelve, 53, and 71% of the final suggested $PM_{2.5}$, PM_{10}, and total PM emission factors rated "highly representative," respectively.

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CHAPTER I

INTRODUCTION

In the U.S., the cotton ginning industry annually processes an average of 17 million 227 kg (500 lb.) bales, which translates to about $7.5 billion per year (USDA, 2013). Large modules of seed-cotton are brought into a cotton gin where the seeds are separated from the cotton fiber. Further, soil, leaf material, unopened bolls, and other non-fiber or non-seed material that was collected during harvest is removed. There are several systems involved in this process, and material is generally conveyed between systems pneumatically. The conveying air in these pneumatic systems is usually passed through a particulate abatement device, such as a cyclone, for cleaning prior to being emitted to the atmosphere.

The U.S. Environmental Protection Agency (EPA) delegates enforcement of the Clean Air Act to each state through a process of permits, and approves State Implementation Plans that are written to attain and maintain the National Ambient Air Quality Standards (NAAQS). More stringent NAAQS levels for particulate and continued increases in cotton gin processing rates led the industry to initiate a proactive national study focused on improving the datasets that characterize the particulate matter (PM) emitted from these systems.

Many state regulatory agencies utilize emission factors found in AP-42 Compilation of Air Pollutant Emission Factors (EPA, 1996) to develop facility construction and/or operating permits. For cotton gins, AP-42 emission factors for total PM and PM with a nominal diameter less than or equal to 10 micrometers (μm) (PM_{10}) have extremely poor quality ratings. Currently, there are no emission factors in AP-42 for PM with a nominal diameter of less than or equal to 2.5 µm ($PM_{2.5}$). For this type of data gap, state regulatory agencies commonly estimate the missing emission factors as a percentage of the available emission factors. When this was done for cotton gins in the state of California, an average facility would have to install additional particulate abatement devices at an estimated cost of $1.4 million to achieve compliance using these estimates (Comis, 2011). If all cotton gins in the U.S. were required to install similar systems it would cost the industry about $950 million, which could put many cotton gins out of business and threaten the entire industry (USDA, 2014).

In an effort to develop emission factors that were representative of actual cotton ginning emissions, cotton gin associations across the U.S. funded a national study (Buser, Whitelock, Boykin, & Holt, 2012b) (hereafter referred to as *National Study*). This study began in 2008 and collected PM emissions data from seven cotton gins in five states across the Cotton Belt. Tests were performed on 17 processing systems common in the industry, using methodologies defined by the EPA. The 17 systems tested included: unloading; 1st, 2nd, and 3rd stage seed-cotton cleaning; 1st, 2nd, and combined lint cleaning; 1st, 2nd, and combined mote; battery condenser; cyclone robber; mote cyclone robber; master trash; overflow (distributer); mote cleaner; and mote trash. Field work and laboratory analysis for the National Study were completed in 2013.

The purpose of this study was to use PM emissions data from the National Study, 1996 AP-42 reference documents, and any other state agency or cotton gin association reports to develop new cotton gin emission factors based on the 2013 EPA emission factor development procedures (Eastern Research Group, 2013). The procedures were designed to maximize the emission factor quality that is developed from the available data to develop a robust set of industry-average set of AP-42 emission factors.

CHAPTER II

REVIEW OF LITERATURE

National Ambient Air Quality Standards (NAAQS)

In 1970, the United States Congress passed the initial framework of the Clean Air Act (CAA), amending it in 1977 and 1990. The CAA was a governmental effort to improve the air quality of cities and industrial centers all across the nation to “protect public health and welfare” (EPA, 2013a). Prior to this, federal involvement had been limited to minimal financial help with research, monitoring, and state assistance. The CAA gave the federal government the authority to regulate emissions from mobile and stationary sources of air pollution (Backmann, 2007). This authority was to be enforced by the newly created U.S. Environmental Protection Agency (EPA), which was established by the National Environmental Policy Act at about the same time as the CAA. To assist with the regulation of stationary sources, four major programs were enacted by the CAA: National Ambient Air Quality Standards (NAAQS), State Implementation Plans (SIPs), New Source Performance Standards (NSPS), and National Emission Standards for Hazardous Air Pollutants (NESHAPs) (Backmann, 2007). Of these four, this review will focus mainly on the NAAQS and their implementation within SIPs.

The goals set for obtaining or maintaining clean air are the driving components of the CAA. These goals aim to set levels of ambient air pollutants that will be safe for the general public, based on the latest scientific findings. After these goals are set, the next step is to determine the current emission levels in all areas that fall under the CAA jurisdiction, which is accomplished by monitoring and inventorying the release of pollutants from emitters. These inventories are used to model the movement of the emissions and to determine their effects on ambient air quality. If an area, through ambient sampling, exceeds the NAAQS, it could be labeled as a non-attainment area. Each industry in the non-attainment area would then be evaluated by the state to determine if it is a major contributor of the pollutant for which the area was in non-attainment. If the industry is determined to be a significant contributor, then the state will determine how much the industry's emissions for that pollutant must be reduced for the area to reach attainment. Once the needed reductions are determined, a plan must be developed to meet those reductions within a certain time period. The plan, once it is made, reviewed, and approved, becomes policy and is then enforced. The results of the plan are tracked and evaluated to determine its effectiveness and whether it needs to be modified. Changes may be needed to reach the goals, or the goals themselves may need to be modified. This entire process is presented in Figure 1.

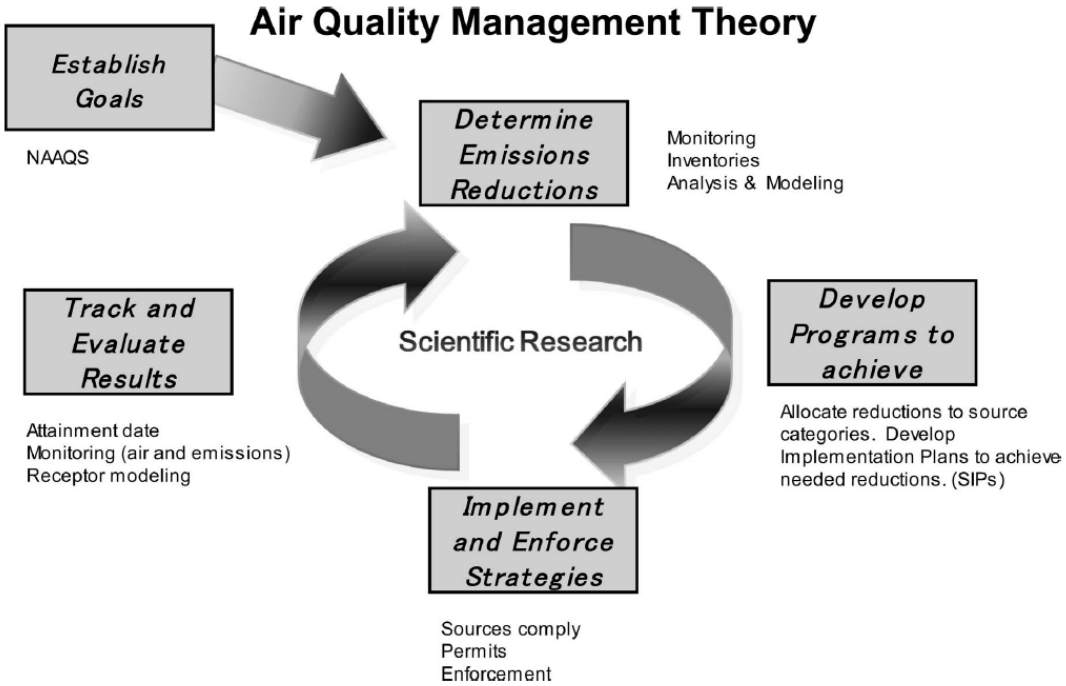


Figure 1. The general operating process of the Clean Air Act (Backmann, 2007).

Criteria Air Pollutants

The CAA requires the EPA to establish NAAQS for criteria air pollutants that, based on the most current scientific findings, might have negative effects on public health and property (EPA, 2012b). These standards were set with what was judged to be an “adequate margin of safety” for protecting populations considered sensitive to air pollution (Backmann, 2007; EPA, 2013a). While the standards are in place to protect sensitive populations, the inclusion of the phrase “margin of safety” implies that, even if the standards are met, the chance of negative health effects will never be zero (Backmann, 2007).

The NAAQS include standards for six criteria pollutants, including: carbon monoxide, lead, nitrogen dioxide, ozone, particle pollution, and sulfur dioxide (EPA, 2012b). Most of these have both a primary standard, which aims to protect parts of the population that are particularly sensitive to air pollution, and a secondary standard, intended to protect the welfare of the general public (EPA, 2012b). Pollutants are measured in terms of parts per million (ppm) by volume, parts per billion (ppb) by volume, or micrograms per cubic meter of air ($\mu g/m^3$). The EPA is directed to set these standards based on the most currently available science, disregarding the cost of implementing the standards, and must also reevaluate the standards every five years to determine if updates are needed (EPA, 2013a). The current standards for these pollutants are listed in Table 1.

State Implementation Plans (SIPs)

Meeting and maintaining the NAAQS is the responsibility of both EPA and individual states (EPA, 2013a). Once NAAQS for a pollutant has been established or updated, states must determine which areas within their borders meet or fall short of the standard(s). The state then sends their determinations to the EPA for approval. Within two years of the acceptance of a NAAQS, the EPA must classify areas as “attainment” if all NAAQS are met, or as “nonattainment” if any one NAAQS standard is not met (EPA, 2013a, 2013c). Areas for which sufficient data is not available for a recommendation of either attainment or nonattainment are categorized as “unclassifiable” and are usually managed in the same manner as attainment areas (EPA, 2013a).

Table 1. The National Ambient Air Quality Standards *(EPA, 2012b)*

Pollutant [final rule cite]		**Primary/ Secondary**	**Averaging Time**	**Level**	**Form**
Carbon Monoxide [76 FR 54294, Aug 31, 2011]		primary	8-hour	9 ppm	Not to be exceeded more than once per year
			1-hour	35 ppm	
Lead [73 FR 66964, Nov 12, 2008]		primary and secondary	Rolling 3 month average	0.15 µg/m3	Not to be exceeded
Nitrogen Dioxide [75 FR 6474, Feb 9, 2010] [61 FR 52852, Oct 8, 1996]		primary	1-hour	100 ppb	98th percentile, averaged over 3 years
		primary and secondary	Annual	53 ppb	Annual Mean
Ozone [73 FR 16436, Mar 27, 2008]		primary and secondary	8-hour	0.075 ppm	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
Particle Pollution Dec 14, 2012	$PM_{2.5}$	primary	Annual	12 $\mu g/m^3$	annual mean, averaged over 3 years
		secondary	Annual	15 $\mu g/m^3$	annual mean, averaged over 3 years
		primary and secondary	24-hour	35 $\mu g/m^3$	98th percentile, averaged over 3 years
	PM_{10}	primary and secondary	24-hour	150 $\mu g/m^3$	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide [75 FR 35520, Jun 22, 2010] [38 FR 25678, Sept 14, 1973]		primary	1-hour	75 ppb (4)	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		secondary	3-hour	0.5 ppm	Not to be exceeded more than once per year

Within three years of a newly announced NAAQS, each state must devise a SIP that “demonstrate[s] that the state has the basic air quality management program components in place to implement a new or revised NAAQS” (EPA, 2012a) and “[identifies] the emissions control requirements the state will rely upon to attain and/or maintain the primary and secondary NAAQS” (EPA, 2013c). However, a SIP must be finalized for nonattainment areas within 18 to 36 months depending on the pollutant(s) for which an area has been designated as “nonattainment” (EPA, 2013c). In most cases, a SIP must demonstrate that nonattainment areas can be brought into compliance with the NAAQS within five years of its implementation. A SIP must have public input before it can be finalized by the state and be submitted to the EPA for review. After reviewing a SIP, the EPA either approves or rejects it. In the case of a rejected SIP (or if no SIP is submitted), EPA must develop its own Federal Implementation Plan for the state (EPA, 2013a).

Prior to 1987, “particulate pollutant” in the NAAQS referred only to total suspended particulates (TSP), which is defined by (EPA, 1995) as “matter emitted from sources as solid, liquid, and vapor forms, but existing in the ambient air as particulate solids or liquids.” In 1987, the EPA changed the NAAQS to only include PM_{10}, and in 1997, EPA split this criteria pollutant into two sections to include PM_{10} and $PM_{2.5}$ (Buser et al., 2012b; EPA, 2012b). While PM_{10} and $PM_{2.5}$ are listed separately in the NAAQS, one is the subset of the other and not separate pollutants. PM_{10} includes $PM_{2.5}$, and TSP includes both PM_{10} and $PM_{2.5}$. Figure 2 demonstrates a size comparison of the two PM designations.

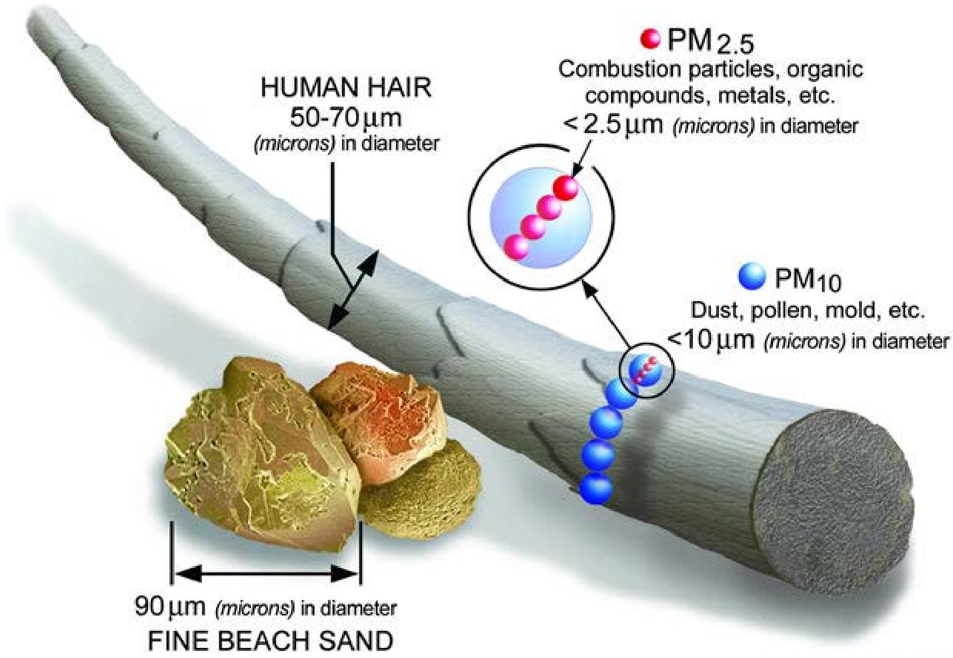


Figure 2. Image illustrating the comparison of PM_{10} and $PM_{2.5}$ to human hair and fine beach sand (EPA, 2013b).

Compilation of Air Pollutant Emission Factors: AP-42

AP-42, *Compilation of Air Pollutant Emission Factors*, is a publication of the U.S. EPA that has been circulated since 1972 (EPA, 1995). This document contains air pollutant emission factors for over 200 industrial air pollution sources and information on the processes conducted at these sources. The last complete edition, 5th edition, was published in 1995. Since then, only updates and supplements have been added (EPA, 1995).

An emission factor is a relationship between a process and the amount of an air pollutant emitted by that process into the atmosphere (EPA, 1995). Emission factors are usually defined as the weight of pollutant emitted per production unit (weight, volume, distance, or duration of the activity producing the pollutant). For example, kg of particulate emitted per cotton bale ginned. These types of relationships have been established from source test data, modeling, material balance studies, and engineering estimates. An AP-42 emission factor is an average of the source specific emission factors that meet EPA’s data submission guidelines (EPA, 1995). It is usually assumed that an emission factor represents the average emissions from an entire population of similar emitting processes (Eastern Research Group, 2013).

EPA's AP-42 includes emission factors for all criteria pollutants and additional pollutants beyond the scope of the NAAQS. These additional pollutant factors include hazardous air pollutants (HAPs); TSP (in addition to PM_{10} and $PM_{2.5}$); organic compounds such as methane, ethane, chlorofluorocarbons, aldehydes, semivolatile compounds, and volatile organic compounds (VOCs); and other toxic or hazardous pollutants (this list is not exhaustive) (EPA, 1995). Emission factors in AP-42 are added and updated as new data are collected and submitted to and accepted by the EPA.

EPA AP-42 chapters correspond to specific industry segments and the sections within each chapter correspond to specific industries. Appendix B.1 of AP-42 contains particle size distribution (PSD) data and emission factors for selected sources (EPA, 1995). The PSDs are displayed as "the cumulative weight percent of particles less than a specified aerodynamic diameter, in micrometers" (EPA, 1995). Emission factors for total PM were provided and used with the cumulative weight percentages to calculate emission factors for particle sizes 2.5, 6, and 10µm. There were no assumptions about the PSD fit to a particular statistical distribution function (i.e., normal, log normal, etc.).

The emission factors in AP-42 can be used in several ways, including preparing emission inventories, facility permitting, and nonattainment area assessment. States utilize emission inventories in their pollution control programs. These inventories assemble estimates of pollutant emissions from facilities within the state, or a specific area of the state, and are used to plan pollution control programs, encourage industry compliance with federal and state regulations, evaluate operating permits, advise rulemaking, and provide required data to the EPA (MPCA, 2003; TCEQ, 2014). While it is preferable to use actual monitoring or stack test data to develop emission inventories, states allow the use of AP-42 emission factors if more site-specific data is not available. Because the factors in AP-42 are meant to be long-term average emissions, representative of an entire pollutant source type, the emission factors will not be as accurate as specific source test data from the facility in question (Eastern Research Group, 2013; EPA, 1995).

When a new facility is to be constructed, significantly renovated, or additions are to be made to an existing facility, a permit is usually required before construction can begin (CEPA, 2011; IDNR, 2013; MDNR, 2013). Before a permit is granted, many states model the emissions from the proposed facility in order to assess the impact the new facility will have on the area's air quality. Some states use data from their own emissions testing for this, while others use AP-42 emission factors for the modeling process (CEPA, 2011). For this reason, it is critical to both industry and state regulatory agencies that the emission factors in AP-42 are as accurate as possible.

States also use modeling when dealing with areas designated as "nonattainment." Often these models are used to determine which sources in the area may be contributing most to the nonattainment status. This determination is used to formulate a SIP and to advise modification of operating permits for facilities within the nonattainment area. If site-specific data are not available, AP-42 emission factors are often used in these models, which makes the accuracy of the factors vital to both industry and regulatory agencies (IDNR, 2013).

While AP-42 is useful to regulatory agencies in a number of ways, there are certain applications for which it should not be used. The emission factors in AP-42 are designed to be long-term averages that are representative of industrial processes. Therefore, AP-42 emission factors should not be used to develop short-term or site-specific estimates, as these can be highly variable based on operating conditions and raw materials. Further, AP-42 emission factors should also not be used as standards or limits for emissions, as they represent industry averages (Eastern Research Group, 2013).

Development of Emission Factors

After a review of their emission factor development process in 2003, the EPA updated the process to make it more objective. EPA also increased public input and made the process more transparent and responsive. These changes affected emission data collection, documentation and evaluation, and emission factor development and assessment (Eastern Research Group, 2013).

Historical Emission Factor Development and Rating Process

Each emission factor in AP-42 was assigned a rating based upon its representativeness of the source category it describes. Historically, this rating was in the form of a letter grade rating, from A (excellent) through E (poor). Most factors within AP-42 still have this type of rating. The emission factor rating reflects the quality of data from which it was derived. The test data from a single source was assigned a rating of A through D based on the methodological soundness and adequacy of detail with which the data was reported. Although the rating system examined certain parameters, source operation, sampling procedures, sampling and process data, and analysis and calculations, the final rating assigned to a test report was a subjective judgment of the reviewer, which was either EPA personnel or a contractor (EPA, 1993).

When an emission factor was derived, the EPA's goal was to use the best test data available. If there were a sufficient number of "A" rated tests, then only "A" rated data would be used for the factor development. The amount of data deemed "sufficient" was based on the estimated number of facilities in existence (sample size vs. total population), the variability of emissions within the industry, the variability of emissions within each facility, and the representativeness of the sample in the total industry, but was still a subjective determination. If there were not sufficient "A" rated tests, then "B" rated data would be used, and the process would continue, using lower quality tests, until sufficient data was amassed for determining an emission factor. (EPA, 1993).

Updated Emission Factor Development and Rating Process

When the EPA updated its emission factor development process, it took advantage of electronic testing information and data reports to make collection, incorporation, and analysis of this data easier (Eastern Research Group, 2013). The Electronic Reporting Tool (ERT) was developed for this purpose and is now the EPA preferred method for submitting data gathered using manual methods. The ERT provides data analysis for emission factor development and requires the following information: four-level Source Classification Code (SCC) specification, process data from existing air permits, process rate levels during actual testing, process flow diagram, sampling locations, test methods used, deviations made to any test method, and output flow rates and pollutant concentrations (Eastern Research Group, 2013).

The ERT is a Microsoft Access® database application that a tester can use to design a test plan, enter data, and submit information to a state regulatory agency and/or the EPA. It provides data fields for all necessary input screens and calculations needed to generate a Project Data Set (PDS) (Eastern Research Group, 2013). A PDS is a Microsoft Access® database that is generated by the ERT and contains the test plan, test plan review, test report data, and the test report assessment for a single test report (AMEC, 2012). Test report data can be entered directly into the PDS, or it can be entered into a Microsoft Excel® spreadsheet and imported into the ERT. The ERT then assigns the dataset a numeric rating. Once all necessary data has been gathered and entered into the ERT, an XML file can be exported to WebFIRE. WebFIRE is the database that houses EPA’s emission factors data, such as test data and supporting documentation, and allows the public to retrieve this information (Eastern Research Group, 2013).

Part of the ERT’s purpose is to develop a test plan prior to testing (Eastern Research Group, 2013). This helps ensure the test data required by the EPA for updating AP-42 emission factors is in the correct form for submission and will have the highest possible quality rating. For tests conducted before ERT implementation (January 1, 2012), if they are to be considered for inclusion in the AP-42, data must be compiled and submitted in a WebFIRE Import Spreadsheet, which consists of a template for data entry and a source test quality rating tool, (EPA, 2011).

A new system of developing and rating emission factors was developed by Eastern Research Group (2013) and was accepted by EPA in August 2013. This system attempts to minimize subjectivity in the process. Emission factors now receive ratings of highly, moderately, or poorly representative, based on the quality of the test data from which the factor was derived and how representative the data is of a source category. Test data receives a numerical score, as opposed to a lettered rating, using an objective scoring system.

Test data that is submitted through ERT to generate new emission factors is assigned a quality rating. Test data is rated based on the following: general information, process and control device information, sampling locations, test methods and reporting requirements, sampling equipment calibrations, sample recovery, laboratory analysis, and documentation (Eastern Research Group, 2013). A source test is rated either in the ERT or using a spreadsheet that is part of the WebFIRE data entry form. This form asks “yes-or-no” questions (Appendix B) about the submitted supporting documents for the source test. Each question is assigned a numeric rating, and these points are summed to give the Individual Test Rating (ITR) for each dataset (Eastern Research Group, 2013). There are two sections of questions: one for the entity submitting the test report and another for a regulatory agency.

The submitter section of questions focuses on the inclusion of data documentation with a source test. This documentation should cover process data, control device information, test method performance, and quality assurance. The numeric score of each question answered “yes” is totaled, divided by the total score possible, and multiplied by 75 to make the maximum ITR possible for the submitter section 75. Up to 4 supplementary points can be gained after the submitter ITR is normalized if the testing company is a certified Air Emission Testing Body (2 points) and the laboratory is certified or accredited to perform the analysis (2 points). This makes the maximum submitter ITR score 79.

The regulatory agency review questions require the agency to assess the quality of the documentation provided by the submitter. This section breaks down the general questions answered by the submitter into more detailed questions and allows for the addition or deduction of points from the pre-normalized submitter score. When this review has been completed, the numeric score of each question answered "yes" is totaled, divided by the total score possible, and multiplied by 100 to make the maximum ITR possible 100. Some questions in the regulatory agency review are not applicable to all testing methods, so the numerical ratings of these questions are not included in the total when the score is normalized (Eastern Research Group, 2013). A list of the submitter and regulatory agency review questions are provided in Appendix B.

Source tests used in developing earlier AP-42 emission factors are also considered in the 2013 emission factor development guidelines. The A to D ratings assigned to the pre-2013 AP-42 emission factors are converted to numerical ITR values as defined by Eastern Research Group (2013): A = 80, B = 60, C = 45, and D = 30.

Once ITRs have been assigned to all source tests, outlier analysis is performed in ProUCL (US EPA, 2009) for all system emission factors if the dataset contains three or more values (note, outlier determination cannot be performed on datasets with less than three values). Test emission factor values are imported into ProUCL and log-transformed. The Dixon test is conducted with a 95% confidence level for datasets containing 3- 24 values. Values identified as outliers are removed from the dataset, and the Dixon test is repeated until no outliers remain. The Rosner test is conducted with a 95% confidence level if the dataset has 25 or more values. Values identified as outliers are removed from the dataset. The Rosner test is repeated if there are still 25 or more values, and the Dixon test is applied if there are 24 or fewer values. The test is repeated until no outliers remain (Eastern Research Group, 2013).

According to the ProUCL technical guide (Singh, Armbya, & Singh, 2010), the Dixon test first orders the dataset containing N emission factors (up to 25) in ascending order, with x_1 and x_N as possible outliers. Then the Dixon test computes the test statistic, C, for $x_1$where:

$$C = \frac{x_2 - x_1}{x_N - x_1} \text{ for } 3 \leq \mathrm{N} \leq 7 \qquad C = \frac{x_2 - x_1}{x_{N-1} - x_1} \text{ for } 8 \leq \mathrm{N} \leq 10$$
$$C = \frac{x_3 - x_1}{x_{N-1} - x_1} \text{ for } 11 \leq \mathrm{N} \leq 13 \qquad C = \frac{x_3 - x_1}{x_{N-2} - x_1} \text{ for } 14 \leq \mathrm{N} \leq 25 \tag{1}$$

If C is greater than critical value for a specified significance level α, then x_1 is an outlier. The process is then repeated for x_N where

$$C = \frac{x_N - x_{N-1}}{x_N - x_1} \text{ for } 3 \leq \mathrm{N} \leq 7 \qquad C = \frac{x_N - x_{N-1}}{x_N - x_2} \text{ for } 8 \leq \mathrm{N} \leq 10$$
$$C = \frac{x_N - x_{N-2}}{x_N - x_2} \text{ for } 11 \leq \mathrm{N} \leq 13 \qquad C = \frac{x_N - x_{N-2}}{x_N - x_3} \text{ for } 14 \leq \mathrm{N} \leq 25 \tag{2}$$

If C is greater than critical value for a specified significance level α, then x_N is an outlier.

The Rosner test first determines the upper limit of possible outliers (r) ($r \leq 10$) then orders the emission factors from smallest to largest (Singh et al., 2010). The possible outlier furthest from the mean (large or small) is removed from the dataset and a test statistic is calculated using the equation:

$$R_{i+1} = \frac{|x_i - \bar{x}_i|}{s_i} \tag{3}$$

where x_i is the possible outlier, $\bar{x}_i$ is the sample mean, and s_i is the standard deviation after the i^{th} most extreme value has been removed. Test statistics are computed for all possible outliers ($R_1 ... R_r$) and then compared to the standard normal distribution critical value, λ_r, obtained from any statistical literature (such as Burt, Barber, & Rigby [2009]), for a specified significance level α. If $R_r > \lambda_r$, then the value is an outlier. If $R_r \leq \lambda_r$, then there are no outliers (Singh et al., 2010).

Once outliers have been identified and removed, source tests are arranged by descending ITR value. The ITRs are then used to develop a Composite Test Rating (CTR). The CTR is an inverse square rating of the summation of ITR values (Equation 4) and ranges from 0 to 100.

$$CTR = \left[\frac{\sum_{i=1}^{n}\left(\frac{1}{ITR}\right)^2}{N}\right]^{-0.5}, \tag{4}$$

where *CTR* is the Composite Test Rating, *ITR* is Individual Test Rating, and *N* is the number of tests included in the candidate data set (Eastern Research Group, 2013). In WebFIRE, a CTR is calculated using the first two tests (those with the highest ITR), then with the first three, and so on until all available tests have been included (Eastern Research Group, 2013).

Once the CTR has been calculated for all test sets, WebFIRE calculates a Factor Quality Index (FQI) using the CTR and number of tests in the candidate data set. The FQI is a numerical indicator of the calculated emission factor's industrial process representativeness, similar to a standard error calculation in statistics. FQI is calculated using equation 5:

$$\mathrm{FQI} = \frac{100}{\mathrm{CTR} * \mathrm{N}^{0.5}} \tag{5}$$

where *FQI* is the Factor Quality Index, *CTR* is the Composite Test Rating associated with the candidate data set selected for deriving the emission factor, and *N* is the number of tests that were included in the CTR calculation (Eastern Research Group, 2013). A lower FQI indicates a more representative emission factor. WebFIRE calculates FQI values for each group of ITR values until a grouping increases the FQI (decreases reliability). The test value that increased the FQI, and all values that received lower ITR values, are omitted from the emission factor calculation. All test values that were included in the FQI calculation are then averaged to calculate an emission factor. The boundary criteria in Table 2 are then used to determine which of three representativeness ratings the factor will receive (Eastern Research Group, 2013). Figure 3 shows the area curves for the boundary criteria pertaining to source categories containing more than 15 sources (Eastern Research Group, 2013). This chart shows the number of tests necessary to fall within a representativeness category based on the CTR value of those tests.

Table 2. FQI and boundary line equations *(Eastern Research Group, 2013).*

If the source category contains…	**Then use these boundary line equations…**	
	Poorly to moderately representative	**Moderately to highly representative**
More than 15 sources	FQI = 0.5774 $N = 30{,}000 * CTR^{-2}$	FQI = 0.3015 $N = 110{,}000 * CTR^{-2}$
15 or fewer sources	FQI = 1 $N = 10{,}000 * CTR^{-2}$	FQI = 0.5774 $N = 30{,}000 * CTR^{-2}$

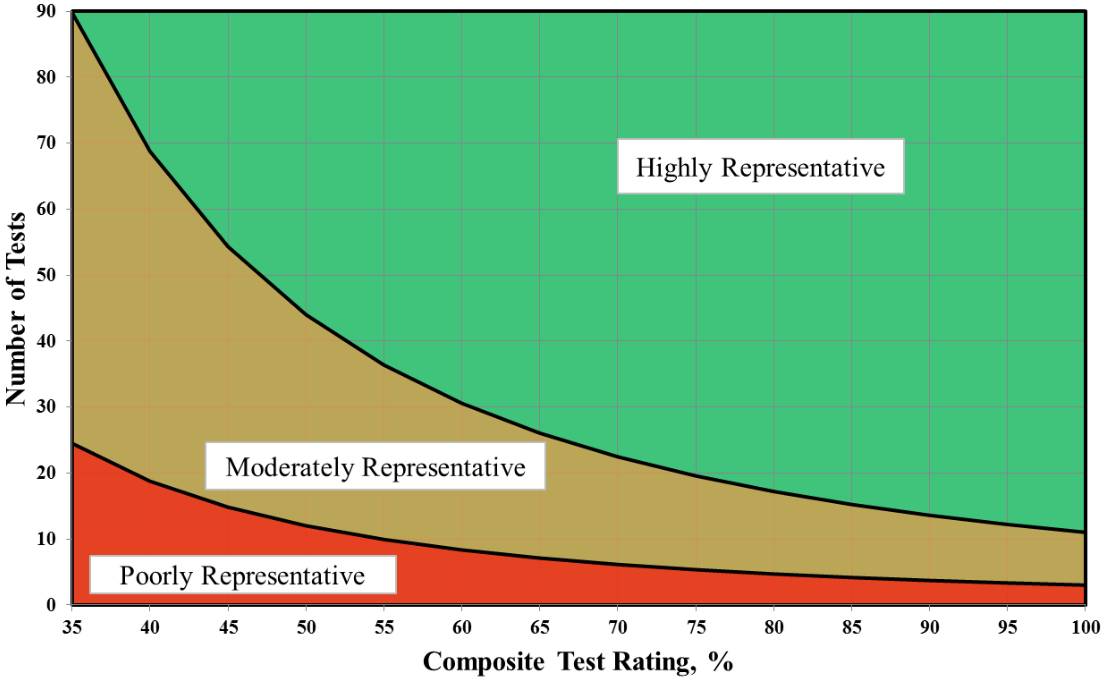


Figure 3. Emission factor representativeness areas for source categories containing more than 15 sources (Eastern Research Group, 2013).

Cotton Ginning

Cotton ginning is a critical step in the overall process of producing cotton and delivering a finished garment to consumers. Cotton is harvested using either picker or stripper machines that detach the cotton, and the seeds it contains, from the plant stem (Faulkner, Wanjura, Boman, Shaw, & Parnell, 2011). The unginned cotton is known as seed-cotton and, before it can be sold, the seeds, along with most other trash collected during harvesting, must be removed. Thus, the main function of a cotton gin is to separate the seed from the lint fibers. Other cotton gin functions include cleaning and drying the fibers once the seeds are removed and packaging the fiber into 227 kg (500 lb.) bales (Anthony & Mayfield, 1994).

The various processes that occur within a cotton gin are carried out by several different processing systems. Figure 4 shows the cotton gin process flow diagram contained in the 1996 AP-42. The following is a list and a short description of the processing systems most commonly found in cotton gins today:

1. Unloading system - unloads seed-cotton from a module or trailer and brings it into the cotton gin
2. Seed-cotton cleaning system - dries seed-cotton and removes foreign matter (can have first-, second-, and third-stages in sequence)
3. Overflow system - maintains proper flow of seed-cotton from the cleaning system into gin stands
4. Gin stand system - separates seeds from cotton fibers (not a pneumatic system- no regulated air emissions)
5. Lint cleaning system - cleans cotton lint after seeds have been removed (can have first- and second-stages in sequence with separate or combined exhausts)
6. Battery condenser system - feeds cleaned lint into a bale press where the lint is compressed and packaged into bales
7. Cyclone robber system - removes material captured by lint cleaning system cyclones; helps eliminate cycling lint issues in lint system cyclones
8. Mote system - conveys trash from lint cleaner system (called motes) to a mote cleaner system (can have first- and second-stages in sequence with separate or combined exhausts)
9. Mote cleaner system - cleans cotton fibers left in the trash from the lint cleaner system
10. Mote cyclone robber system - removes material from mote system cyclones to prevent buildup

11. Mote trash system - handles trash separated from lint material by mote cleaner system
12. Master trash system - pulls all trash from the various cotton gin systems to a single location

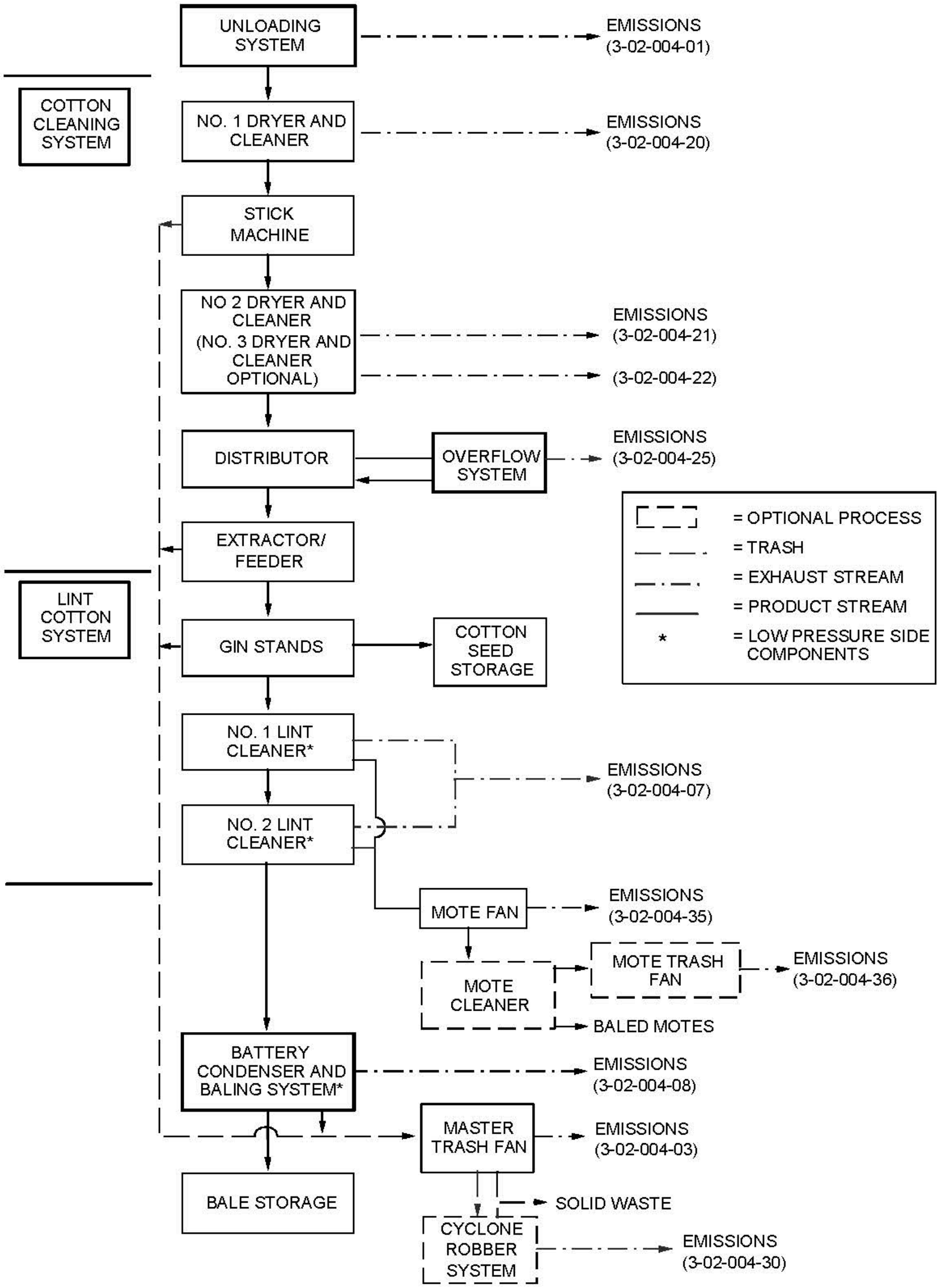


Figure 4. 1996 AP-42 cotton gin process flow diagram (EPA, 1996).

Using the systems listed above, there are 17 different combinations of exhaust streams possible: unloading, 1st stage seed-cotton cleaning, 2nd stage seed cotton cleaning, 3rd seed-cotton cleaning, 1st stage lint cleaning, 2nd stage lint cleaning, combined lint cleaning, 1st stage mote, 2nd stage mote, combined mote, battery condenser, cyclone robber, mote cyclone robber, master trash, overflow, mote cleaner, and mote trash. A single gin stand line, depending on its setup, may have as few as 7 and as many as 15 different exhaust streams. Cotton gins can have parallel gin stand lines consisting of multiples of the same systems with separate exhaust streams. The typical materials handled by each of these systems, including multiple stages of a series of the same system, are shown in Figure 5. More in-depth information is provided for each system in Appendix A.

Cyclones

Typically, cotton is conveyed from system to system within a cotton gin pneumatically. The majority of the materials transported by these air streams are removed prior to the air being released into the atmosphere. Cotton gins utilize several types of abatement devices to clean these air streams, including covered condenser drums, in-line filters, plenum chambers, cyclones, rotary drum filters, and bag houses (Anthony & Mayfield, 1994; Buser, Whitelock, Holt, Armijo, & Wang, 2007).

Cyclones are the most commonly used abatement devices found in cotton gins. Cyclones consist of a tubular upper portion with a tapering lower portion and use centrifugal force to remove trash and PM from the air stream (Figure 6) (Anthony & Mayfield, 1994). The two most commonly used cyclone designs for cotton gins are the 2D2D and 1D3D (known as "high efficiency cyclones"). The upper and cone portions of a 2D2D are each twice as long as the cyclone diameter. The 1D3D has an upper body length that is equivalent to the cyclone diameter and a cone length that is three times the cyclone diameter (EPA, 1996). EC/R Incorporated (1998) reported that a single high efficiency cyclone collected 100% of particles greater than 20µm and 90% of 5µm-sized particles.

(a) Unloading

(e) Overflow

(i) Mote Cleaner

(b) First Stage Seed-Cleaning

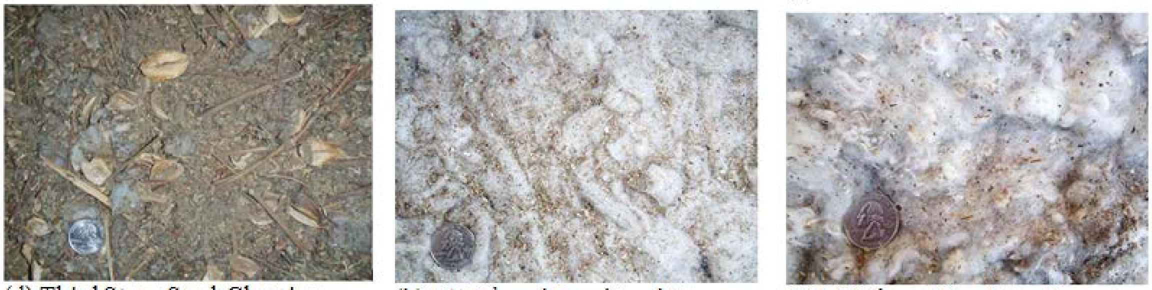
(f) Battery Condenser

(j) Mote Trash

(c) Second Stage Seed-Cleaning

(g) Cyclone Robber

(k) Master Trash



(d) Third Stage Seed-Cleaning

(h) 1st, 2nd, and Combined Stage Lint Cleaning

(l) 1st, 2nd, and Combined Stage Mote and Mote Cyclone Robber

Figure 5. Examples of trash handled by each ginning system

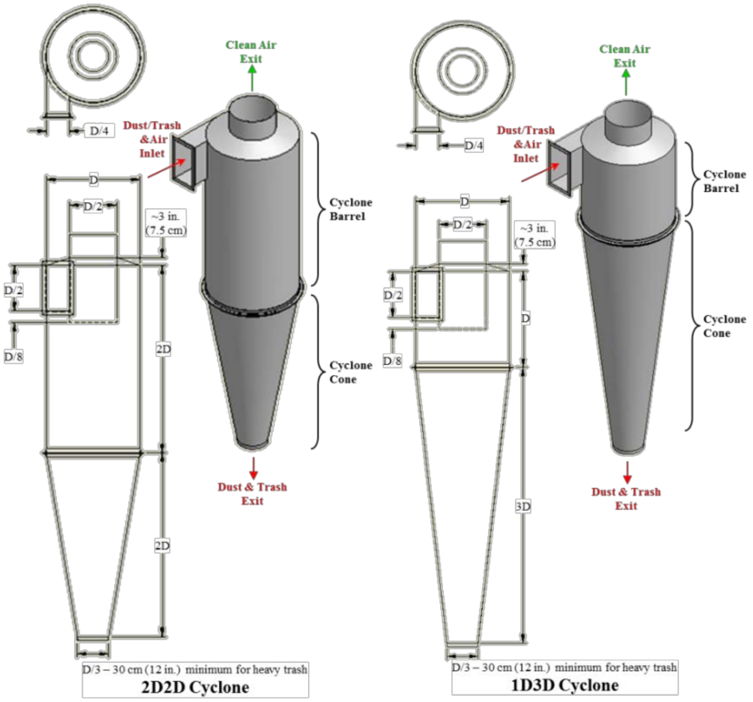


Figure 6. The two most common air abatement cyclone designs used at cotton gins are 2D2D and 1D3D *(Buser, Whitelock, Boykin, & Holt, 2013bc).*

Cotton Gins and AP-42

Because of the mostly mechanical nature of the cotton ginning processes and the agricultural material handled, the majority of air contaminants released by the industry are PM. Limits for PM emissions from cotton gins are generally set in operating permits by state regulatory agencies. The process of setting these limits is often guided by the emission factors listed in AP-42. Cotton gins are covered under AP-42 section 9.7, which was last updated in 1996 and will hereafter be referenced as the “1996 AP-42.” The 1996 AP-42 has an overview of cotton gin systems and contains their emission factors and ratings. Tables 3 and *4* contain the 1996 AP-42 emission factors, their ratings, the number of tests used to develop the factors, and the Source Classification Codes (SCC) of the individual ginning systems for total PM and PM_{10}, respectively (EPA, 1996). The 1996 AP-42 defined a “typical gin” as having an unloading fan, No. 1 and No. 2 dryer and cleaner (1st and 2nd stage seed-cotton systems), overflow fan, lint cleaners, mote fan, battery condenser, and master trash fan.

There are a few issues with the 1996 AP-42. The first is the low cotton gin emission factor ratings (Buser et al., 2012b). Next, the EPA's revised rating system is new, and factors for most industries currently available in the AP-42 are still ranked by the subjective alphabetical system (there are three draft AP-42 sections that use the new rating system) (EPA, 1995). Further, the 1996 AP-42 does not contain emission factors for all systems commonly found in cotton gins. Finally, cotton gin $PM_{2.5}$ emission factors do not exist in the 1996 AP-42.

Source tests from 16 references were used to develop the current cotton gin factors. Of the emissions tests performed on cyclone-equipped systems, as reported in these references, 42 received an "A", 56 received a "B", and 8 received a "D" data quality rating. Of the 16 references, 14 references presented data that was collected within a 50 mile radius of Fresno, California. The other two references presented data collected from Marana, Arizona, and Halls, Tennessee. Because the source tests were almost exclusively from a single geographic area, all cotton gin emission factors for emission sources using cyclone air abatement devices received emission factor ratings of "D," and all factors for screened drums received ratings of "E" (EPA, 1996). The new rating system does not take into account geographic spread when rating source tests or emission factors. Graphs of the 1996 AP-42 data were provided in Appendix D.

Emission factors with low ratings can present problems for regulatory agencies and industry. A low rating indicates that the emission factor may not be representative of the average industry emissions. This allows for interpretation of the emission factors by regulators when setting emission limits for permitting purposes. This interpretation may include using a slightly higher emission rate (or larger "margin of error") when modeling area emissions, which could lead the agency to erroneously identify a facility as a significant cause for an area's air quality degradation. This issue could cost misrepresented industries hundreds of thousands of dollars in abatement improvements and could force many out of business, a real danger for the cotton ginning industry (Buser et al., 2012b).

Table 3. Current AP-42 total PM emission factors and ratings for cotton gins (all systems equipped with cyclones unless otherwise noted) (EPA, 1996).

System	**Source Classification Code (SCC)**	**Total PM kg/bale**	**Total PM lb/bale**	**Emission Factor Rating**	**No. of Tests**
Unloading Fan	3-02-004-01	0.13	0.29	D	8
No. 1 Dryer and Cleaner	3-02-004-20	0.17	0.36	D	7
No. 2 Dryer and Cleaner	3-02-004-21	0.17	0.24	D	7
No. 3 Dryer and Cleaner	3-02-004-22	0.043	0.095	D	2
Overflow fan	3-02-004-25	0.033	0.071	D	4
Lint cleaners	3-02-004-07				
with high-efficiency cyclones		0.26	0.58	D	6
with screened drums or cages		0.49	1.1	E	4
Cyclone robber system	3-02-004-30	0.083	0.18	D	1
Mote fan	3-02-004-35	0.13	0.28	D	9
Mote trash fan	3-02-004-36	0.035	0.077	D	3
Battery Condenser	3-02-004-08				
with high-efficiency cyclones		0.018	0.039	D	5
with screened drums or cages		0.078	0.17	E	4
Master trash fan	2-03-004-03	0.24	0.54	D	4
Typical Gin	3-02-004-03	1.1	2.4	D	50

Table 4. Current AP-42 PM_{10} emission factors an ratings for cotton gins (all systems equipped with cyclones unless otherwise noted) (EPA, 1996).

System	**Source Classification Code (SCC)**	**PM_{10} kg/bale**	**PM_{10} lb/bale**	**Emission Factor Rating**	**No. of Tests**
Unloading Fan	3-02-004-01	0.056	0.12	D	5
No. 1 Dryer and Cleaner	3-02-004-20	0.055	0.12	D	5
No. 2 Dryer and Cleaner	3-02-004-21	0.043	0.093	D	5
No. 3 Dryer and Cleaner	3-02-004-22	0.015	0.033	D	2
Overflow fan	3-02-004-25	0.012	0.026	D	4
Lint cleaners	3-02-004-07	0.11	0.24	D	6
Cyclone robber system	3-02-004-30	0.024	0.052	D	1
Mote fan	3-02-004-35	0.060	0.13	D	6
Mote trash fan	3-02-004-36	0.0095	0.021	D	3
Battery Condenser	3-02-004-08	0.0064	0.014	D	5
Master trash fan	2-03-004-03	0.034	0.074	D	2
Typical Gin	3-02-004-03	0.37	0.82	D	38

Cotton ginning is not the only industry that has low rated AP-42 emission factors. Of the 333 emission factors for food and agricultural industries (AP-42, Ch. 9), no emission factors received a rating of "A" or "B," and only 13.2% of the emission factors received a "C" rating. Most of the emission factors for the food and agricultural industries have ratings of D (26.4%) or E (60.4%), and several industries, such as meat packing and the preserved fruits and vegetables industries, have no emission factors listed (EPA, 1995). Not all industry types within AP-42 have such low factor ratings. Some sections, such as external combustion sources, have industries with several A-rated emission factors. However, many other industries have emission factor ratings as low or lower than the cotton ginning industry, and numerous others do not have any emission factors (EPA, 1995).

A second issue with the 1996 AP-42 emission factors for cotton gin is that it does not contain emission factors for many common systems found in today's cotton gins. Emission factors for 11 cotton gin systems are included in the AP-42, but there are at least 17 different systems possible with emission points common in today's cotton gins (Boykin, Buser, Whitelock, & Holt, 2013a, 2013b, 2013c, 2013d, 2013e; Buser, Whitelock, Boykin, & Holt, 2013r, 2013z, 2013ae, 2013ah, 2013ba; Buser et al., 2013bc; Whitelock, Buser, Boykin, & Holt, 2013a, 2013b, 2013c, 2013d, 2013e, 2013f). For example, the mote cyclone robber system is absent from the 1996 AP-42. Additionally, in the process layout provided in AP-42 (Figure 4), the mote cleaner system feeds directly into the mote trash system without having its own emission point, but there are cases of this system having its own emission point (Buser, Whitelock, Boykin, & Holt, 2012g; Buser et al., 2013ae; Buser, Whitelock, Boykin, & Holt, 2014e).

Another issue is that AP-42 contains only single emission factors for combined systems that are commonly independent of each other. The flow diagram in Figure 4 accounts for separate emissions points from three stages of "dryer and cleaner" systems (seed-cotton cleaning systems) but treats emissions from two stages of lint cleaners as if they are always combined. However, it is common for cotton gins to have two stages of both lint cleaning and mote systems with both stages having separate emissions points. The emissions from separate first and second stages of systems are likely not identical to each other or to a combined exhaust system, which leads to inaccuracies when AP-42 is used to develop emission inventories or in models for permitting purposes (Boykin et al., 2013a, 2013d; Buser et al., 2013r, 2013z; Whitelock et al., 2013b, 2013f). Figure 7 depicts a general cotton gin process flow diagram that is a proposed update to American Society of Agricultural Engineers' standard S582 (American Society of Agricultural Engineers, 2005). This diagram allows for separate first and second stage lint cleaner and mote systems. To create more representative emission inventories for cotton gins, emission factors should be developed for each unique cotton gin emission point.

In 2006, the EPA completed updates to the NAAQS that included more strict standards for $PM_{2.5}$, and in 2008, state regulatory agencies began the process of including limits on $PM_{2.5}$ emissions in cotton gin permits. The 1996 AP-42 does not include any cotton gin $PM_{2.5}$emission factors. The lack of AP-42 cotton gin $PM_{2.5}$ emission factors has not prevented regulatory agencies in several states from estimating $PM_{2.5}$ emission rates as a percentage of total PM emission factors (based on no actual data), modeling cotton gin emissions, and setting permit limits (Buser et al., 2012b). With an average of 680 active cotton gins from 2008-2013, if these limits are put into place across the entire cotton belt, the installation and operation of additional abatement devices could cost the industry around $951 million (USDA, 2014). Preliminary data indicates that regulatory estimates could be overestimating $PM_{2.5}$ emission factors by a factor of 10 or greater (Buser et al., 2012b).

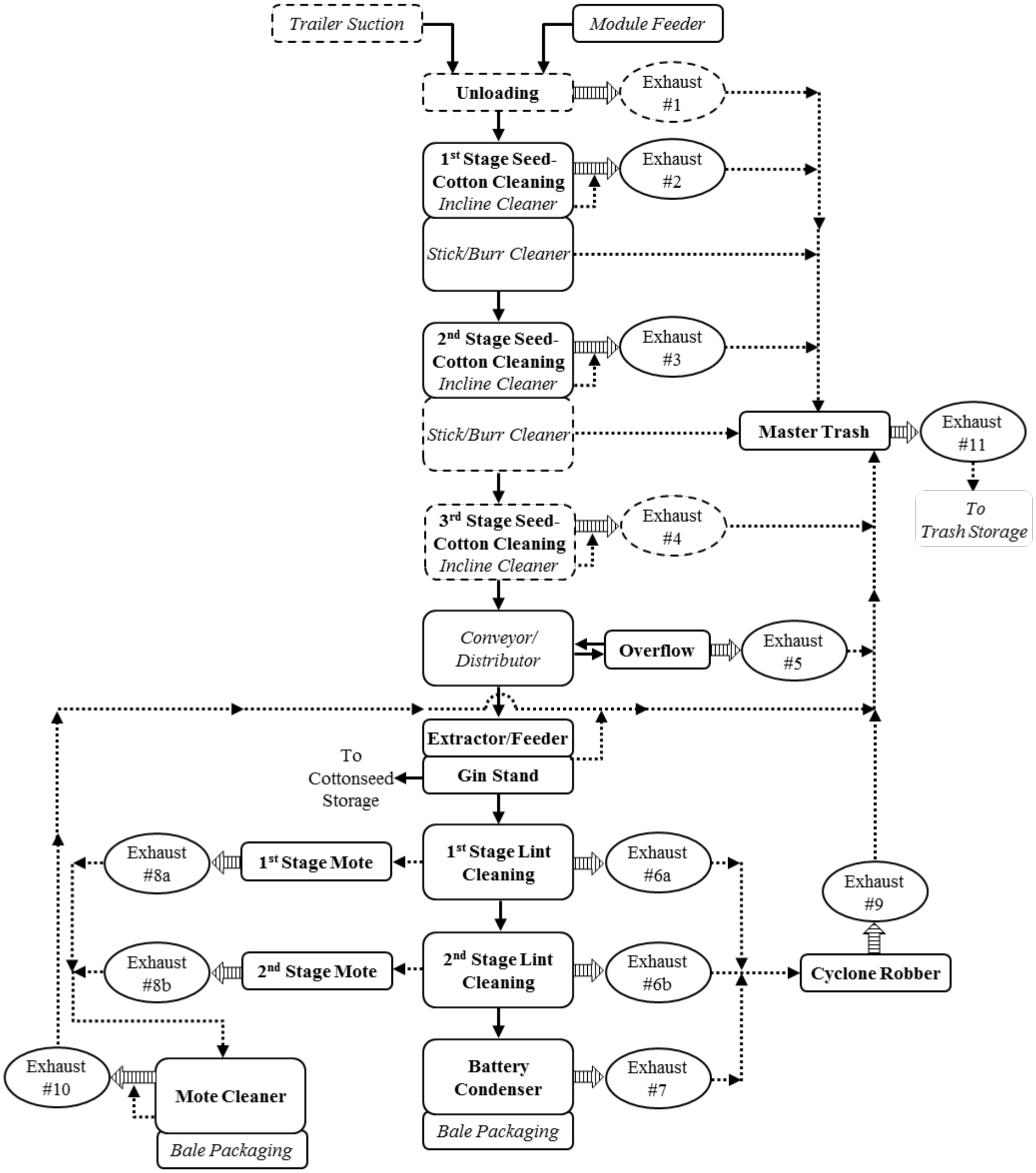


Figure 7. Proposed update for ASAE standard S582 cotton gin system flow diagram (Buser, 2004).

Particle Size Distribution

In addition to the cotton gin emission factors contained in Section 9.7, Appendix B.1 of AP-42 contains PSDs for lint cleaner and battery condenser systems (EPA, 1995). Table 5 shows the cumulative percentages of particles less than 2.5, 6.0, and 10 µm listed in AP-42, Table 6 shows the emission factors derived from the cumulative percentages, and Figure 8 shows the graphs of this data as it appears in AP-42 Appendix B.1 for systems with cyclones. These distributions were developed with data from four sources for lint cleaners and two sources for battery condensers. The emission factor ratings for both systems were E.

Table 5. Cotton gin particle size distributions contained in Appendix B.1 of AP-42.

System	**% < 2.5 µm**	**% < 6.0 µm**	**% < 10 µm**
Lint cleaner	1	20	54
Battery condenser	8	33	62

Table 6. Emission factors derived from Appendix B.1 cotton gin PSD data.

	PM$_{2.5}$		**PM$_6$**		**PM$_{10}$**	
System	**kg/bale**	**lb/bale**	**kg/bale**	**lb/bale**	**kg/bale**	**lb/bale**
Lint cleaner	0.004	0.0088	0.074	0.16	0.20	0.44
Battery condenser	0.007	0.015	0.028	0.062	0.053	0.12

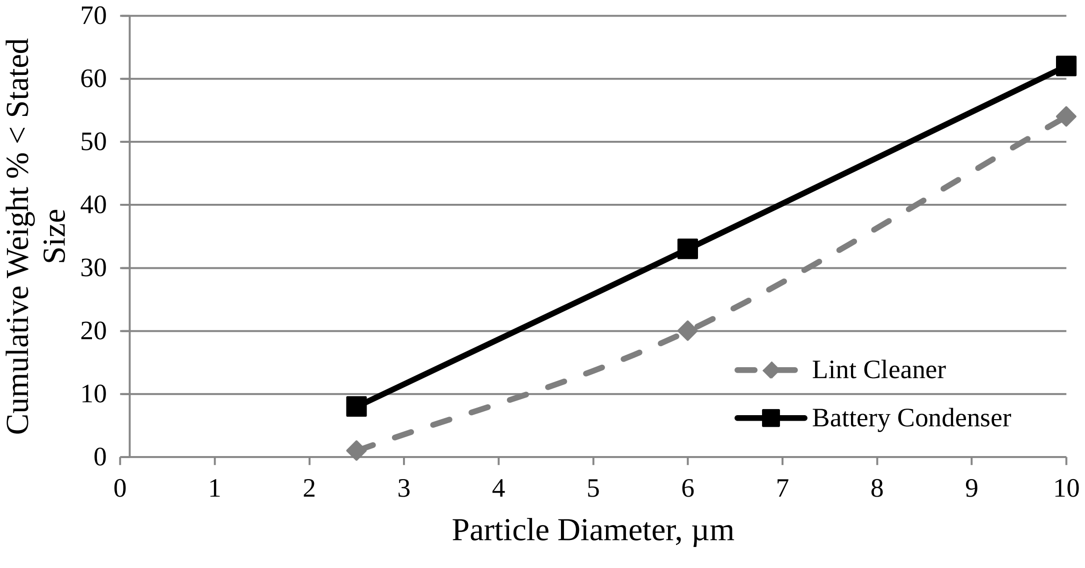


Figure 8. Graphical representation of cotton gin PSD data contained in Appendix B.1 of AP-42.

Cotton Gin Source Sampling Data

National Study

Because of the low emission factor quality ratings, possible lack of representation of industry norms, and limited for $PM_{2.5}$ emission factors, the National, Texas, Southern, Southeastern, and California ginning associations deemed it necessary to collect PM emission factor data from a representative sample of cotton gins across the U.S. (Buser et al., 2012b). A four plus year study, the National Characterization of Cotton Gin Particulate Matter Emissions Project (National Study), was conducted by Oklahoma State University and USDA Agricultural Research Service (ARS) Ginning Laboritories at Lubbock, TX; Mesilla Park, NM; and Stoneville, MS to collect emissions data from seven cotton gin facilities across the U.S. (Buser et al., 2012b).

Two EPA-approved, stack sampling methods for determining PM emissions were used. The two methods were Methods 17- Determination of Particulate Matter Emissions from Stationary Sources and Method 201A- Determination of PM_{10} and $PM_{2.5}$ Emissions from Stationary Sources, found in Title 40 of the Code of Federal Regulations Part 60 (EPA, 2009, 2010). For these methods, a sampling train, consisting of a nozzle, filter, and probe, is inserted through a sampling port into the airstream being sampled (Enthalpy Analytical, 2013). A sample of PM is then withdrawn isokinetically from the airstream. Using Method 201A for $PM_{2.5}$, the sample is drawn through a PM_{10} sizing cyclone, a $PM_{2.5}$ sizing cyclone, and finally collected on a filter. This setup collected $PM_{2.5}$, PM_{10}, and total PM. The same setup is used for PM_{10} but without the $PM_{2.5}$ sizing cyclone. This setup collected PM_{10} and total PM. Method 17 uses a similar setup, but without sizing cyclones, to collect total PM (Figure 9). Once collected, gravimetric analysis is used to determine the mass of each size fraction (Buser et al., 2012b).

For sampling cyclone emissions at cotton gins, the National Study added stack extensions to the cyclone exhausts. Straightening vanes inside a stack extension eliminated the cyclonic flow of the airstream as it exited the cyclone. Sampling ports on the stack extensions allowed for insertion of the sampling heads into the airstream (Buser et al., 2012b).

Figure 9. Sampling heads for Method 201A with PM_{10} and $PM_{2.5}$ sizing cyclones (top), Method 201A with PM_{10} sizing cyclone (middle), and Method 17 (bottom) (Buser et al., 2012b).

Source tests were conducted for 17 systems (described in Appendix A) equipped with cyclone abatement devices. Seven cotton gins across the United States were sampled (Buser et al., 2012b); however, not every cotton gin was equipped with all 17 processing systems. For example, all seven cotton gins had 1st stage seed-cotton cleaning systems, but only gins A, B, C, and F had 1st stage lint cleaning systems. While emissions from covered condenser drums are included in the 1996 AP-42, the National Study did not examine that type of abatement device because of their decline in use by the industry. $PM_{2.5}$, PM_{10}, and total PM samples were collected using EPA Method 201a with PM_{10} and $PM_{2.5}$ cyclones (Table 7) (Boykin et al., 2013a, 2013b, 2013c, 2013d, 2013e; Buser et al., 2013r, 2013z, 2013ae, 2013ah, 2013ba, 2013bc; Whitelock et al., 2013a, 2013b, 2013c, 2013d, 2013e, 2013f). PM_{10} and total PM samples were collected using EPA Method 201a with a PM_{10} cyclone (Table 8) (Boykin, Buser, Whitelock, & Holt, 2014a, 2014b, 2014c, 2014d, 2014e, 2014f; Buser, Whitelock, Boykin, & Holt, 2014a, 2014b, 2014c, 2014d, 2014e, 2014f, 2014l; Whitelock, Buser, Boykin, & Holt, 2014a, 2014b, 2014c, 2014d).

Samples for total PM were collected using EPA Method 17 (Table 9) (Buser, Whitelock, Boykin, & Holt, 2012a, 2012c, 2012d, 2012e, 2012f, 2012g, 2012h, 2012i, 2012j, 2012k, 2012l, 2013t, 2013y, 2013aa, 2013az, 2013bb, 2013bf). Three test runs were performed for each sampling method on each system at each cotton gin, which provided a total of 3, 6, and 9 test runs for $PM_{2.5}$, PM_{10}, and total PM, respectively.

Table 7a. $PM_{2.5}$, PM_{10}, and total PM factors in kg/bale developed by the National Study using EPA Method 201A with $PM_{2.5}$ and PM_{10} cyclones.

Process Stream	**$PM_{2.5}$ (kg/bale)**	**No. of Tests**	**PM_{10} (kg/bale)**	**No. of Tests**	**Total PM (kg/bale)**	**No. of Tests**
Unloading	0.022	8	0.071	3	0.120	6
1st Seed-Cotton Cleaning	0.0082	19	0.073	17	0.107	21
2nd Seed-Cotton Cleaning	0.0036	12	0.038	9	0.063	7
3rd Seed-Cotton Cleaning	0.0040	6	0.022	4	0.029	6
1st Lint Cleaning	0.0086	10	0.054	7	0.109	10
2nd Lint Cleaning	0.0050	9	0.022	9	0.034	9
Combined Lint Cleaning	0.014	9	0.127	4	0.233	9
1st Mote	0.0041	14	0.023	9	0.032	8
2nd Mote	0.0025	11	0.010	9	0.013	10
Combined Mote	0.0095	6	0.137	4	0.141	6
Battery Condenser	0.0037	15	0.012	9	0.037	12
Cyclone Robber	0.0018	11	0.012	7	0.022	8
Mote Cyclone Robber	0.0045	5	0.010	3	0.039	5
Master Trash	0.0042	13	0.036	4	0.142	15
Overflow (Distributer)	0.0040	9	0.018	1	0.041	9
Mote Cleaner	0.0036	3	-	-	0.064	2
Mote Trash	0.0011	6	0.010	4	0.017	5
Typical Gin	0.069	91	0.514	51	0.979	85

(Boykin et al., 2013a, 2013b, 2013c, 2013d, 2013e; Buser et al., 2013r, 2013z, 2013ae, 2013ah, 2013ba, 2013bc; Whitelock et al., 2013a, 2013b, 2013c, 2013d, 2013e, 2013f)

Table 7b. $PM_{2.5}$, PM_{10}, and total PM emission factors in lb/bale developed by the National Study using EPA Method 201A with $PM_{2.5}$ and PM_{10} cyclones.

Process Stream	**$PM_{2.5}$ (lb/bale)**	**No. of Tests**	**PM_{10} (lb/bale)**	**No. of Tests**	**Total PM (lb/bale)**	**No. of Tests**
Unloading	0.049	8	0.157	3	0.265	6
1st Seed-Cotton Cleaning	0.018	19	0.162	17	0.235	21
2nd Seed-Cotton Cleaning	0.0081	12	0.084	9	0.138	7
3rd Seed-Cotton Cleaning	0.0087	6	0.049	4	0.063	6
1st Lint Cleaning	0.019	10	0.118	7	0.24	10
2nd Lint Cleaning	0.011	9	0.048	9	0.074	9
Combined Lint Cleaning	0.030	9	0.281	4	0.513	9
1st Mote	0.0090	14	0.051	9	0.071	8
2nd Mote	0.0055	11	0.022	9	0.029	10
Combined Mote	0.021	6	0.301	4	0.311	6
Battery Condenser	0.0081	15	0.026	9	0.081	12
Cyclone Robber	0.0040	11	0.027	7	0.048	8
Mote Cyclone Robber	0.010	5	0.023	3	0.087	5
Master Trash	0.0092	13	0.080	4	0.314	15
Overflow (Distributer)	0.0088	9	0.040	1	0.09	9
Mote Cleaner	0.0079	3	-	-	0.14	2
Mote Trash	0.0024	6	0.021	4	0.038	5
Typical Gin	0.1526	91	1.13	51	2.16	85

(Boykin et al., 2013a, 2013b, 2013c, 2013d, 2013e; Buser et al., 2013r, 2013z, 2013ae, 2013ah, 2013ba, 2013bc; Whitelock et al., 2013a, 2013b, 2013c, 2013d, 2013e, 2013f)

Table 8a. PM_{10} and total PM emission factors in kg/bale developed by the National Study using EPA Method 201A with a PM_{10} cyclone only.

Process Stream	**PM_{10} (kg/bale)**	**No. of Tests**	**Total PM (kg/bale)**	**No. of Tests**
Unloading	0.108	8	0.131	6
1st Seed-Cotton Cleaning	0.098	21	0.144	20
2nd Seed-Cotton Cleaning	0.039	15	0.056	13
3rd Seed-Cotton Cleaning	0.019	5	0.024	5
1st Lint Cleaning	0.041	12	0.066	12
2nd Lint Cleaning	0.018	11	0.035	10
Combined Lint Cleaning	0.151	8	0.293	8
1st Mote	0.020	15	0.034	11
2nd Mote	0.0082	14	0.011	12
Combined Mote	0.098	6	0.141	3
Battery Condenser	0.016	18	0.034	12
Cyclone Robber	0.010	11	0.018	10
Mote Cyclone Robber	0.028	8	0.039	5
Master Trash	0.056	14	0.152	10
Overflow (Distributer)	0.013	9	0.033	9
Mote Cleaner	0.049	3	0.090	3
Mote Trash	0.011	6	0.021	4
Typical Gin	0.578	99	0.983	81

(Boykin et al., 2014a, 2014b, 2014c, 2014d, 2014e, 2014f; Buser et al., 2014a, 2014b, 2014c, 2014d, 2014e, 2014f, 2014l; Whitelock et al., 2014a, 2014b, 2014c, 2014d)

Table 8b. PM_{10} and total PM emission factors in lb/bale developed by the National Study using EPA Method 201A with a PM_{10} cyclone only.

Process Stream	**PM_{10} (lb/bale)**	**No. of Tests**	**Total PM (lb/bale)**	**No. of Tests**
Unloading	0.237	8	0.289	6
1st Seed-Cotton Cleaning	0.215	21	0.317	20
2nd Seed-Cotton Cleaning	0.087	15	0.123	13
3rd Seed-Cotton Cleaning	0.042	5	0.054	5
1st Lint Cleaning	0.091	12	0.146	12
2nd Lint Cleaning	0.039	11	0.078	10
Combined Lint Cleaning	0.332	8	0.647	8
1st Mote	0.044	15	0.075	11
2nd Mote	0.018	14	0.025	12
Combined Mote	0.215	6	0.310	3
Battery Condenser	0.036	18	0.075	12
Cyclone Robber	0.022	11	0.040	10
Mote Cyclone Robber	0.061	8	0.087	5
Master Trash	0.123	14	0.335	10
Overflow (Distributer)	0.029	9	0.072	9
Mote Cleaner	0.109	3	0.199	3
Mote Trash	0.025	6	0.046	4
Typical Gin	1.27	99	2.17	81

(Boykin et al., 2014a, 2014b, 2014c, 2014d, 2014e, 2014f; Buser et al., 2014a, 2014b, 2014c, 2014d, 2014e, 2014f, 2014l; Whitelock et al., 2014a, 2014b, 2014c, 2014d)

Table 9. Total PM emission factors in kg/bale developed by the National Study using EPA Method 17.

	Total PM		No. of Tests
Process Stream	**kg/bale**	**lb/bale**	
Unloading	0.134	0.296	9
1st Seed-Cotton Cleaning	0.151	0.334	18
2nd Seed-Cotton Cleaning	0.059	0.129	14
3rd Seed-Cotton Cleaning	0.024	0.052	6
1st Lint Cleaning	0.070	0.155	12
2nd Lint Cleaning	0.023	0.050	11
Combined Lint Cleaning	0.211	0.466	9
1st Mote	0.025	0.056	15
2nd Mote	0.010	0.023	15
Combined Mote	0.146	0.321	6
Battery Condenser	0.032	0.070	18
Cyclone Robber	0.020	0.045	12
Mote Cyclone Robber	0.050	0.111	9
Master Trash	0.186	0.411	15
Overflow (Distributer)	0.029	0.063	9
Mote Cleaner	0.105	0.232	3
Mote Trash	0.018	0.039	6
Typical Gin	0.948	2.09	98

(Buser et al., 2012a, 2012c, 2012d, 2012e, 2012f, 2012g, 2012h, 2012i, 2012j, 2012k, 2012l, 2013t, 2013y, 2013aa, 2013az, 2013bb, 2013bf)

In addition to sampling with EPA-approved methods, the National Study also performed particle size analysis on samples collected with Method 17 (Buser et al., 2012b). This PSD analysis was collected to add to and further develop EPA AP-42 Appendix B.1. Particle size analysis was performed on the samples with a Beckman Coulter LS230 laser diffraction system (Beckman Coulter, Brea, CA) with software version 3.29. Table 10 contains the emission factors reported in the National Study PSD technical reports (Buser, Whitelock, Boykin, & Holt, 2013an, 2013ao, 2013ap, 2013aq, 2013ar, 2013as, 2013at, 2013au, 2013av, 2013aw, 2013ax, 2013ay, 2014g, 2014h, 2014i, 2014j, 2014k).

Table 10. Emission factors from the National Study PSD Technical Reports.

	$PM_{2.5}$		PM_{10}	
System	**kg/bale**	**lb/bale**	**kg/bale**	**lb/bale**
Unloading	0.0059	0.0130	0.0837	0.1845
1st Stage Seed-Cotton Cleaning	0.0045	0.0100	0.0720	0.1587
2nd Stage Seed-Cotton Cleaning	0.0014	0.0031	0.0252	0.0555
3rd Stage Seed-Cotton Cleaning	0.00090	0.0020	0.0121	0.0266
1st Stage Lint Cleaning	0.0010	0.0022	0.0142	0.0313
2nd Stage Lint Cleaning	0.00024	0.00052	0.0048	0.0105
Combined Lint Cleaning	0.0032	0.0070	0.0596	0.1313
1st Stage Mote	0.00063	0.0014	0.0091	0.0200
2nd Stage Mote	0.00030	0.00067	0.0039	0.0087
Combined Mote	0.0026	0.0056	0.0521	0.1148
Battery Condenser	0.00036	0.00078	0.0078	0.0171
Cyclone Robber	0.00042	0.00093	0.0061	0.0135
Mote Cyclone Robber	0.0011	0.0024	0.0145	0.0321
Master Trash	0.0035	0.0076	0.0480	0.1059
Distributor/Overflow	0.00048	0.0011	0.0089	0.0196
Mote Cleaner	0.0016	0.0036	0.0335	0.0738
Mote Trash	0.0023	0.0051	0.0042	0.0093
Typical Gin	0.0219	0.0482	0.3572	0.7874

(Buser et al., 2013an, 2013ao, 2013ap, 2013aq, 2013ar, 2013as, 2013at, 2013au, 2013av, 2013aw, 2013ax, 2013ay, 2014g, 2014h, 2014i, 2014j, 2014k)

CHAPTER III

PURPOSE AND OBJECTIVES

This project is part of the National Cotton Gin PM Emissions Study initiated in 2008. Through this National Study, a large dataset of emission factors was generated for total PM, PM_{10}, and $PM_{2.5}$ emissions for 17 cotton ginning systems. The purpose of this project was to use EPA AP-42 emission factor development guidelines to develop a set of proposed total PM, PM_{10}, and $PM_{2.5}$ emission factors with quality ratings to be submitted to EPA for approval. The specific objectives were to:

1. Develop proposed EPA AP-42 $PM_{2.5}$ emission factors with quality ratings.
2. Develop proposed EPA revised AP-42 total PM and PM_{10} emission factors with quality ratings.
3. Develop proposed EPA revised AP-42 Appendix B.1 particle size characteristics and PM_{10} and $PM_{2.5}$ emission factors and quality ratings based on total PM emission factors and PSD analysis.
4. Conduct a sensitivity analysis to determine the amount of additional data needed to achieve higher quality ratings for total PM, PM_{10}, and $PM_{2.5}$.

CHAPTER IV

METHODS AND PROCEDURES

The process of rating the National Study data and merging it with the 1996 AP-42 emission factors included removing statistical outliers using residual analysis and EPA's ProUCL outlier determination methodology; rating individual tests using EPA's methodology; and developing robust industry average emission factors using EPA's data quality ratings. Aside from the initial outlier identification, this process followed the procedures outlined by Eastern Research Group (2013) to evaluate the National Study data in the technical reports.

Statistical Evaluation

In the National Study technical reports, test runs that did not meet the EPA-approved stack sampling methodology isokinetic sampling rate (the velocity of the air entering the sampling probe nozzle was not equal to that of the air flowing in the stack) or sampler cutpoint criteria were eliminated from the test averages. When using EPA's Test Quality Rating Tool, data not meeting these sampling criteria were not removed from the dataset unless the data were identified as outliers. However, the rating tool methodology did assign a lower ITR to the data if specific sampling criteria were not met, such as isokinetic sampling rate. The only National Study test runs that were automatically excluded from this evaluation were those with documented erratic gin operation or sample recovery issues.

Residuals were calculated using the following equation:

$$\hat{\varepsilon} = \frac{a_i - \bar{a}_t}{s_y}, \tag{6}$$

where $\hat{\varepsilon}$ was the residual, a_i was the test run value, $\bar{a}_t$ was the average of the test runs for a_i gin, and s_y was the standard deviation for all the test runs for all cotton gins with system y. Test run values with residuals greater/less than ±2 were considered outliers, as advised by the regents service professor and head of department of statistics at Oklahoma State University, M. E. Payton, Ph.D. (personal communication, June 26, 2014).

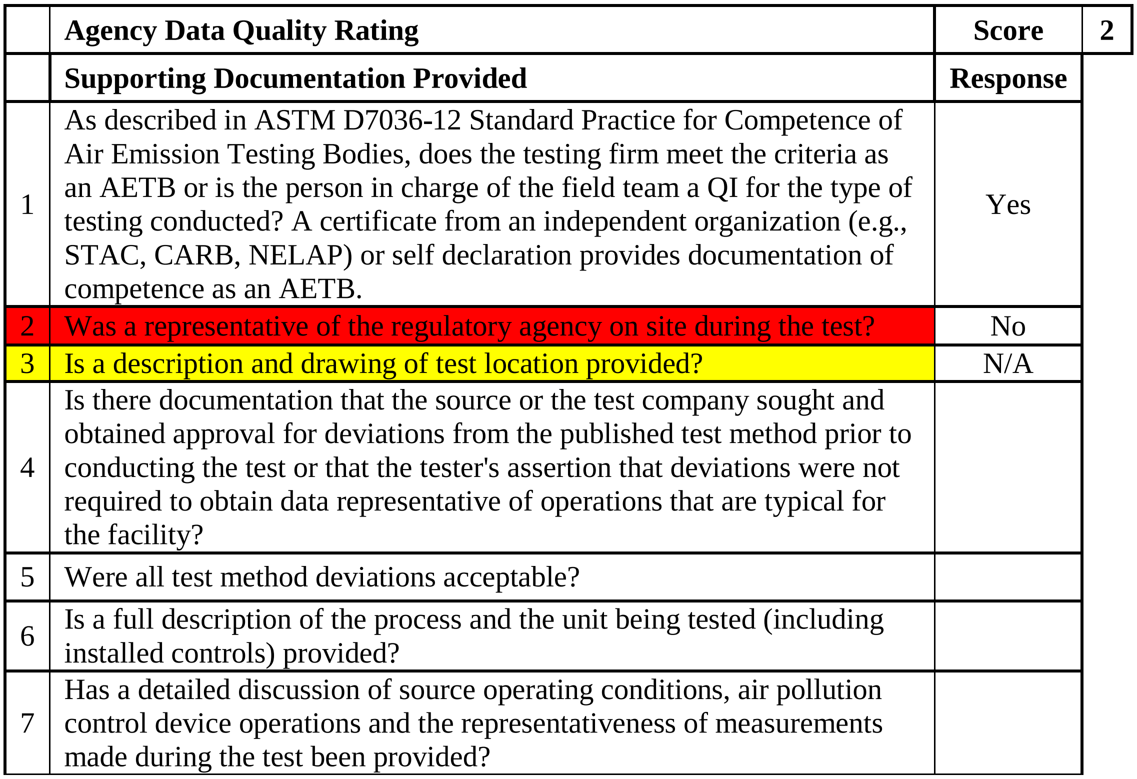
Once test run outliers were determined and removed via residual analyses, the remaining test run emission factor values were log transformed and analyzed with EPA's ProUCL (v.4.1, EPA, 2012, Las Vegas, NV) statistics package according to EPA methodology. Outlier tests with a 5% confidence level were performed separately on individual test run values, stack sampling method averages, and the cotton gin averages for each system. If a dataset had 3 to 24 values, ProUCL applied the Dixon test. For datasets containing more than 24 values, ProUCL applied the Rosner test (Eastern Research Group, 2013). If a value was determined to be an outlier, it was removed from the dataset, and the outlier test was repeated. Outliers were left out of the emission factor calculation.

Data Rating Process

The National Study source tests were published in 68 National Study technical reports (Buser et al., 2012a, 2012c, 2012d, 2012e, 2012f, 2012g, 2012h, 2012i, 2012j, 2012k, 2012l; Buser, Whitelock, Boykin, & Holt, 2013a, 2013b, 2013c, 2013d, 2013e, 2013f, 2013g, 2013h, 2013i, 2013j, 2013k, 2013l, 2013m, 2013n, 2013o, 2013p, 2013q, 2013s, 2013t, 2013u, 2013v, 2013w, 2013x, 2013y, 2013aa, 2013ab, 2013ac, 2013ad, 2013af, 2013ag, 2013ai, 2013aj, 2013ak, 2013al, 2013am, 2013an, 2013ao, 2013ap, 2013aq, 2013ar, 2013as, 2013at, 2013au, 2013av, 2013aw, 2013ax, 2013ay, 2013az, 2013bb, 2013bd, 2013be, 2013bf, 2014g, 2014h, 2014i, 2014j, 2014k). The procedures outlined by Eastern Research Group (2013) were used to evaluate the

National Study technical report data. The first step after eliminating statistical outliers was to develop ITRs that considered a test report's supporting documentation, which was generated during testing. Based on the specific report information, the ITRs were developed by answering an initial series of 16 submitter questions related to the test reports, worth a possible 75 points. Then 47 more in-depth, follow-up regulatory agency review questions were answered about how the tests were conducted. The regulatory review questions could add supplementary points to or subtract points from the submitter review section ITR score and could bring the total ITR score up to 100 points. The questions and their point values are provided in Appendix A. For this project, both the submitter and regulatory review questions were answered by the authors.

An ITR spreadsheet was developed for this study that consisted of the regulatory review questions with their associated number of points plus the pro-rated points from the submitter questions. The spreadsheet followed Eastern Research Group (2013) guidelines. A question response column with a dropdown list of the answers "Yes," "No," or "N/A" (not applicable) was included for each question (Figure 10). The points received for each question were summed and normalized to a maximum score of 100; total points earned divided by the total possible points, then multiplying by 100. If a question was answered "N/A," the points for that question were not included in the total points possible for normalization. Some questions were worth a greater number of points if answered "No" than if answered "Yes." The point value for answering these questions "Yes" was used in the normalization calculation, so that if the question was answered "No," it would subtract points from the score but not from the number of points possible.



	Agency Data Quality Rating	**Score**	**2**
	Supporting Documentation Provided	**Response**	
1	As described in ASTM D7036-12 Standard Practice for Competence of Air Emission Testing Bodies, does the testing firm meet the criteria as an AETB or is the person in charge of the field team a QI for the type of testing conducted? A certificate from an independent organization (e.g., STAC, CARB, NELAP) or self declaration provides documentation of competence as an AETB.	Yes	
2	Was a representative of the regulatory agency on site during the test?	No	
3	Is a description and drawing of test location provided?	N/A	
4	Is there documentation that the source or the test company sought and obtained approval for deviations from the published test method prior to conducting the test or that the tester's assertion that deviations were not required to obtain data representative of operations that are typical for the facility?		
5	Were all test method deviations acceptable?		
6	Is a full description of the process and the unit being tested (including installed controls) provided?		
7	Has a detailed discussion of source operating conditions, air pollution control device operations and the representativeness of measurements made during the test been provided?		

Figure 10. Exert from the individual test rating spreadsheet.

According to the Eastern Research Group (2013) ITR methodology, ITRs are assigned to test reports; however, no specification was given as to what constitutes a test report. In the technical documentation for the National Study, a test report was developed for each sampling methodology for each identified cotton gin system. These reports included tests from one or more cotton gins and each individual test consisted of three test runs. The ITR development questions considered parameters that could be different for each individual test run, such as those relating to isokinetic sampling and sampling time. The ITR methodology was not specific on how to answer specific rating questions when the answers for individual test runs within the same test report for the same system and using the same methodology are different. Further, there was no guidance given as to whether a test run that has an issue (e.g., not meeting isokinetics) that the other test runs for the same evaluation do not have should be ignored in the ITR calculation, be included and possibly lower the overall ITR, or be removed from the test report. For this project, a “test report” was defined as the documentation corresponding to the three individual test runs for a given system at a specific cotton gin using a specific sampling methodology. Because the score could vary between test runs, ITRs were calculated for each individual test run and not each test report. However, due to the lack of specificity in the Eastern Research Group (2013) ITR methodology, it was necessary to determine how the individual test run emission factors and corresponding ITRs were going to be used in calculating system average emission factors, ratings, and the number of tests used in this process. This may seem like a minor issue but how “test” is defined can greatly affect the resulting emission factor and representativeness rating.

To evaluate the potential differences in what constitutes a test, how individual test run ITRs could be used, and how this use could impact the final emission factor values and quality ratings, three different “Test” Designs were developed (Figure 11). For “Test” Design 1, the individual test run ITRs and emission factors for all test runs conducted at a specific cotton gin on a specific cotton ginning system were averaged, resulting in average cotton gin-system ITRs. For “Test” Design 2, the individual test run ITRs and emission factors associated with a specific sampling methodology for a specific cotton ginning system at a specific cotton gin were averaged, resulting in average sampling method ITRs. For “Test” Design 3, there was no averaging of individual test run ITRs or emission factors.

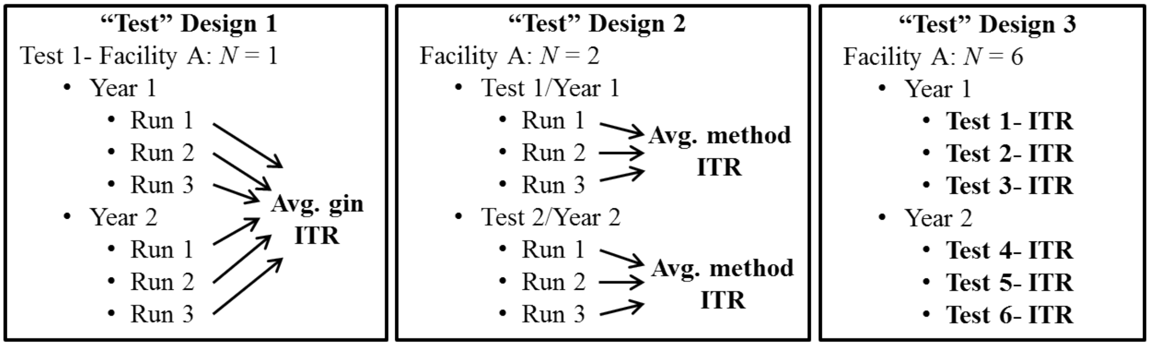


Figure 11. Illistration of the three different “Test” Design configurations that were used to develop emission factors and ratings. (Note: “Year” could designate different testing years, dates within the same year, or different testing methodologies.)

Emissions data from the 1996 AP-42 (EPA, 1996) were also evaluated in this project. ITRs were assigned to the 1996 AP-42 data using two methods. One method used the following scale, provided by Eastern Research Group (2013), to convert the 1996 AP-42 alphabetical rating of these test reports to the numerical ITRs: A = 80, B = 60, C = 45, and D = 30. The second method re-rated the test reports used in the 1996 AP-42 using the Eastern Research Group (2013) ITR methodology that would be used for new data submitted to EPA for inclusion into AP-42. The rerating process assessed and assigned ITRs to individual test runs as previously discussed for new data being submitted to EPA for inclusion into AP-42. The converted ITR ratings for the 1996 AP-42 data were determined for each cotton ginning system for each testing method used or each year it was tested ("Test" Design 2) and not for each individual test run.

Emission Factor Development

Individual Excel™ spreadsheets were developed for "Test" designs 1, 2, and 3 for each of the 17 identified cotton ginning systems. For the "Test" Design 1 spreadsheets, the cotton gin average emission factors and corresponding ITR's were entered for all cotton gins equipped with a given cotton ginning system (e.g., 1st stage seed-cotton cleaning system). This data was sorted in descending ITR order. For the "Test" Design 2 spreadsheets, the method average emission factors and corresponding ITR's were entered for each testing method used at all cotton gins equipped with a given ginning system (e.g., 1st stage seed-cotton cleaning system). This data was sorted in descending ITR order. For the "Test" Design 3 spreadsheets, test run emission factors and corresponding ITRs were entered for all cotton gins equipped with a given cotton ginning system (e.g., 1st stage seed-cotton cleaning system). This data was sorted in descending ITR order. This process was repeated for all 17 systems.

Next, a CTR was calculated using equation 4 (Eastern Research Group, 2013). For a given "Test" Design-cotton gin system spreadsheet, a CTR was calculated for the two highest ITRs, and then again for the top three, then four, and so on until there was a CTR for each possible group of ITRs. Then, an FQI was then calculated for each CTR using equation 5. N was the number of ITRs included in the FQI calculation (Eastern Research Group, 2013). A decrease in FQI indicated an increase in the emission factor data quality. Once an ITR was added that increased the FQI (decreased emission factor quality), the FQI calculations were halted, and the preceding FQI was selected. The emission factors for all "tests" included in FQI calculation prior to the final FQI calculated were averaged to obtain the new AP-42 emission factor. This process as repeated for all "Test" Designs and all 17 cotton ginning systems.

"Representativeness" of the calculated cotton ginning system emission factor was categorized using FQI to determine how well the emission factor statistically characterized the source category emissions for which it was developed. Emission factors with corresponding FQIs less than 0.3015 were rated "highly representative." Emission factors with corresponding FQIs between 0.3015 and 0.5774 were rated "moderately representative." Emission factors with corresponding FQIs greater than 0.5774 were rated "poorly representative" (Eastern Research Group, 2013).

The number of additional tests needed to achieve a "moderately" or "highly" representative rating was determined using equations 7 and 8, respectively:

$$N_a = (30{,}000 * CTR^{-2}) - N \text{ and} \tag{7}$$

$$N_a = (110{,}000 * CTR^{-2}) - N, \tag{8}$$

where N_a was the number of additional tests needed, CTR was the Composite Test Rating for the factor, and N was the number of tests that were used in the emission factor calculation (Eastern Research Group, 2013). The "N_a" calculated with these formulas assumed that the ITRs of any added source tests would not decrease the CTR of the combined tests. Based on the quality (ITR) of the added source tests, N_a could either decrease (with higher quality tests) or increase (with lower quality tests).

The CTR, FQI, and representativeness methods were completed for each of the three "Test" Designs and for each of the 17 cotton ginning systems using only the data from the National Study Method 201a with PM_{10} cyclone only, Method 201a with PM_{10} and $PM_{2.5}$ cyclones, and Method 17. The three "Test" Designs will be subjectively compared to determine the most appropriate method for combining cotton gin PM emission factors for a given system.

Once a "Test" Design was selected, the CTR, FQI and representativeness methods were completed using the selected "Test" Design using the afore mentioned National Study data and the 1996 AP-42 data with converted ITRs. In a third evaluation, the process was repeated using the afore mentioned National Study data and the 1996 AP-42 data with rerated ITRs. The results of these two evaluations, along with the difference between the converted ITRs and the rerated ITRs, will be used to determine whether the 1996 AP-42 data should be rated using the converted ITRs or the rerated ITRs.

In a forth evaluation, the process was repeated with Method 17 PSD data from the National Study. A series of residual analyses was run to determine if the Method 17 PSD data should be combined with the afore mentioned National Study data and the 1996 AP-42 data. In a fifth evaluation, the process was repeated using the afore mentioned National Study data, the 1996 AP-42 data with rerated ITRs, and the Method 17 PSD data from the National Study.

Comparison Process

Emission factors were compared to the 1996 AP-42 emission factors using the percent difference as shown in equation 11:

$$\Delta = \frac{(F_n - F_o)}{F_o} * 100 \tag{9}$$

where Δ was the percent difference, F_n was the emission factor developed in this project, and F_o was the reference emission factor. In addition to comparing the emission factors developed in this study to the 1996 AP-42 emission factors, they were also compared to the emission factors reported in National Study technical reports. The $PM_{2.5}$ emission factors that were compared included those developed using National Study data without PSD and National Study data with PSD. PM_{10} emission factors that were compared included those developed using National Study data without PSD only; National Study data without PSD plus converted 1996 AP-42 data; National Study data without PSD plus rerated 1996 AP-42 data; and National Study data with PSD plus rerated 1996 AP-42 data. The total PM emission factors that were compared included those developed using National Study data only; National Study data plus converted 1996 AP-42 data; and National Study data plus rerated 1996 AP-42 data.

CHAPTER V

RESULTS AND DISCUSSION

Figure 12 shows a graph of the residual analysis results for the $PM_{2.5}$ emission factors (no PSD emission factors) for the unloading system as an example output of the residual analysis. The x-axis corresponds to the order that the test runs were considered in the analysis. Aside from the three test runs conducted for a testing methodology being grouped, the order of the test runs was arbitrary. The y-axis corresponds to residuals calculated using equation 6. The residual analysis results for all 17 cotton ginning systems for $PM_{2.5}$, PM_{10}, and total PM are provided in Appendix C.

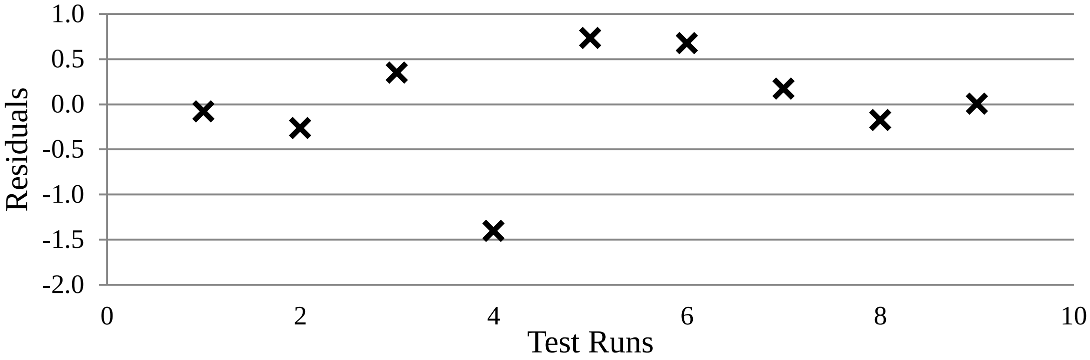


Figure 12. Unloading system residual analysis results for $PM_{2.5}$ test runs.

For the $PM_{2.5}$ data provided by the National Study that used Methods 17 and 201A, three of the 192 test runs were removed from the dataset because of inconsistent gin operation, one test run was removed because of laboratory errors, and one test was removed because it was identified as a residual outlier (Table 11). For the PM_{10} data, nine of the 378 test runs were removed from the dataset for inconsistent gin operation, and two test runs were removed because of laboratory errors. For total PM, eleven of the 576 test runs were removed from the dataset because of inconsistent gin operation, and three test runs were removed because of laboratory errors. For the Method 17 PSD data, five of the 192 test runs were removed from the dataset because of inconsistent gin operation, and eight test runs were removed because of laboratory error.

Table 11. Test runs removed due to inconsistent gin operation, lab errors, and residual tests.

System	**$PM_{2.5}$**	**PM_{10}**	**Total PM**	**PSD**
Unloading		(1) IGO	(1) IGO	
1st Stage Seed-Cotton Cleaning			(1) IGO	(1) IGO
2nd Stage Seed-Cotton Cleaning			(1) IGO	(1) IGO
1st Stage Lint Cleaning	(1) LE	(1) LE	(1) LE	(2) LE
2nd Stage Lint Cleaning		(1) IGO	(1) IGO (1) LE	(1) IGO (6) LE
Combined Lint Cleaning		(1) IGO	(1) IGO	(1) IGO
1st Stage Mote				(1) IGO
2nd Stage Mote	(1) Outlier	(1) IGO	(1) IGO	
Battery Condenser	(1) IGO	(1) IGO	(1) IGO	
Cyclone Robber		(1) IGO	(1) IGO	
Mote Cyclone Robber	(2) IGO	(3) IGO	(3) IGO	
Master Trash		(1) LE	(1) LE	
Mote Trash				
Total	5	11	14	13

IGO = Inconsistent gin operation
LE = Lab error
Outlier = Residual test outlier

ProUCL outlier test results for unloading system $PM_{2.5}$ emissions at a 95% confidence interval were provided in Table 12. The information in Table 12 includes the number of tests that were considered in the analysis (changes with “Test” Design), the critical value associated with the 95% confidence interval, a potential outlier value, the test statistic for the potential outlier value, and whether or not the potential outlier value was an outlier or not. For the Dixon test (number of tests < 25), potential outliers were identified for the upper and lower tails of the dataset. For the Rosner test (number of tests ≥ 25), a potential outlier was only identified for one of the two tails of the dataset. If a dataset contained less than 3 tests, no outlier test was performed. The ProUCL outlier test results for all 17 cotton ginning systems for $PM_{2.5}$, PM_{10}, and total PM were provided in Appendix C.

Table 12. ProUCL outlier test results of $\log_{10}$-transformed $PM_{2.5}$ emissions for unloading system ($\alpha = 0.05$).

	"Test" Design 2	**"Test" Design 3**
Tests	3	9
Critical Value	0.941	0.512
Upper Tail		
Potential Outlier	-1.188	-1.132
Test Statistic	0.142	0.010
Outlier?	No	No
Lower Tail		
Potential Outlier	-1.600	-1.678
Test Statistic	0.858	0.094
Outlier?	No	No

The emission factors and associated industry representativeness ratings calculated from only the National Study data using the three "Test" Designs are shown for $PM_{2.5}$, PM_{10}, and total PM in Tables 13, 14, 15, respectively. "Test" Designs 1 and 2 for the initial $PM_{2.5}$ emission factor dataset produced identical results because only one method was used at each cotton gin. The $PM_{2.5}$ emission factors and corresponding ratings for Designs 2 and 3 were provided in Table 13. Using a 5% confidence level with ProUCL, three cotton gin averages were identified as outliers for "Test" Design 2: 1st stage seed-cotton cleaning, gin A; battery condenser, gin C; and mote cyclone robber, gin D. It should be noted that for the mote cyclone robber system, the gin D average consisted of a single test run because of inconsistent gin operation during the other two runs. Two test runs were identified as outliers for “Test” Design 3: 2nd stage seed-cotton cleaning, gin E- run 1 and 2nd stage mote system, gin A- run 1. For “Test” Design 2, seven of the 17 emission factors were rated as “poorly representative” and ten were rated as “moderately representative” emission factors. “Test” Design 3 produced a total of eight “moderately representative” emission factors and nine “highly representative” emission factors.

Seventy-six percent of the $PM_{2.5}$ system average emission factors were identical for “Test” Designs 2 and 3. Two $PM_{2.5}$ emission factors and corresponding rating, unloading and combined lint cleaning, were the same for both Design 2 and 3. Sixty-five percent of the $PM_{2.5}$ emission factors were the same for both designs but had higher corresponding ratings for Design 3 than Design 2. Designs 2 and 3 produced different emission factors when all of the same test runs were not included in the emission factor development due to statistical outliers being removed or having a low corresponding ITR. The higher ratings for emission factors developed using Design 3 were because *N* increased when using test runs as opposed to sampling method averages. The Design 2 typical gin emission factor was 0.4% higher than the Design 3 typical gin emission factor.

Table 13a. $PM_{2.5}$ emission factors in kg/bale and emission factor ratings for the National Study $PM_{2.5}$ dataset (excluding PSD data) as determined using "Test" Designs 2 and 3.

	"Test" Design 2		**"Test" Design 3**	
System	**Emission Factor**†	**Rating***	**Emission Factor**†	**Rating***
Unloading	0.0221	P	0.0221	M
1st Stage Seed-Cotton Cleaning	0.0081	M	0.0081	H
2nd Stage Seed-Cotton Cleaning	0.0036	M	0.0035	H
3rd Stage Seed-Cotton Cleaning	0.0040	P	0.0040	M
1st Stage Lint Cleaning	0.0085	M	0.0084	M
2nd Stage Lint Cleaning	0.0048	M	0.0048	H
Combined Lint Cleaning	0.0138	M	0.0138	M
1st Stage Mote	0.0039	M	0.0039	H
2nd Stage Mote	0.0022	M	0.0022	H
Combined Mote	0.0095	P	0.0095	M
Battery Condenser	0.0035	M	0.0032	H
Cyclone Robber	0.0016	P	0.0014	H
Mote Cyclone Robber	0.0043	P	0.0026	M
Master Trash	0.0044	M	0.0044	H
Overflow (Distributer)	0.0041	M	0.0041	H
Mote Cleaner	0.0130	P	0.0130	M
Mote Trash	0.0011	P	0.0011	M
Typical Gin	0.0690		0.0687	

*P = Poorly
M = Moderately
H = Highly

†kg/bale

Table 13b. $PM_{2.5}$ emission factors in lb./bale and emission factor ratings for the National Study $PM_{2.5}$ dataset (excluding PSD data) as determined using "Test" Designs 2 and 3.

	"Test" Design 2		**"Test" Design 3**	
System	**Emission Factor†**	**Rating***	**Emission Factor†**	**Rating***
Unloading	0.0488	P	0.0488	M
1st Stage Seed-Cotton Cleaning	0.0178	M	0.0178	H
2nd Stage Seed-Cotton Cleaning	0.0080	M	0.0076	H
3rd Stage Seed-Cotton Cleaning	0.0088	P	0.0088	M
1st Stage Lint Cleaning	0.0188	M	0.0185	M
2nd Stage Lint Cleaning	0.0106	M	0.0106	H
Combined Lint Cleaning	0.0303	M	0.0303	M
1st Stage Mote	0.0085	M	0.0085	H
2nd Stage Mote	0.0048	M	0.0049	H
Combined Mote	0.0209	P	0.0209	M
Battery Condenser	0.0077	M	0.0071	H
Cyclone Robber	0.0035	P	0.0030	H
Mote Cyclone Robber	0.0094	P	0.0058	M
Master Trash	0.0098	M	0.0098	H
Overflow (Distributer)	0.0091	M	0.0091	H
Mote Cleaner	0.0287	P	0.0287	M
Mote Trash	0.0024	P	0.0024	M
Typical Gin	0.1521		0.1515	

*P = Poorly
M = Moderately
H = Highly

†lb/bale

At a 5% confidence level, ProUCL returned no outliers for any of the "Test" Designs for PM_{10}. "Test" Design 1 produced 5 "poorly representative" factors and 12 "moderately representative" factors. "Test" Design 2 produced 15 "moderately representative" factors and 2 "highly representative" emission factors. "Test" Design 3 produced 1 "moderately representative" factor and 16 "highly representative" factors (Table 14).

Thirty-five percent of the PM_{10} system average emission factors were identical for "Test" Designs 1, 2, and 3. No emission factors had the same corresponding rating across all three designs, and 24% of the emission factors had corresponding ratings of "poorly" in Design 1, "moderately" in Design 2, and "highly" in Design 3. Additionally, all but one emission factor, mote cleaner, had corresponding ratings of "highly" in Design 3. This could indicate that Design

3 may overestimate emission factor representativeness of the industry. The Design 2 typical gin emission factor was 0.57% higher than the Design 1 typical gin emission factor. The Design 3 typical gin emission factor was 1.29 and 1.84% lower than the Design 1and Design 2 typical gin emission factors, respectively. The minute differences between the emission factors developed from the different "Test" Designs indicate that the designs have a greater effect on the ratings of the emission factors than on the emission factors themselves.

Table 14a: PM_{10} emission factors in kg/bale and emission factor ratings for the National Study PM_{10} dataset (excluding PSD and 1996 AP-42 data) as determined using "Test" Designs 1, 2, and 3.

	"Test" Design 1		**"Test" Design 2**		**"Test" Design 3**	
System	**Emission Factor†**	**Rating***	**Emission Factor†**	**Rating***	**Emission Factor†**	**Rating***
Unloading	0.1031	M	0.1034	M	0.1029	H
1st Stage Seed-Cotton Cleaning	0.0847	M	0.0847	H	0.0847	H
2nd Stage Seed-Cotton Cleaning	0.0376	M	0.0376	M	0.0376	H
3rd Stage Seed-Cotton Cleaning	0.0209	P	0.0209	M	0.0209	H
1st Stage Lint Cleaning	0.0572	M	0.0599	M	0.0558	H
2nd Stage Lint Cleaning	0.0197	M	0.0197	M	0.0193	H
Combined Lint Cleaning	0.1341	M	0.1369	M	0.1272	H
1st Stage Mote	0.0203	M	0.0203	M	0.0203	H
2nd Stage Mote	0.0099	M	0.0097	M	0.0099	H
Combined Mote	0.1012	P	0.1012	M	0.1012	H
Battery Condenser	0.0179	M	0.0181	H	0.0176	H
Cyclone Robber	0.0104	M	0.0078	M	0.0091	H
Mote Cyclone Robber	0.0265	P	0.0264	M	0.0237	H
Master Trash	0.0559	M	0.0559	M	0.0563	H
Overflow (Distributer)	0.0218	M	0.0218	M	0.0218	H
Mote Cleaner	0.0622	P	0.0598	M	0.0632	M
Mote Trash	0.0107	P	0.0107	M	0.0107	H
Typical Gin	0.5564		0.5596		0.5493	

*P = Poorly
M = Moderately
H = Highly

†kg/bale

Table 14b. PM_{10} emission factors in lb./bale and emission factor ratings for the National Study PM_{10} dataset (excluding PSD and 1996 AP-42 data) as determined using "Test" Designs 1, 2, and 3.

System	"Test" Design 1 Emission Factor†	"Test" Design 1 Rating*	"Test" Design 2 Emission Factor†	"Test" Design 2 Rating*	"Test" Design 3 Emission Factor†	"Test" Design 3 Rating*
Unloading	0.2273	M	0.2279	M	0.2268	H
1st Stage Seed-Cotton Cleaning	0.1868	M	0.1868	H	0.1868	H
2nd Stage Seed-Cotton Cleaning	0.0829	M	0.0829	M	0.0829	H
3rd Stage Seed-Cotton Cleaning	0.0461	P	0.0461	M	0.0461	H
1st Stage Lint Cleaning	0.1260	M	0.1320	M	0.1231	H
2nd Stage Lint Cleaning	0.0434	M	0.0433	M	0.0425	H
Combined Lint Cleaning	0.2957	M	0.3017	M	0.2804	H
1st Stage Mote	0.0447	M	0.0447	M	0.0447	H
2nd Stage Mote	0.0217	M	0.0214	M	0.0219	H
Combined Mote	0.2231	P	0.2231	M	0.2231	H
Battery Condenser	0.0395	M	0.0400	H	0.0388	H
Cyclone Robber	0.0229	M	0.0172	M	0.0202	H
Mote Cyclone Robber	0.0583	P	0.0582	M	0.0522	H
Master Trash	0.1232	M	0.1231	M	0.1241	H
Overflow (Distributer)	0.0481	M	0.0481	M	0.0481	H
Mote Cleaner	0.1371	P	0.1319	M	0.1392	M
Mote Trash	0.0236	P	0.0236	M	0.0236	H
Typical Gin	1.2266		1.2336		1.2110	

*P = Poorly
M = Moderately
H = Highly

†lb/bale

Using a 5% confidence level in ProUCL for total PM, one cotton gin average was returned as an outlier: 1st stage seed-cotton cleaning, gin C. Two outliers were identified for Design 3: 2nd stage seed-cotton cleaning, run 1 from gin D and mote cleaner, run 1 from gin G, both using Method 201A with PM_{10} and $PM_{2.5}$ cyclones. "Test" Design 1 produced 7 "poorly representative" factors and 10 "moderately representative" factors. Design 2 produced 8 "moderately representative" factors and 9 "highly representative" factors. All 17 emission factors developed using Design 3 were "highly representative" (Table 15).

Twenty-nine percent of the total PM system average emission factors were identical for "Test" Designs 1, 2, and 3. No emission factors had the same corresponding rating across all three designs, and 41% of the emission factors had corresponding ratings of "poorly" in Design 1, "moderately" in Design 2, and "highly" in Design 3. Additionally, all emission factor had corresponding ratings of "highly" in Design 3. This could indicate that Design 3 may overestimate emission factor representativeness of the industry. The Design 2 typical gin emission factor was 0.33% lower than the Design 1 typical gin emission factor. The Design 3 typical gin emission factor was 1.92 and 1.59% lower than the Design 1and Design 2 typical gin emission factors, respectively. The minute differences between the emission factors developed from the different "Test" Designs indicate that the designs have a greater effect on the ratings of the emission factors than on the emission factors themselves.

Table 15a. Total PM emission factors in kg/bale and emission factor ratings for the National Study PM_{10} dataset (excluding PSD and 1996 AP-42 data) as determined using "Test" Designs 1, 2, and 3.

	"Test" Design 1		**"Test" Design 2**		**"Test" Design 3**	
System	**Emission Factor**[†]	**Rating***	**Emission Factor**[†]	**Rating***	**Emission Factor**[†]	**Rating***
Unloading	0.1278	P	0.1284	M	0.1281	H
1st Stage Seed-Cotton Cleaning	0.1463	M	0.1360	H	0.1353	H
2nd Stage Seed-Cotton Cleaning	0.0557	M	0.0559	H	0.0570	H
3rd Stage Seed-Cotton Cleaning	0.0257	P	0.0257	M	0.0257	H
1st Stage Lint Cleaning	0.0792	M	0.0813	H	0.0783	H
2nd Stage Lint Cleaning	0.0300	M	0.0334	H	0.0287	H
Combined Lint Cleaning	0.2396	M	0.2459	M	0.2298	H
1st Stage Mote	0.0286	M	0.0286	H	0.0286	H
2nd Stage Mote	0.0122	M	0.0121	H	0.0122	H
Combined Mote	0.1403	P	0.1403	M	0.1403	H
Battery Condenser	0.0352	M	0.0352	H	0.0341	H
Cyclone Robber	0.0174	P	0.0171	M	0.0152	H
Mote Cyclone Robber	0.0451	P	0.0452	M	0.0433	H
Master Trash	0.1610	M	0.1611	H	0.1633	H
Overflow (Distributer)	0.0385	M	0.0385	H	0.0385	H
Mote Cleaner	0.1003	P	0.1003	M	0.1034	H
Mote Trash	0.0190	P	0.0190	M	0.0190	H
Typical Gin	0.9444		0.9413		0.9263	

*P = Poorly
M = Moderately
H = Highly

[†] kg/bale

The emission factors developed using "Test" Designs were different from those in the National Study reports. For the National Study, test runs that did not meet isokinetic sampling rate or cut point criteria were not considered in the average emission factors. For the ITR methodology, test runs that did not meet the isokinetic sampling rate criteria received lower ITRs but were still considered in the emission factor calculations. Cut point criteria was not mentioned in Eastern Research Group (2013), so test runs that did not meet cut point criteria were included in emission factor calculation without a deduction to their ITRs. Because test runs that did not meet isokinetic sampling rate or cut point criteria were considered using the ITR methodology, an additional 22 test runs were considered for PM$_{2.5}$, 80 additional test runs for PM$_{10}$, and 73 additional test runs for total PM. This study also combined test runs from the different sampling methodologies, which was not done by the National Study.

Table 15b. Total PM emission factors in lb./bale and emission factor ratings for the National Study PM$_{10}$ dataset (excluding PSD and 1996 AP-42 data) as determined using "Test" Designs 1, 2, and 3.

	"Test" Design 1		**"Test" Design 2**		**"Test" Design 3**	
System	**Emission Factor†**	**Rating***	**Emission Factor†**	**Rating***	**Emission Factor†**	**Rating***
Unloading	0.2818	P	0.2831	M	0.2823	H
1st Stage Seed-Cotton Cleaning	0.3225	M	0.2999	H	0.2983	H
2nd Stage Seed-Cotton Cleaning	0.1229	M	0.1232	H	0.1257	H
3rd Stage Seed-Cotton Cleaning	0.0567	P	0.0567	M	0.0567	H
1st Stage Lint Cleaning	0.1746	M	0.1793	H	0.1726	H
2nd Stage Lint Cleaning	0.0661	M	0.0736	H	0.0632	H
Combined Lint Cleaning	0.5283	M	0.5420	M	0.5066	H
1st Stage Mote	0.0632	M	0.0632	H	0.0632	H
2nd Stage Mote	0.0268	M	0.0266	H	0.0269	H
Combined Mote	0.3094	P	0.3094	M	0.3094	H
Battery Condenser	0.0776	M	0.0776	H	0.0752	H
Cyclone Robber	0.0383	P	0.0377	M	0.0335	H
Mote Cyclone Robber	0.0993	P	0.0996	M	0.0954	H
Master Trash	0.3549	M	0.3552	H	0.3599	H
Overflow (Distributer)	0.0848	M	0.0848	H	0.0848	H
Mote Cleaner	0.2212	P	0.2212	M	0.2279	H
Mote Trash	0.0419	P	0.0419	M	0.0419	H
Typical Gin	2.0821		2.0751		2.0422	

*P = Poorly
M = Moderately
H = Highly

†lb/bale

The different "Test" Designs, in some instances, resulted in different average emission factors. These differences were attributed to the option of individual test runs in Design 3 to be removed from the dataset, where Design 2 only provides the option for sets of three test runs (test method averages) to be removed. Further, Design 1 only provides the option to remove cotton gin averages, which could include 3 to 9 test runs depending on how many different methods were used at the cotton gin. If a test run was removed based on ProUCL analysis for “Test” Design 3 (but not by the residual test), it would have been included in the method and cotton gin averages for Designs 2 and 1, respectively. The same was true for method averages that could have been outliers in Design 2 but could have remained in Design 1. For example, one of the “Test” Design 2 average PM_{10} emission factors for the cyclone robber system was identified as an outlier by ProUCL analysis and removed from the dataset, but those three test run values were not identified as outliers in Design 3 and were not removed from the dataset. Further, these test values were not removed in Design 1 when incorporated into the cotton gin average. Because those values were higher than most others in the dataset, their removal caused the emission factor for Design 2 to be lower than those in the other Designs. This also occurred for Design 1 with the mote cleaner system PM_{10} emission factor, except the dropped value was lower, which caused the emission factor to increase.

Similar to the variation between “Test” Designs caused by the removal of outliers, the emission factors could also vary between “Test” Designs due to low ITRs. An emission factor from a single test run with a low ITR could have been removed in Design 3. However, when this test run was averaged in with the other test run values from the same testing method or cotton gin, the averaged ITR could have been high enough to include the value. Conversely, for Designs 1 and 2, if multiple ITRs from the same testing method or cotton gin were low, the average could have been low enough to remove those test runs from the emission factor calculation. This would have caused emission factors for individual test runs that could have been included in Design 3 not to be included in Designs 1 or 2.

Another source of variation between the “Test” Designs in this study was caused by the emission factor being the average of averages for Designs 1 and 2. For example, the unloading system had 18 test runs for PM_{10}, and one test run was removed due to inconsistent gin operation. When the Design 3 emission factor was calculated, it used 17 as the denominator in its average emission factor calculation. However, since the number of sampling method averages and cotton gin averages was unchanged, Designs 1 and 2 for the PM_{10} still used 3 and 6, respectively, in the denominators of their average emission factor calculations. This was the reason for the 0.0005 kg per bale difference between Designs 2 and 3 for the unloading system PM_{10} emission factors. Some systems that appear to have the same emission factor for two Designs but were different for the other Design (e.g., PM_{10} for 2^{nd} stage mote system) most likely also have variation caused by averaging averages, but the variation is less than 0.0001 kg per bale. If no test run values were removed from a dataset during data screening, then this issue did not occur for that dataset.

Most of the differences in representativeness ratings were due to the basic unit of consideration of the "Test" Designs, *N* – number of tests. Design 1 had only one *N* per cotton gin, Design 2 had one *N* per method, and Design 3 had one *N* per test run. As long as additional ITRs do not decrease the CTR, increasing *N* will improve the representativeness rating.

While Design 3 eliminates the majority of issues previously identified, it artificially increases *N*. With this Design, a facility could bias an emission factor by having a larger number of test runs performed at one cotton gin the same year. Additionally, because the test runs used for *N* in this design are repeated measures and not replicates, these ratings falsely inflate the factors' actual representativeness of the industry. However, if "Test" Design 1 was used, all tests from a single cotton gin, even over multiple years, would be averaged and used as a single data point. This would greatly reduce the power of the outlier screening. It creates the potential for all data from a single facility to be removed from the system average emission factor if that facility's average emission factor ever became an outlier or the corresponding ITR dropped too low. "Test" Design 2, which uses sampling method averages as *N*, provides the most balanced design for developing cotton gin emission factors. Using the method averages allows for variation between multiple methods to be taken into account and for method averages that are outliers to be removed. Additionally, “Test” Design 2 would allow for tests performed over multiple years at the same cotton gin to be included in the emission factors as separate “test.” This is the same method that was used in the 1996 AP-42, and would allow for the removal of unrepresentative datasets. Since cotton crops and growing conditions vary from year to year, and even from field to field within the same year, it is important that tests be done over multiple years, but it is also important that a mechanism exists to screen for unrepresentative datasets. For these reasons, “Test” Design 2 was selected as the basis for developing cotton gin PM emission factors and was the only “Test” Design used from this point forward in this discussion. The emission factors developed in this section using “Test” Design 2 will hereafter be referred to as *ITR-rated* emission factors.

1996 AP-42 Data

ITRs for the 1996 AP-42 datasets were assigned using the conversion method specified by Eastern Research Group (2013). For PM_{10}, 98% of these datasets had an original rating of “B” (the highest rating of the PM_{10} datasets), which resulted in a converted ITR of 60 (Table 16). One dataset had an original rating of “D,” which resulted in a converted ITR of 30.

The Eastern Research Group (2013) ITR methodology was used to rerate the 1996 AP-42 PM_{10} datasets. The resulting ITRs ranged from 29 to 92. Seventy-eight percent of the rerated 1996 AP-42 datasets had ITRs equal to or greater than 80, 16% of the datasets had ITRs between 60 and 80 (Table 16). Only 7% of rerated PM_{10} 1996 AP-42 datasets had ITRs equal to or less than 60, as compared to 100% when the ITRs were converted from the alphabetical ratings.

New cotton gin PM_{10} emission factors were developed using only the 1996 AP-42 data and converting their alphabetical ratings to numerical ITRs. The resulting emission factors were identical to those in the 1996 AP-42, and all were rated as “poorly representative” (Table 17). The same source tests that were not included in the 1996 AP-42 because of low quality rating were also removed from the datasets.

Table 16. PM_{10} source tests from the 1996 AP-42 with their emission factors, converted ITRs, and rerated ITRs.

System	AP-42 Ref. No.	Emission Factor		ITR	
		kg/bale	lb/bale	Converted	Rerated
Unloading	5	0.10	0.22	60	87
Unloading	6	0.069	0.15	60	86
Unloading	9	0.024	0.053	60	73
Unloading	14	0.035	0.078	60	87
Unloading	16	0.052	0.12	60	87
1st Stage Seed-Cotton Cleaning	4	0.049	0.11	60	88
1st Stage Seed-Cotton Cleaning	5	0.096	0.21	60	87
1st Stage Seed-Cotton Cleaning	6	0.050	0.11	60	86
1st Stage Seed-Cotton Cleaning	9	0.040	0.089	60	73
1st Stage Seed-Cotton Cleaning	13	0.039	0.088	60	85
2nd Stage Seed-Cotton Cleaning	1	0.042	0.093	60	83
2nd Stage Seed-Cotton Cleaning	4	0.11	0.23	60	88
2nd Stage Seed-Cotton Cleaning	6	0.024	0.053	60	86
2nd Stage Seed-Cotton Cleaning	9	0.022	0.048	60	73
2nd Stage Seed-Cotton Cleaning	16	0.018	0.04	60	87
3rd Stage Seed-Cotton Cleaning	2	0.014	0.030	60	29
3rd Stage Seed-Cotton Cleaning	8	0.016	0.035	60	87
Combined Lint Cleaning	5	0.42	0.93	60	87
Combined Lint Cleaning	6	0.072	0.16	60	86
Combined Lint Cleaning	9	0.028	0.062	60	73
Combined Lint Cleaning	13	0.050	0.011	60	87
Combined Lint Cleaning	14	0.10	0.22	60	90
Combined Lint Cleaning	15	0.020	0.043	60	89
Combined Mote	3	0.040	0.089	60	90
Combined Mote	4	0.023	0.050	60	88
Combined Mote	5	0.14	0.30	60	87
Combined Mote	6	0.079	0.17	60	86
Combined Mote	9	0.048	0.11	60	73
Combined Mote*	15	0.029	0.064	30	89
Combined Mote	16	0.027	0.029	60	87
Battery Condenser	6	0.0058	0.013	60	86
Battery Condenser	8	0.0077	0.017	60	87
Battery Condenser	9	0.011	0.025	60	73
Battery Condenser	15	0.0036	0.0079	60	89
Battery Condenser	16	0.0039	0.0085	60	87
Cyclone Robber	14	0.024	0.052	60	90

Table 16 (cont.). PM_{10} source tests from the 1996 AP-42 with their emission factors, converted ITRs, and rerated ITRs.

System	AP-42 Ref. No.	Emission Factor		ITR	
		kg/bale	lb/bale	Converted	Rerated
Master Trash	7	0.051	0.11	60	81
Master Trash	14	0.017	0.038	60	90
Overflow (Distributor)	2	0.016	0.036	60	29
Overflow (Distributor)	6	0.012	0.027	60	86
Overflow (Distributor)	9	0.0020	0.0045	60	73
Overflow (Distributor)	16	0.017	0.038	60	87
Mote Trash	2	0.018	0.040	60	29
Mote Trash	3	0.0021	0.0046	60	90
Mote Trash	14	0.0083	0.018	60	90

* - not used in 1996 AP-42

PM_{10} emission factors were also developed using only the 1996 AP-42 data and rerating the source tests using Eastern Research Group's (2013) ITR methodology. Only four of these emission factors (3rd stage seed-cotton cleaning, combined mote, overflow, and mote trash) were different from the emission factors developed using converted source test ratings, and the typical gin PM_{10} emission factor decreased by 1.5% and included one additional test (Table 17). Fifty-five percent of the rerated PM_{10} emission factors rated as “moderately representative,” which was a significant improvement over the ratings of the emission factors developed using the converted source test ratings.

When the Eastern Research Group's (2013) conversion methodology was used to convert total PM data ratings to ITRs, 67% of the datasets had an original rating of “A,” which resulted in a converted ITR of 80, 20% of the datasets had an original rating of “B,” which resulted in a converted ITR of 60, and 13% of the datasets had an original rating of “D,” which resulted in a converted ITR of 30 (Table 18).

Table 17a. Cotton gin PM_{10} emission factors in kg/bale created using only the 1996 AP-42 data to comapare converting to rerating the data quality ratings.

	Converted AP-42			**Rerated AP-42**		
System	**Emission Factor**†	**Rating***	**No. of Tests**	**Emission Factor**†	**Rating***	**No. of Tests**
Unloading	0.056	P	5	0.056	M	5
1st Stage Seed Cotton Cleaning	0.055	P	5	0.055	M	5
2nd Stage Seed Cotton Cleaning	0.042	P	5	0.042	M	5
3rd Stage Seed Cotton Cleaning	0.015	P	2	0.016	P	1
Combined Lint Cleaning	0.11	P	6	0.11	M	7
Combined Mote	0.059	P	6	0.055	M	7
Battery Condenser	0.0065	P	5	0.0065	M	5
Cyclone Robber	0.024	P	1	0.024	P	3
Master Trash	0.034	P	2	0.034	P	2
Overflow (Distributer)	0.012	P	4	0.011	P	3
Mote Trash	0.0095	P	3	0.0051	P	3
Typical Gin	0.37		38	0.37		39

* P = Poorly
M = Moderately

† kg/bale

When the 1996 AP-42 total PM datasets were rerated using the Eastern Research Group (2013) ITR methodology, 80% of the rerated 1996 AP-42 datasets had ITRs equal to or greater than 80, 11% of the datasets had ITRs between 60 and 80 (Table 18). Only 9% of rerated 1996 AP-42 total PM datasets had ITRs equal to or less than 60, as compared to 33% when the ITRs were converted from the alphabetical ratings.

New cotton gin total PM emission factors were developed using only the 1996 AP-42 data and converting their alphabetical ratings to numerical ITRs. The resulting emission factors were identical to those in the 1996 AP-42. Forty-five percent of the emission factors were rated as “poorly representative,” and 55% were rated as “moderately representative” (Table 19). The same source tests that were not included in the 1996 AP-42 because of low quality rating were also removed from the datasets.

Table 17b. Cotton gin PM_{10} emission factors in lb/bale created using only the 1996 AP-42 data to comapare converting to rerating the data quality ratings.

	Converted AP-42			Rerated AP-42		
System	**Emission Factor†**	**Rating***	**No. of Tests**	**Emission Factor†**	**Rating***	**No. of Tests**
Unloading	0.12	P	5	0.12	M	5
1st Stage Seed Cotton Cleaning	0.12	P	5	0.12	M	5
2nd Stage Seed Cotton Cleaning	0.093	P	5	0.093	M	5
3rd Stage Seed Cotton Cleaning	0.033	P	2	0.035	P	1
Combined Lint Cleaning	0.24	P	6	0.24	M	7
Combined Mote	0.13	P	6	0.12	M	7
Battery Condenser	0.014	P	5	0.014	M	5
Cyclone Robber	0.052	P	1	0.052	P	3
Master Trash	0.074	P	2	0.074	P	2
Overflow (Distributer)	0.026	P	4	0.023	P	3
Mote Trash	0.021	P	3	0.011	P	3
Typical Gin	0.82		38	0.81		39

* P = Poorly
M = Moderately

†lb/bale

Total PM emission factors were also developed using only the 1996 AP-42 data and rerating the source tests using Eastern Research Group's (2013) ITR methodology. Only three of these emission factors (1st stage seed-cotton cleaning, combined lint cleaning, and cyclone robber) were identical to the emission factors developed using converted source test ratings, and the typical gin total PM emission factor decreased by 11% and included the same number of tests (Table 19). Sixty-four percent of the rerated total PM emission factors rated as “moderately representative,” which was a moderate improvement over the ratings of the emission factors developed using the converted source test ratings.

*Table 18.*Total PM source tests from the 1996 AP-42 with their emission factors, converted ITRs and rerated ITRs.

System	AP-42 Ref. No.	Emission Factor		ITR	
		kg/bale	lb/bale	Converted	Rerated
Unloading	5	0.10	0.22	60	87
Unloading	6	0.14	0.30	80	86
Unloading	9	0.041	0.090	80	73
Unloading*	10	0.0078	0.017	30	92
Unloading	11	0.11	0.25	80	91
Unloading	11	0.16	0.36	60	91
Unloading	12	0.18	0.40	60	32
Unloading	14	0.16	0.34	80	87
Unloading	16	0.15	0.15	80	87
1st Stage Seed-Cotton Cleaning	4	0.14	0.30	60	88
1st Stage Seed-Cotton Cleaning	5	0.25	0.54	60	87
1st Stage Seed-Cotton Cleaning	6	0.11	0.24	80	86
1st Stage Seed-Cotton Cleaning	9	0.18	0.39	80	73
1st Stage Seed-Cotton Cleaning*	10	0.027	0.059	30	92
1st Stage Seed-Cotton Cleaning	11	0.16	0.35	80	91
1st Stage Seed-Cotton Cleaning	11	0.18	0.39	80	91
1st Stage Seed-Cotton Cleaning	13	0.14	0.30	80	85
2nd Stage Seed-Cotton Cleaning	1	0.10	0.22	80	83
2nd Stage Seed-Cotton Cleaning	4	0.36	0.79	60	88
2nd Stage Seed-Cotton Cleaning	6	0.047	0.10	80	86
2nd Stage Seed-Cotton Cleaning	9	0.093	0.21	80	73
2nd Stage Seed-Cotton Cleaning*	10	0.017	0.037	30	92
2nd Stage Seed-Cotton Cleaning	11	0.056	0.12	80	91
2nd Stage Seed-Cotton Cleaning	11	0.069	0.15	80	91
2nd Stage Seed-Cotton Cleaning	16	0.050	0.11	80	87
3rd Stage Seed-Cotton Cleaning	2	0.041	0.091	80	29
3rd Stage Seed-Cotton Cleaning	8	0.045	0.099	80	87
Combined Lint Cleaning	5	1.0	2.3	60	87
Combined Lint Cleaning	6	0.13	0.29	80	86
Combined Lint Cleaning	9	0.057	0.13	80	73
Combined Lint Cleaning	13	0.18	0.39	80	87
Combined Lint Cleaning	14	0.14	0.30	80	90
Combined Lint Cleaning	15	0.041	0.090	80	89
Combined Mote	3	0.095	0.21	60	90
Combined Mote	4	0.049	0.11	60	88
Combined Mote	5	0.47	1.0	60	87

Table 17 (cont.). Total PM source tests from the 1996 AP-42 with their emission factors, converted ITRs, and rerated ITRs.

System	**AP-42 Ref. No.**	**Emission Factor**		**ITR**	
		kg/bale	**lb/bale**	**Converted**	**Rerated**
Combined Mote	6	0.15	0.33	80	86
Combined Mote	9	0.076	0.17	80	73
Combined Mote*	10	0.032	0.070	30	92
Combined Mote	11	0.070	0.15	80	91
Combined Mote	12	0.14	0.30	60	32
Combined Mote	15	0.055	0.12	80	89
Combined Mote	16	0.045	0.099	80	87
Battery Condenser	6	0.037	0.082	80	86
Battery Condenser	8	0.019	0.042	80	87
Battery Condenser	9	0.016	0.036	80	73
Battery Condenser	15	0.0059	0.013	80	89
Battery Condenser	16	0.011	0.024	80	87
Cyclone Robber	14	0.083	0.18	80	90
Master Trash*	7	0.18	0.40	80	81
Master Trash	10	0.033	0.073	30	92
Master Trash	11	0.14	0.31	80	91
Master Trash	11	0.57	1.3	80	91
Master Trash	14	0.060	0.13	80	90
Overflow (Distributor)	2	0.046	0.10	80	29
Overflow (Distributor)*	6	0.020	0.044	80	86
Overflow (Distributor)	9	0.005	0.011	80	73
Overflow (Distributor)	10	0.013	0.029	30	92
Overflow (Distributor)	16	0.059	0.13	80	87
Mote Trash*	2	0.031	0.067	80	29
Mote Trash	3	0.051	0.11	60	90
Mote Trash	10	0.020	0.045	30	92
Mote Trash	12	0.075	0.17	30	32
Mote Trash*	14	0.025	0.055	60	90

* - not used in 1996 AP-42

Table 19. Cotton gin Total PM emission factors in kg/bale created using only the 1996 AP-42 data to comapare converting to rerating the data quality ratings.

	Converted AP-42			**Rerated AP-42**		
System	**Emission Factor**†	**Rating***	**No. of Tests**	**Emission Factor**†	**Rating***	**No. of Tests**
Unloading	0.13	M	8	0.12	M	7
1st Stage Seed Cotton Cleaning	0.16	M	7	0.16	M	7
2nd Stage Seed Cotton Cleaning	0.11	M	7	0.061	M	7
3rd Stage Seed Cotton Cleaning	0.043	P	2	0.045	P	1
Combined Lint Cleaning	0.26	M	6	0.26	M	6
Combined Mote	0.13	M	9	0.11	M	9
Battery Condenser	0.018	M	5	0.015	M	5
Cyclone Robber	0.082	P	1	0.082	P	1
Master Trash	0.24	P	4	0.20	M	5
Overflow (Distributer)	0.032	P	4	0.024	P	4
Mote Trash	0.035	P	3	0.032	P	3
Typical Gin	1.08		50	0.96		50

* P = Poorly
M = Moderately

† kg/bale

To further evaluate the differences between converting and rerating the 1996 AP-42 dataset ratings, those datasets were combined with the National Study PM_{10} and total PM datasets. For PM_{10}, when the converted ITRs from the 1996 AP-42 (98% of which had ITRs of 60) were combined with the higher ITRs of the National Study (the lowest of which was 72), they increased FQI and were all omitted from the emission factor calculations for all 11 systems that were included in the 1996 AP-42. After rerating the 1996 AP-42 PM_{10} datasets using the Eastern Research Group's (2013) ITR methodology, 93% of those tests were retained in the emission factor calculations. The typical gin PM_{10} emission factor decreased by 15%, and the number of tests used to calculate that emission factor increased by 64% (Table 21). Thirty-six percent of the PM_{10} emission factors that used the rerated 1996 AP-42 datasets rated “highly representative,” as compared to only 18% of the ones that used the converted 1996 AP-42 datasets. Compared to the ITR-rated typical gin emission factor, the typical gin PM_{10} emission factor developed using the

National Study and the rerated 1996 AP-42 datasets was 15% lower. The same emission factor was 27% higher than the 1996 AP-42 typical gin PM_{10} emission factor (Table 23).

Table 20. Cotton gin Total PM emission factors in lb/bale created using only the 1996 AP-42 data to comapare converting to rerating the data quality ratings.

	Converted AP-42			**Rerated AP-42**		
System	**Emission Factor**†	**Rating***	**No. of Tests**	**Emission Factor**†	**Rating***	**No. of Tests**
Unloading	0.29	M	8	0.27	M	7
1st Stage Seed Cotton Cleaning	0.36	M	7	0.36	M	7
2nd Stage Seed Cotton Cleaning	0.24	M	7	0.14	M	7
3rd Stage Seed Cotton Cleaning	0.095	P	2	0.099	P	1
Combined Lint Cleaning	0.58	M	6	0.58	M	6
Combined Mote	0.28	M	9	0.25	M	9
Battery Condenser	0.039	M	5	0.033	M	5
Cyclone Robber	0.18	P	1	0.18	P	1
Master Trash	0.54	P	4	0.44	M	5
Overflow (Distributer)	0.071	P	4	0.054	P	4
Mote Trash	0.077	P	3	0.070	P	3
Typical Gin	2.4		50	2.1		50

* P = Poorly
M = Moderately

†lb/bale

For total PM, when the converted ITRs from the 1996 AP-42 were combined with the higher ITRs of the National Study (the lowest of which was 72), the datasets that had ITRs of 80 decreased FQI and were included in emission factor calculations. However, the datasets with ITRs lower than 80, 33% of the 1996 AP-42 datasets, increased FQI and were not included in the system average emission factors. After rerating the 1996 AP-42 total PM datasets using the Eastern Research Group's (2013) ITR methodology, an additional 7.7% of those tests were retained in the emission factor calculations. The typical gin total PM emission factor increased by 7%, and the number of tests used to calculate that emission factor increased by 7.6% (Table 22). Seventy-three percent of the total PM emission factors that used the rerated 1996 AP-42 datasets rated “highly representative,” as compared to only 55% of the ones that used the converted 1996 AP-42 datasets. Compared to the ITR-rated typical gin emission factor, the typical gin total PM emission factor developed using the National Study and the rerated 1996 AP-42 datasets was 0.1% lower. The same emission factor was 14% lower than the 1996 AP-42 typical gin total PM emission factor (Table 23).

Table 21a. Comparison of PM_{10} emission factors in kg/bale developed by combining the National Study datasets with 1996 AP-42 datasets that had converted rating and datasets rerated using the ITR system.

	Converted AP-42			**Rerated AP-42**		
System	**Emission Factor**[†]	**Rating***	**No. of Tests**	**Emission Factor**[†]	**Rating***	**No. of Tests**
Unloading	0.1034	M	6	0.0820	M	11
1st Stage Seed Cotton Cleaning	0.0847	H	7	0.0769	H	12
2nd Stage Seed Cotton Cleaning	0.0376	M	5	0.0391	H	10
3rd Stage Seed Cotton Cleaning	0.0209	M	2	0.0199	M	3
Combined Lint Cleaning	0.1369	M	3	0.1223	M	9
Combined Mote	0.1012	M	11	0.0649	H	18
Battery Condenser	0.0181	H	12	0.0147	H	17
Cyclone Robber	0.0078	M	3	0.0104	M	4
Master Trash	0.0559	M	10	0.0553	M	11
Overflow (Distributer)	0.0218	M	4	0.0187	M	7
Mote Trash	0.0107	M	4	0.0088	M	7
Typical Gin	0.5596		58	0.4740		95

* M = Moderately
H = Highly

[†] kg/bale

Table 21b. Comparison of PM_{10} emission factors in lb/bale developed by combining the National Study datasets with 1996 AP-42 datasets that had converted rating and datasets rerated using the ITR system.

	Converted AP-42			**Rerated AP-42**		
System	**Emission Factor**†	**Rating***	**No. of Tests**	**Emission Factor**†	**Rating***	**No. of Tests**
Unloading	0.2279	M	6	0.0820	M	11
1st Stage Seed Cotton Cleaning	0.1868	H	7	0.0769	H	12
2nd Stage Seed Cotton Cleaning	0.0829	M	5	0.0391	H	10
3rd Stage Seed Cotton Cleaning	0.0461	M	2	0.0199	M	3
Combined Lint Cleaning	0.3017	M	3	0.1223	M	9
Combined Mote	0.2231	M	11	0.0649	H	18
Battery Condenser	0.0400	H	12	0.0147	H	17
Cyclone Robber	0.0172	M	3	0.0104	M	4
Master Trash	0.1231	M	10	0.0553	M	11
Overflow (Distributer)	0.0481	M	4	0.0187	M	7
Mote Trash	0.0236	M	4	0.0088	M	7
Typical Gin	1.2336		58	0.4740		95

* M = Moderately †lbs./bale
H = Highly

A notable example of the effects of rerating the 1996 AP-42 is illustrated by comparing a mote trash PM_{10} system average emission factor developed using National Study and converted 1996 AP-42 data to the one developed using National Study and rerated 1996 AP-42 data. The three 1996 AP-42 mote trash system PM_{10} datasets all originally rated “B,” converted to ITRs of 60, and were too low to be included in the emission factor. When rerated, these same datasets had ITRs of 90, 88, and 29. The 90 and 88 were included in the factor calculation, and the 29 was left out. When compared to the emission factor calculated with the converted 1996 AP-42, the new emission factor was 17.4% lower. Due to cases like this, if the 1996 AP-42 PM data has value, it must be rerated using the Eastern Research Group (2013) ITR methodology to be incorporated into the development of new emission factors.

Table 22a. Comparison of total PM emission factors in kg/bale developed by combining the National Study datasets with 1996 AP-42 datasets that had converted rating and datasets rerated using the ITR system.

	Converted AP-42			**Rerated AP-42**		
System	**Emission Factor**[†]	**Emission Factor**	**No. of Tests**	**Emission Factor**[†]	**Rating***	**No. of Tests**
Unloading	0.1247	M	14	0.1255	H	16
1st Stage Seed Cotton Cleaning	0.1390	H	26	0.1427	H	28
2nd Stage Seed Cotton Cleaning	0.0596	H	21	0.0576	H	22
3rd Stage Seed Cotton Cleaning	0.0301	M	8	0.0284	M	8
Combined Lint Cleaning	0.1969	H	14	0.2534	H	15
Combined Mote	0.1124	M	11	0.1244	H	15
Battery Condenser	0.0314	H	23	0.0308	H	23
Cyclone Robber	0.0235	M	10	0.0235	M	10
Master Trash	0.1783	H	19	0.1710	H	20
Overflow (Distributer)	0.0369	H	16	0.0349	H	16
Mote Trash	0.0206	M	17	0.0232	M	9
Typical Gin	0.8792		144	0.9404		155

* M = Moderately
H = Highly

[†] kg/bale

Table 22b. Comparison of total PM emission factors in lb/bale developed by combining the National Study datasets with 1996 AP-42 datasets that had converted rating and datasets rerated using the ITR system.

	Converted AP-42			**Rerated AP-42**		
System	**Emission Factor**[†]	**Emission Factor**	**No. of Tests**	**Emission Factor**[†]	**Rating***	**No. of Tests**
Unloading	0.2748	M	14	0.1255	H	16
1st Stage Seed Cotton Cleaning	0.3064	H	26	0.1427	H	28
2nd Stage Seed Cotton Cleaning	0.1313	H	21	0.0576	H	22
3rd Stage Seed Cotton Cleaning	0.0663	M	8	0.0284	M	8
Combined Lint Cleaning	0.4342	H	14	0.2534	H	15
Combined Mote	0.2478	M	11	0.1244	H	15
Battery Condenser	0.0693	H	23	0.0308	H	23
Cyclone Robber	0.0519	M	10	0.0235	M	10
Master Trash	0.3930	H	19	0.1710	H	20
Overflow (Distributer)	0.0814	H	16	0.0349	H	16
Mote Trash	0.0455	M	17	0.0232	M	9
Typical Gin	1.9383		144	2.0732		155

* M = Moderately
H = Highly

[†] lbs./bale

Table 23. Percent difference of the PM_{10} and total PM emission factors developed using the National Study and rerated 1996 AP-42 data from the 1996 AP-42 and from the ITR-rated National Study emission factors.

	PM_{10}		**Total PM**	
	% Difference from			
System	**1996 AP-42**	**ITR-rated National Study**	**1996 AP-42**	**ITR-rated National Study**
Unloading	51%	-21%	-5%	-2%
1st Stage Seed Cotton Cleaning	41%	-9%	-13%	5%
2nd Stage Seed Cotton Cleaning	-7%	4%	-47%	3%
3rd Stage Seed Cotton Cleaning	33%	-5%	-34%	11%
Combined Lint Cleaning	12%	-11%	-4%	3%
Combined Mote	10%	-36%	-2%	-11%
Battery Condenser	132%	-19%	74%	-12%
Cyclone Robber	-56%	34%	-71%	38%
Master Trash	65%	-1%	-30%	6%
Overflow (Distributer)	59%	-14%	8%	-9%
Mote Trash	-7%	-17%	-33%	22%
Typical Gin	27%	-15%	-14%	-0.10%

Particle Size Distribution

In addition to the EPA approved methods considered thus far, the National Study also conducted PSD analysis on total PM samples collected using Method 17. These PSD datasets were evaluated using the Eastern Research Group (2013) ITR methodology. Seventy-eight percent of the PSD test runs had a corresponding ITR of 100. Nineteen percent of the test runs had ITRs of 99 because processes monitor calibration documentation was unavailable for that cotton gin; all from gin A. The remaining 2.7% of PSD test runs had a corresponding ITR of 75 because the isokinetic sampling rate was not met.

The Table 24 shows the summary statistics mass median diameter (MMD) and geometric standard deviation (GSD) for the particle size distribution data. It also shows the percentage of particles with diameters less than 2.5, 6, and 10 μm, and the coefficient of determination (R^2) as related to the lognormal mean distribution:

$$df = \frac{1}{\sqrt{2\pi}\ln GSD} \exp\left[-\frac{\left(\ln d_p - \ln MMD\right)^2}{2(\ln GSD)^2}\right] dd_p \tag{10}$$

where df is the lognormal frequency distribution, MMD is the mass median diameter in micrometers, GSD is the geometric standard deviation, and d_p is the particle size (Hinds, 1999).

Figure 13 shows a visual comparison of the cumulative log normal distribution to the average cumulative distribution for the unloading system. The lognormal curve correlates well with the PSD data ($R^2 = 0.998$). On the surface, one would assume that using the lognormal curve to determine emission factors for any particle size within the distribution would be a simple and relatively accurate method of determining emission factors. However, the area between the lognormal curve and the PSD data becomes too large to accurately estimate emission factors for particle sizes less than 6.0 μm (Figure 14). For example, the $PM_{2.5}$ unloading system emission factor was 0.0027 kg/bale (0.0059 lb/bale) using the PSD data and 0.0140 kg/bale (0.0309 lb/bale) using the lognormal distribution, an increase of 427%. For PM_6, the unloading system emission factor was 0.0485 kg/bale (0.1070 lb/bale) using the PSD data and 0.0512 kg/bale

(0.1128 lb/bale) using the lognormal distribution, an increase of 5%. Because of this issue, we recommend that emission factors for particle sizes of 6.0 µm or smaller should be determined using the PSD emissions data only and not the lognormal distribution estimates.

Table 24. Particle size distributions for the 17 cotton gin systems and their R^2 fit to a lognormal distribution.

System	**MMD**	**GSD**	**% < 2.5 µm**	**% < 6 µm**	**% < 10 µm**	**R^2**
Unloading	8.0	2.4	3.24	36.2	59.6	0.998
1st Stage Seed-Cotton Cleaning	10.7	2.7	2.99	27.5	47.5	0.999
2nd Stage Seed-Cotton Cleaning	12.2	3.1	2.42	25.1	43.2	0.999
2nd Stage Seed-Cotton Cleaning*	13.2	3.0	1.90	22.52	40.5	0.999
3rd Stage Seed-Cotton Cleaning	9.6	3.1	3.84	32.2	51.5	0.997
1st Stage Lint Cleaning	29.2	4.2	1.39	11.1	20.2	0.999
2nd Stage Lint Cleaning	29.8	4.6	1.04	11.4	20.9	0.999
Combined Lint Cleaning	19.9	3.2	1.50	15.3	28.2	1.000
1st Stage Mote	16.4	3.8	2.49	21.6	36.0	0.998
2nd Stage Mote	16.1	4.2	2.87	23.0	37.3	0.998
Combined Mote	15.8	3.4	1.75	20.4	35.7	0.999
Battery Condenser	24.5	4.1	1.11	13.2	24.3	0.999
Cyclone Robber	20.3	4.0	2.10	17.5	30.3	0.999
Mote Cyclone Robber	21.2	4.2	2.20	16.9	29.0	0.999
Master Trash	20.6	3.0	1.86	14.0	25.7	1.000
Overflow (Distributer)	17.4	3.4	1.87	18.1	32.7	0.999
Overflow (Distributer)†	18.7	3.5	2.07	17.5	31.3	0.999
Mote Cleaner	17.1	3.1	1.53	17.1	31.8	1.000
Mote Trash	23.9	3.3	1.75	13.3	24.2	1.000

* PM_{10} PSD characteristics after removal of ProUCL outlier.

† $PM_{2.5}$ PSD characteristics after removal of ProUCL outlier.

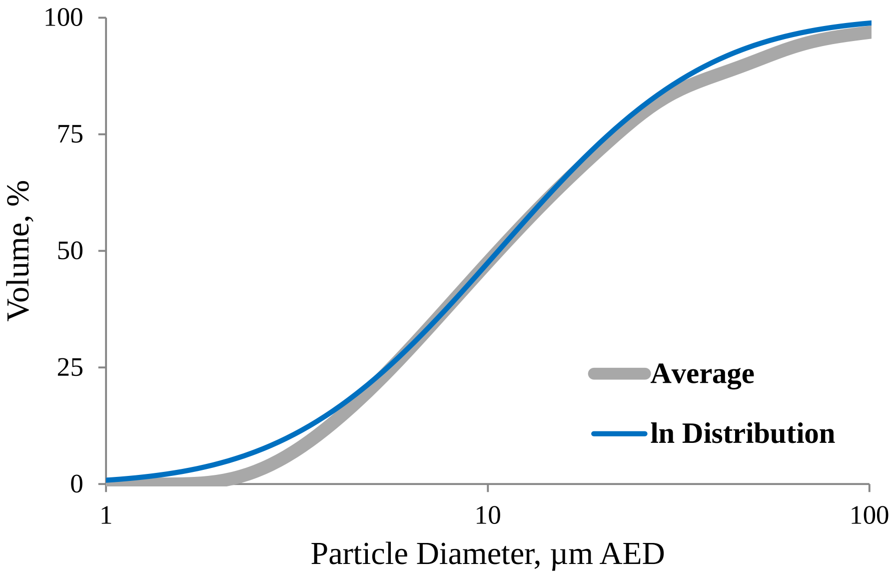


Figure 13. Average unloading system cumulative PSD compared to a best fit lognormal distribution ($R^2 = 0.998$).

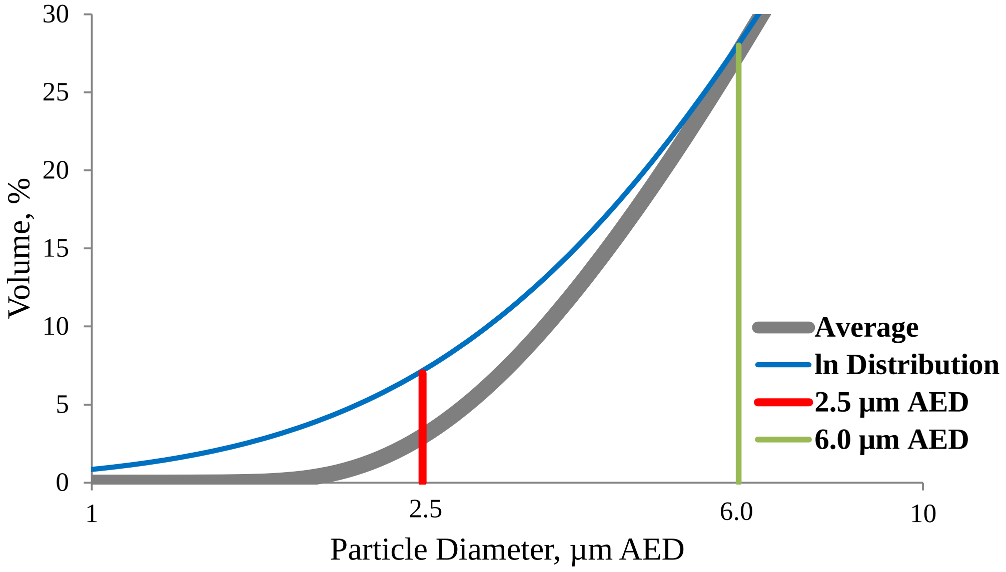


Figure 14. For particle sizes less than 6.0 µm, the difference between the sampled distribution and the lognormal distribution becomes too great to accurately determine emission factors.

Figures 15, 16, 17, and 18 show the cumulative PSD for the pre-cleaning systems, lint cleaning systems, mote systems, and the unloading and trash systems, respectively. These distributions consist of the percent of total particles less than a specified aerodynamic equivalent diameter (AED). An updated EPA AP-42 Appendix B.1 should contain figures similar to Figures 15 through 18.

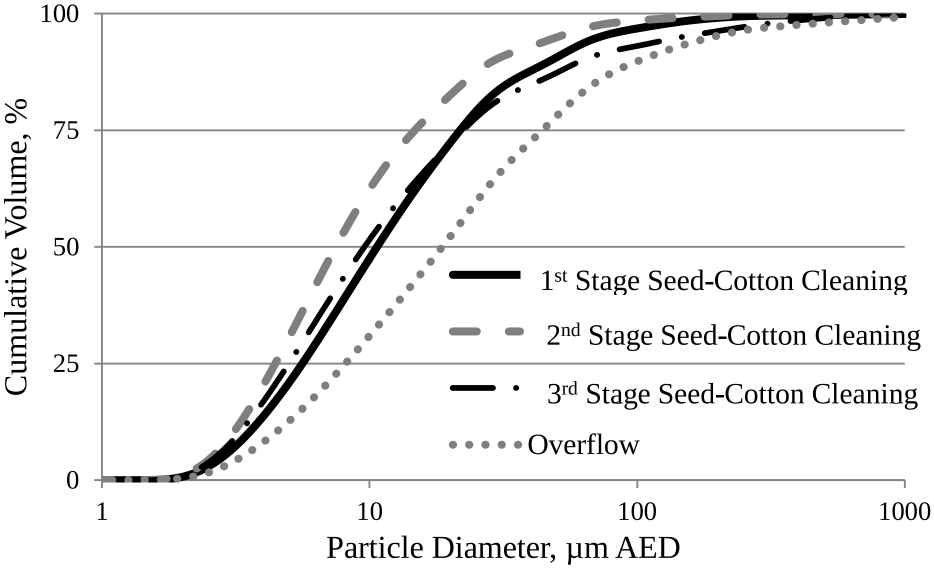


Figure 15. Cumulative particle size distribution for pre-cleaning systems.

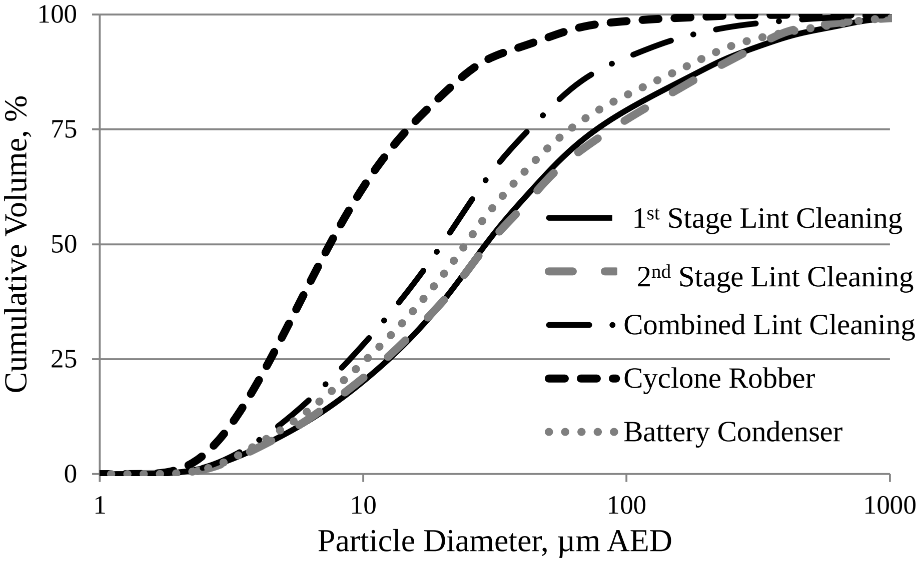


Figure 16. Cumulative particle size distribution for lint cleaning systems.

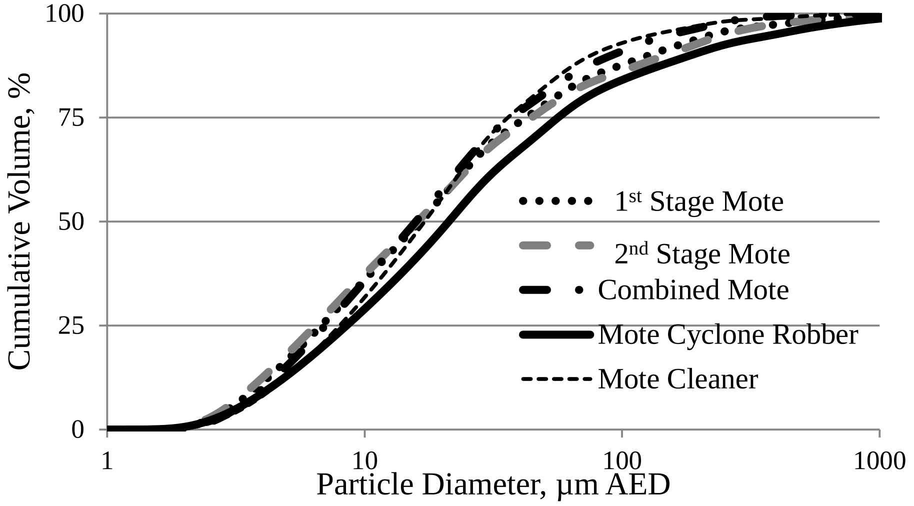


Figure 17. Cumulative particle size distribution for mote systems.

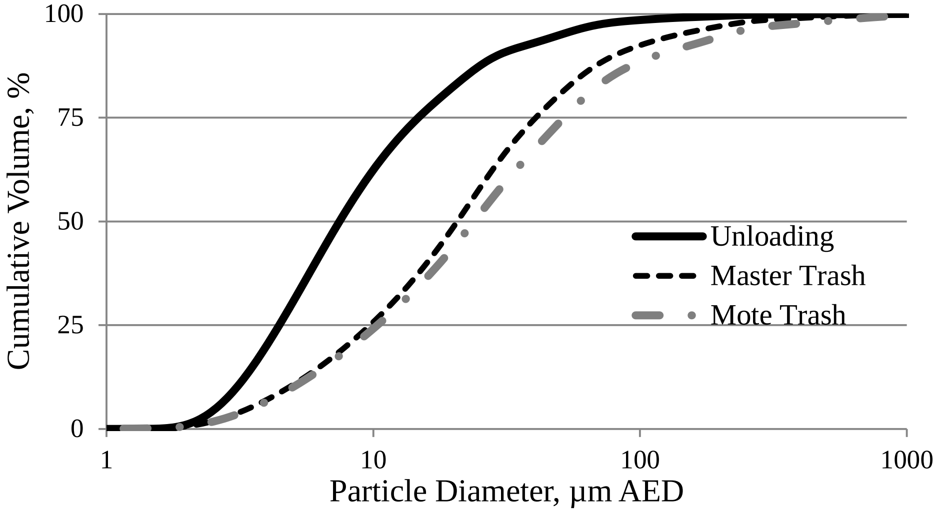


Figure 18. Cumulative particle size distributions for unloading and trash systems.

Table 25 shows emission factors developed from only the National Study PSD data. These emission factors differ from those published in the National Study technical reports (Table 10) because test runs in which isokinetic sampling rate or cut point criteria was not met were not automatically removed from the datasets using the ITR methodology, but some “tests” (method averages) were determined to be outliers by the ProUCL outlier test. The emission factors in Table 25 are the recommended update for Appendix B.1 of the AP-42. When compared to the

PSD emission factors published in the National Study PSD technical reports, the $PM_{2.5}$ and PM_{10} typical gin emission factors developed with the Eastern Research Group (2013) ITR methodology were 15 and 14% lower, respectively. Of the PSD emission factors developed in this study, 41 and 53% of the $PM_{2.5}$ and PM_{10} emission factors, respectively, were lower than those published in the National Study PSD technical reports. The $PM_{2.5}$ typical gin emission factor included two more test runs than were included in the National Study. The PM_{10} typical gin emission factor included 7 fewer test runs than were included in the National Study (Table 26). The National Study technical reports did not include emission factors for PM_6, so no comparison for those can be made here.

Table 25. $PM_{2.5}$ and PM_{10} emission factors and quality ratings developed from the National Study PSD data.

	$PM_{2.5}$		PM_{10}		Emission Factor Rating
System	**kg/bale**	**lb/bale**	**kg/bale**	**lb/bale**	
Unloading	0.0027	0.0059	0.0536	0.1182	P
1st Stage Seed-Cotton Cleaning	0.0050	0.0110	0.0643	0.1418	M
2nd Stage Seed-Cotton Cleaning	0.0013	0.0028	0.0258	0.0568	M
3rd Stage Seed-Cotton Cleaning	0.0012	0.0026	0.0135	0.0297	P
1st Stage Lint Cleaning	0.0010	0.0022	0.0148	0.0326	M
2nd Stage Lint Cleaning	0.00031	0.00068	0.0050	0.0109	P
Combined Lint Cleaning	0.0035	0.0077	0.0552	0.1218	M
1st Stage Mote	0.00064	0.0014	0.0091	0.0201	M
2nd Stage Mote	0.00032	0.00072	0.0043	0.0096	M
Combined Mote	0.0024	0.0053	0.0517	0.1140	P
Battery Condenser	0.00041	0.00091	0.0075	0.0165	M
Cyclone Robber	0.00033	0.00072	0.0047	0.0104	M
Mote Cyclone Robber	0.0013	0.0028	0.0167	0.0369	P
Master Trash	0.0027	0.0059	0.0395	0.0871	M
Overflow (Distributer)	0.00075	0.0016	0.0105	0.0231	M
Mote Cleaner	0.0013	0.0028	0.0275	0.0607	P
Mote Trash	0.00031	0.00069	0.0038	0.0084	P
Typical Gin	0.0187	0.0412	0.3081	0.6792	

*P = Poorly
M = Moderately

Updating Appendix B.1 of AP-42 using the PSD data from the National Study and the ITR methodology will greatly improve the usefulness of the Appendix. This will increase the number of systems that have PSD information from 2 to 17. Compared to the systems that are available in the current Appendix B.1, the battery condenser was 94 and 87% lower for $PM_{2.5}$ and PM_{10} emission factors, respectively. The lint cleaner was 5 and 72% lower for $PM_{2.5}$ and PM_{10} emission factors, respectively. Of the 8 systems found in a typical cotton gin, 75% would be rated "moderately representative." Additionally, information would be available for the entire distribution as opposed to just three particle sizes (2.5, 6, and 10 µm). This would allow modelers and regulators to determine emission factors for any particle size within the distribution, but, again, it is recommended that only the actual sampled data be used for $PM_{2.5}$ and smaller. The datasets that were used to develop the current Appendix B.1 should not be used to update it due to their poor quality and lack of documentation.

When compared to the (non-PSD the ITR-rated National Study emission factors, the PSD-based emission factors were lower for all systems, and the PSD-based $PM_{2.5}$ and PM_{10} emission factors for a typical gin were 73% and 45% lower, respectively. However, when combined with the National Study datasets and analyzed with the residual outlier test, the PSD residuals were well within the ±2 rejection range, as demonstrated for the 1st stage Seed-Cotton cleaning system in Figure 19. In some cases, the standard deviation for the combined PSD and non-PSD datasets was greater than any of the PSD test run values. This resulted in residual plots similar to Figure 20, which is a residual plot for the overflow system or $PM_{2.5}$. This system had a standard deviation of 0.0034 kg/bale (0.0074 lbs/bale), and the largest PSD test run value was 0.0015 kg/bale (0.0032 lb/bale), which produced residuals all less than ±0.2.

Table 26. Percent differnce of the PSD system average emission factors developed using the Eastern Research Group (2013) ITR methodology from the emission factors published in the National Study PSD technical reports and the difference in number of test runs.

	% Difference from National Study PSD Technical Reports		**Difference in No. of Test Runs**	
System	**PM$_{2.5}$**	**PM$_{10}$**	**PM$_{2.5}$**	**PM$_{10}$**
Unloading	-55%	-36%	-3	-3
1st Stage Seed Cotton Cleaning	10%	-11%	+2	-1
2nd Stage Seed Cotton Cleaning	-11%	2%	-	-3
3rd Stage Seed Cotton Cleaning	29%	12%	+1	+1
1st Stage Lint Cleaning	1%	4%	-	-
2nd Stage Lint Cleaning	32%	4%	-1	-1
Combined Lint Cleaning	11%	-7%	-	-
1st Stage Mote	3%	1%	-	-
2nd Stage Mote	7%	10%	-	-
Combined Mote	-5%	-1%	-	-
Battery Condenser	16%	-4%	-	-
Cyclone Robber	-23%	-23%	-	-
Mote Cyclone Robber	14%	15%	-	-
Master Trash	-23%	-18%	-	-
Distributor/Overflow	56%	18%	+3	-
Mote Cleaner	-21%	-18%	+3	+3
Mote Trash	-87%	-10%	-	-
Typical Gin	-15%	-14%	2	-7

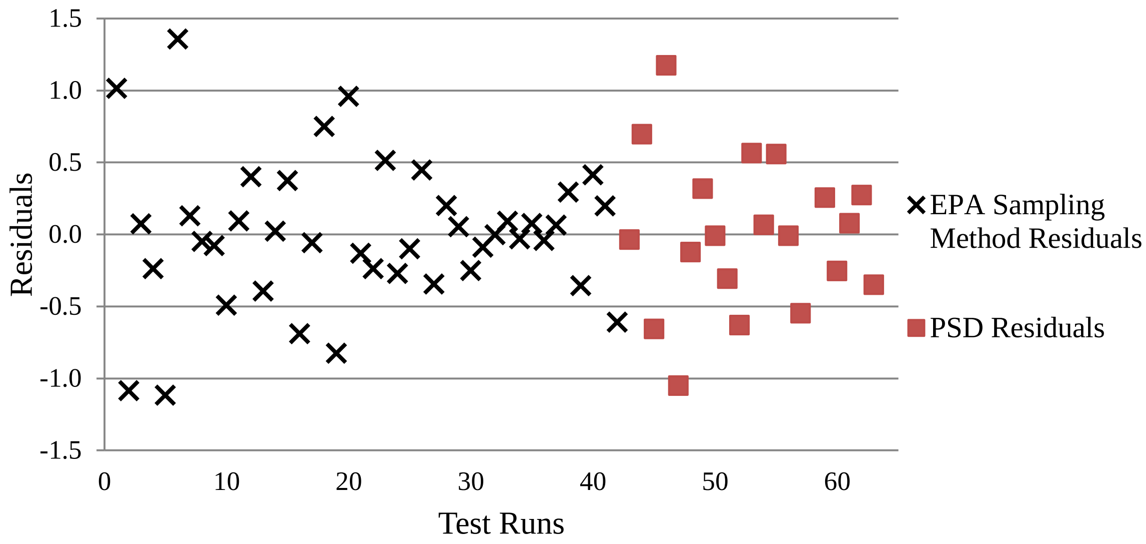


Figure 19. Residual outlier test for the 1st stage seed-cotton cleaning system with EPA approved sampling and PSD methods for PM$_{10}$.

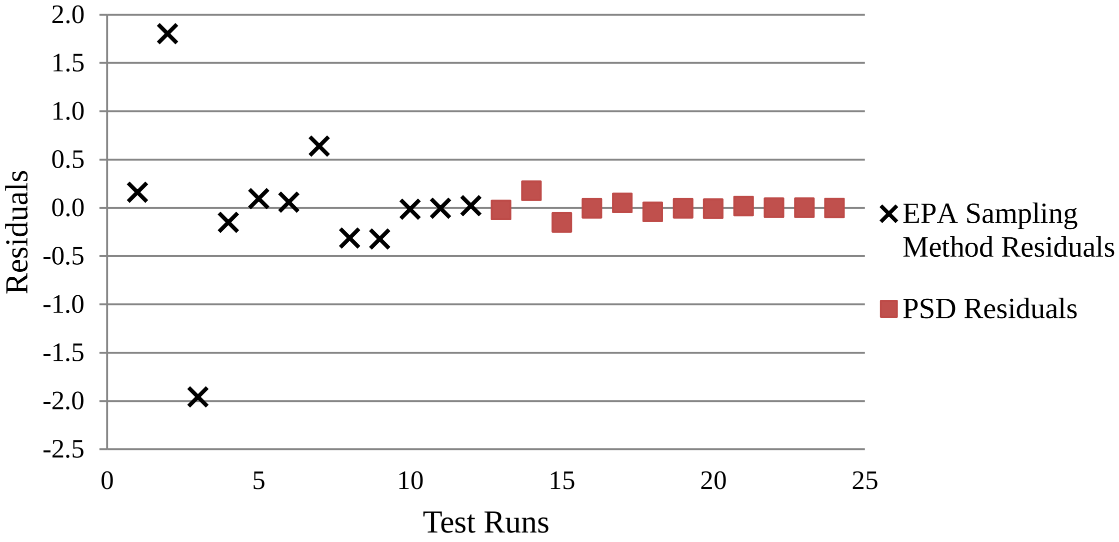


Figure 20. Residual outlier test for the overflow system with EPA approved sampling and PSD methods for $PM_{2.5}$.

When PSD was used as a separate method in the ITR-rating process, no method averages were found to be outliers by the ProUCL outlier test for any system. Because the PSD datasets were not found to be outliers by either the residual test or ProUCL, they should be combined with the National Study and rerated 1996 AP-42 datasets when calculating new emission factors. With their high ratings, combining the PSD datasets with the National Study and rerated 1996 AP-42 datasets would increase the dataset size for all systems, which would improve the representativeness ratings of the final emission factors.

Final Suggested Emission Factors

Based on the preceding analysis and results, $PM_{2.5}$, PM_{10}, and total PM emission factors and quality ratings of 17 cotton ginning systems and a typical gin (as defined in the 1996 AP-42) were developed using ITR-rating methodology and included National Study data collected by Method 201A with both PM_{10} and $PM_{2.5}$ sizing cyclones, Method 201A with only a PM_{10} sizing cyclone, Method 17, Method 17 with PSD, and ITR methodology rerated 1996 AP-42 data (Table 27). Based on this recommended method, for $PM_{2.5}$, 15 emission factors rated as “moderately representative," and 2 rated as "highly representative." For PM_{10}, 7 emission factors rated as "moderately representative," and 10 rated as "highly representative." For total PM, 5 emission factors rated as "moderately representative," and 12 rated as "highly representative." No factors received a rating of "poorly representative," which is an improvement over the ratings of "D" (below average) in the 1996 AP-42 for PM_{10} and total PM. They are also an improvement over the ratings of the ITR-rated emission factors developed using just the National Study data, in which no $PM_{2.5}$, 2 PM_{10}, and 9 total PM emission factors rated as "highly representative" (Tables 13-15)

Table 27a. Final suggested cotton gin emission factors in kg/bale developed using National Study, rerated 1996 AP-42, and National Study PSD data.

	$PM_{2.5}$		**PM_{10}**		**Total PM**	
System	**Emission Factor†**	**Rating***	**Emission Factor†**	**Rating***	**Emission Factor†**	**Rating***
Unloading	0.0145	M	0.0832	H	0.1255	H
1st Stage Seed-Cotton Cleaning	0.0065	H	0.0763	H	0.1427	H
2nd Stage Seed-Cotton Cleaning	0.0024	M	0.0353	H	0.0576	H
3rd Stage Seed-Cotton Cleaning	0.0026	M	0.0181	M	0.0284	M
1st Stage Lint Cleaning	0.0047	M	0.0350	M	0.0813	H
2nd Stage Lint Cleaning	0.0028	M	0.0156	M	0.0334	H
Combined Lint Cleaning	0.0086	M	0.1089	H	0.2534	H
1st Stage Mote	0.0023	M	0.0166	H	0.0286	H
2nd Stage Mote	0.0014	M	0.0079	H	0.0121	H
Combined Mote	0.0060	M	0.0685	M	0.1244	H
Battery Condenser	0.0019	H	0.0128	H	0.0308	H
Cyclone Robber	0.0010	M	0.0108	M	0.0235	M
Mote Cyclone Robber	0.0028	M	0.0232	M	0.0452	M
Master Trash	0.0036	M	0.0504	H	0.1710	H
Overflow (Distributer)	0.0023	M	0.0160	H	0.0349	H
Mote Cleaner	0.0071	M	0.0491	M	0.1003	M
Mote Trash	0.00070	M	0.0076	M	0.0232	M
Typical Gin	0.0459		0.4514		0.9404	

* M = Moderately
H = Highly

† kg/bale

Table 28 shows the percent differences of the final suggested $PM_{2.5}$ emission factors as compared to the National Study technical reports, the ITR-rated National Study, and the ITR-rated PSD emission factors. For a typical gin, the final suggested $PM_{2.5}$ emission factor was 33% lower than both the National Study technical report and the National Study ITR-rated $PM_{2.5}$ emission factors. The percent differences for the final suggested $PM_{2.5}$ emission factors were similar for these two datasets and were all negative except for the mote cleaner system from the National Study technical report. This emission factor was 100% lower than the final suggested $PM_{2.5}$ mote cleaner emission factor because one of the two EPA-approved tests performed on that system was removed from the technical reports but included in this study. However, since the mote cleaner is not a system included in the typical gin, the relatively large percent difference in that system is not reflected in the percent difference for the typical gin emission factor.

All of the final suggested $PM_{2.5}$ emission factors were higher than the ITR-rated PSD emission factors. The final suggested typical gin $PM_{2.5}$ emission factor was 146% higher than the ITR-rated PSD typical gin emission factor. The greatest differences between the final suggested and ITR-rated PSD emission factors are for the 1st and 2nd stage lint cleaning systems (384 and 819% higher, respectively). The large difference was likely caused by the lint handled by those systems bypassing the sizing cyclones used in the EPA-approved sampling methods, which suggests that those methods may not be the best suited for accurately determining PM emissions from lint-handling systems.

Table 27b. Final suggested cotton gin emission factors in lb./bale developed using National Study, rerated 1996 AP-42, and National Study PSD data.

	$PM_{2.5}$		**PM_{10}**		**Total PM**	
System	**Emission Factor†**	**Rating***	**Emission Factor†**	**Rating***	**Emission Factor†**	**Rating***
Unloading	0.0320	M	0.1834	H	0.2767	H
1st Stage Seed-Cotton Cleaning	0.0144	H	0.1682	H	0.3145	H
2nd Stage Seed-Cotton Cleaning	0.0054	M	0.0778	H	0.1271	H
3rd Stage Seed-Cotton Cleaning	0.0057	M	0.0398	M	0.0627	M
1st Stage Lint Cleaning	0.0105	M	0.0772	M	0.1793	H
2nd Stage Lint Cleaning	0.0063	M	0.0344	M	0.0736	H
Combined Lint Cleaning	0.0190	M	0.2401	H	0.5585	H
1st Stage Mote	0.0050	M	0.0365	H	0.0632	H
2nd Stage Mote	0.0030	M	0.0175	H	0.0266	H
Combined Mote	0.0131	M	0.1509	M	0.2744	H
Battery Condenser	0.0043	H	0.0283	H	0.0680	H
Cyclone Robber	0.0021	M	0.0237	M	0.0519	M
Mote Cyclone Robber	0.0061	M	0.0511	M	0.0996	M
Master Trash	0.0079	M	0.1111	H	0.3770	H
Overflow (Distributer)	0.0052	M	0.0353	H	0.0770	H
Mote Cleaner	0.0158	M	0.1081	M	0.2212	M
Mote Trash	0.0015	M	0.0167	M	0.0513	M
Typical Gin	0.1013		0.9951		2.0732	

* M = Moderately †lb/bale
H = Highly

Table 29 shows the percent differences of the final suggested PM_{10} emission factors as compared to the 1996 AP-42, the National Study technical reports, the ITR-rated PSD, and the National Study combined with the rerated AP-42 emission factors. For a typical gin, the final suggested PM_{10} emission factor was 22% higher than the 1996 AP-42, 22% lower than the National Study technical report, 47% higher than the ITR-rated PSD, and 4.8% lower than the National Study combined with the rerated 1996 AP-42 emission factors. For the final suggested PM_{10} emission factors, 73, 12, and 18% were higher than the 1996 AP-42, the National Study technical report, and the National Study combined with the rerated AP-42 PM_{10} emission factors, respectively.

Table 28. The percent difference of the final suggested $PM_{2.5}$ emission factors as compared to the National Study technical reports, National Study ITR-rated, and PSD ITR-rated emission factors.

System	**National Study Technical Reports**	**ITR-Rated National Study**	**ITR-Rated PSD**
Unloading	-35%	-34%	446%
1st Stage Seed Cotton Cleaning	-20%	-19%	31%
2nd Stage Seed Cotton Cleaning	-33%	-30%	93%
3rd Stage Seed Cotton Cleaning	-36%	-35%	121%
1st Stage Lint Cleaning	-45%	-44%	384%
2nd Stage Lint Cleaning	-43%	-41%	819%
Combined Lint Cleaning	-37%	-37%	146%
1st Stage Mote	-45%	-42%	250%
2nd Stage Mote	-45%	-37%	324%
Combined Mote	-37%	-37%	146%
Battery Condenser	-47%	-44%	374%
Cyclone Robber	-48%	-40%	190%
Mote Cyclone Robber	-39%	-35%	119%
Master Trash	-15%	-20%	33%
Overflow (Distributer)	-41%	-43%	214%
Mote Cleaner	100%	-45%	463%
Mote Trash	-35%	-36%	126%
Typical Gin	-33%	-33%	146%

All of the final suggested PM_{10} emission factors were higher than the ITR-rated PSD emission factors. The final suggested typical gin PM_{10} emission factor was 47% higher than the ITR-rated PSD typical gin emission factor. The greatest differences between the final suggested and ITR-rated PSD emission factors are for the 1st and 2nd stage lint cleaning systems (137 and 215% higher, respectively). The large difference was likely caused by the lint handled by those systems bypassing the sizing cyclones used in the EPA-approved sampling methods, which suggests that those methods may not be the best suited for accurately determining PM emissions from lint-handling systems.

Table 29. The percent difference of the final suggested PM_{10} emission factors as compared to the 1996 AP-42, National Study technical reports, National Study ITR-rated, and PSD ITR-rated emission factors.

System	1996 AP-42	National Study Technical Reports	ITR-Rated PSD	National Study + Rerated AP-42
Unloading	53%	-23%	55%	1.5%
1st Stage Seed Cotton Cleaning	40%	-22%	19%	-1%
2nd Stage Seed Cotton Cleaning	-16%	-11%	37%	-10%
3rd Stage Seed Cotton Cleaning	21%	-5%	34%	-9%
1st Stage Lint Cleaning	-	-15%	137%	-42%
2nd Stage Lint Cleaning	-	-12%	215%	-20%
Combined Lint Cleaning	0.05%	-28%	97%	-11%
1st Stage Mote	-	-17%	82%	-18%
2nd Stage Mote	-	-3%	82%	-18%
Combined Mote	16%	-30%	32%	5.5%
Battery Condenser	102%	-22%	71%	-13%
Cyclone Robber	-54%	8%	127%	3%
Mote Cyclone Robber	-	-16%	38%	-12%
Master Trash	50%	-10%	27%	-9%
Overflow (Distributer)	36%	22%	53%	-15%
Mote Cleaner	-	-0.78%	78%	-18%
Mote Trash	-20%	-33%	100%	-14%
Typical Gin	22%	-22%	47%	-4.8%

Table 30 shows the percent differences of the final suggested total PM emission factors as compared to the 1996 AP-42, the National Study technical reports, and the National Study combined with the rerated AP-42 emission factors. For a typical gin, the final suggested total PM emission factor was 14% lower than the 1996 AP-42, 0.81% lower than the National Study technical report, and 0.10% lower than the ITR-rated National Study total PM emission factors. For the final suggested total PM emission factors, 12, 53 and 47% were higher than the 1996 AP-42, the National Study technical report, and the ITR-rated National Study emission factors, respectively. Note that 35% of the final suggested total PM emission factors were identical to the ITR-rated National Study emission factors because no additional datasets were added to those systems.

In addition to using the typical gin as defined by the 1996 AP-42, the additional systems included in the current study allow for emission factors for a typical gin with first and second stage lint cleaning systems and first and second stage mote systems, as opposed to only combined systems. The emission factors for a typical gin with split lint cleaning and mote systems were 5% and 35% lower for PM_{10} and total PM, respectively, than the emission factors for a typical gin in the 1996 AP-42. When compared to the final suggested emission factors in Table 27, the emission factors for a typical gin with split lint cleaning and mote systems were 7.3%, 23%, and 24% for $PM_{2.5}$, PM_{10}, and total PM, respective, as compared to the typical gin.

Table 30. The percent difference of the final suggested total PM emission factors as compared to the 1996 AP-42, National Study technical reports, and National Study ITR-rated emission factors.

System	**1996 AP-42**	**National Study Technical Reports**	**ITR-Rated National Study**
Unloading	-4.6%	-6.5%	-2.2%
1st Stage Seed Cotton Cleaning	-13%	-5.8%	4.9%
2nd Stage Seed Cotton Cleaning	-47%	-1.5%	3.1%
3rd Stage Seed Cotton Cleaning	-34%	21%	11%
1st Stage Lint Cleaning	-	16%	0%
2nd Stage Lint Cleaning	-	47%	0%
Combined Lint Cleaning	-3.7%	20%	3.05%
1st Stage Mote	-	13%	0%
2nd Stage Mote	-	16%	0%
Combined Mote	-2.02%	-15%	-11%
Battery Condenser	74%	-3%	-12%
Cyclone Robber	-71%	15%	38%
Mote Cyclone Robber	-	-10%	0%
Master Trash	-30%	-8%	6.2%
Overflow (Distributer)	8%	22%	-9.2%
Mote Cleaner	-	-5%	0%
Mote Trash	-33%	31%	22%
Typical Gin	-14%	-0.81%	-0.10%

Table 31 shows the number of tests (*N*), as defined by the ITR-rating methodology (method averages), that were used to develop the final emission factors. It also shows the additional number (*N)* of tests needed, as calculated from equation 11, to improve factor ratings to “highly representative.” There are several systems, such as the 1st and 2nd stage mote, that only need one additional test to attain a rating of “highly representative.” However, these numbers assume that additional datasets will have ITRs similar to the datasets that have already been assessed. If the additional ITRs, are too low they will either not lower the FQI enough to increase the rating or will increase the FQI and be excluded from the emission factor calculation.

Table 31. Total number of tests (*N*) used for each emission factor calculation and additional *N* needed to raise factor ratings to "highly representative" based on final CTRs.

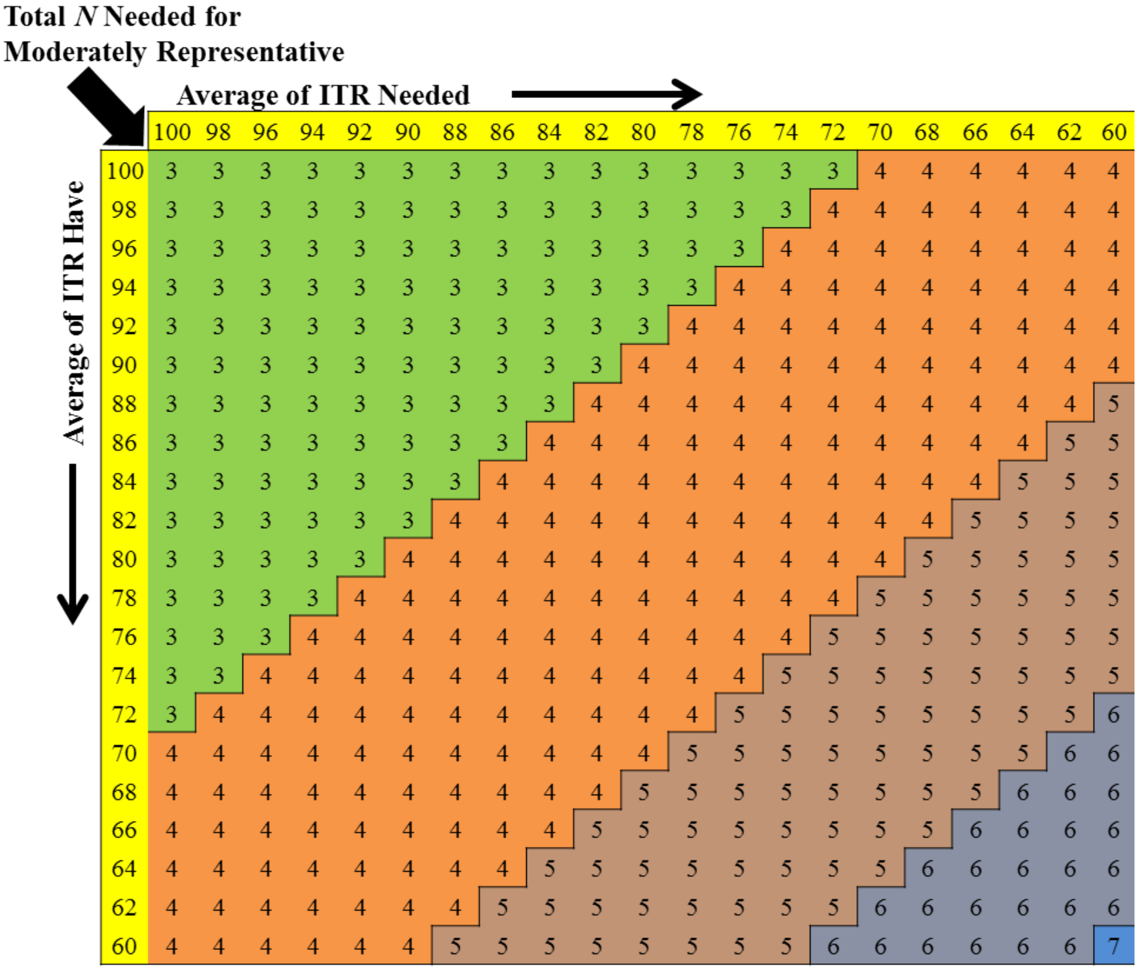
	$PM_{2.5}$		PM_{10}		Total PM	
System	**Total *N***	**Additional *N* Needed for Highly**	**Total *N***	**Additional *N* Needed for Highly**	**Total *N***	**Additional *N* Needed for Highly**
Unloading	6	5	14	0	17	0
1st Stage Seed-Cotton Cleaning	14	0	26	0	28	0
2nd Stage Seed-Cotton Cleaning	10	2	20	0	22	0
3rd Stage Seed-Cotton Cleaning	4	7	8	5	7	5
1st Stage Lint Cleaning	8	4	12	0	12	0
2nd Stage Lint Cleaning	7	5	11	1	12	0
Combined Lint Cleaning	6	5	15	0	15	0
1st Stage Mote	10	1	15	0	15	0
2nd Stage Mote	10	1	15	0	15	0
Combined Mote	4	7	13	2	15	0
Battery Condenser	12	0	23	0	23	0
Cyclone Robber	6	5	9	3	10	2
Mote Cyclone Robber	6	6	9	3	9	5
Master Trash	10	1	17	0	20	0
Overflow (Distributer)	8	3	16	0	16	0
Mote Cleaner	4	7	6	5	6	8
Mote Trash	4	7	9	4	9	4
Typical Gin	70	23	144	2	156	0

Since CTR changes with the addition of each *N* and ITR, adding *N* with high ITRs could potentially reduce the total *N* needed, and low ITRs could increase total *N* needed. Knowing the data quality of the additional datasets needed would allow for better assessment of additional data needs. By substituting average ITR into equation 8, we get that CTR is approximately equal to average ITR. Then, by replacing CTR with average ITR in equation 5, setting FQI to the value needed to be moderately (0.5774) or highly (0.3015) representative, and solving for N, the following (with some rounding) are obtained:

$$N = \frac{88000}{(\overline{ITR}_h + \overline{ITR}_n)^2} \tag{11}$$

$$N = \frac{440000}{(\overline{ITR}_h + \overline{ITR}_n)^2} \tag{12}$$

Where N is total number of tests, $\overline{ITR}_h$ is the average of the ITRs that are had, and $\overline{ITR}_n$ is the average of the ITRs needed. Figure 21 uses equation 11 to allow for the determination of total N needed to obtain moderately representative emission factors, and Figure 22 uses equation 12 to do the same for highly representative emission factors. For example, if $\overline{ITR}_h$ is 88, then total N needed for highly representative would be 14 if $\overline{ITR}_n$ was between 90 and 94. By subtracting N that is had, additional N needed could be determined.



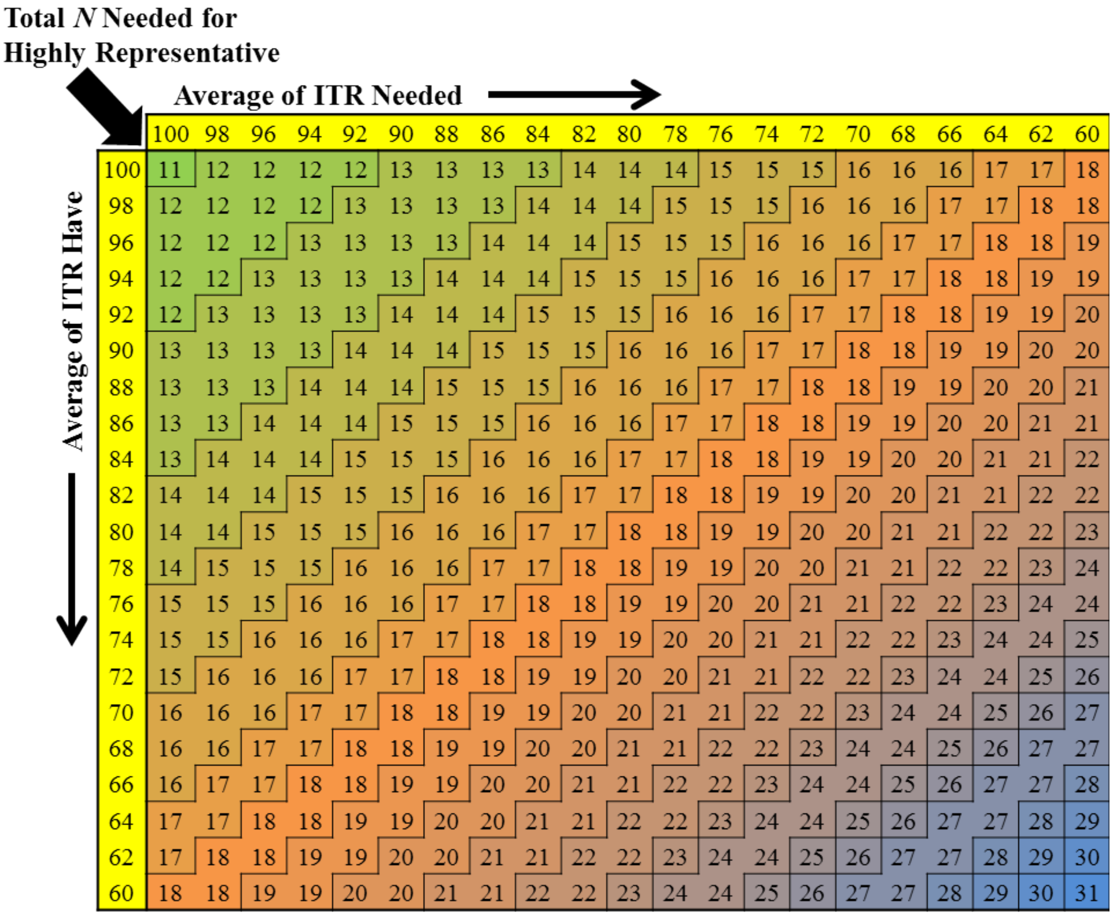
Total *N* Needed for Moderately Representative

Average of ITR Needed →

Average of ITR Have ↓

	100	98	96	94	92	90	88	86	84	82	80	78	76	74	72	70	68	66	64	62	60
100	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4
98	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4
96	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4
94	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
92	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4
90	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4
88	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5
86	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5
84	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5
82	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5
80	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5
78	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5
76	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5
74	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5
72	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6
70	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6	6
68	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6	6	6
66	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6	6	6	6
64	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6	6	6	6	6
62	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6	6	6	6	6	6
60	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6	6	6	6	6	6	7

Figure 21. Chart for determining the number of “Tests” needed to obtain moderately representative based on current process system average ITR and the expected average ITR for the additional “Tests.”



Total *N* Needed for Highly Representative

Average of ITR Needed →

Average of ITR Have ↓

	100	98	96	94	92	90	88	86	84	82	80	78	76	74	72	70	68	66	64	62	60
100	11	12	12	12	12	13	13	13	13	14	14	14	15	15	15	16	16	16	17	17	18
98	12	12	12	12	13	13	13	13	14	14	14	15	15	15	16	16	16	17	17	18	18
96	12	12	12	13	13	13	13	14	14	14	15	15	15	16	16	16	17	17	18	18	19
94	12	12	13	13	13	13	14	14	14	15	15	15	16	16	16	17	17	18	18	19	19
92	12	13	13	13	13	14	14	14	15	15	15	16	16	16	17	17	18	18	19	19	20
90	13	13	13	13	14	14	14	15	15	15	16	16	16	17	17	18	18	19	19	20	20
88	13	13	13	14	14	14	15	15	15	16	16	16	17	17	18	18	19	19	20	20	21
86	13	13	14	14	14	15	15	15	16	16	16	17	17	18	18	19	19	20	20	21	21
84	13	14	14	14	15	15	15	16	16	16	17	17	18	18	19	19	20	20	21	21	22
82	14	14	14	15	15	15	16	16	16	17	17	18	18	19	19	20	20	21	21	22	22
80	14	14	15	15	15	16	16	16	17	17	18	18	19	19	20	20	21	21	22	22	23
78	14	15	15	15	16	16	16	17	17	18	18	19	19	20	20	21	21	22	22	23	24
76	15	15	15	16	16	16	17	17	18	18	19	19	20	20	21	21	22	22	23	24	24
74	15	15	16	16	16	17	17	18	18	19	19	20	20	21	21	22	22	23	24	24	25
72	15	16	16	16	17	17	18	18	19	19	20	20	21	21	22	22	23	24	24	25	26
70	16	16	16	17	17	18	18	19	19	20	20	21	21	22	22	23	24	24	25	26	27
68	16	16	17	17	18	18	19	19	20	20	21	21	22	22	23	24	24	25	26	27	27
66	16	17	17	18	18	19	19	20	20	21	21	22	22	23	24	24	25	26	27	27	28
64	17	17	18	18	19	19	20	20	21	21	22	22	23	24	24	25	26	27	27	28	29
62	17	18	18	19	19	20	20	21	21	22	22	23	24	24	25	26	27	27	28	29	30
60	18	18	19	19	20	20	21	21	22	22	23	24	24	25	26	27	27	28	29	30	31

Figure 22. Chart for determining the number of “Tests” needed to obtain highly representative based on current process system average ITR and the expected average ITR for the additional “Tests.”

By splitting the parameter total tests (*N*) in equations 11 and 12 into tests had and additional tests needed, 3-dimensional data needs charts were created. Figures 23 and 24 allow for the use of tests had and the average ITR of those tests to determine both additional tests needed and the average ITR for those tests for moderately and highly representative emission factors, respectively. For example, Point 1 in Figure 24 is situated at *N* had = 10 and the average ITR had = 75. To be a highly representative emission factor, an additional 7 tests with an average ITR of 85 would need to be added to the dataset. While these charts are not meant to replace emission factor rating calculation, they could be useful tools in planning future emissions sampling projects.

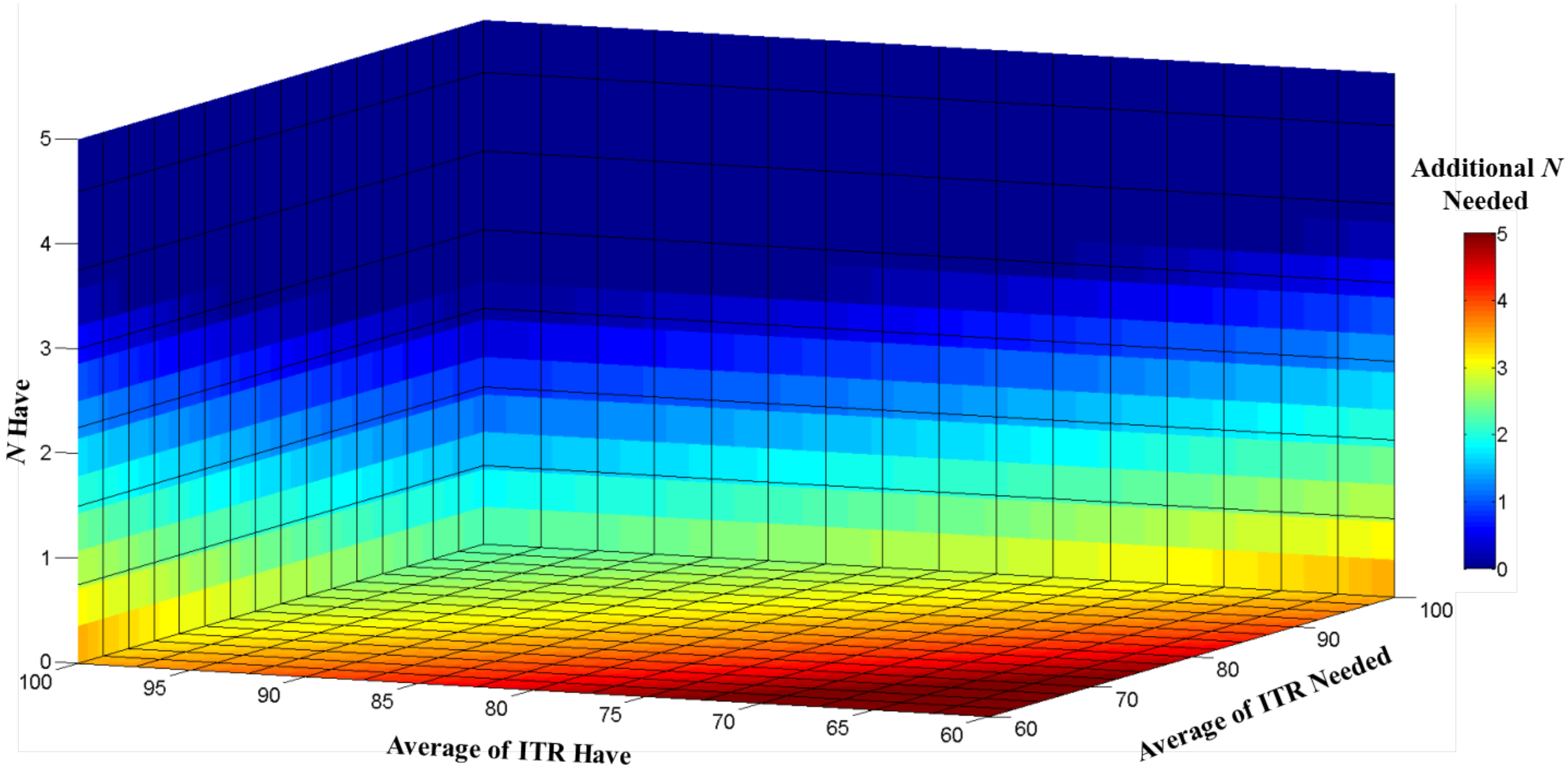


Figure 23. 3D chart for determining data additional needs for developing moderately representative emission factors.

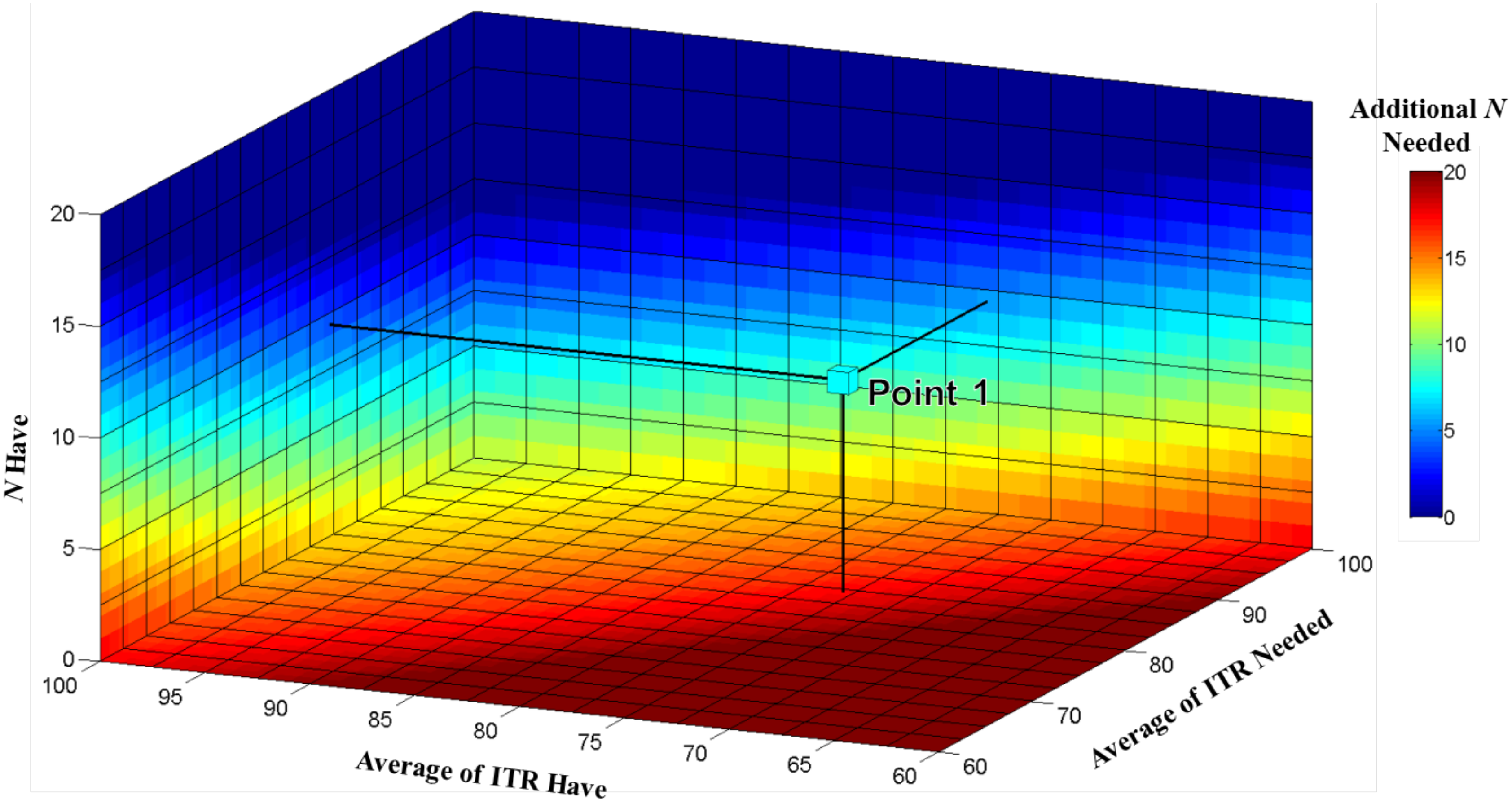


Figure 24. 3D chart for determining additional data needs for developing highly representative emission factors.

CHAPTER VI

CONCLUSIONS

Emission factors and corresponding representativeness ratings for $PM_{2.5}$, PM_{10}, and total PM were updated for 17 common cotton gin systems using data collected from a national stack sampling study and the 1996 AP-42 data using EPA's emission factor development and rating procedures for inclusion in AP-42 Section 9.7. Of the three designs used to develop emission factors, "Test" Design 2 (ITR-rating methodology), that averaged test runs for a test method, was best suited to account for variation from year to year, screen out unrepresentative data, and avoid overestimation of the representativeness of the emission factor. Emission factor datasets consisting of data collected with EPA-approved methodology, PSD data, and a combination of both were developed. Additionally, emission factors and corresponding representativeness ratings for $PM_{2.5}$, $PM_{6,}$ and PM_{10} along with PSD characteristics were developed for 17 common cotton gin systems using PSD data collected from the national stack sampling study for inclusion in AP-42 Appendix B.1.

PM_{10} and total PM emissions datasets from the 1996 AP-42 were included in calculating the new emission factors. The current study found that the conversion method specified by Eastern Research Group (2013) for the 1996 AP-42 datasets did not accurately reflect the true representativeness of the data. To accurately develop new emission factors and determine their representativeness, datasets from the 1996 AP-42 should be rerated with the ITR process.

PSD data for $PM_{2.5}$ and PM_{10} from the National Study was included in calculating the emission factors along with the data collected using EPA-approved methodologies and the 1996 AP-42 data. While the emission factors developed from just the PSD data were lower than the factors developed with other methods, no PSD datasets were removed as outliers by either the residual test or ProUCL when combined with the other datasets. For this reason, PSD datasets should be combined with the datasets collected using EPA-approved methods.

The 1996 AP-42 considers a typical gin to consist of an unloading, 1st and 2nd stage seed-cotton cleaning, overflow, combined lint cleaning, combined mote, battery condenser, and master trash systems. AP-42 lists emission factors of 0.37 and 1.1 kg per bale for PM_{10} and total PM, respectively, for this typical gin. Using the final factors determined for this project in, the same cotton gin setup would have emission factors of 0.046, 0.452, and 0.940 kg per bale for $PM_{2.5}$, PM_{10}, and total PM, respectively. This is an increase of 22% from the 1996 AP-42 PM_{10} emission factor and a decrease of 15% from the AP-42 total PM emission factor. For the typical gin factors, all of the emission factors for total PM were rated “highly representative,” as were all but one of the factors for PM_{10}. For $PM_{2.5}$, which did not exist in the 1996 AP-42, two of the factors in the typical gin setup were rated “highly representative,” and the other six were rated “moderately representative.” These new emission factor quality ratings are a significant improvement over the 1996 AP-42 emission factors, which all rated below average.

Sensitivity analysis was conducted to determine additional data needs to improve emission factors ratings to either “moderately” or “highly representative.” Because emission factor ratings are dependent on both the quantity and quality of the source data, the outputs of the sensitivity analysis included two-dimensional and three-dimensional charts that took both of these parameters into account. These charts could serve to guide future data collection efforts.

CHAPTER V

FUTURE WORK

The answers to the ITR regulatory review questions were highlighted and denoted within the National Study reports as the questions were answered for the current study. These reports and their associated data must now be entered into EPA's WebFIRE template to be submitted to the EPA for review. While all of the emission factors developed by the current study received ratings of either "moderately" or "highly" representative, it is possible that the National Study source tests will receive different ITRs from the EPA, which would result in different representativeness ratings.

To improve all of the new emission factor ratings to "highly representative," additional source tests will need to be conducted or located, rated for quality, and submitted to the EPA. Some possible sources of cotton gin emissions tests include Capareda, Parnell, Shaw, & Wanjura (2005), Hughs et al. (2004), California Cotton Ginners Association (2004), Columbus & Anthony (1993), and Parnell Jr. & Baker (1979).

REFERENCES

AMEC. (2012). *Electronic Reporting Tool (ERT) User's Guide*.

American Society of Agricultural Engineers. (2005). *Cotton Gins- Methods of Utilizing Emission Factors in Determining Emission Parameters*.

Anthony, W. S., & Mayfield, W. D. (Eds.). (1994). *Cotton Ginners Handbook*. Washington, D.C.

Backmann, J. (2007). Will the Circle Be Unbroken: A History of the U.S. National Ambient Air Quality Standards. *Journal of the Air & Waste Management Association (Taylor & Francis Ltd), 57*, 652–697. http://doi.org/10.3255/1047-3289.57.6.652

Boykin, J. C., Buser, M. D., Whitelock, D. P., & Holt, G. A. (2013a). Combined Mote System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science*, *17*, 447–456.

Boykin, J. C., Buser, M. D., Whitelock, D. P., & Holt, G. A. (2013b). Cyclone Robber System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science*, *17*, 414–424.

Boykin, J. C., Buser, M. D., Whitelock, D. P., & Holt, G. A. (2013c). Overflow System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science, 17*, 357–367.

Boykin, J. C., Buser, M. D., Whitelock, D. P., & Holt, G. A. (2013d). Second Stage Lint Cleaning System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science*, *17*, 380–390.

Boykin, J. C., Buser, M. D., Whitelock, D. P., & Holt, G. A. (2013e). Second Stage Seed-Cotton Cleaning System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science*, *17*, 333–345.

Boykin, J. C., Buser, M. D., Whitelock, D. P., & Holt, G. A. (2014a). Combined Lint Cleaning System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 248–257.

Boykin, J. C., Buser, M. D., Whitelock, D. P., & Holt, G. A. (2014b). First Stage Mote System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 278–288.

Boykin, J. C., Buser, M. D., Whitelock, D. P., & Holt, G. A. (2014c). Mote Cyclone Robber System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 319–328.

Boykin, J. C., Buser, M. D., Whitelock, D. P., & Holt, G. A. (2014d). Overflow System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 216–225.

Boykin, J. C., Buser, M. D., Whitelock, D. P., & Holt, G. A. (2014e). Third Stage Seed-Cotton Cleaning System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 207–215.

Boykin, J. C., Buser, M. D., Whitelock, D. P., & Holt, G. A. (2014f). Unloading System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclone. *Journal of Cotton Science*, *18*, 173–182.

Burt, J. E., Barber, G. M., & Rigby, D. L. (2009). *Elementary Statistics for Geographers* (3rd ed.). New York: The Guildford Press.

Buser, M. D. (2004, May). *Errors Associated With Particulate Matter Measurements on Rural Sources: Appropriate Basis for Regulating Cotton Gins*. Texas A&M University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2012a). *Battery Condenser System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-36)* (p. 112). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2012b). Characterization of Cotton Gin Particulate Matter Emissions- Project Plan. *Journal of Cotton Science*, *16*, 105–116.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2012c). *Combined Mote System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-40)* (p. 50). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2012d). *Cyclone Robber System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-37)* (p. 82). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2012e). *First Stage Mote System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-38)* (p. 96). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2012f). *Master Trash System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-42)* (p. 96). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2012g). *Mote Cleaner System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-65)* (p. 50). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2012h). *Mote Robber System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-41)* (p. 66). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2012i). *Mote Trash System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-64)* (p. 49). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2012j). *Overflow System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-63)* (p. 81). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2012k). *Second Stage Mote System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-39)* (p. 96). Stillwater, OK: Oklahoma State Univsersity.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2012l). *Second Stage Seed-Cotton Cleaning System Total Particulate Emission Factors and Rates for Cotton (Technical Report No.: OSU 12-31)* (p. 98). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013a). *1st Stage Lint Cleaning System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-05 Ver. 2.0)* (p. 89). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013b). *1st Stage Lint Cleaning System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-19 Ver. 2.0)* (p. 86). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013c). *1st Stage Mote System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-10 Ver. 2.0)* (p. 106). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013d). *1st Stage Mote System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-24 Ver. 2.0)* (p. 103). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013e). *1st Stage Seed-Cotton Cleaning System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-02 Ver. 2.0)* (p. 139). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013f). *1st Stage Seed-Cotton Cleaning System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-16 Ver. 2.0)* (p. 136). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013g). *2nd Stage Lint Cleaning System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-06 Ver. 2.0)* (p. 89). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013h). *2nd Stage Lint Cleaning System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-20 Ver. 2.0)* (p. 87). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013i). *2nd Stage Mote System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-11 Ver. 2.0)* (p. 106). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013j). *2nd Stage Mote System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-25 Ver. 2.0)* (p. 103). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013k). *2nd Stage Seed-Cotton Cleaning System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-03 Ver. 2.0)* (p. 107). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013l). *2nd Stage Seed-Cotton Cleaning System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-17 Ver. 2.0)* (p. 104). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013m). *3rd Stage Seed-Cotton Cleaning System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-04 Ver. 2.0)* (p. 56). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013n). *3rd Stage Seed-Cotton Cleaning System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-18 Ver. 2.0)* (p. 53). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013o). *Battery Condenser System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-08 Ver. 2.0)* (p. 122). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013p). *Battery Condenser System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-22 Ver. 2.0)* (p. 120). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013q). *Combined Lint Cleaning System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-07 Ver. 2.0)* (p. 72). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013r). Combined Lint Cleaning System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science*, *17*, 391–401.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013s). *Combined Lint Cleaning System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-21 Ver. 2.0)* (p. 70). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013t). *Combined Lint Cleaning System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-35 Ver. 2.0)* (p. 66). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013u). *Combined Mote System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-12 Ver. 2.0)* (p. 55). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013v). *Combined Mote System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-26 Ver. 2.0)* (p. 53). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013w). *Cyclone Robber System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-09 Ver. 2.0)* (p. 90). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013x). *Cyclone Robber System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-23 Ver. 2.0)* (p. 87). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013y). *First Stage Lint Cleaning System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-33 Ver. 2.0)* (p. 82). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013z). First Stage Mote System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science*, *17*, 425–435.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013aa). *First Stage Seed-Cotton Cleaning System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-30 Ver. 2.0)* (p. 127). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013ab). *Master Trash System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-14 Ver. 2.0)* (p. 107). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013ac). *Master Trash System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-28 Ver. 2.0)* (p. 103). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013ad). *Mote Cleaner System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-59 Ver. 2.0)* (p. 55). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013ae). Mote Cleaner System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science*, *17*, 457–467.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013af). *Mote Cleaner System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-62 Ver. 2.0)* (p. 55). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013ag). *Mote Cyclone Robber System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-13 Ver. 2.0)* (p. 73). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013ah). Mote Cyclone Robber System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science*, *17*, 468–478.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013ai). *Mote Cyclone Robber System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-27 Ver. 2.0)* (p. 70). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013aj). *Mote Trash System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-58 Ver. 2.0)* (p. 55). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013ak). *Mote Trash System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-61 Ver. 2.0)* (p. 53). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013al). *Overflow System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-57 Ver. 2.0)* (p. 89). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013am). *Overflow System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-60 Ver. 2.0)* (p. 87). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013an). *Particle Size Distribution Characteristics of Cotton Gin 2nd Stage Lint Cleaning System Total Particulate Emissions (Technical Report No.: OSU 13-07)* (p. 95). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013ao). *Particle Size Distribution Characteristics of Cotton Gin 2nd Stage Mote System Total Particulate Emissions (Technical Report No.: OSU 13-11)* (p. 112). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013ap). *Particle Size Distribution Characteristics of Cotton Gin 2nd Stage Seed-Cotton Cleaning System Total Particulate Emissions (Technical Report No.: OSU 13-03)* (p. 114). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013aq). *Particle Size Distribution Characteristics of Cotton Gin 3rd Stage Seed-Cotton Cleaning System Total Particulate Emissions (Technical Report No.: OSU 13-02)* (p. 65). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013ar). *Particle Size Distribution Characteristics of Cotton Gin Battery Condenser System Total Particulate Emissions (Technical Report No.: OSU 13-09)* (p. 129). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013as). *Particle Size Distribution Characteristics of Cotton Gin Combined Lint Cleaning System Total Particulate Emissions (Technical Report No.: OSU 13-08)* (p. 95). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013at). *Particle Size Distribution Characteristics of Cotton Gin Combined Mote System Total Particulate Emissions (Technical Report No.: OSU 13-12)* (p. 59). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013au). *Particle Size Distribution Characteristics of Cotton Gin Cyclone Robber System Total Particulate Emissions (Technical Report No.: OSU 13-13)* (p. 93). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013av). *Particle Size Distribution Characteristics of Cotton Gin Mote Cyclone Robber System Total Particulate Emissions (Technical Report No.: OSU 13-14)* (p. 76). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013aw). *Particle Size Distribution Characteristics of Cotton Gin Mote Trash System Total Particulate Emissions (Technical Report No.: OSU 13-16)* (p. 64). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013ax). *Particle Size Distribution Characteristics of Cotton Gin Overflow System Total Particulate Emissions (Technical Report No.: OSU 13-05)* (p. 95). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013ay). *Particle Size Distribution Characteristics of Cotton Gin Unloading System Total Particulate Emissions (Technical Report No.: OSU 13-01)* (p. 76). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013az). *Second Stage Lint Cleaning System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-34 Ver. 2.0)* (p. 82). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013ba). Third Stage Seed-Cotton Cleaning System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science*, *17*, 346–356.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013bb). *Third Stage Seed-Cotton Cleaning System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-32 Ver. 2.0)* (p. 50). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013bc). Unloading system $PM_{2.5}$ emission factors and rates for cotton gins: Method 201A combination PM_{10} and $PM_{2.5}$ sizing cyclones. *Journal of Cotton Science*, *17*, 309–319.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013bd). *Unloading System $PM_{2.5}$ Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-01 Ver. 2.0)* (p. 71). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013be). *Unloading System PM_{10} Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-15 Ver. 2.0)* (p. 71). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2013bf). *Unloading System Total Particulate Emission Factors and Rates for Cotton Gins (Technical Report No.: OSU 12-29 Ver. 2.0)* (p. 66). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2014a). Battery Condenser System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 258–267.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2014b). First Stage Lint Cleaning Systems Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 226–236.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2014c). First Stage Seed-Cotton Cleaning System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 183–194.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2014d). Master Trash System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 338–347.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2014e). Mote Cleaner System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 309–318.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2014f). Mote Trash System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 329–337.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2014g). *Particle Size Distribution Characteristics of Cotton Gin 1st Stage Lint Cleaning System Total Particulate Emissions (Technical Report No.: OSU 13-06 Ver. 2.0)* (p. 98). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2014h). *Particle Size Distribution Characteristics of Cotton Gin 1st Stage Mote System Total Particulate Emissions (Technical Report No.: OSU 13-10 Ver. 2.0)* (p. 117). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2014i). *Particle Size Distribution Characteristics of Cotton Gin 1st Stage Seed-Cotton Cleaning System Total Particulate Emissions (Technical Report No.: OSU 13-02 Ver. 2.0)* (p. 154). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2014j). *Particle Size Distribution Characteristics of Cotton Gin Master Trash System Total Particulate Emissions (Technical Report No.: OSU 13-17 Ver. 2.0)* (p. 33). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2014k). *Particle Size Distribution Characteristics of Cotton Gin Mote Cleaner System Total Particulate Emissions*

(Technical Report No.: OSU 13-15 Ver. 2.0) (p. 33). Stillwater, OK: Oklahoma State University.

Buser, M. D., Whitelock, D. P., Boykin, J. C., & Holt, G. A. (2014l). Second Stage Mote System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 289–299.

Buser, M. D., Whitelock, D. P., Holt, G. A., Armijo, C. B., & Wang, L. (2007). Collection efficiency evaluation of baffle-type pre-separator configurations: Effects of baffle location and inlet velocities. *Applied Engineering in Agriculture*, *23*(3), 347–355.

California Cotton Ginners Association. (2004). *Cotton Gin Emission Factor Handbook- Version 1.4*. Fresno, CA: California Cotton Ginners Association.

Capareda, S. C., Parnell, C. B., Shaw, B. W., & Wanjura, J. D. (2005). Particle Size Distribution Analysis of Agricultural Dusts and Report of True PM_{10} Concentrations. Paper No.: 054044. Presented at the ASAE Annual International Meeting, ASAE.

CEPA. (2011). *Permit Streamlining Guidance Document*. Retrieved from http://www.arb.ca.gov/ba/psgd.htm

Columbus, E. P., & Anthony, W. S. (1993). Particle Size Distribution of Cotton Gin Dust from Across the Cotton Belt (pp. 1597–1661). Presented at the Proc. Beltwide Cotton Production Converences, National Cotton Council.

Comis, D. (2011). Blowing in the Wind. *Agriculture Research*, *59*, 9–13.

Eastern Research Group, I. (2013). *Recommended Procedures for Development of Emissions Factors and Use of the WebFIRE Database* (No. EPA-453/D-13-001). Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Sectors Policies & Programs Division, Measurement Policy Group. Retrieved from http://www.epa.gov/ttnchie1/efpac/procedures/procedures81213.pdf

EC/R Incorporated. (1998). *Stationary Source Control Techniques Document for Fine Particulate Matter* (No. EPA Contract No. 68-D-98-026). Research Triangle Park, NC: US Environmental Protection Agency, Integrated Policy and Strategies Group.

Enthalpy Analytical, I. (2013). Emissions Measurements: EPA Method 5, 17 & 201a. Retrieved from http://www.enthalpy.com/emissions-measurement/methods/epa-method-5-201a-a-17

EPA. (1993). *Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections* (No. EPA-454/B-93-050). Research Triangle Park, NC.

EPA. (1995). *Compilation of Air Pollutant Emission Factors*. Research Triangle Park, NC. Retrieved from http://www.epa.gov/ttn/chief/ap42/

EPA. (1996). *Emission Factor Document for AP-42 Section 9.7: Cottong Ginning- Final Report*. Research Triangle Park, NC.

EPA. Determination of Particulate Matter Emissions From Stationary Sources, 40 CFR 60. Appendix A Agency, Environmenal Protection (Federal Registry 2009).

EPA. Methods for Measurement of Filterable PM_{10} and $PM_{2.5}$ and Measurement of Condensable PM Emissions From Stationary Sources, EPA-HQ-OAR-2008-0348 Agency, Environmental Protection (Federal Register 2010).

EPA. (2011). *WebFIRE Spreadsheet Template Instructions*.

EPA. (2012a, March 27). State Implementation Plan Overview [Web Page]. Retrieved from http://www.epa.gov/airquality/urbanair/sipstatus/overview.html

EPA. (2012b, December 14). National Ambient Air Quality Standards (NAAQS) [Webpage]. Retrieved April 1, 2011, from http://www.epa.gov/air/criteria.html

EPA. (2013a). *The Clean Air Act in a Nutshell: How It Works*. U.S. Environmental Protection Agency. Retrieved from http://www.epa.gov/air/caa/pdfs/CAA_Nutshell.pdf

EPA. (2013b, March 18). Particulate Matter (PM): Basic Information. Retrieved from http://www.epa.gov/airquality/particulatematter/basic.html

EPA. (2013c, September 13). State Implementation Plan Development Process [Web Page]. Retrieved from http://www.epa.gov/airquality/urbanair/sipstatus/process.html

Faulkner, W. B., Wanjura, J. D., Boman, R. K., Shaw, B. W., & Parnell, C. B. J. (2011). Evaluation of Modern Cotton Harvest Systems on Irrigated Cotton: Harvester Performance. *Applied Engineering in Agriculture*, *27*(4), 497–506.

Hinds, W. C. (1999). *Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles* (2nd. ed.). New York: John Wiley & Sons, Inc.

Hughs, S. E., Buser, M. D., & Isom, R. (2004). Emission Factors for First- and Second-Pick Pima Cotton. *Transactions of the ASAE*, *47*(1), 29–35.

IDNR. (2013). *Air Dispersion Modeling Guidelines For Non-PSD, Pre-Construction Permit Applications*. Retrieved from http://www.iowadnr.gov/Portals/idnr/uploads/air/insidednr/dispmodel/modeling_guidelines.pdf

MDNR. (2013). *Air Pollution Control Program: Permits Section*. Retrieved from http://www.environmentalworks.com/wp-content/uploads/2013/10/Susan-Heckencamp-Air-Permitting-Presentation.pdf

MPCA. (2003). *Citizens' Guide to Air Pollutant Emission Inventories*. St. Paul, MN. Retrieved from http://www.pca.state.mn.us/index.php/view-document.html?gid=2377

Parnell Jr., C. B., & Baker, R. V. (1979). *Particulate Emissions of a Cotton Gin in the Texas Stripper Area. Production Research Report No. 149*. Washington, D.C.: U.S. Department of Agriculture, Agricultural Research Service.

Singh, A., Armbya, N., & Singh, A. (2010). *ProUCL Version 4.1. 00 Technical Guide (Draft)*. US EPA/600/R-07/041 (May 2010).

TCEQ. (2014). *2013 Emissions Inventory Guidelines* (No. RG-360/13). Austin, TX. Retrieved from http://www.tceq.texas.gov/assets/public/comm_exec/pubs/rg/rg360/rg36013/RG-360.pdf

USDA. (2013). *Cotton Price Statistics- 2012-2013* (No. mp_cn830). Memphis, TN.

USDA, N. (2014). *Cotton Ginnings Annual Summary* (No. 2159-7804). Retrieved from http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1042

US EPA. (2009). Statistical Software ProUCL 4.1.00 for Environmental Applications for Data Sets with and without Nondetect Observations (Version 4.1.01). Retrieved from http://www.epa.gov/osp/hstl/tsc/software.htm

Whitelock, D. P., Buser, M. D., Boykin, J. C., & Holt, G. A. (2013a). Battery Condenser System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science*, *17*, 402–413.

Whitelock, D. P., Buser, M. D., Boykin, J. C., & Holt, G. A. (2013b). First Stage Lint Cleaning System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science*, *17*, 368–379.

Whitelock, D. P., Buser, M. D., Boykin, J. C., & Holt, G. A. (2013c). First Stage Seed-Cotton Cleaning System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science*, *17*, 320–332.

Whitelock, D. P., Buser, M. D., Boykin, J. C., & Holt, G. A. (2013d). Master Trash System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science*, *17*, 489–499.

Whitelock, D. P., Buser, M. D., Boykin, J. C., & Holt, G. A. (2013e). Mote Trash System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science*, *17*, 479–488.

Whitelock, D. P., Buser, M. D., Boykin, J. C., & Holt, G. A. (2013f). Second Stage Mote System $PM_{2.5}$ Emission Factors and Rates from Cotton Gins: Method 201A Combination PM_{10} and $PM_{2.5}$ Sizing Cyclones. *Journal of Cotton Science*, *17*, 436–446.

Whitelock, D. P., Buser, M. D., Boykin, J. C., & Holt, G. A. (2014a). Combined Mote System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 300–308.

Whitelock, D. P., Buser, M. D., Boykin, J. C., & Holt, G. A. (2014b). Cyclone Robber System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 268–277.

Whitelock, D. P., Buser, M. D., Boykin, J. C., & Holt, G. A. (2014c). Second Stage Lint Cleaning System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 237–247.

Whitelock, D. P., Buser, M. D., Boykin, J. C., & Holt, G. A. (2014d). Second Stage Seed-Cotton Cleaning System PM_{10} Emission Factors and Rates for Cotton Gins: Method 201A PM_{10} Sizing Cyclones. *Journal of Cotton Science*, *18*, 195–206.

APPENDIX A

TYPICAL COTTON GIN SYSTEMS

Unloading System: The unloading system of a cotton gin (Figure A - 1) brings seed-cotton from modules or trailers to a feed control unit that meters seed cotton to the gin's cotton cleaning systems. For cotton modules, the unloading system generally utilizes a module feeder consisting of spiked cylinders that pull the cotton apart from the module. For cotton brought in on a trailer, a telescoping suction pipe is often used to remove the cotton from the trailer.

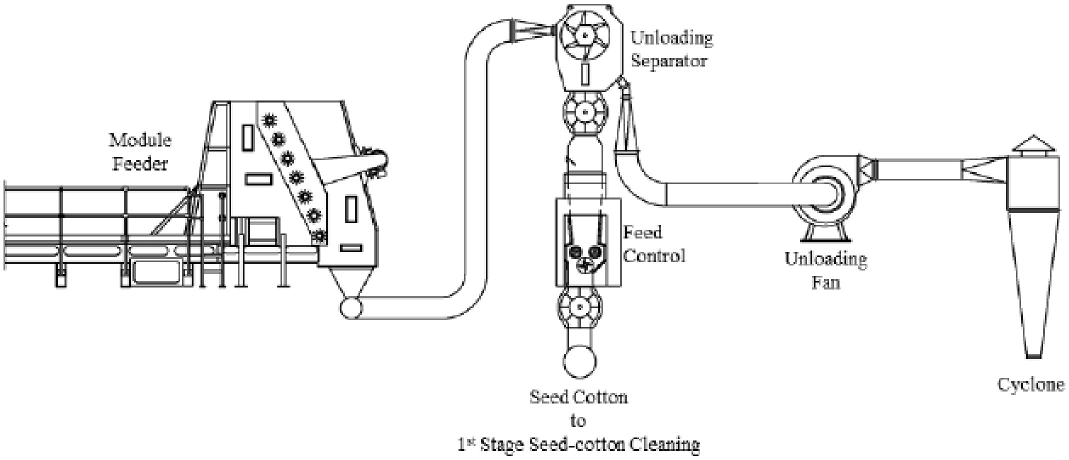


Figure A - 1. Typical cotton gin unloading system layout (Courtesy Lummus Corporation, Savannah, GA).

After seed cotton is removed from the module or trailer it is transported pneumatically into a screened separator that pulls the cotton out of the airstream. This transport is usually done with heated air to dry the seed cotton. After being separated from the airstream, the cotton is deposited into a feed control device that regulates its flow into the next system.

The airstream used to transport the seed cotton from the module feeder to the unloading separator is then conveyed through one or more cyclones of either 1D3D or 2D2D design. The airstream entering these cyclones usually contains soil, small leaves, rocks, sticks and hulls.

First Stage Seed-Cotton Cleaning System: After seed cotton passes through the unloading system, it is fed into a seed-cotton cleaning system. Multiple systems can be used in the cleaning process. These systems dry the seed cotton and remove foreign matter before it is ginned.

In the typical 1st stage seed-cotton cleaning system (Figure A - 2), seed cotton is pneumatically conveyed with heated air from either the feed control or module feeder through a dryer to the seed-cotton cleaning machinery. This cleaning system may use air heated up to 117ºC (350ºF) at the seed cotton and air mixing point to accomplish drying during transport. The seed cotton is pulled directly into the seed-cotton cleaning machinery and separated from the conveying airstream by the cleaning mechanism (called a “hot-air” cleaner) or separated from the conveying air via a screened separator and dropped into the cleaning machinery.

Seed-cotton cleaning machinery includes cleaners or extractors. Each stage often employs two cleaners in series. This system removes foreign matter that includes rocks, soil, sticks, hulls, and leaf material. The airstream from the 1st stage seed-cotton cleaning system continues through a centrifugal fan to an abatement system, generally one or more 1D3D or 2D2D cyclones. The material handled by the abatement system is typically the same as that removed by the seed-cotton cleaning machinery (rocks, soil, sticks, hulls, and leaf material), plus lint extracted with the trash.

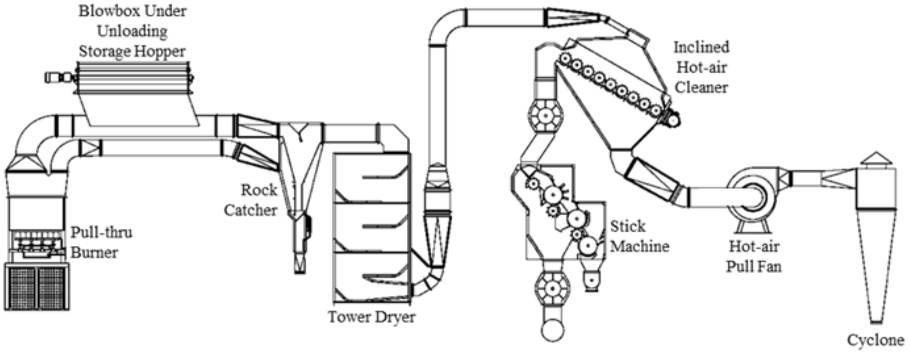


Figure A - 2. Typical cotton gin 1st stage seed-cleaning system layout (Courtesy Lummus Corporation, Savannah, GA).

Second Stage Seed-Cotton Cleaning Machinery: In the typical 2nd stage seed-cotton cleaning system (Figure A - 3), seed cotton drops from the 1st stage seed-cotton cleaning system machinery into the hot air pneumatic conveying system of the 2nd stage seed-cotton cleaning system via a rotary airlock and blow box. This cleaning system may use air heated up to 117ºC (350ºF) at the seed cotton and air mixing point to accomplish drying during transport. The seed cotton is pulled directly into the 2nd stage seed-cotton cleaning machinery and separated from the conveying airstream by the cleaning mechanism (called a "hot-air" cleaner) or separated from the conveying air via a screened separator and dropped into the cleaning machinery.

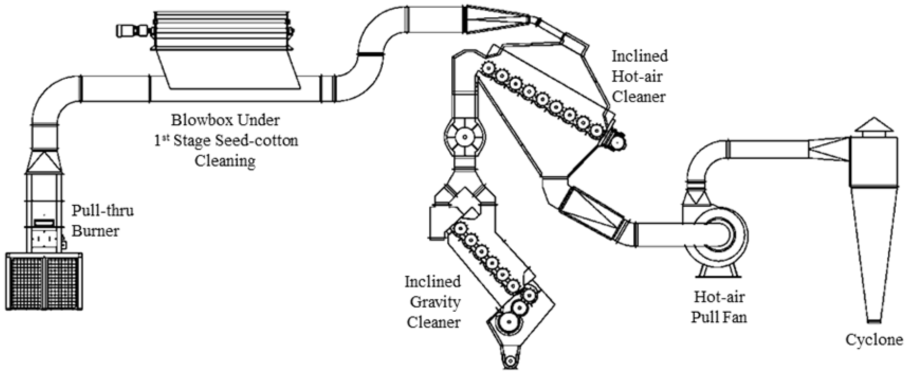


Figure A - 3. Typical cotton gin 2nd stage seed-cotton cleaning system layout (Courtesy Lummus Corporation, Savannah, GA).

The 2^{nd} stage seed-cotton cleaning machinery also includes cleaners or extractors and often employs two cleaners in series. This system removes foreign matter that includes rocks, soil, sticks, hulls, and leaf material. The airstream from the 2^{nd} stage seed-cotton cleaning system continues through a centrifugal fan to an abatement system; generally one or more 1D3D or 2D2D cyclones. The material handled by the abatement system is typically the same as that removed by the seed-cotton cleaning machinery (rocks, soil, sticks, hulls, and leaf material) and lint extracted with the trash.

Third Stage Seed-Cotton Cleaning System: *see Second Stage Seed-Cotton Cleaning System*- While this system is identical to the second stage seed-cotton cleaning system, being third in a series should reduce its emissions enough to warrant a separate emission factor for the third stage lint cleaning system.

Overflow System: Overflow systems (Figure A - 4) follow the seed-cotton cleaning systems and are used to help maintain proper flow of seed cotton to the gin stands. Seed cotton drops from the last stage of seed-cotton cleaning into the conveyor distributor, where it is distributed to the extractor feeders that meter cotton to each gin stand (cotton gins typically split the seed cotton among multiple, parallel gin stands). Excess seed cotton in the conveyor distributor is conveyed to the overflow system storage hopper, recirculated pneumatically, and dropped back into the conveyor distributor via a screened separator as needed. The airstream from the screened separator of the overflow system continues through a centrifugal fan to one or more 1D3D or 2D2D particulate abatement cyclones. The material handled by the overflow system cyclones typically includes soil, small leaf, and lint fiber.

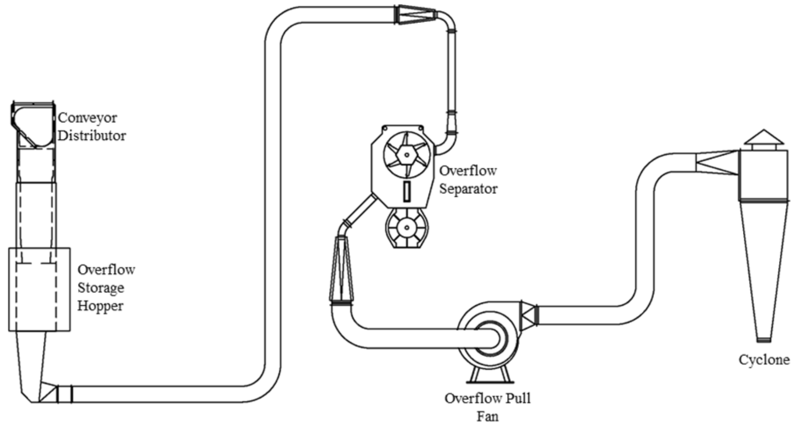


Figure A - 4. Typical cotton gin overflow system layout (Courtesy Lummus Corporation, Savannah, GA).

First Stage Lint Cleaning System: After the seed cotton is ginned (seed is separated from the cotton lint), the cotton lint is cleaned in the lint cleaning systems (Figure A - 5). In the typical 1st and 2nd stage lint cleaning system, cotton fiber or lint is pneumatically conveyed from the gin stands, through a centrifugal lint cleaner, to the 1st stage lint cleaners for further foreign matter removal. Cotton gins typically split the pre-cleaned seed cotton among multiple, parallel gin stand/lint cleaning lines that are recombined at packaging. The lint is removed from the airstream with a rotating, screened separator drum and directed into the lint cleaner feed works.

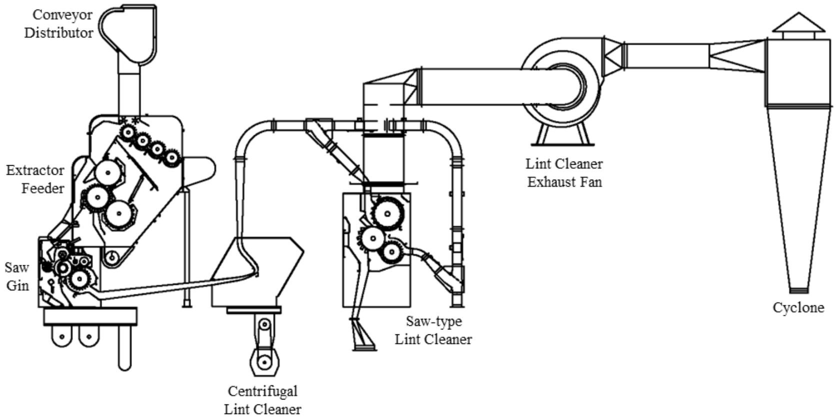


Figure A - 5. Typical cotton gin 1st stage lint cleaning system layout (Courtesy Lummus Corporation, Savannah, GA).

Lint cleaners remove fine trash, seed, and some lint. The material removed by lint cleaners is referred to as “motes”. Lint is directed from the lint cleaner to either a subsequent stage of lint cleaning or into the bale packaging system. A 2nd stage of lint cleaning is sometimes used and is essentially identical to the 1st stage

The airstream from the lint cleaner screened separators continues through a centrifugal fan to one or two 1D3D or 2D2D particulate abatement cyclones. Some lint cleaning systems utilize a vane-axial fan, but these systems typically do not have cyclones and exhaust directly to ambient air. The pneumatic systems of the two lint cleaning stages may share a fan and abatement device or may operate independently, as is the case with 1st stage lint cleaning systems. The material handled by the lint cleaner cyclones typically includes small trash and particulate, and lint fibers.

Second Stage Lint Cleaning System: *see First Stage Lint Cleaning System*- While this system is identical to the first stage lint cleaning system, being second in a series should reduce its emissions enough to warrant a separate emission factor for the second stage lint cleaning system.

Combined Lint Cleaning System: A combined lint cleaning system is one in which two lint cleaning systems in series share the same exhaust point. The combined exhaust may have close to the same emission factor as the summation of the factors for first and second stage lint cleaning systems, but having a separate factor would provide more accurate estimates for emission inventories.

Battery Condenser System: Lint from the final stages of lint cleaning is pneumatically conveyed to the bale packaging system via the lint flue and separated from the airstream by a large, screened, rotating drum separator called the “battery condenser”. A schematic of the battery condenser system is shown in Figure A - 6.

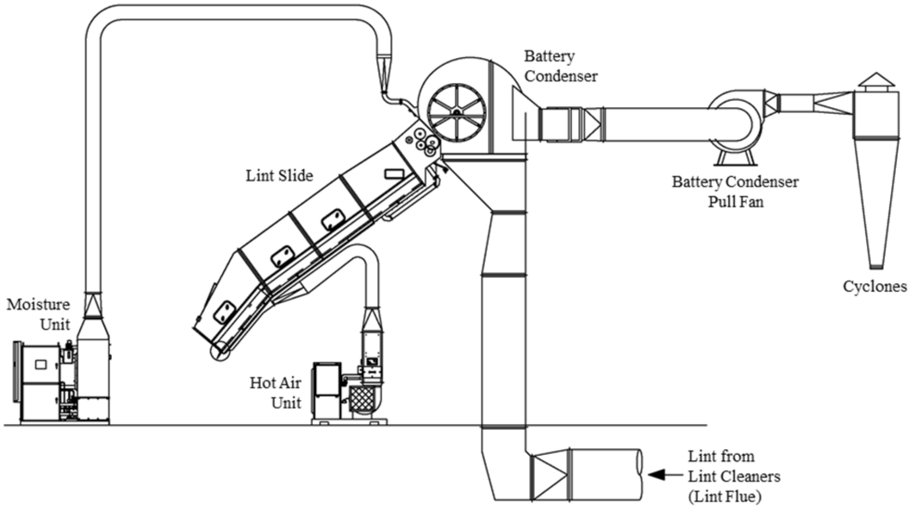


Figure A - 6. Typical cotton gin battery condenser system layout (Courtesy Lummus Corporation, Savannah, GA).

The battery condenser drops the lint onto the lint slide, which feeds lint into the bale press for compressing and packaging the lint into a 227 kg (500 lb.) bale. The airstream from the battery condenser system continues through a large centrifugal fan to one or more 1D3D or 2D2D particulate abatement cyclones. Some battery condenser systems utilize a vane-axial fan, but these systems typically do not have cyclones and exhaust directly to ambient air. The material handled by the battery condenser cyclones typically includes small trash and particulate, and lint fibers.

Cyclone Robber System: Cyclone robber systems are typically used to remove material captured by battery condenser and lint cleaning system cyclones (Figure A - 7). Material captured by these cyclones must be handled and conveyed from the trash exit of the cyclone, or the materials would build up and eventually choke or block the airflow in the cyclone, reducing or stopping its cleaning ability.

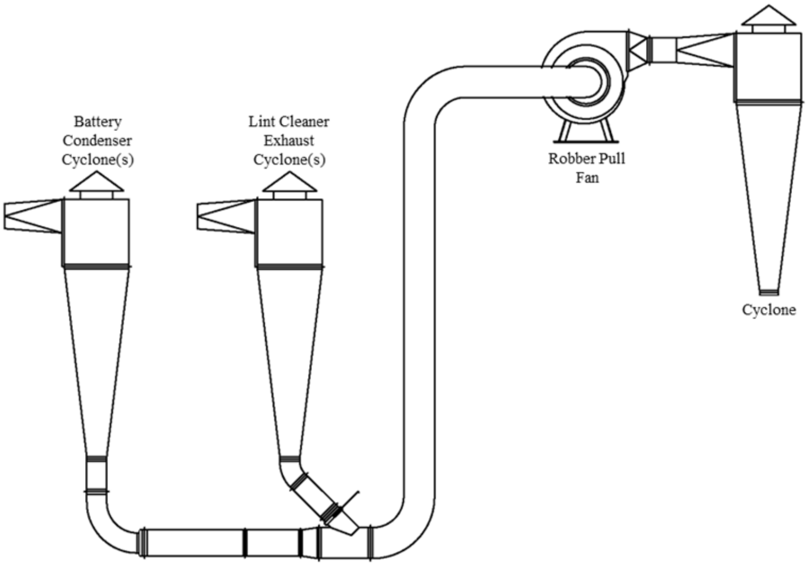


Figure A - 7. Typical cotton gin cyclone robber system layout (Courtesy Lummus Corporation, Savannah, GA).

In the case of cyclones that handle airstreams laden with higher amounts of lint (battery condenser and lint cleaning cyclones), it may not be practical to convey the high lint content material mechanically, as the lint tends to "rope-up" and collect on the moving parts. Also, this high lint content material, referred to as "motes", has considerable value, especially when cleaned slightly. Thus, this material is pulled by suction from the trash exit of the cyclones and pneumatically conveyed via a cyclone robber system to another cyclone, which drops the motes either directly into another trash system or into a machine for cleaning. The systems that remove material from mote cyclones and deposit the motes into a mote cleaner system are termed mote cyclone robbers (Figure A - 8). The material handled by the cyclone robber cyclones typically includes the combined trash or motes handled by the lint handling systems mentioned above – small trash and particulate and large amounts of lint fibers.

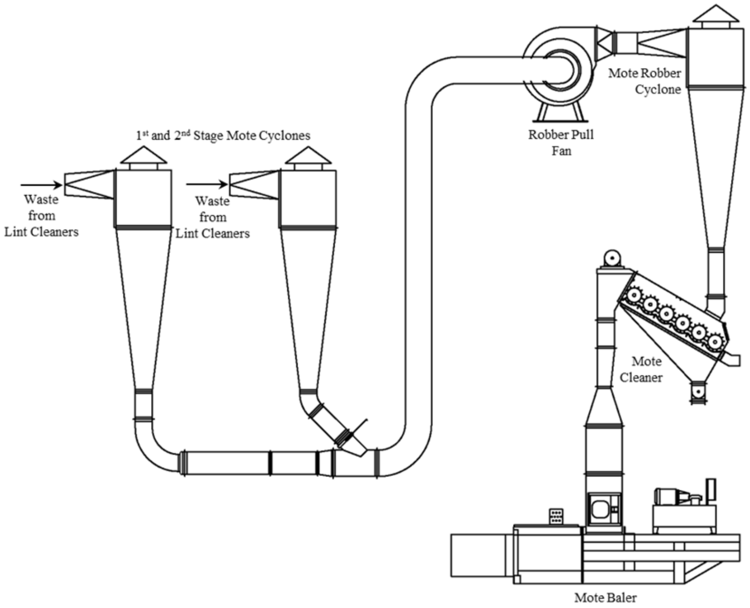


Figure A - 8. Typical cotton gin mote cyclone robber system layout (Courtesy Lummus Corporation, Savannah, GA).

First Stage Mote System: After the cotton seed and lint are separated at the gin stand, the lint is further cleaned by one or more stages of lint cleaners. Lint cleaners remove fine trash, seed, and some lint. The material removed by lint cleaners is referred to as “motes”. This material is handled by the mote systems (Figure A - 9). Motes are pneumatically conveyed by suction away from the lint cleaners, through a centrifugal fan, to one or more 1D3D or 2D2D cyclones. The material handled by the mote cyclones typically includes small trash and particulate, and large amounts of lint fibers.

Second Stage Motes System: *see First Stage Mote System*- While this system is identical to the first stage mote system, being second in a series should reduce its emissions enough to warrant a separate emission factor for the second stage lint cleaning system.

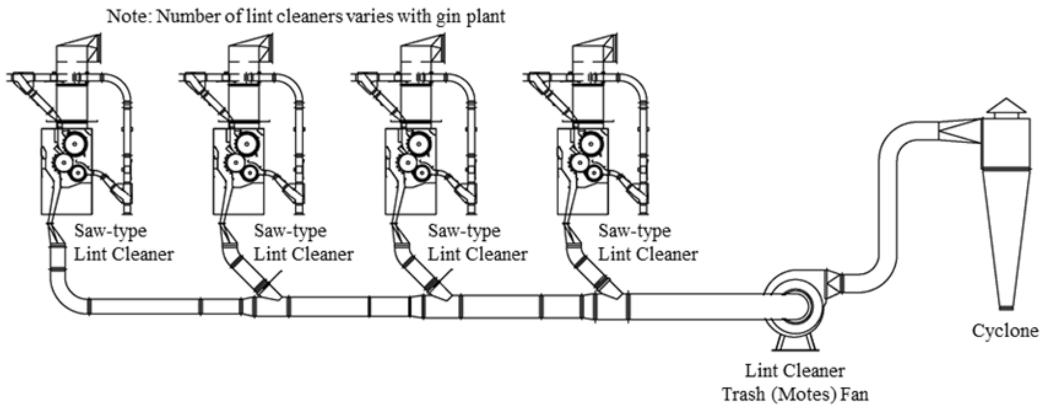


Figure A - 9. Typical cotton gin 1st stage mote system layout (Courtesy Lummus Corporation, Savannah, GA).

Combined Mote System: Depending on the cotton gin facility, the 1st and 2nd stages of lint cleaning may share a mote system, thus sharing a fan and abatement devices. The function of the 1st and 2nd stage mote systems with separate or combined exhausts is the same, and it is expected that the PM emissions from a combined exhaust system would be similar to summation of the 1st and 2nd stage mote systems with separate exhausts. However, having separate emission factors for combined exhaust systems would allow for more accurate use of AP-42.

Master Trash System: Many of the cotton gin systems produce some type of by-product or trash as a result of processing the cotton or lint, or further processing a by-product. In each case, the stream of trash must be removed from the machinery and handled by trash systems (Figure A - 10).

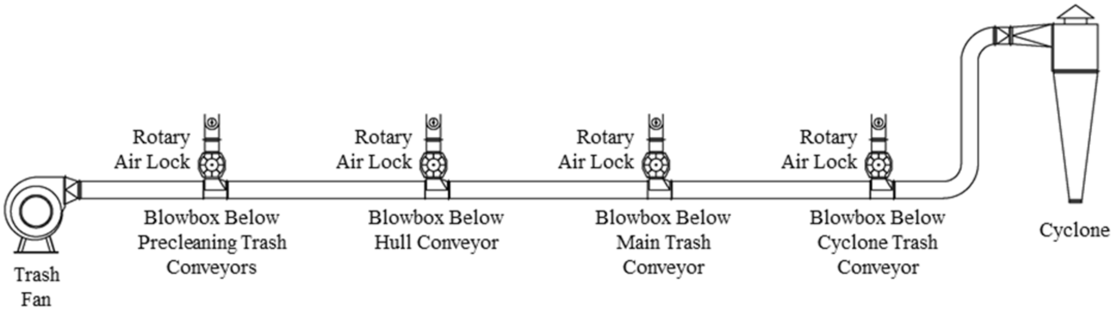


Figure A - 10. Typical cotton gin master trash system layout (Courtesy Lummus Corporation, Savannah, GA).

Typically, all trash at cotton gins is consolidated into one storage area for subsequent removal. In some cases, the cyclones for different cotton gin systems are located over a trash hopper, and thus a main trash system is not necessary. In many other cases, a master trash system will pull trash from systems throughout the cotton gin pre-cleaning systems' trash conveyors, gin stands' trash conveyor, and the main trash conveyor (often located under the unloading system, seed-cotton cleaning system, overflow system, and other systems' cyclones). The trash is pneumatically conveyed to one or two master trash 1D3D or 2D2D cyclones located over either a storage hopper or a trash pile. The material handled by the master trash cyclones typically includes any and all types of trash encountered by the cotton gin systems (rocks, soil, sticks, hulls, leaf material, and lint), and these cyclones are often quite heavily loaded.

Mote Cleaner System: 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 (Figure A - 11). In mote cleaner systems 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.

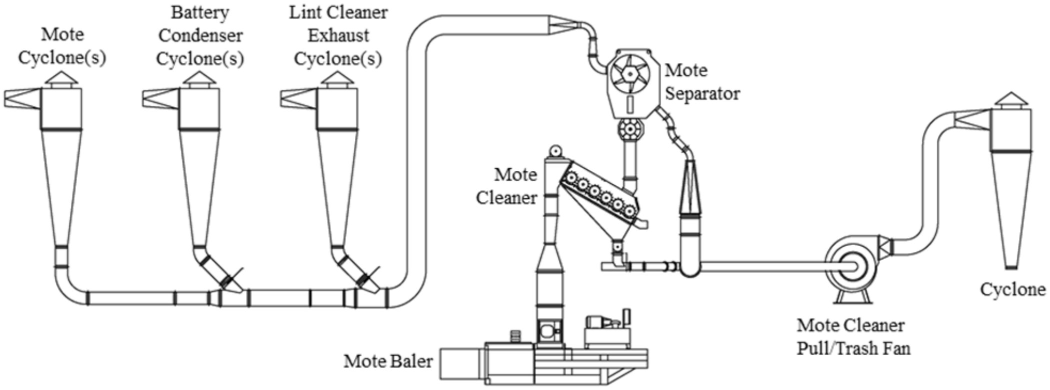


Figure A - 11. Typical cotton gin mote cleaner system layout (Courtesy Lummus Corporation, Savannah, GA).

The airstream from the screened separator continues through a centrifugal fan to one or two 1D3D or 2D2D 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.

Mote Trash System: In facilities where a mote cyclone robber system drops motes directly into the mote cleaner (Figure A - 12), the mote trash may be handled separately by a mote trash system. In this system, the mote trash is pulled by suction from the trash exit of the mote cleaner and pneumatically conveyed through a centrifugal fan to the mote trash cyclone. The material handled by the mote trash cyclone typically includes particulate, small leaf material, and lint fibers.

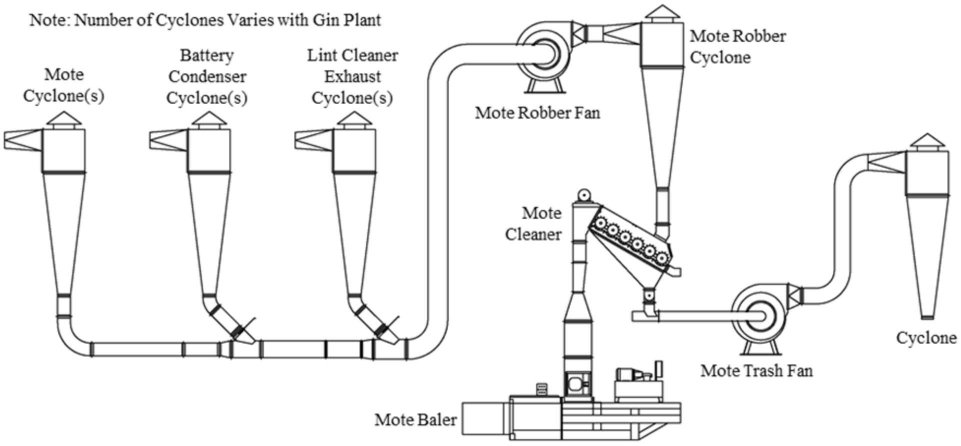


Figure A - 12. Typical cotton gin mote trash system layout (Courtesy Lummus Corporation, Savannah, GA).

APPENDIX B

TEST QUALITY RATING TOOL QUESTIONS

Table B - 1. Submitter review questions for individual test rating development (Eastern Research Group, 2013).

Supporting Documentation Provided	**Point Value**
As described in ASTM D7036-12 Standard Practice for Competence of Air Emission Testing Bodies, does the testing firm meet the criteria as an AETB or is the person in charge of the field team a QI for the type of testing conducted? A certificate from an independent organization (e.g., Stack Testing Accreditation Council (STAC), California Air Resources Board (CARB), National Environmental Laboratory Accreditation Program (NELAP)) or self declaration provides documentation of competence as an AETB.	2
Is a description and drawing of test location provided?	3
Has a description of deviations from published test methods been provided, or is there a statement that deviations were not required to obtain data representative of typical facility operation?	6
Is a full description of the process and the unit being tested (including installed controls) provided?	3
Has a detailed discussion of source operating conditions, air pollution control device operations and the representativeness of measurements made during the test been provided?	6
Were the operating parameters for the tested process unit and associated controls described and reported?	60
Is there an assessment of the validity, representativeness, achievement of DQO's and usability of the data?	9
Have field notes addressing issues that may influence data quality been provided?	0
Dry gas meter (DGM) calibrations, pitot tube and nozzle inspections?	54
Was the Method 1 sample point evaluation included in the report?	12
Were the cyclonic flow checks included in the report?	12
Were the raw sampling data and test sheets included in the report?	126
Did the report include a description and flow diagram of the recovery procedures?	30

Table B - 1 (cont.). Submitter review questions for individual test rating development (Eastern Research Group, 2013).

Supporting Documentation Provided	**Point Value**
Was the laboratory certified/accredited to perform these analyses?	2
Did the report include a complete laboratory report and flow diagram of sample analysis?	132
Were the chain-of-custody forms included in the report?	12

Table B - 2. Regulatory agency review questions for individual test rating development (Eastern Research Group, 2013).

Regulatory Agency Review Questions	**Point Value**
As described in ASTM D7036-12 Standard Practice for Competence of Air Emission Testing Bodies, does the testing firm meet the criteria as an AETB or is the person in charge of the field team a QI for the type of testing conducted? A certificate from an independent organization (e.g., STAC, CARB, NELAP) or self-declaration provides documentation of competence as an AETB.	2
Was a representative of the regulatory agency on site during the test?	1
Is a description and drawing of test location provided?	4
Is there documentation that the source or the test company sought and obtained approval for deviations from the published test method prior to conducting the test or that the tester's assertion that deviations were not required to obtain data representative of operations that are typical for the facility?	8
Were all test method deviations acceptable?	0
Is a full description of the process and the unit being tested (including installed controls) provided?	4
Has a detailed discussion of source operating conditions, air pollution control device operations and the representativeness of measurements made during the test been provided?	8
Is there documentation that the required process monitors have been calibrated and that the calibration is acceptable?	16
Was the process capacity documented?	16
Was the process operating within an appropriate range for the test program objectives?	16
Were process data concurrent with testing?	16
Were data included in the report for all parameters for which limits will be set?	16
Did the report discuss the representativeness of the facility operations, control device operation, and the measurements of the target pollutants, and were any changes from published test methods or process and control device monitoring protocols identified?	12
Were all sampling issues handled such that data quality was not adversely affected?	0

Table B – 2 (cont.). Regulatory agency review questions for individual test rating development (Eastern Research Group, 2013).

Regulatory Agency Review Questions	**Point Value**
Was the DGM pre-test calibration within the criteria specified by the test method?	12
Was the DGM post-test calibration within the criteria specified by the test method?	12
Were thermocouple calibrations within method criteria?	12
Was the pitot tube inspection acceptable?	12
Were nozzle inspections acceptable?	12
Were flow meter calibrations acceptable?	12
Were the appropriate number and location of sampling points used?	16
Did the cyclonic flow evaluation show the presence of an acceptable average gas flow angle?	16
Were all data required by the method recorded?	16
Were required leak checks performed and did the checks meet method requirements?	40
Was the required minimum sample volume collected?	24
Did probe, filter, and impinger exit temperatures meet method criteria (as applicable)?	32
Did isokinetic sampling rates meet method criteria?	32
Was the sampling time at each point greater than 2 minutes and the same for each point?	24
Was the recovery process consistent with the method?	8
Were all required blanks collected in the field?	8
Where performed, were blank corrections handled per method requirements?	12
Were sample volumes clearly marked on the jar or measured and recorded?	12
Was the laboratory certified/accredited to perform these analyses?	2
Did the laboratory note the sample volume upon receipt?	12
If sample loss occurred, was the compensation method used documented and approved for the method?	9
Were the physical characteristics of the samples (e.g., color, volume, integrity, pH, temperature) recorded and consistent with the method?	12
Were sample hold times within method requirements?	12
Does the laboratory report document the analytical procedures and techniques?	8
Were all laboratory QA requirements documented?	20
Were analytical standards required by the method documented?	16
Were required laboratory duplicates within acceptable limits?	16
Were required spike recoveries within method requirements?	16
Were method-specified analytical blanks analyzed?	16
If problems occurred during analysis, is there sufficient documentation to conclude that the problems did not adversely affect the sample results?	15
Was the analytical detection limit specified in the test report?	8
Is the reported detection limit adequate for the purposes of the test program?	8
Do the chain-of-custody forms indicate acceptable management of collected samples between collection and analysis?	16

APPENDIX C

STATISTICAL ANALYSIS

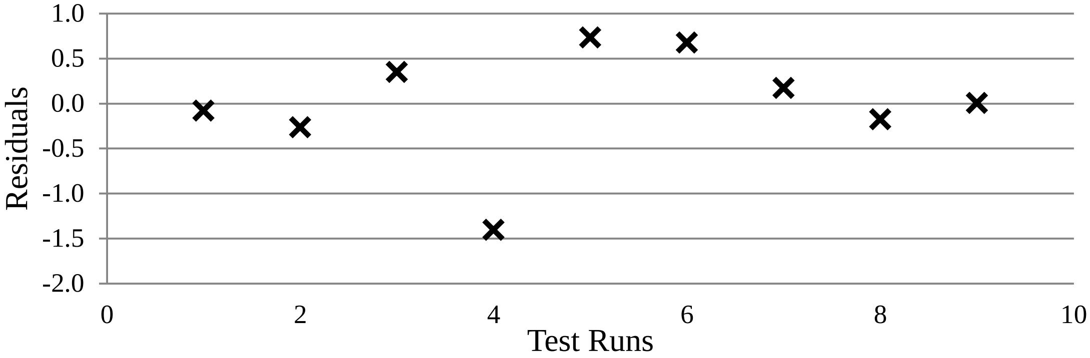


Figure C - 1. Unloading system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 1. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ unloading system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 3**
Tests	3	9
Critical Value	0.941	0.512
Upper Tail		
Potential Outlier	-1.189	-1.132
Test Statistic	0.142	0.010
Outlier?	No	No
Lower Tail		
Potential Outlier	-1.600	-1.678
Test Statistic	0.858	0.094
Outlier?	No	No

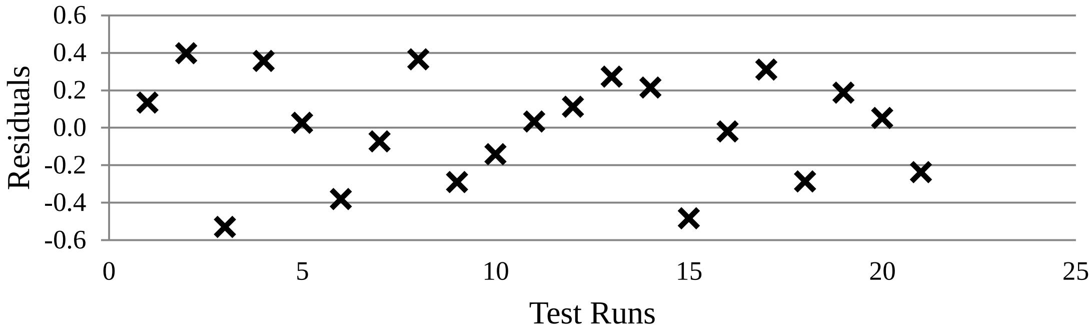


Figure C - 2. 1st stage seed-cotton cleaning system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 2. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ 1st stage seed-cotton cleaning system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 3**
Tests	7	21
Critical Value	0.507	0.44
Upper Tail		
Potential Outlier	-1.415	-1.373
Test Statistic	0.430	0.164
Outlier?	No	No
Lower Tail		
Potential Outlier	-2.012	-2.126
Test Statistic	0.044	0.170
Outlier?	No	No

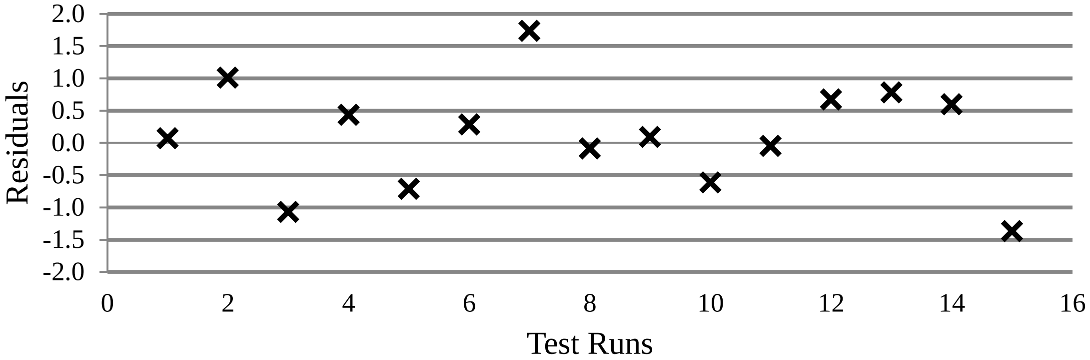


Figure C - 3. 2nd stage seed-cotton cleaning system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 3. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ 2^{nd} stage seed-cotton cleaning system emission factors (no PSD data; α = 0.05).

	"Test" Design 1	**"Test" Design 3**
Tests	5	15
Critical Value	0.642	0.525
Upper Tail		
Potential Outlier	-2.010	-1.883
Test Statistic	0.188	0.534
Outlier?	No	Yes
Lower Tail		
Potential Outlier	-2.204	-2.277
Test Statistic	0.385	0.408
Outlier?	No	No

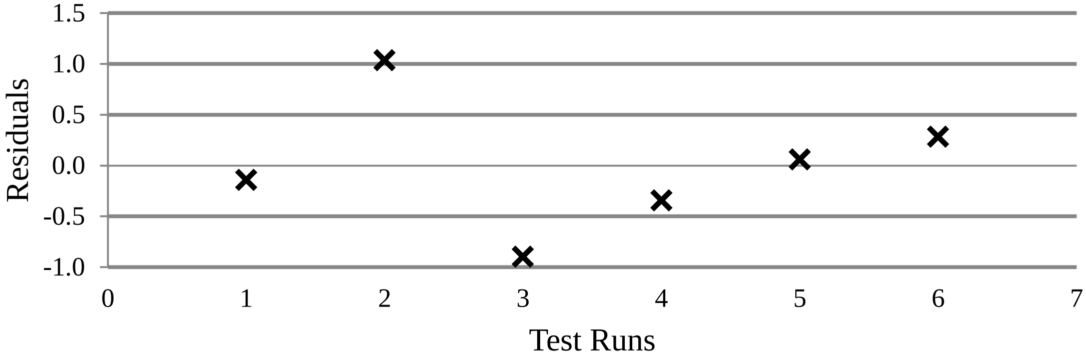


Figure C - 4. 3^{rd} stage seed-cotton cleaning system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 4. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ 3^{rd} stage seed-cotton cleaning system emission factors (no PSD data; α = 0.05).

	"Test" Design 1	**"Test" Design 3**
Tests	No Test	6
Critical Value		0.56
Upper Tail		
Potential Outlier		-1.939
Test Statistic		0.057
Outlier?		No
Lower Tail		
Potential Outlier		-2.367
Test Statistic		0.407
Outlier?		No

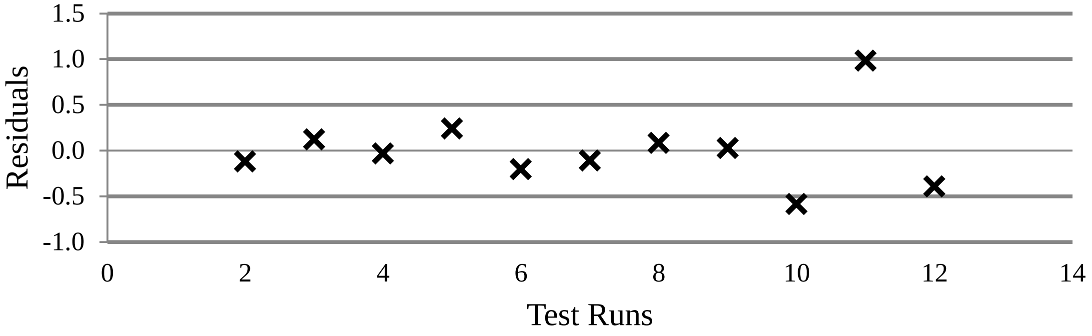


Figure C - 5. 1st stage lint cleaner system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 5. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ 1st stage lint cleaner system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 3**
Tests	4	11
Critical Value	0.765	0.576
Upper Tail		
Potential Outlier	-1.412	-1.269
Test Statistic	0.300	0.268
Outlier?	No	No
Lower Tail		
Potential Outlier	-2.269	-2.436
Test Statistic	0.292	0.255
Outlier?	No	No

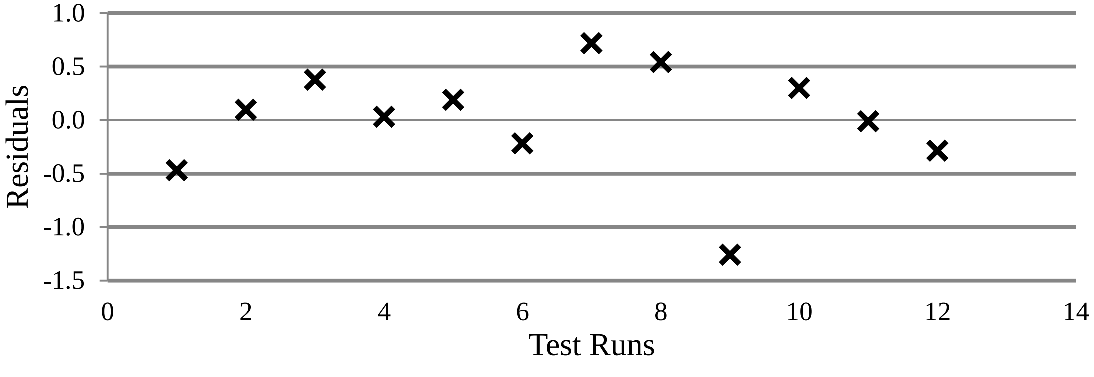


Figure C - 6. 2nd stage lint cleaner system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 6. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ 2^{nd} stage lint cleaner system emission factors (no PSD data; α = 0.05).

	"Test" Design 1	**"Test" Design 3**
Tests	4	12
Critical Value	0.765	0.546
Upper Tail		
Potential Outlier	-1.751	-1.712
Test Statistic	0.448	0.132
Outlier?	No	No
Lower Tail		
Potential Outlier	-2.210	-2.388
Test Statistic	0.177	0.130
Outlier?	No	No

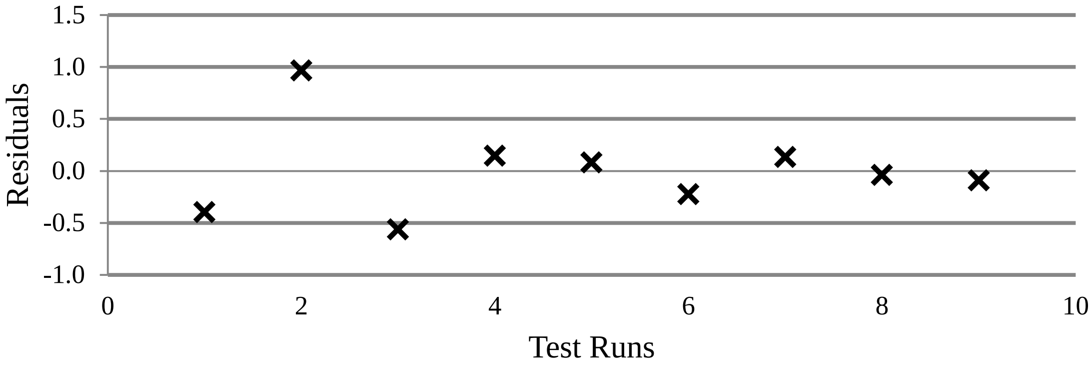


Figure C - 7. Combined lint cleaner system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 7. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ combined lint cleaner system emission factors (no PSD data; α = 0.05).

	"Test" Design 1	**"Test" Design 3**
Tests	3	9
Critical Value	0.941	0.512
Upper Tail		
Potential Outlier	-1.259	-1.117
Test Statistic	0.423	0.231
Outlier?	No	No
Lower Tail		
Potential Outlier	-2.015	-2.118
Test Statistic	0.577	0.076
Outlier?	No	No

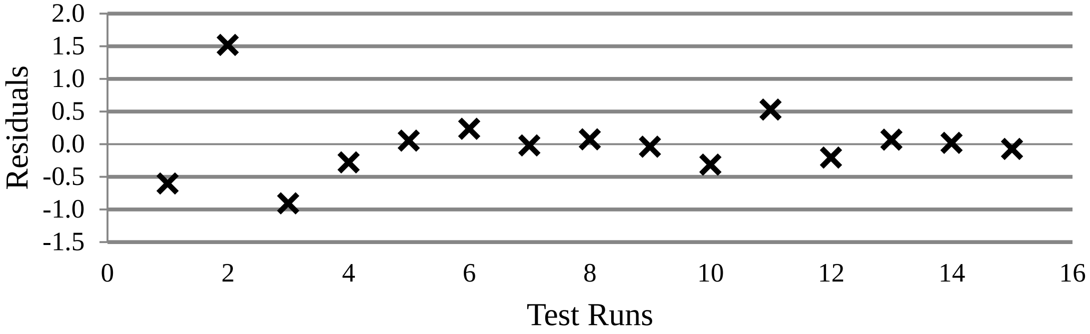


Figure C - 8. 1st stage mote system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 8. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ 1st stage mote system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 3**
Tests	5	15
Critical Value	0.642	0.525
Upper Tail		
Potential Outlier	-1.785	-1.599
Test Statistic	0.245	0.320
Outlier?	No	No
Lower Tail		
Potential Outlier	-2.566	-2.607
Test Statistic	0.382	0.140
Outlier?	No	No

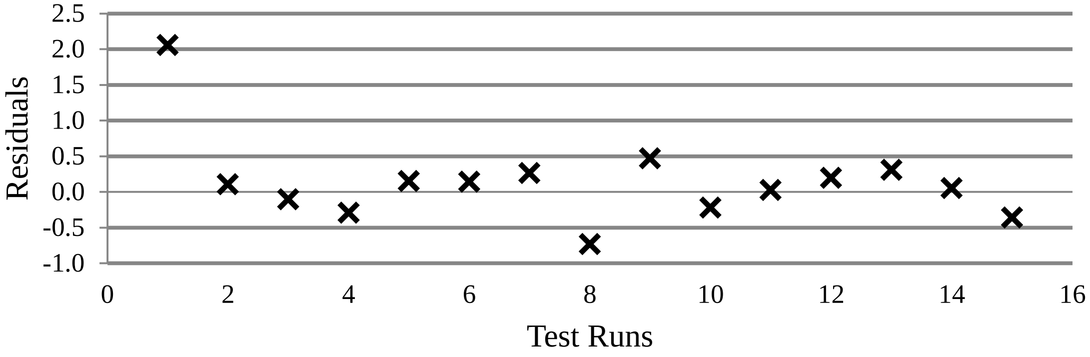


Figure C - 9. 2nd stage mote system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 9. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ 2^{nd} stage mote system emission factors (no PSD data; α = 0.05).

	"Test" Design 1	**"Test" Design 3**
Tests	5	14
Critical Value	0.642	0.546
Upper Tail		
Potential Outlier	-2.082	-2.060
Test Statistic	0.421	0.108
Outlier?	No	No
Lower Tail		
Potential Outlier	-2.539	-2.644
Test Statistic	0.121	0.276
Outlier?	No	No

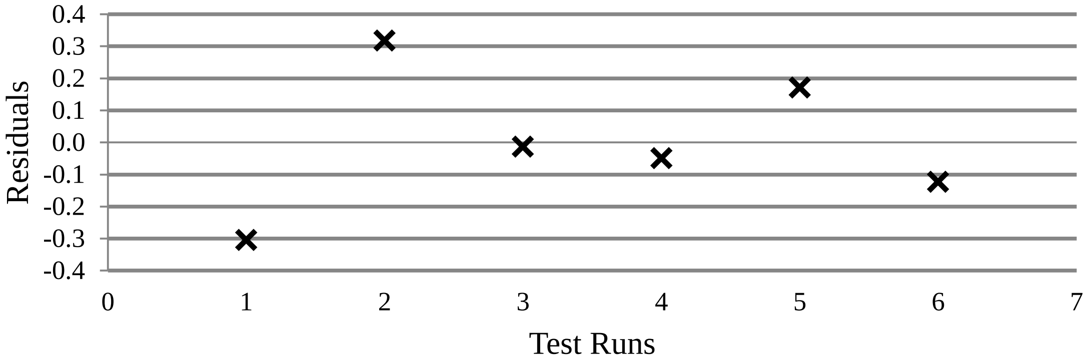


Figure C - 10. Combined mote system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 10. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ combined mote system emission factors (no PSD data; α = 0.05).

	"Test" Design 1	**"Test" Design 3**
Tests	No Test	6
Critical Value		0.56
Upper Tail		
Potential Outlier		-1.501
Test Statistic		0.100
Outlier?		No
Lower Tail		
Potential Outlier		-1.919
Test Statistic		0.054
Outlier?		No

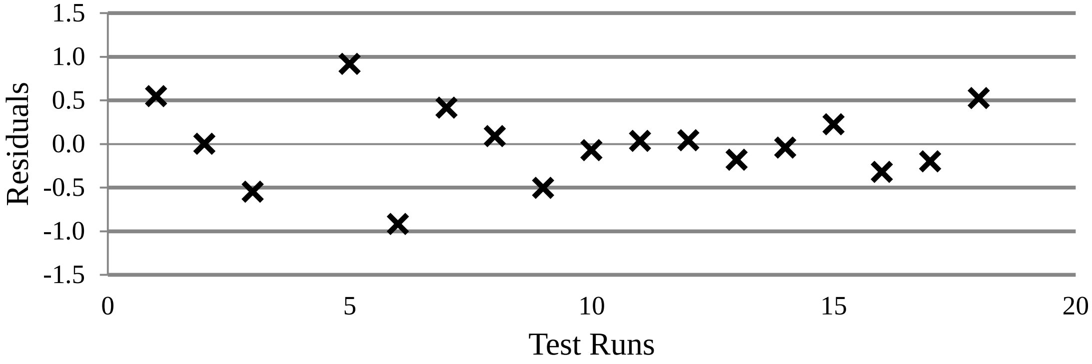


Figure C - 11. Battery condenser system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 11. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ battery condenser system emission factors (no PSD data; α = 0.05).

	"Test" Design 1	**"Test" Design 3**
Tests	6	18
Critical Value	0.56	0.475
Upper Tail		
Potential Outlier	-1.768	-1.664
Test Statistic	0.376	0.311
Outlier?	No	No
Lower Tail		
Potential Outlier	-2.542	-2.710
Test Statistic	0.033	0.179
Outlier?	No	No

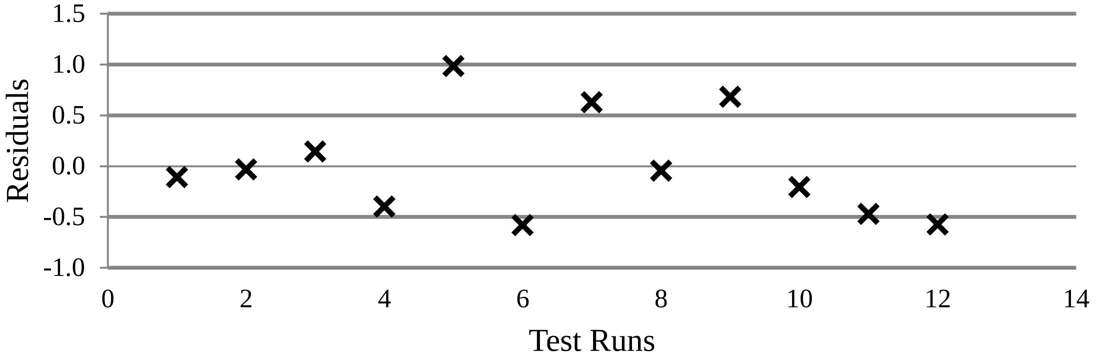


Figure C - 12. Cyclone robber system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 12. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ cyclone robber system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 3**
Tests	3	12
Critical Value	0.941	0.546
Upper Tail		
Potential Outlier	-0.006	-2.088
Test Statistic	0.780	0.217
Outlier?	No	No
Lower Tail		
Potential Outlier	-0.002	-3.335
Test Statistic	0.220	0.416
Outlier?	No	No

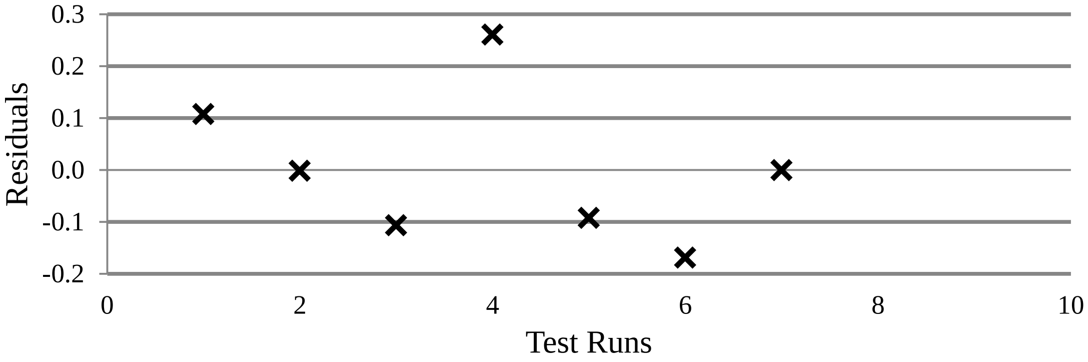


Figure C - 13. Mote cyclone robber system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 13. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ mote cyclone robber system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 3**
Tests	3	9
Critical Value	0.941	0.512
Upper Tail		
Potential Outlier	-1.657	-1.335
Test Statistic	0.907	0.119
Outlier?	No	No
Lower Tail		
Potential Outlier	-2.560	-2.816
Test Statistic	0.093	0.102
Outlier?	No	No

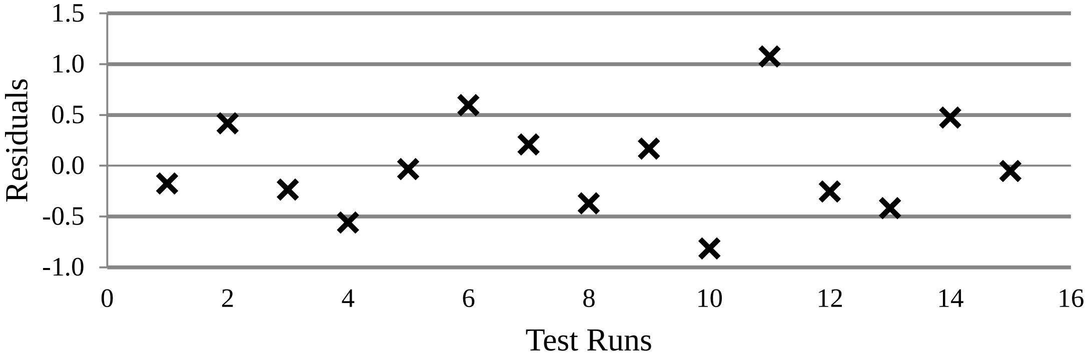


Figure C - 14. Master trash system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 14. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ master trash system emission factors (no PSD data; $\alpha = 0.05$).

	“Test” Design 1	**“Test” Design 3**
Tests	5	15
Critical Value	0.642	0.525
Upper Tail		
Potential Outlier	-1.715	-1.581
Test Statistic	0.337	0.245
Outlier?	No	No
Lower Tail		
Potential Outlier	-2.275	-2.472
Test Statistic	0.075	0.073
Outlier?	No	No

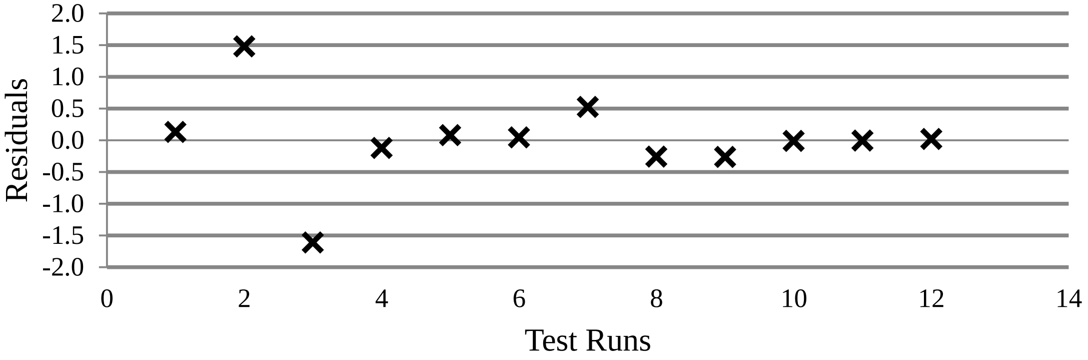


Figure C - 15. Overflow system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 15. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ overflow system system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 3**
Tests	4	12
Critical Value	0.765	0.546
Upper Tail		
Potential Outlier	-1.729	-1.494
Test Statistic	0.260	0.261
Outlier?	No	No
Lower Tail		
Potential Outlier	-2.781	-2.810
Test Statistic	0.527	0.060
Outlier?	No	No

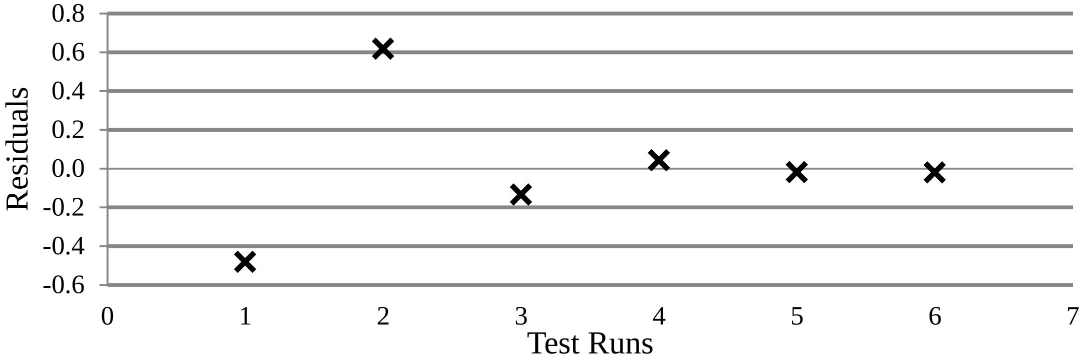


Figure C - 16. Mote cleaner system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 16. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ mote cleaner system emission factors (no PSD data; $\alpha = 0.05$)

	"Test" Design 1	**"Test" Design 3**
Tests	No Test	6
Critical Value		0.56
Upper Tail		
Potential Outlier		-1.190
Test Statistic		0.154
Outlier?		No
Lower Tail		
Potential Outlier		-2.131
Test Statistic		0.002
Outlier?		No

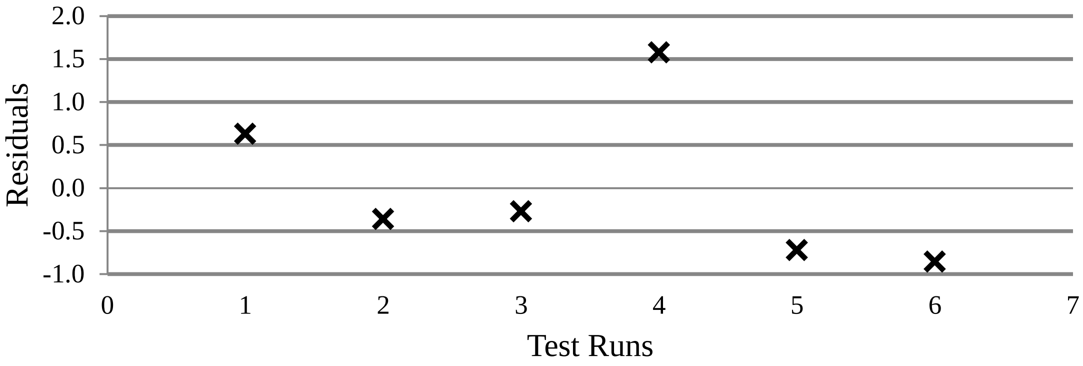


Figure C - 17. Mote trash system $PM_{2.5}$ emission factor residual plot (no PSD data).

Table C - 17. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ mote trash system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 3**
Tests	No Test	6
Critical Value		0.56
Upper Tail		
Potential Outlier		-2.523
Test Statistic		0.094
Outlier?		No
Lower Tail		
Potential Outlier		-2.733
Test Statistic		0.070
Outlier?		No

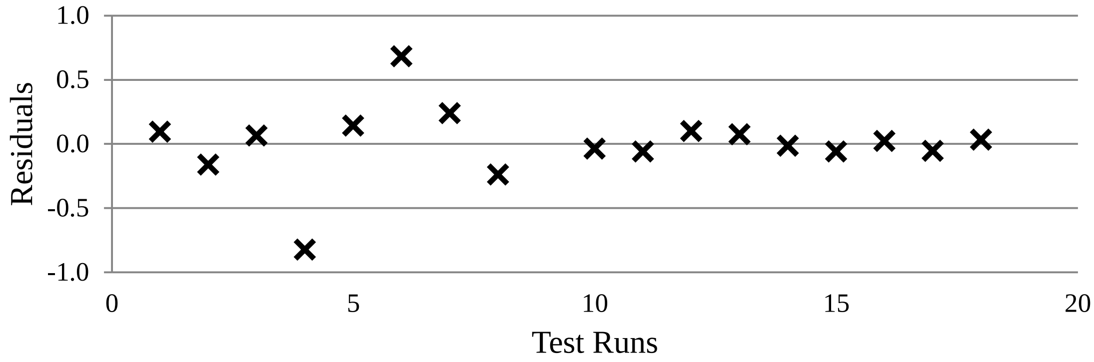


Figure C - 18. Unloading system PM_{10} emission factor residual plot (no PSD data).

Table C - 18. ProUCL outlier test results for Log_{10}-transformed PM_{10} unloading system emission factors (no PSD data; α = 0.05).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	3	6	17
Critical Value	0.941	0.56	0.49
Upper Tail			
Potential Outlier	-0.462	-0.452	-0.367
Test Statistic	0.304	0.033	0.139
Outlier?	No	No	No
Lower Tail			
Potential Outlier	-1.001	-1.044	-1.078
Test Statistic	0.696	0.139	0.062
Outlier?	No	No	No

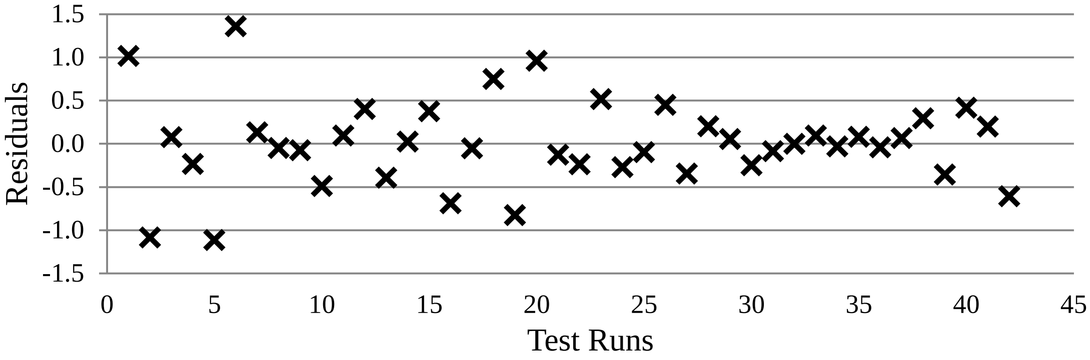


Figure C - 19. 1^{st} stage seed-cotton cleaning system residual plot for PM_{10} test runs.

Table C - 19. ProUCL outlier test results for Log_{10}-transformed PM_{10} 1^{st} stage seed-cotton cleaning system emission factors (no PSD data; α = 0.05).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	7	14	42
Critical Value	0.507	0.546	3.06
Upper Tail			
Potential Outlier	-0.571	-0.536	
Test Statistic	0.171	0.117	
Outlier?	No	No	
Lower Tail			
Potential Outlier	-1.028	-1.052	-1.209
Test Statistic	0.270	0.100	2.253
Outlier?	No	No	No

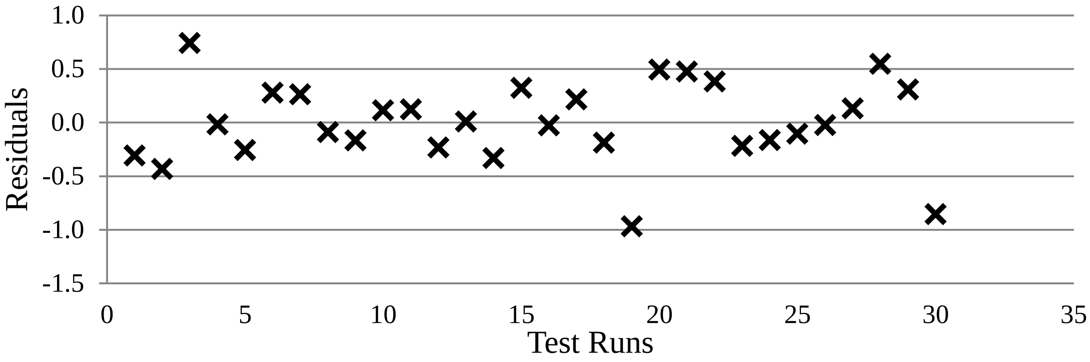


Figure C - 20. 2nd stage seed-cotton cleaning system PM_{10} emission factor residual plot (no PSD data).

Table C - 20. ProUCL outlier test results for Log_{10}-transformed PM_{10} 2nd stage seed-cotton cleaning system emission factors (no PSD data; α = 0.05).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	5	10	30
Critical Value	0.642	0.477	2.91
Upper Tail			
Potential Outlier	-0.871	-0.814	
Test Statistic	0.126	0.223	
Outlier?	No	No	
Lower Tail			
Potential Outlier	-1.389	-1.439	-1.880
Test Statistic	0.309	0.186	2.817
Outlier?	No	No	No

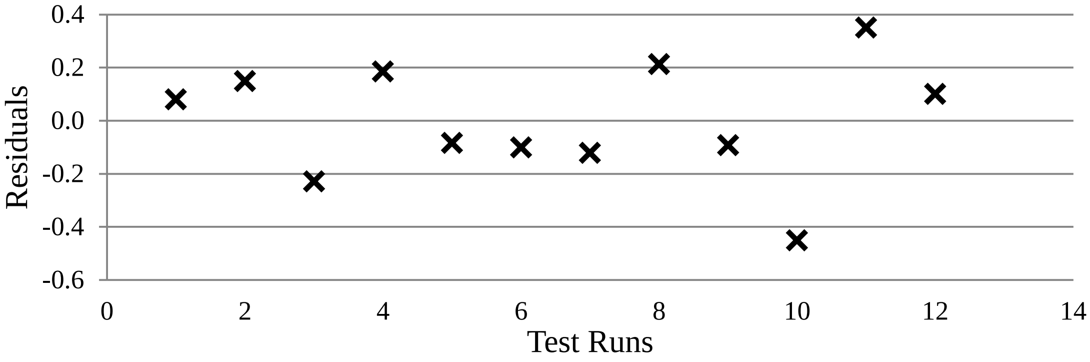


Figure C - 21. 3rd stage seed-cotton cleaning system PM_{10} emission factor residual plot (no PSD data).

Table C - 21. ProUCL outlier test results for Log_{10}-transformed PM_{10} 3rd stage seed-cotton cleaning system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	No Test	4	12
Critical Value		0.765	0.546
Upper Tail			
Potential Outlier		-1.112	-1.067
Test Statistic		0.231	0.176
Outlier?		No	No
Lower Tail			
Potential Outlier		-1.654	-1.716
Test Statistic		0.158	0.078
Outlier?		No	No

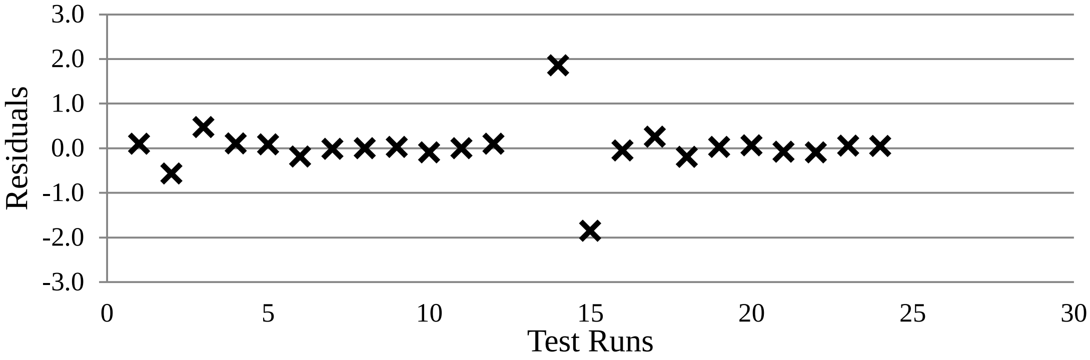


Figure C - 22. 1st stage lint cleaner system PM_{10} emission factor residual plot (no PSD data).

Table C - 22. ProUCL outlier test results for Log_{10}-transformed PM_{10} 1st stage lint cleaner system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	4	8	23
Critical Value	0.765	0.554	0.421
Upper Tail			
Potential Outlier	-0.712	-0.471	-0.267
Test Statistic	0.045	0.245	0.330
Outlier?	No	No	No
Lower Tail			
Potential Outlier	-1.518	-1.622	-1.664
Test Statistic	0.649	0.205	0.096
Outlier?	No	No	No

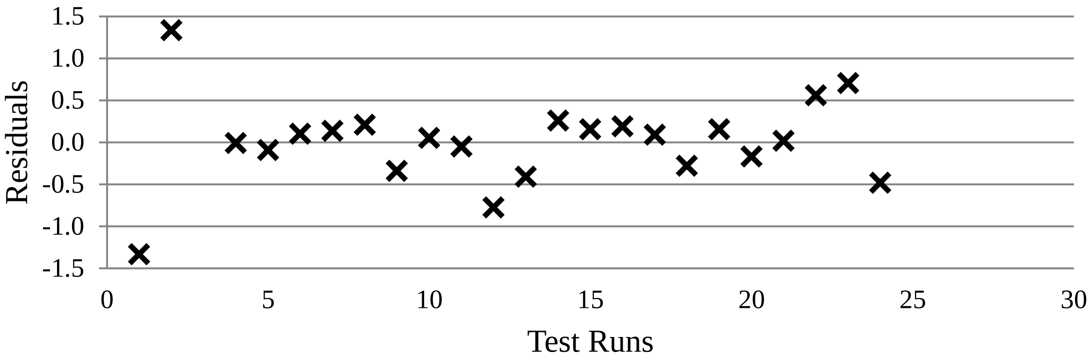


Figure C - 23. 2^{nd} stage lint cleaner system PM_{10} emission factor residual plot (no PSD data).

Table C - 23. ProUCL outlier test results for Log_{10}-transformed PM_{10} 2^{nd} stage lint cleaner system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	4	8	23
Critical Value	0.765	0.554	0.421
Upper Tail			
Potential Outlier	-1.204	-1.138	-0.988
Test Statistic	0.105	0.166	0.195
Outlier?	No	No	No
Lower Tail			
Potential Outlier	-1.704	-1.764	-1.885
Test Statistic	0.514	0.152	0.122
Outlier?	No	No	No

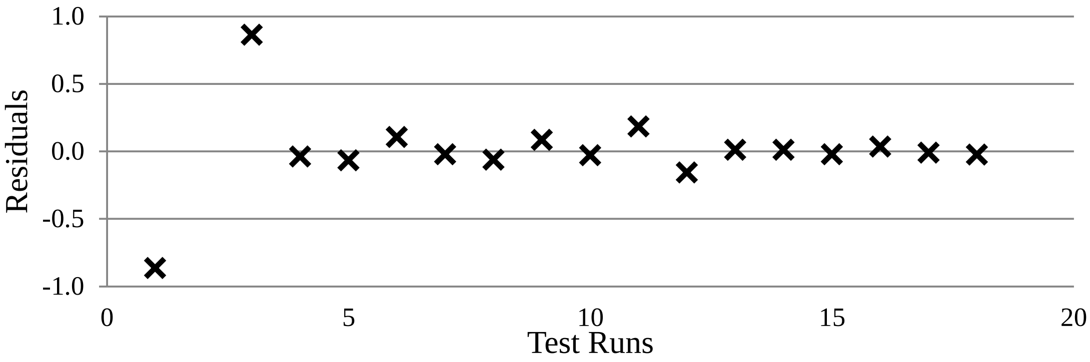


Figure C - 24. Combined lint cleaning system PM_{10} emission factor residual plot (no PSD data).

Table C - 24. ProUCL outlier test results for Log_{10}-transformed PM_{10} combined lint cleaning system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	3	6	17
Critical Value	0.941	0.56	0.49
Upper Tail			
Potential Outlier	-0.255	-0.178	-0.072
Test Statistic	0.455	0.142	0.239
Outlier?	No	No	No
Lower Tail			
Potential Outlier	-1.048	-1.144	-1.178
Test Statistic	0.545	0.180	0.089
Outlier?	No	No	No

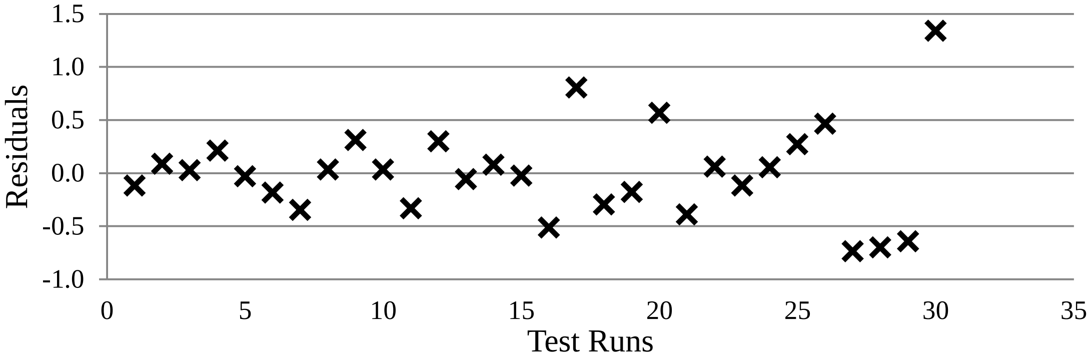


Figure C - 25. 1st stage mote system PM_{10} emission factor residual plot (no PSD data).

Table C - 25. ProUCL outlier test results for Log_{10}-transformed PM_{10} 1st stage mote system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	5	10	30
Critical Value	0.642	0.477	2.91
Upper Tail			
Potential Outlier	-1.149	-1.132	
Test Statistic	0.148	0.083	
Outlier?	No	No	
Lower Tail			
Potential Outlier	-1.654	-1.764	-1.999
Test Statistic	0.388	0.333	2.706
Outlier?	No	No	No

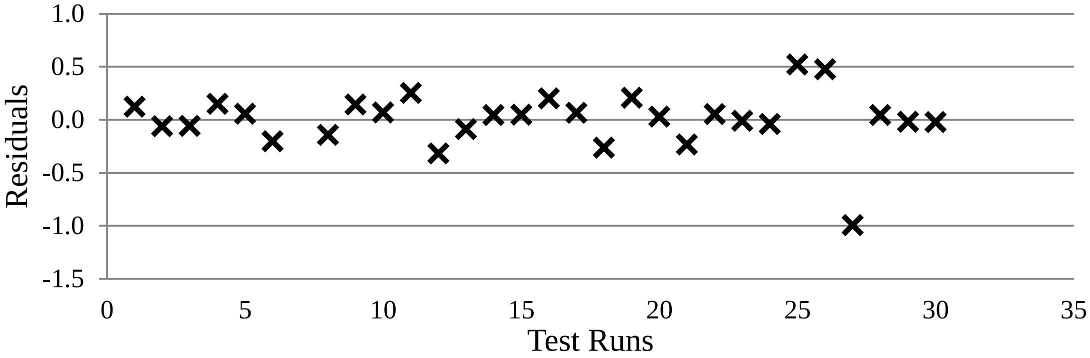


Figure C - 26. 2nd stage mote system PM_{10} emission factor residual plot (no PSD data).

Table C - 26. ProUCL outlier test results for Log_{10}-transformed PM_{10} 2nd stage mote system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	5	10	29
Critical Value	0.642	0.477	2.89
Upper Tail			
Potential Outlier	-1.339	-1.284	-1.226
Test Statistic	0.537	0.161	2.049
Outlier?	No	No	No
Lower Tail			
Potential Outlier	-1.987	-2.066	
Test Statistic	0.225	0.063	
Outlier?	No	No	

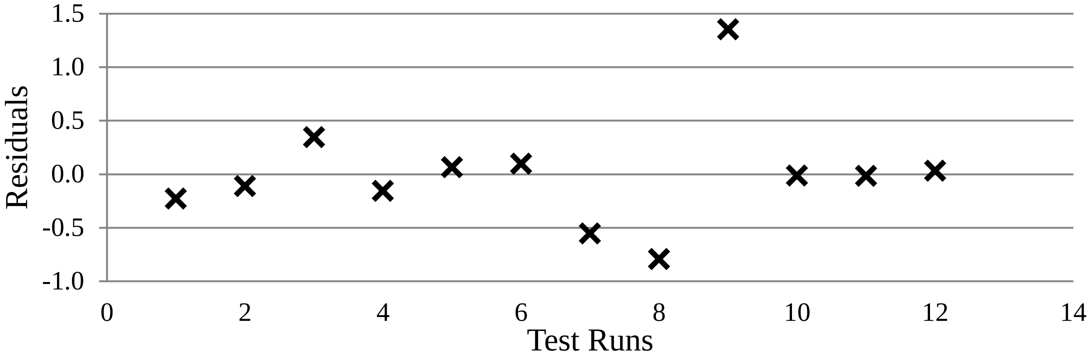


Figure C - 27. Combined mote system PM_{10} emission factor residual plot (no PSD data).

Table C - 27. ProUCL outlier test results for Log_{10}-transformed PM_{10} combined mote system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	No Test	4	12
Critical Value		0.765	0.546
Upper Tail			
Potential Outlier		-0.471	-0.321
Test Statistic		0.233	0.393
Outlier?		No	No
Lower Tail			
Potential Outlier		-0.905	-0.911
Test Statistic		0.268	0.043
Outlier?		No	No

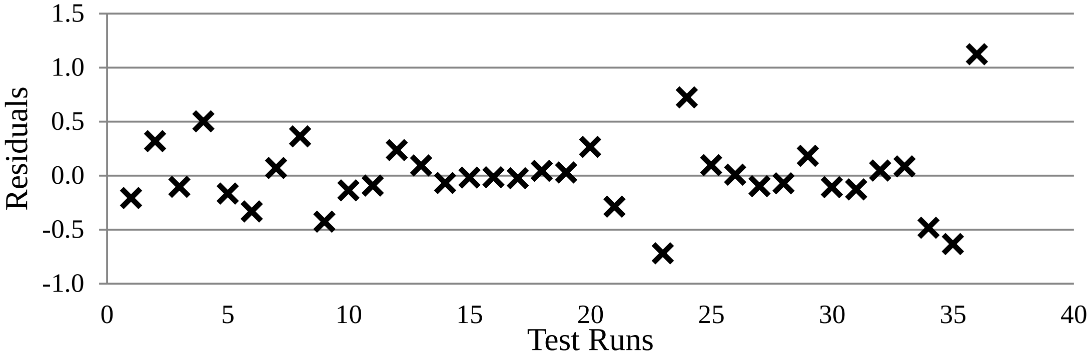


Figure C - 28. Battery condenser system PM_{10} emission factor residual plot (no PSD data).

Table C - 28. ProUCL outlier test results for Log_{10}-transformed PM_{10} battery condenser system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	6	12	35
Critical Value	0.56	0.546	2.98
Upper Tail			
Potential Outlier	-1.157	-1.100	
Test Statistic	0.061	0.075	
Outlier?	No	No	
Lower Tail			
Potential Outlier	-2.046	-2.088	-2.187
Test Statistic	0.559	0.538	2.244
Outlier?	No	No	No

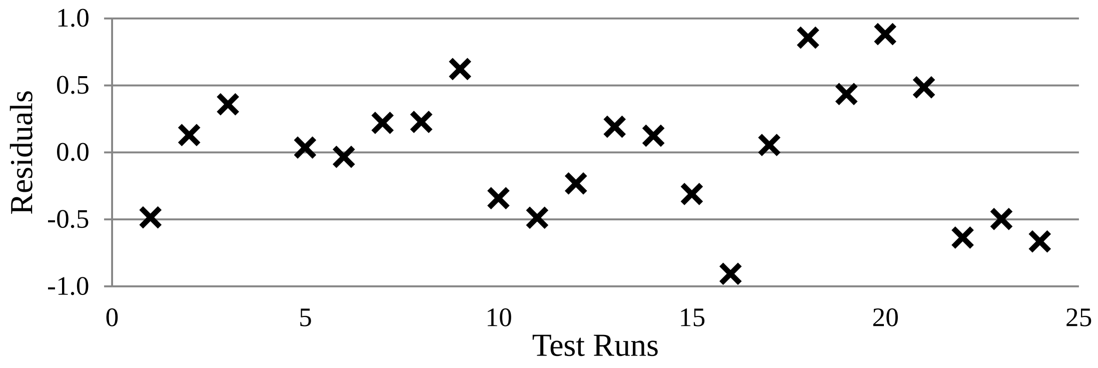


Figure C - 29. Cyclone robber system PM_{10} emission factor residual plot (no PSD data).

Table C - 29. ProUCL outlier test results for Log_{10}-transformed PM_{10} cyclone robber system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	3	5	23
Critical Value	0.941	0.642	0.421
Upper Tail			
Potential Outlier	-1.432	-1.649	-1.243
Test Statistic	0.832	0.514	0.242
Outlier?	No	No	No
Lower Tail			
Potential Outlier	-1.833	-1.856	-2.141
Test Statistic	0.168	0.210	0.058
Outlier?	No	No	No

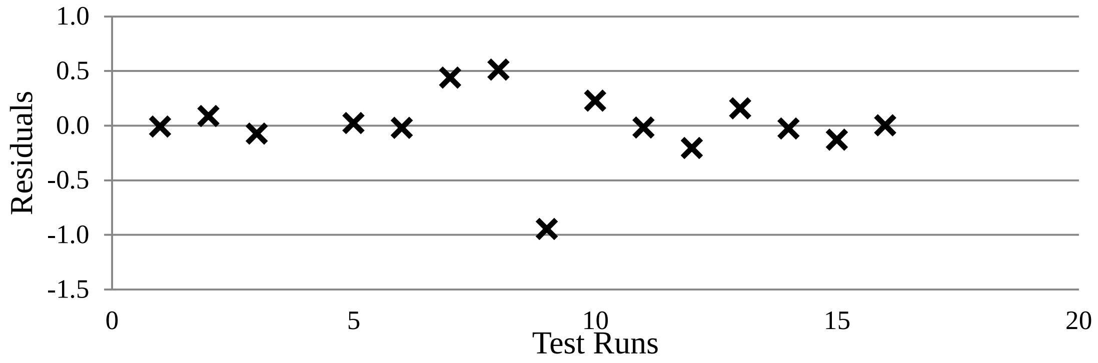


Figure C - 30. Mote cyclone robber system PM_{10} emission factor residual plot (no PSD data).

Table C - 30. ProUCL outlier test results for Log_{10}-transformed PM_{10} mote cyclone robber system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	3	6	15
Critical Value	0.941	0.56	0.525
Upper Tail			
Potential Outlier	-0.927	-0.923	-0.848
Test Statistic	0.892	0.026	0.115
Outlier?	No	No	No
Lower Tail			
Potential Outlier	-1.584	-1.642	-1.863
Test Statistic	0.108	0.113	0.223
Outlier?	No	No	No

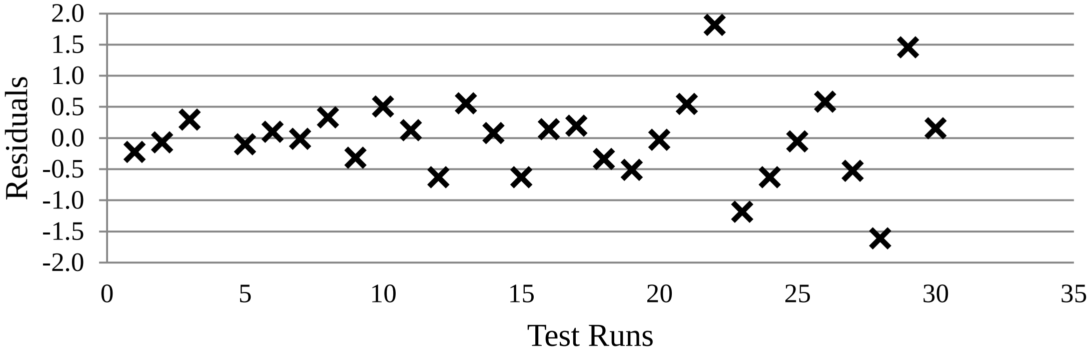


Figure C - 31. Master trash system PM_{10} emission factor residual plot (no PSD data).

Table C - 31. ProUCL outlier test results for Log_{10}-transformed PM_{10} master trash system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	5	10	29
Critical Value	0.642	0.477	2.89
Upper Tail			
Potential Outlier	-0.774	-0.726	
Test Statistic	0.375	0.192	
Outlier?	No	No	
Lower Tail			
Potential Outlier	-1.029	-1.140	-1.246
Test Statistic	0.080	0.348	2.042
Outlier?	No	No	No

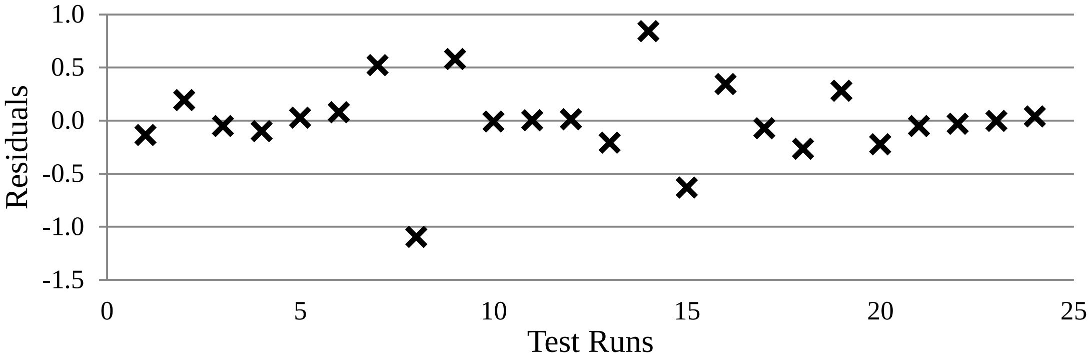


Figure C - 32. Overflow system PM_{10} emission factor residual plot (no PSD data).

Table C - 32. ProUCL outlier test results for Log_{10}-transformed PM_{10} overflow system emission factors (no PSD data; $\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	4	8	24
Critical Value	0.765	0.554	0.413
Upper Tail			
Potential Outlier	-1.051	-1.028	-0.950
Test Statistic	0.272	0.051	0.074
Outlier?	No	No	No
Lower Tail			
Potential Outlier	-2.021	-2.078	-2.098
Test Statistic	0.700	0.108	0.037
Outlier?	No	No	No

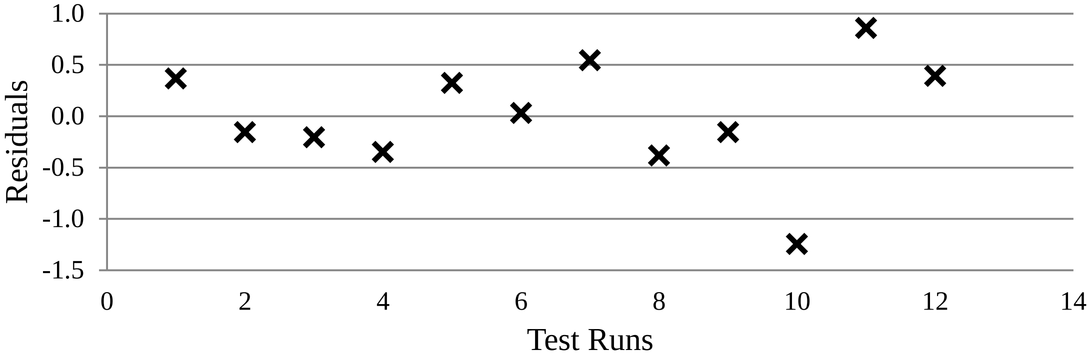


Figure C - 33. Mote cleaner system PM_{10} emission factor residual plot (no PSD data).

Table C - 33. ProUCL outlier test results for Log$_{10}$-transformed PM$_{10}$ mote cleaner system emission factors (no PSD data; α = 0.05).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	No Test	4	11
Critical Value		0.765	0.576
Upper Tail			
Potential Outlier		-0.784	-0.734
Test Statistic		0.086	0.293
Outlier?		No	No
Lower Tail			
Potential Outlier		-1.015	-1.015
Test Statistic		0.234	0.244
Outlier?		No	No

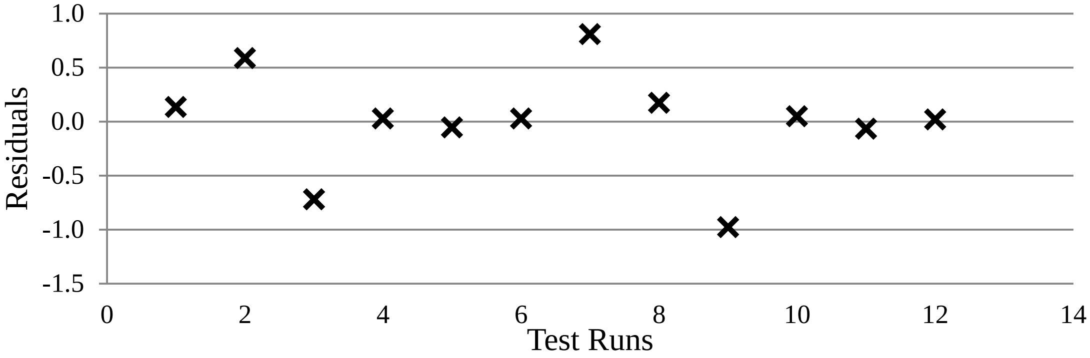


Figure C - 34. Mote trash system PM$_{10}$ emission factor residual plot (no PSD data).

Table C - 34. ProUCL outlier test results for Log$_{10}$-transformed PM$_{10}$ mote trash system emission factors (no PSD data; α = 0.05).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	No Test	4	12
Critical Value		0.765	0.546
Upper Tail			
Potential Outlier		-1.490	-1.397
Test Statistic		0.078	0.146
Outlier?		No	No
Lower Tail			
Potential Outlier		-1.893	-1.915
Test Statistic		0.429	0.080
Outlier?		No	No

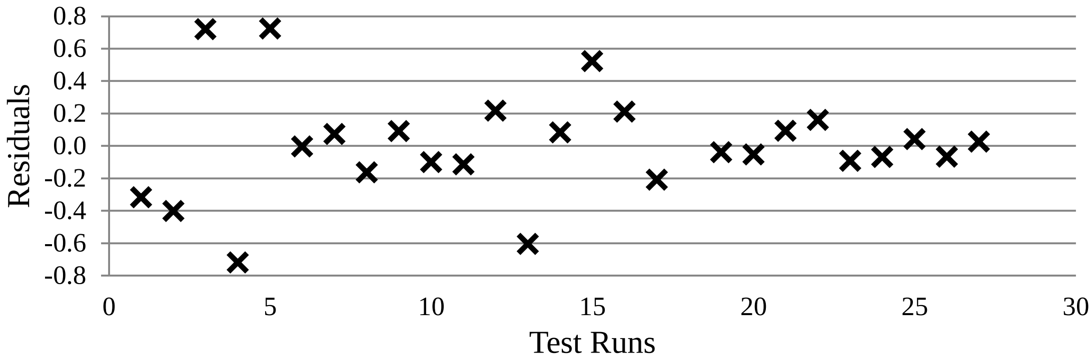


Figure C - 35. Unloading system total PM emission factor residual plot.

Table C - 35. ProUCL outlier test results for Log_{10}-transformed total PM unloading system emission factors ($\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	3	9	26
Critical Value	0.941	0.512	2.84
Upper Tail			
Potential Outlier	-0.353	-0.301	
Test Statistic	0.425	0.142	
Outlier?	No	No	
Lower Tail			
Potential Outlier	-0.872	-1.029	-1.066
Test Statistic	0.575	0.315	1.824
Outlier?	No	No	No

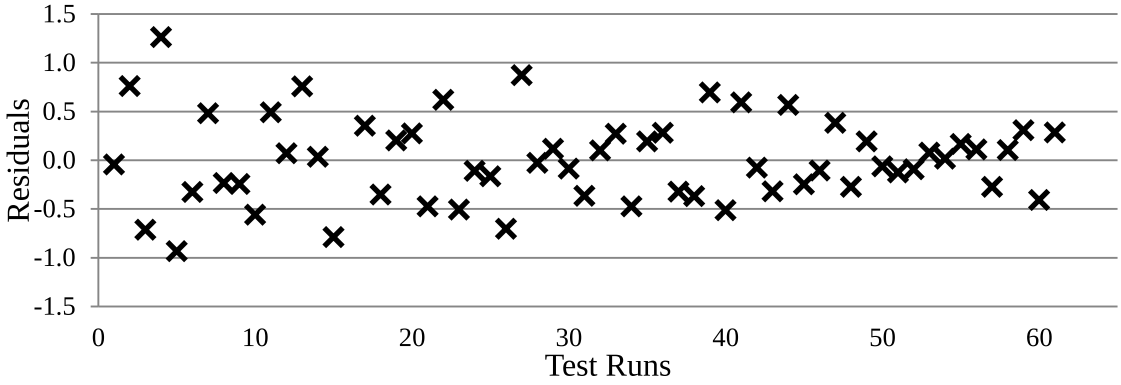


Figure C - 36. 1^{st} stage seed-cotton cleaning system total PM emission factor residual plot.

Table C - 36. ProUCL outlier test results for Log$_{10}$-transformed total PM 1st stage seed-cotton cleaning system emission factors (α = 0.05).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	7	21	62
Critical Value	0.507	0.44	3.212
Upper Tail			
Potential Outlier	-0.388	-0.282	
Test Statistic	0.197	0.133	
Outlier?	No	No	
Lower Tail			
Potential Outlier	-0.802	-0.920	-1.049
Test Statistic	0.607	0.122	2.491
Outlier?	Yes	No	No

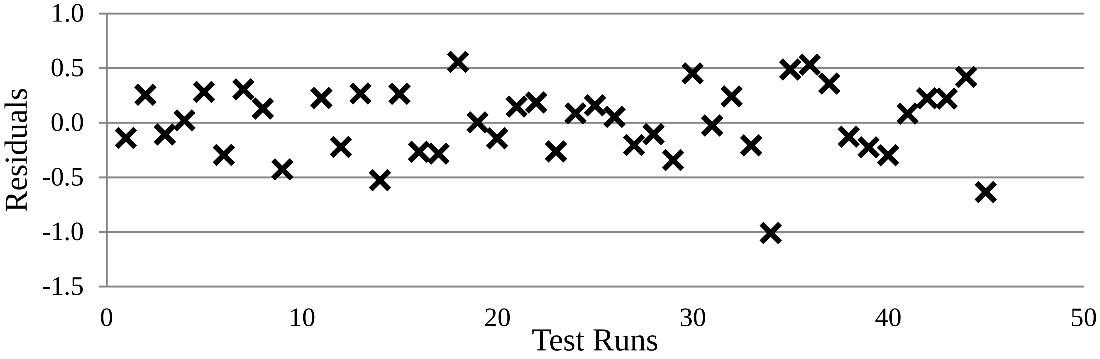


Figure C - 37. 2nd stage seed-cotton cleaning system total PM emission factor residual plot.

Table C - 37. ProUCL outlier test results for Log$_{10}$-transformed total PM 2nd stage seed-cotton cleaning system emission factors (α = 0.05).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	5	15	44
Critical Value	0.642	0.525	3.08
Upper Tail			
Potential Outlier	-0.742	-0.667	
Test Statistic	0.017	0.169	
Outlier?	No	No	
Lower Tail			
Potential Outlier	-1.225	-1.367	-1.753
Test Statistic	0.346	0.325	3.238
Outlier?	No	No	Yes

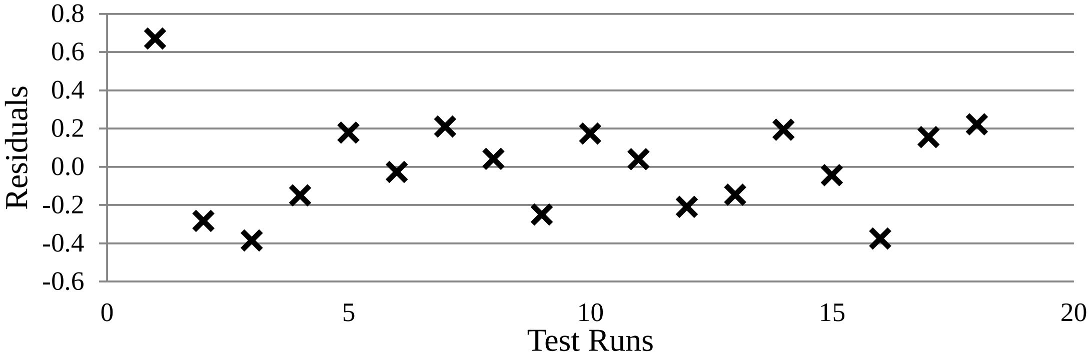


Figure C - 38. 3rd stage seed-cotton cleaning system total PM emission factor residual plot.

Table C - 38. ProUCL outlier test results for Log_{10}-transformed total PM 3rd stage seed-cotton cleaning system emission factors (α = 0.05).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	No Test	6	18
Critical Value		0.56	0.475
Upper Tail			
Potential Outlier		-1.010	-0.984
Test Statistic		0.227	0.124
Outlier?		No	No
Lower Tail			
Potential Outlier		-1.532	-1.705
Test Statistic		0.033	0.166
Outlier?		No	No

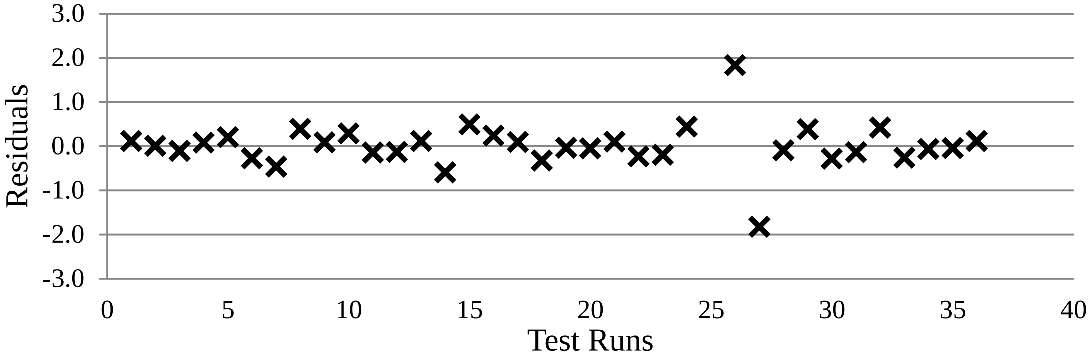


Figure C - 39. 1st stage lint cleaner system total PM emission factor residual plot.

Table C - 39. ProUCL outlier test results for Log_{10}-transformed total PM 1st stage lint cleaner system emission factors ($\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	4	12	35
Critical Value	0.765	0.546	2.98
Upper Tail			
Potential Outlier	-0.605	-0.383	
Test Statistic	0.015	0.324	
Outlier?	No	No	
Lower Tail			
Potential Outlier	-1.132	-1.237	-1.606
Test Statistic	0.480	0.273	2.788
Outlier?	No	No	No

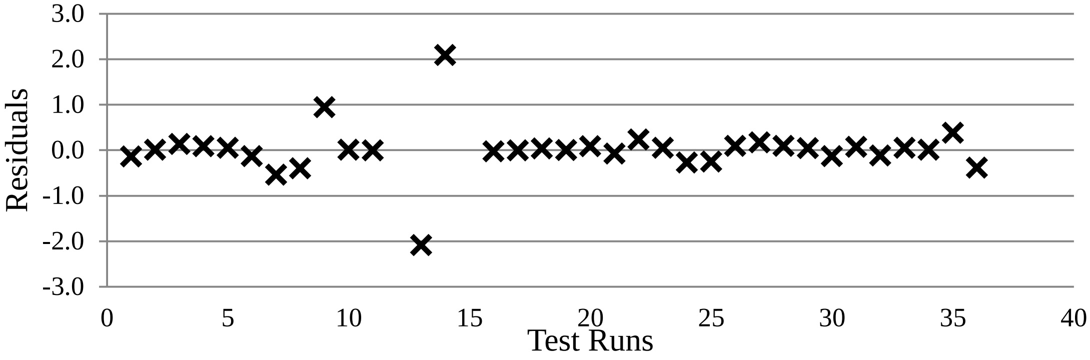


Figure C - 40. 2nd stage lint cleaner system total PM emission factor residual plot.

Table C - 40. ProUCL outlier test results for Log_{10}-transformed total PM 2nd stage lint cleaner system emission factors ($\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	4	12	34
Critical Value	0.765	0.546	2.97
Upper Tail			
Potential Outlier	-0.999	-0.799	-0.604
Test Statistic	0.124	0.342	2.425
Outlier?	No	No	No
Lower Tail			
Potential Outlier	-1.589	-1.695	
Test Statistic	0.478	0.273	
Outlier?	No	No	

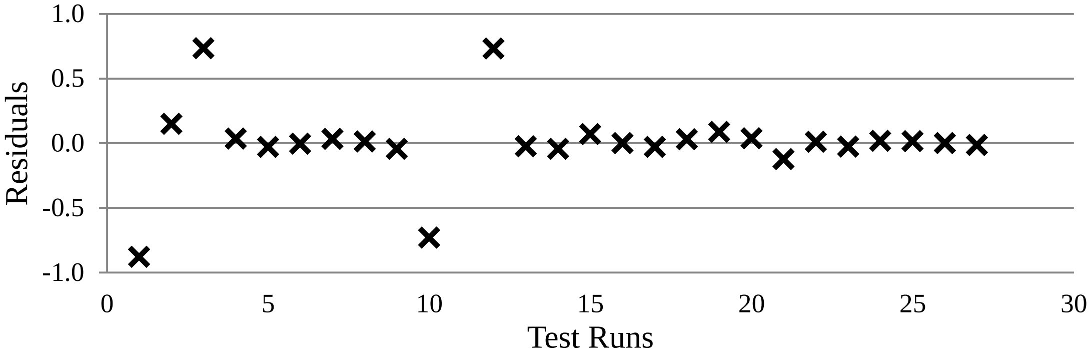


Figure C - 41. Combined lint cleaning system total PM emission factor residual plot.

Table C - 41. ProUCL outlier test results for Log_{10}-transformed total PM combined lint cleaning system emission factors (α = 0.05).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	3	9	26
Critical Value	0.941	0.512	2.84
Upper Tail			
Potential Outlier	-0.038	0.165	0.254
Test Statistic	0.491	0.129	1.832
Outlier?	No	No	No
Lower Tail			
Potential Outlier	-0.916	-1.019	
Test Statistic	0.509	0.105	
Outlier?	No	No	

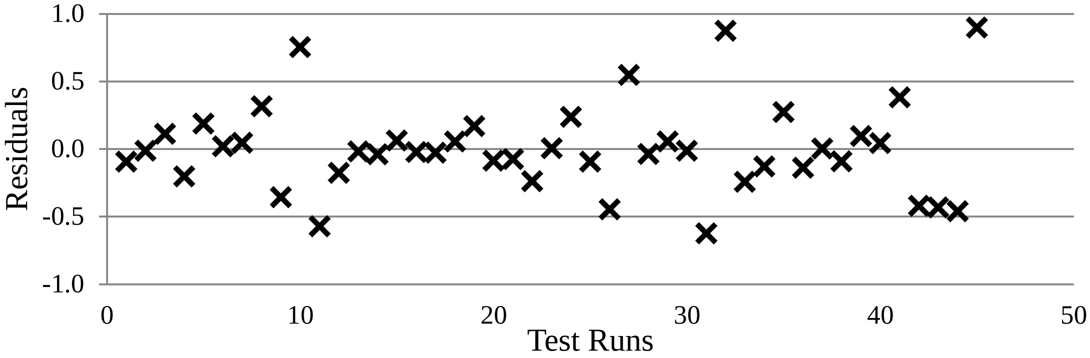


Figure C - 42. 1^{st} stage mote system total PM emission factor residual plot.

Table C - 42. ProUCL outlier test results for Log_{10}-transformed total PM 1st stage mote system emission factors ($\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	5	15	45
Critical Value	0.642	0.525	3.09
Upper Tail			
Potential Outlier	-0.982	-0.915	
Test Statistic	0.108	0.166	
Outlier?	No	No	
Lower Tail			
Potential Outlier	-1.460	-1.592	-1.729
Test Statistic	0.079	0.136	2.061
Outlier?	No	No	No

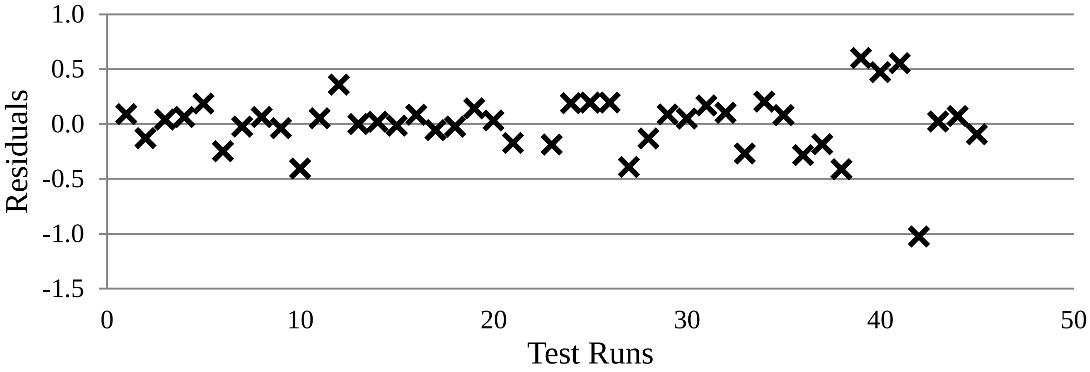


Figure C - 43. 2nd stage mote 2nd stage mote system total PM emission factor residual plot.

Table C - 43. ProUCL outlier test results for Log_{10}-transformed total PM 2nd stage mote system emission factors ($\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	5	15	44
Critical Value	0.642	0.525	3.08
Upper Tail			
Potential Outlier	-1.280	-1.198	-1.143
Test Statistic	0.562	0.285	2.257
Outlier?	No	No	No
Lower Tail			
Potential Outlier	-1.851	-1.894	
Test Statistic	0.167	0.162	
Outlier?	No	No	

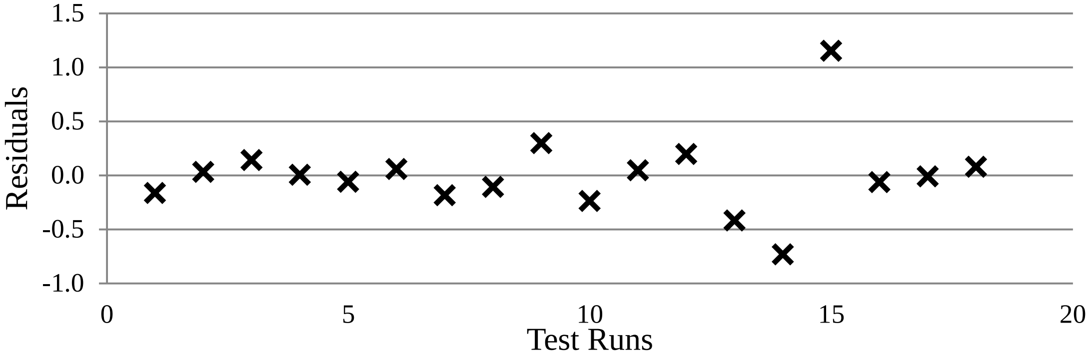


Figure C - 44. Combined mote system total PM emission factor residual plot.

Table C - 44. ProUCL outlier test results for Log$_{10}$-transformed total PM combined mote system emission factors (α = 0.05).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	No Test	6	18
Critical Value		0.56	0.475
Upper Tail			
Potential Outlier		-0.351	-0.235
Test Statistic		0.090	0.272
Outlier?		No	No
Lower Tail			
Potential Outlier		-0.751	-0.770
Test Statistic		0.157	0.044
Outlier?		No	No

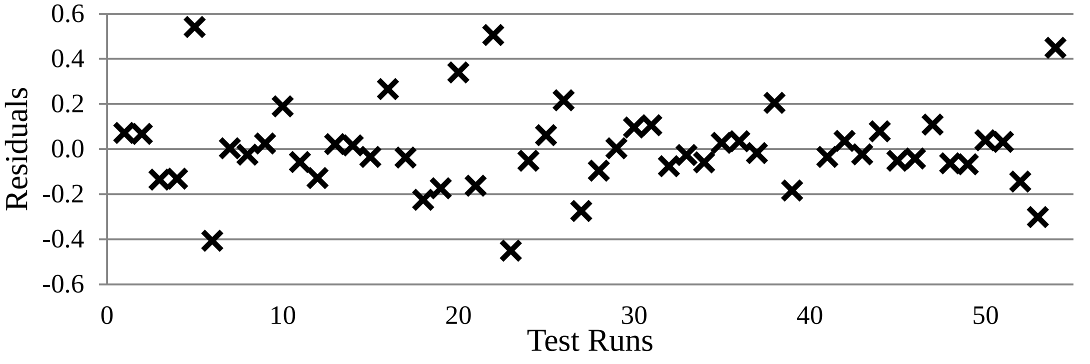


Figure C - 45. Battery condenser system total PM emission factor residual plot.

Table C - 45. ProUCL outlier test results for Log$_{10}$-transformed total PM battery condenser system emission factors (α = 0.05).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	6	18	53
Critical Value	0.56	0.475	3.151
Upper Tail			
Potential Outlier	-0.692	-0.673	
Test Statistic	0.326	0.042	
Outlier?	No	No	
Lower Tail			
Potential Outlier	-1.876	-2.068	-2.195
Test Statistic	0.432	0.199	2.519
Outlier?	No	No	No

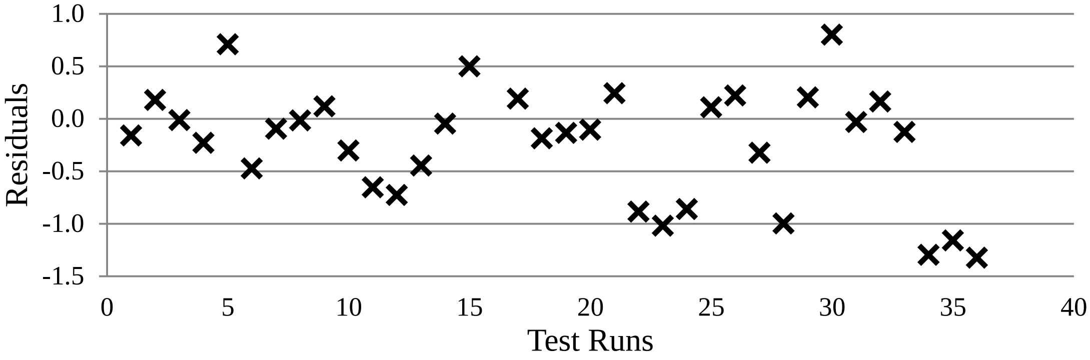


Figure C - 46. Cyclone robber system total PM emission factor residual plot.

Table C - 46. ProUCL outlier test results for Log$_{10}$-transformed total PM cyclone robber system emission factors (α = 0.05).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	3	9	35
Critical Value	0.941	0.512	2.98
Upper Tail			
Potential Outlier	-1.207	-1.138	-1.054
Test Statistic	0.683	0.114	1.959
Outlier?	No	No	No
Lower Tail			
Potential Outlier	-1.653	-1.670	
Test Statistic	0.317	0.041	
Outlier?	No	No	

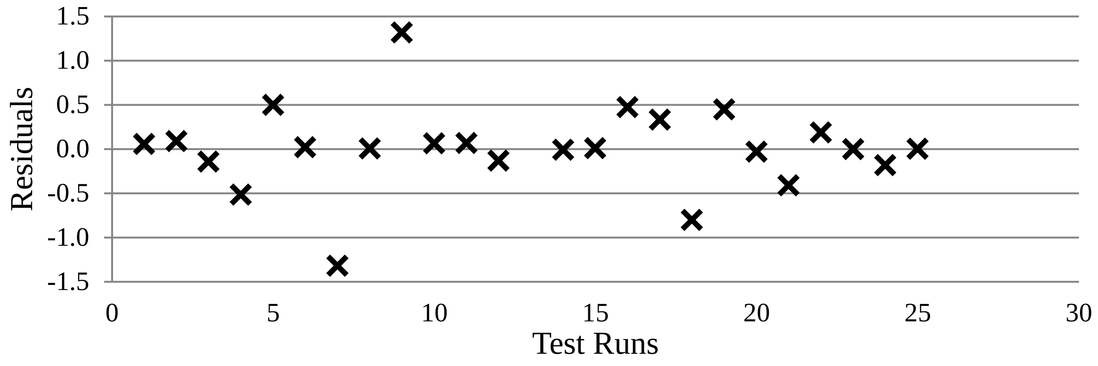


Figure C - 47. Mote cyclone robber system total PM emission factor residual plot.

Table C - 47. ProUCL outlier test results for Log$_{10}$-transformed total PM mote cyclone robber system emission factors (α = 0.05).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	3	9	24
Critical Value	0.941	0.512	0.413
Upper Tail			
Potential Outlier	-0.782	-0.757	-0.641
Test Statistic	0.851	0.033	0.102
Outlier?	No	No	No
Lower Tail			
Potential Outlier	-1.211	-1.331	-1.611
Test Statistic	0.149	0.011	0.304
Outlier?	No	No	No

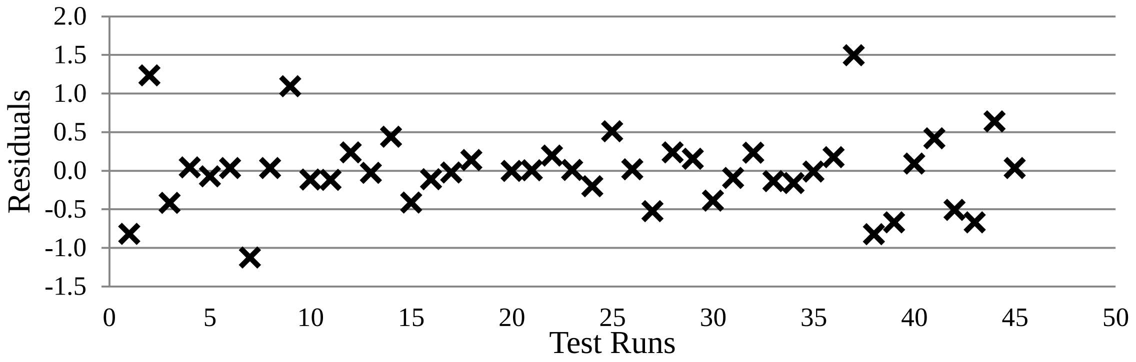


Figure C - 48. Master trash system total PM emission factor residual plot.

Table C - 48. ProUCL outlier test results for Log_{10}-transformed total PM master trash unloading system emission factors ($\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	5	15	44
Critical Value	0.642	0.525	3.08
Upper Tail			
Potential Outlier	-0.261	-0.143	
Test Statistic	0.170	0.245	
Outlier?	No	No	
Lower Tail			
Potential Outlier	-0.869	-0.929	-0.982
Test Statistic	0.506	0.150	2.001
Outlier?	No	No	No

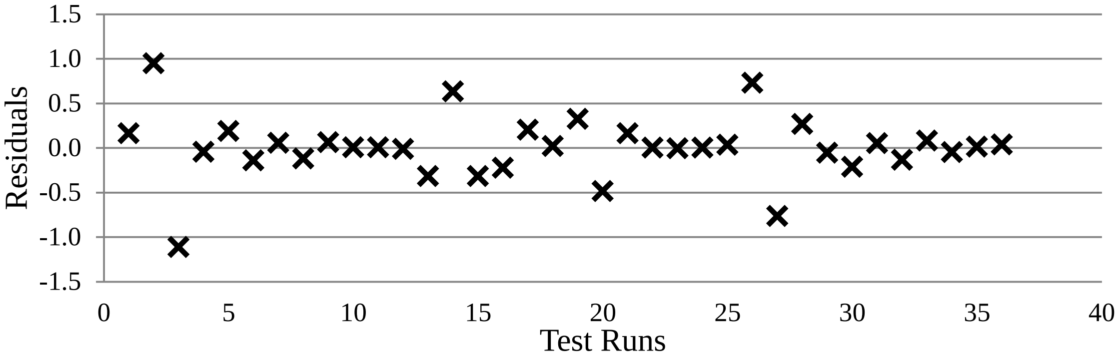


Figure C - 49. Overflow system total PM emission factor residual plot.

Table C - 49. ProUCL outlier test results for Log_{10}-transformed total PM overflow system emission factors ($\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	4	12	36
Critical Value	0.765	0.546	2.99
Upper Tail			
Potential Outlier	-0.843	-0.742	
Test Statistic	0.098	0.121	
Outlier?	No	No	
Lower Tail			
Potential Outlier	-1.863	-1.955	-1.965
Test Statistic	0.682	0.119	1.819
Outlier?	No	No	No

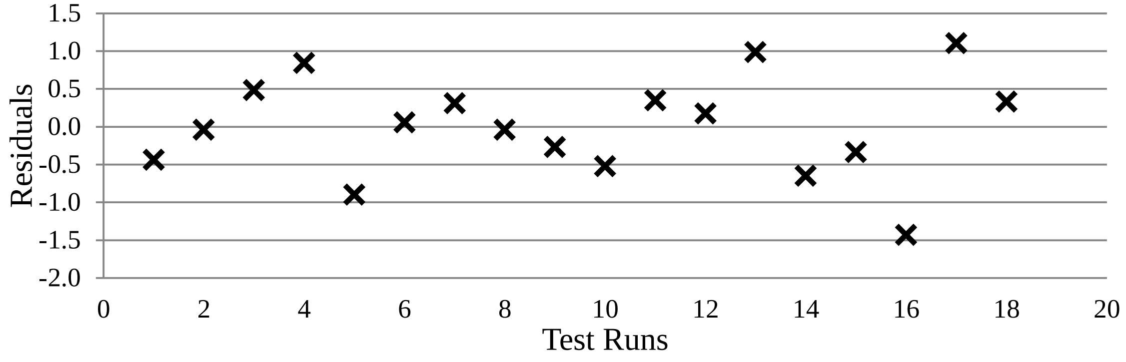


Figure C - 50. Mote cleaner system total PM emission factor residual plot.

Table C - 50. ProUCL outlier test results for Log$_{10}$-transformed total PM mote cleaner system emission factors (α = 0.05).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	No Test	6	18
Critical Value		0.56	0.475
Upper Tail			
Potential Outlier		-0.606	-0.547
Test Statistic		0.039	0.188
Outlier?		No	No
Lower Tail			
Potential Outlier		-0.782	-0.970
Test Statistic		0.462	0.577
Outlier?		No	Yes

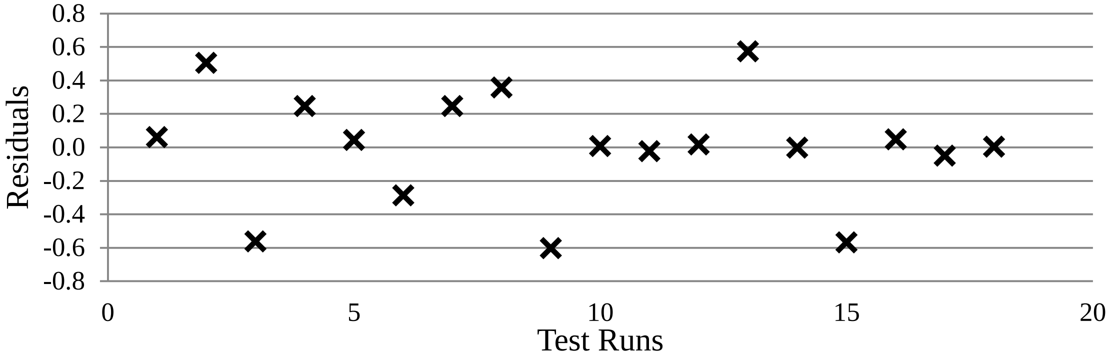


Figure C - 51. Mote trash system total PM emission factor residual plot.

Table C - 51. ProUCL outlier test results for Log_{10}-transformed total PM mote trash system emission factors ($\alpha = 0.05$).

	"Test" Design 1	**"Test" Design 2**	**"Test" Design 3**
Tests	No Test	6	18
Critical Value		0.56	0.475
Upper Tail			
Potential Outlier		-1.193	-1.140
Test Statistic		0.033	0.041
Outlier?		No	No
Lower Tail			
Potential Outlier		-1.711	-1.732
Test Statistic		0.300	0.073
Outlier?		No	No

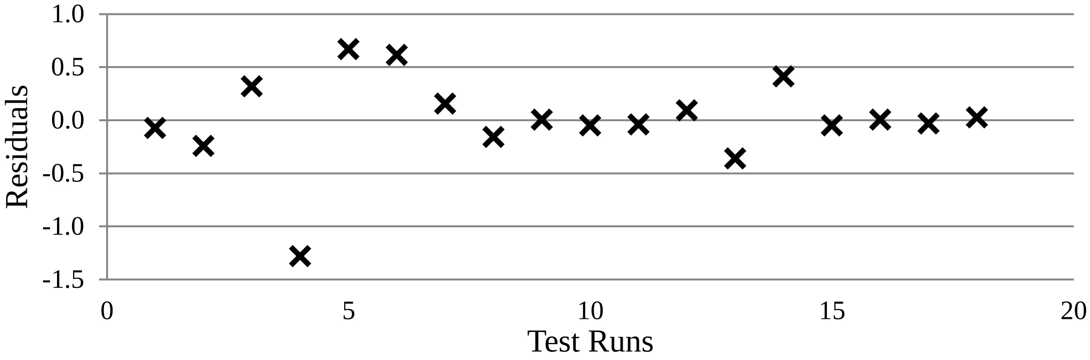


Figure C - 52. Unloading system residual plot for $PM_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 52. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ unloading system final suggested emission factors (National Cotton Ginning Study with PSD data; $\alpha = 0.05$).

	"Test" Design 2
Tests	6
Critical Value	0.56
Upper Tail	
Potential Outlier	-1.189
Test Statistic	0.055
Outlier?	No
Lower Tail	
Potential Outlier	-2.244
Test Statistic	0.022
Outlier?	No

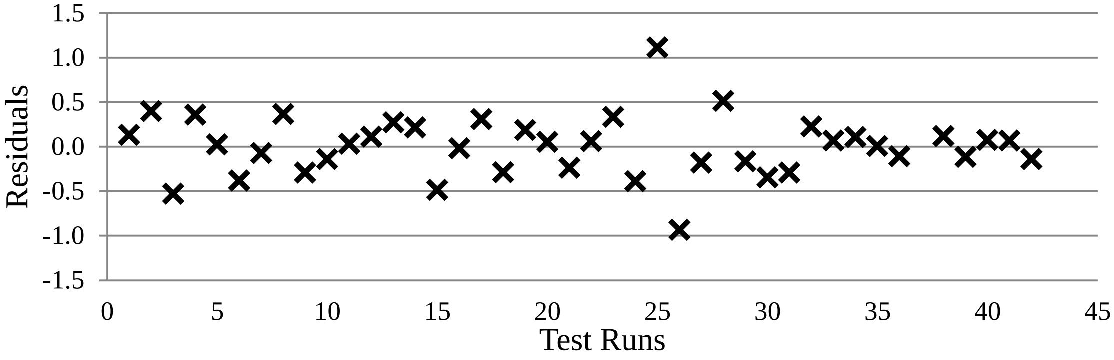


Figure C - 53. 1st stage seed-cotton cleaning system residual plot for $PM_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 53. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ 1st stage seed-cotton cleaning system final suggested emission factors (National Cotton Ginning Study with PSD data; $\alpha = 0.05$).

	"Test" Design 2
Tests	14
Critical Value	0.546
Upper Tail	
Potential Outlier	-1.415
Test Statistic	0.358
Outlier?	No
Lower Tail	
Potential Outlier	-2.345
Test Statistic	0.317
Outlier?	No

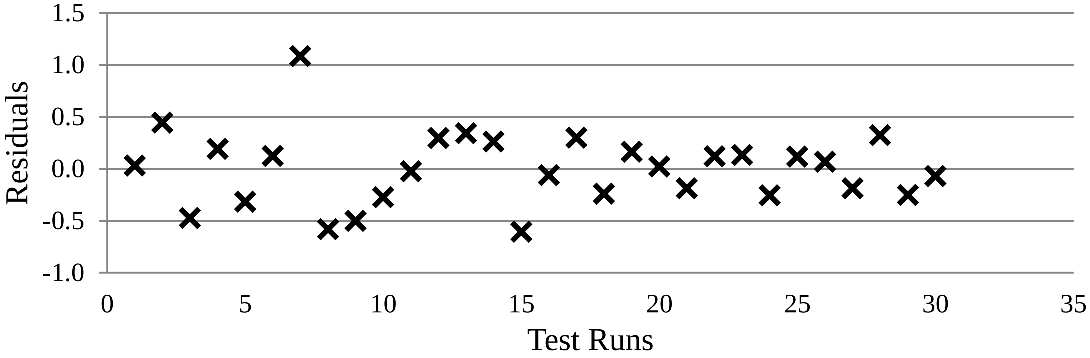


Figure C - 54. 2nd stage seed-cotton cleaning system residual plot for $PM_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 54. ProUCL outlier test results for Log$_{10}$-transformed PM$_{2.5}$ 2nd stage seed-cotton cleaning system final suggested emission factors (National Cotton Ginning Study with PSD data; $\alpha = 0.05$).

	"Test" Design 2
Tests	10
Critical Value	0.477
Upper Tail	
Potential Outlier	-2.010
Test Statistic	0.054
Outlier?	No
Lower Tail	
Potential Outlier	-2.774
Test Statistic	0.118
Outlier?	No

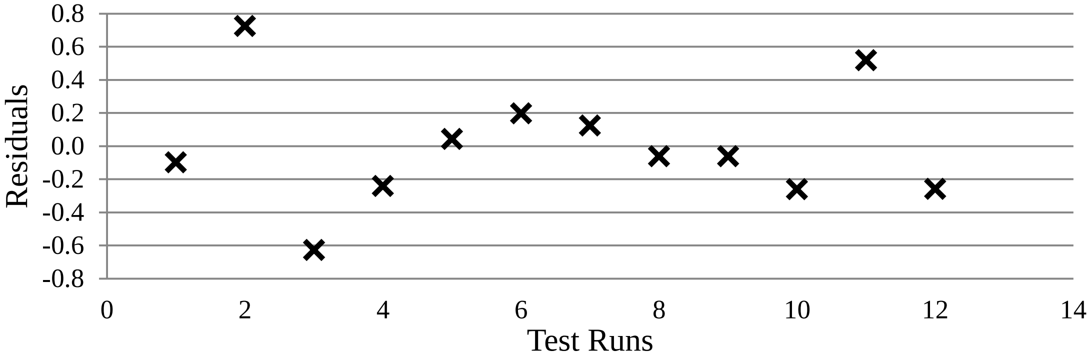


Figure C - 55. 3rd stage seed-cotton cleaning system residual plot for PM$_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 55. ProUCL outlier test results for Log$_{10}$-transformed PM$_{2.5}$ 3rd stage seed-cotton cleaning system final suggested emission factors (National Cotton Ginning Study with PSD data; $\alpha = 0.05$).

	"Test" Design 2
Tests	4
Critical Value	0.765
Upper Tail	
Potential Outlier	-1.970
Test Statistic	0.187
Outlier?	No
Lower Tail	
Potential Outlier	-3.020
Test Statistic	0.610
Outlier?	No

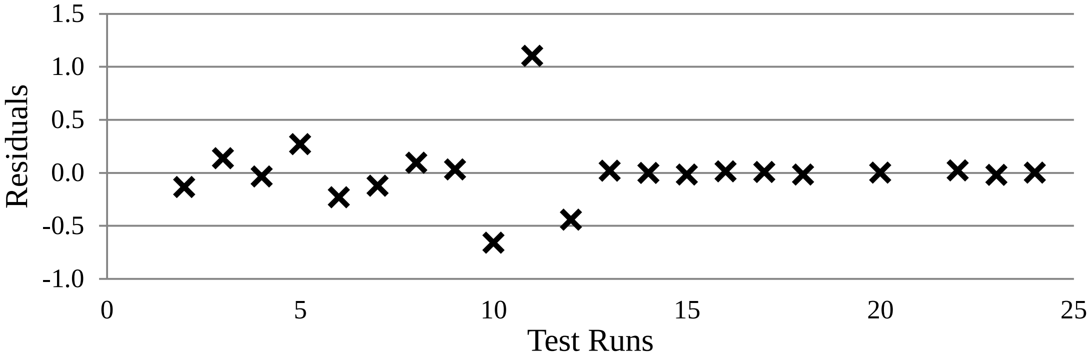


Figure C - 56. 1st stage lint cleaner system residual plot for $PM_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 56. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ 1st stage lint cleaner system final suggested emission factors (National Cotton Ginning Study with PSD data; $\alpha = 0.05$).

	"Test" Design 2
Tests	8
Critical Value	0.554
Upper Tail	
Potential Outlier	-1.412
Test Statistic	0.194
Outlier?	No
Lower Tail	
Potential Outlier	-2.797
Test Statistic	0.050
Outlier?	No

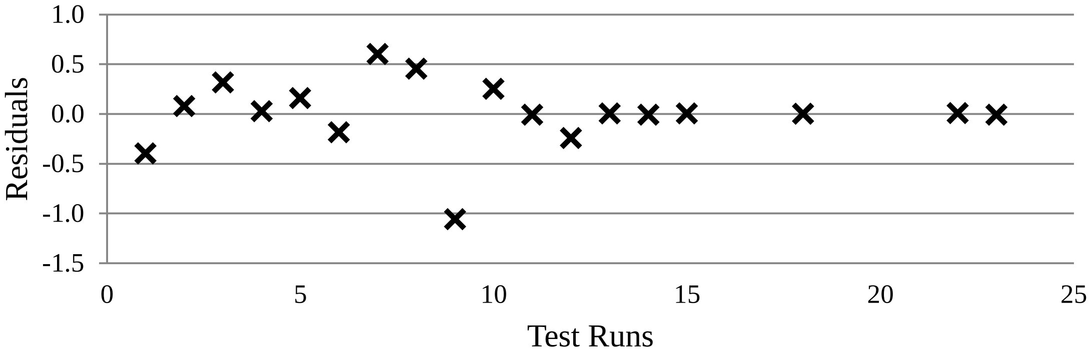


Figure C - 57. 2nd stage lint cleaner system residual plot for $PM_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 57. ProUCL outlier test results for Log$_{10}$-transformed PM$_{2.5}$ 2nd stage lint cleaner system final suggested emission factors (National Cotton Ginning Study with PSD data; α = 0.05).

	"Test" Design 2
Tests	7
Critical Value	0.507
Upper Tail	
Potential Outlier	-1.751
Test Statistic	0.103
Outlier?	No
Lower Tail	
Potential Outlier	-3.756
Test Statistic	0.251
Outlier?	No

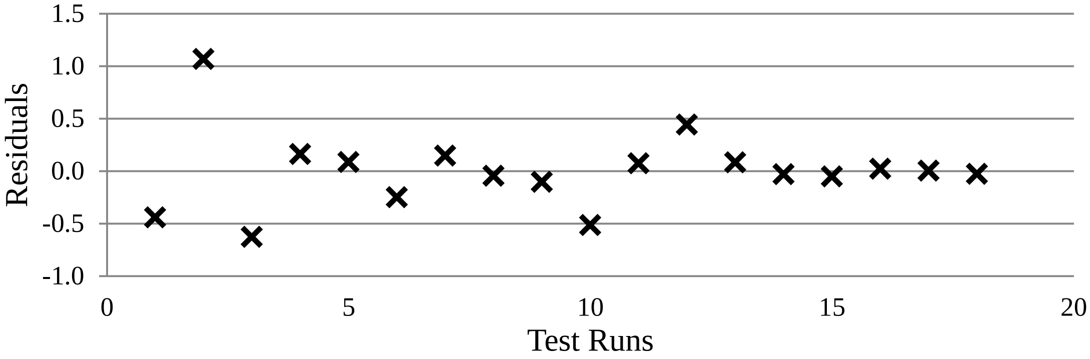


Figure C - 58. Combined lint cleaner system residual plot for PM$_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 58. ProUCL outlier test results for Log$_{10}$-transformed PM$_{2.5}$ combined lint cleaner system final suggested emission factors (National Cotton Ginning Study with PSD data; α = 0.05).

	"Test" Design 2
Tests	6
Critical Value	0.56
Upper Tail	
Potential Outlier	-1.259
Test Statistic	0.222
Outlier?	No
Lower Tail	
Potential Outlier	-2.701
Test Statistic	0.239
Outlier?	No

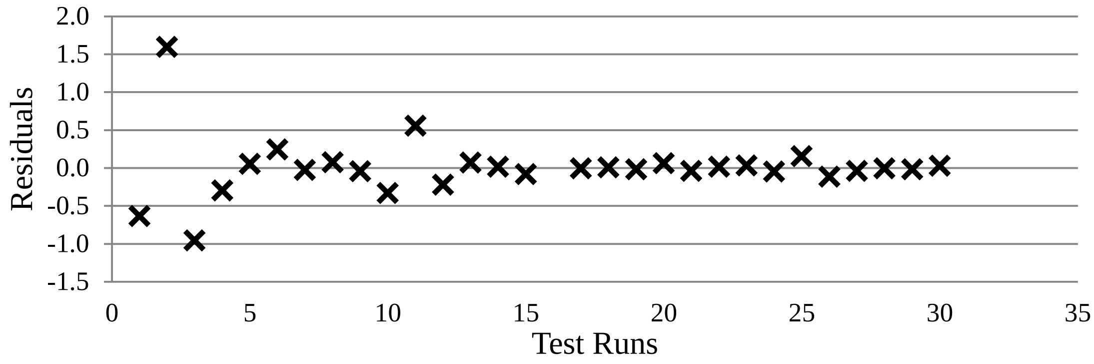


Figure C - 59. 1st stage mote system residual plot for $PM_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 59. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ 1st stage mote system final suggested emission factors (National Cotton Ginning Study with PSD data; α = 0.05).

	"Test" Design 2
Tests	10
Critical Value	0.477
Upper Tail	
Potential Outlier	-1.784
Test Statistic	0.142
Outlier?	No
Lower Tail	
Potential Outlier	-3.232
Test Statistic	0.076
Outlier?	No

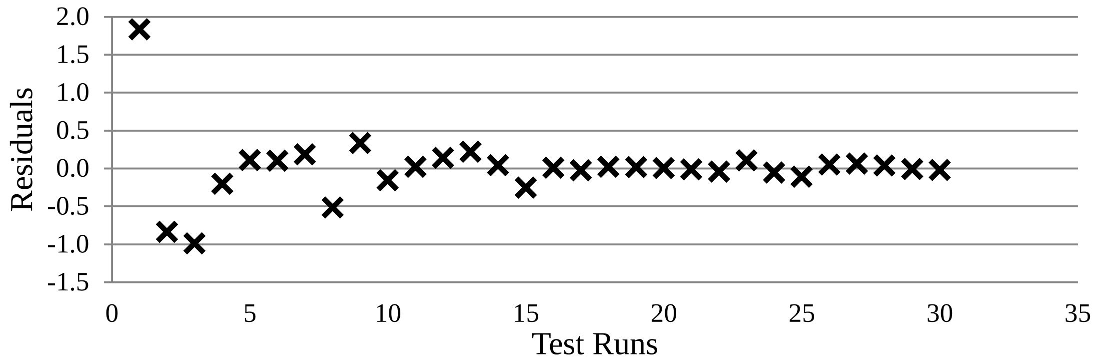


Figure C - 60. 2nd stage mote system residual plot for $PM_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 60. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ 2nd stage mote system final suggested emission factors (National Cotton Ginning Study with PSD data; $\alpha = 0.05$).

	"Test" Design 2
Tests	10
Critical Value	0.477
Upper Tail	
Potential Outlier	-2.082
Test Statistic	0.105
Outlier?	No
Lower Tail	
Potential Outlier	-3.496
Test Statistic	0.087
Outlier?	No

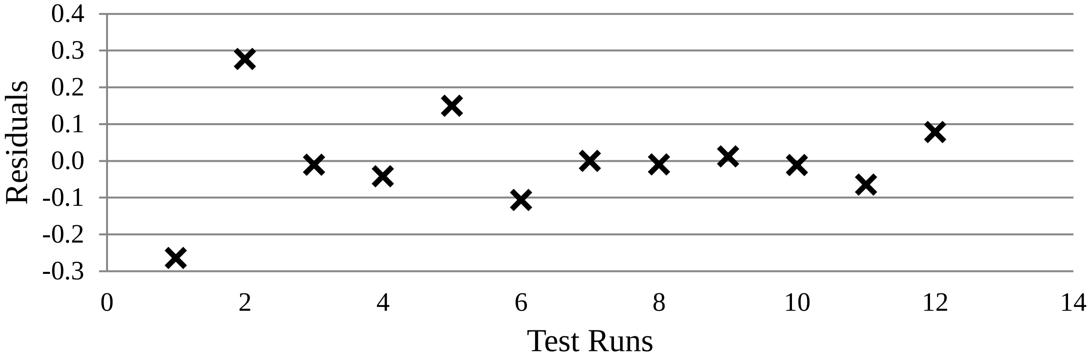


Figure C - 61. Combined mote system residual plot for $PM_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 61. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ combined mote system final suggested emission factors (National Cotton Ginning Study with PSD data; $\alpha = 0.05$).

	"Test" Design 2
Tests	4
Critical Value	0.765
Upper Tail	
Potential Outlier	-1.541
Test Statistic	0.442
Outlier?	No
Lower Tail	
Potential Outlier	-2.311
Test Statistic	0.096
Outlier?	No

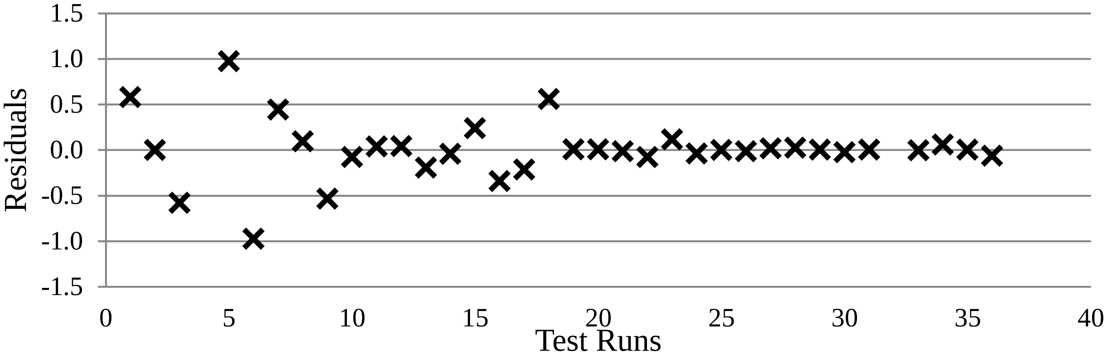


Figure C - 62. Battery condenser system residual plot for $PM_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 62. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ battery condenser system final suggested emission factors (National Cotton Ginning Study with PSD data; $\alpha = 0.05$).

	"Test" Design 2
Tests	11
Critical Value	0.546
Upper Tail	
Potential Outlier	-1.768
Test Statistic	0.177
Outlier?	No
Lower Tail	
Potential Outlier	-4.266
Test Statistic	0.429
Outlier?	No

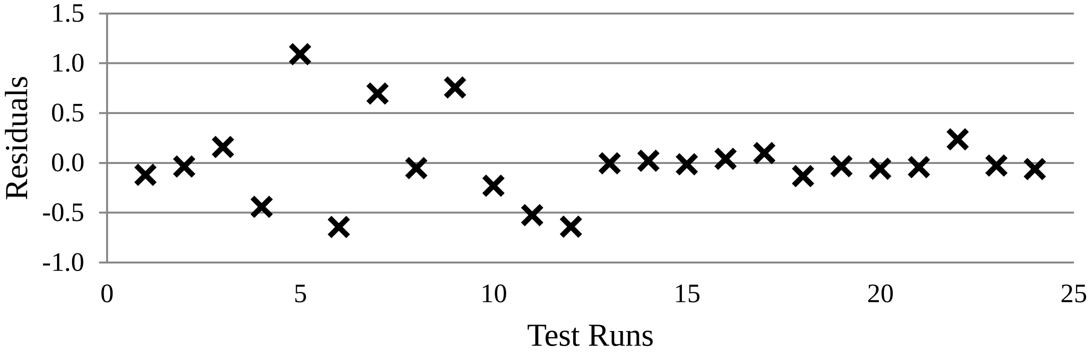


Figure C - 63. Cyclone robber system residual plot for $PM_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 63. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ cyclone robber system final suggested emission factors (National Cotton Ginning Study with PSD data; $\alpha = 0.05$).

	"Test" Design 2
Tests	6
Critical Value	0.56
Upper Tail	
Potential Outlier	-2.219
Test Statistic	0.255
Outlier?	No
Lower Tail	
Potential Outlier	-3.609
Test Statistic	0.232
Outlier?	No

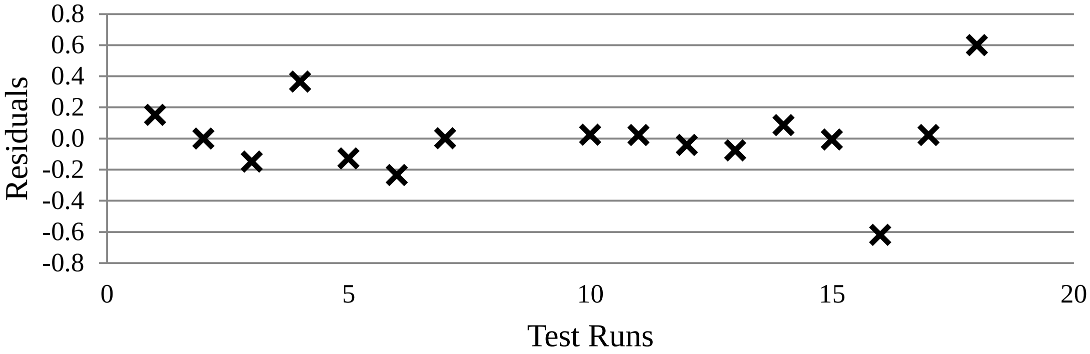


Figure C - 64. Mote cyclone robber system residual plot for $PM_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 64. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ mote cyclone robber system final suggested emission factors (National Cotton Ginning Study with PSD data; $\alpha = 0.05$).

	"Test" Design 2
Tests	6
Critical Value	0.56
Upper Tail	
Potential Outlier	-1.657
Test Statistic	0.481
Outlier?	No
Lower Tail	
Potential Outlier	-2.912
Test Statistic	0.090
Outlier?	No

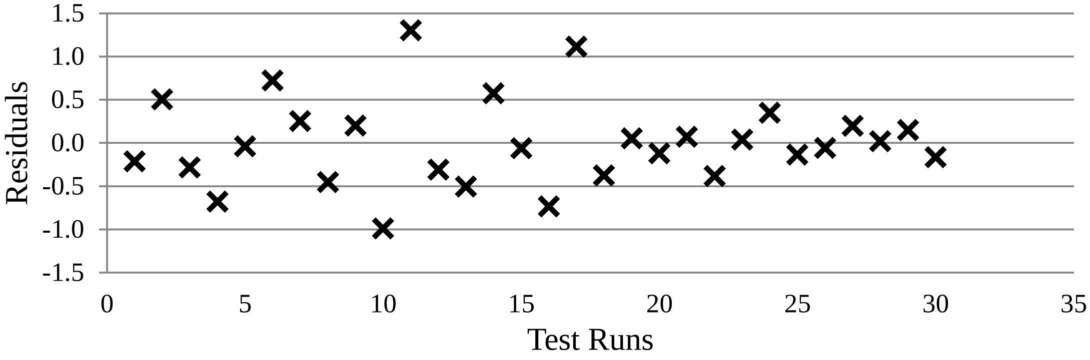


Figure C - 65. Master trash system residual plot for $PM_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 65. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ master trash system final suggested emission factors (National Cotton Ginning Study with PSD data; $\alpha = 0.05$).

	"Test" Design 2
Tests	10
Critical Value	0.477
Upper Tail	
Potential Outlier	-1.715
Test Statistic	0.296
Outlier?	No
Lower Tail	
Potential Outlier	-2.433
Test Statistic	0.154
Outlier?	No

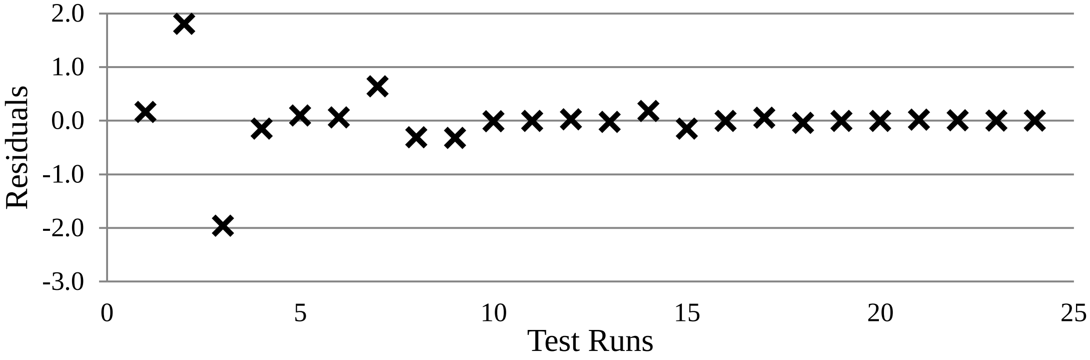


Figure C - 66. Overflow system residual plot for $PM_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 66. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ overflow system final suggested emission factors (National Cotton Ginning Study with PSD data; $\alpha = 0.05$).

	"Test" Design 2
Tests	8
Critical Value	0.554
Upper Tail	
Potential Outlier	-1.729
Test Statistic	0.234
Outlier?	No
Lower Tail	
Potential Outlier	-3.718
Test Statistic	0.478
Outlier?	No

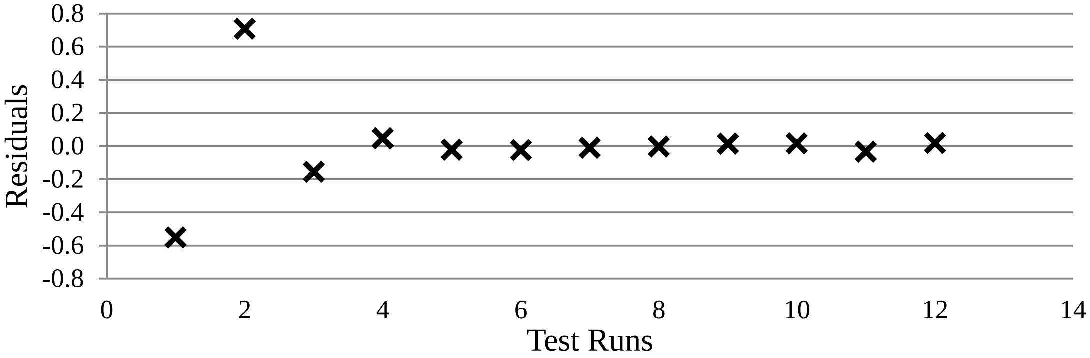


Figure C - 67. Mote cleaner system residual plot for $PM_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 67. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ mote cleaner system final suggested emission factors (National Cotton Ginning Study with PSD data; $\alpha = 0.05$).

	"Test" Design 2
Tests	4
Critical Value	0.765
Upper Tail	
Potential Outlier	-1.305
Test Statistic	0.574
Outlier?	No
Lower Tail	
Potential Outlier	-2.690
Test Statistic	0.175
Outlier?	No

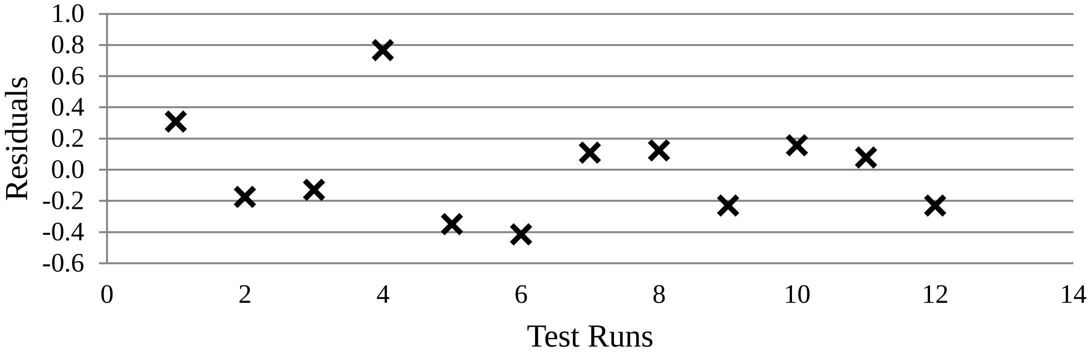


Figure C - 68. Mote trash cleaner system residual plot for $PM_{2.5}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 68. ProUCL outlier test results for Log_{10}-transformed $PM_{2.5}$ mote trash system final suggested emission factors (National Cotton Ginning Study with PSD data; $\alpha = 0.05$).

	"Test" Design 2
Tests	4
Critical Value	0.765
Upper Tail	
Potential Outlier	-2.590
Test Statistic	0.079
Outlier?	No
Lower Tail	
Potential Outlier	-3.303
Test Statistic	0.344
Outlier?	No

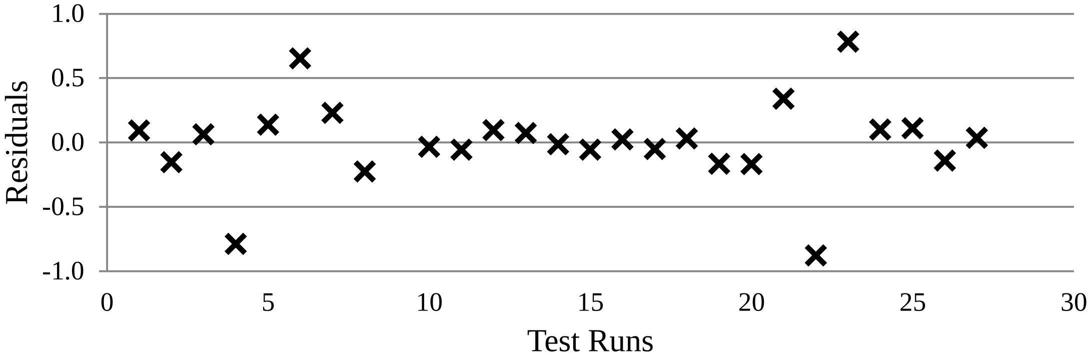


Figure C - 69. Unloading system residual plot for PM_{10} test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 69. ProUCL outlier test results for Log$_{10}$-transformed PM$_{10}$ unloading system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; α = 0.05).

	“Test” Design 2
Tests	14
Critical Value	0.546
Upper Tail	
Potential Outlier	-0.452
Test Statistic	0.030
Outlier?	No
Lower Tail	
Potential Outlier	-1.276
Test Statistic	0.209
Outlier?	No

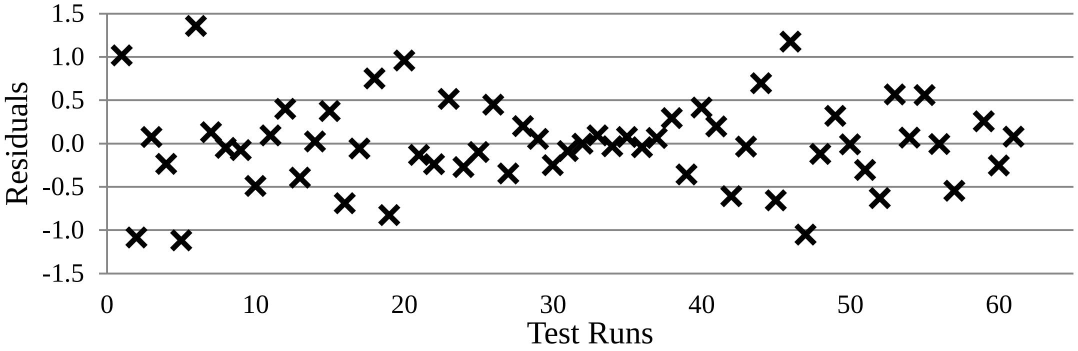


Figure C - 70. 1st stage seed-cotton cleaning system residual plot for PM$_{10}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 70. ProUCL outlier test results for Log$_{10}$-transformed PM$_{10}$ 1st stage seed-cotton cleaning unloading system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; α = 0.05).

	“Test” Design 2
Tests	26
Critical Value	2.84
Upper Tail	
Potential Outlier	-0.522
Test Statistic	1.692
Outlier?	No
Lower Tail	
Potential Outlier	
Test Statistic	
Outlier?	

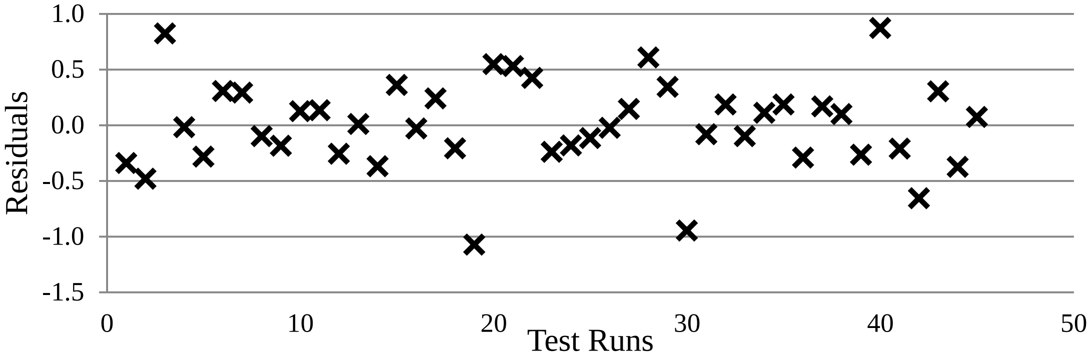


Figure C - 71. 2^{nd} stage seed-cotton cleaning system residual plot for PM_{10} test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 71. ProUCL outlier test results for Log_{10}-transformed PM_{10} 2^{nd} stage seed-cotton cleaning system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; α = 0.05).

	"Test" Design 2
Tests	20
Critical Value	0.45
Upper Tail	
Potential Outlier	-0.638
Test Statistic	0.387
Outlier?	No
Lower Tail	
Potential Outlier	-1.439
Test Statistic	0.081
Outlier?	No

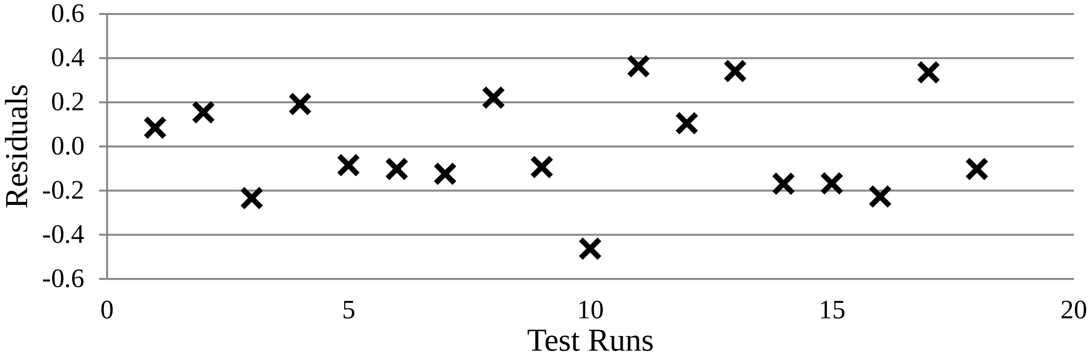


Figure C - 72. 3^{rd} stage seed-cotton cleaning system residual plot for PM_{10} test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 72. ProUCL outlier test results for Log$_{10}$-transformed PM$_{10}$ 3rd stage seed-cotton cleaning system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; α = 0.05).

	“Test” Design 2
Tests	8
Critical Value	0.554
Upper Tail	
Potential Outlier	-1.112
Test Statistic	0.231
Outlier?	No
Lower Tail	
Potential Outlier	-1.888
Test Statistic	0.359
Outlier?	No

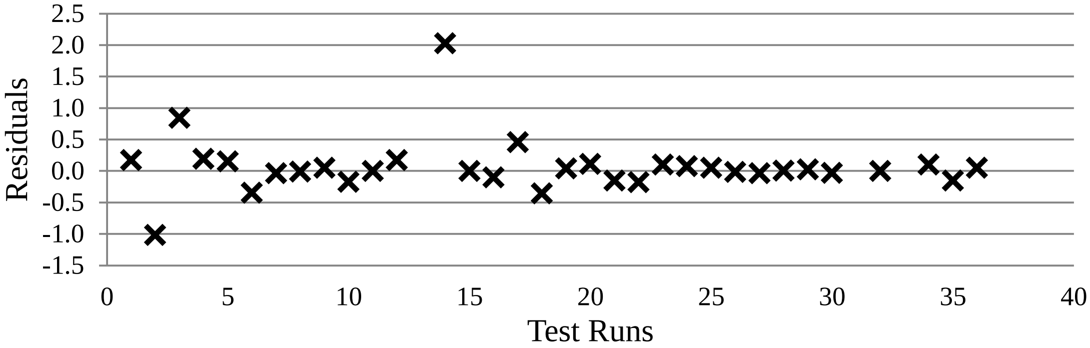


Figure C - 73. 1st stage lint cleaner system residual plot for PM$_{10}$ test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 73. ProUCL outlier test results for Log$_{10}$-transformed PM$_{10}$ 1st stage lint cleaner system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; α = 0.05).

	“Test” Design 2
Tests	12
Critical Value	0.546
Upper Tail	
Potential Outlier	-0.708
Test Statistic	0.176
Outlier?	No
Lower Tail	
Potential Outlier	-1.726
Test Statistic	0.156
Outlier?	No

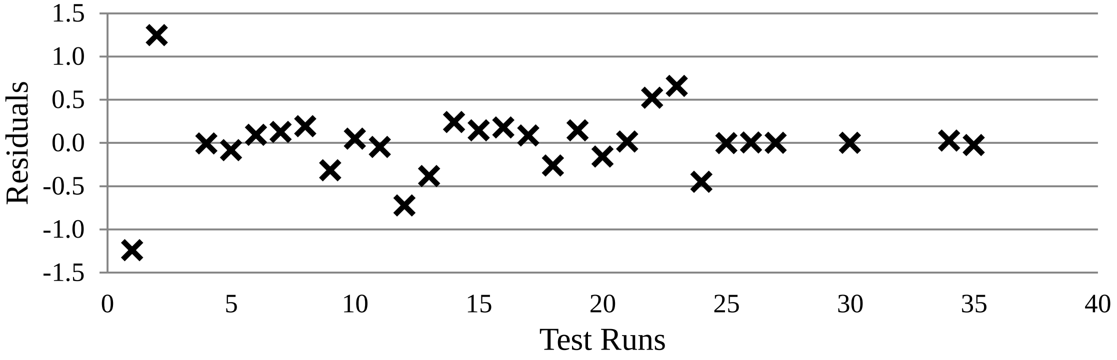


Figure C - 74. 2^{nd} stage lint cleaner system residual plot for PM_{10} test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 74. ProUCL outlier test results for Log_{10}-transformed PM_{10} 2^{nd} stage lint cleaner system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; $\alpha = 0.05$).

	"Test" Design 2
Tests	11
Critical Value	0.576
Upper Tail	
Potential Outlier	-1.138
Test Statistic	0.133
Outlier?	No
Lower Tail	
Potential Outlier	-2.336
Test Statistic	0.383
Outlier?	No

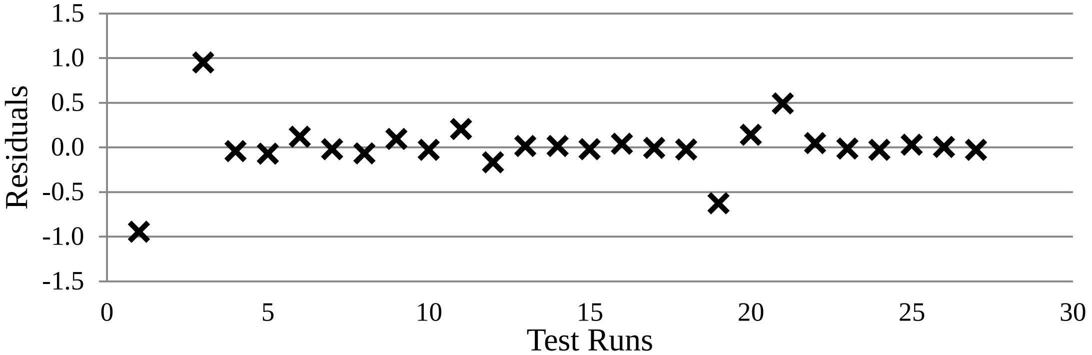


Figure C - 75. Combined lint cleaning system residual plot for PM_{10} test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 75. ProUCL outlier test results for Log_{10}-transformed PM_{10} combined lint cleaning system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; $\alpha = 0.05$).

	"Test" Design 2
Tests	15
Critical Value	0.525
Upper Tail	
Potential Outlier	-0.032
Test Statistic	0.213
Outlier?	No
Lower Tail	
Potential Outlier	-1.959
Test Statistic	0.360
Outlier?	No

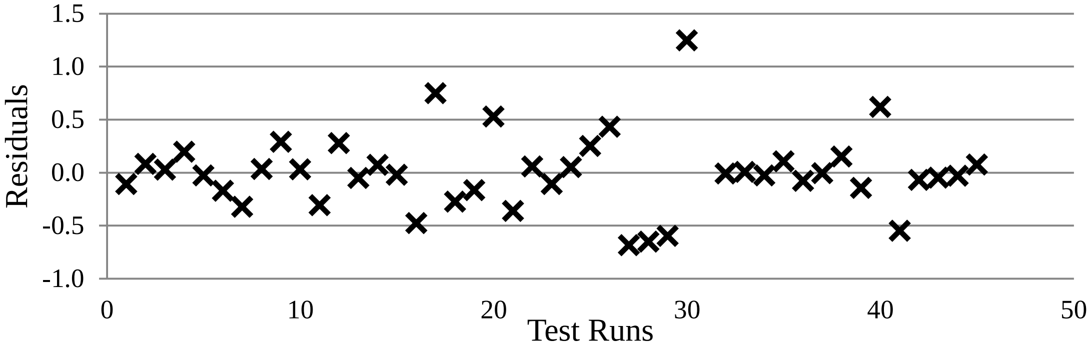


Figure C - 76. 1st stage mote system system residual plot for PM_{10} test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 76. ProUCL outlier test results for Log_{10}-transformed PM_{10} 1st stage mote system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; $\alpha = 0.05$).

	"Test" Design 2
Tests	15
Critical Value	0.525
Upper Tail	
Potential Outlier	-1.132
Test Statistic	0.079
Outlier?	No
Lower Tail	
Potential Outlier	-2.018
Test Statistic	0.229
Outlier?	No

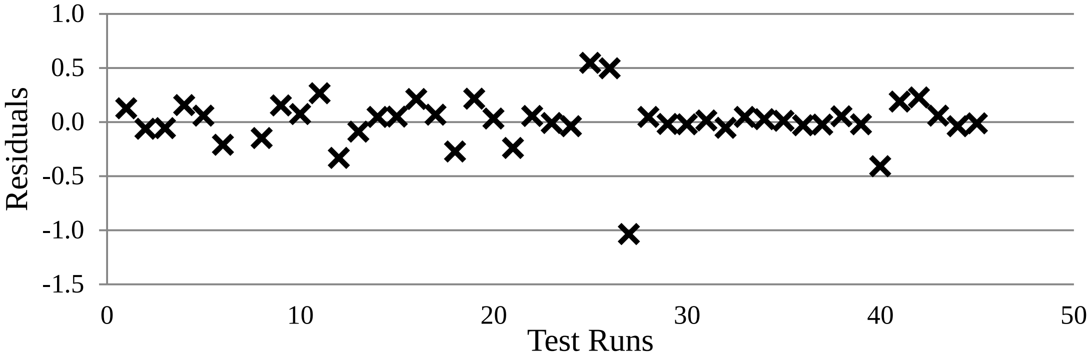


Figure C - 77. 2^{nd} stage mote system system residual plot for PM_{10} test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 77. ProUCL outlier test results for Log_{10}-transformed PM_{10} 2^{nd} stage mote system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; α = 0.05).

	“Test” Design 2
Tests	15
Critical Value	0.525
Upper Tail	
Potential Outlier	-1.284
Test Statistic	0.390
Outlier?	No
Lower Tail	
Potential Outlier	-2.447
Test Statistic	0.359
Outlier?	No

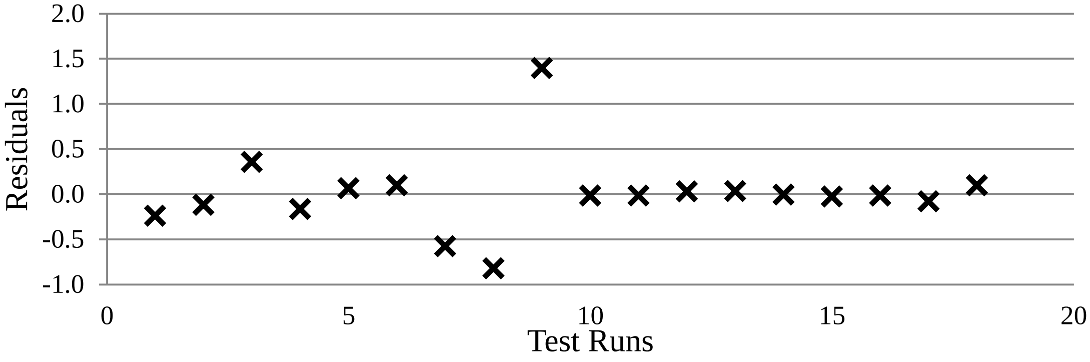


Figure C - 78. Combined mote system system residual plot for PM_{10} test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 78. ProUCL outlier test results for Log_{10}-transformed PM_{10} combined mote system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; $\alpha = 0.05$).

	"Test" Design 2
Tests	13
Critical Value	0.521
Upper Tail	
Potential Outlier	-0.471
Test Statistic	0.134
Outlier?	No
Lower Tail	
Potential Outlier	-1.301
Test Statistic	0.138
Outlier?	No

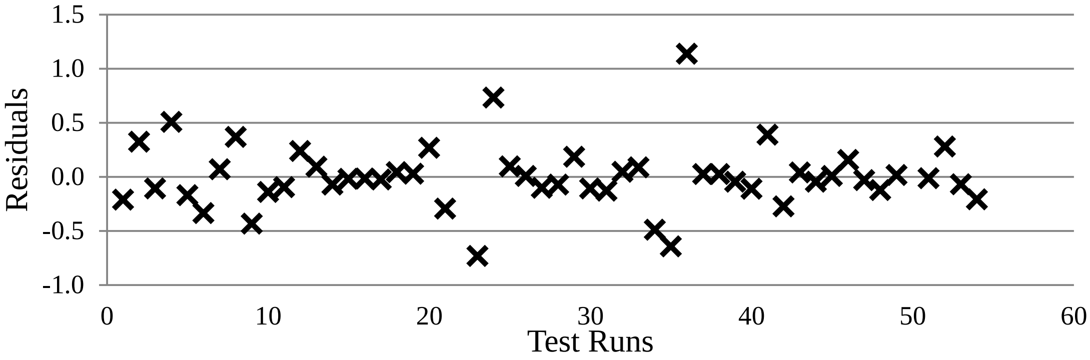


Figure C - 79. Battery condenser system system residual plot for PM_{10} test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 79. ProUCL outlier test results for Log_{10}-transformed PM_{10} battery condenser system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; $\alpha = 0.05$).

	"Test" Design 2
Tests	23
Critical Value	0.421
Upper Tail	
Potential Outlier	-1.100
Test Statistic	0.068
Outlier?	No
Lower Tail	
Potential Outlier	-2.726
Test Statistic	0.400
Outlier?	No

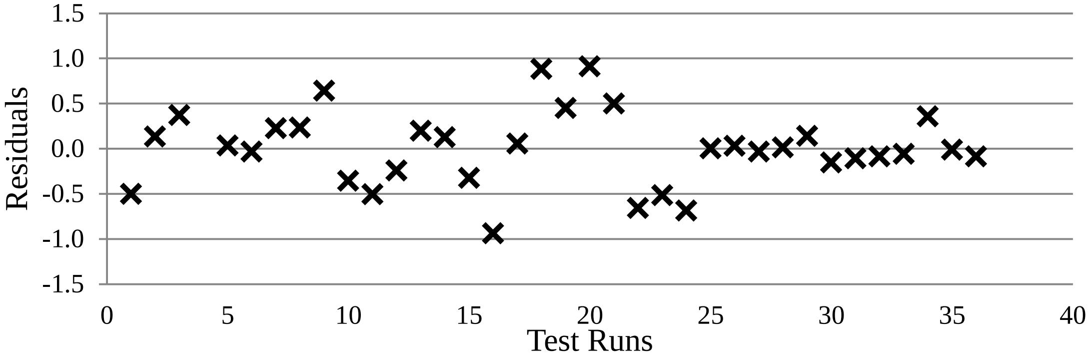


Figure C - 80. Cyclone robber system system residual plot for PM_{10} test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 80. ProUCL outlier test results for Log_{10}-transformed PM_{10} cyclone robber system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; $\alpha = 0.05$).

	"Test" Design 2
Tests	9
Critical Value	0.512
Upper Tail	
Potential Outlier	-1.284
Test Statistic	0.083
Outlier?	No
Lower Tail	
Potential Outlier	-2.118
Test Statistic	0.333
Outlier?	No

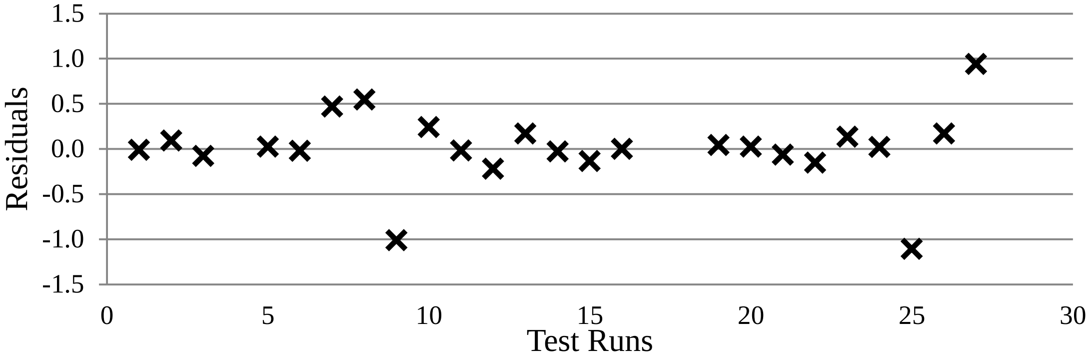


Figure C - 81. Mote cyclone robber system system residual plot for PM_{10} test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 81. ProUCL outlier test results for Log_{10}-transformed PM_{10} mote cyclone robber system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; $\alpha = 0.05$).

	"Test" Design 2
Tests	9
Critical Value	0.512
Upper Tail	
Potential Outlier	-0.923
Test Statistic	0.023
Outlier?	No
Lower Tail	
Potential Outlier	-1.790
Test Statistic	0.072
Outlier?	No

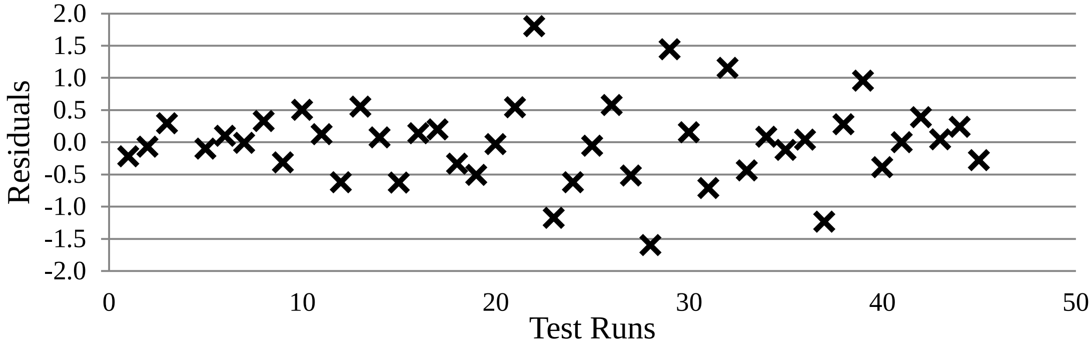


Figure C - 82. Master trash system residual plot for PM_{10} test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 82. ProUCL outlier test results for Log_{10}-transformed PM_{10} master trash system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; $\alpha = 0.05$).

	"Test" Design 2
Tests	17
Critical Value	0.49
Upper Tail	
Potential Outlier	-0.726
Test Statistic	0.216
Outlier?	No
Lower Tail	
Potential Outlier	-1.420
Test Statistic	0.386
Outlier?	No

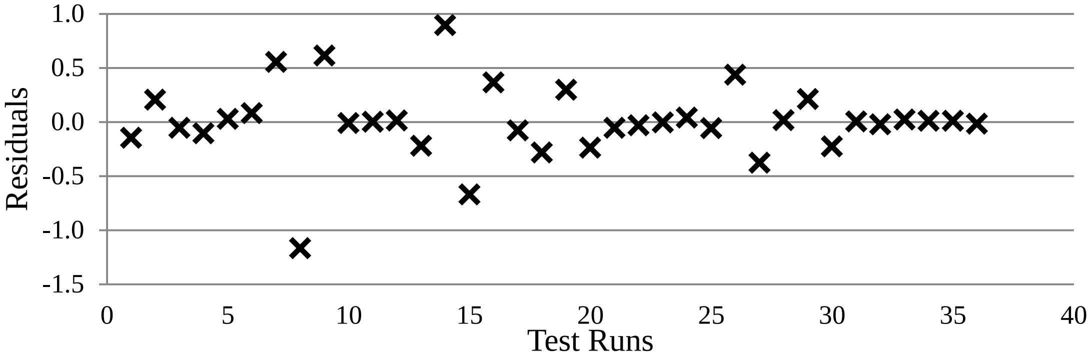


Figure C - 83. Overflow system residual plot for PM_{10} test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 83. ProUCL outlier test results for Log_{10}-transformed PM_{10} overflow system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; $\alpha = 0.05$).

	“Test” Design 2
Tests	16
Critical Value	0.454
Upper Tail	
Potential Outlier	-1.028
Test Statistic	0.182
Outlier?	No
Lower Tail	
Potential Outlier	-2.347
Test Statistic	0.239
Outlier?	No

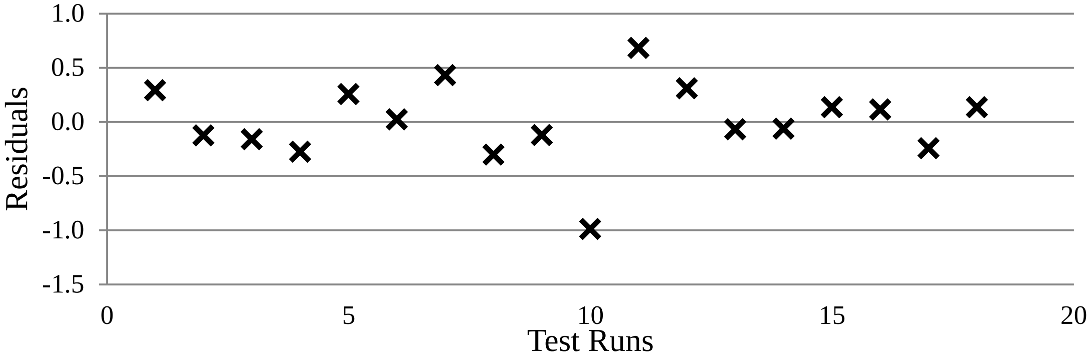


Figure C - 84. Mote cleaner system residual plot for PM_{10} test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 84. ProUCL outlier test results for Log_{10}-transformed PM_{10} mote cleaner system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; $\alpha = 0.05$).

	"Test" Design 2
Tests	6
Critical Value	0.56
Upper Tail	
Potential Outlier	-0.784
Test Statistic	0.037
Outlier?	No
Lower Tail	
Potential Outlier	-1.320
Test Statistic	0.348
Outlier?	No

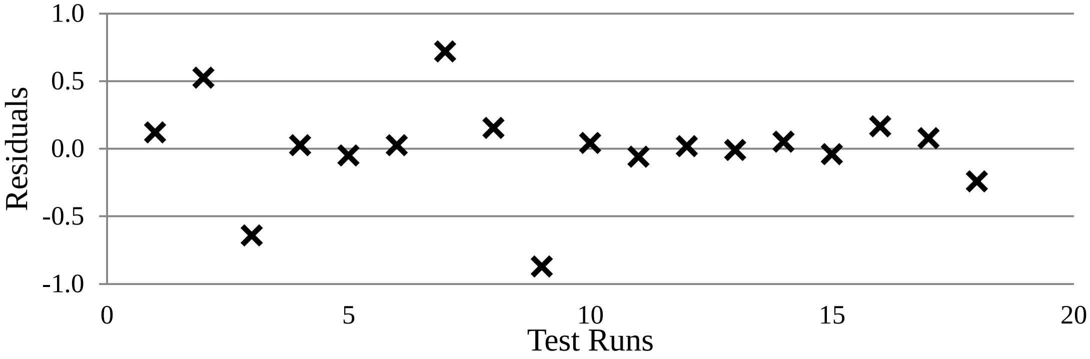


Figure C - 85. Mote trash system residual plot for PM_{10} test runs used in final suggested emission factors (National Cotton Ginning Study with PSD).

Table C - 85. ProUCL outlier test results for Log_{10}-transformed PM_{10} mote trash system final suggested emission factors (National Cotton Ginning Study with PSD and 1996 AP-42 data; $\alpha = 0.05$).

	"Test" Design 2
Tests	9
Critical Value	0.512
Upper Tail	
Potential Outlier	-1.398
Test Statistic	0.127
Outlier?	No
Lower Tail	
Potential Outlier	-2.337
Test Statistic	0.252
Outlier?	No

Table C - 86. ProUCL outlier test results for Log_{10}-transformed total PM unloading system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; α = 0.05).

	"Test" Design 2
Tests	18
Critical Value	0.475
Upper Tail	
Potential Outlier	-0.301
Test Statistic	0.116
Outlier?	No
Lower Tail	
Potential Outlier	-1.770
Test Statistic	0.535
Outlier?	Yes

Table C - 87. ProUCL outlier test results for Log_{10}-transformed total PM 1st stage seed-cotton cleaning system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; α = 0.05).

	"Test" Design 2
Tests	29
Critical Value	2.89
Upper Tail	
Potential Outlier	
Test Statistic	
Outlier?	
Lower Tail	
Potential Outlier	-1.229
Test Statistic	3.285
Outlier?	Yes

Table C - 88. ProUCL outlier test results for Log_{10}-transformed total PM 2nd stage seed-cotton cleaning system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; α = 0.05).

	"Test" Design 2
Tests	23
Critical Value	0.421
Upper Tail	
Potential Outlier	-0.102
Test Statistic	0.530
Outlier?	Yes
Lower Tail	
Potential Outlier	-1.431
Test Statistic	0.345
Outlier?	No

Table C - 89. ProUCL outlier test results for Log_{10}-transformed total PM 3rd stage seed-cotton cleaning system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; $\alpha = 0.05$).

	“Test” Design 2
Tests	7
Critical Value	0.507
Upper Tail	
Potential Outlier	-1.004
Test Statistic	0.011
Outlier?	No
Lower Tail	
Potential Outlier	-1.532
Test Statistic	0.032
Outlier?	No

Table C - 90. ProUCL outlier test results for Log_{10}-transformed total PM 1st stage lint cleaning system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; $\alpha = 0.05$).

	“Test” Design 2
Tests	12
Critical Value	0.546
Upper Tail	
Potential Outlier	-0.383
Test Statistic	0.324
Outlier?	No
Lower Tail	
Potential Outlier	-1.237
Test Statistic	0.273
Outlier?	No

Table C - 91. ProUCL outlier test results for Log_{10}-transformed total PM 2nd stage lint cleaning system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; $\alpha = 0.05$).

	“Test” Design 2
Tests	12
Critical Value	0.546
Upper Tail	
Potential Outlier	-0.799
Test Statistic	0.342
Outlier?	No
Lower Tail	
Potential Outlier	-1.695
Test Statistic	0.273
Outlier?	No

Table C - 92. ProUCL outlier test results for Log_{10}-transformed total PM combined lint cleaning system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; α = 0.05).

	“Test” Design 2
Tests	15
Critical Value	0.525
Upper Tail	
Potential Outlier	-0.362
Test Statistic	0.264
Outlier?	No
Lower Tail	
Potential Outlier	-1.046
Test Statistic	0.128
Outlier?	No

Table C - 93. ProUCL outlier test results for Log_{10}-transformed total PM 1st stage mote system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; α = 0.05).

	“Test” Design 2
Tests	15
Critical Value	0.525
Upper Tail	
Potential Outlier	-0.915
Test Statistic	0.166
Outlier?	No
Lower Tail	
Potential Outlier	-1.592
Test Statistic	0.136
Outlier?	No

Table C - 94. ProUCL outlier test results for Log_{10}-transformed total PM 2nd stage mote system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; α = 0.05).

	“Test” Design 2
Tests	15
Critical Value	0.525
Upper Tail	
Potential Outlier	-1.198
Test Statistic	0.285
Outlier?	No
Lower Tail	
Potential Outlier	-1.894
Test Statistic	0.162
Outlier?	No

Table C - 95. ProUCL outlier test results for Log$_{10}$-transformed total PM combined mote system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; $\alpha = 0.05$).

	"Test" Design 2
Tests	15
Critical Value	0.525
Upper Tail	
Potential Outlier	0
Test Statistic	0.404
Outlier?	No
Lower Tail	
Potential Outlier	-1.155
Test Statistic	0.256
Outlier?	No

Table C - 96. ProUCL outlier test results for Log$_{10}$-transformed total PM battery condenser system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; $\alpha = 0.05$).

	"Test" Design 2
Tests	23
Critical Value	0.421
Upper Tail	
Potential Outlier	-0.673
Test Statistic	0.034
Outlier?	No
Lower Tail	
Potential Outlier	-2.102
Test Statistic	0.025
Outlier?	No

Table C - 97. ProUCL outlier test results for Log$_{10}$-transformed total PM cyclone robber system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; $\alpha = 0.05$).

	"Test" Design 2
Tests	10
Critical Value	0.477
Upper Tail	
Potential Outlier	-0.745
Test Statistic	0.434
Outlier?	No
Lower Tail	
Potential Outlier	-1.670
Test Statistic	0.037
Outlier?	No

Table C - 98. ProUCL outlier test results for Log_{10}-transformed total PM mote cyclone robber system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; α = 0.05).

	"Test" Design 2
Tests	9
Critical Value	0.512
Upper Tail	
Potential Outlier	-0.757
Test Statistic	0.033
Outlier?	No
Lower Tail	
Potential Outlier	-1.331
Test Statistic	0.011
Outlier?	No

Table C - 99. ProUCL outlier test results for Log_{10}-transformed total PM master trash system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; α = 0.05).

	"Test" Design 2
Tests	20
Critical Value	0.45
Upper Tail	
Potential Outlier	0.114
Test Statistic	0.419
Outlier?	No
Lower Tail	
Potential Outlier	-1.137
Test Statistic	0.301
Outlier?	No

Table C - 100. ProUCL outlier test results for Log_{10}-transformed total PM overflow system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; α = 0.05).

	"Test" Design 2
Tests	16
Critical Value	0.507
Upper Tail	
Potential Outlier	-0.742
Test Statistic	0.121
Outlier?	No
Lower Tail	
Potential Outlier	-1.959
Test Statistic	0.122
Outlier?	No

Table C - 101. ProUCL outlier test results for Log$_{10}$-transformed total PM mote cleaner system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; $\alpha = 0.05$).

	"Test" Design 2
Tests	6
Critical Value	0.56
Upper Tail	
Potential Outlier	-0.606
Test Statistic	0.039
Outlier?	No
Lower Tail	
Potential Outlier	-0.782
Test Statistic	0.462
Outlier?	No

Table C - 102. ProUCL outlier test results for Log$_{10}$-transformed total PM mote trash system final suggested emission factors (National Cotton Ginning Study with 1996 AP-42 data; $\alpha = 0.05$).

	"Test" Design 2
Tests	9
Critical Value	0.512
Upper Tail	
Potential Outlier	-0.959
Test Statistic	0.393
Outlier?	No
Lower Tail	
Potential Outlier	-1.712
Test Statistic	0.300
Outlier?	No

APPENDIX D

1996 AP-42 DATA GRAPHS

The 16 emissions tests used in the 1996 AP-42 for cotton gins and their locations are listed in Table D - 1. The graphical spreads of the data for each system for total PM and PM_{10} follow with the reference number on the x-axis and emission factor on the y-axis.

Table D - 1. List of the emissions tests used in the 1996 AP-42 for cotton gins, their reference numbers, and locations.

Ref. No.	Gin	Location
1	Westfield Gin	Riverdale, California
2	Airways Gin	Fresno, California
3	Mount Whitney Cotton Gin	Five Points, California
4	Stratford Growers Gin	Stratford, California
5	County Line Gin	Hanford, California
6	County Line Gin	Hanford, California
7	Westfield Gin	Riverdale, California
8	West Valley Cotton Growers	Riverdale, California
9	Dos Palos Cooperative Gin	Dos Palos, California
10	Halls Gin	Halls, Tennessee
11	Marana Gin	Marana, Arizona
12	Westside Farmers’ Cooperative Gin No. 5	Tranquility, California
13	Elbow Enterprises	Visalia, California
14	Stratford Growers	Stratford, California
15	Alta Vista Gin	Mendota, California
16	Dos Palos Cooperative Gin	Dos Palos, California

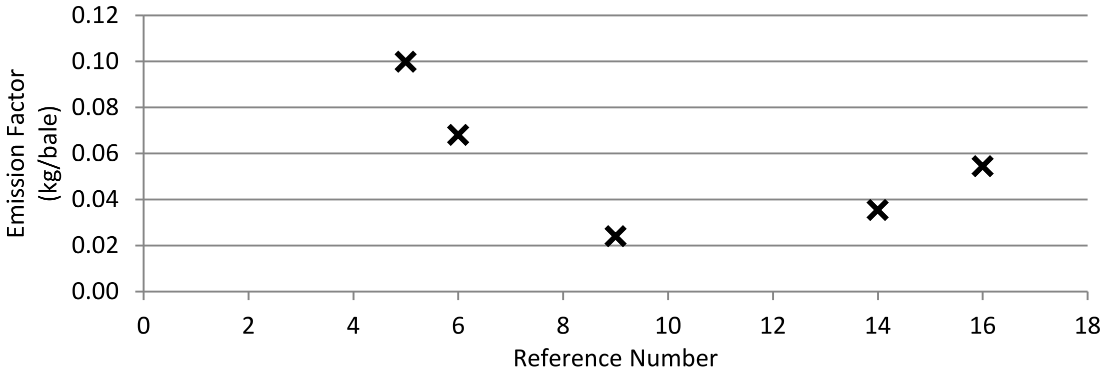


Figure D - 1. 1996 AP-42 unloading system PM_{10} data.

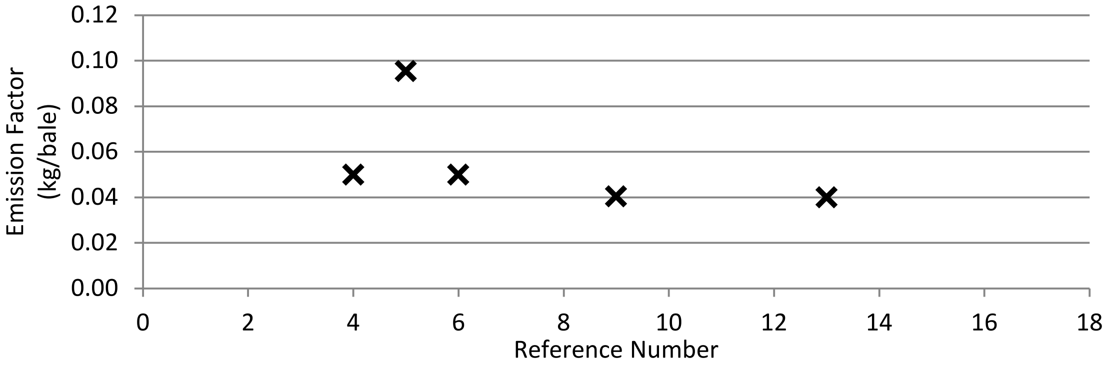


Figure D - 2. 1996 AP-42 1st stage seed-cotton cleaning system PM_{10} data.

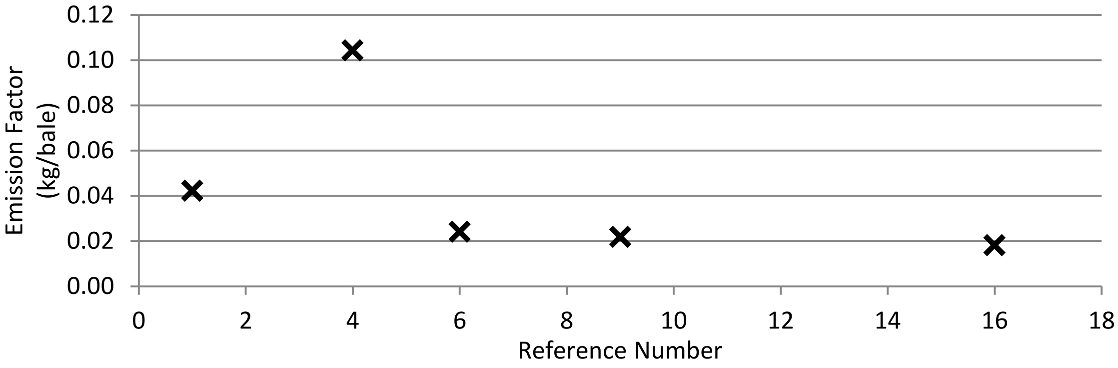


Figure D - 3. 1996 AP-42 2nd stage seed-cotton cleaning system PM_{10} data.

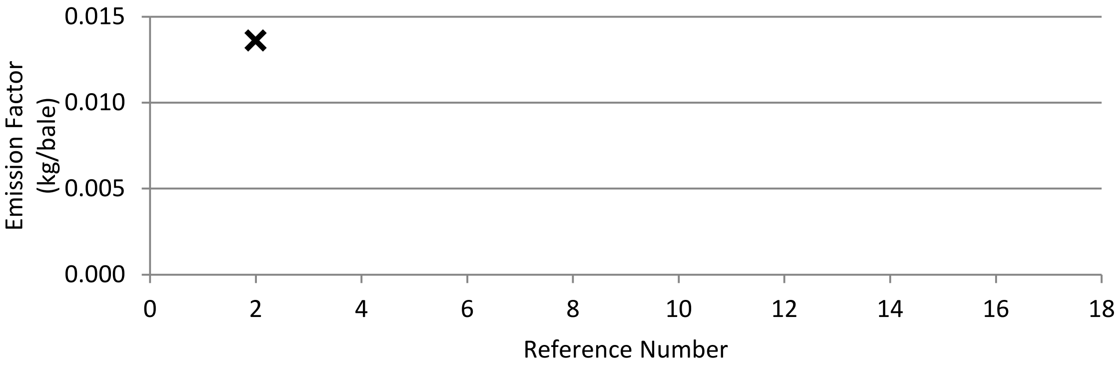


Figure D - 4. 1996 AP-42 3rd stage seed-cotton cleaning system PM_{10} data.

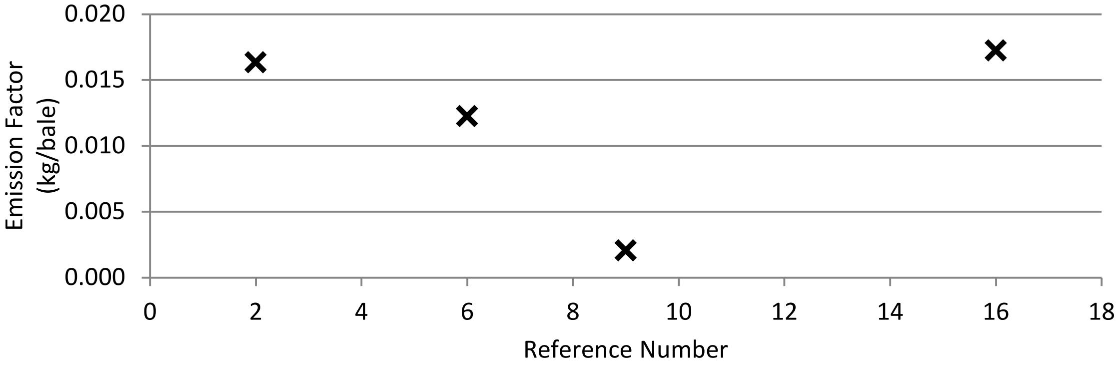


Figure D - 5. 1996 AP-42 overflow system PM_{10} data.

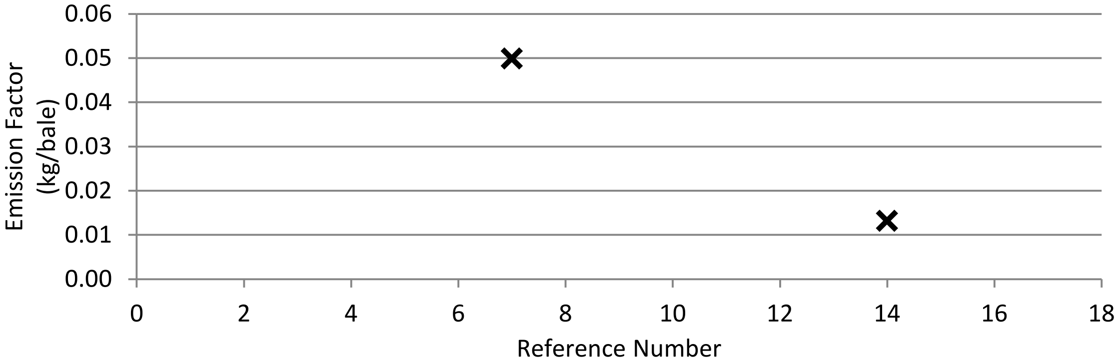


Figure D - 6. 1996 AP-42 master trash system PM_{10} data.

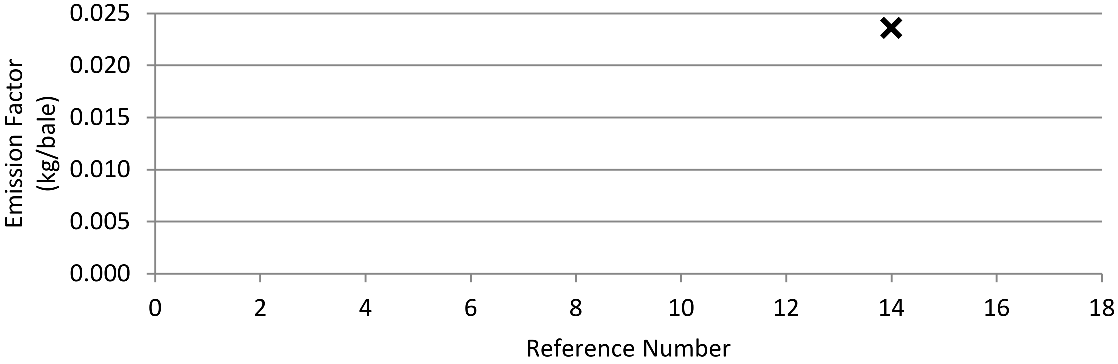


Figure D - 7. 1996 AP-42 cyclone robber system PM_{10} data.

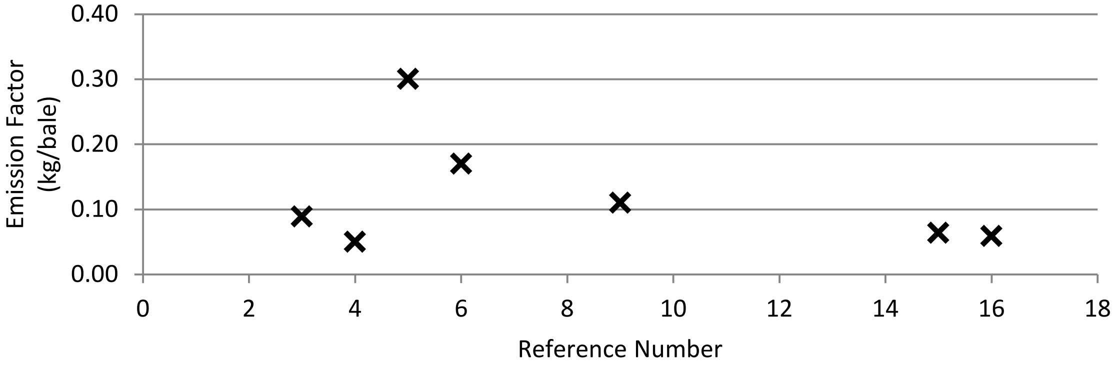


Figure D - 8. 1996 AP-42 mote cleaner system PM_{10} data.

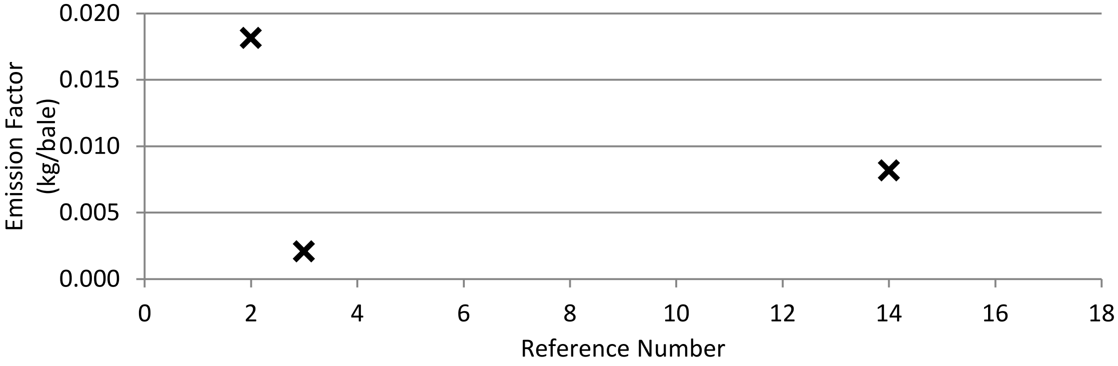


Figure D - 9. 1996 AP-42 mote trash system PM_{10} data.

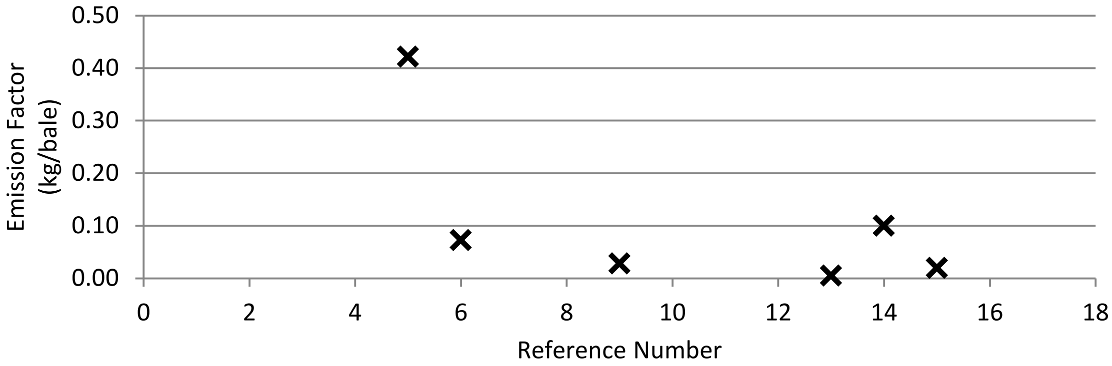


Figure D - 10. 1996 AP-42 lint cleaner system PM_{10} data.

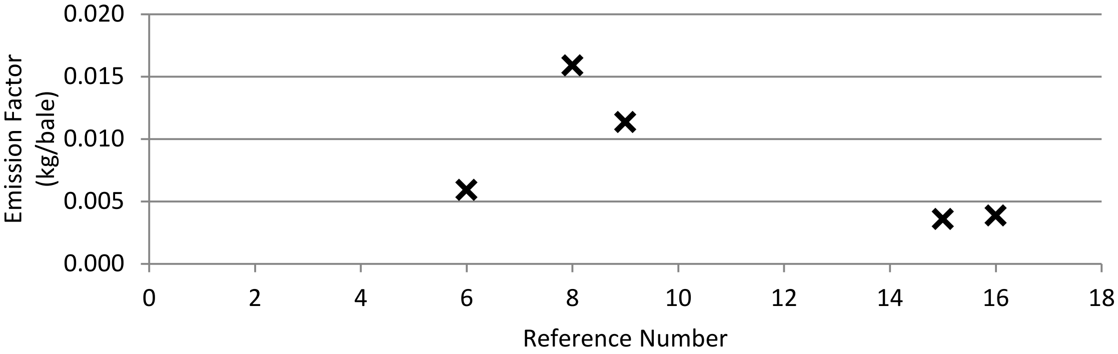


Figure D - 11. 1996 AP-42 battery condenser system PM_{10} data.

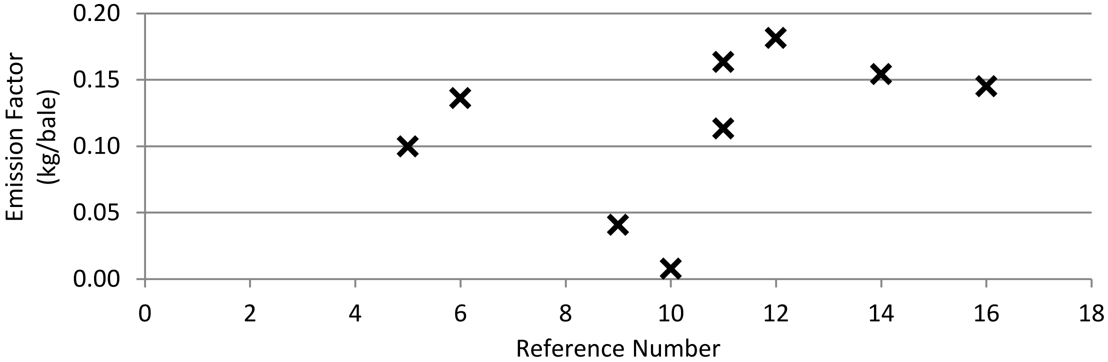


Figure D - 12. 1996 AP-42 unloading system total PM data.

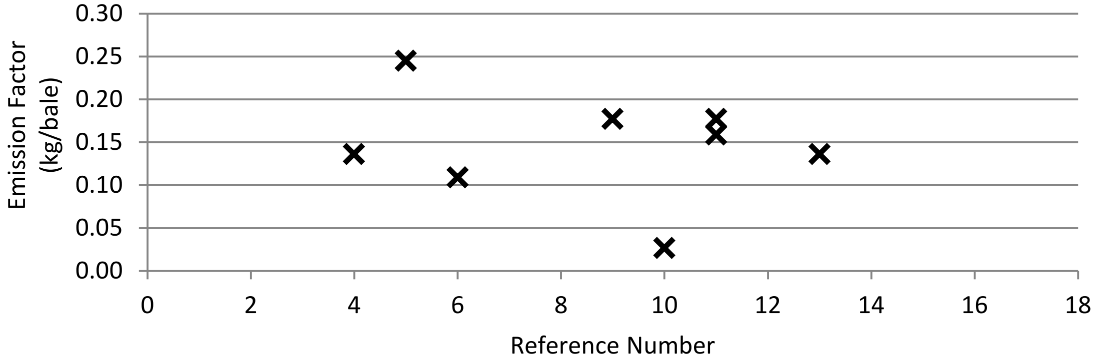


Figure D - 13. 1996 AP-42 1st stage seed-cotton cleaning system total PM data.

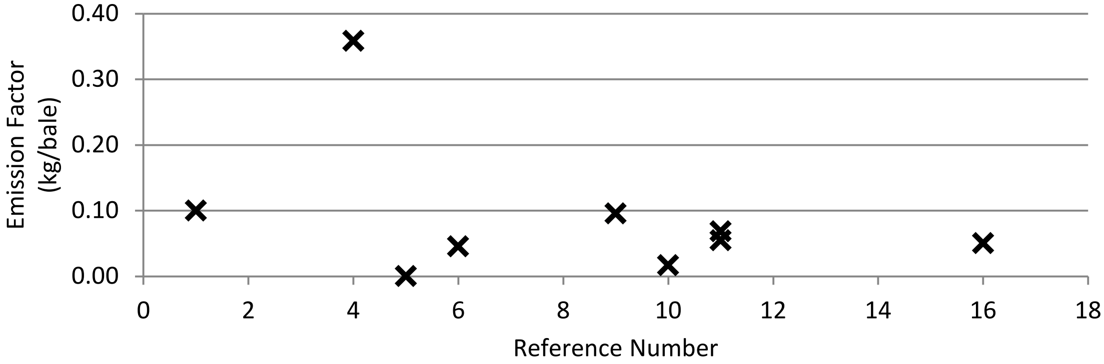


Figure D - 14. 1996 AP-42 2nd stage seed-cotton cleaning system total PM data.

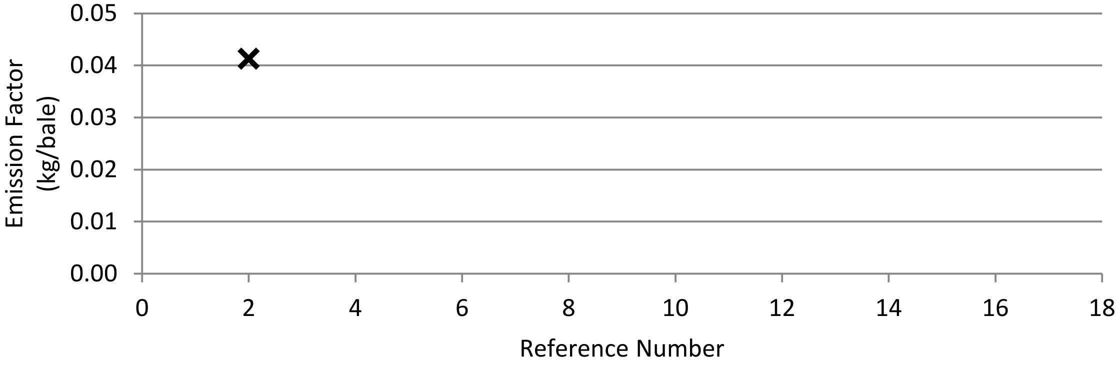


Figure D - 15. 1996 AP-42 3rd stage seed-cotton cleaning system total PM data.

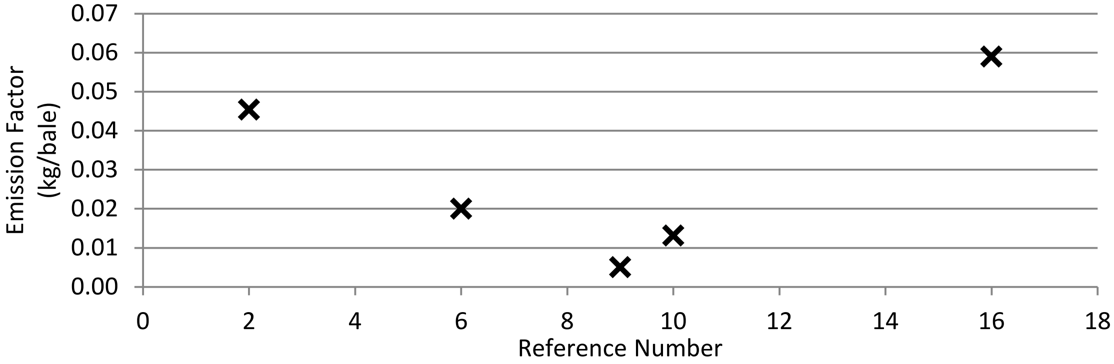


Figure D - 16. 1996 AP-42 overflow system total PM data.

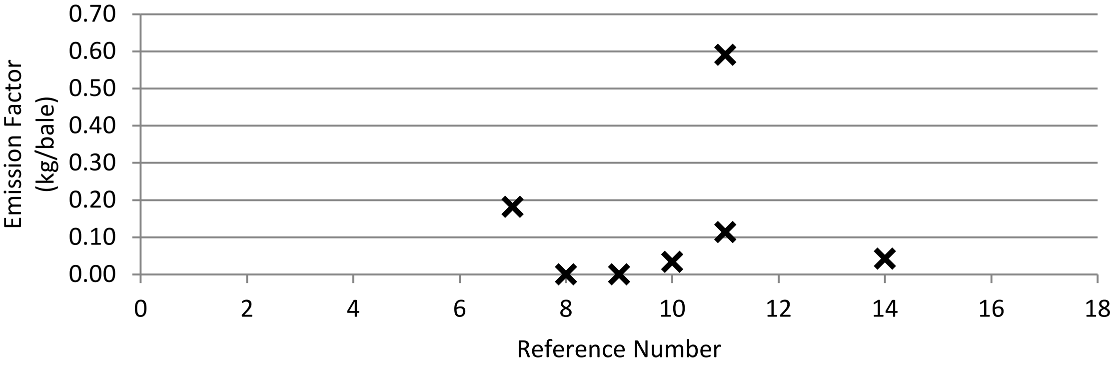


Figure D - 17. 1996 AP-42 master trash system total PM data.

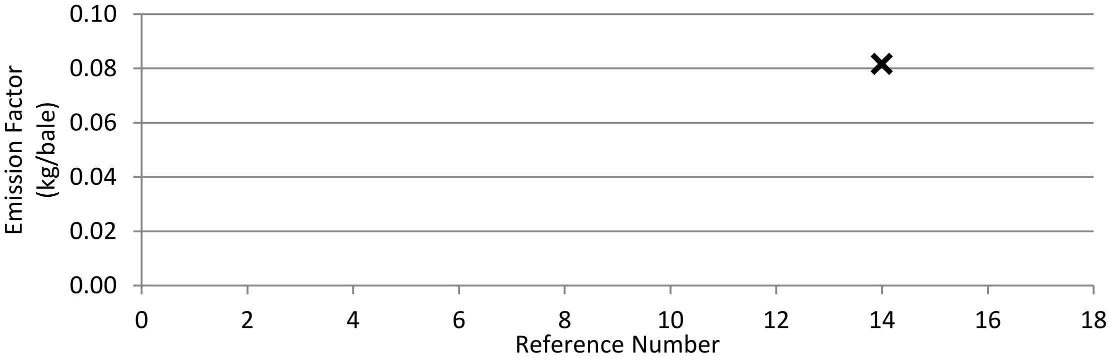


Figure D - 18. 1996 AP-42 cyclone robber system total PM data.

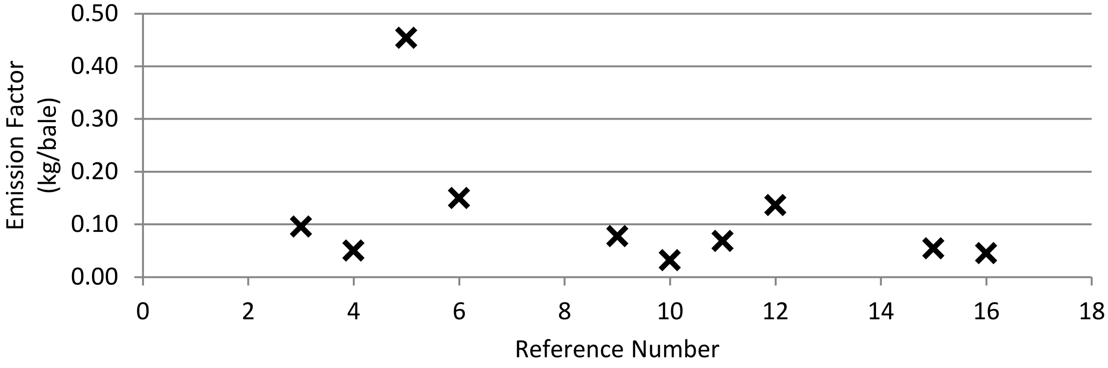


Figure D - 19. 1996 AP-42 mote cleaner system total PM data.

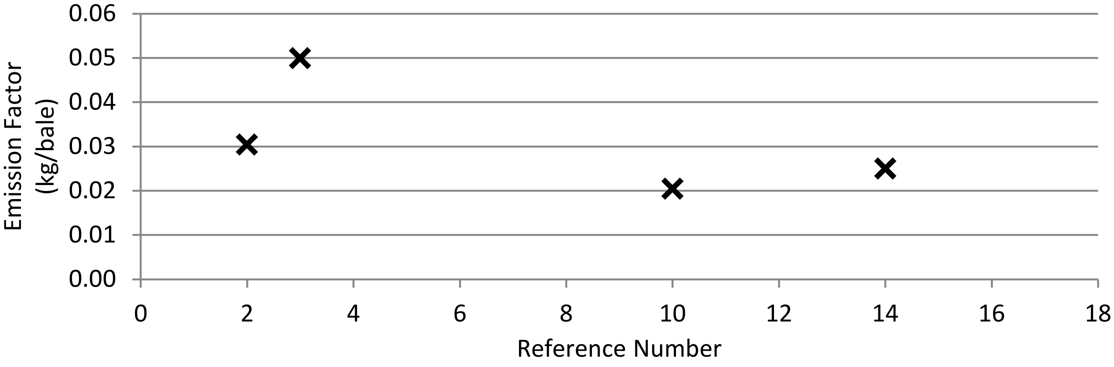


Figure D - 20. 1996 AP-42 mote trash system total PM data.

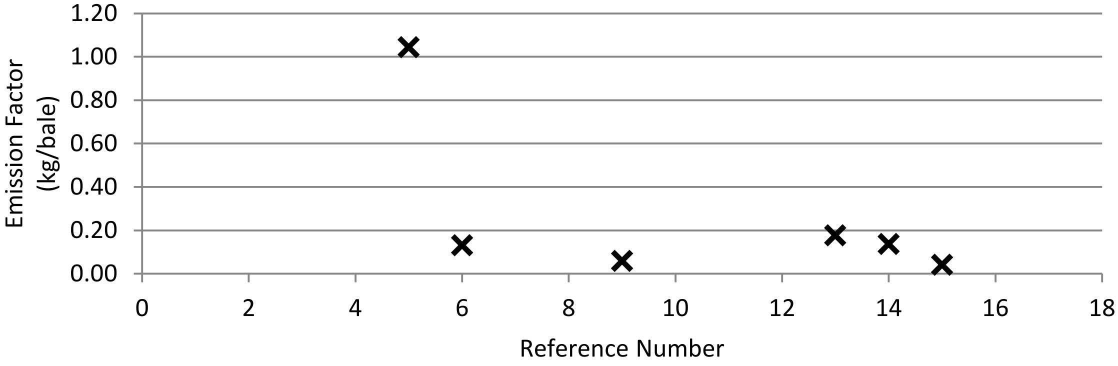


Figure D - 21. 1996 AP-42 lint cleaner system total PM data.

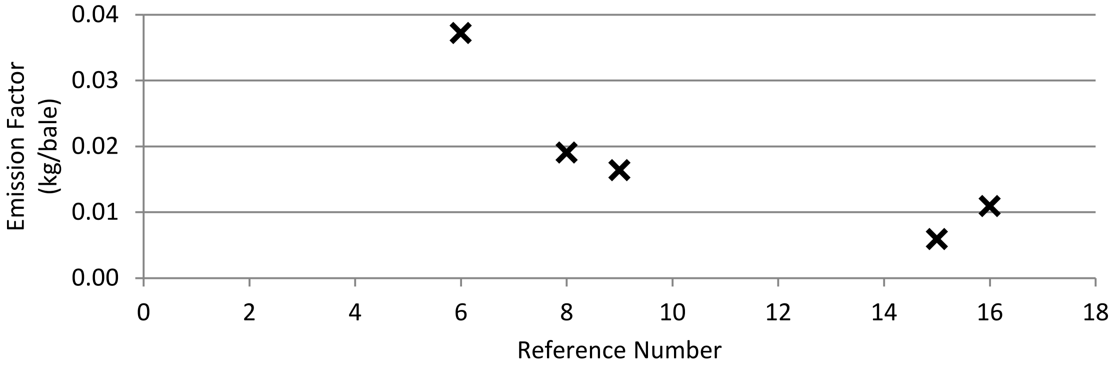


Figure D - 22. 1996 AP-42 battery condenser system total PM data.

VITA

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