MINIMUM COST AIR POLLUTION CONTROL FOR COTTON GINS

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Abstract

With the implementation of the 1990 Federal Clean Air Act Amendments (FCAA, 1990), State Air Pollution Regulatory Agencies (SAPRA's) are regulating agricultural operations across the U.S. more vigorously. Some of these agricultural operations experiencing the increased level of scrutiny are grain elevators, confined animal feeding operations (CAFO's), cattle feedlots, and cotton gins. Cotton gins across the cotton belt emit particulate matter as a consequence of pneumatic conveying systems used to convey seed cotton, seed and gin trash. Particulate matter (PM) less than 10 (EPA, 1987) and 2.5 micrometers (EPA, 1997), referred to as PM10 and PM2.5 are regulated pollutants with corresponding National Ambient Air Quality Standards (NAAQS). Some cotton gins are having to obtain operating permits from their respective SAPRA for the first time. Other gins are being forced by SAPRAs to reduce their PM emission rates in order to comply with lower allowable emission rates (AER). Some are in the dilemma of choosing the appropriate air pollution abatement equipment that will allow them to comply with SAPRA regulations. Each SAPRA is approaching the regulation of air pollution associated with cotton gins differently. The amount of money that a cotton gin has to invest in air pollution control, in order to achieve compliance with air pollution regulations, reduces the profit margin of the ginning operation. Presently, the number of viable operating gins in the U.S. has declined and the imposition of expensive controls to comply with SAPRA rules and regulations may continue or accelerate this trend. The goal of this research is to develop procedures that can be used by the ginning community across the cotton belt to comply with SAPRA rules and regulations while minimizing the cost of compliance.

Introduction

Cotton ginning is an essential part of the cotton industry. Seed cotton consists of lint, seed and trash and is the product delivered to the cotton gin resulting from the harvesting process. The cotton ginning process separates seed cotton into seed, lint fiber, and trash. A farmer's income from a cotton crop is the market value of the seed and fiber resulting from the ginning process. Cotton ginning consists of a number of different cleaning and conditioning processes. The primary method used to convey seed cotton, lint, and seed between processes and trash from inside the gin to an external location is pneumatic conveying. As materials are pneumatically conveyed, particulate matter is entrained in the conveying air. State Air Pollution Regulatory Agencies (SAPRAs) have the responsibility of limiting the particulate matter (PM) emission rates from all industries including cotton gins. SAPRAs utilize permitting and enforcement to insure that the state air pollution regulations are met. A permit is a detailed description of the air pollution abatement systems utilized by a cotton gin to reduce PM emission rates. Emission factors are ratios of pollutant emission rates and processing rates. The typical units of cotton ginning emission factors are pounds of particulate matter emitted per bale of cotton processed (lbs/bale). SAPRAs use permits and emission factors to determine the allowable PM emission rates (AERs).

The trash content of the incoming seed cotton is the amount of foreign material harvested with the seed cotton and delivered to the gin. This foreign material may include sticks, leaves, and soil. The two harvesting methods utilized in the U.S. are stripper and picker. Cotton harvested by strippers will contain 318 to 454 kilograms (kg) [700 to 1000 pounds (lbs)] of gin trash while cotton harvested by machine pickers will contain 45 to 91 kg (100 to 200 lbs). It is this foreign material that is the primary source of the PM emitted by cotton gins. The exhausts of each pneumatic conveying system are the sources of air pollution from cotton gins.

A cotton gin can be characterized as a stripper or picker gin meaning that the cotton processed by the gin has been harvested by a picker or stripper. A gin is also described by its size (ginning rate) in units of bales per hour (bph). Each bale of seed cotton will contain 360 kg (800 lbs) of cotton seed and 227 kg (500 lbs) of lint. Approximately 1000 kg (2200 lbs) of stripped seed cotton will yield one bale of lint, whereas 681 kg (1500 lbs) of picked seed cotton will yield one bale of lint. The ginning rates of the 1500 cotton gins across the cotton belt range from less than 10 bales per hour to greater than 30 bales per hour. The ginning rate or size will determine the volume rate of flow needed to convey materials from one process to another and the extent of the air pollution abatement system needed to comply with SAPRA regulations.

Cooper and Alley (1993) define air pollution as follows: "Air pollution is the presence in the outdoor atmosphere of any one or more substances or pollutants in quantities which are harmful or injurious to human health or welfare, animal or plant life or property… "**-** (health effects standard) "… or unreasonably interfere with the enjoyment of life or property, including outdoor recreation." -(nuisance standard). By definition, air pollution is measured by pollutant concentrations off the property. Cotton gins, for

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the most part, are regulated under the nuisance standard. The regulation of air pollution under the nuisance standard is not based upon any potential or real impact on public health. If the pollutant emission rate interferes with the normal use and enjoyment of one's property downwind from the source, the SAPRA has the authority to force the source of the pollutant to reduce their emission rate. In other words, a cotton ginner can be forced by a SAPRA to reduce the PM emission rate of his or her gin if a neighbor were to complain and it were determined that the PM emission rate was interfering with the neighbor's normal use of his or her property. Strong odors from a source can result in SAPRA enforcement, as can lint on trees and bushes, although neither of these conditions are related to public health. Regulation problems may also arise if the downwind concentrations exceed the National Ambient Air Quality Standards (NAAQS). NAAQS are established by EPA and are based upon health effects. In other words, a violation of the NAAQS could be interpreted as impacting public health downwind from the source. Some SAPRAs are attempting to use dispersion modeling in the permitting process to determine whether the AER from a source results in PM concentrations that exceed the NAAQS. If this occurs, the AER is reduced such that the concentration downwind does not exceed the NAAQS.

In air pollution regulation, there are three levels of controls:

- Reasonably Available Control Technology (RACT) **-** The FCAA mandated that all sources of NO_x install RACT in ozone non-attainment areas. This level of control is not as sophisticated as Best Available Control Technology (BACT), is less costly and must include consideration for economic reasonableness. It is accepted in Texas that a level of control that costs more than $2,000 per ton of reduced emissions would exceed the economic reasonableness associated with RACT.
- Best Available Control Technology (BACT) **-** All permitted cotton gins in Texas must have BACT installed. BACT must include consideration for economic reasonableness, but the criteria for establishing whether an abatement strategy is economically unreasonable has not been established. It is likely that this criteria will be more than $2,000 per ton of reduced emissions.
- Maximum Achievable Control Technology (MACT) **-** This level of controls is associated with the Lowest Achievable Emission Rate (LAER). This level of regulation is used for polluters in non-attainment areas of a regulated pollutant. There is no required consideration of economic reasonableness for MACT. It is the premise of this research that imposed controls that result in a gin going out of business are more stringent than BACT. Some could argue that it is the imposition of MACT. No cotton gin should be subject to MACT if it is located in an attainment area for PM10.

The location of a cotton gin can play an important role in determining the allowable emission rate (AER). Gins located in populated areas are more likely to be subject to complaints and are more likely to be forced to install more sophisticated air pollution abatement systems with associated lower AERs. Most cotton gins across the cotton belt are not located in PM_{10} non-attainment areas. However, those gins that are will likely have to install more elaborate air pollution abatement systems and have significantly lower AERs. The level of air pollution control that is most commonly encountered across the cotton belt is Baseline BACT. In Texas, Baseline BACT is defined as high efficiency cyclones (1D3D or 2D2D) on all centrifugal fan exhausts and covered condenser drums with 70-100 mesh screens on all axial flow fan exhausts. This is the minimum air pollution abatement strategy that will be approved as BACT by the Texas SAPRA. Most cotton gins across the cotton belt utilize an air pollution abatement strategy similar to the Texas Baseline BACT. However, when a gin must install more elaborate air pollution abatement systems as a consequence of complaints from neighbors or they are located in a non-attainment area, their systems may include replacing covered condenser drums with cyclones, placing plenum chambers prior to their cyclones, installing rotary drum filters (RDFs) as secondary collectors and utilizing cyclone series systems.

The cyclones that are most commonly encountered across the cotton belt are 1D3D and 2D2D. Parnell et al, (1990), reported results of laboratory tests on model cyclones in the laboratory and concluded that properly designed 1D3D and 2D2D cyclones can achieve emission concentrations of less than 70 milligrams per dry standard cubic meter (mg/dscm) [0.03 grains/dry standard cubic feet (gr/dscf)] with inlet loading rates of as much as 9 grams per cubic meter (g/m^3) of fine corn dust and 40 g/m^3 of gin trash containing 10% fine corn dust. With the exception of the pneumatic conveying system moving cotton gin trash from the gin to an external location, the inlet loading rates of air pollution abatement systems from picker cotton gins range from 1 to 13 g/m^3; from stripper gins range from 1 to 90 g/m^3. 1D3D or 2D2D cyclones are easyto maintain, have pressure drops of 995- 1244 Pa [4-5 inches of water (in wg)] and cost approximately $35 per cubic meter per minute (cmm) [$1.00 per cubic feet per minute (cfm)].

The use of covered condenser drums is the most common abatement strategy encountered across the cotton belt to reduce PM emissions from axial flow fans. This abatement strategy is merely the condenser drum covered with 70-100 mesh screen wire or perforated metal (Columbus et al, 1991). The screen covering facilitates the formation of a bat of lint fiber which subsequently filters PM. Covered condenser drums are among the least expensive controls available. The fine dust collection efficiency of a covered condenser drum is estimated to be 50% (Parnell et al., 1994). The pressure drop associated with covered condenser drums is approximately 249-373 Pa (1-1.5 in wg) and the cost is approximately $18/cmm ($0.50/cfm).

Another air pollution abatement device that is becoming more prevalent are rotary drum filters (RDF). RDFs are primarily utilized in California. They are expensive, approximately $88.00/cmm ($2.50/cfm), and maintenance intensive air pollution control devices (Yarlagadda et al., 1994). A RDF consist of a large drum covered with a special filter media. It is generally located in a chamber such that air with PM must pass into the chamber and through the filter media. The filtered air exits through the drum axis. The drum is rotated with vacuum nozzles removing the collected materials. Most RDFs installed at cotton gins are preceded by cyclones. Yarlagadda et al., (1994), performed performance tests on rotary drum filters in the laboratory and concluded that the efficiency ranges from 80-90% at a loading rate of 3 g/m^3. This compares to efficiencies in excess of 98% for 1D3D cyclones for the same loading rate. Estimated installed and operating costs of RDFs are very expensive when compared with cyclones. For example, an RDF cost $88/cmm ($2.50/cfm) compared to a cyclone costs of $35/cmm ($1.00/cfm)..

Mihalski et al., (1994) reported research results on the baffle type pre-separator (plenum chamber). The goal of his research was to increase the resulting air pollution abatement efficiencies of a series system with the plenum chamber serving to remove the large trash prior to high efficiency cyclones. The justification of this research was the knowledge that the emission concentrations of cyclones used to separate trash and fine dust are always higher than when the cyclone is used to collect fine dust only. If an inexpensive, low energy system could be developed (baffle type pre-separator) to remove the trash component of a gin's exhaust prior to the cyclone, the following benefits were possible: (1) reduction in PM emission rates, (2) the life of the cyclone would be increased due to less wear, and (3) a more uniform size cyclone could be used for multiple exhausts. Mihalski et al., (1994) performed tests on various baffle type pre-separator (plenum chambers) designs and determined that a pre-collection plenum chamber would increase the efficiency of particulate removal from cotton gin exhausts. Table 1 shows the results of Mihalski's tests.

One air pollution abatement strategy that is being utilized by cotton ginners across the cotton belt, when faced with compliance problems, has been replacing the covered condenser drums with cyclones. In order to utilize this strategy, a cotton ginner was required to replace the axial flow fans with in-line centrifugal fans to compensate for the higher pressure drops associated with cyclones compared to the covered condenser drums (1 in wg vs. 4 in wg). (The increase in pressure drop of the cyclone reduced the volume rate of flow of the axial flow fans such that the condenser drums would not function to remove lint from the air stream.) The cost of the cyclone/fan combination was estimated to be $20,000 per gin. Simpson et al. (1995) reported research results describing a new cyclone that could be used to retrofit axial flow fan systems without replacing the axial flow fans thereby decreasing the cost of replacing covered condenser drums with cyclones. This new 1D2D cyclone has two attractive characteristics: (1) It has a very low pressure drop (less than 1.5 in wg) allowing the ginner to continue using the existing axial flow fans and (2) It achieved higher than expected particulate removal efficiencies.

In addition, Simpson reported that the 1D2D cyclone solved the cycling lint problem. Cycling lint was a problem that had been encountered with 1D3D cyclones during operation with inlet loadings with high lint trash. It is described as lint fiber circulating near the base of the 1D3D cone rather than exiting the dust outlet during tests with high lint trash loadings. This phenomena was not observed with fine dust loadings. This cycling lint associated with the 1D3D cyclone resulted in reentrainment of fine particulate matter which decreased efficiencies and increased the emission concentrations. It was reported that the 1D2D cyclone had a higher collection efficiency and minimum problems with cycling lint when compared to the 1D3D cyclone with similar inlet concentrations of high lint trash and fine dust.

Yarlagadda et al. (1995) and Ramaiyer et al. (1997) reported research findings associated with developing minimum cost compliance strategies for cotton gins. The primary focus of their work was addressing a problem for Texas cotton gins where the Texas Natural Resources Conservation Commission (TNRCC) was considering redefining BACT such that every new cotton ginning permit would be required to install the air pollution abatement perceived to attain the lowest emission rate irrespective of cost. Several different air pollution abatement strategies were investigated and the economic impact on different size cotton gins were analyzed. These strategies consisted of different combinations of air pollution control equipment in an attempt to develop recommendations for the least cost strategies for different size gins. The equipment considered included 1D3D and 2D2D cyclones, pre-separator/cyclone systems, covered condenser drums, and rotary drum filters. In addition, some of the strategies used included replacing the axial fans (low pressure) with centrifugal fans (high pressure), to allow for the use of equipment such as rotary drum filters and high efficiency cyclones on axial flow fan emission points. Two economic methods were evaluated in an attempt to develop the best procedure to compare abatement strategies and to define the "economic reasonableness" criteria of BACT. It was reported that the use of cost per tonne of reduced emissions was the best economic indicator of whether an imposed strategy was economically reasonable. A value of $10,000/tonne of reduced emissions was considered as a possible value that could be used by SAPRAs to determine if a strategy met the best available control technology (BACT) requirement of "consideration for economic reasonableness". Additionally, Ramaiyer et al. (1996) reported performance data including achievable emission concentrations for various air pollution abatement strategies including RDFs. These emission concentrations were based on test results performed in laboratories and observations made in field studies. See Table 2.

Objectives

The goal of the Department of Agricultural Engineering, Texas A&M University's research program is to impact the air pollution regulatory process to minimize cost of compliance and insure that agricultural operations are fairly regulated. The goal of this research was to address the problem faced by many gins that must reduce their PM emission rates as a consequence of regulatory actions. It was assumed that the gin was utilizing baseline BACT (BBACT), but was required to further reduce their emission rates. The objectives of this research were as follows:

- To develop a procedure to estimate individual exhaust emission concentrations.
- To develop air pollution control strategies that will allow cotton gins in each state to comply with State Air Pollution Regulatory Agencies (SAPRAs) at a minimum cost to the gin.
- To develop a procedure to estimate the economic impacts of implementing additional air pollution control strategies on cotton gins.

Method

Cotton Gin Emissions

Several methods have been used to estimate cotton gin emission rates. These are generally associated with source sampling and emission factor calculations. In order to calculate or measure emission concentrations, it essential that the flow rate (volume rate of flow) through the process system be known or measured. Source sampling refers to direct measurement of the PM concentration leaving the abatement device. The California SAPRA requires that all gins perform source sampling prior to being permitted. The cost of this process is approximately $3,000 per cyclone or emitting point. The results of the source sampling can be influenced by many variables, such as the foreign matter content of the cotton, harvesting method, time of harvest, abatement strategy and the ginning rate. Source sampling is time consuming and expensive, and the data collected are susceptible to a great deal of variation. Emission concentrations can also be calculated using emission factors and flow rates. EPA (1988) published emission factors for each of 10 processing systems in a cotton gin. In 1996, EPA revised cotton ginning emission factors, but only included 8 process stream exhausts while raising the overall emission factor of a gin from the 1988 value of 1 kg/bale (2.24 lbs/bale) to 1.4 kg/bale (3.1 lbs/bale).

It was a premise of this research that the least costly approach to complying with air pollution regulations would result if a cotton gin could selectively utilize air pollution abatement strategies for the emission points with the highest concentration first, the second highest, second etc.. This approach would result in a maximum decrease in the gin's emission factor or PM emission rate per dollar spent on controls. It would also allow for an economic evaluation of the proposed strategy. In order to use this approach, a method was needed to allocate to each emission point its corresponding emission factor and volume rate of flow. With these data, emission concentrations and/or emission factors could be calculated.

Standard Gin

A typical cotton gin will have process streams (pneumatic conveying systems) associated with the required processes such as drying seed cotton, removing foreign matter, separating lint and seed and packaging lint fiber. These process streams are (1) unloading system, (2) first push/pull, (3) second push/pull, (4) distributer separator, (5) master trash, (6) overflow separator, (7) mote system, (8) first stage lint cleaning, (9) second stage lint cleaning, and (10) battery condenser. These 10 processing streams correspond to a minimum of 10 emission factors described in the 1988 EPA AP-42. Different size gins will have different flow rates and a process stream may have more than one emitting point. For example, a 20 bale per hour gin may have three first stage lint cleaners, each having an exhaust point. It is usually assumed that each emitting point has the same air pollution abatement equipment and the PM concentration from each exhaust point of the first stage lint cleaning system will be the same. The emission factor for first stage lint cleaning process stream will be the ratio of the total mass emission rate of all three emitting points of PM and the processing rate.

The concept of introducing a "standard gin" was conceived to facilitate the evaluation of alternative abatement strategies. A standard gin would be a gin with 10 process streams, 10 emission factors and 10 flow rates. With the emission factors and flow rates known, the concentrations for each process stream in the gin can be calculated. The following assumptions were made in the development of the standard gin: (1) Baseline Bact was the air pollution abatement strategy used by the standard gin with the 1995 EPA AP-42 total emission factor of 1.4 kg/bale (3.05 lbs/bale). (2) This total emission factor could be apportioned to the 10 process exhausts. (3) The total air flow rate of stripper and picker gins could be apportioned to the 10 process exhausts of a standard gin.

Table 3 illustrates the ten processing systems for the "standard" gin and the type of fan (centrifugal or axial flow) that is normally associated with each process.

Air Flow Model

Ramaiyer et al. (1996) developed the air flow model using data from Shaw et al. (1977), which reported fan horsepower requirements for both picker and stripper gins, as well as for different size gins. Additionally, minimum conveying rates defined by Baker et al. (1994) were also utilized. Using these data and the Cotton Ginners Handbooks suggested air flow requirements of 198 m^3/min/b/hr (7,000 cfm/b/hr) and 227 m^3/min/b/hr (8,000 cfm/b/hr) for picker and stripper gins, respectively, a distribution of the air flow through a cotton gin was developed. Two distributions were developed to account for the differences in air flow requirements of picker gins and stripper gins. The distributions of flow rates were separated into process steams associated with centrifugal fans and process streams associated with axial flow fans. The results were that centrifugal fans utilize 60% and 55% of the total airflow for stripper gins and picker gins, respectively; axial flow fans utilize 40% and 45% of the total air flow in a cotton gin for stripper gins and picker gins, respectively. The percentages of the required air flow rates for centrifugal and axial flow fans for each process steam are listed in table 4.

The assumptions and descriptive parameters associated with the development of this model are as follows:

A bale of picker and stripper cotton delivered to the gin for processing (seed cotton) contains 680 & 998 kg (1,500 & 2,200 lbs) of lint, seed and trash, respectively.

- A bale of seed cotton contains 227 kg (500 lbs) of lint and 363 kg (800 lbs) of seed. Typical picked and stripped seed cotton contains 91 & 408 kg (200 & 900 lbs) of gin trash, respectively.
- All but 22.7 kg (50 lbs) of trash are removed by the seed cotton cleaning system for both picked and stripped cotton. The remaining 22.7 kg (50 lbs) are removed by the lint cleaning systems.
- One half of the gin trash in the seed cotton minus the 22.7 kg (50 lbs) that passes through the gin stand to the lint cleaning system is removed by the first push/pull. The remaining gin trash removed by the seed cotton cleaning system is removed by the second push/pull. For example: A 20 bph gin processing stripped cotton will contain 408 kg (900 lbs) of gin trash. 22.7 kg (50 lbs) of the trash will remain with the lint following the lint-seed separation. Of the 386 kg (850 lbs) removed by the seed cotton cleaning system, 193 kg (425 lbs) are removed by the first push/pull system and 193 kg (425 lbs) are removed by the second push/pull.
- A minimum of 1.56 cubic meters per kilogram (25 ft^3/lb) of material is needed to reliably convey materials. A minimum of 1.87 cubic meters per kilogram (30 ft^3/lb) of air is needed for the unloading system as a consequence of the high moisture content of some cotton entering the ginning process.
- Processing systems 1-7 are associated with centrifugal fan exhausts; 8-10 are associated with axial-flow fan exhausts.
- The Q_i for an individual process stream is a fraction of the total Q_T. For example, a 20 bph picker gin will utilize a total of 140,000 cfm with 63,000 cfm, (0.45*140,000), for the axial flow process streams. Approximately 30% of the total Q for the axial flow system is utilized for the first stage lint cleaning system, 18,900 cfm. This process stream may consist of three lint cleaners with one behind each of three gin stands. Each lint cleaner will utilize 6,300 cfm.

The percentages of the total air flow rate used by picker and stripper gins for each process stream are shown in Figure 1. The following example illustrates how the data in Figure 1 should be used:

> A 20 bph cotton gin processing picker cotton will have a total airflow of 140,000 cfm (Q_T), (20 bph * 7,000 cfm/bph). This cotton gin will have 77,000 cfm (140,000 cfm * 55%) for centrifugal fan process streams and 63,000 cfm (140,000 cfm * 45%) for axial flow fan process streams. The flowrate through the unloading system will be 18,200 cfm (140,000 cfm * 13%).

Emission Factor Model

The "standard gin" air flow model includes a conveying system from the second stage seed cotton cleaning system to the auger distributer and separate exhausts for the first-stage and second-stage lint cleaning systems. This is similar to the system described in the 1988 AP-42. The 1996 AP-42 emission factors effectively combined the first and second stage lint cleaning emission factors into one and did not include an emission factor for the emitting point associated with the distributor separator.

The 1996 AP-42 total emission factor (sum of all the individual emission factors) is 3.05 lbs/b (TSP), which is an increase from the 1988 AP-42 total emission factor of 2.24 lbs/b (TSP). It was assumed that a typical gin would have a distributer separator exhaust and separate exhausts for each stage of lint cleaning. The emission factor model consisted of redistributing the total emission factor of 3.05 lbs/b for seven process streams associated with the 1996 AP-42 to ten process streams of our "standard gin". The following equation was used to distribute the sum of the 1996 AP-42 emission factors associated with centrifugal fan exhausts to the seven centrifugal fan exhausts associated with the "standard gin".

$$MCEF_i = \left(\frac{1988\ PEF_i}{1988\ TCEF_i} - \frac{1996\ PEF_i}{1996\ TCEF_i} \right) \left(1996\ TCEF_i - 1988\ TCEF_i \right) + 1996\ PEF_i \qquad \text{(Eq. 1)}$$

where: $MCEF_i$ = modified 1996 AP-42 centrifugal fan process emission factors,
PEF_i= process stream emission factors,
$TCEF_i$= total centrifugal emission factor, and
i= centrifugal fan process.

The following equation was used to apportion the 1996 AP-42 single lint cleaner emission factor into the first and second stage lint cleaner emission factors associated with the standard gin:

$$MLCEF = \left(\frac{1988\ SLCEF}{1988\ 1^{st}LCEF + 1988\ 2^{nd}LCEF} \right) (1996\ LCEF) \quad \text{(Eq. 2)}$$

where: MLCEF = modified 1996 AP-42 lint cleaning emission factor,
SLCEF= emission factor associated with stage of lint cleaning, and
LCEF= lint cleaning emission factor.

The following equation was used to calculate emission factors for a particular exhaust given ginning rate, flow rate and emission concentration:

$$EF = \frac{(EC)(Q_{exhaust})(CF)}{(GC)} \quad \text{(Eq.3)}$$

where: EF = emission factor (lb/b),
EC = average emission concentration (mg/m^3),
$Q_{exhaust}$ = exhaust flow rate (cfm),
GC= ginning capacity (bales/hr), and
CF = conversion factor = $3.74*10^{-6}$.

Table 5 lists the 1988 AP-42, the 1996 AP-42, and the modified AP-42 emission factors. The 1996 AP-42 and the modified AP-42 total emission factor (TEF) were maintained at 3.05 lb/b.

Results

Emission Concentration Method

The development of the “standard gin” emission factors and flow rates for the ten process streams provides the means whereby emission concentrations for each process stream or exhaust can be calculated given emission factors and visa versa. Tables 6 and 7 include the resulting concentrations calculated from the modified 1996 AP-42 emission factors and the ranking of the emission concentrations for a 20 bph picker and stripper gin, respectively. Note that in both tables 6 and 7, the flowrates associated with the axial flow fans are approximately the same for stripper and picker gins (63,000 cfm versus 64,000 cfm). It was assumed that the mass of lint and trash leaving the gin stand and entering the first stage lint cleaning process would be the same whether the gin was processing picked or stripped cotton.

The last column of tables 6 and 7 contains the priority that would be used by an engineer to reduce the PM emission rate of a cotton gin at minimum cost to the gin. The degree of AER reduction required to comply with SAPRA requirements will dictate the depth into the ranking that is needed. The master trash fan has the highest emission concentration. The AER or total emission factor can be reduced by simply augmenting the air pollution control system for the master trash exhaust. However, if the resulting reduction is not sufficient to achieve compliance with SAPRA regulations, the next step would be to add controls to the first stage lint cleaning process (the next highest concentration). This would be followed by the mote system. If further reduction is necessary, the priority ranking suggests that the abatement systems associated with the unloading, first and second stages of seed cotton cleaning systems should be augmented. Some of the exhausts in tables 6 and 7 are not ranked in the priority strategy. They are not ranked because their emission concentrations are very low, and additional controls on these exhausts would not significantly effect the gin’s PM emission rate and the cost per mass of PM reduced ($/ton of reduced emissions) associated with augmentation of abatement strategies for these exhausts would be very expensive. Hence, additional controls on these exhaust would be an unwise use of gin resources. This method is simple and easy to follow. It also allows the gin to comply with SAPRA regulations while minimizing the cost of compliance.

Economic Analysis

The economic analyses for the air pollution abatement strategies were developed using the following estimates and procedure developed by Ramaiyer et al. (1996): The cost factor for fans and rotary drum filters (RDF) was obtained from equipment manufacturers. The fan cost used in the following analyses for both centrifugal and axial flow fans was approximately $8.80 per m^3/min ($0.25/cfm) of air flow installed. Rotary drum filter cost was determined to be $88.30 per m^3/min ($2.50/cfm) installed. Pre-separator (baffle type) and fine mesh screens were estimated to be approximately $17.65 per m^3/min ($0.50/cfm) installed. A questionnaire was circulated among cyclone manufacturers in order to develop a better estimate of cyclone costs. The resulting cost factor for cyclones was estimated to be $35.31 per m^3/min ($1.00/cfm), including transitions and installation. Additional costs associated with the installation of air pollution abatement system for cotton gins include $24,000 for burr hoppers and $7,000 for augers. The energy cost was estimated to be $0.10/kwh.

The method used to perform economic analysis of various abatement strategies consisted of calculating the cost per tonne or kilogram of reduced PM emissions. In order to perform this calculation, the total particulate emitted per season was required. Equation 4 was used for this calculation:

$$MP = (GV)(EF) \quad \text{(Eq.4)}$$

where: MP = mass of particulate emitted per season (kg or lbs),
GV = ginning volume per season (bales), and
EF = emission factor (kg/b or lbs/b).

Table 8 lists the mass of total suspended particulate matter (TSP) emitted per season of four different size cotton gins used in this study. (It was assumed that these gins had installed baseline BACT, the standard gin season was 1,000 hours and the gins were operating at 100% capacity.)

The emission concentration method (ECM) for complying with SAPRA regulations consists of the following steps:
(1) Selecting the exhaust point with the highest emission concentration.
(2) Selecting the abatement strategy that will be used to reduce the emission rate of this exhaust.
(3) Performing an economic analysis by calculating the ratio of the installed cost per tonne of reduced emissions.

A critical step in the calculation of tonnes of reduced emissions, is the calculation of the emission rate of the exhaust with the augmented air pollution abatement system installed. The procedure used incorporates data on the expected emission concentrations, the standard gin model and equation 3. Incorporating the results of equation 3 into equation 4 yielded mass of TSP emitted per season (MP_2) with the additional abatement strategy installed. The cost of the additional controls (I) was calculated using cost per cfm multiplied by the flow rates listed for the standard gin, figure 1. With the cost of the abatement strategy and the total amount of particulate reduced, the cost per tonne of reduced emissions was determined using equation 5:

$$CPTRE = \frac{I}{MP_1 - MP_2} \qquad \text{(Eq.5)}$$

where: CPTRE = cost per tonne of reduced emission in \$/tonne (\$/ton),
I = investment cost for abatement strategy augmentation(\$),
MP_1 = mass of particulate presently emitted in tonnes (ton), and
MP_2 = mass of particulate emitted after installing new abatement strategy in tonnes (ton).

Air Pollution Abatement Strategies

The goal of this research was the development of a methodology that could be used to allow cotton ginners to comply with SAPRA regulations at least cost. It was assumed that the gin was operating with baseline BACT and was “in trouble”. A neighbor has complained and/or the ambient level of PM10 or PM2.5 was such that the AER of the gin was reduced by the SAPRA. The gin management was faced with the situation of having to reduce the gin’s PM emission rate by the installation of additional air pollution abatement equipment to achieve compliance with SAPRA regulations. The recommended approach is to address the emitting point with the highest concentration followed by the second highest and so on. But what equipment should be used on which processing system? An attempt was made in this section to propose air pollution abatement equipment(strategies) that would be the least costly and most effective utilizing the most recent research findings. The order of the strategies was a consequence of the ranking of the emission concentrations using the Standard Gin, air flow, and emission factor models. The following is a summary of the strategies and the process streams that have to be augmented with air pollution abatement equipment:

Strategy #1 - master trash fan
Strategy #2 - master trash fan + 1st lint cleaner
Strategy #3 - master trash fan + 1st lint cleaner + mote fan
Strategy #4 - master trash fan + 1st lint cleaner + mote fan + (unloading + 1st and second push pull)

It was assumed that the ginner and SAPRA personnel would be able to incrementally address the AER such that compliance could be achieved by first applying strategy #1. If strategy #1 was not sufficient, the gin would proceed with strategy #2, etc. The following are descriptions of each of the four strategies and the engineering logic used in the selection of the abatement equipment.

Strategy #1

The first suggested air pollution abatement strategy proposed is the reduction in the master trash exhausts emission concentration. Prior to deciding on the equipment to reduce the emission concentration of any exhaust, the characteristics of the particulate matter that the abatement system is likely to encounter were considered. This is important because it has been recognized that some abatement devices perform less efficiently when encountering high lint trash. Generally the master trash fan handles all of the collected trash from the ginning operation. This means that the system will handle approximately 68 kg/bale (150 lb/bale) for picker gins and 386 kg/bale (850 lb/bale) for stripper gins. Furthermore, the master trash fan has a high lint content. Typically, the master trash fan already utilizes a high efficiency cyclone on its exhaust. There are several methods and abatement devices that can be utilized to reduce the emission concentration of this exhaust. For this proposed strategy, it was assumed that the gin already had a high efficiency cyclone installed. Hence, the most economical choice was a series system. There are several series systems that are available for this purpose. As previously discussed, two high efficiency cyclones in series should be able to achieve emission concentrations of 23 mg/m^3 (0.01 gr/dscf). However, in order to minimize cost, this type of system may require the addition of either larger centrifugal fans and/or the addition of other centrifugal fans to overcome the additional pressure drop across another high efficiency cyclone. High efficiency cyclones in series have a pressured drop of 2240 Pa (9 in H_2O). In addition, depending on the type of cyclone presently in place, the high lint content of the trash may create problems for the cyclones effectiveness due to the cycling lint problem that has been experienced by the 1D3D cyclone. Another possible method to reduce the master trash fan’s emission concentration would be to place a pre-separator plenum chamber prior to the existing cyclone. This type of abatement system is capable of achieving 28 mg/m^3 (0.015

gr/dscf) and has very little cost associated with its implementation and operation. However, there has been trouble with the baffle type pre-separator/cyclone systems when handling high lint trash. Lint fiber tends to penetrate the pre-separator to the cyclone resulting in cycling lint in the cyclone increasing concentrations, therefore, the emission concentration may not be sufficiently reduced.

The abatement device proposed for strategy #1 consists of placing the recently developed barrel cyclone prior to the existing high efficiency cyclone (Tullis et al., 1997). This cyclone was designed to handle high lint trash. Recent performance testing on the barrel cyclone indicates that it is very effective in removing gin trash having a high lint content. Laboratory tests indicate that this system in series with high efficiency cyclones should result in emission concentrations of 28 mg/m^3 (0.015 gr/dscf). Another benefit of using this cyclone in series with the existing high efficiency cyclone is that there is a relatively small system pressure increase. The pressure drop across the barrel cyclone is 324 Pa (1.3 in H_2O). It is likely that no additional fans will be needed to compensate for the increase in pressure drop of the system. Strategy #1 is represented in Figure 2.

As a result of the implementation of strategy #1, the overall emission factor for the master trash fan was reduced from 0.44 lb/bale to 0.036 lb/bale for a 20 bph picker gin and from 0.44 lb/bale to 0.051 lb/bale for a 20 bph stripper gin. The total emission factor for the gin was reduced by 13% for both picker and stripper gins. See tables 9 and 10.

The approximate installed cost of adding a barrel cyclone to the master trash fan was $5,600 for a picker gin and $8,000 for a stripper gin. The resulting strategy cost per ton of reduced emissions (CPTRE) was approximately $2,000/tonne. Table 11 shows the reduction per season that can be expected for various size gins and the CPTRE for both picker and stripper gins if the gins were operating at 100% of capacity. (100% capacity refers to ginning at the rated ginning rate for 1,000 hours or ginning 20,000 bales per season for a 20 bph gin.) Furthermore, table 11 also shows the CPTRE for gins that run at 50% utilization (10,000 bales per season for a 20 bph gin). Notice the increase in CPTRE.

Strategy #2

If the amount of reduction achieved by strategy #1 is not sufficient, then the next exhaust whose emission concentration should be reduced will be the #1 Lint Cleaner. Again, this exhaust stream will have a high lint content and this should be taken into account when choosing the additional abatement equipment. The use of a plenum chamber was not utilized due to the poor performance characteristics with high lint trash. Traditionally, lint cleaning exhausts have used covered condenser drums. The material used to cover the condenser is either mesh screen (70-100 mesh) or the equivalent perforated metal. Typically, when gins reduce the emission concentrations of the first lint cleaning operation they replace the axial fan with centrifugal fans and place a high efficiency cyclone on the system. This is very effective in reducing the emission concentration. However, this is an expensive change. There is an alternative choice. Utilizing a 1D2D cyclone will effectively reduce the emission concentration (Simpson et al, 1996). Simpson et al reported that the 1D2D cyclone can achieve a lower emission concentration than 1D3D or 2D2D cyclones when the inlet loading contained high concentrations of lint fiber. It was assumed that the 1D2D cyclone could achieve 69 mg/m^3 (0.03 gr/dscf) when loaded with high lint trash. The cost benefit of choosing the 1D2D cyclone is that the axial fan system will not have to be replaced. The 1D2D cyclone was developed specifically to handle the lint cleaning exhausts of cotton gins. Figure 3 describes strategy #2.

The implementation of strategy #2 will result in a decrease in the gins emission factor. A summary of the anticipated reductions in PM emissions are presented in tables 12 and 13. It was estimated that by placing a 1D2D cyclone on the first lint cleaning process stream, the expected emission concentration would be reduced to 69 mg/m^3 (0.03 gr/dscf). The emission factor for the first stage lint cleaning operation was reduced from 0.42 kg/bale (0.93 lb/bale) to 0.114 kg/bale (0.252 lb/bale), for a picker gin and from 0.42 kg/bale (0.93 lb/bale) to 0.112 kg/bale (0.247 lb/bale) for a stripper gin. The overall gin emission factor was reduced by 35% for both picker and stripper gins utilizing strategy #2.

The cost of adding a 1D2D cyclone to the first lint cleaning system was estimated to be $19,600 for picker gins and $19,200 for stripper gins. Implementation of strategy #2 for a 20 bph picker and stripper gin will be $25,200 and $27,200, respectively. The lint cleaning abatement augmentation alone, without the master trash fan augmentation, yields a reduction of 22% in the gins emission factor. One might wonder if a gin can get 22% reduction by augmenting the first lint cleaning system and 13% reduction for augmenting the master trash fan, why not first reduce the first lint cleaning prior to the master trash and get more reduction. The reason the master trash fan was chosen for strategy #1, besides having the highest emission concentration, was the cost of implementation. The cost of augmenting the master trash fan was approximately $11,000-$14,000 less than augmenting the first lint cleaning, depending on the type of gin. Strategy #2 has CPTRE value of approximately $2,700 for picker and stripper gins operating at 100% utilization and $5,200 for gins operating at 50% utilization. Table 14 shows the amount of reduction and costs of implementation for various size gins.

Strategy #3

The system addressed in strategy #3 was the motes operation. The mote operation has the third highest emission concentration. Again, the exhaust stream has a high lint content. A pre-separator plenum will likely not perform adequately for this exhaust stream either. It was assumed that the mote system, like the master trash fan, had an existing high efficiency cyclone on the exhaust. For the same reasons as the master trash fan, a high efficiency cyclone series is not the most economical system of choice. A barrel cyclone or 1D2D cyclone in series with the existing high efficiency cyclone will perform ideally for this exhaust stream. Figure 4 describes strategy #3.

The results of utilizing strategy #3 are shown in tables 15 & 16. The mote system emission factors were reduced from 0.135 kg/bale (0.298 lb/bale) to 0.025 kg/bale (0.054 lb/bale) for picker gins and from 0.135 kg/bale (0.298 lb/bale) to 0.033 kg/bale (0.072 lb/bale) for stripper gins. It is estimated that the utilization of strategy #3 will reduce the original emission factor by 43% for both picker and stripper gins.

The cost associated with the implementation of strategy #3 was between $33,000-$38,500 for the 20 bph gins. The cost of the barrel or 1D2D cyclone that would be used for the picker and stripper gins was $8,400 and $11,200, respectively. The approximate CPTRE for strategy #3 was $2,800 at 100% utilization and $6,000 for 50% utilization. Table 17 shows the resulting seasonal PM emission reductions and the costs for implementation of Strategy #3 for various size gins.

Strategy #4

If the first three strategies have not achieved the AER required, the next step would be to select the process stream with the next highest concentration. As indicated in tables 6 and 7, the fourth strategy priority would be a reduction in emission concentration of either the unloading, first push/pull system and second push/pull system exhausts. All three of these exhausts have emission concentrations that are approximately the same. The difference in the amount of reduction in the gin's total PM emission rate that would result if either the first or second push/pull systems or the unloading system were augmented was small. It was assumed that three of these exhausts contain small quantities of lint fiber in the trash that would enter the abatement device. Since the lint content of the trash/PM is low, a plenum chamber in series with the existing high efficiency cyclones would be ideal for these exhaust streams. Tables 18, 19 and 20 show that the level of decrease in the cotton gins overall emissions, when the plenum chamber is placed in series with either the first push/pull, second push/pull system or unloading system is minimal. The cotton gin's overall emission factor, if individual exhaust streams are augmented, will be reduced by 48%-51%. When all three exhaust are augmented with a plenum chamber, the resulting emission factor for the gin will be reduced 65 %. Therefore, strategy #4 will focus on the reduction of the emission factors of all three of these process streams. The cost of plenum chamber is $17.65 per m^3/min ($0.50 per cfm). Strategy #4 consists of augmenting the first push/pull, second push/pull system and the unloading system with a baffle type pre-separator plenum chamber. By placing the plenum chamber in series with the existing high efficiency cyclones, the achievable emission concentration was estimated to be 28 mg/m^3 (0.015 gr/dscf) for each individual exhaust. Figure 5 represents the results of utilizing abatement strategy #4.

Tables 21 and 22 show the resulting change in emission concentrations and emission factors of strategy #4. The resulting emission factors for the individual exhaust streams of a picker gin were as follows: the first push/ pull was reduced from 0.152 kg/bale (0.334 lb/bale) to 0.041 kg/bale (0.09 lb/bale), the second push/pull system from 0.095 kg/bale (0.210 lb/bale) to 0.0327 kg/bale (0.072 lb/bale), and the unloading process stream from 0.172 kg/bale (0.38 lb/bale) to 0.0531 kg/bale (0.117 lb/bale). The resulting emission factors for the individual exhaust streams of a stripper gin were as follows: for the first push/pull system from 0.152 kg/bale (0.334 lb/bale) to 0.0513 kg/bale (0.113 lb/bale); for the second push/pull system from 0.095 kg/bale (0.210 lb/bale) to 0.0422 kg/bale (0.093 lb/bale) and the unloading process stream from 0.172 kg/bale (0.38 lb/bale) to 0.0653 kg/bale (0.144 lb/bale). The overall emission factor for both picker and stripper gins was reduced by 65%. Tables 21 and 22 show the results of the implementation of strategy #4 for both the 20 bph picker and stripper gins, respectively. In addition, each process stream that has been augmented with only see an increase in pressure of 373 Pa (1.5 in H_2O) due to the addition of the plenum chamber. The CPTRE of strategy #4 were reported in table 23. A gin operating at 100% utilization implementing strategy #4 can expect a CPTRE of approximately $3,200. If the gin was operating at 50% utilization, then the CPTRE would be approximately $6,400.

Economic Analysis Utilizing CPTRE

Many cotton gins in the U.S. do not operate at 100% of utilization. To illustrate how this economic indicator could be used, consider the following example:

(1) A 20 bph cotton gin processing picked cotton typically gins 10,000 bale per season (50% of utilization).

(2) The gin management utilizes Baseline BACT but they have not achieved compliance with SAPRA regulations and must augment the gin's air pollution abatement system to lower their emission rates and achieve compliance.

(3) The SAPRA would like for the gin to "minimize" its PM emission rate but the SAPRA does not want the gin to go out of business. If the negotiated limit for BACT in this state were $5,500/tonne ($6,000/ton) of reduced emissions, the SAPRA would not be able to mandate more than strategy #2. (See table 24). The CPTRE of strategy #3 is $5,648

which is in excess of $5,500.If the gin were processing stripped cotton, the SAPRA would not be able to mandate more than strategy #1. (See table 25.) The CPTRE for strategy #2 is $5,608 which is in excess of $5,500.

Discussion

With the available abatement devices and knowledge of the process exhausts, an economic approach to reducing a cotton gins emissions can be achieved. With the aforementioned information individual exhaust emission concentrations can be determined. With these emission concentration, an approach to reduce a cotton gins emission can be developed with minimum expenditure in mind. Using the method described in this paper, a cotton gin can achieve compliance at a minimum cost. It is important to recognize that the suggested abatement strategies do not augment certain process exhausts of a cotton gin. In addition, no suggested strategy replaces the axial fans with centrifugal fans with high efficiency cyclones on either lint cleaning processes or the battery condenser. As mentioned prior, it is becoming increasingly normal to replace axial fan with centrifugal fans and add high efficiency cyclones to these exhausts in order to reduce the cotton gins emissions. The developed strategies, in accordance with the goal of this research, do not suggest this as an alternative method of reducing a cotton gins emissions. The cost associated with this alteration is extremely expensive, and the reduction in emissions is not sufficient enough to justify the cost.

When a SAPRA lowers a cotton gins AER, and expects the cotton gin to comply, there has to be some limit ($) that is associated with the decrease in emissions. In California, BACT has an associated cost of $10,000. Meaning that any additional air pollution equipment can not exceed a CPTRE value of $10,000. However, the majority of cotton gins in California are located in PM non-attainment areas. The majority of cotton gins throughout the cotton belt are not located in PM non-attainment areas. There cost limit for BACT should be lower than that of gins in PM non-attainment areas. If RACT has an associated cost of $2,000 and PM non-attainment areas have a BACT value of $10,000, then the cotton gin and the SAPRA regulator need to negotiate for a suitable value in between these limits. For example, for illustrative purposes we will use a value of $6,000 for BACT. This is between RACT ($2,000) and the California BACT ($10,000).

In looking at the economic impacts of implementing any of the four suggested air pollution control strategies, there are a couple of indirect cost that are not taken into account. These indirect cost include depreciation, interest and maintenance costs. The CPTRE that is associated with each strategy, does not incorporate these indirect costs. When looking at implementation of any of the suggested strategies, the cotton gin and SAPRA need to be aware of the additional costs associated with the strategy, so as to determine the best choice of strategies that will allow the cotton gin to be in compliance as well as maintain economic viability. It should also be noted that as the utilization of the gin decreases, the CPTRE value will increase. For instance, a comparison of a 100% utilization and 50% utilization for a 20 bph picker gin, the CPTRE for strategy #1 is doubled. The CPTRE at 100% utilization is $1,556 and the CPTRE at 50% utilization is $3,111. Similar effects can be expected for different utilizations. For an example of these effects on a 20 bph gin see tables 24 and 25.

DISCUSSION OF RESULTS

The cost of complying with SAPRA regulations has increased and will continue to increase for all industries including those associated with agriculture such as cotton gins. A method was developed in this paper that provides an approach to reducing the cost of compliance. This method included the following:

- A "standard gin" with 10 process stream results corresponding to the 1988 EPA AP-42 description of a cotton gin.
- A flow rate model that allocates specific flow rates for each process stream associated with the "standard gin".
- An emission factor model allocating the 1996 EPA total emission factor of 3.05 lbs/bale to each of the 10 process stream results associated with the "standard gin".
- With emission factors and flow rates known, concentrations for each process stream exhaust could be calculated. <u>The minimum cost approach consisted of augmenting the air pollution abatement system for the exhaust with the highest concentration first, the second highest concentration second and so on.</u> This approach incorporates the principle that it is less costly to augment the air pollution abatement system for the process stream with the least volume rate of flow and the highest emission concentration.
- Four abatement strategies were proposed for the situation where a cotton gin had an existing abatement strategy corresponding to Baseline BACT but did not comply with SAPRA regulations to demonstrate the utility of the minimum cost approach.
- An economic model was presented utilizing a cost per ton of reduced emissions (CPTRE) approach to evaluating the viability of the four proposed strategies. CPTRE has been used in the past to establish limits of the cost of abatement strategies associated with Reasonably Available control Technology (RACT) associated with an EPA mandated reduction in NOx in ozone non-attainment areas in Texas of $1800/tonne ($2,000/ton). In the

non-attainment areas of California, BACT for cotton gins is viewed as costing less than $9,000/tonne ($10,000/ton) It was assumed that the SAPRA and representatives of the state's cotton ginning community would be able to negotiate a value between these two limits that would place some limits on costs of compliance.

- Many gins do not operate at 100% utilization (20,000 bales per season for a 20 bph gin). Tables were presented to illustrate how a defined limit for BACT in an attainment area such as $5,500/tonne ($6,000/ton) could be beneficial in the negotiating of a least cost compliance system.

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Table 1. Average Emission Concentrations (mg/m^3) of different Air Pollution Abatement Systems. Four different baffle preseparator designs(PC1, PC2, PC3, PC4) prior to 1D3D and 2D2D cyclones were compared to results obtained with 1D3D and 2D2D cyclones with no preseparator. The 1D3D cyclones were attached to the baffle preseparator using a flat top transition. (A minimum of three replications were performed for each test.)

	Inlet Loadings (10% fine dust and 90% Trash)		
	30 g/m^3	60 g/m^3	90 g/m^3
1D-3D	17	88	169
2D-2D	22	116	199
PC1 + 1D3D	16	31	83
PC1 + 2D2D	11	54	109
PC2 + 1D3D	19	53	89
PC2 + 2D2D	11	55	133
PC3 + 1D3D	39	84	148
PC3 + 2D2D	16	55	151
PC4 + 1D3D	6	11	16
PC4 + 2D2D	6	14	28

Table 2. Achievable Emission Concentrations and Expected pressure Drops for Typical Air Pollution Abatement Equipment Used with Cotton Gins

Abatement Equipment or Series	Achievable Emission Concentration mg/m^3 (gr/dscf)	Approximate Pressure Drop Pa (in H_2O)
Fine mesh screen on condenser drums	253 mg/m^3 (0.11 gr/dscf)	249-373 Pa (1-1.5 in H_2O)
1D2D, 2D2D, 1D3D or Barrel cyclone (>3g/m^3 fine dust loading)	69 mg/m^3 (0.03 gr/dscf)	498-1120 Pa (2-4.5 in H_2O)
1D2D, 2D2D, 1D3D or Barrel cyclone (<3g/m^3 fine dust loading)	34.5 mg/m^3 (0.015 gr/dscf)	498-1120 Pa (2-4.5 in H_2O)
Baffle type pre-separator & cyclone in series	28 mg/m^3 (0.015 gr/dscf)	1493 Pa (6 in H_2O)
High Eff. Cyclone & RDF in series	23 mg/m^3 (0.01 gr/dscf)	1368 Pa (5.5 in H_2O)
High Eff. Cyclone in series	23 mg/m^3 (0.01 gr/dscf)	2240 Pa (9 in H_2O)

Table 3. "Standard Gin" Process Streams.

Exhaust #	Process	Fan Type
1	Unloading system	CF
2	1st Push/Pull	CF
3	2nd Push/Pull	CF
4	Distributor Separator	CF
5	Master Trash	CF
6	Overflow Separator	CF
7	Mote system	CF
8	1st Stage Lint Cleaning	AF
9	2nd Stage Lint Cleaning	AF
10	Battery Condenser	AF

*CF- Centrifugal Fan
AF- Axial Flow Fan

Table 4. Flow Rate Distributions for each of the 10 Processing Systems of a Standard Stripper or Picker Gin.

Centrifugal Fan Exhausts (60% stripper, 55% picker of total flow)	% Flow	Axial Fan Exhausts (40% stripper, 45% picker of total flow)	% Flow
Unloading	23	1st Lint Cleaning	30
1st Push/Pull	19	2nd Lint Cleaning	30
2nd Push/Pull	15	Battery Condenser	40
Separator	12		
Overflow	12		
Trash	8		
Motes	11		
Total	100	Total	100

Table 5. EPA AP-42's Emission Factors and Modified Emission Factors for the Standard Gin in units of pounds per bale (lbs/bale).

Process	'88 AP-42	'96 AP-42	
		Original	Modified
1	0.32	0.29	0.38
2	0.18	0.36	0.33
3	0.10	0.24	0.21
4	0.04	---	0.03
5	0.17	0.54	0.44
6	0.08	0.07	0.09
7	0.20	0.28	0.30
CF Total	1.09	1.78	1.78
8	0.81	1.10	0.93
9	0.15		0.17
10	0.19	0.17	0.17
AF Total	1.15	1.27	1.27
Total	2.24	3.05	3.05

Table 6. Calculated Emission Concentrations for a 20 bph Picker Gin using the Air Flow Rates from the Air Flow Model and Modified AP-42 Emission Factors and Priorities for augmentation of air pollution abatement systems.

PICKER

Gin Size 20 bale/hr

Flowrate 7000 cfm/bale/hr

Total 140000 cfm

Process	% Flow	Flow Rate (cfm)	Emission Factor (lbs/bale)	Emission Rate (lbs/hr)	Emission Concentration (gr/ft^3)	Emission Concentration (mg/m^3)	Strategy Priority
1	13%	18200	0.38	7.600	0.049	111	4
2	10%	14000	0.33	6.680	0.056	127	4
3	8%	11200	0.21	4.200	0.044	100	4
4	7%	9800	0.03	0.500	0.006	14	---
5	4%	5600	0.44	8.760	0.182	418	1
6	7%	9800	0.09	1.880	0.022	51	---
7	6%	8400	0.30	5.960	0.083	189	3
CF Total	55%	77000	1.78	35.580			
8	14%	19600	0.93	18.540	0.110	253	2
9	14%	19600	0.17	3.400	0.020	46	---
10	17%	23800	0.17	3.480	0.017	39	---
AF Total	45%	63000	1.27	25.420			
Total	100%	140000	3.05	61.000			

Table 7. Calculated Emission Concentrations for a 20 bph Stripper Gin using the Air Flow Rates from the Air Flow Model and Modified AP-42 Emission Factors and Priorities for augmentation of air pollution abatement systems.

STRIPPER

Gin Size 20 bale/hr

Flowrate 8000 cfm/bale/hr

Total 160000cfm

Process	% Flow	Flow Rate (cfm)	Emission Factor (lbs/bale)	Emission Rate (lbs/hr)	Emission Concentration (gr/ft^3)	Emission Concentration (mg/m^3)	Strategy Priority
1	14%	22400	0.38	7.600	0.040	91	4
2	11%	17600	0.33	6.680	0.044	101	4
3	9%	14400	0.21	4.200	0.034	78	4
4	7%	11200	0.03	0.500	0.005	12	---
5	5%	8000	0.44	8.760	0.128	292	1
6	7%	11200	0.09	1.880	0.020	45	---
7	7%	11200	0.30	5.960	0.062	142	3
CF Total	60%	96000	1.78	35.580			
8	12%	19200	0.93	18.540	0.113	258	2
9	12%	19200	0.17	3.400	0.021	47	---
10	16%	25600	0.17	3.480	0.016	36	---
AF Total	40%	64000	1.27	25.420			
Total	100%	160000	3.05	61.000			

Table 8. Total Suspended Particulate Matter Emitted per 1000 hour season for four gin sizes and an emission factor of 3.05 pounds per bale operating at 100% capacity.

Gin Size (bales/hr)	Particulate Matter Emitted per Season , tonnes (tons)
10	13.8 (15.3)
20	27.7 (30.5)
30	41.5 (45.8)
40	55.4 (61.0)

Table 9. Results of utilizing Abatement Strategy #1 - Emission Concentrations and Emission Factors for a 20 bph Picker Gin; 7,000 cfm/bale; Q_T = 140,000 cfm.

Process	% Flow	Flow Rate (cfm)	Initial Emission Factor (lbs/bale)	Initial Emission Rate (lbs/hr)	Initial Emission Conc. (gr/dscf)	Initial Emission Conc. (mg/m3)	Resulting Emission Conc. (gr/dscf)	Resulting Emission Conc. (mg/m3)	Resulting Emission Factor (lbs/bale)
Unloading	13.00%	18200	0.380	7.600	0.049	112	0.049	112	0.380
1st Push/Pull	10.00%	14000	0.334	6.680	0.056	127	0.056	127	0.334
2nd Push/Pull	8.00%	11200	0.210	4.200	0.044	100	0.044	100	0.210
Separator	7.00%	9800	0.025	0.500	0.006	14	0.006	14	0.025
Master Trash	4.00%	5600	0.438	8.760	0.182	418	0.015	34	0.036
Overflow	7.00%	9800	0.094	1.880	0.022	51	0.022	51	0.094
Mote Fan	6.00%	8400	0.298	5.960	0.083	190	0.083	190	0.298
Centrifugal Total	55.00%	77000	1.779	35.580					1.377
1st Lint Cleaning	14.00%	19600	0.927	18.540	0.110	253	0.110	253	0.927
2nd Lint Cleaning	14.00%	19600	0.170	3.400	0.020	46	0.020	46	0.170
Battery Condenser	17.00%	23800	0.174	3.480	0.017	39	0.017	39	0.174
Axial Total	45.00%	63000	1.271	25.420					1.271
Total	100.00%	140000	3.050	61.000					2.648

Table 10. Results of utilizing Abatement Strategy #1 - emission concentrations and emission factors for a 20 bph Stripper Gin; 8,000 cfm/bale; Q_T = 160,000 cfm.

Process	% Flow	Flow Rate (cfm)	Initial Emission Factor (lbs/bale)	Initial Emission Rate (lbs/hr)	Initial Emission Conc. (gr/dscf)	Initial Emission Conc. (mg/m3)	Resulting Emission Conc. (gr/dscf)	Resulting Emission Conc. (mg/m3)	Resulting Emission Factor (lbs/bale)
Unloading	14.00%	22400	0.380	7.600	0.040	91	0.040	91	0.380
1st Push/Pull	11.00%	17600	0.334	6.680	0.044	101	0.044	101	0.334
2nd Push/Pull	9.00%	14400	0.210	4.200	0.034	78	0.034	78	0.210
Separator	7.00%	11200	0.025	0.500	0.005	12	0.005	12	0.025
Master Trash	5.00%	8000	0.438	8.760	0.128	292	0.015	34	0.051
Overflow	7.00%	11200	0.094	1.880	0.020	45	0.020	45	0.094
Mote Fan	7.00%	11200	0.298	5.960	0.062	142	0.062	142	0.298
Centrifugal Total	60.00%	96000	1.779	35.580					1.392
1st Lint Cleaning	12.00%	19200	0.927	18.540	0.113	258	0.113	258	0.927
2nd Lint Cleaning	12.00%	19200	0.170	3.400	0.021	47	0.021	47	0.170
Battery Condenser	16.00%	25600	0.174	3.480	0.016	36	0.016	36	0.174
Axial Total	40.00%	64000	1.271	25.420					1.271
Total	100.00%	160000	3.050	61.000					2.663

Table 11. Results of Economic Analysis of utilizing Strategy #1 using Cost Per Tonne of Reduced Emissions (CPTRE) for a 20 bph picker and stripper gins operating at 100% (20,000 bales per season) and 50 % of seasonal capacity (10,000 bale per season).

Gin Size	Annual Emis. Rate (tonnes)	20 bph Picker Gin PM Reduced (tonnes)	Cost	CPTRE 100%	CPTRE 50%	20 bph Stripper Gin PM Reduced	Cost	CPTRE 100%	CPTRE 50%
10	13.8	1.8	$2,800	$1,556	$3,111	1.8	$4,000	$2,222	$4,444
20	27.7	3.6	$5,600	$1,556	$3,111	3.6	$8,000	$2,222	$4,444
30	41.5	5.4	$8,400	$1,556	$3,111	5.4	$12,000	$2,222	$4,444
40	55.4	7.2	$11,200	$1,556	$3,111	7.2	$16,000	$2,222	$4,444

Table 12. Results of utilizing Abatement Strategy #2 - Emission Concentrations and Emission Factors for a 20 bph Picker Gin; 7,000 cfm/bale; Q_T = 140,000 cfm.

Process	% Flow	Flow Rate (cfm)	Initial Emission Factor (lbs/bale)	Initial Emission Rate (lbs/hr)	Initial Emission Conc. (gr/dscf)	Initial Emission Conc. (mg/m3)	Resulting Emission Conc. (gr/dscf)	Resulting Emission Conc. (mg/m3)	Resulting Emission Factor (lbs/bale)
Unloading	13.00%	18200	0.380	7.600	0.049	112	0.049	112	0.380
1st Push/Pull	10.00%	14000	0.334	6.680	0.056	127	0.056	127	0.334
2nd Push/Pull	8.00%	11200	0.210	4.200	0.044	100	0.044	100	0.210
Separator	7.00%	9800	0.025	0.500	0.006	14	0.006	14	0.025
Master Trash	4.00%	5600	0.438	8.760	0.182	418	0.015	34	0.036
Overflow	7.00%	9800	0.094	1.880	0.022	51	0.022	51	0.094
Mote Fan	6.00%	8400	0.298	5.960	0.083	190	0.083	190	0.298
Centrifugal Total	55.00%	77000	1.779	35.580					1.377
1st Lint Cleaning	14.00%	19600	0.927	18.540	0.110	253	0.030	69	0.252
2nd Lint Cleaning	14.00%	19600	0.170	3.400	0.020	46	0.020	46	0.170
Battery Condenser	17.00%	23800	0.174	3.480	0.017	39	0.017	39	0.174
Axial Total	45.00%	63000	1.271	25.420					0.596
Total	100.00%	140000	3.050	61.000					1.973

Table 13. Results of utilizing Abatement Strategy #2 - emission concentrations and emission factors for a 20 bph Stripper Gin; 8,000 cfm/bale; Q_T = 160,000 cfm..

Process	% Flow	Flow Rate (cfm)	Initial Emission Factor (lbs/bale)	Initial Emission Rate (lbs/hr)	Initial Emission Conc. (gr/dscf)	Initial Emission Conc. (mg/m3)	Resulting Emission Conc. (gr/dscf)	Resulting Emission Conc. (mg/m3)	Resulting Emission Factor (lbs/bale)
Unloading	14.00%	22400	0.380	7.600	0.040	91	0.040	91	0.380
1st Push/Pull	11.00%	17600	0.334	6.680	0.044	101	0.044	101	0.334
2nd Push/Pull	9.00%	14400	0.210	4.200	0.034	78	0.034	78	0.210
Separator	7.00%	11200	0.025	0.500	0.005	12	0.005	12	0.025
Master Trash	5.00%	8000	0.438	8.760	0.128	292	0.015	34	0.051
Overflow	7.00%	11200	0.094	1.880	0.020	45	0.020	45	0.094
Mote Fan	7.00%	11200	0.298	5.960	0.062	142	0.062	142	0.298
Centrifugal Total	60.00%	96000	1.779	35.580					1.392
1st Lint Cleaning	12.00%	19200	0.927	18.540	0.113	258	0.030	69	0.247
2nd Lint Cleaning	12.00%	19200	0.170	3.400	0.021	47	0.021	47	0.170
Battery Condenser	16.00%	25600	0.174	3.480	0.016	36	0.016	36	0.174
Axial Total	40.00%	64000	1.271	25.420					0.591
Total	100.00%	160000	3.050	61.000					1.983

Table 14. Results of Economic Analysis of utilizing Strategy #2 using Cost Per Tonne of Reduced Emissions (CPTRE) for 20 bph picker and stripper gins operating at 100% (20,000 bales per season) and 50 % of seasonal capacity (10,000 bale per season).

Gin Size	Annual Emis. Rate (tonnes)	20 bph Picker Gin PM Reduced (tonnes)	Cost	CPTRE @ 100%	CPTRE @ 50%	20 bph Stripper Gin PM Reduced (tonnes)	Cost	CPTRE @ 100%	CPTRE @ 50%
10	13.8	4.8	$12,600	$2,625	$5,250	4.8	$11,600	$2,417	$4,833
20	27.7	9.7	$25,200	$2,598	$5,196	9.7	$27,200	$2,804	$5,608
30	41.5	14.5	$37,800	$2,607	$5,214	14.5	$40,800	$2,814	$5,628
40	55.4	19.4	$50,400	$2,598	$5,196	19.4	$54,400	$2,804	$5,608

Table 15. Results of utilizing Abatement Strategy #3 - Emission Concentrations and Emission Factors for a 20 bph Picker Gin; 7,000 cfm/bale; Q_T = 140,000 cfm

Process	% Flow	Flow Rate (cfm)	Initial Emission Factor (lbs/bale)	Initial Emission Rate (lbs/hr)	Initial Emission Conc. (gr/dscf)	Initial Emission Conc. (mg/m3)	Resulting Emission Conc. (gr/dscf)	Resulting Emission Conc. (mg/m3)	Resulting Emission Factor (lbs/bale)
Unloading	13.00%	18200	0.380	7.600	0.049	112	0.049	112	0.380
1st Push/Pull	10.00%	14000	0.334	6.680	0.056	127	0.056	127	0.334
2nd Push/Pull	8.00%	11200	0.210	4.200	0.044	100	0.044	100	0.210
Separator	7.00%	9800	0.025	0.500	0.006	14	0.006	14	0.025
Master Trash	4.00%	5600	0.438	8.760	0.182	418	0.015	34	0.036
Overflow	7.00%	9800	0.094	1.880	0.022	51	0.022	51	0.094
Mote Fan	6.00%	8400	0.298	5.960	0.083	190	0.015	34	0.054
Centrifugal Total	55.00%	77000	1.779	35.580					1.133
1st Lint Cleaning	14.00%	19600	0.927	18.540	0.110	253	0.030	69	0.252
2nd Lint Cleaning	14.00%	19600	0.170	3.400	0.020	46	0.020	46	0.170
Battery Condenser	17.00%	23800	0.174	3.480	0.017	39	0.017	39	0.174
Axial Total	45.00%	63000	1.271	25.420					0.596
Total	100.00%	140000	3.050	61.000					1.729

Table 16. Results of utilizing Abatement Strategy #3 - emission concentrations and emission factors for a 20 bph Stripper Gin; 8,000 cfm/bale; Q_T = 160,000 cfm.

Process	% Flow	Flow Rate (cfm)	Initial Emission Factor (lbs/bale)	Initial Emission Rate (lbs/hr)	Initial Emission Conc. (gr/dscf)	Initial Emission Conc. (mg/m3)	Resulting Emission Conc. (gr/dscf)	Resulting Emission Conc. (mg/m3)	Resulting Emission Factor (lbs/bale)
Unloading	14.00%	22400	0.380	7.600	0.040	91	0.040	91	0.380
1st Push/Pull	11.00%	17600	0.334	6.680	0.044	101	0.044	101	0.334
2nd Push/Pull	9.00%	14400	0.210	4.200	0.034	78	0.034	78	0.210
Separator	7.00%	11200	0.025	0.500	0.005	12	0.005	12	0.025
Master Trash	5.00%	8000	0.438	8.760	0.128	292	0.015	34	0.051
Overflow	7.00%	11200	0.094	1.880	0.020	45	0.020	45	0.094
Mote Fan	7.00%	11200	0.298	5.960	0.062	142	0.015	34	0.072
Centrifugal Total	60.00%	96000	1.779	35.580					1.166
1st Lint Cleaning	12.00%	19200	0.927	18.540	0.113	258	0.030	69	0.247
2nd Lint Cleaning	12.00%	19200	0.170	3.400	0.021	47	0.021	47	0.170
Battery Condenser	16.00%	25600	0.174	3.480	0.016	36	0.016	36	0.174
Axial Total	40.00%	64000	1.271	25.420					0.591
Total	100.00%	160000	3.050	61.000					1.757

Table 17. Results of Economic Analysis of utilizing Strategy #3 using Cost Per Tonne of Reduced Emissions (CPTRE) for 20 bph picker and stripper gins operating at 100% (20,000 bales per season) and 50 % of seasonal capacity (10,000 bale per season).

Gin Size	Emissions (tonnes)	Picker Gin Reduction	Cost	CPTRE	50%	Stripper Gin Reduction	Cost	CPTRE	50%
10	13.8	5.9	$16,200	$2,746	$5,492	5.9	$17,200	$2,915	$5,831
20	27.7	11.9	$33,600	$2,824	$5,647	11.9	$38,400	$3,227	$6,454
30	41.5	17.9	$50,400	$2,816	$5,631	17.9	$57,600	$3,218	$6,436
40	55.4	23.8	$67,200	$2,824	$5,647	23.8	$76,800	$3,227	$6,454

Table 18. Resulting Concentrations and Emission Factors by Augmented the Abatement System for the First Push/Pull System.

Process	Initial Emission Factor (lbs/bale)	Picker Gin: Resulting Emission Conc. (gr/dscf)	Picker Gin: Resulting Emission Conc. (mg/m3)	Picker Gin: Resulting Emission Factor (lbs/bale)	Stripper Gin: Resulting Emission Conc. (gr/dscf)	Stripper Gin: Resulting Emission Conc. (mg/m3)	Stripper Gin: Resulting Emission Factor (lbs/bale)
Unloading	0.380	0.049	112	0.380	0.040	91	0.380
1st Push/Pull	0.334	0.015	34	0.090	0.015	34	0.113
2nd Push/Pull	0.210	0.044	100	0.210	0.034	78	0.210
Separator	0.025	0.006	14	0.025	0.005	12	0.025
Master Trash	0.438	0.015	34	0.036	0.015	34	0.051
Overflow	0.094	0.022	51	0.094	0.020	45	0.094
Mote Fan	0.298	0.015	34	0.054	0.015	34	0.072
Centrifugal Total	1.779			0.889			0.946
1st Lint Cleaning	0.927	0.030	69	0.252	0.030	69	0.247
2nd Lint Cleaning	0.170	0.020	46	0.170	0.021	47	0.170
Battery Condenser	0.174	0.017	39	0.174	0.016	36	0.174
Axial Total	1.271			0.596			0.591
Total	3.050			1.485			1.536

Table 19. Resulting Concentrations and Emission Factors by Augmented the Abatement System for the Second Push/Pull System.

Process	Initial Emission Factor (lbs/bale)	Picker Gin: Resulting Emission Conc. (gr/dscf)	Picker Gin: Resulting Emission Conc. (mg/m3)	Picker Gin: Resulting Emission Factor (lbs/bale)	Stripper Gin: Resulting Emission Conc. (gr/dscf)	Stripper Gin: Resulting Emission Conc. (mg/m3)	Stripper Gin: Resulting Emission Factor (lbs/bale)
Unloading	0.380	0.049	112	0.380	0.040	91	0.380
1st Push/Pull	0.334	0.056	128	0.336	0.044	101	0.332
2nd Push/Pull	0.210	0.015	34	0.072	0.015	34	0.093
Separator	0.025	0.006	14	0.025	0.005	12	0.025
Master Trash	0.438	0.015	34	0.036	0.015	34	0.051
Overflow	0.094	0.022	51	0.094	0.020	45	0.094
Mote Fan	0.298	0.015	34	0.054	0.015	34	0.072
Centrifugal Total	1.779			0.997			1.047
1st Lint Cleaning	0.927	0.030	69	0.252	0.030	69	0.247
2nd Lint Cleaning	0.170	0.020	46	0.170	0.021	47	0.170
Battery Condenser	0.174	0.017	39	0.174	0.016	36	0.174
Axial Total	1.271			0.596			0.591
Total	3.050			1.593			1.638

Table 20. Resulting Concentrations and Emission Factors by Augmented the Abatement System for the Unloading System.

Process	Emission Factor (lbs/bale)	Picker Gin: Resulting Emission Conc. (gr/dscf)	Picker Gin: Resulting Emission Conc. (mg/m3)	Picker Gin: Resulting Emission Factor (lbs/bale)	Stripper Gin: Resulting Emission Conc. (gr/dscf)	Stripper Gin: Resulting Emission Conc. (mg/m3)	Stripper Gin: Resulting Emission Factor (lbs/bale)
Unloading	0.380	0.015	34	0.117	0.015	34	0.144
1st Push/Pull	0.334	0.056	128	0.336	0.044	101	0.332
2nd Push/Pull	0.210	0.044	101	0.211	0.034	78	0.210
Separator	0.025	0.006	14	0.025	0.005	12	0.025
Master Trash	0.438	0.015	34	0.036	0.015	34	0.051
Overflow	0.094	0.022	51	0.094	0.020	45	0.094
Mote Fan	0.298	0.015	34	0.054	0.015	34	0.072
Centrifugal Total	1.779			0.873			0.928
1st Lint Cleaning	0.927	0.030	69	0.252	0.030	69	0.247
2nd Lint Cleaning	0.170	0.020	46	0.170	0.021	47	0.170
Battery Condenser	0.174	0.017	39	0.174	0.016	36	0.174
Axial Total	1.271			0.596			0.591
Total	3.050			1.469			1.519

Table 21. Results of utilizing Abatement Strategy #4 - Emission Concentrations and Emission Factors for a 20 bph Picker Gin; 7,000 cfm/bale; Q_T = 140,000 cfm

Process	% Flow	Flow (cfm)	Emission Factor (lbs/bale)	Emission Rate (lbs/hr)	Emission Conc. (gr/dscf)	Emission Conc. (mg/m3)	Resulting Emission Conc. (gr/dscf)	Resulting Emission Conc. (mg/m3)	Resulting Emission Factor (lbs/bale)
Unloading	13.00%	18200	0.380	7.600	0.049	112	0.015	34	0.117
1st Push/Pull	10.00%	14000	0.334	6.680	0.056	127	0.015	34	0.090
2nd Push/Pull	8.00%	11200	0.210	4.200	0.044	100	0.015	34	0.072
Separator	7.00%	9800	0.025	0.500	0.006	14	0.006	14	0.025
Master Trash	4.00%	5600	0.438	8.760	0.182	418	0.015	34	0.036
Overflow	7.00%	9800	0.094	1.880	0.022	51	0.022	51	0.094
Mote Fan	6.00%	8400	0.298	5.960	0.083	190	0.015	34	0.054
Centrifugal Total	55.00%	77000	1.779	35.580					0.488
1st Lint Cleaning	14.00%	19600	0.927	18.540	0.110	253	0.030	69	0.252
2nd Lint Cleaning	14.00%	19600	0.170	3.400	0.020	46	0.020	46	0.170
Battery Condenser	17.00%	23800	0.174	3.480	0.017	39	0.017	39	0.174
Axial Total	45.00%	63000	1.271	25.420					0.596
Total	100.00%	140000	3.050	61.000					1.084

Table 22. Results of utilizing Abatement Strategy #4 - Emission Concentrations and Emission Factors for a 20 bph Stripper Gin; 8,000 cfm/bale; Q_T = 160,000 cfm

Process	% Flow	Flow (cfm)	Emission Factor (lbs/bale)	Emission Rate (lbs/hr)	Emission Conc. (gr/dscf)	Emission Conc. (mg/m3)	Resulting Emission Conc. (gr/dscf)	Resulting Emission Conc. (mg/m3)	Resulting Emission Factor (lbs/bale)
Unloading	14.00 %	22400	0.380	7.600	0.040	91	0.015	34	0.144
1st Push/Pull	11.00 %	17600	0.334	6.680	0.044	101	0.015	34	0.113
2nd Push/Pull	9.00%	14400	0.210	4.200	0.034	78	0.015	34	0.093
Separator	7.00%	11200	0.025	0.500	0.005	12	0.005	12	0.025
Master Trash	5.00%	8000	0.438	8.760	0.128	292	0.015	34	0.051
Overflow	7.00%	11200	0.094	1.880	0.020	45	0.020	45	0.094
Mote Fan	7.00%	11200	0.298	5.960	0.062	142	0.015	34	0.072
Centrifugal Total	60.00 %	96000	1.779	35.580					0.592
1st Lint Cleaning	12.00 %	19200	0.927	18.540	0.113	258	0.030	69	0.247
2nd Lint Cleaning	12.00 %	19200	0.170	3.400	0.021	47	0.021	47	0.170
Battery Condenser	16.00 %	25600	0.174	3.480	0.016	36	0.016	36	0.174
Axial Total	40.00 %	64000	1.271	25.420					0.591
Total	100.00 %	160000	3.050	61.000					1.183

Table 23. Results of Economic Analysis of utilizing Strategy #4 using Cost Per Tonne of Reduced Emissions (CPTRE) for 20 bph picker and stripper gins operating at 100% (20,000 bales per season) and 50 % of seasonal capacity (10,000 bale per season).

		20 bph Picker Gin				20 bph Stripper Gin			
Gin Size	Annual Emis. Rate (tonnes)	PM Reduced (tonnes)	Cost	CPTRE (100%)	CPTRE (50%)	PM Reduced (tonnes)	Cost	CPTRE (100%)	CPTRE (50%)
10	13.8	9.0	$27,050	$3,006	$6,011	9.0	$30,800	$3,422	$6,844
20	27.7	18	$55,300	$3,072	$6,144	18	$65,600	$3,644	$7,289
30	41.5	27	$82,950	$3,072	$6,144	27	$98,400	$3,644	$7,289
40	55.4	36	$110,600	$3,072	$6,144	36	$131,200	$3,644	$7,289

Table 24. 20 bph Picker Gin Utilization Effects on CPTRE.

	Utilization				
	10%	25%	50%	75%	100%
Strategy	CPTRE	CPTRE	CPTRE	CPTRE	CPTRE
#1	$15,560	$6,224	$3,111	$2,078	$1,556
#2	$25,980	$10,392	$5,196	$3,464	$2,598
#3	$28,240	$11,296	$5,648	$3,765	$2,824
#4	$30,720	$12,288	$6,144	$4,096	$3,072

Table 25. 20 bph Stripper Gin Utilization Effects on CPTRE.

	Utilization				
	10%	25%	50%	75%	100%
Strategy	CPTRE	CPTRE	CPTRE	CPTRE	CPTRE
#1	$22,220	$8,888	$4,444	$2,962	$2,222
#2	$28,040	$11,216	$5,608	$3,739	$2,804
#3	$32,270	$12,908	$6,454	$4,302	$3,227
#4	$36,440	$14,576	$7,288	$4,858	$3,644

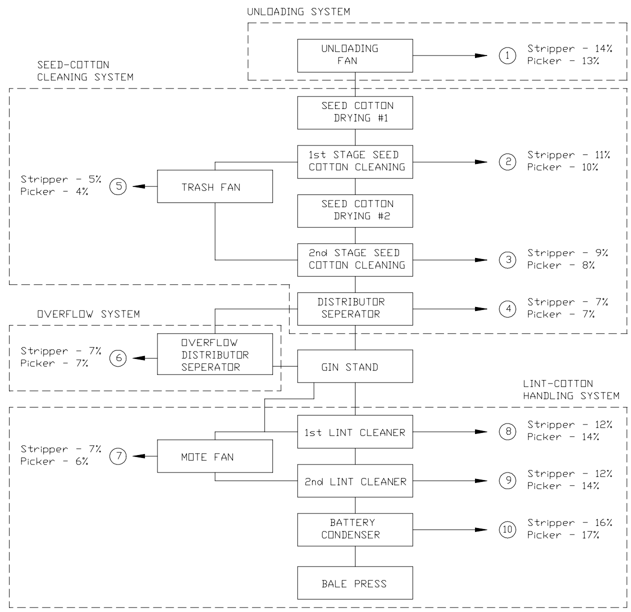

Figure 1. Distribution of the Total Volume Rate of Flow (Q_T) for Picker and Stripper "Standard" Gins.

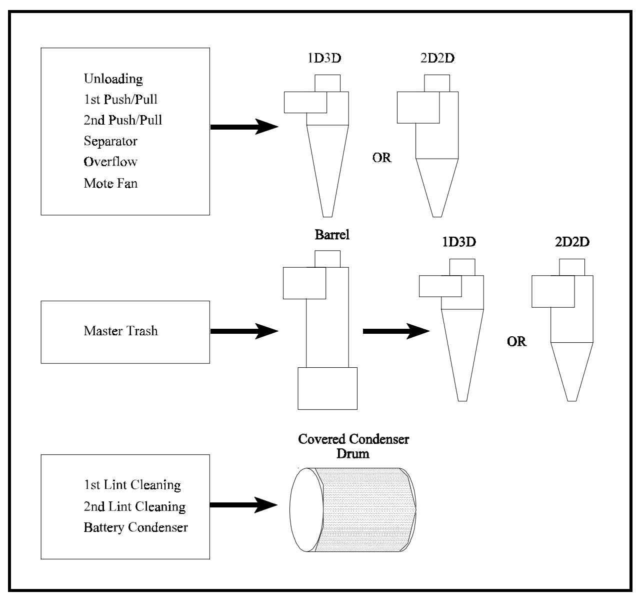

Figure 2. Strategy #1, Barrel Cyclone Pre-Separator in Series with High Efficiency Cyclone on Master Trash Fan.

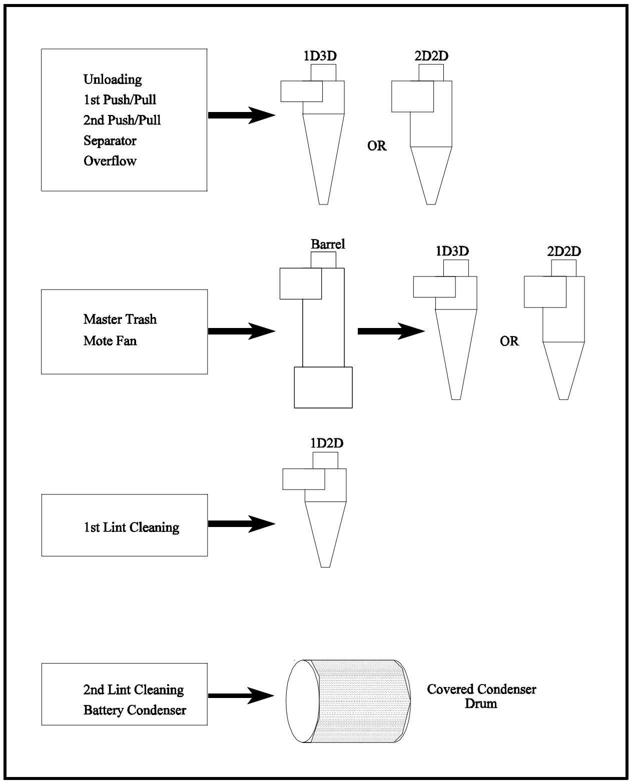

Figure 3. Abatement Strategy #2

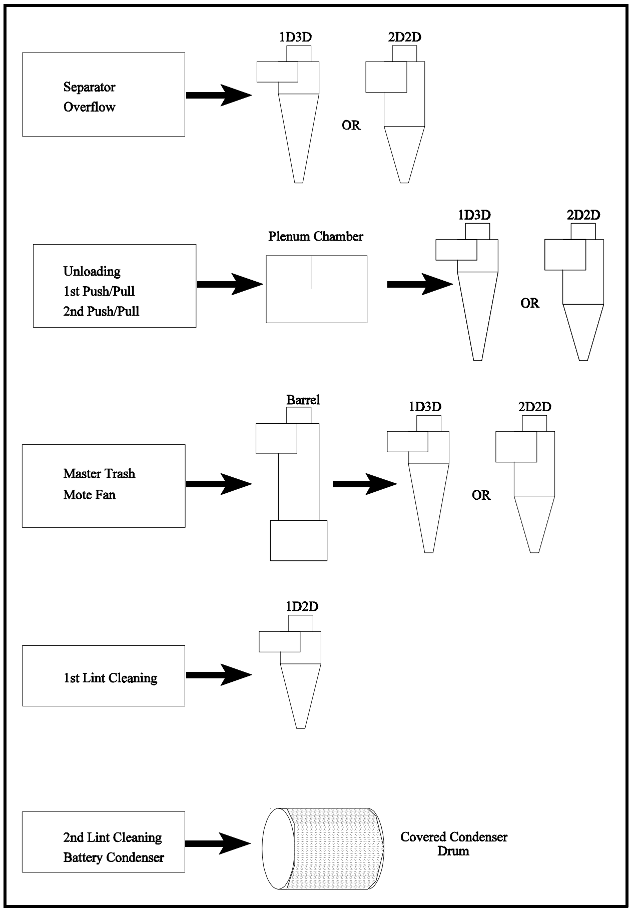

Figure 4. Abatement Strategy #3

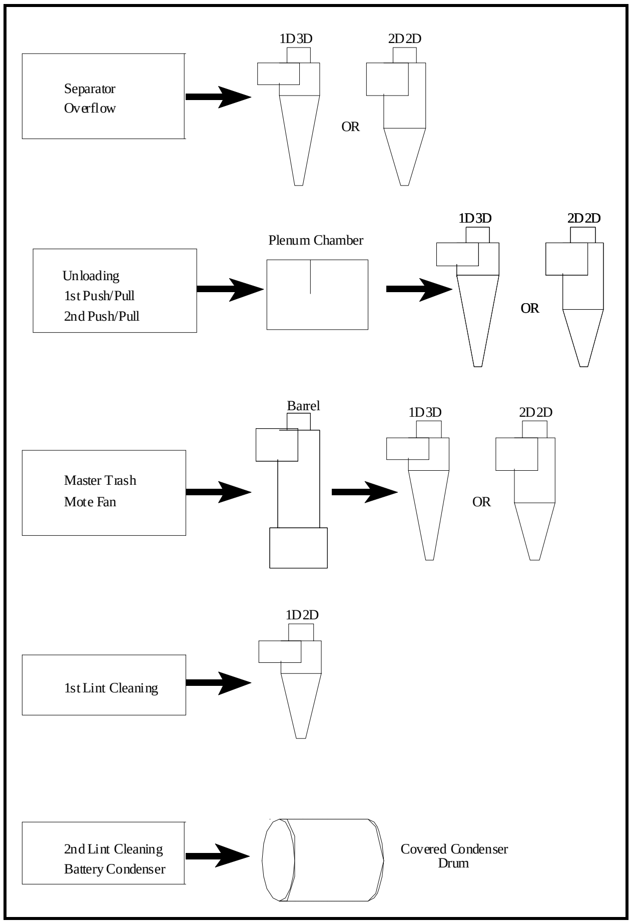

Figure 5. Abatement Strategy #4