SUMMARY OF AIR QUALITY RESEARCH

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Abstract

Cost effective control of particulate emissions has become a major objective of most U.S. cotton ginners. An effective trash handling and emission control system has also become an essential element in modern high-production ginning. As a result, a lot of research has been conducted during the past few years to improve operational effectiveness of modern trash and particulate collection systems at U.S. cotton gins, and to further reduce particulate emissions to the atmosphere. A summary of numerous studies conducted during the past 5 years at Texas A&M and at the USDA ARS ginning laboratories on pre-separators for cyclones, various modifications and improvements to the conventional cyclone collector, several new cyclone designs, and the physical and chemical properties of cyclone emissions are reviewed in this paper.

Introduction

A considerable amount of research has been conducted at Texas A&M and at the USDA ARS ginning laboratories over the past few years to address various air quality issues at cotton gins. The research program at Texas A&M is conducted within the Agricultural Engineering Department, and is not limited to the air quality concerns of cotton gins. This program addresses a broad range of air quality issues in agriculture and industry including emission studies at feed mills and cattle feed yards, dispersion modeling of particulate matter from many types of agricultural operations, modeling of SO_2 emissions from power plants, as well as numerous studies involving cotton gin pre-separation systems and improved cyclone configurations. The goal of the research at Texas A&M is to impact the regulatory process to minimize cost of compliance and insure that agricultural operations are fairly regulated.

Air quality research at the USDA ginning laboratories is more narrowly focused in that most of it is directed toward the development and/or evaluation of improved trash collection and dust abatement systems for cotton gins. Despite differences in scope, however, researchers at the USDA ginning laboratories and Texas A&M cooperate closely to achieve a broad based air quality research program that will provide the U. S. cotton ginning industry with needed information and techniques to ensure compliance with a vast array of state and national air quality regulations.

Since the air quality research activities of these three groups are too broad to cover in a single presentation, the authors chose to concentrate on recent research activities (1993-98) related directly to cyclone collectors. The Texas A&M group, along with researchers at the Southwestern Cotton Ginning Research Laboratory, Mesilla Park, NM, and the research group at the Cotton Harvesting and Ginning Research Laboratory, Lubbock TX have conducted numerous studies over the past few years to investigate pre-separators for cyclones, various modifications and improvements to the conventional cyclone collector, several new cyclone designs, and the physical and chemical properties of cotton-gin cyclone emissions across the cotton belt.

The research protocol used by the above groups varies from the small-scale systems at Texas A&M (about 1/9th scale) and Mesilla Park (1/3rd scale), to the full-scale system at the Lubbock laboratory. Each of these protocols has its advantages. At Texas A&M for example, the test equipment is small enough (4-in. dia. cyclones) to be utilized in a well-controlled, almost ideal, laboratory setting. This advantage, in combination with the use of standardized gin trash and corn dust having a highly repeatable particle size distribution, creates a highly sensitive, precise, and rapid protocol for the study of many cyclone configurations (Mihalski et al., 1992).

The protocol at Mesilla Park also uses model cyclones (12-in. dia.), but differs from the Texas A&M protocol in that actual gin-run trash from picker cotton is employed as the test material (Hughs and Baker, 1996a). Both of these "model" systems avoid the necessity of having to use expensive and complex sampling equipment to evaluate cyclone emissions. In these model systems, all of the cyclone exhaust air is passed through a filter for complete collection of the emissions. The collection filters can then be analyzed by the Coulter Counter method developed at Texas A&M to estimate the emission's particle size distribution (Parnell et al., 1979).

The full-scale system (34-in. dia. cyclones) used at Lubbock also has some advantages (Baker et al., 1995). It offers researchers the opportunity to evaluate dust abatement equipment in an environment that is closer to "real world" conditions than that of either of the model protocols. It also allows the use of bulky gin-run trash, such as that from stripper harvested cotton, as a test material to evaluate equipment under highly loaded conditions. The

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:463-468 (1998)
National Cotton Council, Memphis TN

exhaust air from the full-scale cyclones is sampled using standard EPA sampling protocol (method 201A) that yields a direct measure of PM_{10} and larger dust fractions. The full-scale protocol is, however, a lot more time consuming and expensive than either of the previously mentioned model protocols. Consequently, it is generally practical to use it only for evaluation of equipment that has shown a lot of promise in previous model studies. The model protocols, being less time consuming and expensive, are the ideal vehicle for evaluating a wide variety of dust abatement possibilities. The full-scale protocol can then be employed to corroborate the model studies and to investigate other related real-world factors that are difficult to evaluate using scale models.

The progression of research from the idealized world of the laboratory to the full-scale studies lends a high degree of confidence to the final results, and increases the credibility of resulting equipment recommendations. Also, the synergism that has resulted from these closely related studies has been extremely beneficial to all of the research groups, and consequently, provided substantially greater benefits to the cotton ginning industry than would have accrued from the individual efforts of each research group alone.

Pre-Separators

A number of gins in Alabama, Arizona, California and Texas have installed pre-separation devices, sometimes called plenum chambers, to settle out most of the large trash particles from the exhaust air before it reaches the cyclone collectors (Mihalski et al., 1993; Parnell 1994; Baker et al., 1995; Green, 1995). Consequently, these chambers take a considerable load off the cyclones, which in turn tends to prolong their useful life and to reduce annual maintenance costs. Since the air from several exhausts is combined in a pre-separation chamber, it can then be redistributed to a number of like-size cyclones attached directly to the chamber. This arrangement simplifies not only the initial installation, but it also helps ensure accurate sizing of the cyclones for maximum overall system performance.

The pre-separator/cyclone system also offers ginners a lot of flexibility when fan size or speed changes have to be made in one or more of their exhaust systems. The extra air generated by such changes is evenly distributed in the pre-separator to all the cyclones, and often the small additional load on each cyclone is not enough to exceed recommended inlet air velocity specifications. Even in cases when the increased air flow is too large to distribute properly, an additional cyclone can be easily added to the chamber to bring the entire cyclone system back into the proper inlet air velocity range.

The impact of commercial pre-separation chambers on particulate emissions from a ginning system has not been well documented. In the first place, the pre-separation/cyclone systems found at most commercial gins are huge installations with many individual cyclone exhausts. This makes complete source sampling of all exhausts very difficult and expensive. So much so in fact, that it has never been done. Another complicating factor is when a new pre-separation system is installed, the old cyclone system is normally dismantled. So, there no longer exists the means for comparative testing of the two systems. Source tests of a few selected exhausts before and after installation of pre-separation equipment tend to show lower emissions for the pre-separation system. This type of data has to be interpreted very carefully, however, since the before and after tests were usually performed in different years and with different cottons. Despite these limitations in performance data, however, most ginners who have installed pre-separation systems have been pleased with their performance and feel that they have produced noticeable reductions in visible emissions from their cyclones.

Even though it has not been possible to source test a complete pre-separation system in the field, several small-scale studies of the pre-separation process have been conducted at Texas A&M University and at the USDA ARS ginning laboratories. Mihalski, et al. (1994) reported the results of small-scale tests on several pre-separator designs for 4 in. dia. 1D3D and 2D2D cyclones collecting a combination of coarse gin trash and corn dust. These investigations included comparative data with and without pre-separation for 3 critical air velocities in the pre-separators as well as for two baffle locations. Most of the comparisons were made using pre-separators equipped with a baffle located about one-third of the way between the inlet and outlet. This baffle arrangement, which is similar to that found in most commercial installations, was tested at critical air velocities of 1080, 1296, and 1620 fpm on the inlet side of the baffle. Velocities on the outlet side of the baffle were about one-half that on the inlet side. One study was also made using a pre-separator equipped with a baffle centered halfway between the inlet and outlet. The critical air velocity in this study was 1080 fpm on both sides of the centered baffle.

In the A&M study, the pre-separators equipped with baffles located one-third the way between the inlet and outlet significantly reduced emission concentrations for the 2D2D cyclone in 8 of 9 comparisons. These same pre-separators, however, had mixed effects on the emission concentrations of the 1D3D cyclone. This type of pre-separator significantly reduced emissions from 1D3D cyclones in 4 of 9 comparisons, but offered little improvement in the other comparisons. Performance problems were also noted in this and a previous study (Milhalski, et al. 1993) due to the type of connection used between the pre-separator and the cyclone, and to problems of excessive lint re-circulation in 1D3D cyclones. Inverted transitions and direct connecting ducts exactly matching the cyclone's inlet width and height were found to adversely affect the performance of pre-separator systems for 1D3D cyclones. In these studies, the optimum connection between the pre-separator and 1D3D cyclone was the original flat-top inlet transition. Pre-separators, regardless of design, did not remove lint fiber that was present in the trash, and this fiber tended to accumulate and re-circulate in the 1D3D cyclone and greatly increased its dust emissions.

There was also some evidence in these studies that the location of the baffle in the pre-separation chamber might influence performance, especially when the system was used with 1D3D cyclones. The best combination of pre-separator design and 1D3D cyclone evaluated in these studies was the pre-separator with a baffle centered halfway between the pre-separator's inlet and outlet, a critical velocity in the pre-separator of 1080 fpm, and a flat top transition between the pre-separator and cyclone.

Columbus (1994) reported on a test of 3 pre-separator designs ahead of 24 in. dia. and 26 in. dia. 1D3D and 2D2D cyclones. Dust and small trash material from a small-scale seed cotton separator handling picker-harvested cotton at a rate of 1 bale/h was fed to a pre-separator at a rate of about 0.5 lb/h. Even at this low feed rate, the pre-separator collected about 16 percent of the finely divided trash material while the cyclone following the pre-separator collected an additional 81 percent of the original trash. The combined collection efficiency of both collectors averaged about 97 percent. In this study the cyclones were not tested without the pre-separator. So, comparative data with and without pre-separation was not obtained.

Experiments were conducted at the Lubbock ginning laboratory (Baker et al. 1995) to evaluate several combinations of pre-separators and cyclones for the collection of gin trash from stripper cotton. Both 1D3D and 2D2D cyclones (34-in. dia.) were evaluated using a pre-separator that could be adjusted in width to produce a variety of critical velocities in the separation zone. Pre-separator efficiency tended to increase as the separation velocity in the pre-separator was decreased, but those differences in velocity below 1600 fpm were too small to be of any practical importance. A pre-separator efficiency of about 90% was obtained at velocities below 1600 fpm. At this velocity the pre-separator reduced dust emissions from a 2D2D cyclone by about 9 percent, but offered no such improvements for a 1D3D cyclone. In 2 of 3 experiments the pre-separator actually tended to slightly increase emissions from the 1D3D cyclone. These adverse effects were attributed to a problem of lint re-circulation in the cyclone's lower cone section near the trash outlet that was similar to that experienced previously by Mihalski et al. (1993). Much of the fiber in the gin trash escaped the pre-separator and entered the cyclones. This fiber interfered with the performance of the cyclones, especially that of the long-cone, 1D3D type. Pre-separation tended to exacerbate this problem for the 1D3D cyclone design. Special techniques were used in a later study to eliminate the lint re-circulation problem in the 1D3D cyclone (Baker et al. 1996). After this problem was eliminated, the pre-separator no longer had any adverse effects on particulate emissions from a 1D3D cyclone. Its use, however, did not in these studies result in significant reductions in emissions from 1D3D cyclones handling trash from stripper cotton.

Laboratory tests using a pre-separator designed for one inlet duct and one outlet cyclone may not fully duplicate a field installation with multiple inlets and several outlet cyclones. While a laboratory test of a single-inlet pre-separator can provide important performance information on the underlying effects of separating large trash prior final collection of the dust by a cyclone, it cannot measure the benefits of distributing the emissions of a heavily loaded exhaust among several cyclones or of providing the means for more accurately sizing the cyclones. What can be deduced from this research and from field observations is that pre-separators can improve a gin's trash handling system by reducing wear and tear on the cyclones and, in some cases, by ensuring more accurately sized cyclones. When fibrous trash is avoided, pre-separators should at the very least maintain maximum cyclone performance, and sometimes they may even improve cyclone performance. Such improvements are especially likely in cases where the use of a pre-separator improves the accuracy of sizing the cyclones for the optimum inlet air velocity, where visible emissions are more equitably distributed among several cyclones, or where heavy, bulky trash is interfering with the fine dust collection performance of cyclones.

Improved Trash Exits

Recent studies (Mihalski et al.,1994; Baker et al., 1995) have shown that re-circulation of lint and trash material in the lower portion of a 1D3D cyclone's cone section is associated with an increase in particulate emissions from the cyclone. It is also felt that this re-circulation problem causes excessive wear and premature failure of the lower cone. Fiber is one of the primary causes of re-circulation in the cyclone . The fiber, and to some extent other light trash, tends to make many cycles around the lower portion of the cyclone cone before being forced out of the exit by additional material moving spirally down the cone. Heavy trash material tends to exit more easily than the light material and, consequently, tends to help force the light material out the exit. Also, unsealed trash systems that allowed air to be induced into the cyclone through its trash exit contributed greatly to this re-circulation problem.

Cyclone trash exit designs and discharge conditions that caused a small amount of air to exit the cyclone with the trash eliminated any visual evidence of re-circulation and produced the lowest particulate emissions encountered in these studies (Baker et al., 1996). These conditions were created by an air bleed system that used a small fan to extract a small amount of air along with the trash, and a design that featured a short straight rib attached to the wall of the lower cone. A sealed large expansion chamber in the lower cone also effectively reduced re-circulation when used with a well-sealed trash system. Even though this system did not completely eliminate re-circulation, it produced a marked improvement in emission performance over that of the regular 1D3D cone. Actually, the large expansion chamber produced emissions that were roughly comparable to those of the air bleed and straight rib designs.

Relatively poor control of the re-circulation problem was provided by sealed and unsealed regular cones, and unsealed large and small expansion chambers. These four arrangements also tended to produce the study's highest particulate emissions. Of the three designs producing the lowest emissions, a sealed system with the large expansion chamber appears to be the one that could be most easily adopted at existing cotton gins. The other two low-emission systems, while effective from an emission standpoint, suffer the disadvantage of not completely separating collected trash material from the air.

New and Modified Cyclones

Cyclones have been used as trash and dust collectors at cotton gins for many years. Early cyclones were large-diameter, low-velocity units that were designed primarily for the collection of large trash. At that time, fine dust collection was a secondary consideration. Then, in the 1960's, dust abatement became a much more important consideration for cotton gins. New State and Federal air quality regulations promulgated during that era caused the ginning industry to search for more effective dust abatement equipment. One result of this effort was the introduction to the ginning industry of the high-efficiency, small-diameter cyclone commonly referred to today as the 2D2D design (Harrell and Moore, 1962, Baker and Stedronsky, 1967). Later the current 1D3D design was developed at Texas A&M (Parnell and Davis, 1979; Parnell, 1980). Thus, cotton gin cyclone design has evolved from a device suitable mainly for rough trash collection, to very efficient designs that collect virtually all dust over about 20µm in size.

While the ginning industry has made a lot of progress over the last 30 years in cleaning up the environment around cotton gins, additional improvements will be needed in the future to meet the public's ever increasing air quality expectations. Although present technology will meet current air quality standards in most areas, our industry needs to continue to pursue research and technology transfer efforts that will anticipate and provide for future air quality needs. To meet these needs, several research groups continue to pursue objectives related to cotton gin air quality. A part of this ongoing program includes attempts to improve the cyclone collector, and to extend its range of application.

For example, a special low-pressure 1D2D design was recently introduced for control of dust and lint-fly emissions from lint cleaner condenser exhausts (Kaspar et al., 1994; Simpson and Parnell, 1995). This cyclone was designed to have a low static pressure drop (<2 in. water) so that it could be used on condenser exhausts powered by standard vane-axial fans. It was initially felt that the 1D2D design would not be highly efficient because of its short length and low inlet velocity (2400 fpm). In recent laboratory tests, however, 1D2D cyclones produced efficiencies that were substantially higher than those first envisioned. At Texas A&M, a 4-in. diameter 1D2D model actually outperformed 1D3D and 2D2D cyclones when collecting high-fiber trash and corn dust. However, in these same studies it was found to be less efficient than these conventional cyclones when collecting dust alone (Simpson and Parnell, 1995). Similar results were obtained at the Mesilla Park ginning laboratory using a 12 in. dia. model of the 1D2D and trash and dust from machine picked cotton. In the Mesilla Park study, the 1D2D cyclone emitted 11 to 40% more dust than did a standard 1D3D cyclone. In both studies the pressure drop of the 1D2D cyclone was considerably lower than that of the standard cyclone.

The 1D2D design includes a much larger-than-normal trash exit (D/2) to improve its ability to handle fibrous waste such as condenser emissions. However, Simpson and Parnell (1995) indicated that this feature failed to completely eliminate re-circulation of fiber in the cone of this type of cyclone. Consequently, they developed an air bleed system to assist in the removal of the fibrous waste causing the re-circulation problem. A bleed system that pulled about 4% of the process air out through the trash exit along with the waste eliminated re-circulation and significantly lowered the cyclone's dust emissions.

Another new cyclone design coming out of the Texas A&M research program is the recently developed barrel cyclone. It was developed in 1997 to solve a grain dust sampling problem at elevators. Initially, it was designed as a pre-separator to remove a high percentage of dust entrained in the sampled air prior to the final collection of fine particulate by a filter. The design of the barrel cyclone is similar to the design of the 1D2D cyclone with the exception that it is not equipped with a lower cone section. Tullis et al. (1997) and Zwicke et al. (1997) reported results of laboratory tests of the $1D3D_s$ (standard inlet), $1D3D_2$ (a 1D3D with a 2D2D inlet), 2D2D, 1D2D, and barrel cyclone using inlet loadings of (1) a combination of gin trash containing a high fraction of lint fiber and corn dust, and (2) corn dust only. The results were similar to results reported by Simpson and Parnell (1995) for the 1D2D cyclone. The barrel and 1D2D cyclones had significantly lower emission concentrations than either the 1D3D or 2D2D cyclones for inlet loadings of high-lint trash/fine dust. For example, at an inlet loading of 60 g/m^3 of high-lint trash and fine dust, the barrel cyclone produced an average emission concentration of 80 mg/m^3 compared to 150 mg/m^3 for the

2D2D and 200 mg/m^3 for the 1D3D. The performances of the 1D3D and 2D2D cyclones were adversely affected by the re-circulation of fiber in their lower cone sections. The re-circulation problem, however, affected the performance of the 1D3D cyclone more than it did that of the 2D2D cyclone.

The static pressure drop across the barrel and 1D2D cyclones averaged about 1.5 in. water in this study when the cyclones were operated at a design inlet velocity of 2400 fpm. This pressure drop level is 65 - 70% less than those of the 1D3D and 2D2D cyclones at their respective design inlet velocities. The data from high-lint trash tests seem to indicate that these new cyclones are more efficient than the 1D3D or 2D2D cyclones. However, when these cyclones were tested with inlet loadings of fine dust only, both the 1D3D and 2D2D produced significantly lower emission concentrations than did either of these new designs.

Research has also been conducted at the USDA ARS ginning laboratories in Mesilla Park, NM and Lubbock, TX on other cyclone designs that showed promise for improved performance in high-pressure applications at cotton gins. Hughs and Baker (1996a) described the results of laboratory studies using 12 in. dia. models of several cyclone designs. One promising design that was identified in this study was a long cone cyclone with a 2D2D type inlet, tapered outlet duct, and a larger than normal trash exit opening. This new cyclone reduced particulate emissions in the Mesilla Park study by 10 to 15% as compared to a standard 1D3D cyclone.

Two versions of the long cone cyclone design were later compared to the standard 1D3D cyclone in full-scale (34 in. dia. cyclones) follow up tests at Lubbock. Both versions of the long cone cyclone featured a 0.75D body, a 0.5D by 0.25D inlet, a 0.33D trash exit, and an outlet tube that was tapered from 0.5D at its bottom to 0.63D at it top. This tapered outlet design produced what was essentially a pressure-recovery evasé (Jorgensen, 1961) of the type sometimes used on the discharge ends of air lines to recover a portion of the escaping air's velocity pressure. A 4.25D length cone was used for one version of the cyclone , and a combination cone and expansion chamber having a total length of 4.25D was used for the other version. Both of the long cone cyclone designs were found to be highly efficient in this study (Baker and Hughs, 1997).

Basically, the long cone cyclone design features 4 major departures from that of the conventional 1D3D cyclone. Besides the obvious difference in cone length, the long cone design also features a different type of inlet, a different outlet design, and a larger trash exit opening. Which of these design differences was responsible for the long cone cyclone’s improved dust collection performance and lower pressure drop was not determined in these preliminary tests, but are currently the subject of new and expanded research. Since most of these design changes could be easily incorporated into a modified 1D3D design, it is important to determine the independent effects of each new design factor. Ultimately, it might be easier to retrofit our existing cyclone designs with improved features than to introduce a completely new cyclone design.

Research at Texas A&M and at the USDA ARS ginning laboratories has also included a number of studies to document the effects on performance of various modifications to the 1D3D cyclone. These studies have included research to investigate the effects of inlet transition design on the performance of 1D3D cyclones. Research at Texas A&M (Mihalski et al. 1994) has shown that a 1D3D cyclone equipped with the original flat-top inlet transition was substantially more efficient, from an emission control standpoint, than one equipped with an inverted transition. The inverted arrangement, however, is often preferred in the field because it is more trouble free than the original design. The Mesilla Park study measured the effects of both the original and inverted transitions on cyclone performance, as well as the effects of a center-inlet design. A 1D3D cyclone equipped with the flat-top transition was found to emit 28% less particulate than the inverted design, and 15% less than the center-inlet design (Hughs and Baker, 1996a).

These studies highlighted a problem with the original 1D3D cyclone design. The original design featured a tall, narrow inlet (8:1 aspect ratio) connected to a round conveying pipe by means of a round-to-rectangular transition. The round entry to the original transition was offset toward the top of the transition. The offset placed the top surface of the entry pipe in a plane that was approximately level with the top of the cyclone body. Unfortunately, however, many ginners have been unable to operate heavily loaded 1D3D cyclones as originally designed because of frequent chokages in the lower part of the flattop transitions. For cyclones used on heavily loaded trash lines, some ginners invert the original transition so that most of the trash is conveyed along the flat bottom of the transition. While the inverted arrangement keeps the transition swept free of troublesome accumulations, it also forces much of the trash to enter the cyclone near the bottom of the upper barrel and outlet duct. This change in entry point is apparently the factor responsible for the inverted transition’s adverse effects on cyclone collection performance.

The shorter and wider inlet (2:1 aspect ratio) on a 2D2D cyclone allows the use of a compact transition that encourages a gentle expansion and transition of the airstream without creating dead air spaces or excessive eddy currents. These simple inlets and transitions have also, over the years, proven themselves to be relatively trouble free in thousands of cotton gin applications. Therefore, another purpose of recent cyclone research has been to investigate the possibility of substituting the 2D2D type inlet for the tall, narrow inlet on a 1D3D cyclone. In recent research at both Texas A&M and at the ginning laboratory at Mesilla

Park, a 1D3D cyclone with a 2D2D type inlet emitted significantly less particulate than did a conventional 1D3D cyclone (Hughs and Baker, 1996a; Zwicke et al., 1997).

An additional study this past year was conducted at the USDA ARS laboratory at Lubbock to further investigate this promising design modification using full-sized (34-in. dia.) cyclones and stripper cotton trash. A 2D2D type cyclone inlet was substituted for the tall, narrow inlet of the standard 1D3D cyclone in an attempt to overcome choking problems when using the standard flat-top inlet transition, or performance problems when using an inverted transition. This inlet modification lowered the modified cyclone's particulate emissions by about 8%, and slightly reduced its static pressure requirements.

The 1D3D cyclone equipped with a 2D2D inlet operated satisfactorily with either the standard 1D3D type air outlet duct, or the shorter 2D2D type air outlet. The size of the cyclone's trash exit was also investigated in this study. A larger (D/3) size exit produced PM10 emissions that were about 8% lower than those resulting from use of the standard, small-diameter (D/4) exit. Basically, this study re-confirmed that the troublesome tall and narrow inlet of a standard 1D3D cyclone could be replaced with a more reliable 2D2D inlet without any adverse effects on cyclone performance. Also, the study illustrated the importance of trash exit size on cyclone performance.

Physical and Chemical Properties of Gin Emissions

Besides improving the collection efficiency of cyclone collectors, a related concern is the nature of the material actually emitted from well controlled gin exhausts. A series of field and laboratory studies were conducted to better define gin particulate emissions. Field tests were conducted in California and New Mexico to estimate the size distribution of particulate emissions from commercial gins in those areas (Hughs and Wakelyn, 1996b). Overall conclusions were as follows:

1. For the limited number of exhaust streams sampled, the average total suspended particulate (TSP) concentrations emitted from high efficiency cyclone exhausts were in the range of 0.069 to 0.092 g/m^3 (0.03 to 0.04 gr/dscf).

2. The percentage of TSP that was PM10 ranged from 10 to 70% (averaged 35%) when measured by California Method 501, and from 38 to 85% (averaged 69%) when measured by the Coulter Counter technique.

3. The amount of TSP that was determined by the Coulter Counter method to be PM2.5 varied between 0.4 and 2.5% with 2.3% being the average in New Mexico and 0.7% the average in California.

4. Even though opacity generally increases as TSP concentrations increase, opacity is currently not useful as a means of determining levels of TSP being emitted from cotton gins.

In related studies (Hughs et al., 1996c), particulate emissions collected at laboratory gins processing both Midsouth and Western cottons were analyzed. The amounts and composition varied across the cotton belt, but in general, the largest constituent of the particulate mass, both exhausted and caught by a cyclone, was plant material other than cellulose (43 to 66%), followed by cellulose (17 to 40%), then native soil (13 to 20%), and lastly moisture (6 to 11%). For both the Midsouth and Western cottons, the heavier soil particles tended to be captured by the unloading cyclone early in the ginning process.

This research also included elemental analyses of the particulates from across the cotton belt. The probable sources were identified as primarily plants and native soils, but some small amount may come from wear of gin processing machinery. One element, arsenic, was not found in particulate from Midsouth cottons, but was detected at low levels in some Western cotton particulate. Arsenic can be a natural soil component and can also come from residual amounts left in soil from past applications of harvest aid and post-emergent herbicide chemicals. None of the elements was found at unusual levels over that found in the native soil. Their total emission amount or estimated airborne concentration through an average ginning season is far below problem threshold levels for either EPA or OSHA regulations.

Determinations of agricultural chemicals in gin external emissions was also determined (Hughs et al., 1996c). DEF (from defoliation) is the only substance found routinely in gin external emissions. Exposure at the boundary line (100 meters from the gin exhaust) to any of the substances detected was fractions of parts per billion (ppb) or in the case of DEF an average of less than 1 ppb (1 ng/m^3), well below levels that would produce any health concerns. For a 20,000 bale/year gin, the total weight of any of the chemicals released is estimated to be less than one pound per year. Also, none of the substances detected occurred at levels of any concern for meeting either EPA or OSHA regulations.

Endotoxin levels were also determined and were found in both particulate caught by a cyclone as well as particulate emitted by a lint cleaner exhaust (Hughs and Wakelyn, 1997). However, the levels of endotoxin present were well below limits of concern for even the most sensitive individual as suggested by a NIOSH study for year round workers in textile mills.

Current and Future Research

Additional air quality studies are either in the planning stage or already in progress in several important areas. The Lubbock ginning laboratory plans to further investigate modifications to the basic 1D3D cyclone design. These modifications will include the 2D2D type inlet, a tapered outlet duct, and expansion chambers with large trash exits. At the Mesilla Park laboratory, additional research is planned on trash outlet size and inlet velocity requirements for modified 1D3D cyclones. At Texas A&M, research is underway on the sizing of very fine particulate and on evaluation of the Federal Reference Method for sampling PM2.5 and its potential impact on agricultural operations.

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