PHYSICAL EVALUATION OF CYCLONE EMISSION CHARACTERISTICS

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Abstract

A series of particulate emission tests were conducted on cotton gins in New Mexico and California. All exhausts measured used high- efficiency cyclones as emission-control devices. Total suspended particulate (TSP) for all gins averaged between 0.03 and 0.04 grains per dry standard cubic foot (gr/dscf) of air emitted. The PM10 fraction of the TSP ranged between 35 and 69% depending on the method of determination. Levels of PM2.5 were determined to be between 0.4 and 2.5% of TSP. Opacity readings taken both during these tests and in earlier tests did not correlate with TSP and cannot be used to estimate TSP concentrations. The Hand-held Aerosol Monitor (HAM) correlates well with PM10 levels determined by the Coulter Counter and may be used by gin management for quick evaluation of emission- control systems.

Introduction

The Environmental Protection Agency (EPA) regulates airborne pollutants including criteria pollutants as National Ambient Air Quality Standards (NAAQS)and hazardous air pollutants (HAP) as National Emission Standard for Hazardous Air Pollutants (NESHAP) (Wakelyn, 1995). Particulate matter (PM), one of seven criteria pollutants regulated by the EPA as a NAAQS, is the generic term for dust and other diverse types of particles in the air. In general, PM is the only pollutant of concern for cotton gins.

In 1987, EPA promulgated significant revisions to the PM standard (52 FR 24624;July 1, 1987). EPA changed the indicator for PM from total suspended particulate (TSP) to PM10 emissions (particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers). However, TSP is still a regulated pollutant because of new sources performance standard (NSPS) requirements. Since both TSP and PM10 are regulated pollutants under the Clean Air Act (CAA), they can be regulated by states, and TSP is still regulated as the PM indicator in some states. However, on October 16, 1995 EPA issued a Guidance Memorandum that clarifies that for applicability of Title V, sources of PM should be based on emissions of PM10 instead of TSP (Wagman, 1995). So most states will be changing to PM10 as the regulated pollutant for PM. Currently the national primary and secondary 24-hour ambient-air quality standard for PM in a particular area cannot exceed an average 24-hour PM10 concentration of 150 micrograms/cubic meter ($\mu g/m^3$) more than once a year. The current national annual PM10 standard is 50 $\mu g/m^3$ annual arithmetic mean (40 CFR 50.6). The California standard is at 50 $\mu g/m^3$ for 24 hours and 30 $\mu g/m^3$ for the annual.

EPA is presently required by a court order to complete the review and any revision of the PM NAAQS by January 31, 1997, with a proposed decision by June 30, 1996 (American Lung Association v. Brownar, CIV-93-643-TVC-ACM to Ariz., Oct. 6, 1994). There are indications that the 24-hour PM10 standard may be changed to PM2.5 and a PM2.5 annual standard added to the PM10 annual standard (EPA, OAQPS staff paper, 1995). Any change in this standard will have an impact on the regulation and licensing of cotton gins.

Currently, the permitting requirements for cotton gins varies greatly between states. Usually the performance standard is expressed in terms of weight of TSP or PM10 per bale of ginned cotton. Conformance with this standard can be determined by measuring emissions with an EPA Method 5 or equivalent stack sampler (40 CFR 60, App. A, Method 5). Some states also are particularly concerned with the "prevention of significant deterioration" of the area around a facility. This is determined by process weight tables and/or monitoring. These are beyond the scope of this paper but are addressed by others.

Some states included in their permit agreement an opacity standard for visible emissions. Opacity is an indicator of the amount of visible light in percent that is blocked by a plume. This standard was developed from the Ringlemann scale which compared the shade of gray of smoke emissions with that of a chart (Beutner, 1974). The Ringlemann scale is useful only for black-smoke emissions. Today, opacity readers are trained to judge the equivalent opacity of emissions of any color (EPA Method 9; 40 CFR, App. A, Method 9). However, the results are dependent on the position of the sun relative to the observer, and errors can be made on overcast days. Obviously, no observations can be made at night. Also, at lower opacity numbers (10 to 20%), human errors greatly increase. Opacity has the advantage in that it is relatively quick and easy to read. For this reason, it is often used as an indicator of compliance with a permitting agreement, but opacity has not been tied to gin-particulate-emission rates.

Research has been done to determine if the opacity reading of a particular exhaust can be used as an indicator of dust loading (Beutner, 1974,). Instruments have been developed to continuously monitor optical density (opacity) to provide a measurement of the dust loading being emitted by a

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process. There can be shown to be a correlation between opacity and dust loading, if the particle-size distribution is known and constant.

Other research has developed general empirical relationships between opacity and dust loading for various materials (Ensor and Pilat, 1971). These general equations only hold if the particle size and refractive index are known and are constant. Recently, the State of New Mexico attempted to apply the relationships developed by Ensor and Pilat (1971) to predict dust loading from opacity measurements taken at a cotton gin. The State estimated dust emissions in the range of 30 to 50 pounds per bale based on these theoretical relationships, but AP-42 for cotton gins indicates that the average dust loading per bale is 2.24 pounds. This inconsistencies in gin-emission rate suggests that,without knowing particle size distribution and refractive index of particulate emitted by cotton gins, the equations for relating opacity to dust loading cannot be used. Koontz and Flowers (1992) collected both gin-particulate emission concentrations and opacity readings for a cotton gin in Tennessee, but did not attempt to correlate the opacity data with TSP.

Columbus and Hughs (1993) and Columbus et. al (1995) did some preliminary work to characterize the particulate emissions from cotton gins. Various cottons were collected from across the cotton belt and ginned at either the Mesilla Park or Stoneville Ginning Laboratories. Particulate emissions from the unloading cyclone and the first lint-cleaner condenser were sampled and analyzed for both particle-size and chemical composition, and significant differences were found in both particle-size distribution and chemical composition. There were also differences in these parameters between cottons. For example, the particle size distribution (PSD) from the unloading cyclone, as indicated by the percentage of PM10, ranged from 70 to 89%, and PM10 from the lint-cleaner exhaust ranged from 44 to 69%. Cotton from the western states had higher PM10 counts from the unloading exhaust and lower counts from the lint-cleaner exhaust than did cotton from the southern and eastern parts of the cotton belt. These data were collected on laboratory ginning systems using small lots of seed cotton. It is not known if commercial ginning systems processing at normal cotton flow rates would alter the average PSD.

More information is needed on the characteristics of particulate emitted from commercial ginning systems, as well as the relationship between opacity and other methods which measure dust loading. There is also interest in finding a rapid and inexpensive method of estimating cyclone dust emissions without having to use the Method 5 sampler or rely on opacity measurements. Having such a method would allow cotton gins to fine tune their particulate-emission control systems or to pinpoint high-emission sources before regulatory problems developed. This paper discusses studies conducted at commercial cotton gins during the 1994 ginning season. The studies gathered more information about emissions PSD and attempted to define a relationship between opacity and other measurement methods as well as to evaluate the utility of the Hand-held Aerosol Monitor (HAM) in estimating PM and PM10 concentrations determined by other measurement methods.

Procedures

During the 1994 ginning season, compliance testing was being done using Method 5 type samplers at several gins in California and one in New Mexico. Permission was granted to ginning researchers to monitor the tests and either simultaneously collect dust samples from the cyclone exhausts while they were being measured or, in the case of New Mexico, obtain the data and the Method 5 filters for further PSD analysis. A Hand-Held Aerosol Monitor (HAM) was obtained from Shofner Enterprises and was used to take data simultaneously with Method 5 sampling. The HAM data was then correlated against particulate concentrations obtained from Method 5 measurements to determine its utility in estimating particulate emissions.

Particulate emission measurements of the gin in New Mexico were performed by the State of New Mexico Environmental Improvement Bureau and were done to determine compliance with emission levels stipulated in its permit to operate. The gin plant measured is a combo-gin processing both roller-ginned Pima and saw-ginned upland cottons under the same roof. Method 5 measurements were made on five selected 1D3D exhausts to determine the TSP being emitted from each exhaust. Opacity readings were also taken by a qualified opacity reader from four of the selected exhausts during this test period. Also, multiple HAM readings were taken by ginning researchers during the duration of each Method 5 sampling run. Each selected exhaust was only measured once by the State of New Mexico for a total of five data points. After the State was finished with the Method 5 filters, they gave the filters to the Mesilla Park Ginning Laboratory for use in determining the PSD on the filters by means of a Coulter Counter (Coulter Electronics, 1975). The end result was that information was obtained for 5 gin emission points that had simultaneous Method 5, HAM, and related opacity readings, and correlations could then be made between the measurement methods.

Emission tests in California were source tests made on selected exhausts at five gin plants. The tests were coordinated by the California Cotton Ginners Association and were conducted by a contractor, AIR_x Testing of Ventura, California. Selected 1D3D cyclone exhausts at each gin plant were tested in triplicate. Sampling was done using Method 5 for TSP and Method 501 for PM10. The sampling trains operated simultaneously. The Method 501 is similar in concept and operation to EPA Method 5 except that the front of the probe has a precollector immediately

followed by an impactor. The precollector and separator are designed to separate the particulate collected into fractions greater than and less than PM10. This method is used by the California Air Resources Board (CARB) for source testing of particulate emissions.

Each of the cyclone exhausts sampled at the California gins were fitted with a candy cane-stack that routed the exhaust from the top of the cyclone to the ground. During the majority of the tests, particulate emitted from the candy-cane stack was collected onto a glass fiber filter using a Hi-Vol sampler (40 CFR 50, App. B) operating simultaneously with the Method 5 and 501 samplers. The Method 501 sampler is a method designation made by the CARB and is similar in function to the EPA Method 201A (40 CFR 51, App. M) for determining PM10. The Hi-Vol filter samples were used to obtain PSD readings by the Coulter Counter. Also, during many of the test runs, multiple HAM readings were taken for comparison.

Results and Discussion

Table 1 is a summary of the data from the emissions tests conducted by the State of New Mexico. The TSP concentrations and the opacity readings were determined by the State using the EPA Method 5 and Method 9 protocols, respectively. The average PM2.5 and PM10 were determined by the Coulter Counter (Coulter Electronics, 1975) using the particulate collected on the Method 5 filters. The PM2.5 and PM10 figures are the average of 3 determinations. The TSP concentrations ranged from 0.02 to 0.05 grains per dry standard cubic foot (gr/dscf) of exhaust air. This range of particulate emission concentration is similar to that reported by others (Parnell and Mihalski, 1992, and Koontz and Flowers, 1992).

The percentage of particles whose aerodynamic diameter is less than or equal to 10 microns (PM10) is currently being used by most regulators as 50% of TSP. Table 1 shows that the PM10 emissions from the New Mexico Gin as determined by the Coulter Counter ranged from 62 to 75% of TSP. PM2.5 determined by the same method ranged from about 2.1 to 2.5% of TSP.

Opacity was low on all exhausts and ranged from 0 up to 5%. The highest opacity reading was taken from the exhaust of the first hot-air cylinder cleaner. During the 1993 ginning season, this exhaust had been read at 40 to 45% opacity. Prior to the 1994 season, the air flow to these cyclones was adjusted to within design specifications and product receivers added to the bottom of the cone to stabilize the vortex. The result was that the opacity reading was reduced from 45% to 5% which is well within the gin's permit limit of 20% opacity.

Table 2 shows the results of the more-extensive gin emission tests that were conducted in California during the 1994 ginning season. As stated earlier, different exhausts from five different gins were measured during the season. Even though all of the same exhausts from each gin were not measured, it is possible to group all of the exhausts measured into related categories for discussion. The particulate concentration varied from 0.0090 to 0.1205 gr/dscf, with the average over 33 measured exhausts being 0.038 gr/dscf.

All exhausts used high-efficiency cyclones, but the differences in TSP concentrations reflect the differences of input loading to the cyclones at the different process points. The unloading and first drying system exhausts are usually among the highest concentrations, because they are the first systems that begin the seed-cotton cleaning process. Gin cleaners are proportional devices with the first cleaners in line removing proportionately more than subsequent cleaners. The battery condenser is the last exhaust in line, so that very little particulate is found in its exhaust air.

PM10 for the California tests were determined two ways, one being by the Coulter Counter data which used particulate collected by a HI-Vol sampler, and the other by the method 501. Samples were collected simultaneously by both methods so that their results could be statistically compared. Table 2 shows that the average PM10 by the Coulter Counter and method 501 was 67.58 and 34.9%, respectively. An analysis of variance (SAS, 1987) shows that the measurement averages are significantly different at the 5% level. Using PM10 from the Coulter Counter to predict PM10 from method 501 in a regression gives a coefficient of determination (R^2) of only 0.16 with the slope of the prediction curve being negative. In other words, the PM10 as determined from the Coulter Counter does not compare with that from Method 501, not even in the same direction. One indicator of PM10 decreases while the other increases.

From the California data, it is not possible to determine which PM10 measurement better estimates the "actual" size of the particulate being emitted. However, it is important to recognize the differences in actual measurement and how they are used. Method 501 is used in the State of California for testing gins for compliance to their operating permits and is a legal basis for determining that compliance. The Coulter Counter has been used for some time by researchers as a laboratory tool for determining the results of emissions control research.

The California data indicates that, in general, the PM10 from the Coulter Counter is about twice the magnitude of PM10 from Method 501. Using the Coulter Counter measurement to predict field measurement of PM10 by Method 501 would give a very conservative result.

The overall average of PM2.5 from Table 2 is 0.68% with a high of 1.51 and a low of 0.42%. This is somewhat lower than the New Mexico data in Table 1 (average PM2.5 = 2.3%). If a PM2.5 standard for particulate emissions is

adopted, the relative quantity emitted by cotton gins will be very low.

Figure 1 is a plot of the HAM readings versus PM10 concentration for the California Gins as determined by the Coulter Counter. A regression analysis was performed using the HAM readings as the dependent variable and PM10 determinations by both the Coulter Counter and Method 501 as the independent variable. The model R^2 for the HAM readings versus the Coulter Counter PM10 is 0.89 (plotted in Figure 1). The model R^2 for the HAM data versus the Method 501 PM10 is lower at 0.70. The HAM reading more nearly duplicates the PM10 data from the Coulter Counter than similar data from the Method 501. The regression equation of best fit is:

PM concentration (gr/dscf) = ((HAM reading)+ 1.95)÷1188

Table 3 shows gin opacity readings versus particulate emission concentration. A regression analysis was performed using the opacity readings as the dependent variable and particulate concentration as the independent variable. There is a significant relationship between opacity and particulate concentration but the model R^2 is 0.51. In general, as the gin particulate emission concentration increases the opacity will also tend to increase. However, the relationship is so variable that a given particulate concentration could result in a wide range of opacity readings. For example, from Table 3, a particulate concentration of 0.01 gr/dscf could result in an opacity reading from 0 to 10. This kind of variability would make opacity unusable as a tool for determining particulate emission concentrations from cotton gin exhausts.

Conclusions

A series of particulate emissions tests were conducted at cotton gins in New Mexico and California. Particulate emissions were estimated using several different methods, and the conclusions are:

1. Average TSP concentrations from high-efficiency cyclone exhausts can be as high as 0.1205 gr/dscf on very heavy exhausts, but the average concentration is in the range of 0.03 to 0.04 gr/dscf.

2. The percentage of TSP that is PM10 varies from 35 to 69%, depending on the type of determination used. The rule of thumb that PM10 is approximately 50% of TSP is still a reasonable estimate until the reason for the differences between methods of PM10 determination can be determined.

3. There is very good agreement between the estimate of the PM10 fraction of the TSP emitted from gins in New Mexico and California using the Coulter Counter, 69.4 and 67.6%, respectively. This occurred even though there was some difference in how the particulate was collected. The Method 5 filters were used directly in New Mexico, while an auxiliary Hi-Vol sampler was used in California.

4. Using the Coulter Counter, the amount of 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. These numbers indicate that if a PM2.5 standard is adopted for cotton gins, particulate emissions in this range are very low and gins are not a significant source of PM2.5 emissions.

5. There is good correlation (model $R^2 = 0.89$) between the experimental readings of the Hand-held Aerosol Monitor (HAM) and PM10 as determined by the Coulter Counter. The correlation between the HAM and PM10 as determined by Method 501 is not as good (model $R^2 = 0.70$), but still reasonable. The HAM may be a useful tool for a quick field determination of the PM10 emissions from a gin without having to do Method 5 testing, and could be used by gin management or ginning associations to monitor and fine tune emission control systems.

6. 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.

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Table 1. New Mexico Gin Emissions Data.

Exhaust Description	TSP	Average PM2.5	Average PM10	Average Opacity
	gr/dscf	%	%	%
Unloading	0.0368	2.09	68.92	1
First Hot Air Cleaner	0.0526	2.45	70.95	5
Second Hot Air Cleaner	0.0314	2.51	61.83	<1
Incline Over Distributor	0.0191	2.24	70.87	0
Motes	0.0295	2.20	74.54	-
Average	0.0339	2.30	69.42	-

Table 2. California Gin Emissions Data Averages.

Exhaust Description	PM2.5 by Coulter Counter	PM10 by Coulter Counter	PM10 by M501	TSP
	%	%	%	gr/dscf
Unloading & First Dryer	1.51	78.96	39.5	0.1205
Remaining Seed Cotton Cleaning	0.70	72.92	27.5	0.0428
Lint Cleaner Trash	0.42	54.57	41.1	0.0090
Battery Condenser	0.64	59.49	41.6	0.0022
Motes Trash	0.57	71.81	38.5	0.0529
Overall Average[1]	0.68	67.58	34.9	0.0382

[1] Average of a total of 33 data points.

Table 3. Opacity and Emission Concentration Measurements.

Observation number [1]	Opacity	Emission concentration
	%	gr/dscf
1	0	0.003
2	0	0.003
3	0	0.003
4	0	0.010
5	0	0.019
6	1	0.034
7	1	0.037
8	0 to 5	0.020
9	5	0.008
10	5	0.050
11	5	0.053
12	5 to 10	0.009
13	15 to 20	0.080

[1] Observations 5, 6, 7, and 11 are from the New Mexico Gin and the other observations are from Koontz and Flowers (1992).

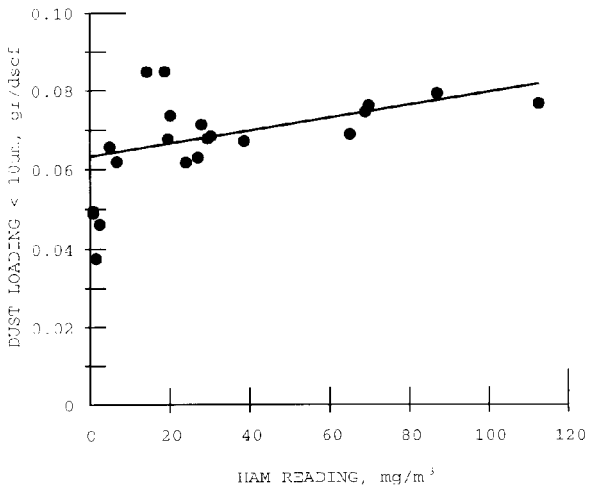

Figure 1. Dust loading vs HAM reading.