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Collecting Particles from Gin Lint Cleaner Air Exhausts

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ABSTRACT

MEETING strict particulate emission standards is currently a problem for the ginning industry. Small-diameter cyclones are currently used as primary collectors on gin seed-cotton system exhausts. A study was conducted to determine the effectiveness of small-diameter cyclones (1D3D design) as primary collectors on lint-cleaner exhausts. A wet scrubber was also evaluated as a secondary cleaner on the cyclone exhaust. The cyclone collectors captured an average of 90.8 percent by weight of exhaust particulates as a primary cleaner. The scrubber then removed an average of 73.5 percent by weight as a secondary cleaner. The combined collection efficiency of the cyclone and wet scrubber system averaged 97.6 percent. This information should be useful to the ginning industry in designing particulate collection systems to meet particulate emission standards.

INTRODUCTION

The encroachment of cities into once rural areas coupled with the increased public concern about air pollution is putting pressure on the ginning industry to reduce particulate emissions. Gins have used or are using small-diameter cyclones (Harrell and Moore, 1962), skimmers (Kirk et al., 1976), and unifilter collectors (McCaskill and Wesley, 1976) on many of their high-pressure exhausts and unifilter collectors, screen cages (Harrell and Moore, 1962), and inline air filters (Alberson and Baker, 1964) on their low-pressure exhausts to reduce particulate emissions. However, very low permissible emission levels and increased public pressure is forcing the ginning industry to search for still better methods of particulate emission control.

The staff at the Southwestern Cotton Ginning Research Laboratory has been conducting research concentrating on finding new ways of applying current technology to the gin particulate emission problem. An earlier paper (Gillum et al., 1980) gave a preliminary report of the effectiveness of cyclone collectors as primary and a wet scrubber as a secondary particulate collector on a lint-cleaner exhaust. Gillum et al. gave data of Environmental Protection Agency (EPA) source emission tests of coton gins in Arizona and California (Table 1). The seed-cotton system or the lint system exhaust alone exceeded allowable emissions in the majority of the cases, shown in Table 1. In all cases, the sum of the emissions of the two systems exceeded allowable levels by factors anywhere from 1.26 to 3.38.

Gillium et al. showed preliminary results that indicated that unabated lint-cleaner exhaust emissions could be reduced by as much as 97 percent, and that controlled lint exhaust emissions could be further reduced by at least 50 percent. This paper gives a description of the emission control system tested by Gillum et al. and the final test results.

TEST INSTALLATION

Fig. 1 shows a schematic of the long-cone cyclone and cyclone wet-scrubber test installation at a commercial gin. A set of small-diameter (1D3D design) long-cone cyclone collectors (Parnell and Davis, 1979) were installed on the No. 1 lint-cleaner air exhaust to serve as primary collectors (Fig. 2). A second vane axial fan was installed prior to the cyclones to overcome the additional back pressure created in the lint-cleaner exhaust line by the addition of the cyclones.

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TABLE 1. COTTON GIN SOURCE TEST RESULTS

State	Seed cotton process rate†	Lint process rate	Total emissions	Seed cotton system emissions	Lint system emissions	Total allowable emissions‡
	kg/h(lb/h)	Bales/h	kg/h(lb/h)	kg/h(lb/h)	kg/h(lb/h)	kg/h(lb/h)
Arizona	2318(5100)	3.4	3.4(7.5)	1.9(4.1)c	1.5(3.4)l	2.7(6.0)
Arizona	5864(12900)	8.6	13.4(29.5)	7.3(16.1)c	6.1(13.5)l	5.1(11.2)
California	8864(19500)	13.0	23.7(52.2)	11.9(26.2)c	11.8(26.0)l	7.0(15.4)
California	14045(30900)	20.6	15.6(34.3)	10.0(22.0)u+c	5.6(12.4)*u+c	9.3(20.4)
California	15682(34500)	23.0	18.0(39.6)	9.5(20.9)*u+c	8.5(18.8)u+c	9.9(21.8)

*Not measured, a calculated estimate, c = cyclones, l = lint cages, u = unifilter. Some of the low-pressure exhausts may have not been going into the unifilter.
†Using 682 kg(1500 lb) of seed cotton per bale of cotton lint.
‡From process weight table for appropriate state, at time of test.

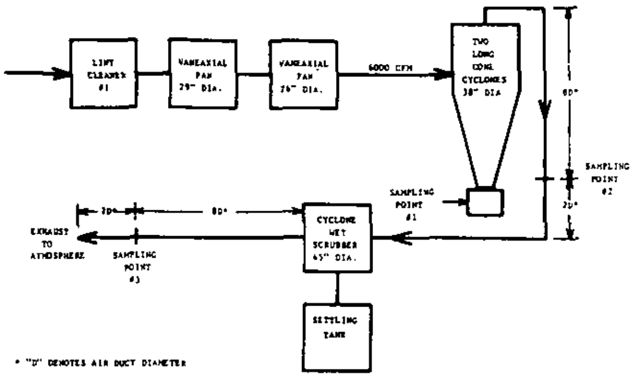

FIG. 1 Cyclone test installation.

A cyclone wet scrubber was installed after the long-cone cyclones to serve as a secondary particulate collector. The scrubber consisted of a sheet metal cylinder 1.14 m (3.75 ft) in diameter and 4.88 m (16 ft) tall. The exhaust air from the primary long-cone cyclones was induced tangentially at the bottom of the scrubber with an average velocity of 384.6 m/min. (1262 ft/min.) and flowed out the top of the scrubber. The average pressure drop through the cyclone wet scrubber at the 384.6 m/min (1262 m/min.) inlet air velocity was approximately 10 mm (0.4 in.) of water. The air inlet section of the cyclone wet scrubber resembled the inlet section of a cyclone. There were two high-volume water-spray nozzles located along the center line of the cyclone wet scrubber. These nozzles sprayed downward against the airflow through the scrubber. The nozzles were 33 cm (13 in.) apart with the lower nozzle 45.7 cm (18 in.) above the top of the scrubber air inlet. Each nozzle was rated at 76.8 L/min. (20.3 gpm) at the operating pressure of 197 kPa (28.6 psi). Spray water collected at the botton of the scrubber and was drained by gravity to the settling tank. From the settling tank, the water was then recirculated by two 1.49 kW (2-hp) pumps back through the spray nozzles in the cyclone wet scrubber.

The test installation was constructed so that dust sampling could be done at the long-cone cyclone collectors, between the long-cone cyclone collectors and the cyclone wet scrubber, and after the wet scrubber. The dust-sampling station at the long-cone cyclone collectors consisted of a "Y-valve" installed at the botton of each cyclone collector. Plastic bags were attached to the

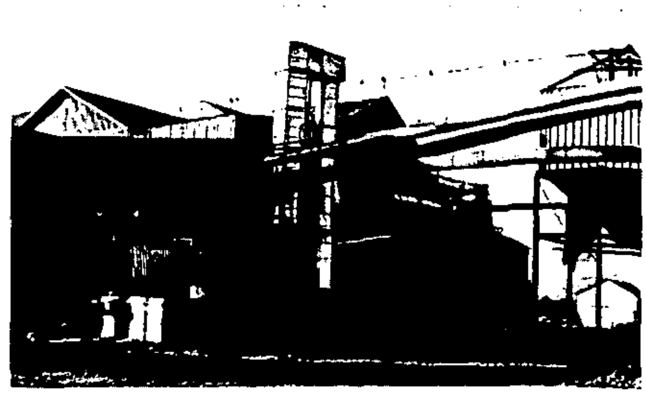

FIG. 2 Cyclone and wet scrubber installation—long-cone cyclones, right of center by seed hopper, cyclone wet scrubber, center, and sludge tanks, left side directly in front of car.

outlets of the valves. Dust and cotton lint removed from the exhaust air stream were collected in the plastic bags during sampling periods. The bags were removed at the end of each 4-hour test run and weighed to determine the total amount of trash caught by the cyclone collectors. Sampling at other points was done using Environmental Protection Agency (EPA) Method 5 procedures (Environmental Protection Agency (EPA), 1977). A sampling station for a Method 5 sampling train was located on the air discharge duct of the long-cone cyclone collectors. Another Method 5 sampling station was located on the air discharge of the cyclone wet scrubber. The two Method 5 sampling stations were used simultaneously to determine the rate of particulate emissions from the long-cone collectors and the cyclone wet scrubber. Data from all three sampling points gave a complete picture of the rate of emissions and effectiveness of the devices used to control emissions. Eleven measurements were made during the entire ginning season and while processing both machine-picked and ground-harvested upland cotton.

RESULTS AND DISCUSSION

The primary long-cone cyclones and secondary cyclone wet scrubber equipped with a recirculating water system and settling tank were operated without cleaning for 425 h while ginning about 2500 bales. The settling tank was then emptied of residue by a septic tank cleaning service into a sewage truck and disposed of like any septic tank residue. Table 2 gives the particulate emission test

TABLE 2. EMISSION DATA FOR CYCLONE AND WET SCRUBBER

Lot no.	Ginning rate, bales/h	Cyclone collection rate, g/s(lb/h)	Cyclone emission rate, g/s(lb/h)	Wet scrubber emission rate, g/s(lb/h)	Cyclone efficiency, percent	Scrubber efficiency, percent	Combined efficiency, percent
1	8.5	0.431(3.42)	0.0432(0.343)	0.0217(0.172)	90.86	49.91	95.42
2	5.5	0.394(3.13)	0.0523(0.415)	0.0120(0.095)	88.29	77.11	97.32
3	5.3	0.605(4.80)	0.0753(0.598)	0.0210(0.167)	88.93	72.07	96.91
4	7.5	0.546(4.33)	0.0549(0.436)	0.0140(0.111)	90.85	74.53	97.65
5	7.8	0.743(5.90)	0.0610(0.484)	0.0156(0.124)	92.41	74.49	98.07
6	7.3	0.649(5.15)	0.0519(0.412)	0.0110(0.087)	92.59	78.84	98.43
7	6.5	0.592(4.70)	0.0436(0.346)	0.0106(0.084)	93.14	75.80	98.34
8	7.3	0.489(3.88)	0.0554(0.440)	0.0155(0.123)	89.81	71.95	97.14
9	8.3	0.706(5.60)	0.0627(0.498)	0.0173(0.137)	91.83	72.53	97.76
10	5.0	1.428(11.33)	0.1571(1.247)	0.0258(0.205)	90.08	83.58	98.37
11	6.3	0.993(7.88)	0.1034(0.821)	0.0227(0.180)	90.56	78.07	97.93
Average	6.8	0.689(5.47)	0.0692(0.549)	0.0170(0.135)	90.85	73.54	97.58
Standard deviation	1.2	0.295(2.34)	0.0336(0.267)	0.0052(0.041)	1.54	8.56	0.88
Coefficient of variation	17.8	42.91	48.70	30.22	1.69	11.65	0.90

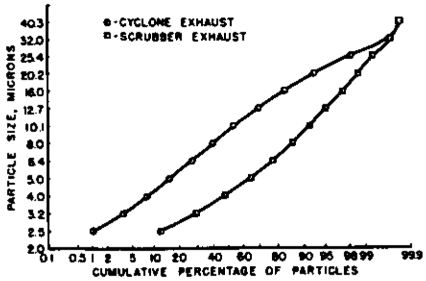

FIG. 3 Particle size vs. cumulative weight percentage of particles in exhaust sample.

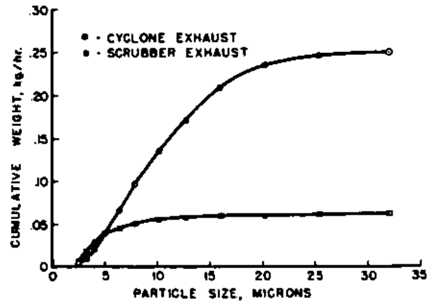

FIG. 4 Cumulative weight of particles emitted vs. particle size.

results. Table 2 shows that the long-cone cyclones collected an average of 0.689 g/s (5.47 lb/h) of trash and emitted an average of 0.069 g/s (0.549 lb/h) of trash at an average ginning rate of 6.8 bales of lint per hour. This collection rate yields an average cyclone collection efficiency of 90.85 percent. Inlet velocity to and airflow through the cyclone during the test averaged 13.2 m/s (2592 ft/min) and 2.66 m^3/s (5640 dscfm), respectively.

Table 2 shows that of the average 0.069 g/s (0.549 lb/h) of particulates emitted by the cyclones, the cyclone wet scrubber captured all but 0.017 g/s (0.135 lb/h) for an average collection efficiency of 73.53 percent. Inlet velocity to and airflow through the wet scrubber during the test averaged 6.41 m/s (1262 ft/min) and 2.38 m^3/s (5042 dscfm), respectively. The difference in airflow through the cyclone and wet scrubber is accounted for by leakage to the atmosphere. The average combined cyclone and cyclone wet scrubber system efficiency was 97.58 percent. This system collection efficiency did not vary appreciably through the ginning season as the input material varied from clean, first-picked to trashy late-season ground-harvested seed cotton. Total first lint-cleaner-exhaust loading rates varied during this time from 0.446 g/s (3.54 lb/h) to 1.585 g/s (12.58 lb/h).

Fig. 3 gives the cumulative percentages of particle sizes determined by the Coulter counter (Coulter Electronics, Inc., 1975) from EPA Method 5 particulate samples taken from the long-cone-cyclone and wet-scrubber exhausts. There are virtually no particles greater than 32 microns exhausted from the cyclones and 95 percent of the particles have a diameter of approximately 22 microns or less. These data are in close agreement with Parnell and Davis (1979). Parnell and Davis found that long-cone cyclones did not emit particles above 18 microns in diameter when tested under different loading conditions using grain dust.

The cyclone wet scrubber greatly reduced the larger fraction of particles emitted from the cyclone. Referring to Fig. 3, 95 percent of the particles emitted from the scrubber had a diameter of 12.7 microns or less compared to approximately 22 microns for the cyclone. Fig. 4 shows the cumulative weight of particles emitted from both the cyclone and cyclone wet scubber versus particle size. Fig. 4 shows that the cyclone wet scrubber does not effectively remove particles 5 microns in diameter or less, but the scrubber's collection efficiency increases rapidly as particle size increases from 5 to 20 microns. Fig. 3 and 4 show that the cyclone wet scrubber collected virtually all particles greater than 12.7 microns in diameter.

APPLICATIONS

The first three gins shown in Table 1 used lint cages on their lint system exhausts. The particulate collection efficiency of screen cages is unknown but is undoubtedly low. This study shows that a cyclone-cyclone wet scrubber system added to an unabated lint system exhaust has a collection efficiency of 97 percent. It should be a reasonable assumption that replacing the lint cages on the first three gins in Table 1 with a cyclone-cyclone wet scrubber system would result in at least an additional reduction in lint system emissions of 80 percent.

McCaskill and Wesley (1976) showed that the unifilter had an average particulate collection efficiency on cotton gin emissions of 99.5 percent. Gillum et al. (1980) showed that high-efficiency cyclones had collection efficiencies that averaged 99.6 percent on gin trash. Research has shown that 97 to 98 percent of gin trash is made up of particles whose diameter is greater than 25 to 50 microns (Wesley et al., 1970). The cyclones high efficiency comes from the fact that it captures virtually all these particles above 25 microns. The cyclones collection efficiency on particles less than 25 microns gets lower as the particle diameter gets smaller. The unifilter also gets its high collection efficiency from collecting particles in the same size range as does the cyclone. Therefore, the size characteristics of the particulates emitted by both cyclones and unifilters should be very similar. It has been shown that a cyclone wet scrubber has an average collection efficiency of 73.5 percent on cyclone particulate emissions. Therefore, a cyclone wet scrubber should have a collection efficiency of at least 70 percent on unifilter particulate emissions. The last two gins using unifilters shown in Table 1, should be able to reduce their emissions by 70 percent with the addition of a cyclone wet scrubber on their unifilter exhausts. The characteristics of the particulates in seed-cotton system and lint system exhausts using cyclones as collectors should be identical, other than perhaps for loading rates. Therefore, the gins in Table 1 using cyclones ontheir seed-cotton system exhaust should be able to reduce those emissions by an additional 70 percent.

Taking all assumptions together, 80 percent reduction

TABLE 3. PREDICTED GIN SOURCE TEST EMISSIONS

State	Lint process rate, bales/h	Seed cotton system emissions, kg/h(lb/h)	Lint system emissions, kg/h(lb/h)	Total emissions, kg/h(lb/h)	Total allowable emissions,* kg/h(lb/h)
Arizona	3.4	0.56(1.23)	0.31(0.68)	0.87(1.91)	2.7(6.0)
Arizona	8.6	2.19(4.83)	1.22(2.70)	3.42(7.53)	5.1(11.2)
California	13.0	3.56(7.86)	2.36(5.20)	5.92(13.06)	7.0(15.4)
California	20.6	2.99(6.60)	1.69(3.72)	4.68(10.32)	9.3(20.4)
California	23.0	2.84(6.27)	2.56(5.64)	5.40(11.91)	9.9(21.8)

*As shown in Table 1, current standards may have changed.

of lint-cage emissions, 70 percent reduction of unifilter emissions and 70 percent reduction of seed-cotton system cyclone emissions, the figures in Table 1 would look like the figures in Table 3. If the assumptions are correct, all the gins shown would be able to meet their total allowable emission requirements as shown in Table 1. It may not be necessary to install a cyclone wet scrubber or a cyclone-cyclone wet scrubber system on all gin exhausts to bring them in compliance with emission standards. Many gin exhausts such as the seed handling system and press-condenser exhausts are lightly loaded compared to seed-cotton unloading and number one lint cleaning exhausts. Additions of a cyclone wet scrubber or a cyclone-cyclone wet-scrubber system on only these more heavily loaded exhausts may bring a gin in compliance with emission standards.

It is not recommended that wet scrubbers be used as primary emission control devices because of the much larger volume of wet residue that would have to be disposed of. Also, gins handling stripper cotton might be expected to achieve similar particulate collection efficiencies as discussed in this paper. However, the amount of residue that would be collected and have to be disposed of might be expected to increase by a factor of 2 or more.

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