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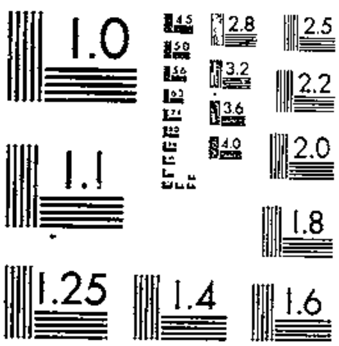

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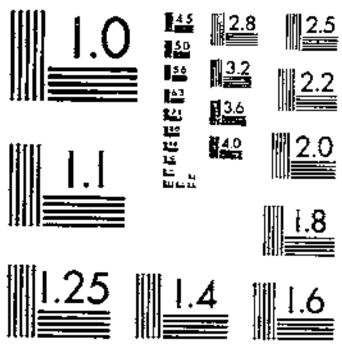

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An Evaluation of the Cyclone Collector for Cotton Gins

Technical Bulletin No. 1439

Agricultural Research Service
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An Evaluation of the Cyclone Collector for Cotton Gins

By Richard A. Wesley, William D. Mayfield, and Oliver L. McCaskill, *agricultural engineers, Agricultural Engineering Research Division, Agricultural Research Service*

Since 1960, more and more cotton has been harvested by machine. Because of the speed with which the harvesting machines work, cotton arrives at the gin plant at a much faster pace and contains more foreign matter. Because of this, numerous changes have been made in various segments of the cotton industry. Ginning plants, for instance, have had to increase their capacity to cope with the increased rate of harvesting. To increase the capacity of a cotton gin requires greater volumes of high-pressure air to move the machine-harvested cotton through the plant. This increase in the volume of high-pressure air required to convey the machine-harvested cotton has created an air pollution problem. Separating and collecting the foreign matter from high volumes of air is a sizeable problem. At present, the small diameter cyclone is the most practical device for collecting the foreign matter from the high-volume, high-pressure air systems of modern ginning plants.

This is a report of experiments conducted over a 3-year period at the U.S. Cotton Ginning Laboratory, Stoneville, Miss., to determine the collection efficiency of the Atomic Energy Commission (AEC) small-diameter cyclone.

OBJECTIVES

The primary objectives of this study were to determine the collection efficiency of the Atomic Energy Commission (AEC) cyclone, and the size and concentration of particles exhausted from it. Efficiency of the cyclone and size and concentration of the exhausted particles were to be determined for two trash sizes, various operating air velocities, and trash input concentrations. A secondary objective was to determine the particle size composition of normal gin trash from machine-picked cotton. Data obtained from this study could be applied to the design of future trash-collecting systems for cotton gins.

REVIEW OF LITERATURE

Harrel and Moore [1] found that the small-diameter AEC cyclone collector was more efficient for collecting small gin trash than was the large-diameter cyclone. For average trash feed rate of 0.080 pound per minute and an air velocity of about 3,000 feet per minute, and with the trash exit closed, they found that the small-diameter cyclone was 84.34 percent efficient. The collection efficiency for the large-diameter cyclone operating with the trash exit closed was 63.03 percent.

Baker and Stedronsky [2] found that the small-diameter cyclone was 99.94 percent efficient on large trash removed from stripper cotton when the cyclone operated with an inlet air velocity of approximately 3,000 feet per minute (the recommended velocity) and a trash feed rate of 1.4 pounds per minute. A statistically significant increase in efficiency from this 99.94 percent was found when the feed rate was increased to 40.8 pounds per minute At the higher feed rate, the efficiency was 99.96 percent. The dust concentration of the exhaust air was 0.002325 grain per cubic foot for the 1.4 pounds per minute feed rate and 0.044799 grain per cubic foot for the 40.8 pounds per minute feed rate.

Baker and Stedronsky also found that the 30-inch-diameter cyclone used in their experiments performed more efficiently at inlet air velocities of 3,000 feet per minute or lower.

EQUIPMENT AND INSTRUMENTATION

A schematic of the piping system for the test layout is shown in figure 1. The system consisted of a feed hopper, the cyclone, a gate valve, and a centrifugal fan.

The feed hopper (fig. 2) was designed, constructed, and calibrated so that the quantity of trash might be accurately controlled and uniformly introduced into the air stream. The feed hopper consisted of a grooved roller, 5 inches in diameter, connected to an electronic, variable-speed motor with dial-setting controls. The feed hopper also contained an elapsed time meter to record the operating time, and a vibrator to prevent bridging of the trash in the feed hopper and to assure uniform feeding. As an operating unit, the feed hopper allowed a variation of input feed rates from 0 to 20 pounds per minute. The input concentrations for this experiment, based on the cyclone's operating air volume were

[1] Harrel, E. A., and Moore, V. P. TRASH COLLECTING SYSTEMS AT COTTON GINS. U.S. Dept. Agr., ARS 42-62. 22 pp. 1962.

[2] Baker, Roy V., and Stedronsky, V. L. GIN TRASH COLLECTION EFFICIENCY OF SMALL DIAMETER CYCLONES. U.S. Dept. Agr., ARS 42-133. 16 pp. 1967.

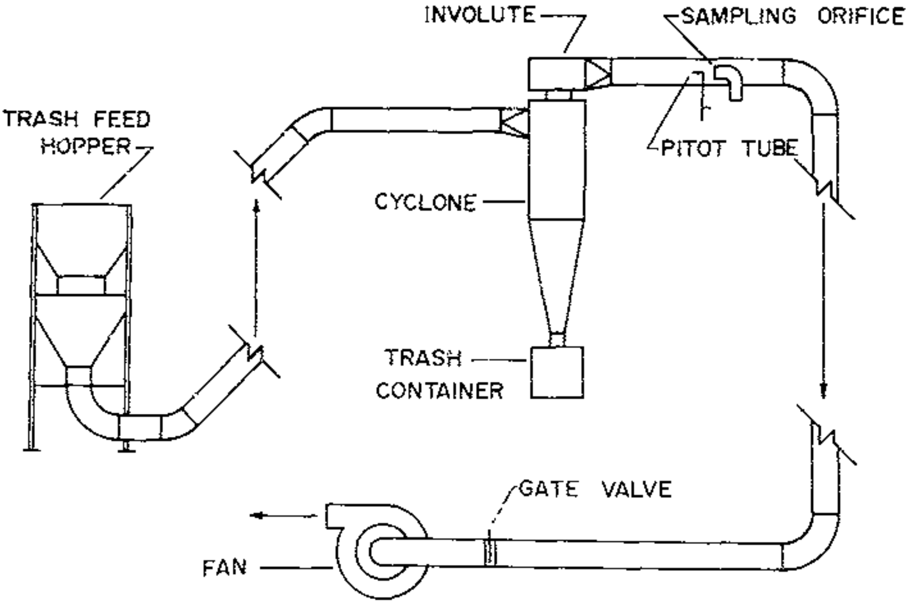

FIGURE 1.—Schematic of the piping system for the test layout.

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FIGURE 2.—Trash feed hopper for cyclone evaluation test.

equivalent to a range of from 4.4 to 189 grains per cubic foot of air handled.

To minimize the loss of trash from the system, the equipment was designed to operate on negative pressure. This required an airtight metal container attached to the trash exit of the cyclone. After each experiment the container was removed, dumped, cleaned, and replaced on the cyclone for the next experimental lot.

The cyclone was 16 inches in diameter and designed according to the AEC standards as described by Harrel and Moore and shown in figure 3. An involute was attached to the exit of the cyclone to minimize the turbulence of air leaving the cyclone. This allowed a more accurate measuring and sampling of the exhausted air by the pitot tube and sampling orifice.

The high-volume air sampler (fig. 4) was connected to the 2-inch sampling orifice by a 2-inch diameter flexible hose. In sampling the exhausted air, the high-volume air sampler was equipped with a

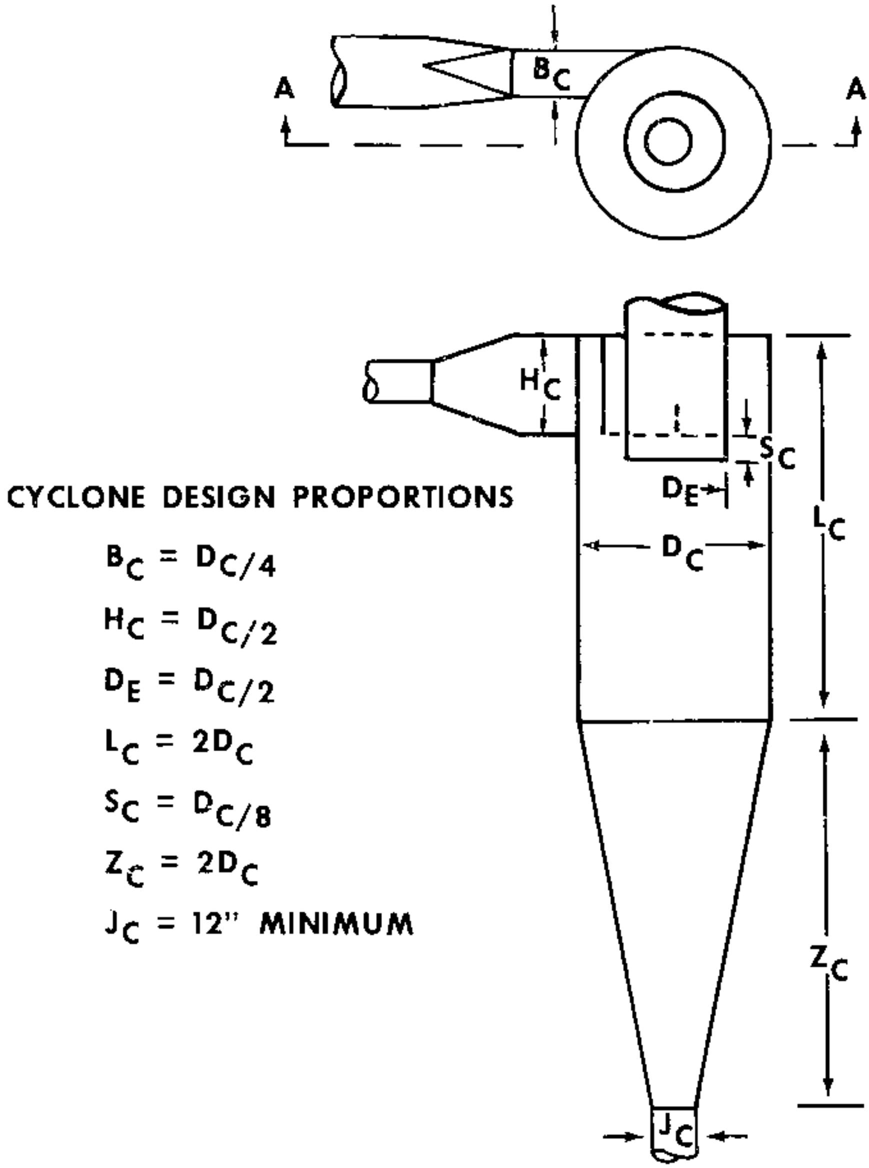

FIGURE 3.—Relative dimensions for an Atomic Energy Commission, small-diameter cyclone.

relay switch connected to the feed hopper. This relay switch insured that the sampling time would be the same as the feeding time and eliminated the possibility of the high-volume air sampler operating when not exposed to desired test conditions.

Samples were drawn through a 2-inch sampling orifice located 10 pipe diameters from the cyclone. Other equipment included a pitot tube and manometers, a variable-speed, high-volume air sampler, a barometer, and a hygrothermograph.

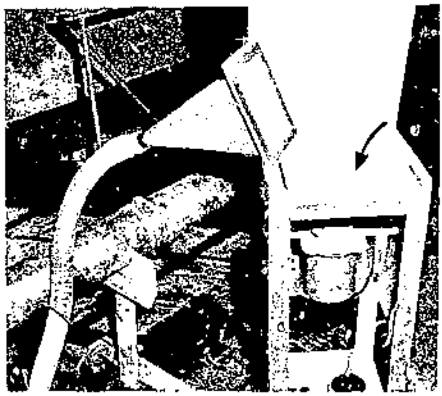

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FIGURE 4.—High-volume sampler showing Fiberglas filter.

METHODS AND PROCEDURES

Operational Procedures

The collection of the trash size groups required separate screening of regular gin trash. The two size groups were obtained by screening regular gin trash through 8- by 8- and 16- by 16-mesh corrugated wire. The gin trash from each screening was kept separate and precisely weighed before it was fed into the system. All trash was obtained from late-season, machine-picked Mississippi Delta cotton.

After the trash was introduced into the experimental system, the feed hopper and dial-setting controls were set at a precalibrated position for each desired test condition. When the feed unit was started, the time was recorded at both the feed unit and the high-volume air sampler. Time was also recorded at both locations upon completion of each test run. The actual input concentration to the cyclone was determined from the elapsed time, the weight of trash introduced, and the total air volume handled.

The sampling station was designed so that the 2-inch sampling orifice was centered in the 7-inch pipe with the open end facing into the direction of airflow (fig. 5). The pitot tube was also centered in the 7-inch pipe and located 4 inches ahead of the orifice opening. These units were installed so that the velocity pressure could be accurately determined immediately ahead of the sampling orifice. The desired settings for operating air volumes were obtained using a manometer connected to the pitot tube to determine the air velocity pressure, and a gate valve located 8 feet ahead of the centrifugal fan to vary the air volume. Velocity pres-

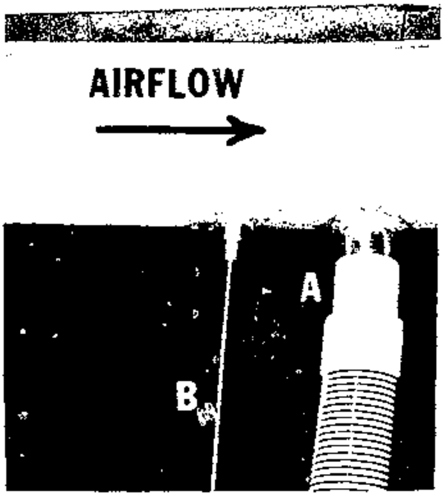

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FIGURE 5.—Air-sampling orifice and pitot tube.

sure, static pressure, relative humidity, barometric pressure, and temperature were recorded at the sampling station (fig. 6).

From these data air velocity and volume were calculated. The volume of air to be sampled through the high-volume air sampler for isokinetic sampling was determined from these data. (Isokinetic sampling is the condition where the air velocity in the sampling orifice is exactly equal to the velocity in the conduit being sampled.) With the aid of a variable voltage supply, the intake air volume through the sampler could be adjusted to any desired reading from 0 to 70 cubic feet per minute. For each test run, the velocity pressure was measured, and calculations were made for intake air volume. The high-volume air sampler was adjusted so that the exhausted air could be sampled isokinetically.

PN 2499

FIGURE 6.—Data recording station for velocity pressure, static pressure, relative humidity, barometric pressure, and temperature.

Before starting each test run, a clean, preconditioned, preweighed, Type A Fiberglas filter was placed on the intake of the high-volume air sampler. Upon completion of each test run the Fiberglas filter with all particles filtered from the air stream was removed from the sampler with extreme care. Each filter was carefully folded and placed in a protective envelope for analysis in the laboratory.

Laboratory Procedures

To determine the amount of dust collected, the filters were conditioned in the laboratory for 24 hours at 65 percent relative humidity and 70° F. and weighed both before and after use to the nearest one-thousandth of a gram on the analytical balance. The amount of dust collected was determined by subtracting the original clean filter weight from the final filter weight for each filter.

After correcting the intake volume of air through the high-volume air sampler to standard atmospheric conditions, the exhaust concentrations were calculated in grains per cubic foot of air handled. From these dust concentrations, along with time and the air volume handled by the system, the cyclone collection efficiency was obtained for all test conditions.

A count and size determination was made of the trash particles from the test filters using a microscope with an image-splitting measuring eyepiece attachment (fig. 7). In this image-splitting attachment, a prism system produces a double image of the microscope field of view. Rotating the micrometer screw rotates the prisms and produces a double image of the particle. The images of the particle traverse one another in the field of view. Particle size is determined by reading on the micrometer screw the amount of prism rotation necessary to place the double images of the object exactly edge to edge in the desired axis of measurement.

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FIGURE 7.—Image-splitting measuring eyepiece attachment used to measure particle size.

EXPERIMENTAL DESIGN

The 1968 experiment consisted of one trash size, three levels of inlet air velocity to the cyclone, and three trash input concentrations. The trash used in the experiment was sifted through 16- by 16-mesh corrugated wire and was classified as small gin trash. The experiment was conducted as a randomized complete block design and replicated three times.

In 1969 a similar experiment was conducted but a second trash size was added to determine the effects of trash size on cyclone collection efficiency and exhaust dust concentration. This second trash size was sifted through 8- by 8-mesh screen wire and was referred to as large gin trash. The only difference in the two trash sizes was that the large gin trash contained some larger particles along with the usual small particles. The 1969 experiment consisted of two trash sizes, and the same three levels of inlet air velocity and trash input concentrations. The experiment was a 3 by 3 by 2 factorial, arranged in a randomized complete block design and replicated three times.

The 1970 experiment was designed to study the same relationships as the previous experiments, but at lower trash input concentrations. These lower concentrations were in the range expected under normal cyclone operating conditions at a cotton gin. The four input concentrations averaged 4.4, 38.3, 70.5, and 105.0 grains per cubic foot of air handled. The same two trash sizes and three inlet air velocities were used as in the previous experiments. The 1970 experiment was a 3 by 4 by 2 factorial, arranged in a randomized complete block design and replicated three times.

Each experimental test lot consisted of an exact amount of gin trash. This quantity of material was placed in the trash feed hopper and uniformly introduced into the experimental setup (fig. 5). The high-volume air sampler was used to sample the exhaust air from the cyclone. For each experimental test lot, the weight of the material trapped on the filter of the high-volume air sampler was determined. From this data, along with the input concentration, air volume handled, barometric pressure, and temperature, the collection efficiency of the cyclone and the dust concentration in the exhaust air were determined.

EXPERIMENTAL RESULTS AND ANALYSIS

Total Gin Trash Composition

An anlysis by weight of total gin trash composition for particles larger than 150 microns was obtained by screening regular gin trash through 100- by 100-mesh stainless steel wire. Experimental results indicated that 96.49 percent of regular gin trash was too large to pass through the 100-mesh screen and was classified as gin trash greater than 150 microns in diameter. The amount of gin trash passing through the 100- by 100-mesh wire was classified as smaller than 150 microns and amounted to 3.51 percent by weight of the total trash composition. The trash particles smaller than 150 microns were separated into smaller categories with a sonic sifter with automatic pulse operation and various sizes of precision sieves (fig. 8).

The composition of gin trash in late-season, machine-picked Mississippi Delta cotton was as follows:

Particle Size *Microns*	Trash Content *Percent*
> 150	96.49
75 to 150	1.82
30 to 75	1.34
10 to 30	.34
< 10	.01
Total	100.00

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FIGURE 8.—Sonic sifter with automatic pulse operation used to separate trash particles smaller than 150 microns.

Cyclone Exhaust Dust Concentration

High Input Concentrations

The results of the 1968 and 1969 experiments which included average input concentrations of 115 to 189 grains per cubic foot were similar in analysis. By an analysis of variance on both 1968 and 1969 data, it was found that operating air velocity and input concentration significantly affected (at the 0.005 level) the dust concentration in the cyclone exhaust.

Evidence of this significant difference can be seen by comparing the treatment means shown in table 1. It should be noted that as the input concentrations increased and inlet air velocity exceeded 3,000 feet per minute, the dust concentration in the cyclone exhaust increased significantly.

An analysis of variance of the 1969 data for average input concentrations in the range of 134 to 189 grains per cubic foot revealed that the introduction of a different trash size had no statistically significant effect on the dust concentration in the cyclone exhaust.

Low Input Concentration

Data from the 1970 experiments, which included input concentrations from 4.4 to 105 grains per cubic foot, revealed that trash size, operating air velocity, and input concentrations had statistically significant effects on the dust concentration in the cyclone exhaust. All factors were statistically significant at the 0.005 probability level. The treatment means of these significant factors are shown in table 1.

A total composite curve of exhaust dust concentration representing data for both trash sizes and the entire range of operating air velocities and input concentrations is plotted in figure 9. The coefficient of determination for this curve is 0.56.

Cyclone Collection Efficiency

High Input Concentration

Analysis of variances for the 1968 and 1969 experiments involving average input concentrations of 115 to 189 grains per cubic foot revealed that operating air velocity had a significant effect on the collection efficiency of the cyclone. These effects were statistically significant at the 0.025-probability level. Both years' data show a

TABLE 1.—*Treatment means of exhaust dust concentration for experiments, 1968–70*

Year	Relative trash size	Mean dust concentration	Average inlet air velocity	Mean dust concentration	Average input concentration	Mean dust concentration
		Gr. per cu. ft.	*F.p.m.*	*Gr. per cu. ft.*	*Gr. per cu. ft.*	*Gr. per cu. ft.*
1968	Small	0.152	1890	0.137	115	0.145
			2880	.135	137	.146
			3780	.182	166	.164
1969	Small	.092	1800	.077	134	.071
	Large	.089	2727	.081	166	.097
			3470	.113	189	.103
1970	Small	.0443	1800	.034	4.4	.0031
	Large	.0347	2700	.039	38.3	.0248
			3600	.045	70.5	.0503
					105.0	.0799

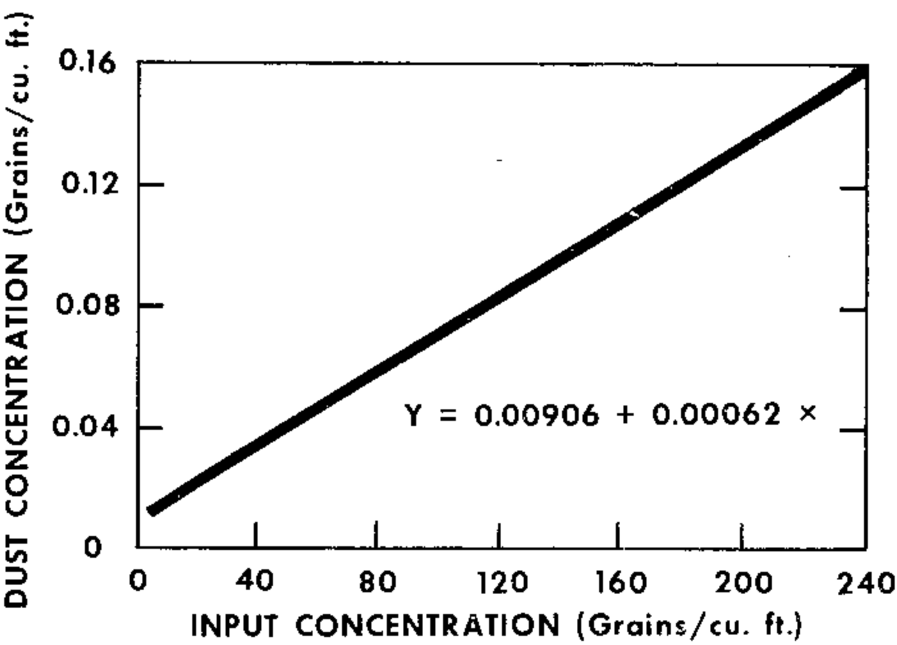

FIGURE 9.—Total composite curve of cyclone dust concentration representing both trash sizes and all test conditions.

sharp decrease in collection efficiency when the recommended inlet velocity of 3,000 feet per minute is exceeded.

The analysis for each year indicated that trash input concentration had no significant effect on the collection efficiency. The 1969 experiment revealed that the introduction of a different trash size had no statistically significant effect on the collection efficiency of the cyclone.

The treatment means of cyclone collection efficiencies are shown in table 2. It should be noted that data for 1968 represent collection efficiency on small trash only. Data for 1969 represent overall collection efficiencies for large and small trash.

Low Input Concentrations

Test data from the 1970 experiments involving input concentrations of 4.4 to 105 grains per cubic foot revealed that trash sizes, operating air velocity, and input concentrations significantly affected the collection efficiency of the cyclone. All factors were statistically significant at the 0.005-probability level. The treatment means for collection efficiency for these tests are shown in table 2.

A composite of all data indicated that the cyclone operated at an average collection efficiency of 99.927 percent. It is evident from the treatment means that the collection efficiency decreases as operating air velocity exceeds the recommended 3,000 feet per minute.

Size Distribution of Emitted Particles

1968-69-70 Experiments

Dust particles emitted from the cyclone and collected on the filters of the high-volume air samplers were measured and counted with the image-splitting microscope at-

TABLE 2.—*Treatment means of cyclone collection efficiency for experiments, 1968–70*

Year	Relative trash size	Mean cyclone efficiency	Average inlet air velocity	Mean cyclone efficiency	Average input concentration	Mean cyclone efficiency
		Pct.	*F.p.m.*	*Pct.*	*Gr. per cu. ft.*	*Pct.*
1968	Small	99.884	1890	99.893	115	99.868
			2880	99.894	137	99.888
			3780	99.863	166	99.896
1969	Small	99.944	1800	99.952	134	99.947
	Large	99.946	2727	99.949	166	99.942
			3470	99.934	189	99.947
1970	Small	99.923	1800	99.938	4.4	99.935
	Large	99.938	2700	99.934	38.3	99.936
			3600	99.920	70.5	99.929
					105.0	99.924

tachment. Accumulative percentages were used to express the particle size distribution. Particles collected by the air filters from one replication of the 1968 experiment, two replications of the 1969 experiment, and one replication of the 1970 experiment were measured and counted under the microscope. From each filter five separate dust slides were prepared, each from a different area of the filter. From each slide, several distinct areas were viewed, and the particles were measured and counted. A minimum of 25 separate areas were counted from each filter. Approximately 45,000 dust particles were viewed, measured, and counted during this 3-year study.

Regression equations, which were calculated for each factor for each experiment, were similar for particle size distribution. Because of this observation, all data were combined to yield a composite equation as follows:

$$Y = 107.57020 - 146.91170 \frac{1}{X}$$

where Y = accumulative percentage of particles and X = particle size in microns.

This equation is plotted in figure 10. This composite curve represents both trash sizes and all test conditions for the 3 years' experiments. The coefficient of determination for the above equation was 0.990.

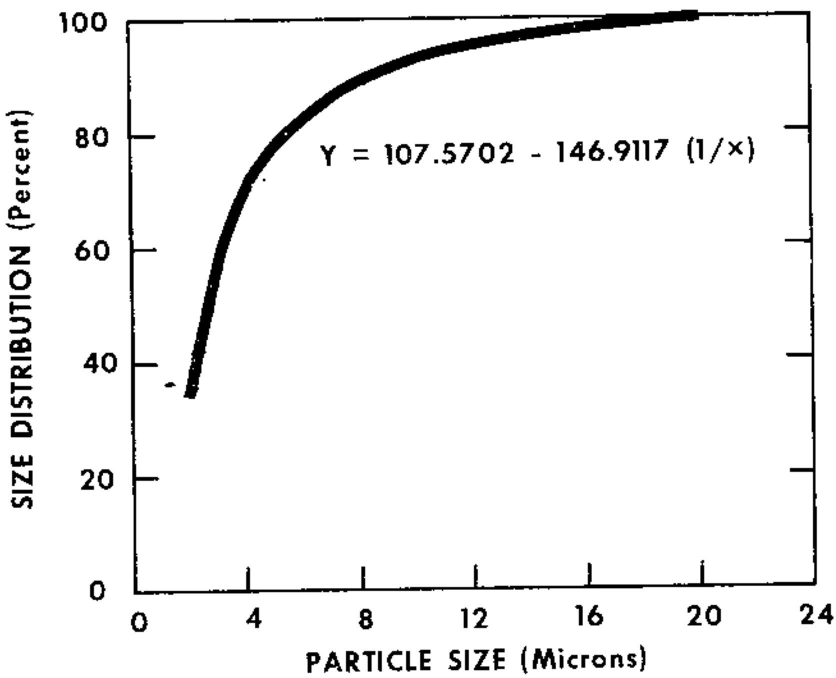

Figure 10.—Composite of accumulative particle size distribution for all test conditions.

SUMMARY AND CONCLUSIONS

Experiments conducted over a 3-year period at the U.S. Cotton Ginning Research Laboratory at Stoneville, Miss., show that the Atomic Energy Commission cyclone is virtually 100 percent efficient on particles larger than 20 microns in diameter. Particles smaller than 20 microns were partly collected in decreasing amounts as they became smaller. The AEC cyclone was found to have an average overall collection efficiency on small gin trash of 99.927 percent.

Other significant results obtained from the 3-year experiments were as follows:

1. Operating air velocities significantly affect the cyclone's collection efficiency with greatest efficiencies being in the range of 3,000 feet per minute.
2. For the high input concentrations, neither trash size nor input concentrations significantly affected the collection efficiency of the cyclone.
3. For input concentration normally encountered by the cyclone at a cotton gin (less than 105 grains per cubic foot) the experiments indicated that trash sizes, operating air velocities, and input concentrations had a significant effect on the collection efficiency of the cyclone.
4. For the high input concentrations, test results revealed that opening air velocities and input concentrations significantly affected the dust concentration in the exhaust air from the cyclone.
5. For the high input concentrations, the trash size had no significant effect on dust concentration in the exhaust air from the cyclone.
6. For the low input concentrations (less than 105 grains per cubic foot), data revealed that trash sizes, operating air velocities, and input concentrations significantly affected the dust concentration in the exhaust air from the cyclone.

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