Performance Characteristics for the 1D2D, 2D2D, 1D3D and Barrel Cyclones

by

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Abstract

The results of performance testing of four different cyclone designs are included in this paper. The 1D3D, 2D2D, 1D2D and Barrel cyclone designs are cyclone designs typically used to abate particulate matter (PM) emitted by cotton gins. The PM used for testing included three types of cotton gin trash (with and without lint fiber) and fly ash. The performance tests were conducted at different total trash inlet loading rates and at different fine dust inlet loading rates based on the fine dust fractions associated with each trash. The results were used to define the performance characteristics of different cyclone designs. With these characteristics, cotton ginners can utilize different cyclone designs for different processing streams to minimize PM concentrations emitted.

Introduction

The cotton ginning process separates lint fiber from cottonseed while removing the trash from seed cotton and lint fiber. The materials in this system are pneumatically conveyed with numerous processing streams and exhaust points. Cotton gins are considered a stationary emission source and regulated under the nuisance standard. They are required to have air pollution abatement equipment to comply with State Air Pollution Regulatory Agency's (SAPRAs') rules and regulations.

The office of Air Quality of the TNRCC requires all cotton gins not "grandfathered" to use Best Available Control Technology (BACT). A "grandfathered" gin is a facility that was in operation in 1972 and one that has had no changes in the system such that the total particulate matter (PM) emission rate has increased (Simpson et al, 1996). Baseline BACT (BBACT) has been defined by TNRCC as consisting of either 2D2D or 1D3D cyclones on all the centrifugal fan exhausts, and fine mesh screens on the condenser drums of all axial fan exhausts. The emission factor for a BBACT air pollution abatement system is 3.05 pounds of total suspended PM per bale (lbs/b). In cases where the TNRCC has received complaints or where the location of the gin is problematic, the TNRCC has required that reductions in the allowable emission rate (AER). A reduction in the AER is accomplished by installing more efficient air pollution abatement systems that have the effect of reducing the PM concentration being emitted. The process of reducing the AER is accomplished by the TNRCC permitting process and the air pollution abatement system that would reduce the AER to less than that associated with BBACT is defined as BACT "plus". The emission factor of a BACT "plus" system would be less than 3.05 lbs/b.

Cyclones have been used as the primary air pollution control equipment in the cotton ginning industry for many years. The most commonly used cyclone designs are the 2D2D cyclone (Shepherd and Lapple, 1939) and 1D3D cyclone (Parnell and Davis, 1979). There are two new cyclone designs recently developed for the cotton ginning industry. They are the 1D2D low pressure cyclone (Kaspar and Parnell, 1993 and Simpson et al, 1996) and the Barrel cyclone (Tullis.et al, 1997). The 1D2D cyclone was developed to replace the relatively inefficient covered condenser screens in order to respond to gins who were required to utilize BACT "plus". It is more efficient than the covered condenser drums and has a relatively low pressure drop. The goal of this cyclone design was to provide an economical alternative control device for axial-flow fan exhausts (Simpson et al, 1996).

According to the previous research conducted by Texas A&M University (TAMU), the1D3D and 2D2D are the most efficient collectors for fine dust. The 1D3D cyclone has been reported as a more efficient cyclone than the 2D2D for fine dust collection. As a consequence, a number of states have classified the 1D3D as BACT and in many cases required that all emitting points of a gin utilize the 1D3D for the abatement system.

One of the problems with the regulation of PM from cotton gins is the perception by SAPRA engineers that if a cyclone is "the most efficient", it will the best cyclone for all emitting points. In reality, a cyclone's performance characteristics are highly dependent upon the characteristics of the PM in the inlet air stream. Mihalski et al (1993) and Baker (1996) reported "cycling lint" near the trash exit for the1D3D and 2D2D cyclone designs when the PM in the inlet air stream contained lint fiber. Mihalski reported a significant increase in the exit PM concentration for these high efficiency cyclone designs and attributed this to small balls of lint fiber "cycling" near the trash exit causing the fine PM that would normally be collected to be diverted to the clean air exit stream. The development of the new 1D2D and barrel cyclone designs addressed this problem. Tulles et al (1997) and Flannigan et al (1997) reported significantly lower PM concentrations emitted by the barrel and 1D2D cyclone designs when the inlet air stream contained cotton gin trash/fine dust and the gin trash contained a relative high fraction of lint fiber (high lint gin trash/fine dust). These results suggest that if a SAPRA were to require that the 1D3D cyclone design be used on all emitting points of a cotton gin under the assumption that this design will result in the least PM emitted by the gin, they would be incorrect! A simpler, low pressure drop cyclone design (1D2D or barrel) would result in a lower emission rate of PM for all exhausts containing a significant fraction of lint fiber.

Flannigan et al (1997) defined a standard gin consisting of ten process streams similar to EPA AP-42 (1987). These are as follows:
(1) Unloading Separator
(2) 1st Push-Pull
(3) 2nd Push-Pull

(4) Trash
(5) Distributor Separator
(6) Overflow Separator
(7) 1st Stage Lint Cleaner
(8) 2nd Stage Lint Cleaner
(9) Battery Condenser
(10)Mote

The volume rate of flow (Q), trash/PM concentration (C) and the characteristics of the trash/PM entraining in the airflow vary for each process stream. In addition, each process stream will often have multiple emission points. The trash/PM entrained in the air stream of process streams 1,2,3,5 and 6 consists of fine PM (soil and small organic particles) with relatively low fractions of lint fiber. These process streams contain very little large trash. Process stream #4 will contain the largest concentration of large trash. The trash/PM entrained in process streams 7, 8, 9, and 10 will contain fine PM and a relatively high fraction of lint fiber with a relatively small fraction of large trash.

The hypothesis of this research was that different cyclone designs should be used for different process streams in a cotton ginning system to minimize the total PM emissions. In other words, a different cyclone design should be used for the low lint trash/PM process (LLT/PM) streams (1, 2, 3, 5, and 6) than are used for the high lint trash/PM (HLT/PM) process streams (7, 8, 9, and 10) to minimize the PM emission concentrations.

Objective

The overall goal of this research was characterize the different cyclone designs for varying inlet concentrations of HLT/PM, LLT/PM , and fine PM (fly ash). Cotton gin trash was obtained from the USDA Cotton Ginning Research Laboratories located in Messilla Park, N.M and Lubbock, Tex. The stripper gin trash from Lubbock, Tex. contained burs and sticks and was processed through a hammer mill to reduce the trash particle sizes to facilitate testing. Two trash types were obtained from Messilla Park, N. M. laboratory. These were collected from two different process streams. One was characterized as fine trash and the other coarse gin trash. The four cyclone designs were tested with different inlet concentrations of the three types of gin trash. Measurements were made of the fine dust (<100 μm) fraction of each gin trash prior to testing. The testing protocol for one test sequence was to maintain the fine dust concentrations between trash types. A second protocol was to maintain the total trash concentrations constant between trash types. The following were the objectives of this research effort:

1. Compare the testing results to determine which cyclone design is the best suited for LLT/PM.
2. Compare the testing results to determine which cyclone design is the best suited for HLT/PM.
3. Compare the testing results to determine which cyclone design is the best suited for Fine PM (fly ash).
4. Compare the testing results to determine which cyclone design is the best suited for fine or large trash without lint fiber.

5. Quantify the effect of the cycling lint on emission concentrations from 1D3D and 2D2D cyclone designs.

Testing Procedures

Cyclones

The testing focused on a 1D2D, 2D2D, 1D3D and Barrel cyclone designs. The cyclones tested were as follow:

1D2D ----- 6 inch diameter; (metal)	Barrel ----- 5 inch diameter; (metal)
2D2D ----- 6 inch diameter; (metal)	Barrel ----- 5 inch diameter; (plastic)
1D3D ----- 6 inch diameter; (metal) with 2D2D inlet	Barrel ----- 6 inch diameter; (metal)

Test Materials

There are ten processing streams for a cotton ginning system. The trash/PM characteristics entering the cyclone for the different process streams are very different. The trash can include varying quantities of large gin trash (burs and sticks), fine gin trash (leaf and bract), lint fiber, and soil particles. We combined the fine gin trash and soil into one category that we referred to as fine PM. We hypothesized that the fraction of fine PM and fraction of lint fiber in each test material would significantly impact the resulting emission concentration. The following is a rough classification of the different trash/PM characteristics entering the cyclone for our testing:

1. fine dust - soil and fine (<100 μm) trash particles. We used fly ash to test the performance of the different cyclones for fine dust only. The fly ash will typically have a lower mass median diameter PM than the soil and fine dust fraction of gin trash. Hence, the emission concentrations will likely be higher than that associated with gin trash fine dust. Typically, process streams 1, 2, 3, 5, and 6 could have trash/PM characteristics entering the cyclone that would predominantly be fine dust.
2. LLT/PM (low lint trash/PM) – This material can vary between process streams by the fraction of fine PM present. If the motes are not added back to the trash going to the burr hopper, process stream 4 would have this trash/PM characteristic. Depending upon the mass of trash present, process streams 1, 2, 3, 5, and 6 could have material entering the cyclone with this description.
3. HLT/PM (high lint trash/PM) – All exhausts associated with lint cleaner and battery condensers, and mote fan systems – process streams 7, 8, 9, and 10.

One goal of this research has been to use “real world” materials of cotton gin trash to evaluate different cyclone designs. The testing materials were as follows:

Trash A----- gin trash (hammer milled) from Lubbock, TX. (see Fig.1)
It is a HLT/PM material.
Trash B----- picker gin trash (coarse) from Mesilla, NM (see Fig.2)
It is a LLT/PM material.
Trash C----- picker gin trash (fine) from Mesilla, NM (see Fig.3)
It is a LLT/PM material.

Trash D----- trash A after picking out lint fiber
Trash E----- trash B after picking out lint fiber
Trash F----- trash C after picking out lint fiber

The purpose of generating trash D, E and F was for testing material to determine the cycling lint effect on emission concentrations of different cyclone designs. This was accomplished by comparing the testing results (emission concentrations) between materials A, B, and C with D, E, and F.

An air wash system was constructed to wash the trash in order to determine the fine dust (<100 μm) fractions of each test material. The system consisted of a fine mesh (100μm openings) screen box that was enclosed in a wooden box. A filter was placed on a filter holder between the wooden box and the fan/motor. The trash was sealed in the screen box and the wooden box was closed. The system was started and the motor pulled air through the system while the screen box rotated. Particulate matter less than 100μm were pulled through the fine mesh screen and accumulated on the filter. The screen box was rotated to allow all particles less than 100 μm to be separated out. By weighing the filter before and after air washing, we obtained the fine dust (<100μm) contents in the trash. The fine dust fractions were determined by dividing net fine dust weights by sample weights.

A Combustion Engineering TYLER, Inc. Portable sieve shaker model RX-24 was used to obtain lint fiber contents of each gin trash. The results of fine dust contents and lint fiber contents for each test material are shown in table 1.

A Coulter Counter Multisizer was used to perform particle size distributions (PSD's) on 3 representative samples of the fine dust components of each trash (see Fig. 4, 5 and 6). The PSD's indicated that 20% of fine dust component of trash A was less than 10 μm aerodynamic equivalent diameter (AED). By multiplying this fraction times the fine dust fraction (Table 1) we determined that 2.4% of trash A was less 10 micrometers AED (PM10). For trash B, 22% of fine dust was less than 10 μm (0.62% PM10); for trash C, 16% of fine dust was less than 10 μm (3.9% PM10).

Fly Ash
Tests were conducted using fly ash to determine cut points of the cyclones and emission concentrations. The fly ash PSD is shown in Fig. 7. The fly ash contained 34% PM10.

Testing

Setting the air flow rates of the testing systems:
A testing system (Fig.8) similar to the one developed and constructed by Mihalski (1992) was used for testing. According to the previous research at Texas A & M University, different cyclone designs should be used at the different design velocities. A dramatic increase in exit concentrations has been observed at velocities significantly higher and lower than the design velocities (Parnell, 1996). The air-flow rates of the testing

systems were determined by using Texas A & M cyclone design (TCD) velocity for each cyclone design. The design velocities and air-flow rates are shown in table 2.

Tests were conducted to evaluate the performances of different cyclone designs with a varying inlet loading rates at design velocities. The cyclone collection hopper and dust filter were placed in their respective positions, and the system components were connected and sealed. The pressure drop across the orifice meter was monitored during testing to ensure that the proper air flow rate was maintained during the test. The filter was conditioned in an environmental chamber for 24 hours and weighed before and after testing to determine total penetrating weights. Additional replications were made with special filters to facilitate determination of PSDs. The feeding rates, emission concentrations and collection efficiencies were determined with the following equations:

$$F = L * Q \qquad (1)$$

where

F = Feeding rate (g/min),
L = Total inlet loading rate (g/m^3), and
Q = System air flow rate (m^3/min).

$$EC = \frac{W2-W1}{Q * T} * 1000 \qquad (2)$$

where

EC = Emission concentration (mg/m^3),
W1 = Pre-weight of filter (g),
W2 = Post-weight of filter (g), and
Q = system air flow rate (m^3/min .)
T = Testing time for each sample (min)

$$EF = \frac{TD-FD}{TD} * 100 \qquad (3)$$

where,

EF = Cyclone collection efficiency (%),
TD = Total inlet loading (g), and
FD = Total filter loading = W2-W1 (g).

Three or more tests were performed for each inlet loading rate, to obtain an average emission concentration. For each test, testing time was 3 minutes. The system was cleaned between tests.

PSD's were obtained for a minimum of two of the exposed filters. These PSD's were used to determine fractional efficiency curves of each cyclone design, and to determine PM10 emission concentration.

The inlet and outlet concentration of a certain size range were calculated using inlet and outlet dust concentrations and the fraction of particulate in that size range. The outlet concentration was divided by the corresponding inlet concentration for each particle size range and subtracted from one, the resulting values were the fractional efficiencies for each particle size range. Equation (4) shows this calculation:

$$\eta j = (1- Con._{out\,j} / Con._{in\,j}) \text{ ----------------------- } (4)$$

where

ηj = Fraction efficiency of j^{th} particle size range,
$Con._{out\,j}$ = oulet concentration of j^{th} particle size range, and
$Con._{in\,j}$ = inlet concentration of j^{th} particle size range.

The outlet concentrations were multiplied by the cumulative fraction of particulate less than 10 μm in order to obtain an estimate of PM10 concentrations.

Setting the inlet loading rates:
Tests were conducted to determine the performances of the cyclones at the same fine dust inlet loading rates (1.5 g/m^3) and at the same total trash inlet loading rates (15 g/m^3).

Protocol 1. The same fine dust inlet loading rates at 1.5 g/m^3
It was hypothesized that the emission concentration for a specific cyclone design would be directly related to the fine dust inlet loading. Since there is a large difference of fine dust contents in the different gin trash used for test materials, the total trash inlet loading rates varied significantly when the goal was to maintain a constant fine dust inlet loading rate. The total inlet loading rates for each trash at the same 1.5 g/m^3 fine dust inlet loading rates were as follows:

Trash A -----12.79 g/m^3	Trash D ------ 11.36 g/m^3
Trash B ----- 53 g/m^3	Trash E ------ 32.12 g/m^3
Trash C ----- 6.13 g/m^3	Trash F ------- 5.46 g/m^3

Fig.9 illustrates this difference.

Protocol 2. The same total trash inlet loading rates at 15 g/m^3
For each trash, the fine dust inlet loading rates at the same total inlet loading rates were as follows:

Trash A ------ 1.76 g/m^3	Trash D ------ 1.98 g/m^3
Trash B ------ 0.43 g/m^3	Trash E ------ 0.7 g/m^3
Trash C ------ 3.70 g/m^3	Trash F ------ 4.1 g/m^3

Fig. 10 shows the difference of the fine dust inlet loading rates for the trash/PM test materials at a constant (15 g/m^3) total inlet loading rate.

Test Results and Discussion

Average Emission Concentration

1D3D & 2D2D Cyclones

Tables 3 –16 contain the emission concentrations and collection efficiencies for the tests conducted on the 1D3D and 2D2D cyclone designs. The results suggest that with the exception of the tests conducted with fly ash, there was no difference between the emission concentrations for the 1D3D and 2D2D for all tests with trash materials A-F. However, the fly ash results indicate that the 1D3D cyclone design is significantly more efficient for fine dust collection – 50 mg/m^3 (1D3D) versus 67 mg/m^3 (2D2D). This would suggest that the cut-point of the 1D3D is significantly lower than the 2D2D cyclone design. Another significant observation was the number of times 1D3D and 2D2D cyclone designs "choked" with trash materials A and B. The choking of these two high efficiency cyclones for trash A was attributed to the high fraction of lint fiber and the cycling lint problem. Choking with trash B was likely a consequence of the very high trash concentrations of the inlet air stream (53 g/m^3 (trash B) versus 13 g/m^3 (trash A). The 53 g/m^3 was needed in order to maintain the fine dust concentration for trash B at 1.5 g/m^3. It was observed that lint fiber and bulky trash clumped together in the cyclone and developed into a ball which remained near the dust exit which ultimately resulted in a cyclone choke.

The average emission concentration associated with testing 1D3D and 2D2D cyclone designs with trash A, B and C are 2 to 3 times larger than concentrations obtained with trash D, E and F. Since trash materials D, E and F are identical to A, B and C, respectively, with the exception that the lint fiber had been removed, it is apparent that the lint fiber fraction in the trash affected the 1D3D and 2D2D emission concentrations. The most profound effect can be seen by comparing the emission concentrations for trash A and D for the 1D3D or 2D2D cyclone designs. For example the average emission concentration for the 1D3D was 27 mg/m^3 (trash A, table 3) versus 7 mg/m^3 (trash D, table 6). Trash A had the highest lint fiber fraction.

The difference between 1D3D or 2D2D emission concentrations with trash C and F at 1.5 g/m^3 fine dust inlet loading rates (6 g/m^3 total trash inlet loading rate) are much lower than that at 15 g/m^3 total trash inlet loading rates. The emission concentration in table 5 for the 6 and 15 g/m^3 loading rates were 23 and 90 mg/m^3 , respectively. Whereas, the emission concentration in table 8 for the 6 and 15 g/m^3 loading rates were 10 and 37 mg/m^3 , respectively. This suggests that as the total trash feed rate increased (with 1%

fiber), the emission concentration of 1D3D or 2D2D increased more rapidly. This was attributed to the cycling lint. Cycling lint greatly affects the emission concentrations and collection efficiencies of 1D3D and 2D2D cyclone designs.

For trash D, E and F (without lint fiber or with much lower lint fiber), 1D3D and 2D2D had higher collection efficiencies and much lower emission concentrations both at the same fine dust inlet loading rates (1.5 g/m^3) and at the same total trash inlet loading rates (15 g/m^3). Comparing the 15 g/m^3 emission concentration results for trash D, E, and F (tables 6, 7, and 8), there was no difference between the emission concentrations (11 mg/m^3)for the 1D3D cyclone with trash D and E tests even though the fine dust fraction was much higher for trash D (13% versus 5%). However, the results from the trash F tests suggests that the fine dust fraction does play a role in the emission concentration (table 8). At the same inlet loading rate, the emission concentration increased from 11 to 37 mg/m^3 for a fine dust fraction of 27%.

For fine dust only or LLT/PM, the 1D3D and 2D2D had low emission concentrations and relatively high collection efficiencies.

1D2D Cyclone

The test results of 1D2D cyclone design are included in tables 17 - 23.

For trash A (HLT/PM) and trash C (LLT/PM), the 1D2D cyclone design had lower average emission concentrations for both at the same fine dust inlet loading rates (1.5 g/m^3) and the same total trash inlet loading rates (15 g/m^3). (See tables 3, 5, 10, 12, 17, and 19.) There was no cycling lint effect on 1D2D emission concentrations.

For trash B (low lint fiber / bulky trash) and trash E (large trash without lint fiber), the 1D2D cyclone design had higher emission concentrations for both the1.5 g/m^3 fine dust inlet loading and the 15 g/m^3 total trash inlet loading. (See tables 4, 7, 11, 14, 18, and 21.)

The results of testing the 1D3D cyclone for the HLT/PM (Trash A) compared to LLT/PM (Trash D) were dramatic with emission concentrations decreasing from 27 to 7 mg/m^3 (tables 3 and 6). This reduction in emission concentration was attributed to removing the lint fiber from trash A to form trash D. However, when the 1D2D cyclone was tested with trash D, the average emission concentration was 17 mg/m^3 (table 20) suggesting that the 1D2D cyclone design is not as good as the 1D3D for trash without lint fiber. Again, for very high fine dust loading without lint fiber (trash E @ 27% fine dust) the 1D2D results were not as good as the 1D3D or the 2D2D – 17 versus 38 mg/m^3 (tables 7 and 21).

The 1D2D cyclone design emission concentrations with fly ash were higher than that of 1D3D and 2D2D suggesting that it is not as good fine dust collector as either the 1D3D or the 2D2D. It is a much better collector for HLT/PM.

Barrel Cyclones

There were three Barrel cyclones used for testing. The test results of the Barrel cyclone design are included in tables 24 - 43.

Three Barrel cyclones used in testing were the same design, but there were some problems with 5-inch metal Barrel and 6-inch metal Barrel cyclones. The vortex inverter of 5-inch Barrel cyclone was fixed. We were not able to adjust the inverter to the desire height and it was not located at the optimum placement. For 6-inch metal Barrel cyclone, there was a big deviation of the axis of vortex inverter relative the cyclone's axis. This problem resulted in the big trash remaining in the relative narrow opening between inverter and the wall of the cyclone. This problem was not detected until after the test were conducted and is the reason why there were higher emission concentrations for the 6-inch Barrel cyclone with trash B, C, and F (table 46) compared with 5-inch metal Barrel cyclones. If the vortex inverter and the cyclone's vertical axis were aligned and the inverter were positioned properly, the 6-inch metal Barrel cyclone would have the same performance as 5-inch metal Barrel cyclone.

The roughness of the cyclone inside surface greatly affected the cyclone's emission concentrations, especially when the cyclone was tested with HLT/PM. The 5-inch plastic Barrel cyclone had the lowest emission concentrations of all cyclones tested for trash A, B, and C. (See table 46.) These results were attributed to the smooth inside surface of the plastic Barrel cyclone.

For trash A, B, C, D, E, and F, the Barrel cyclone (5P) had lowest emission concentrations of all cyclones tested. (See table 47.) For fly ash, the 5-inch plastic Barrel cyclone had an average emission concentration of 76 mg/m^3 compared to 75 and 67 mg/m^3 for the 1D2D and 2D2D cyclone designs, respectively. This suggests that the cut points of these three cyclones are similar.

Collection Efficiencies

Table 44 shows the total trash collection efficiencies of the cyclones and the fine dust (less than 100 μm) collection efficiencies for all the cyclones tested. The fine dust collection efficiencies were obtained from the cumulative values of cyclone fractional efficiencies multiplied by the inlet fraction of particulate in a certain size range.

PM10 Emission Concentrations & Cut-Point

The table 45 shows the PM10 emission concentrations of the cyclones for each test material and an estimate of the cut-points for each of the cyclones tested.

Comparisons of Average Emission Concentration and PM10 Concentrations

Table 46 and 47 allow for comparisons of the emission concentrations of different cyclone designs. The following observations were noted :

1. For trash B, the Barrel cyclone design had lowest emission concentrations and PM10 concentrations without the choke problem. The Barrel cyclone is the best suited for bulky gin trash with low lint fiber.
2. For trash A and C, the 1D2D cyclone design had the lowest emission concentrations and PM10 Concentrations both at 1.5 g/m^3 fine dust inlet loading rates and at 15 g/m^3 total trash inlet loading rates. There was minimum effect of cycling lint on emission concentrations for this cyclone design..
3. 1D3D and 2D2D emission concentrations and PM10 concentrations significantly decreased from trash A, B and C to trashes D, E and F both at 1.5 g/m^3 fine dust inlet loading rates and at 15 g/m^3 total trash inlet loading rates. These results suggest that as lint fiber fraction of the trash increases, the emission concentration will increase at a rate that is not linear.
4. The difference between 1D3D and 2D2D emission concentration with trash C and trash F at 1.5 g/m^3 fine dust inlet loading are much lower than that at 15 g/m^3 total trash inlet loading rates. As the lint fiber contents in the trash increased , the emission concentrations of 1D3D and 2D2D cyclones increased substantially because of the increase in cycling lint.
5. Cycling lint greatly affected the emission concentrations and PM10 concentrations of 1D3D and 2D2D.
6. Cyclone emission concentrations are not only a function of inlet fine dust loading rates. There is a suggestion that the emission concentration is a function of total trash inlet loading rates.
7. 1D3D and 2D2D designs had the lowest emission concentration and PM10 concentrations with fine dust trash or large trash without lint fiber.

Conclusion

1. The 1D3D and 2D2D cyclone designs are high efficiency collectors for fine dust and large trash, but lint fiber will greatly affect their performance. The cycling lint problem was observed in the 1D3D and 2D2D with trash A and C. It resulted in large emission concentration increase. There were choking problems with trash B for the 1D3D and 2D2D cyclone designs, even though the lint fiber content in this trash was much lower.
2. No cycling lint affected the 1D2D performance. The 1D2D cyclone design had much lower emission concentrations with trash A (high lint fiber / fine dust) and trash C (low lint fiber / high fine dust) than all other cyclones tested, except for the plastic Barrel cyclone.
3. Barrel cyclone had low emission concentration with lint fiber /bulky gin trash, but further research needs to be done to find the best location of the vortex inverter and to find a good way to insure that the axis of cyclone and inverter aligned.

Guidelines for cotton ginners to use different cyclone design:

The concept of using the different cyclone designs for the different processing streams in a cotton ginning system depending upon the trash characteristics in the stream is worthwhile.

(1). Barrel cyclone is the best design for lint fiber/large trash.
(2). 1D2D cyclone is the best design for lint fiber/ fine dust gin trash.
(3). 1D3D and 2D2D are the best designs for fine dust only or large trash without lint fiber.

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