MODIFICATIONS FOR 1D3D CYCLONES

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Abstract

A 2D2D type cyclone inlet was substituted for the tall, narrow inlet of the standard 1D3D cyclone in an attempt to overcome choking problems when using the standard flat-top inlet transition, or performance problems when using an inverted transition. This inlet modification lowered the modified cyclone's emissions by 8 to 9%, and slightly reduced its static pressure requirements. The 1D3D cyclone equipped with a 2D2D inlet operated satisfactorily with either the standard 1D3D type air outlet duct, or the shorter 2D2D type outlet. The size of the cyclone's trash exit significantly affected PM10 emissions. A larger (D/3) size exit produced PM10 emissions that were about 8% lower than those resulting from use of the standard, small-diameter (D/4) exit.

Introduction

Many cotton ginners have been troubled with chokages when operating 1D3D cyclones equipped with the original flat-top inlet transition. For heavily loaded cyclones, many ginners now turn the original transition upside down so that most of the trash is conveyed along the flat bottom of the transition. While this arrangement keeps the transition swept free of troublesome accumulations, it also forces much of the trash to enter the cyclone near the bottom of the upper barrel and outlet duct. Recent research indicates that lowering the entry point of a cyclone in such a manner may adversely affect its particulate collection performance (Mihalski et al., 1994; Hughs and Baker 1996).

The shorter and wider inlet on a 2D2D cyclone allows the use of a compact transition that encourages a gentle expansion and transition of the airstream without creating dead air spaces or excessive eddy currents. These simple inlets and transitions have also, over the years, proven themselves to be relatively trouble free in thousands of cotton gin applications. Hughs and Baker (1996) and Zwicke et al. (1997) investigated the possibility of replacing the tall, narrow inlet of the standard 1D3D cyclone with a 2D2D type inlet. This work, using 4-inch diameter and 12-inch diameter laboratory models, indicated that the substitution of inlets had no adverse effect on cyclone performance. Actually, in these small-scale studies the cyclones equipped with the 2D2D inlet performed significantly better than the standard 1D3D cyclone. Therefore, one of the purposes of the research described in this report was to further investigate the impact of the 2D2D type inlet on 1D3D cyclone performance using full-scale (34-inch dia.) cyclones. In addition, we wanted to determine what effect air outlet duct length had on the performance of a modified 1D3D cyclone. The outlet duct used in the previous study was the long type normally used in the standard 1D3D cyclone. We wanted to determine whether it was necessary to continue to use the long outlet duct in 1D3D cyclones equipped with 2D2D inlet, or whether we could use the shorter outlet duct found in 2D2D cyclones.

Yet another purpose of this research was to investigate the role that trash exit size has on cyclone performance, especially as related to the recirculation problem. Recent research studies (Baker et.al., 1996) have documented a troublesome recirculation problem in the lower cone section of 1D3D cyclones. Recirculation was found to be related not only to the amount of fiber in the gin trash, but also to the amount of air that was inadvertently induced into the trash exit when the trash receiving system was not perfectly sealed. The cone of the 1D3D cyclone appears to be particularly susceptible to this problem because of its tendency to create a large negative pressure just below the trash exit. Recirculation of trash in the lower cone not only increases the cyclone's dust emissions, but it also causes the cone to erode much more quickly than normal.

Equipment and Materials

Test Cyclones

Six cyclone configurations were evaluated in this experiment, Figure 1. The six configurations were the product of three cyclone body types times two types of lower cones. The body types included (1) a standard 1D3D body, (2) a modified 1D3D body equipped with a 2D2D inlet and a standard 1D3D outlet duct, and (3) a modified 1D3D body equipped with a 2D2D inlet and a short 2D2D type outlet duct. All cyclone bodies were 34 inches in diameter. The cones of all cyclones were two-piece units consisting of an upper section that was 68 inches in height and a lower tail cone section that was 34 inches in height. The upper cone sections used for all cyclone configurations were 34 inches in diameter at the top and 17 inches in diameter at the bottom, producing a sidewall taper of 7.1 degrees. Two types of tail cone sections were evaluated. A standard tail cone with a 8.5-inch diameter trash exit was compared to a modified tail cone having a 11.3-inch diameter exit. The taper of the side walls of the standard tail cone was 7.1 degrees while the taper of the tail cone with the enlarged trash exit was 4.8 degrees. All cyclone bodies and cone sections were constructed of 20 ga. galvanized sheet metal, and each cyclone body was

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equipped with a flat-top inlet transition that was 36 inches in length.

Test Setup

The trash handling system used in this study was similar to that used in earlier studies (Baker et al., 1995). Basically, an auger feeder was used to feed gin trash into a 12-inch diameter air suction line leading to a centrifugal trash fan. A cone shaped air control device at the inlet of this air line was used to regulate air flow. From the fan the trash was delivered to the unmodified cyclone, or to one of the modified cyclones by means of routing valves located in the trash conveying line. Trash collected by the cyclones dropped into a 12-inch diameter trash auger positioned under the Laboratory's bank of cyclones. The trash auger was covered with metal lids, and the other cyclones not used during the test were sealed off from the auger by means of a valve located under each pair of cyclones. Even though we attempted to seal the auger by these means, a considerable amount of air leaked into the auger when the test cyclones created a negative static pressure at their trash exits. Air leaked into the auger around the metal lids as well as through a vacuum dropper that was used to drop the trash into a high-pressure trash conveying line leading to a conventional overhead bur hopper.

Sampling Procedures

The air discharging from each cyclone was directed through an 18-inch diameter exhaust line to dust sampling ports located about 3 feet from the end of the line. The line was arranged in a "candy cane" design to provide a suitable sampling location for an EPA Method 201A sampling probe (EPA, 1990). A standard Method 5 sampling train equipped with an in-stack sizing cyclone was used to isokinetically collect samples at four traverse points across each of 2 diameters (8 points) in the 18-inch diameter exhaust lines. The sampling location was 20 feet (13.3 diameters) downstream from the 90° elbow on the cyclones' 17-inch-diameter exhaust outlets, and about 3 feet (2 diameters) from the end of the exhaust lines (Baker et al. 1995).

Method 201A requires the use of a constant air sampling rate in order to maintain a constant 10µm cut point (D_{50}) in the sizing cyclone. Isokinetic sampling must be maintained within ± 20% by selection of appropriately sized sampling nozzles. Fortunately, in our case, the velocity heads at the 8 sampling points did not vary excessively and we were able to use the same sampling nozzle at all points without violating the isokinetic sampling requirements. The particulate that passes through the sizing cyclone is collected by a final glass fiber filter, and this material along with that removed by washing the cyclone's outlet tube with acetone is by definition referred to as PM10 in Method 201A. The particulate collected by the sizing cyclone, and that removed by washing the interior of the sampling nozzle and cyclone body, is considered to be larger than PM10. The sum of these 2 size ranges is referred to as "total suspended particulate" (TSP).

Pre-Test Calibrations

Pitot traverses were made prior to these tests to evaluate the sampling locations, to leak check the system, and to calibrate the standard pitot tube mounted in the center of the exhaust line ahead of the particulate sampling location. In addition to these pre-test measurements, we also checked the calibration of the dry gas meter used in the stack sampling train with a wet test meter.

Trash Material

The trash used in these experiments was from stripper harvested cotton that had been ginned in our Laboratory's full-scale gin plant during the 1996-97 ginning season. It consisted of trash that had been collected with our battery of 2D2D cyclones. Basically, the trash consisted of material removed by our unloading separator, airline cleaner, two hot-air inclined cleaners, two stick extractors, an overflow separator, a separator over the distributor, the feeder and gin stand, and two saw-type lint cleaners. The trash material contained 1.7% fiber and 3.3% dust smaller than 100 microns in size. Initially, the trash was collected in a conventional overhead bur hopper. It was then dumped into a truck and delivered to a nearby metal building for storage until needed in these studies. Trash feed rates of approximately 890 lb/h were used in these tests to provide a typical stripper-trash loading rate for the cyclones of about 4.6 lb/1000 ft^3 of conveying air.

Data Analysis

This study was statistically analyzed as a factorial experiment consisting of three cyclone body types times two sizes of trash exits. The six cyclone configurations were replicated five times in a randomized complete block arrangement. Standard analysis of variance techniques were used to analyze the data, and statistically significant differences among the three cyclone body types and between the two trash exit sizes were determined by Duncan's Multiple Range Test at the 0.10 level of significance.

Results

Air Flow Characteristics

The static pressure drop across the six cyclones configurations are presented in Table 1 for standard air at a cyclone inlet velocity of 3200 fpm. These measurements, made prior to emission testing, were made without the exhaust sampling ducts and without trash in the system. Static pressure drop was not affected by trash exit size or outlet duct length, but there were modest differences in pressure drop due to cyclone inlet type. The cyclones equipped with the 2D2D inlets produced lower static pressure drops, by 0.6 to 0.7 inch w.g., than did the conventional 1D3D cyclone. Similar differences and trends in cyclone static pressures were measured during particulate emission testing, Table 2.

The static pressure at the trash exit ranged from -0.3 to -0.4 inches w.g. for the large trash exits, Table 1. Corresponding static pressures under the standard 1D3D trash exits were much more pronounced, and ranged from -1.6 to -2.1 inches w.g. The larger trash exit diameter (D/3) was apparently responsible for a near neutral static pressure under the modified tail cone sections.

At the beginning of each emission test run, the air flow into the test cyclones was adjusted to provide an initial inlet air velocity of 3200 fpm. The required air flow for the 34-inch diameter cyclones used in this study was 3200 cfm. Air flow varied slightly during the tests due to the presence of trash in the air stream. Also, the volume of air exhausting the cyclone was affected slightly by the amount of air induced into the cyclones at their trash exits, Table 2.

Very little air was induced into the cyclones equipped with the modified tail cones because of the absence of strong negative pressures at their trash exits. The exhaust air flow data in Table 2 show an average exhaust volume for the large trash exits (modified tail cones) of 3190 cfm--a value very near the initial input air volume of 3200 cfm. However, the cyclones equipped with the small trash exits discharged an average of 3310 cfm, or 3.8% more air than those with the larger exits. These results suggest that this extra exhaust air was probably induced into the cyclones through their trash exits as a result of the large negative pressures created under the small, standard trash exit holes.

Particulate Emissions

It has been found in past research that air induced into a cyclone through its trash exit can adversely affect its particulate collection performance (Baker et al. 1996). The air (3.8%) induced into the 1D3D cyclones equipped with the small trash exits in this year's test was apparently large enough to adversely affect collection performance. The small, standard trash exits produced PM10 emissions that were significantly higher by about 9% than those produced by the large, modified exits, Table 2. There were, however, no significant differences due to exit size in emissions greater than PM10. Total particulate emissions, being more heavily influenced by PM10 that by the larger material, were also significantly affected by trash exit size.

PM10 emissions were also significantly affected by cyclone inlet type. The two cyclones equipped with the 2D2D type inlet produced PM10 emissions that were 8 to 9% lower than that of the cyclone equipped with the standard 1D3D type inlet. Cyclone inlet type, however, had no statistically significant effects on emissions larger than PM10 or on total emissions. Generally, the emission results of the two cyclone inlet types in this study were similar to those found in earlier small-scale tests (Hughs and Baker 1996; Zwicke et al., 1977). The results of these past studies and the current one, when taken together, suggest that a 2D2D type inlet has no adverse effects on the emission collection performance of the 1D3D cyclone. Actually, there was some evidence in all of these studies that the 2D2D type inlet slightly improved the performance

The 1D3D and 2D2D type outlet ducts in the modified cyclones produced very similar emission results. Consequently, this study indicates no particular preference between 1D3D and 2D2D type outlet ducts for 1D3D cyclones equipped with the 2D2D type inlet. Apparently, as long as the bottom of the outlet duct protrudes below the bottom of the cyclone inlet by a distance of at least D/8, the overall length of the outlet duct is not a critical factor with respect to cyclone performance.

Summary

Six cyclone configurations were evaluated to: (1) investigate the impact on performance of modifying the 1D3D cyclone by replacing its standard tall, narrow inlet with a shorter and wider 2D2D type inlet, (2) determine what effect the length of the outlet duct had on the performance of a modified 1D3D cyclone, and (3) evaluate a larger than normal trash exit opening size. The use of a 2D2D type inlet on a 1D3D cyclone reduced PM10 emissions by 8 to 9% and lowered the cyclone's static pressure drop by about 0.6 inch w.g. There were no significant differences in the performance of a 1D3D cyclone equipped with a 2D2D inlet due to shortening the outlet duct from its original 1D3D length down to that normally found in the 2D2D cyclone. The large, modified trash exits produced PM10 emissions that were significantly lower, by about 9%, than those produced by the small, standard exits. This difference in PM10 emissions was apparently due to a difference in amount of air induced into the cyclones through the two sizes of trash exits. The large trash exit produced only a slight negative pressure under the cyclone. Consequently, very little air was induced into the cyclones through the large trash exits. The small exits, on the other hand, created a large negative pressure under the cyclone which caused a considerable amount air (about 3.8%,) to be induced into the cyclone. This induced air was associated with the significantly lower PM10 collection performance.

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Table 1. Basic Airflow Characteristics*

Cyclone Body Type	Standard Trash Exit	Large Trash Exit
Static Pressure Drop, in. w.g.•		
Standard 1D3D Body	5.8	5.9
Modified Body with 2D2D Inlet, 1D3D Outlet	5.2	5.2
Modified Body with 2D2D Inlet & Outlet	5.1	5.2
Static Pressure at Trash Exit, in. w.g. □		
Standard 1D3D Body	-2.1	-0.4
Modified Body with 2D2D Inlet, 1D3D Outlet	-1.6	-0.3
Modified Body with 2D2D Inlet & Outlet	-2.0	-0.3

* All data were adjusted to standard air conditions (0.075 lb/ft^3 air density).

• Average static pressure measured ahead of the inlet transition of each cyclone while handling air only at an inlet velocity of 3200 fpm. The dust sampling ducts were removed from the cyclone outlets for these measurements.

□ Average static pressure at the cyclone trash exit when discharging into a sealed collection system.

Table 2. Summary of emission test data.■

Cyclone Body Type Name	Inlet	Outlet	Trash Exit Size Standard	Large	Avg. Effect of Body Type
Exhaust Air Flow, acfm•					
Standard	1D3D	1D3D	3310	3200	3255a*
Modified	2D2D	1D3D	3290	3150	3220a
Modified	2D2D	2D2D	3330	3220	3275a
Avg. Effect of Exit Size				3310a	3190b
Cyclone Static Pressure, in. w.g.◦					
Standard	1D3D	1D3D	4.9	4.8	4.85a
Modified	2D2D	1D3D	4.3	4.3	4.30b
Modified	2D2D	2D2D	4.3	4.4	4.35b
Avg. Effect of Exit Size				4.50a	4.50a
PM10 Emissions, lb/1000 lb trash					
Standard	1D3D	1D3D	1.39	1.34	1.37a
Modified	2D2D	1D3D	1.35	1.16	1.26b
Modified	2D2D	2D2D	1.29	1.20	1.25b
Avg. Effect of Exit Size				1.34a	1.23b
>PM10 Emissions, lb/1000 lb trash					
Standard	1D3D	1D3D	0.48	0.48	0.48a
Modified	2D2D	1D3D	0.60	0.50	0.55a
Modified	2D2D	2D2D	0.54	0.53	0.51a
Avg. Effect of Exit Size				0.54a	0.51a
Total Emissions, lb/1000 lb trash					
Standard	1D3D	1D3D	1.87	1.82	1.85a
Modified	2D2D	1D3D	1.95	1.66	1.81a
Modified	2D2D	2D2D	1.83	1.73	1.78a
Avg. Effect of Exit Size				1.88a	1.74

■ There were no statistically significant interactions between cyclone body type and trash exit size in this study.

• Actual exhaust airflow measured during emission tests. Air density averaged 0.067 lb/ft^3.

◦ Average static pressure at the inlet transition of the cyclones during emission tests.

* Means for body type averages or trash exit averages followed by the same lower case letter are not significantly different at the 0.10 level of significance.

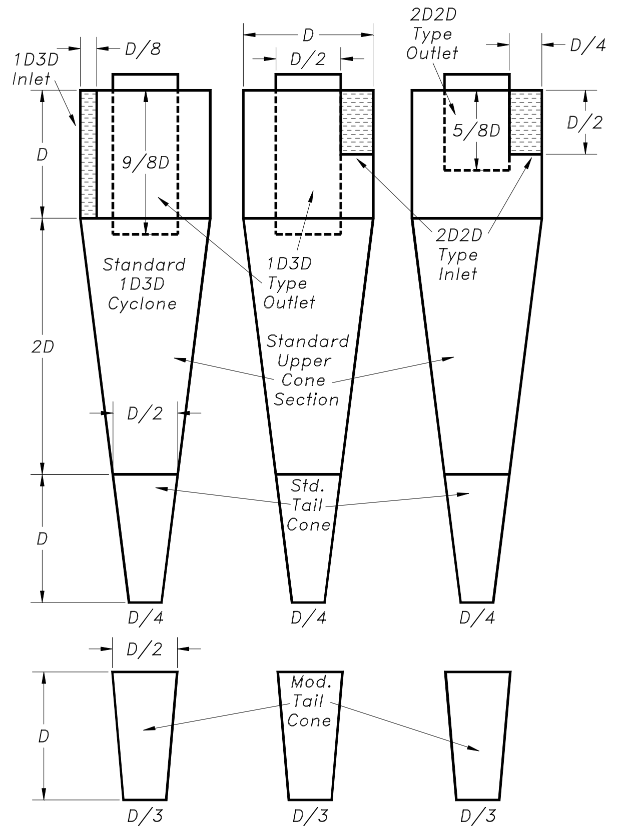

Figure 1. Basic dimensions of 3 cyclone body types and 2 tail cone designs evaluated in this experiment. D = 34 inches.