This is not a peer-reviewed article.
Pp. 040-044 in Air Pollution from Agricultural Operations III, Proceedings of the 12-15 October 2003 Conference (Research Triangle Park, North Carolina USA), Publication Date 12 October 2003.
ASAE Publication Number 701P1403, ed. H. Keener.

EVALUATING AN ON-LINE DUST CYCLONE PERFORMANCE MONITOR

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ABSTRACT

Laboratory experiments on cyclone designs and operating parameters using EPA Reference Method 201A is labor intensive. The intent of this experiment was to evaluate an electronic particulate monitor as an alternative dust cyclone performance measurement instrument. The particulate monitor was installed in line with fiberglass filters that captured dust escaping from test cyclones. Mass on the filters was compared to particulate monitor output. Three cyclones, four loading rates and four replicates were run in random order. A linear correlation of about 85% was observed when data was separated by cyclone size. Cost and time savings are promising, but dust loading across a range of various particle size distributions still needs to be evaluated.

KEYWORDS. Cotton gin, Dust cyclone, Particulate monitoring.

INTRODUCTION

Reducing dust emissions from cotton gins has been a research topic for many years. Periodic changes in air pollution permitting requirements necessitate renewed efforts to improve dust cyclone efficiency. Anticipating many more years of cyclone research, a potential means of automating part of the data collection process was investigated. The apparatus of interest was developed by PCME, Ltd. (UK) for detecting dust levels in flue gas passing from bag house filter systems. Currently data acquisition is performed using EPA Reference Method 201A, which is labor intensive. Comparable results were sought with less effort and expense.

Objective. Evaluate an on-line particulate monitor for laboratory use, potentially automating the quantification of dust cyclone emissions during experiments.

MATERIALS AND METHODS

Evaluated Instrument

The on-line device tested was a StackMASSter II Electrodynamic Cross-Correlation Mass Emissions Monitor by PCME, Ltd, Cambridgeshire, UK. Unit output is available in mg/m^3, and the unit also provides velocity (high accuracy) by a double rod sensor. Velocity coupled with concentration enables mass emissions to be calculated and given as an output from one instrument. PCME Ltd have a variety of techniques which offer a mass output. This was a beta version sent to the Cotton Ginning Research Lab at Lubbock, TX for evaluation. It was intended to be applied in a large industrial stack. In the Cotton Ginning Research Lab at Mesilla Park, NM (tests reported in this paper) the device was installed between the cyclone and the fiberglass filter (Figure 1) in a small 15 cm (6 inch) diameter duct.

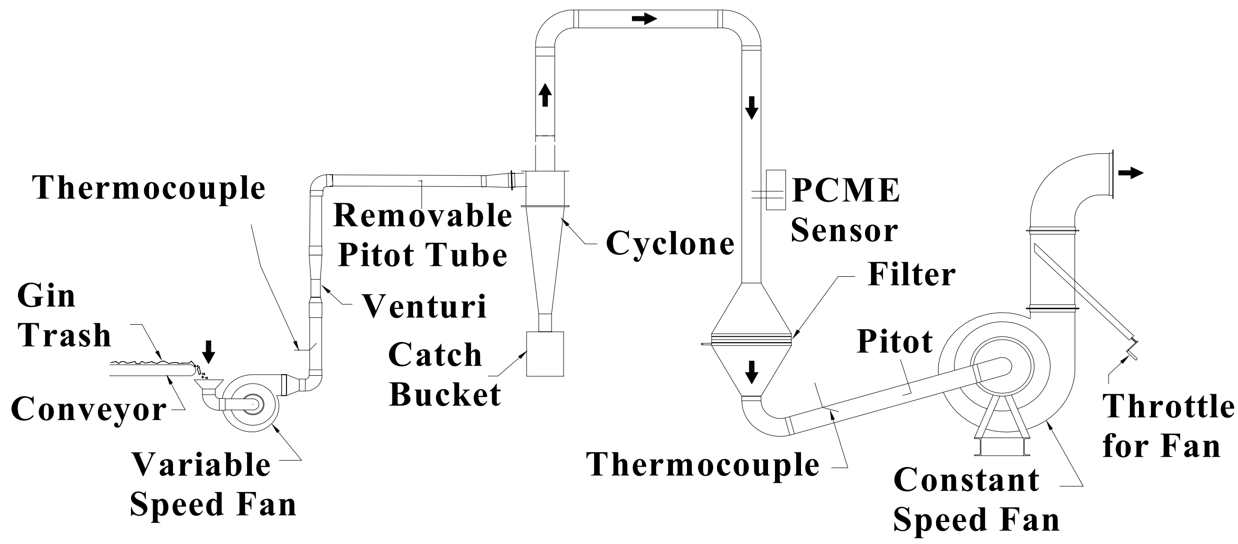

Figure 1. Configuration of equipment used to evaluate PCME device. System hardware and test methods remained the same for both cyclone sizes.

Dust Cyclones

Two sizes, 0.305 m (12 inch) and 0.432 m (17 inch) diameter 1D3D style dust cyclones were used in this experiment. Both cyclones had the 2D2D style inlet. A 0.432 m (17 inch) diameter 2D2D style cyclone was also tested. The larger cyclones were run at half the design entrance velocity as part of a separate experiment (Baker et al., 2002). Gin trash used in this study was collected from the unloading fan separator screen and contained a small amount of lint fiber, as well as leaf trash and fine dust. The particle size distribution of this trash was appropriate for the model tests conducted in this study (Baker et. al, 2002). Four trash loading rates were used, including initial average cyclone inlet concentrations of 2, 4, 8, and 16 g/m^3 (0.875, 1.75, 3.5, and 7.0 grain/ft^3). A randomized complete block design was used with four replicates serving as the blocks. Within each block were 12 test runs (3 cyclones x 4 trash loading rates) conducted in a different random order for each block.

Protocols

Each test run was 2 minutes long. Prior to each test, gin trash was measured and distributed evenly along a cloth conveyor belt that was driven by a variable-speed motor (Figure 1). At the start of each test, the variable speed fan was adjusted to give the desired air velocity to the cyclone inlet. During the test, trash was pulled into the system from the moving conveyor belt by the fan, then forced into the selected cyclone. Dust removed by the cyclone was collected in a bucket sealed tightly to the bottom of the cyclone cone. Exhaust air was pulled from the top of the cyclone by a second fan. Dust in the cyclone exhaust was collected on a fiberglass filter with an exposed area of 58.4 x 58.4 cm (23.0 x 23.0 inches). The second fan was necessary to overcome the additional flow resistance of the filter. It had a throttle to balance air flows.

Airflows

A Venturi meter, installed between the variable speed fan and the cyclone, was used to determine airflow through the cyclone (Figure 1). The pressure drop was recorded at 1 second intervals during the test. The pressure drop was also monitored, and fan speed adjusted to keep the airflow within 2% of the desired level of 0.19 m^3/s (400 ft^3/min). The airflow was the same regardless of cyclone size, due to the needs of a separate experiment. A Pitot tube, installed in the duct between the filter and the second fan, was used to determine airflow from the cyclone exhaust. The pressure difference for the Pitot tube was recorded at 1 second intervals during the test. The pressure difference was also monitored, and fan throttle opening manually adjusted to keep the airflow within 5% of the desired level. Airflow through each segment of the system was the same.

Pressure drops through the cyclone and across the filter were recorded at 1 second intervals during the test, as were temperatures at each of the airflow measuring sites. Room air temperature, barometric pressure, and relative humidity were determined once during each test.

Standard of Comparison

Each test used a new fiberglass filter that was conditioned at 21 ^{o}C (70 ^{o}F) and 50 % relative humidity prior to being initially weighed. After each test, the used filter was carefully folded and placed in a sealed envelope, then returned to the conditioning chamber for at least 48 hours before determining the final weight. Dust in the cyclone exhaust was calculated from the difference in the two weights. Dust removed by the cyclone was determined for each test by the change in weight of the catch bucket. It was this filter catch that was used to evaluate the effectiveness of the PCME in monitoring Mass Emission on-line.

RESULTS AND DISCUSSIONS

There was a linear relationship between stackMASSter cumulative output and the mass of dust collected on the filters. However, the results were dependent on the size of the cyclone body being tested. Figures 2 and 3 show these linear relationships. It appears it would be necessary to calibrate the stackMASSter for each particular test configuration. Correlation coefficients for each cyclone size are on figures 2 and 3. For research instrumentation we would like to get a better curve fit so our confidence interval is in the neighborhood of 95%, not 85%. However, the existing system (EPA Reference Method 201A) is only accurate when mass median diameter is 10 microns, but cotton gin exhaust emission mass median diameter can be as high as 25 microns, at which point Method 201A can overestimate emissions by a factor of three (Buser et. al., 2003). Furthermore, the tested system has not been optimized for this application. Considering that, this is a very promising technology and definitely merits further investigation.

The differing response with cyclone size was surprising. The same air flow passed the sensor regardless of cyclone size. The same weight of dust was in that air. One possible explanation is that because of differing entrance velocities there were changes in the particle size distribution, and the PCME device responded to different particle size distributions differently. Future investigations need to be conducted over a range of particle size distributions.

CONCLUSION

Cost and time savings resulting from convenience make this concept an attractive alternative to EPA Method 201A assays of dust cyclone emissions during laboratory tests where dust must be quantified repeatedly. The method needs to be validated over a range of particle size distributions.

Acknowledgements

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Disclaimer

Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U. S. Department of Agriculture.

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APPENDIX

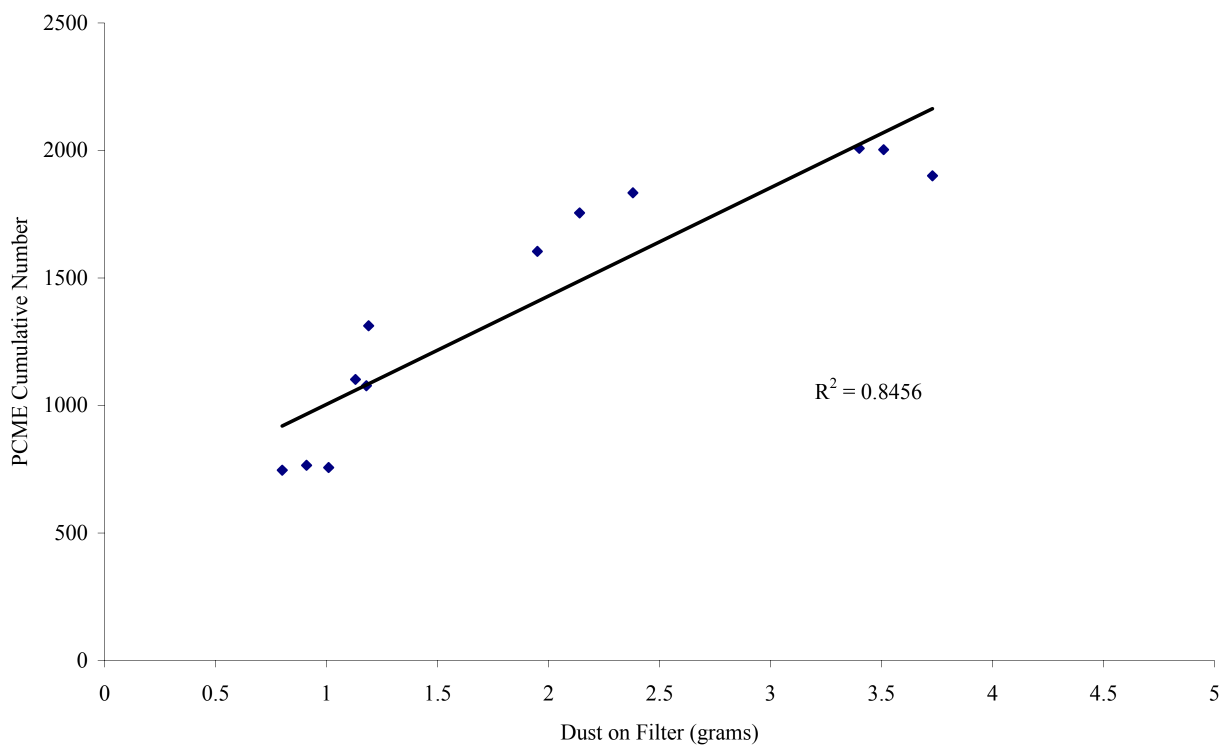

Figure 2. Comparison of PCME data to filter catch for 0.31 m (12 inch) cyclone.

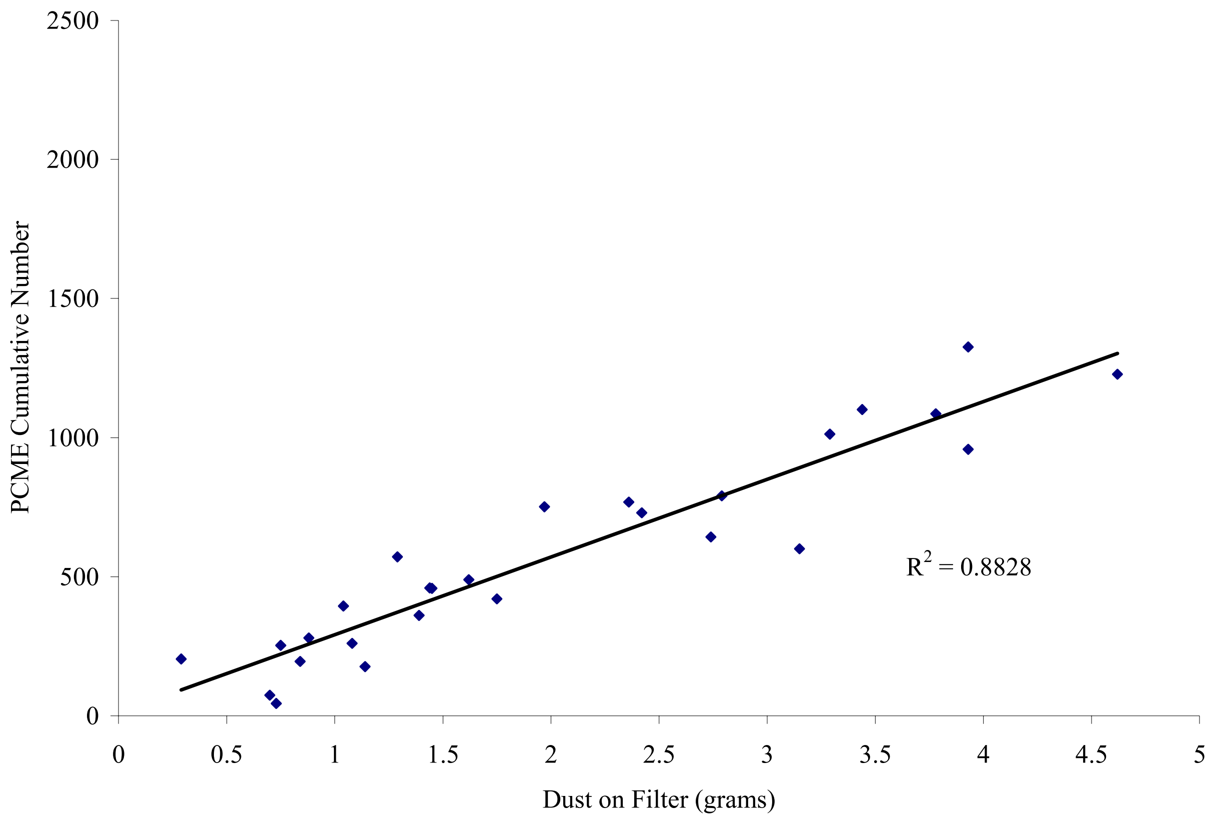

Figure 3. Comparison of PCME data to filter catch for 0.43 m (17 inch) cyclones.