

Optimizing Kiln Operations by Improving Baghouse Performance

99-311

Christopher J. Polizzi and John R. Darrow

W. L. Gore & Associates, Inc., 101 Lewisville Road, Elkton, MD 21921

Gary J. Cooper

Giant Cement Company, P.O. Box 218, Harleyville, SC 29448

ABSTRACT

Over the past several years, the U.S. cement industry has reaped the rewards of extremely high consumption. Record outputs have been seen reaching over 96% of capacity. While this window of opportunity presents itself, many cement producers are actively seeking ways to maximize production.

One cement producer that operates several wet process cement rotary kilns and burns supplemental waste fuels had a unique challenge: to maximize its output in order to meet the high demand for cement and increase the utilization of waste fuels. In order to meet both objectives and stay well within the boiler and industrial furnace (BIF) regulations, they looked for ways to improve the kiln operation.

The company knew that the baghouse had a significant impact on its overall plant operations. Using standard fiberglass fabric filter media, the plant was experiencing continuous reactive maintenance, short overall filter media life and occasional opacity issues. It was proposed that changing to a filter media with lower filter resistance would allow more flexible operation in the kiln.

The project began with a trial comparing the traditional fiberglass filter media to the proposed filter media, expanded polytetrafluoroethylene (ePTFE) membrane/fiberglass fabric. During a one-year trial, a comprehensive evaluation would determine if there would be an acceptable return on the investment in higher priced filter bags. Five years after the trial began and four years (to date) after complete implementation in two kiln baghouses, the findings include: fewer incidents of high opacity, longer bag life, more consistent differential pressure, and less preventive maintenance. This improved baghouse operation enabled the company to meet their objectives of high production and increased use of alternative waste fuels. Based on the results to date, the company recently replaced the filter bags in the remaining kiln baghouse with ePTFE membrane bags.

INTRODUCTION

Giant Cement Company, a subsidiary of Giant Cement Holding, Inc., has a long history in the U.S. cement industry. In 1883, the original plant began producing cement at a facility in

southeastern Pennsylvania. The second facility, located in Harleyville, South Carolina, was originally an alumina plant. It was purchased in 1947 from the War Assets Administration and converted to a cement manufacturing plant. This was the first cement plant in the Carolinas, and production began in 1948. Originally the Harleyville plant operated only one rotary kiln with an annual capacity of approximately 110,000 tons/year. Over the years, the plant has reaped the rewards of a favorable business climate and construction activity in the Southeastern United States. The 1,500 acre facility has undergone four major expansions and currently operates four long, wet-process kilns (Kilns# 2 through #5 [Kiln #1 has been shut down]) and is rated at approximately 900,000 tons per year.

Giant Cement Holding, Inc. firmly recognizes and embraces the balance that must be maintained between industry and the environment. Keystone Cement Company, a Giant Holding subsidiary, was one of the first cement producers to develop a supplemental fuel program utilizing waste materials. Giant Resource Recovery (GRR), another Giant subsidiary, was a pioneer in the development of innovative, environmentally-sound methods for the reuse of waste materials. During 1981, Giant Cement Company began investigating the feasibility of supplementing its primary source of fuel with alternative fuels. Today GRR is an integral part of Giant Cement Company's operation, providing 50% to 60% of Giant's fuel. GRR is located adjacent to the Giant Cement manufacturing plant in Harleyville.

BACKGROUND

Normal kiln operation involves firing a combination of coal, liquid wastes, and solid wastes. Prior to unloading, the supplemental fuels are tested for BTU content, water content, and chemical characteristics (including ash content). Giant uses a three-part mix in the slurry production and these components are blended, with consideration for the ash in the fuels, to achieve the quality of clinker desired. With all of these variables, the primary concern is to maintain stability of kiln operation. The baghouse has to respond to changes in airflow as controlled by the kiln's induced draft fan. In addition to the airflow, the baghouse is subjected to a wide range of moisture content and variation in dust composition, e.g. calcium oxide content. Giant's strategy was to source a filter media that would perform consistently over the wide range of possible operating conditions.

At a cement production facility, exhaust gases from the kiln contain the largest volume of particulate matter for potential emissions.¹ During 1995, each of the four long, wet-process kilns utilized reverse air dust collectors as its primary air pollution control device. The kiln dust collectors were equipped with fiberglass fabric filter bags with an acid resistant finish. A set of bags typically attained an eighteen-month life, with holes developing in some bags after twelve months of use.

Over the eighteen-month bag life, there were several concerns with baghouse performance. These include: an increase in individual module differential pressure, occasional opacity, dust build-up on the clean air plenum floor, inconsistency of fan and temperature control, and holes in the bags. These changes in baghouse performance would, in turn, affect the amount of waste fuel that could be fired, as well as the amount of clinker produced. In the case of increased opacity, the permit required Giant Cement to discontinue waste fuel firing when the opacity reached 20%.

Giant had previous experience with W. L. Gore & Associates, Inc. (Gore). The company had solved a problem in a finish mill baghouse where the previous filter media limited production. The GORE-TEX® ePTFE membrane bags eliminated the problem of pressure drop increasing over time. Giant hypothesized that Gore filter media might provide the same consistent differential pressure and consistent airflow in a kiln baghouse. This performance (a stable low pressure drop) would allow them to produce more clinker and use more alternative fuels, while operating within the BIF limits of their permit. After discussions with Gore, Giant decided to conduct a trial to compare its filter media to the current fiberglass bags. Together, Giant and Gore developed a plan to compare performance of the two media in a kiln baghouse.

TRIAL OVERVIEW

During December 1995, a trial was initiated in the Kiln #4 exhaust baghouse. During a scheduled bag changeover, the new filter bags were installed in one compartment; the traditional bags used at the plant were installed in another compartment. The objective of the trial was to compare the operating performance of the two side-by-side compartments. The Kiln #4 dust collector is a reverse air baghouse with the design parameters shown in Table 1.

Compartments #1 and #10 were chosen for the trial; both situated closest to the inlet of the baghouse. The layout of the kiln baghouse is shown in Figure 1.

Compartment #1 (control compartment) was equipped with a new set of acid resistant fiberglass fabric filter bags (14 oz/yd²), the filter media traditionally used by Giant Cement.

Compartment #10 was equipped with new GORE-TEX® ePTFE membrane/acid resistant fiberglass fabric filter bags (10 oz/yd²) supplied by Gore. In the trial, real time measurements were made on static pressure loss and velocity pressure for each compartment.

Standard acid resistant fiberglass fabric filter bags (14 oz/yd²) operate on the basis of depth filtration. Depth filtration requires the formation of a primary dust cake before efficient filtration can occur. The primary dust cake ‘plugs’ and ‘clogs’ the interstices of woven fabrics and felts that naturally occur in the filter media. Until this ‘seasoning’ occurs, felts and fabrics are inefficient as filters. A secondary dust is then collected on the surface of the primary dust cake. The secondary dust cake is shed periodically through in-situ cleaning when the differential pressure becomes elevated above a predetermined level.

Over time, the primary cake penetrates further into the fabric or felt, resulting in a continuing increase in the pressure drop across the media. When a pressure drop cannot be recovered through the cleaning cycle, the material is considered blinded. This results in a loss of airflow. Due to the relatively large spaces naturally occurring between the fibers, which make up fabrics and felts, attempts to remove the imbedded particles disrupt the primary cake.

Until the primary cake is reformed, emissions occur whenever the secondary dust cake is removed. Emissions also occur when the pressure drop becomes so high that particulate matter migrates completely through the fabric or felt. Dust-to-fiber abrasion can lead to a loss in fiber strength, which can result in rips, holes, and tears in the fabric. Any of these operating deficiencies (loss of airflow, emissions, or fabric strength loss) can be reason to replace filter bags.

The ePTFE membrane/acid resistant fiberglass fabric filter bags (10 oz/yd²) installed in Compartment #10 operate under the principle of surface filtration. The ePTFE membrane is microporous so it captures the particulate on its surface, where it can be easily dislodged during the cleaning cycle. The inherent efficiency of the membrane, up to 99.99% for particles down to submicron in size, prevents the particulate from reaching the support material or substrate (acid resistant fiberglass—10 oz/yd²). Dust to fiber abrasion is minimized, and bag life is substantially increased.

In order to qualify and quantify the performance of the two trial compartments, the following actions were performed periodically over a six-month period:

1. Recorded relative airflow and filter media differential pressure for each compartment. Data was recorded in real time using field equipment designed specifically for that purpose.
2. Monitored the total baghouse system airflow.
3. Routinely inspected the interiors of compartments, identified any bag-related problems, and quantified any dust that collected on the cell plate in the clean air plenums.
4. Performed quarterly laboratory analyses on representative filter bags from both compartments. The analyses consisted of permeability testing, Mullen burst strength testing, and comprehensive visual inspections.
5. Recorded any/all maintenance that took place in each compartment.

TEST RESULTS

Over the course of the first six months, real time airflow through each compartment was monitored simultaneously with filter media differential pressure. The six-month time frame was chosen in order to allow the primary dust cake to form completely and secondary dust cake cleaning to take effect on the standard fiberglass bags. Data was collected four times over a continuous 24-hour period. Table 2 shows the average of the four data points taken immediately after the respective cleaning cycle for each compartment. This point in the cleaning cycle is representative of the highest airflow through each compartment as newly-cleaned bags have the lowest differential pressure, allowing airflow to take the path of least resistance.

Table 2 shows that the GORE-TEX[®] ePTFE membrane filter bags in Compartment #10 averaged 24% more airflow than the standard fiberglass bags in Compartment #1. This indicated that the ePTFE membrane bags cleaned down to a lower differential pressure.

The concept of filter drag is commonly used to predict a filter media's resistance to flow at certain air/cloth ratios. Filter drag is defined by Equation 1:

Equation 1. Filter drag.

$$\text{Filter drag (" w.g./ft/min)} = \frac{\Delta P}{A/C}$$

where:

ΔP = actual differential pressure (" w.g.)

A/C = air-to-cloth (ft/min)

Table 3 shows that the ePTFE membrane filter media operated at higher overall average airflow, resulting in higher air/cloth ratios. (The amount of cloth area in each compartment was identical.)

Table 2 represents the difference in peak airflow (immediately after cleaning) and Table 3 represents the difference in average airflow (over the cleaning cycle). In either case, the ePTFE membrane bags demonstrated higher airflow (24% at peak or 12% on average). Based on the test results, Gore hypothesized that a complete set of ePTFE membrane filter bags would allow more airflow with current energy requirements or the same airflow with a lower differential pressure. In actuality, Giant was more interested in flexibility of kiln operation that could be achieved with a consistent differential across the baghouse.

As bag life is an important part of an economic justification, several factors were investigated in order to predict bag life. Strength of the filter media was evaluated using a Mullen burst strength test. This test is a measure of the two-dimensional, or planar, strength of the media, measured in pounds per square inch. The ePTFE membrane filter bags retained greater than 70% of their strength after 12 months of operation, while the standard fiberglass bags retained less than 50%. It is typical for fiberglass filter bags to drop 10% to 25% in strength very shortly after they are put into service.

Additionally, comparisons were made between the operating parameters of the Kiln #4 baghouse at Giant Cement and other long-term cement applications using similar filter bags supplied by Gore. This was done in an effort to predict with reasonable accuracy the expectation of overall filter bag life. Analyzing both the strength data and past empirical data suggested the GORE-TEX[®] ePTFE membrane/acid resistant fiberglass fabric filter bags (10 oz/yd²) should operate a minimum of five years. Based on the results of the trial, the analyses performed on the test bags, and previous experience in kiln applications, Gore offered a guarantee on performance as follows:

- Airflow between 155,000 acfm (minimum) and 170,000 acfm (maximum).
- Emissions guarantee of less than the permitted value.
- Bag life of 60 months.

Table 4 shows the results of an analysis of the out-of-pocket costs for a filter bag changeout. Taking into consideration only the bag cost (with cap and clamp) and the installation labor, there was a significant premium associated with the ePTFE membrane bags. Gore did a net present value (NPV) analysis based on an 8% interest rate and a 10-year life cycle comparing standard fiberglass bags lasting 1½ years to a 5-year life with ePTFE membrane bags. The total difference in NPV is about \$105,000 lower for the standard fiberglass bags with a 1½-year life. Gore believed that Giant Cement would have to generate \$10,000 to \$11,000 per year in increased revenue or reductions in operating costs over a 10-year period in order to justify the use of ePTFE membrane bags.

Based on the results of the trial, the performance guarantee, and their own internal economic evaluation, Giant Cement decided to install ePTFE membrane bags. In January 1997 and February 1997, the company installed 1,400 ePTFE membrane/acid resistant fiberglass fabric (10.5 oz/yd²) bags in each baghouse for Kilns #4 and #5.

OPERATING RESULTS

Since installation, both baghouses have operated at low stable differential pressures and more consistent fan and temperature control than with the previous bag material. The cleaning cycle has been increased from less than 60 minutes to over 90 minutes. The cleaning intensity has also been reduced. The combined effect of less frequent and gentler cleaning should dramatically improve bag life.

It is extremely difficult to relate total production rate directly to baghouse performance. This is especially true for a BIF kiln, where there are many factors that are constantly changing. From 1996 to 1998, there was a significant increase in moisture content in the rock from the quarry. The increase in moisture puts a strain on the baghouse, requiring more airflow per ton of cement produced. Giant Cement is certain that the production level in 1998 would have been considerably lower without the ePTFE membrane bags.

The variation in supplemental fuels may require an adjustment in the slurry. This, in turn, can create a variation in the dust and gas composition exhausted to the baghouse. Considering the changing waste composition, the significant increase in waste fuel burned from 1996 to 1997 and the incremental addition in 1998 were noteworthy. The ePTFE bags continued to clean consistently—even with the variation of dust and gas. Thus, one of the variables in kiln operation has been eliminated—the baghouse adjustments previously required to compensate for the changing composition of the dust and gas stream.

During the seven quarters prior to installing the Gore bags, Kiln #4 had 20 instances of opacity problems and Kiln #5 had 28. As a result of opacity problems, there were 48 times that Giant had to stop firing the supplemental waste fuel in one of the kilns. During the seven quarters after the Gore installation, there were only nine opacity incidents for Kilns #4 and #5. Eight of the incidents were due to the Kiln #4 baghouse. These problems occurred in Compartment #4, which was brought on-line in error while the doors were open for maintenance. A few bags that were obviously damaged were replaced immediately. Over the next several weeks, there were seven more occurrences of bag failures in Compartment #4 attributed to the same incident. In general, emissions (as evident by opacity) have decreased significantly with the GORE-TEX[®] ePTFE membrane bags.

CONCLUSION

Since January 1997, the ePTFE filter bags continue to provide worry-free performance. In comparison to the previous fiberglass bags, which began developing holes after one year and had to be replaced in eighteen months, the ePTFE bags have shown no degradation in operating performance—even after several years.

Since installation of the ePTFE bags, opacity incidents were reduced from 48 to 9. Eight of these incidents were attributed to a maintenance oversight. This decrease in opacity incidents was dramatically demonstrated in the Kiln #5 baghouse, where incidents dropped from 28 to 1. The reduction in opacity incidents allowed more stable kiln operation by eliminating the need to switch fuels as required by permit.

During this two-year period, Giant Cement was able to achieve high production levels—in spite of the increase in moisture from the quarry rock. In addition, the company increased its utilization of waste fuels by nearly 10%. All of this was accomplished with a significant reduction in baghouse maintenance. Giant Cement is convinced that the positive findings are clearly attributable to the consistent cleaning capability of the new filter media.

Based on these successful results, Giant Cement has installed ePTFE membrane bags furnished by Gore in Kiln #3 in March 1999.

ACKNOWLEDGMENTS

The authors would like to acknowledge Amy Gilbert of W. L. Gore & Associates, Inc., who prepared the final manuscript for this paper.

REFERENCE

1. U.S. Environmental Protection Agency, *Supplement A to Compilation of Air Pollutant Emission Factors*, Vol. I, Sec. 8.6.2, AP-42, PB87-150959, Oct. 1986.

®GORE-TEX is a registered trademark of W. L. Gore & Associates, Inc.

©Copyright 2001 W. L. Gore & Associates, Inc.

Table 1. Baghouse design conditions.

Airflow	143,250 acfm
Temperature	450°F
Modules	10
Bags/Module	140
Bag Diameter	8 inches
Bag Length	311 inches
Rings per Bag	5
Air-to-Cloth Ratio	1.84:1 gross
Air-to-Cloth Ratio	2.05:1 net
Reverse Air Volume	8,500 cfm

Table 2. Peak airflow following a cleaning cycle.

Date	Trial Time	Airflow Compartment #10: GORE-TEX [®] Membrane Filter Bags	Airflow Compartment #1: Standard Fiberglass Bags	Difference in Airflow
01/01/1996	1 month	18,002 acfm	13,808 acfm	30.37%
02/20/1996	2 months	19,177 acfm	14,913 acfm	28.59%
05/09/1996*	5 months	13,026 acfm	11,985 acfm	8.69%
05/30/1996	6 months	21,197 acfm	16,854 acfm	25.77%
Average Values:		17,851 acfm	14,390 acfm	24.05%

*The kiln was operated on 100% coal with a 20% reduction in overall airflow, which affected the relative airflow measurements.

Table 3. Average airflow and filter drag (filter resistance) over the cleaning cycle.

Date	Trial Time	Compartment #	Average Airflow	Average Air/Cloth (ft/min)	Average ΔP (" w.g.)	Average Filter Drag (" w.g./ft/min)
05/31/1996	6 months	#10: GORE-TEX® membrane filter bags	12,733 acfm	1.68	3.12	1.86
05/31/1996	6 months	#1: Standard Traditional Fiberglass	11,231 acfm	1.48	2.95	2.00
07/31/1996	8 months	#10: GORE-TEX membrane filter bags	11,949 acfm	1.57	3.56	2.26
07/31/1996	8 months	#1: Standard Traditional Fiberglass	10,746 acfm	1.41	3.41	2.41

Table 4. Out-of-pocket costs for filter bag changeout.

	Standard Fiberglass – 18 month	ePTFE Membrane/ Fiberglass – 5 year
Bag Cost – 1 set	\$58,156	\$273,742
Installation Cost (each set)	\$11,200	\$11,200
Replacement Cost (each set)	\$69,356	\$284,942
Total – 10 year	\$462,605*	\$569,884
NPV @ 8%	\$373,389	\$478,869

*Calculated at 6.67 replacement bags.

Figure 1. Plan view of baghouse from drawings.

