FIELD TESTING OF THE ADVANCED HYBRID PARTICULATE COLLECTOR, A NEW CONCEPT FOR FINE-PARTICLE CONTROL

Stanley Miller (smiller@eerc.und.nodak.edu, [701] 777-5210)
Michael Jones (mjones@eerc.und.nodak.edu, [701] 777-5152)
Energy & Environmental Research Center

Kenneth Walker (kwalker@wlgore.com, [410] 506-3300)
Richard Gebert (rgebert@wlgore.com, [410] 506-3218)
John Darrow (jdarrow@wlgore.com, [410] 506-3316)
W.L. Gore & Associates, Inc.

Dr. Henry Krigmont (alentec@alentecinc.com, [714] 799-9895)
Allied Environmental Technologies Company

Thomas Feeley (feeley@fetc.doe.gov, [412] 386-6134)
U.S. Department of Energy

William Swanson (wswanson@otpco.com, [605] 862-8125)
Otter Tail Power Company

KEYWORDS: Fine-particle control and coal-fired boiler

INTRODUCTION

A new concept in particulate control, called an advanced hybrid particulate collector (AHPC), is being developed at the Energy & Environmental Research Center (EERC) with U.S. Department of Energy (DOE) funding. In addition to DOE and the EERC, the project team includes W.L. Gore & Associates, Inc., Allied Environmental Technologies, Inc., and the Big Stone power station (jointly owned by three partners: Northwestern, Montana–Dakota Utilities, and Otter Tail Power Company.) The AHPC combines the best features of electrostatic precipitators (ESPs) and baghouses in a unique approach to develop a compact but highly efficient system. Filtration and electrostatics are employed in the same housing, providing major synergism between the two collection methods, both in the particulate collection step and in the transfer of dust to the hopper. The AHPC provides ultrahigh collection efficiency, overcoming the problem of excessive fine-particle emissions with conventional ESPs, and solves the problem of reentrainment and re-collection of dust in conventional baghouses.

The goals for the AHPC are as follows: >99.99% particulate collection efficiency for particle sizes from 0.01 to 50 μm, applicable for use with all U.S. coals, and cost savings compared to existing technologies.

The electrostatic and filtration zones are oriented to maximize fine-particle collection and minimize pressure drop. Ultrahigh fine-particle collection is achieved by removing over 90% of the dust before it reaches the fabric and using a GORE-TEX® membrane fabric to collect the particles that reach the filtration surface. Charge on the particles also enhances collection and minimizes pressure drop, since charged particles tend to form a more porous dust cake. The goal is to employ only enough ESP plate area to precollect approximately 90% of the dust. ESP models predict that 90% to 95% collection efficiency can be achieved with full-scale precipitators with a specific collection area (SCA) of less than 100 ft^2/kacfm [1]. Fabric filter models predict that face velocities greater than 12 ft/min are possible if some of the dust is precollected and the bags can be adequately cleaned. The challenge is to operate at an air-to-cloth (A/C) ratio of 12 ft/min or greater for economic benefits while achieving ultrahigh collection efficiency and controlling pressure drop. The combination of GORE-TEX® membrane filter media, small SCA, high A/C ratio, and unique geometry meets this challenge.

Studies have shown that fabric filter collection efficiency is likely to deteriorate significantly when the face velocity is increased [2, 3]. For high collection efficiency, the pores in the filter media must be effectively bridged (assuming they are larger than the average particle size). With conventional fabrics at low A/C ratios, the residual dust cake serves as part of the collection media, but at high A/C ratios, only a very light residual dust cake is acceptable, so the cake cannot be relied on to achieve high collection efficiency. The solution is to employ a sophisticated fabric that can ensure ultrahigh collection efficiency and endure frequent high-energy cleaning. In addition, the fabric should be reliable under the most severe chemical environment likely to be encountered (such as high SO_3). A fabric that meets these requirements is GORE-TEX® membrane on GORE-TEX® felt. GORE-TEX® membrane filter bags consist of a microporous, expanded polytetrafluoroethylene (PTFE) membrane laminated to a felted or fabric backing material. Consequently, even fine, nonagglomerating particles do not penetrate the filter, resulting in significant improvements in filtration efficiency, especially for submicron particles. This fabric is also rugged enough to hold up under rigorous cleaning, and the all-PTFE construction alleviates concern over chemical attack under the most severe chemical environments.

Assuming that low particulate emissions can be maintained through the use of advanced filter materials and that 90% of the dust is precollected, operation at face velocities in the range from 12–24 ft/min should be possible, as long as the dust can be effectively removed from the bags and transferred to the hopper without significant redispersion and re-collection. With pulse-jet cleaning, heavy residual dust cakes are not typically a problem because of the fairly high cleaning energy that can be employed. However, the high cleaning energy can lead to significant redispersion of the dust and subsequent re-collection on the bags. The combination of a very high-energy pulse and a very light dust cake tends to make the problem of redispersion much worse. The barrier that limits operation at high A/C ratios is not so much the dislodging of dust from the bags as it is transferring the dislodged dust to the hopper. The AHPC achieves enhanced bag cleaning by employing electrostatic effects to precollect a significant portion of the dust and by trapping in the electrostatic zone the redispersed dust that comes off the bags following pulsing.

CONCEPT DEVELOPMENT AND FIELD TESTING

Phase I of the development effort consisted of design, construction, and testing of a 200-acfm working AHPC model [4, 5]. Since all of the developmental goals of Phase I were met, the approach was scaled up in Phase II to a size of 9000 acfm and installed at the Big Stone power station (see specification in Table 1 and top view in Figure 1).

Big Stone power plant was commissioned for service in 1975. The unit is a 450-MW-rated, Babcock and Wilcox cyclone-fired boiler. The primary fuel for the first 20 years of operation was North Dakota lignite, but four years ago, the primary fuel was switched to Powder River Basin subbituminous coal. This fuel has approximately one-half of the moisture and one-third more heat than North Dakota lignite. Almost all of the effects of this new fuel have been positive. However, one challenge that has occurred is the decreased efficiency of the ESP, due to an increase in resistivity of the fly ash. The combination of a very fine particle size produced from the cyclone-fired boiler and high ash resistivity make this a challenging test dust for the AHPC.

After completing the shakedown testing, the field AHPC unit was started on July 29, 1999. Based on shakedown testing, the initial secondary current was set at 50 mA and the bag cleaning trigger point was set at 8 in. W.C. to initiate pulsing all four rows of bags in sequence. The flow rate was set to a nominal 12 ft/min based on pitot readings. However, since the fan speed was not automatically controlled by the flow rate, there was always an increase in flow rate after pulsing. With the increase in flow after pulsing, the integrated average flow rate throughout the pulsing cycles was typically in the range from 12 to 13 ft/min during the first 6-week test period.

Over the course of the first 6 weeks, there were a number of interruptions to the operation. During this time, there were six unplanned outages to the plant ranging from a few hours up to 24 hours. In each case, the outage caused the induced-draft (ID) fan to shut down automatically, and the AHPC was then brought on-line manually when the plant was up to stable operating conditions. There were also two occurrences where significant rainfall led to water leaking into the AHPC around an insulator, which resulted in arcing and automatic shutdown of the ESP power supply. In these cases, the AHPC remained on-line, but the pulse interval increased significantly without ESP power.

While the multiple unplanned outages added difficulty to the AHPC operation, they also provided a severe test of the ruggedness of the AHPC during multiple start-ups, power outages, and moisture in the compartment. In spite of all of these interruptions, the AHPC continued to operate with a reasonable pulse-cleaning interval in the range from 10–30 minutes.

Two inlet and two outlet U.S. Environmental Protection Agency (EPA) Method 17 dust loadings were completed after 3 weeks of operation (see Table 2). Based on these measurements, the collection efficiency was at least 99.99%. However, the measured efficiency was somewhat limited by the weighing accuracy of the filters before and after sampling. The sampling time for the second outlet dust loading was extended to 17 hours to lower the detection limit. The ultrahigh collection efficiency was confirmed by the perfectly clean outlet filter, even after sampling for 17 hours. The flue gas moisture values of 12% along with leak checks of the sampling trains before and after sampling provide quality control checks that the indicated flue gas volume was the actual volume sampled. Another indication of ultrahigh collection is that inspection of the clean plenum area of the AHPC following 6 weeks of operation showed the tube sheet to be completely clean.

Since the dust is known to cause operational difficulties for the Big Stone ESP because of high resistivity, it was expected that resistivity problems might also be an issue with the AHPC. Significant sparking and back corona were present from the first days of operation. Visual inspection through the sight ports during periods of severe sparking showed that sparking always was between the discharge electrodes and plates rather than between the electrodes and bags. In spite of a total of 150,000 sparks during the 6 weeks and some arcing when water leaked into the compartment, sparks were never observed going to the bags. In addition, after pulling bags and inspecting, there was no evidence of sparking damage.

Bag samples were analyzed using a microscope to determine if the high A/C ratio caused dust penetration. Under magnification of 10–50x, the media surface was clear of particulate matter after brushing, which indicates no dust penetration into the membrane.

The air permeability analysis of the AHPC filter bag media was performed in the lab using a Frazierometer. This device measures the amount of air that flows through a flat sample of media 3.5 in. in diameter and correlates it to a Frazier number. The Frazier number describes the volume of air (ft^3/min) passing through 1 ft^2 of media at a differential pressure of 0.5 in. W.C. A Frazier number of 1.0 indicated 1 $ft^3/min/ft^2$ at 0.5 in. W.C. Canceling units of ft^2, the Frazier number units are expressed as ft/min at 0.5 in. W.C.

Samples of the three AHPC filter bags were cut from the top, middle, and bottom bag locations. The average Frazier numbers for the three bags were 1.9, 1.8, and 2.4 ft/min at 0.5 in. W.C. Next, the samples were carefully brushed to remove the primary dust layer from the membrane surface. The samples were retested in the exact locations to measure the permeability change after brushing. The average bag permeabilities were 3.0, 3.0, and 4.6 ft/min at 0.5 in. W.C. These media permeability values are typical of filter bags from coal-fired boiler applications. As a baseline, the new media Frazier number is generally within the range of 3.5–6.0 ft/min at 0.5 in. W.C.

SUMMARY

After 6 weeks of operation, the bags seasoned to an on-line cleaned condition filter drag of 0.5 in. W.C./ft/min, which is considered typical for a coal-fired boiler application, and there was no evidence of sparking to or across the media. The AHPC has met Phase II experimental objectives of operation, including A/C ratio of 12 ft/min, dissipation of charge and spark potential, particulate release upon pulse-jet cleaning, low-particulate matter emissions, and recoverability from AHPC system upsets.

REFERENCES

1. Oglesby, S.; Nichols, G.B. , Electrostatic Precipitation, Marcel Dekker, Inc.: New York 1978.

2. Dennis, R. et al., Filtration Model for Coal Fly Ash with Glass Fabrics, EPA-600/7-77-084 Aug 1977.

3. Leith, D.; Rudnick, S.N.; First, M.W. High-Velocity, High-Efficiency Aerosol Filtration, EPA-600/2-76-020 Jan 1976.

4. Miller, S.J., Schelkoph, G.L.; Dunham, G.E.; Krigmont, H.V.; Walker, K.E. Advanced Hybrid Particulate Collector, A New Concept for Fine Particle Control. Partec 98, International Congress for Particle Technology, 4th European Symposium Separation of Particles from Gases, Nürnberg, Germany, March 10–12, 1998.

5. Miller, S.J. Advanced Hybrid Particulate Collector, A New Concept for Air Toxics and Fine Particle Control. Presented at the Advanced Coal-Based Power and Environment Systems '98 Conference, Pittsburgh, PA, July 21–23, 1998.

TABLE 1

AHPC Specifications

Flow Rate	8646 acfm at 12 ft/min 11,520 acfm at 16 ft/min
Bags	32 (4 rows × 8 bags/row) 5.75 in. d. × 15 ft long
Bag Type	GORE-TEX® all ePTFE No-Stat®
Collection Plates	18 gauge, 29-in. spacing 14 ft 4 in. × 7 ft 3 in.
Discharge Electrodes	Rigid mast type with directional spikes toward plates
Discharge Electrode Spikes to Plate Distance	5 in.
Discharge Electrode Spike to Bag Distance	6.5 in.
Rappers	Pneumatic vibrator type for both plates and discharge electrodes
HV Power	ABB switched integrated rectifier (SIR)

TABLE 2

AHPC Dust Loadings Taken 8/18/99

Inlet		Sample
Grains/scf	% H_2O	Time
1.17	12.84	25 min
1.36	12.84	15 min

Outlet		Sample	Removal
Grains/scf	% H_2O	Time	Efficiency %
0.0000913	12.2	4 hr	99.993
0.0000398	11.8	17 hr	99.997

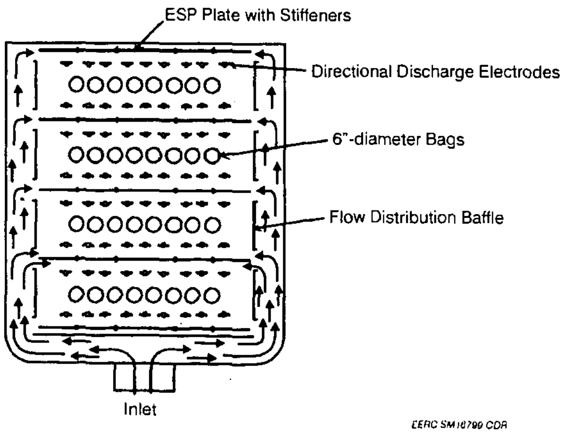

Figure 1. Top view of the 9000-acfm AHPC.