Boiler Derates Caused by Inadequate Fabric Filter Performance: Lessons Learned at a Midwest Utility Plant

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The Kansas City Power and Light (KCP&L) Hawthorn Station Unit 5 is a nominal 550 MW, Powder River Basin pulverized coal-fired boiler equipped with an SCR, air-preheater, two spray dry absorbers (SDA) and a B&W pulse-jet fabric filter (PJFF) to maintain PM_{10} emissions below 0.018 lb/MMBtu and SO_2 emissions below 0.12 lb/MMBtu (30 day rolling average).

The original filter bags supplied by the manufacturer were a nominal 16 oz/yd² scrim supported PPS needle felt with a dipped Teflon coating and experienced a bag life of approximately 3 ½ years, which is beyond the normal industry bag life for this filter media in this application. Nominal bag size was 150mm diameter by 8 meters.

Between the 30th to 38th months of operation the system pressure drop had gradually increased to over 10" w.g. and even with constant, rapid pulse cleaning at 100 psi, the unit could not recover sufficiently, which resulted in the boiler being de-rated on several occasions.

Several original filter bags were sent to an outside laboratory for analysis where it was determined that the manufactuer's needle felt PPS filter bags had developed a heavy and tenacious dust cake on the surface which resulted in a significant decrease in fabric permeability causing the high differential pressures. The condition made the filters unrecoverable and in late 2004 the plant decided to change out all 13,520 filter bags.

KCP&L determined that the original PPS filter bags met all regulatory requirements for PM (filterable and condensable) and SO_2 emissions but wanted to evaluate the opportunity to increase filter bag reliability and decrease total operational costs, while continuing to meet and exceed the regulatory requirements.

KCP&L and GE met to discuss the potential to improve the overall operational reliability of the PJFF system with an emphasis on methods to increase the original filter bag life. Operational data and independent lab tests were reviewed.

After this full system evaluation, GE recommended that KCP&L consider upgrading the filter bags to a 15.5 oz/yd², scrim supported, proprietary blended PPS filter media laminated with a high durability ePTFE to the collection surface.

What is ePTFE Membrane?

Expanded polytetrafluoroethylene (ePTFE) membrane is a technology that provides some of the highest efficiency of any available filtration media. Through a controlled manufacturing process, PTFE resin is expanded into a membrane film, composed of millions of microscopic pores in a three-dimensional web-like structure. These micro pores are small enough to capture sub-micron ash, yet large enough for the passage of airflow. The membrane can be laminated by various methods to most available needle-felt and woven filtration medias.

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To confirm the efficiency of the suggested filter media, test data was reviewed with KCP&L comparing both the original OEM needle-felt PPS and PPS with ePTFE membrane. Testing was done internally using the same protocol used in the Environmental Protection Agency's Environmental Technology Verification (ETV) program.

Test Protocol and Results

Testing of KCP&L's original OEM filter media along with GE's recommended 15.5 oz/yd² PPS with ePTFE membrane filter media was performed in-house following testing protocol used in EPA's ETV program using the same type of equipment utilized by EPA/ETV and in accordance with ASTM Test Method D6830-02 along with the test specifications and conditions as detailed in Generic Verification Protocol for Baghouse Filtration Products (BFP). The protocol was adopted from German VDI Method 3926 and modified for the ETV.

A 6-inch-diameter fabric filter sample is challenged with a standard dust (particulate matter) under simulated baghouse conditions at specified rates for air and dust flow. The test

Reprinted with revisions to format, from the April 2011 edition of **POWER ENGINEERING**

TABLE 1 TEST RESULTS

Verification Test Results	16 oz PPS	15.5 oz PPS w/ ePTFE
Mean Outlet Particle Conc. $PM_{2.5}$ (gr/dscf)	0.0001834	0
Mean Outlet Particle Conc. Total mass (gr/dscf)	0.0001834	0
Initial Residual Pressure Drop (in. w.g.)	1	1.3
Change in Residual Pressure Drop (in w.g.)	0.07	0.02
Average Residual Pressure Drop (in w.g.)	1.04	1.32
Mass Gain of Filter Sample (grams)	2.18	0.11
Average Filtration Cycle Time (s)	136	222
Number of Pulses	53	32
Permeability		
Initial Perm $ft^3/min/ft^2$ (CFM) @ .5" H_2O	40.8	4.7
Perm After Testing	2.99	2.98
Percent Retained Perm	7.30%	63.40%
Removal Efficiency (%)		
Dust Conc. (gr/dscf)	8.23	8.23
$PM_{2.5}$ *	99.997119	100
Total Mass **	99.997771	100

* (Dust Concentration * .7735) – PM2.5 Outlet Concentration * 100 Dust Concentration * .7735
** Dust Concentration – Total Mass Outlet Concentration * 100 Dust Concentration

consists of three test runs. Each run consists of three sequential phases or test periods during which dust and gas flow rates are constantly maintained to test specification. The test phases are:

- A conditioning period of 10,000 rapid pulse filtration cycles (every 3 seconds)
- A recovery period to allow the test sample to recuperate from rapid pulsing where the filter is pulsed only when the differential pressure reaches 4" w.c.
- A 6-hour performance test period during which measurements for particulate emissions are determined by gravimetric measurement of the particulate matter that, passes through the sample. Particulate used for the test is 1.5 micron mass mean diameter with at least 50 percent less than 2.5 microns.

Test Conditions Throughout the Test Were as Follows:

- Test dust: Pural NF Alumina (1.5 ± 1 micron mass mean diameter)
- Inlet dust feed rate: 8.0 ± 1.6 gr/dscf (18.4 ± 3.6 g/dscm)
- Filtration velocity: 6.6 ± .5 fpm (120 ± 6 m/hr)
- Gas temperature: 78 ± 4 F (25 ± 2 C)
- Pulse cleaning pressure: 75psi
- Testing was conducted to determine the filter sample's performance with respect to the following parameters:
- Outlet particulate emissions ($PM_{2.5}$)
- Outlet particulate emissions (total mass)
- Initial residual pressure drop
- Increase in residual pressure drop
- Average residual pressure drop
- Mass weight gain of the filter sample
- Average filtration cycle time
- Number of filtration cycles

In December 2004, KCP&L made the decision to rebag the entire PJFF with the recommended 15.5 oz/yd^2, scrim supported 100 percent PPS with ePTFE membrane laminated to the filtration surface.

Filter Bag Media Performance

The Hawthorn Unit 5 PJFF operation was reviewed over time comparing the pressure drop, cleaning frequency, gas flow and other parameters between the two styles of filtration media. The most obvious improvement for KCP&L was a filter bag life from 38 months to 62 months while still compliant with all regulations.

The condition made the filters unrecoverable and in late 2004 the plant decided to change out all 13,520 filter bags.

In April 2005, a small leak in a filter was detected in compartment No.5. When this compartment was isolated to change the filter bag, the pulsing system was inadvertently left off on the entire baghouse for a prolonged period of time and the pressure drop across the baghouse system exceeded +15"w.g. before the fan tripped out (fan set to trip at 16.0"w.g.). Once the pulsing system was turned back on, the filters were able to recover back down to the 6.0" to 7.0"w.g. established as the target PJFF system pressure drop between KCP&L and GE Energy.

On several occasions there were ammonia slips upwards of 10 ppm typically as a result of SCR catalyst erosion. Ammonia slip can have a substantial negative impact on filter bag performance in the form of high differential pressure and difficult recovery. The ammonia slip forms ammonium bisulphate and creates a dense

and sticky cake structure as shown in the picture below.

When these events occurred the differential pressure increased across the PJFF unit, but came back down within a reasonable time to a normal operating differential pressure simply because the membrane surface is a slick surface that sheds the dustcake much better than the original OEM, non-membrane PPS filter bag.

PJFF system pressure drop averaged between 6.0"w.g. to 7.0"w.g. over the life of the membrane filter bags compared to over 10"w.g. at the end of the life cycle of the non-membrane PPS filter bags. This consistent differential pressure across the PJFF system allowed KCP&L to operate continuously at the required load without any derates of the boiler due to the PJFF system.

Pulse cleaning pressure used to clean the filters was reduced from up to 100 psi with the original supplied non-membrane filter bags to 75 psi during the life cycle of the membrane filter bags. The baghouse cleaning cycle, which is defined as the amount of times the baghouse cleans each filter per day, averaged between 45 to 55 cycles. During the last 30 -to 38-month life of the original filters, the baghouse was in a continuous cleaning mode, pulsing approximately between every 30 seconds down to 10 seconds.

And finally, PM_{10} emissions remained well below the 0.018 lbs/MMBtu regulation limit through out the 62-month life cycle.

Operational Results

PM_{10} emissions test data was performed annually on both types of filter medias and documented. The ePTFE membrane PPS filter media performed well below Kansas City Power & Light's PM_{10} regulation of 0.018 lbs/MMBtu and at a fairly level rate over the entire 62-month life cycle.

Data on differential pressure measured across the PJFF system was acquired from KCP&L DCS. Data is not available from years 2000 through 2002 due to the unavailability of the data from the DCS. During the last two years of data collection from the original PPS filters, the adverse effect of filter age (especially 30th to 38th month), ammonia slips and filter media bleed through causing an average of +10"w.g. across the system resulting in de-rating of the boiler on several occasions.

In comparison, the PPS membrane filters show a more consistent system pressure drop over the 62-month life cycle with an average between ~6.0"w.g. and ~7.0"w.g. During the evaluation of filter media candidates, KCP&L took into consideration the energy cost reduction with the potential lower system pressure loss as part of the economic evaluation between the two medias as well as expected life expectancy and PM_{10} efficiencies.

Conclusions

Long-term operational results conclude that upgrading the original PPS media to PPS with laminated ePTFE membrane filter media provided KCP&L Hawthorn 5 PJFF system a more reliable system. Filter life increased from 38 months to 62 months, lower operational costs were realized, PM_{10} regulations were well below limits and no boiler de-rates were experienced due to high differential pressure drops across the PJFF. pe

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