Long-Term COHPAC Baghouse Performance at Alabama Power Company's E. C. Gaston Units 2 & 3

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Abstract: Following a successful pilot-scale baghouse testing program and after reviewing the performance of Luminant's COHPAC (EPRI's patented Compact Hybrid Particulate Collector technology) baghouse installation at its Big Brown Station, Alabama Power Company (APCO) decided to install a COHPAC baghouse on Unit 3 at its E. C. Gaston Steam Plant located near Wilsonville, Alabama in late 1996. A second COHPAC baghouse was installed at Gaston Unit 2 in 1999. These baghouse systems were designed with the low pressure/high volume pulse-jet cleaning technology (Hamon Research-Cottrell) that orients the bags in concentric rings and uses rotating pulse manifold arms. Performance of these systems at Plant Gaston Unit 3 and Unit 2 has been excellent during the past eleven and a half and nine years, respectively. Original 3.0 and 2.7 denier Ryton felted fabrics have given way to higher permeability 7.0 denier PPS felt bags in both units. Overall flange-to-flange and tubesheet pressure drop performance has improved without compromising particulate collection efficiency. Recent filter drag values of 0.5 in. H_2O/ft/min on Unit 3 and 0.3 in. H_2O/ft/min on Unit 2 have been experienced at air-to-cloth values of 8.0 ft/min. Average pulsing frequencies have ranged from 0.2 pulses per bag per hour for recently installed 7.0 denier PPS felted bags up to 0.7 pulses per bag per hour for older 2.7 denier Ryton felt bags. COHPAC baghouse installation has successfully reduced stack opacity. Comparing the average of the last eleven years of operation (1997 – 2007) to the average of the two years prior to COHPAC baghouse installation on Unit 3 (1995 – 1996), the average opacity has been reduced 50% and the number of hours per month that the average opacity has exceeded 20% has been reduced 95%. Similar results have been experienced on Unit 2. Except for early bag failure episodes on each unit caused by bag-to-bag abrasion, bag life has been very good. The original 3.0 denier Ryton felted bags in the rear modules of the Unit 3 baghouse remained in service for five years accumulating over 39,500 hours of exposure to flue gas with few bag failures. Front module bags in Unit 3, however, had much shorter bag lives because of a higher incidence of bag failures. Average service lives for the 3.0 and 2.7 denier filter bags were similar to those of the follow-on 7.0 denier PPS felted fabrics, typically two to three years, 19,000 to 27,000 hours of exposure to flue gas. Evaluation of the performance of various test bags has been ongoing for several years. Early tests compared the performance of 6.0 denier and 7.0 denier PPS felts with traditional 2.7 denier felts. 7.0 denier felted fabrics performed very well. More recently, various dual-density felts have been tested. Results after 20,000 hours of flue gas exposure indicate that the Dual Density Torcon – 9058 felt is the best of the four test fabrics. The test program is continuing. COHPAC baghouse performance for Alabama Power Company has exceeded expectations and continues to provide an excellent air pollution control benefit.

Keywords: Fabric filter, baghouse, COHPAC

1 INTRODUCTION

1.1 COHPAC Technology

COHPAC technology was developed by the Electric Power Research Institute in the early 1990s. COHPAC is an acronym for Compact Hybrid Particulate Collector. COHPAC incorporates a small, pulse-jet baghouse installed downstream of a poorly performing electrostatic precipitator (for example) to act as a particulate polishing unit to allow the combined ESP/baghouse system to successfully meet federal or state mandated particulate emission limits. This eliminates the need for costly ESP retrofits or rebuilds. The small pulse-jet baghouse, able to operate at higher than normal filtering velocities (4.0-6.0 cm/s (8-12 ft/min) versus 0.75-2.5 cm/s (1.5-5.0 ft/min) for a conventional baghouse) because of the relatively low inlet mass concentration, requires a significantly smaller footprint compared to a low-ratio fabric filter. The use of a baghouse also overcomes the sensitivity of electrostatic precipitator particulate collection efficiency to variations in particulate and flue gas properties. A United States Patent, Number 5,024,681, was issued on June 18, 1991. [1,2].

1.2 E. C. Gaston Electric Generating Plant

Alabama Power Company (APCO), a Southern Company subsidiary, owns and operates the E. C. Gaston Electric Generating Plant located near Wilsonville, Alabama, approximately 40 miles southeast of Birmingham, Alabama. This plant consist of four (4) 270 MW balanced draft and one (1) 900 MW forced draft, coal-fired boilers. Each boiler is outfitted with hot-side electrostatic precipitators for control of particulate emissions. All five boilers burn low sulfur, eastern bituminous coals. At Plant Gaston a single stack services Units 1 through 4. Units 1 and 2 share a common stack liner; Units 3 and 4 share a second common stack liner. Although the coals used at Plant Gaston were originally treated with sodium sulfate to enhance performance of the hot-side ESPs, load reductions and frequent ESP washings were required to maintain acceptable opacity levels. Alabama Power in the mid-1990s began to investigate ways to remedy this problem. After studying the experience of the first full-scale COHPAC installation at Luminant's (formerly TXU) Big Brown station [3], EPRI and Southern Company Services (SCS) in September 1995 installed a 1-MW scale COHPAC pilot plant at APCO's J. H. Miller Steam Electric Generating facility in anticipation of using this technology at their E. C. Gaston plant.

1.3 Pilot Plant Testing

Prior to the application of the COHPAC technology to the Plant Gaston full-scale utility, coal-fired boiler, there was a period of pilot plant testing that took place at a separate Alabama Power Company plant, the James H. Miller Steam Electric Generating Plant. This site was chosen because the coal-fired boiler incorporated a hot-side electrostatic precipitator followed by an air heater similar to the E. C. Gaston units and the coal supply was similar to that used at Plant Gaston. The Miller Station pilot plant was installed downstream of the existing Unit 2 hot-side ESP and air preheater and utilized a low pressure/high volume pulse-jet cleaning technology, similar to the Hamon Research-Cottrell design that was ultimately used at Plant Gaston. The pilot plant was modified to operate with interstitial can velocities of less than 1,000 feet per minute while filtering at nominal air-to-cloth ratios of 8.5 to 10.0 feet per minute, and utilizing, exclusively, an on-line cleaning mode of operation. This was done to ensure that this method of operation was viable and reliable prior to implementing it on a full-scale basis.

Ryton felt filter bags (18 oz.yd^2) were installed in the pilot baghouse. To achieve the desired filtration velocities the bags were 23-feet long. Testing with both timed- and pressure-drop-initiated cleaning took place to maintain desired pressure drop levels across the pilot unit. The COHPAC pilot facility operated very well during its two-year test program, with no significant problems [4]. The low pressure/high volume pulse cleaning technology with on-line cleaning successfully maintained tubesheet pressure drops of 4 inches w.c. with 8.5 to 10.0 foot per minute air-to-cloth ratios. Pulse frequencies were easily kept at or below one pulse per bag per hour on average.

2 COHPAC BAGHOUSE INSTALLATION

Because of the success of the COHPAC pilot testing at Alabama Power Company's Miller Station and the experiences at Luminant's Big Brown Station (two 575 MW COHPAC units), Alabama Power decided to install a full-scale COHPAC baghouse to filter the flue gases on their E. C. Gaston Unit 3 coal-fired boiler. Alabama Power contracted with Hamon Research-Cottrell in early 1996 to install a COHPAC, pulse-jet-cleaned, fabric filter system downstream of Unit 3's existing hot-side electrostatic precipitator and air heater. Following the installation, startup, and successful operation of the COHPAC system on Unit 3, Alabama Power again selected Hamon Research-Cottrell in early 1998 to install a similar system on Unit 2. Both systems were nearly identical in scope, design, and complexity[5].

Due to site and space restrictions each COHPAC system was installed in two (per unit) abandoned cold-side ESP casings located on the cold-side of the existing Ljungstrom air pre-heaters. These units were located directly under the existing hot-side precipitators, and between Units 1 and 4, which were in full operation during the construction phase of the program. These unusual site conditions made the installation of these two systems extremely difficult, especially because of the relatively short outage windows available.

2.1 Description of the COHPAC Baghouse Installation

Each of the COHPAC baghouses was designed to treat flue gas volumes of 1,070,000 acfm at 290 F, producing a design gross filtration velocity of 8.5 feet per minute with all compartments in service. Each baghouse casing (two casings per unit using the old cold-side ESP boxes) consisted of four (4) isolatable compartments, two compartments per air-preheater identified as Side A or B. Each compartment consisted of two bag bundles (modules) oriented in the direction of gas flow, each having a total of 544, 23-foot long, filter bags. The original equipment bag was a 3.0 denier Ryton felt having a nominal weight of 18 oz./yd^2. There were 1,088 bags per compartment, or 2,176 bags per casing. Fig. 1 shows an elevation view of the COHPAC baghouse/bag module arrangement.

Due to the limited size of the abandoned cold-side ESP casings, and to be able to accommodate the design flue gas volumes and provide the specified air-to-cloth ratios, each original ESP casing was extended by approximately 12 feet in length. The two isolatable compartments in each casing are separated by a central flue gas bypass section. The bypass system can be 100% opened to handle the full flow of the casing or can be regulated to maintain the proper air-to-cloth ratio in the single compartment that is not isolated. To allow inspection and /or maintenance of any given compartment, a bypass condition is mandated on the side being entered. Each compartment is equipped with a multi-louver inlet damper and a guillotine outlet damper to allow isolation during periods of inspection and/or maintenance.

Each compartment is outfitted with individual, low leakage, purge/ventilation poppet dampers designed to allow the introduction of ambient air into the compartment to purge the compartment of flue gases. The poppets are mounted below the tubesheet. These dampers also serve as a vacuum breaker to aid in opening the roof hatches. The dampers open automatically when a single compartment is isolated or when the entire baghouse is either bypassed or shut down. Purge air is then drawn through the purge poppets using the system's induced draft fans.

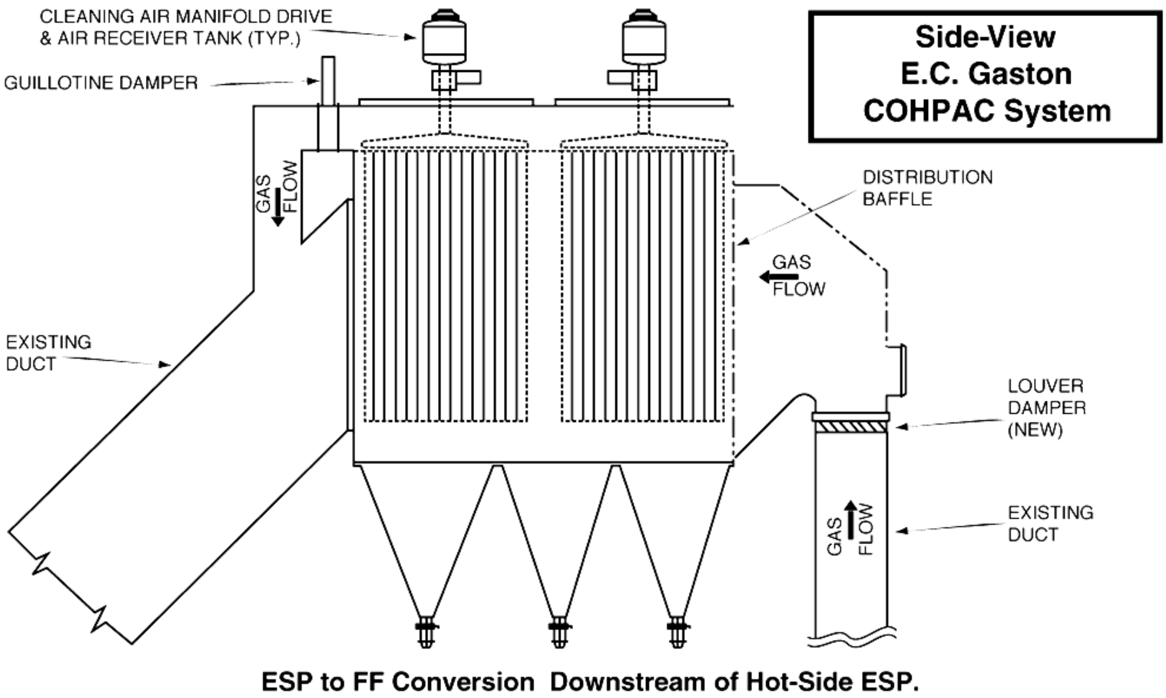

Fig. 1 E. C. Gaston COHPAC Baghouse System Elevation View

Access to the individual compartments is provided through roof mounted hatches which are located over each individual bag bundle. Each hatch is separated into two (2) hinged halves. A short ladder allows access to the top of the tubesheet. The tubesheet is about five (5) feet below the compartment roof. The low pressure/high volume pulse-jet cleaning system, with its rotating pulse manifold, simplifies access to each filter bag since individual blowpipes do not have to be removed. Unit 3's blowers are located at grade behind the unit's induced draft fans and abandoned stacks, while Unit #2's blowers (now at grade) were originally located directly above the Unit #3 COHPAC system on a platform located under the hot-side ESP's return ductwork.

Prior to the completion of the final design of each baghouse system, a model study was performed to confirm flow profiles from the inlet and outlet ductwork configurations. There was limited headroom between the top of the casing and the bottom of the hot-side ESP directly above the baghouse. This necessitated the use of split filter-bag cages. In addition, baghouse construction was quite challenging because crane access to the area was highly restricted. [6]

2.2 Remote Monitoring System

Southern Research Institute installed individual remote baghouse monitoring systems on both Unit 2 and Unit 3. These systems can be accessed via modem to allow real-time monitoring of the system operation, along with current and long-term trend analysis. [7] These monitoring systems were functional at the startup of each baghouse system and remain in service to this day. These systems were developed by Mr. Ray Wilson of Ray Wilson Consulting. The proprietary software packages retrieve, display and store the COHPAC baghouse performance data. Besides performance, date, time, boiler load, and stack opacity are also logged and displayed. The datalogging system's software also stores the data for later retrieval, archiving, and preparation of historical trend graphs.

3 LONG-TERM UNIT 3 BAGHOUSE PERFORMANCE

The first E. C. Gaston COHPAC baghouse was installed on Unit 3 and began operation on December 26, 1996. Through the end of 2007 the Unit 3 COHPAC baghouse had accumulated 94,428 "clock hours" (total number of hours the filter bags could have been exposed to flue gas, equivalent to the number of hours between bag installation and removal) of operational time.

3.1 Pressure Drop and Air-to-Cloth Ratio

The baghouses were designed to operate at a nominal air-to-cloth ratio of 8 to 8.5 ft/min. Typical flange-to-flange pressure drop and air-to-cloth ratio performance data collected during the first half of 2007 are shown in Fig. 2.

Pressure transducers to track tubesheet pressure drop were not installed on the Unit 3 baghouse compartments.

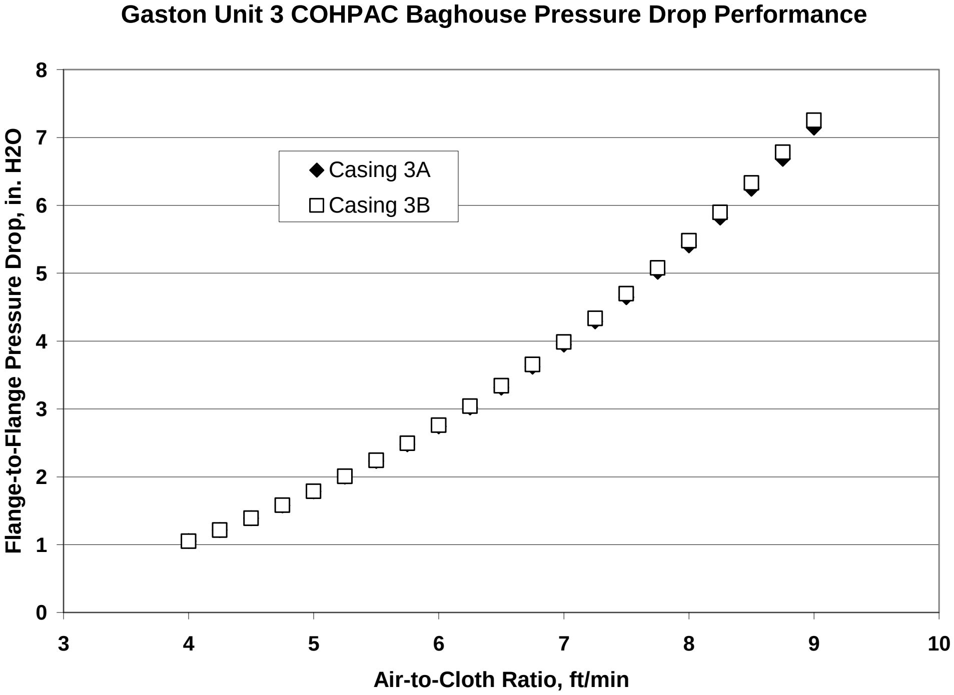

Fig. 2 Gaston Unit 3 COHPAC baghouse pressure drop performance. The relationships are based on over 2,700 data points (hourly averages) from the first half of 2007. Points on polynomial curve fits to the data for each casing are shown

The relationships shown in Fig. 2 were developed as polynomial equations fitted to over 2,700 data points (hourly averages) from operating data collected during the first half of 2007. Air-to-cloth values ranged from 4 to 9 ft/min as the boiler load varied from about 70 to 270 megawatts. The flange-to-flange pressure drop performance for Casing A and Casing B was almost identical.

At an air-to-cloth value of 8 ft/min the average flange-to-flange pressure drop is about 5.45 in. H_2O. The baghouse supplier estimated that the difference in pressure drop between the flange-to-flange and tubesheet pressure drop values at an air-to-cloth value of about 8 ft/min would be 1.25 in. H_2O. The estimated value of the tubesheet pressure drop then would be about 4.2 in. H_2O for the data shown in Fig. 2. The tubesheet drag value then would be about 0.5 in. H_2O/ft/min, a desirable value for COHPAC baghouse operation.

3.2 Pulsing Frequency

As described earlier, each baghouse casing has two compartments separated by a bypass duct. Each compartment contains two bag bundles (modules) oriented in the direction of gas flow. Each bundle contains 544 filter bags, except module 3B11 which contains 18 additional filter bags. The bags are arranged in 14 concentric circles or rows. A rotating dual arm pulse manifold delivers pulse air to the tops of the filter bags. One arm has rectangular nozzles oriented over the even rows, while the other manifold arm cleans the odd rows. The pulse manifolds rotate at approximately 1 rpm. Pulse pressure is maintained at 10 psig. When cleaning is initiated the pulsing alternates between the four pulse manifolds in each casing. This allows time for the air reservoir mounted above each pulse manifold to recharge before the next pulse. Bags are cleaned randomly depending on the location of the pulse arm when pulsing occurs. The baghouse control system was programmed to count the number of pulses in each five minute period continuously. These data are fed to the baghouse monitoring system and are used to calculate a pulse frequency, pulses per bag per hour (p/b/h). If continuous cleaning is in progress, approximately 57 pulses per five minutes are counted, a rate of about 4.2 p/b/h.

The baghouse was designed for bag cleaning to be initiated in one of three ways. These were pressure drop initiation/termination, drag initiation/termination, or time. When the baghouse was first started up the system used drag initiation and termination set points to control cleaning. Eventually, because test programs on Unit 3 in 2000 and 2001 required pressure drop initiation and termination set point cleaning, this became the normal mode to control cleaning of the bags. Timed cleaning has always been the third method. The timed cleaning set point has always been five hours between cleaning events.

During the first half of 2007 typical average cleaning frequencies for Casing A and Casing B were 0.21 and 0.17 pulses per bag per hour, respectively. These rates are typical for the 7.0 denier PPS felt bags currently installed. During operation with 3.0 and 2.7 denier Ryton felt bags, pulsing frequencies would range from 0.4 to 0.7 p/b/h, with occasional excursions over 1.0 p/b/h depending on how long the bags had been in service and the performance of the upstream hot-side

ESP. A cleaning frequency of 0.5 p/b/h or less is a desirable value for COHPAC baghouse operation.

3.3 Baghouse Emissions and Unit 3&4 Opacity

Since startup of the baghouse Alabama Power Company has had outlet particulate concentrations (gr/dscf) from the Unit 3 baghouse measured on a yearly basis. They provided these data for this report. Testing was performed separately on the outlet of Casing A and Casing B. These data are shown in Fig. 3 as a bar chart. It is likely that the higher particulate emissions measured in March 1997 were caused by bag failures or improperly installed bags that had not yet been located and corrected after startup. Outlet emissions degraded each year until the filter bags in the four front bag modules were replaced in October 2000. Outlet emissions have remained relatively low since that time. The trend toward higher outlet emissions in 2006 and 2007 reflect the aging of the 7.0 denier PPS bags installed in Casing 3B in 2003 and Casing 3A in 2005. These bags were scheduled to be replaced in December 2007 and March 2008, respectively. While the preceding data reflect the outlet emissions of the Unit 3 COHPAC baghouse alone, data have also been collected over the years regarding the opacity of the stack containing the flue gases from both Unit 3 and Unit 4. While the baghouse installed on Unit 3 greatly improved the overall opacity for the Unit 3 and 4 stack, the values, of course, have also been dependent on the performance of the hot-side ESP on Unit 4 since it is that unit's sole particulate control device.

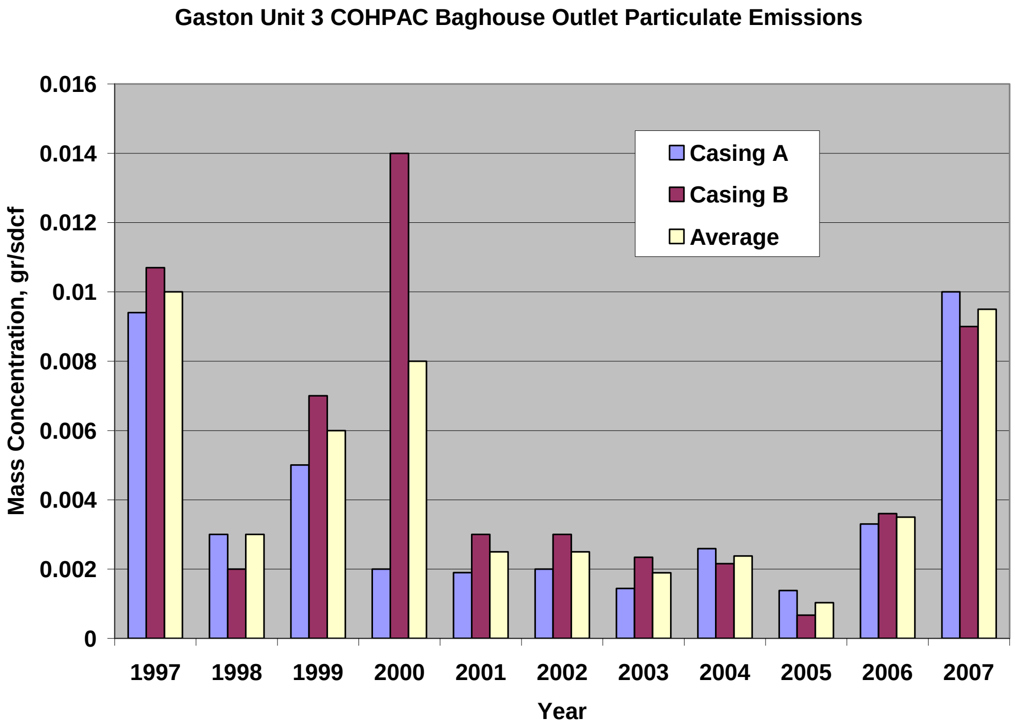

Fig. 3 Gaston Unit 3 COHPAC baghouse outlet average particulate mass concentrations by year since startup

Fig. 4 shows the monthly averages for stack opacity and the number of hours each month that the average opacity exceeded 20%. These data represent only those times when both units were in operation simultaneously and no baghouse compartments were bypassed. As can be seen in the figure, after the installation of the baghouse there was a significant reduction in stack opacity values. The effect of baghouse installation on the hours per month when opacity exceeded 20% was dramatic. Notice the improvement in opacity near the end of 2000 (68 months) when the filter bags in the four front modules of the baghouse were replaced. Comparing the average of the last eleven years of operation to the average of the two years prior to baghouse installation, the average opacity has been reduced 50% (12.7% to 6.3%) and the number of hours per month that the average opacity has exceeded 20% has been reduced 95% (140 to 7).

3.4 A Discussion of Bag Life

The filter bags are the major O&M cost of baghouse operation. The goal is to maximize the performance and life of the bag, thereby minimizing the frequency of bag replacement. Bag life at Gaston Unit 3 has in general been very good. The baghouse started up with 3.0 denier Ryton felt bags (provided by the OEM) installed in all compartments. Grubb Filtration Testing Services (Delran, NJ) has provided advice on bag replacement and conducted special testing of used bags removed from the baghouse throughout its life.

Since startup all filter bags have been replaced twice. The baghouse is currently on its fourth set of filter bags. The filter bags in Casing B were replaced during a fall 2007 outage. The filter bags in Casing A werereplaced during a March 2008 outage. Filter bags in the front modules (A10, A20, B10, B20) have been replaced more frequently than those in the rear modules.

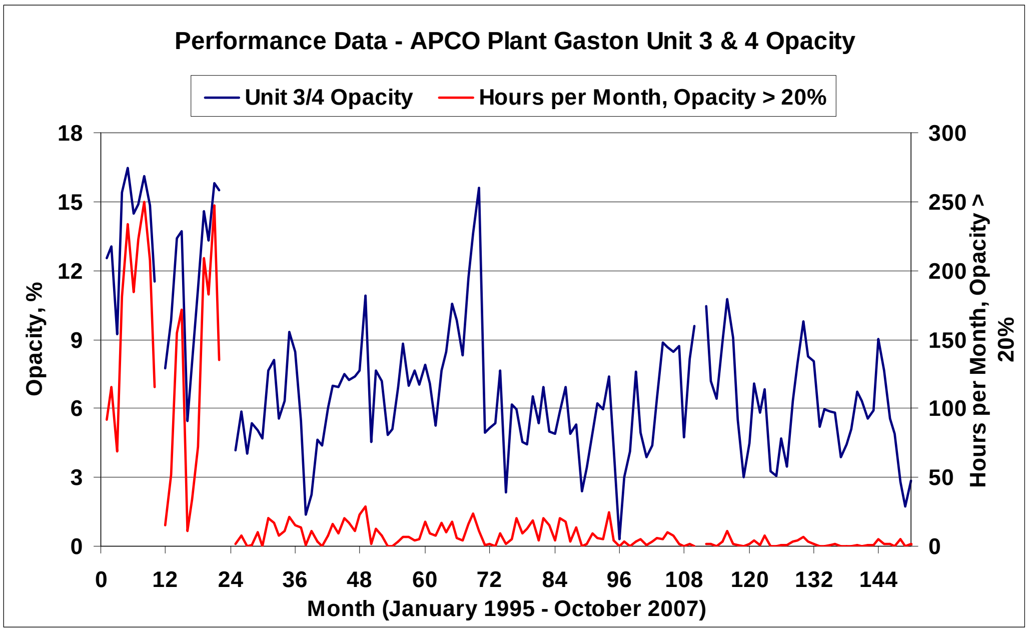

Fig. 4 Monthly average opacity and 20% opacity exceedence from January 1995 though October 2007 for Gaston Units 3 and 4

There were early bag failures in the front modules of both casings (A10, A20, B10, B20) caused by bag-to-bag abrasion. This occurred mainly on the bags located near the sides of the modules closest to the compartment walls. Even though there were perforated plates at the inlet to the compartments to even the flow across the face of the bag bundles, flue gas tended to sweep around the bundle and attempt to pass between the bundle and the compartment walls. This resulted in excessive bag swinging and rubbing against other bags. Bag inspection confirmed more failed bags on the sides of the bag bundles adjacent to the compartment walls. Inspection of the perforated plates installed downstream of the compartment inlet dampers also showed areas of ash buildup that resulted in uneven flow across the face of the plate and sneakage under the plate. Compartment particulate emissions continued to climb until a full replacement of the filter bags in the four front bag modules in October 2000. Opacity values were significantly lower following the replacement of these bags, as can be seen in Fig. 4 (October 2000, 68 months).

During that outage a novel solution to the bag swinging/abrasion problem was implemented. Two concentric rings were installed on each of the four front bag bundles. These tubular rings were mounted inside and outside the outer row of bags about six inches above the bottom of the bags. This minimized bag movement and reduced bag-to-bag abrasion. Fig. 5 shows a photograph of these rings installed on one of the bag bundles.

In addition to these retaining rings, vibrators were attached to the perforated plates to prevent buildup of ash that could block the holes and cause flow stratification.

Baghouse emissions remained low through 2004. In December 2003 in the B casing and in May 2005 in the A casing 7.0 denier PPS felt filter bags were installed. These bags were designed for higher permeability (lower pressure drop at similar flow rates), but they are not as good a barrier for ash penetration. While pressure drop performance of these bags has been excellent, there has been a steady increase in outlet emissions since these bags were replaced. This has not been noticeable in the opacity data because of lower average load values over the last couple of years.

3.5 Summary

The COHPAC I baghouse on E.C. Gaston Station Unit #3 has operated exceptionally well. Other than a few initial mechanical problems, the unit has operated better than anticipated. The COHPAC I technology has provided Alabama Power with a high degree of system flexibility; it has moderated ESP opacity spikes and reduced average stack outlet opacity levels by almost 50%. This has increased the choice of acceptable fuels that can be used on this unit, and has reduced overall operating costs. Alabama Power has also been able to eliminate the use of sodium sulfate (an ash resistivity modifier) on Units #3 and #4 and reduce the frequency of ESP washings. [8,9,10]

4 LONG-TERM UNIT 2 BAGHOUSE PERFORMANCE

The second COHPAC baghouse installed at Alabama Power Company's E. C. Gaston plant was on Unit 2. The design of this fabric filter was almost identical to the Unit 3 baghouse. The only significant change was a different bag arrangement pattern for the eight tubesheets even though there was the same number of filter bags per bag module.

The Unit 2 COHPAC baghouse started up on June 14, 1999. Through December 2007 the baghouse had accumulated 74,938 "clock hours" (total number of hours the filter bags could have been exposed to flue gas, equivalent to the number of hours between bag installation and removal) of operating time.

Performance of the Unit 2 baghouse has been very similar to that experienced by the Unit 3 baghouse and a detailed discussion will not be presented. Highlights have been included in the abstract. Additional information may be obtained from the authors.

Fig. 5 Photograph of concentric tubular stainless-steel rings installed on Gaston Unit 3 COHPAC baghouse bag bundle 3A10. There were installed to reduce bag movement and bag-to-bag abrasion

5 SPECIAL FILTER BAG TEST PROGRAMS

Various test bags have been evaluated at the Gaston COHPAC baghouses since 2000. These include filter bags that have become the current replacement filter bags, plus special non-standard bags especially manufactured for testing. Filter bag performance has been measured by the use of a special drag measurement device designed for low pressure/high volume oval (Carter-Day/Howden) filter bags. This device allows the drag of individual bags to be measured. It consists of a fan, venturi, flexible hose, and a gasketed adaptor that fits over and around the cage's top flange to seal with the tubesheet. This insures that the induced flow is pulled only through the bag being tested. Pressure taps are located to measure the pressure drop across both the venturi and the filter bag. Knowledge of the venturi flow rate and pressure drop across the filter bag allows calculation of the bag's drag (in. H_2O/ft/min).

Test programs have taken place with both the Unit 2 and Unit 3 COHPAC baghouses. Prior to the rebagging of the entire Unit 2 baghouse with 7.0 denier PPS felt bags in November 2003, a small number of these bags were installed in the 2A11 bag module in June 2001. In addition the entire B casing on Unit 2 was rebagged with 6.0 denier Ryton felt bags in December 2001. Drag testing of these bags took place in May 2002 and March 2003. Comparative drag measurements were conducted on selected 2.7 denier Ryton felt bags from Unit 2 and Unit 3 at the same time. The test results for the 7.0 denier PPS felt bags are presented in Table 1.

The average drag for the eighteen 7.0 denier PPS felt bags was 0.18 in. H_2O/ft/min. The average drag for 10 adjacent 2.7 denier PPS felt bags was 0.31 in. H_2O/ft/min. An additional 27 randomly located 2.7 denier PPS felt bags were tested.

Table 1 Drag Measurements Conducted on May 6, 2002 in Bag Module 2A11

Bag Type	Average Drag	Stn. Dev.	# of Bags	Service Hours	Comments
	(in. H_2O/ft/min)				
7.0 denier PPS	0.18	0.03	18	7,500	Average of all bags
2.7 denier PPS	0.31	0.09	10	7,500	Average of all bags

2.7 denier PPS	0.35	0.14	27	7,500	Average of all bags
2.7 denier PPS	0.31	0.06	24	7,500	Average excludes three Row 15 bags

Their average drag was 0.35 in. H_2O/ft/min. Three of the bags had exceptionally high drag. If they are excluded from the average, the remaining 24 2.7 denier PPS felt bags also had an average drag of 0.31 in. H_2O/ft/min., identical to the average drag of the ten 2.7 denier bags adjacent to the 7.0 denier bags. After 7,500 hours of operation the 7.0 denier PPS felt bags had 42% lower drag on average than the 2.7 denier PPS felt bags.

Drag measurements on the 6.0 denier PPS felt bags installed in December 2001 were conducted in May 2002 and March 2003. Additional comparative measurements on 2.7 denier PPS felt bags from Unit 3 also took place in March 2003. Bags from modules 3B10, 3B11, 3B20, and 3B21 were tested. The test results are presented in Table 2 below.

Table 2 Drag Measurements on 6.0 denier PPS and 2.7 denier PPS Felt Bags

Bag Module	Bag Type	Average Drag	Stn. Dev.	# of Bags	Service Hours	Comments
		(in. H_2O/ft/min)				
2B10	6.0 den. PPS	0.24	0.10	37	3,650	Average of all bags
2B10	6.0 den. PPS	0.41	0.07	42	10,870	Average of all bags
3B10	2.7 den. PPS	038	0.04	28	20,370	Average of all bags
3B11	2.7 den. PPS	0.32	0.08	32	11,000	Average of all bags
3B20	2.7 den. PPS	0.39	0.05	28	20,370	Average of all bags
3B21	2.7 den. PPS	0.29	0.10	25	11,000	Excludes 6 bags with high drag

The average drag values for the 6.0 denier PPS felt bags after both 3,650 hours and 10,870 hours (0.24 and 0.41 in H_2O/ft/min) were higher than the average drag value for the 7.0 denier bags at 7,500 hours (0.18 in. H_2O/ft/min). Drag values for the 2.7 denier PPS felt bags at 11,000 and 20,000 hours were slightly higher than the values measured after 7,500 hours (Table 2). The average drag values for the bags in the front modules (3B10, 3B20) were higher than the drag values for the bags from the rear modules (3B11, 3B21) because of their longer service life.

The latest test program with the Unit 3 baghouse is an ongoing program that is evaluating the performance of special dual-density PPS felt filter bags. These bags were installed in May 2005. The test bags are installed in baghouse module 3A11. Subsequent measurements of filter drag took place in February 2006 and November 2007. There are four fabrics being evaluated, including the current "standard bag," a 7.0 denier Torcon PPS felt. The fabrics are described in below. Additional information is provided in Table 3.

1) High Permeability Dual-Density Torcon PPS Felt (Blended/Lined Face Out)-Midwesco Filter Resources Product Number FWA429-9058 (12 bags).
2) 7-Denier Procon PPS Felt (BHA Group Product Number 02985898) (24 bags).
3) High Permeability Dual-Density Torcon PPS Felt (7-Denier/Unlined Face Out)-Midwesco Filter Resources Product Number FWA429-9059 (11 bags).
4) "Standard" 7.0 denier Torcon PPS felt (9 bags).

Table 3 Test Fabric Properties – QA Test Results

Test Fabric (QA Test Results)	Weight (oz/yd^2)	Thickness (inches)	Permeability (cfm @ 0.5 in. H_2O)	Mullen (psi, gross)
7-denier Procon	16.69	0.105	128	505
Dual-Density (9058)*	15.36	0.097	86	444
Dual Density (9059)*	14.67	0.098	109	399

*Note from Grubb Filtration – These fabrics from the same master roll were just singed on opposite faces. We suspect that the samples submitted for QA testing exhibited normal variations in weight and permeability throughout the master roll. It is not conclusive, based on testing only one sample from the roll ends, whether there was any real difference in the average fabric properties for the 9058 and 9059 test bag sets.

The high permeability, dual-density fabrics are essentially dual-density versions of the standard 7-denier Torcon PPS felt bags that are used at Plant Gaston. The only differences were that the batt on one face would be a 50/50 blend of 2.7-denier and 7-denier Torcon (rather than all 7-denier) and that the permeability would be 85 ± 15 cfm (rather than 125 ± 20 cfm).

Half of the bags were to be made from fabric singed on the blended-denier (lined) face (9058) and the rest of the bags were to be made from fabric singed on the 7-denier (unlined) face (9059).

Table 4 presents the test results. The table includes the number of filter bags originally installed of each type. The bags were alternately installed in the 14th row, the next to outer row.

Table 4 Test Bag Drag Measurements for Special Dual-Density Felts

Bag Description	# of Bags	Installation Date	Test Date	Clock Hours	Exposure Hours	Drag (in. H_2O/ft/min)	Stnd. Dev.
7-denier Torcon PPS	9	5/23/2005	2/23/2006	6,527	6,399	0.20	0.06
7-denier Torcon PPS	9	5/23/2005	11/26/2007	20,631	19,661	0.48	0.13
7-denier Torcon PPS	11	2/23/2006	11/26/2007	13,713	13,262	0.56	0.14
Dual-Density .Torcon – 9058	10	5/23/2005	2/23/2006	6,527	6,399	0.25	0.04
Dual-Density Torcon – 9058	10	5/23/2005	11/26/2007	20,631	19,661	0.45	0.05
Dual-Density Torcon – 9059	9	5/23/2005	2/23/2006	6,527	6,399	0.22	0.06
Dual-Density Torcon – 9059	9	5/23/2005	11/26/2007	20,631	19,661	0.52	0.09
7.0 denier Procon	17	5/23/2005	2/23/2006	6,527	6,399	0.25	0.05
7.0 denier Procon	17	5/23/2005	11/26/2007	20,631	19,661	0.54	0.10

Note-Eleven Standard bags installed 2/23/2006 replaced failed or missing test bags. All bags were in the front two quadrants. No failed or missing bags were observed on 11/26/2007.

Note that the drag values on average approximately doubled during the 14,000 hours between the first measurements in February 2006 and the most recent measurements in November 2007. The eleven "standard bags" installed in February 2006 to replace the failed or missing bags had the highest drag values in November 2007, even with only about 13,500 hours of exposure. This is likely attributable to the fact that they were front quadrant bags that would have been exposed to the highest dust loading.

The apparent best performer after 20,000 hours of exposure appears to be the Dual-Density Torcon – 9058. This can be seen visually in Fig. 6 that shows the average drag value plus standard deviation for each of the four bag types. The Dual-Density Torcon -9058 clearly has the lowest average drag and smallest standard deviation of the four fabric types. Testing of these filter bags will continue with additional measurements planned for the fall of 2008.

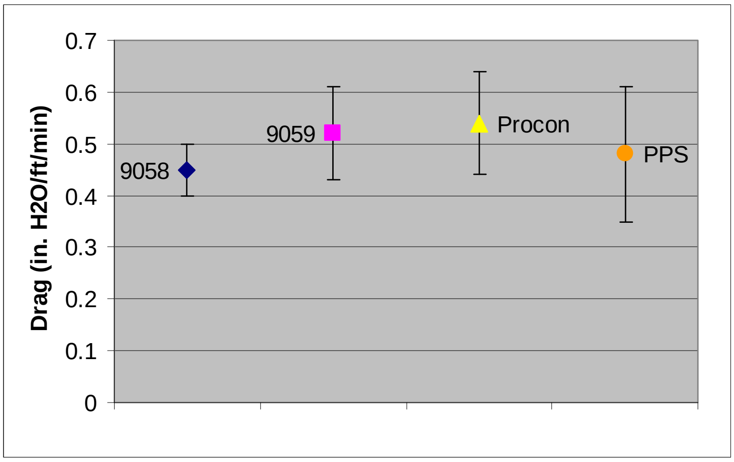

Fig. 6 Drag values and standard deviation ranges for November 2007 measurements

6 CONCLUSION AND RECOMMENDATIONS

Following a successful pilot-scale baghouse testing program and after reviewing the performance of Luminant's COHPAC (EPRI's patented Compact Hybrid Particulate Collector technology) baghouse installation at its Big Brown Station, Alabama Power Company (APCO) decided to install a

COHPAC baghouse on Unit 3 at its Gaston Steam Plant in late 1996. A second COHPAC baghouse was installed at Gaston Unit 2 in 1999. These baghouse systems were designed with the low pressure/high volume pulse-jet cleaning technology that orients the bags in concentric rings and uses rotating pulse manifold arms.

Original 3.0 and 2.7 denier Ryton felted fabrics have given way to higher permeability 7.0 denier PPS felt bags in both units. Overall flange-to-flange and tubesheet pressure drop performance has improved without compromising particulate collection efficiency. Early bag failures caused by bag-to-bag abrasion in the four front bag modules on both units were minimized by the installation of two concentric tubular stainless steel rings to restrain movement of the outer ring of filter bags. Recent filter drag values of 0.5 in. H_2O/ft/min on Unit 3 and 0.3 in. H_2O/ft/min on Unit 2 have been experienced at air-to-cloth values of 8.0 ft/min. The lower drag values for Unit 2 reflect the younger age of its filter bags. Average pulsing frequencies have ranged from 0.2 pulses per bag per hour for recently installed 7.0 denier PPS felted bags up to 0.7 pulses per bag per hour for older 2.7 denier Ryton felt bags. Continuous cleaning resulting from heavy ash accumulation has not been a problem unless the performance of the upstream hot-side electrostatic precipitators degrades.

Special felted bag fabrics have been tested in the Gaston baghouses since 2000. Early tests compared the performance of 6.0 denier and 7.0 denier PPS felts with traditional 2.7 denier felts. 7.0 denier felted fabrics performed very well. This led to full rebagging with this filter material in both baghouses. More recently, various dual-density felts have been tested. Results after 20,000 hours of flue gas exposure indicate that the Dual Density Torcon – 9058 felt is the best of the four test fabrics. The test program is continuing.

COHPAC baghouse installation has successfully reduced stack opacity and eliminated the need for load reduction. Unit 3 outlet mass concentrations have averaged 0.0046 gr/dscf. Comparing the average of the last eleven years of operation to the average of the two years prior to COHPAC baghouse installation, the average opacity for Units 3 and 4 has been reduced 50% and the number of hours per month that the average opacity has exceeded 20% has been reduced 95%. For Unit 2's eight years of operation, the comparable values for the Unit 1 and 2 stack have been 38% and 89%, respectively. Unit 2 outlet mass concentrations have also averaged 0.0046 gr/dscf.

Except for early bag failure episodes on each unit caused by bag-to-bag abrasion, bag life has been very good. The original 3.0 denier Ryton felted bags in the rear modules of the Unit 3 baghouse remained in service for five years accumulating over 39,500 hours of exposure to flue gas with few bag failures. Front module bags in Unit 3, however, had much shorter bag lives because of a higher incidence of bag failures. Average service lives for the 3.0 and 2.7 denier filter bags were similar to those of the follow-on 7.0 denier PPS felted fabrics, typically two to three years, 19,000 to 27,000 hours of exposure to flue gas.

COHPAC baghouse performance for Alabama Power Company has exceeded expectations and continues to provide an excellent air pollution control benefit. Monitoring of the performance of these baghouse should continue to insure the future success of this technology for Plant Gaston.

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REFERENCES

1. R. L. Chang, U. S. Patent No. 5,024,681. Compact Hybrid Particulate Collector. Issued on June 18, 1991.
2. R. L. Chang. COHPAC compacts emission equipment into smaller, denser unit. Power Engineering, July 1996, pp. 22-25.
3. R. L. Miller. Advanced Technology Development Dry Filtration Systems. Council of Industrial Boiler Owners – ADVANCED TECHNOLOGIES II ROUNDTABLE, July 1996, Washington, DC.
4. W. A. Harrison, K. M. Cushing, R. L. Miller, R. L. Chang. Recent COHPAC Data for Fine Particulate Matter & Air Toxics Removal from Coal-Fired Power Plants. In Proceedings: Power-Gen International 96, Orlando, FL, December 4-6, 1996.
5. R. Miller, W. Harriosn, B. Corina, K. Cushing, R. Chang. COHPAC (Compact Hybrid Particulate **C**ollector) The Next Generation in Particulate Control Technology Alabama Power Company's E. C. Gaston Units #2 and #3 'A Success Story'. in Proceedings: EPRI-DOE-EPA Combined Utility Air Pollutant Control Symposium, Atlanta, Georgia, August 16-20, 1999, Electric Power research Institute, Palo Alto, CA.
6. R. Jones. Gaston Rebuild Project Tops Site Difficulty. Clear Stacks, Reinhold Environmental Ltd., December, 1996.
7. K.M. Cushing. SRI Remote Baghouse Monitoring System for Plant Gaston. Clear Stacks, Reinhold Environmental Ltd., December, 1996.
8. R. Miller, W. Harrison, D. Prater, R. Chang. Alabama Power Company E. C. Gaston 272 MW Electric Steam Plant – Unit No. 3 Enhanced COHPAC I Installation. In Proceedings: EPRI-DOE-EPA Combined Utility Air Pollutant Control Symposium, Washington, DC, August 25-29, 1997; Electric Power Research Institute Report No. TR-108683-V3, August 1997.

9. K.M. Cushing, R. R. Wilson, W.A. Harrison, D. B. Prater, R.L. Chang. Performance Monitoring of a COHPAC I Baghouse System on Unit 3 (270 MWe) at Alabama Power Company's E.C. Gaston Electric Generating Plant. In Proceedings: EPRI-DOE-EPA Combined Utility Air Pollutant Control Symposium, Washington, DC, August 25-29, 1997; Electric Power Research Institute Report No. TR-108683-V3, August 1997.

10. R. Miller. COHPAC: Full-Scale Demonstrations of an Advanced Particulate Collector. ICAC Clean Air Technology News, Winter 1999.