July 13, 2011

LG&E and KU Energy Company, LLC
Attn: Gary Revlett
220 West Main St
Louisville, KY 40202-1346

RE: Update on Passive Deposition Sampling Study
RJ Lee Group Project Number: TLH104154

This report summarizes the status of the passive air monitoring program being conducted at three locations near the LG&E Cane Run power plant located in the Louisville, KY area. Based on the results obtained from the analysis of the surface samples which suggested impact from LG&E sources, a passive monitoring program was established to monitor particulate emissions over time. For the initial sampling effort, three passive deposition samplers and one UNC passive sampler were deployed at each location. The passive deposition samplers have a tacky collection surface which retains particles that deposit on the sampler. Three passive deposition samplers were deployed at the same time at each location and collected over different time periods. One sampler was removed after one week, a second sampler was removed after two weeks and the third sampler was removed after four weeks (see Table 1). The purpose of this multi-day sampling approach was to monitor particle deposition over time and to gain knowledge on the amount of time necessary to achieve an appropriate particle loading for detailed individual particle analysis. The goal is to obtain a uniform particle loading (mono-layer) with a minimum of particles in contact. Samples of this nature are well suited for particle analysis using scanning electron microscopy (SEM) techniques.

The UNC passive aerosol sampler is a different type of passive sampler that was developed by Wagner and Leith[1,2] at the University of North Carolina. The UNC passive sampler is unique as it has the ability to estimate ambient concentrations ($\mu g/m^3$). The UNC passive sampler is less than 2 cm in diameter and because it collects particles in a passive manner, and it does not require a pump for the collection of particulate matter thus making it suitable to place almost anywhere. Typical sampling periods for ambient sampling are on the order of a week to a month. The UNC sampler (see Figure 1) consists of a standard SEM stub, a collection substrate, and a protective mesh cap. During sampling, particles are transported by gravitational settling and diffusion through the cap mesh consisting of ≈150 mm diameter holes and deposited on a substrate mounted on the stub. The stub is oriented such that the substrate is horizontal. After returning the sample to the laboratory, the mesh cap is removed, the stub is placed in the SEM, and the particles are counted, sized, and composition assayed using computer controlled-SEM (CCSEM) techniques. The UNC passive sampler has recently been used by the US

[1] Wagner, J., Leith, D., 2001a. Passive Aerosol Sampler. I: Principle of Operation, Aerosol Sci. Technol. 34, 186-192.
[2] Wagner, J., Leith, D., 2001b. Passive Aerosol Sampler. II: Wind Tunnel Experiments, AerosolSci.Technol. 34, 193-201.

Environmental Protection Agency to monitor coarse particles ($PM_{10-2.5}$) in the Cleveland, Ohio area.[3] For ambient sampling a rain shield is required.[4]

In the initial sampling, the UNC passive sampler was used to collect samples over a one month period (see Table 2) and was used to provide a measure of PM_{10} concentrations.

Figure 1. UNC Passive Aerosol Sampler and schematic view.

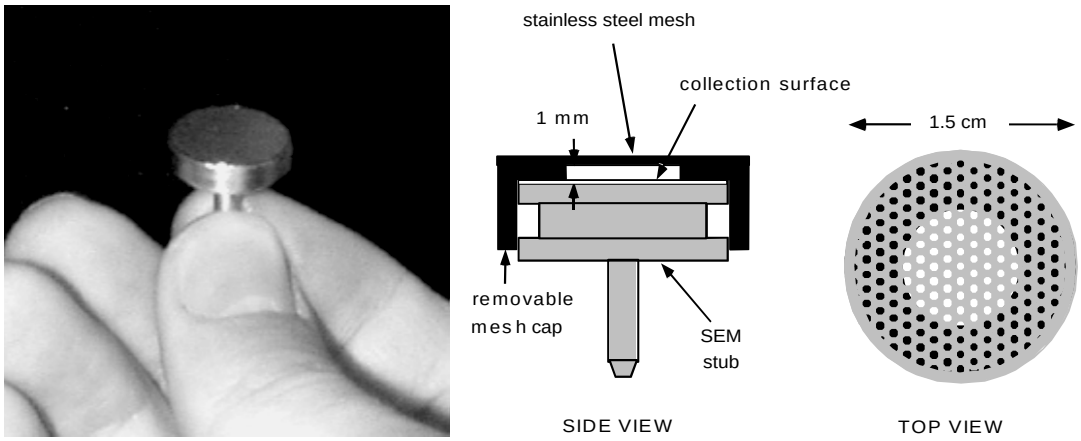


Table 1. List of Passive Deposition Samples

RJLG Field Sample Identification	LG&E Sample Description	Collection Start Date	Collection End Date	RJLG Sample Number
105S20002	#1 7d PM	05-09-11	05-16-11	3077609
105S20009	#2 7d PM	05-09-11	05-16-11	3077610
105S20010	#3 7d PM	05-09-11	05-16-11	3077611
105S20006	#1-14d PM	05-09-11	5-23-11	3077657
105S20008	#2-14d PM	05-09-11	5-23-11	3077659
105S20005	#3-14d PM	05-09-11	5-23-11	3077661
105S20004	#1-28 d PM	05-09-11	06-06-11	3077770
105S20007	#2-28 d PM	05-09-11	06-06-11	3077771
105S20003	#3-28 d PM	05-09-11	06-06-11	3077772

[3] Willis, R., Norris, G., Watkins, T., Sawyer, E., Boysen, D., Kumar, N., Peters, T., Casuccio, G., 2009. Characterization of Coarse PM Using Passive Samplers, presented to 2009 National Ambient Air Monitoring Conference, Nashville, TN, November 2009.

[4] Ott, D.K.; Peters, T M., 2008. A Shelter to Protect a Passive Sampler for Coarse Particulate Matter, $PM_{10-2.5}$, Aerosol Sci. Technol. 42, 299–309.

Table 2. List of UNC Passive samplers collected from May 9 to June 6, 2011

RJLG Field Sample Identification	LG&E Sample Description	RJLG Sample Number
Shelter 4	#1-PM	3077773
Shelter 5	#2-PM	3077774
Shelter 6	#3-PM	3077775

Evaluation of Passive Deposition Samples

Preparation of the samples for SEM analysis initially consisted of cutting the sample in half. One portion of the sample was archived for potential future analysis. The other half of the sample was coated with a thin layer of graphitic carbon under vacuum to bleed off the charge induced by the electron beam in the SEM. Analysis of the passive deposition samples was performed using manual SEM techniques. X-ray mapping was not performed due to the light particle loadings, however computer controlled SEM (CCSEM) techniques were applied on the two week samples.

Summary of Results for the One Week Passive Deposition Samples

Each of the passive deposition samples collected from May 9 to May 16, 2011 had a light particle loading with little evidence of particles visible by eye. Figure 2 provides photographs of the as-received one week samples. Examination of the samples in the optical microscope at a magnification of 50x (see Figure 3) indicates that the particles only accounted for <1 percent of the total area on each sample based on image analysis techniques. Examination of the samples in the SEM did not reveal the presence of fly ash/bottom ash particles at Location 1, and only a few fly ash particles were observed on the Location 2 and Location 3 samples. However, a few large (50-100um) bundles of fly ash were observed on the Location 3 sample. Other potential particles of interest included calcium-sulfate crystals that appeared to have grown on the Location 1 and 2 samples. Location 3 had no evidence of these crystals. Table 3 summarizes the results for the one week samples. The combination of the light particle loading and the small amount of fly ash/bottom ash observed indicates that these particles were only present at trace levels on the one week samples.

Figure 2. Photographs of As-received Passive Deposition Samples Collected from May 9 - 16, 2011

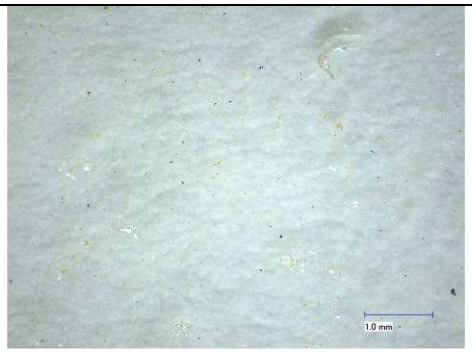
#1-7d PM

#2-7 d PM

#3-7 d PM

Figure 3. Optical Microscope Images (50x) of the Passive Deposition Samples Collected from May 9 - 16, 2011


#1-7d PM


#2-7d PM


#3-7d PM

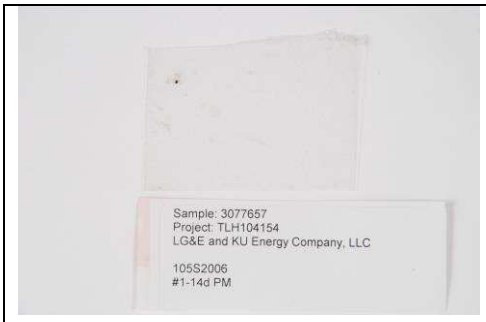
Table 3. Summary of Results for the Passive Deposition Samples Collected from May 9 - 16, 2011

RJLG Sample Number	3077609	3077610	3077611
LG&E Sample ID	#1 7d PM	#2 7d PM	#3 7d PM
LG&E Location ID	Location 1	Location 2	Location 3
Particle loading by eye	Little to no evidence of particles	Little to no evidence of particles	Little to no evidence of particles
Particle loading (Optical Microscopy)	0.5% by area	0.3% by area	0.5% by area
Fly Ash/Bottom Ash, Num % (SEM)	None observed	<1%	1-5% (bundles observed)
Calcium-Sulfur (SEM)	growth crystals	growth crystals	none observed

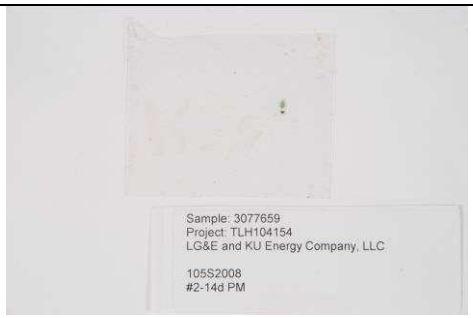
Summary of Results for Passive Deposition Two Week Samples

The samples collected from May 9 to May 23, 2011 also had a light particle loading. Examination by eye indicated a small number of particles were present on each sample. Figure 4 provides photographs of the as-received two week samples. Examination of the samples in the optical microscope indicated that the particles only accounted for ≈1 to ≈2 percent of total area based on image analysis techniques (see Figure 5). Examination in the SEM revealed that fly ash/bottom ash particles were observed at Locations 1 and 2 and were estimated to account for 1 to 5 percent of the particle population. For Location 3, fly ash/bottom ash appeared to be present in higher concentrations accounting for approximately 5-10 percent of the particle population. In addition, a few large bundles of fly ash were observed at this location. No calcium-sulfur particles were observed at any location. This appears to be in conflict with the one week samples which reported calcium sulfur crystals on two on the samples. However, the two week samples were exposed to rainfall which may have an effect on the crystal formation. Table 4 summarizes the manual observation results for the two week passive deposition samples.

Figure 4. Photographs of As-received Passive Deposition Samples Collected from May 9 - 23, 2011



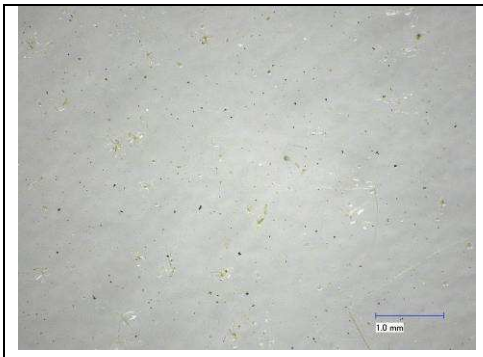
#1-14d PM



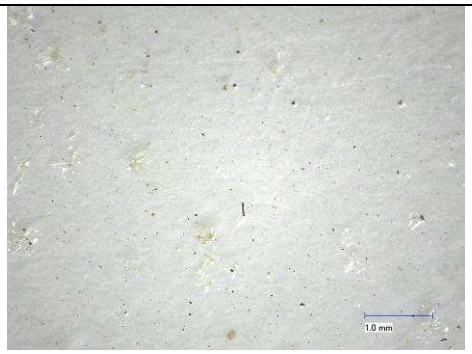
#2-14d PM

#3-14d PM

Figure 5. Optical Microscope Images (50x) of the Two Week Passive Deposition Samples Collected from May 9 - 23, 2011



#1-14d PM



#2-14d PM

#3-14d PM

Table 4. Summary of Results for Passive Deposition Samples Collected From May 9 - 23, 2011

RJLG Sample Number	3077657	3077659	3077661
LG&E Sample ID	#1-14d PM	#2-14d PM	#3-14d PM
LG&E Location ID	Location 1	Location 2	Location 3
Particle loading by eye	some evidence of particles	some evidence of particles	some evidence of particles
Particle loading (optical microscope)	1% by area	1.1% by area	1.7% by area
Fly Ash/Bottom Ash, Num % (SEM)	1-5%	1-5%	5-10%; (bundles observed)
Calcium-Sulfur (SEM)	None observed	None observed	None observed

CCSEM was conducted on the two week samples. CCSEM performs analysis of individual particles in an automated manner by placing the SEM and the x-ray analysis system under computer control. During the analysis, CCSEM scans the substrate on the SEM stub for individual particles and provides a X-ray spectrum of each particle. The analysis is performed by rastering the electron beam over the sample while monitoring the resultant backscattered signals. At each point, the image intensity is compared to a preset threshold level. Once a coordinate is reached where the signal is above the threshold level, the electron beam is driven across the particle in a preset pattern to determine the size of the particle. Upon measurement of the particle size, the elemental composition of the particle is determined through collection of characteristic X-rays using energy dispersive spectroscopy (EDS) techniques. Individual particles characterized during the CCSEM analysis are grouped into particle classes based on their elemental composition. The mass of an individual particle was calculated by multiplying the assigned density of the particle by its volume. CCSEM analysis was conducted for particles >5 μm in size. Results for the initial two week samples are provided in Table 5. Overall, the combination of the light particle loading and the small amount of fly ash/bottom ash observed during the manual and CCSEM analysis indicates that fly ash/bottom ash was present only at trace levels on the two week samples.

Table 5. Summary of CCSEM Results for Passive Deposition Samples Collected From May 9 - 23, 2011

Sample Location	1		2		3	
Sample number	#1-14d PM		#2-14d PM		#3-14d PM	
	Number %	**Weight %**	**Number %**	**Weight %**	**Number %**	**Weight %**
Fly ash	8	3	3	1	9	3
Ca-rich (lime)	18	34	17	33	15	41
Ca/S	2	1	4	3	1	<0.5
Si-rich (Soil)	34	27	32	23	35	23
Al-Si (Soil)	29	27	25	23	34	26
Fe-rich	5	6	11	9	3	5
C-rich	3	1	3	1	1	<0.5
Misc.	2	1	5	8	2	3

Summary of Results for Passive Deposition Four Week Samples

The four week samples were collected from May 9 to June 6, 2011. To the eye, particles were readily observed on the samples, but the loading was still light. Figure 6 provides photographs of the as-received samples. Based on optical microscopy image analysis, the particles accounted for between ≈1 to ≈3% of the samples (see Figure 7). Through manual examination in the SEM, it is estimated that fly ash/bottom ash accounted for approximately 5-10% for the particles at Location 1. Lesser amounts (1-5%) of calcium-sulfur particles were observed at this location. Location 2 was estimated to have approximately 1-5 percent fly ash/bottom ash and no calcium-sulfur particles were observed. Fly ash/bottom ash was estimated to account for approximately 5-10% at Location 3. A few large bundles of fly ash were observed on this sample and there was also a trace amount of calcium-sulfur particles. The combination of the light particle loading and the low concentrations of fly ash/bottom ash observed indicate that fly ash/bottom ash was present only at trace levels on the four week samples. Table 6 summarizes the results for the four week samples.

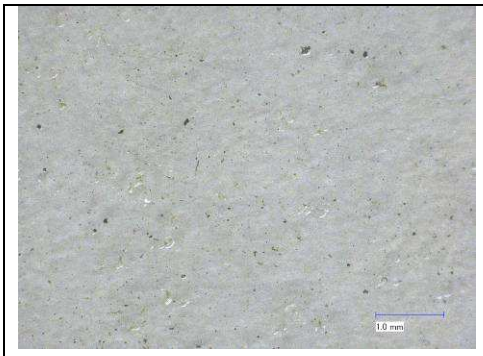
Figure 6. Photographs of As-received Deposition Samples Collected From May 9 to June 6, 2011

#1–28d PM

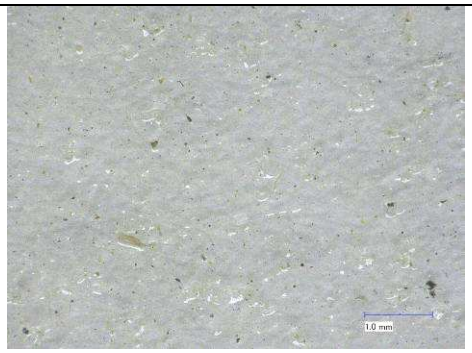
#2–28d PM

#3–28d PM

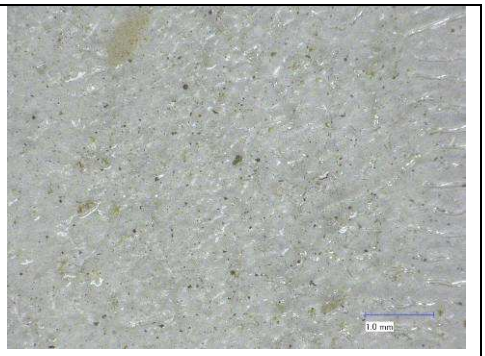
Figure 7. Optical Microscope Images (50x) of the Four Week Passive Deposition Samples Collected from May 9 to June 6, 2011



#1-28d PM



#2-28d PM



#3-28d PM

Table 6. Summary of Results for Passive Deposition Samples Collected from May 9 to June 6, 2011

RJLG Sample Number	3077770	3077771	3077772
LG&E Sample ID	#1 28d PM	#2 28d PM	#3 28d PM
LG&E Location ID	Location 1	Location 2	Location 3
Particle loading by eye	evidence of particles	evidence of particles	evidence of particles
Particle loading (optical microscope)	1.3% by area	1.5% by area	3.3% by area
Fly ash/Bottom Ash, Num % (SEM)	5-10%	1-5%	5-10%
Calcium-sulfur (SEM)	5-10%	none observed	< 5%

Evaluation of UNC Passive Samples

Upon receipt of the UNC passive samples at the laboratory, the stainless steel mesh cap was removed from the SEM pin mount. The pin mounts containing particles on filter substrates were coated with a thin layer of carbon to provide the electrically conductive surface needed for CCSEM analysis.

The CCSEM individual particle data are processed via the Wagner-Leith model to estimate ambient concentrations. Based on this process, the PM_{10} concentrations ranged from 9.4 to 14.7 $\mu g/m^3$ (average over sampling period). Table 7 provides a summary of the CCSEM results for the UNC passive samplers.

Table 7. UNC Passive Aerosol Sampler Results for Sample Collected from May 9 – Jun 6, 2011

LG&E Sample Location	1		2		3	
Sample number	3150		3151		3152	
PM_{10} ($\mu g/m^3$)	14.7		10.0		9.4	
Particle Type	**Number%**	**Weight %**	**Number %**	**Weight %**	**Number %**	**Weight %**
Fly ash	2	2	3	3	6	6
Ca-rich (lime)	17	19	19	19	12	19
Ca/S	41	33	10	3	12	2
Si-rich (soil)	10	21	23	25	16	18
Al-Si (soil)	15	11	20	28	30	34
Fe-rich	3	1	2	2	6	5
C-rich	8	6	16	16	10	10
Misc.	3	6	7	5	8	6

In summary, the number of fly ash/bottom ash on the passive deposition samples and the UNC passive aerosol samples appears to correlate well with the passive deposition samplers in that fly ash/bottom ash was a small component of the particulate matter collected on the initial set of samples. However, the results from the passive monitoring program do not correlate with the surface dust sample results. Given this discrepancy, it is recommended that sampling continue on an ongoing basis with the passive deposition samplers and the UNC passive samplers.

Should you have any questions regarding this information, please do no hesitate to contact me.

Sincerely,

Gary S Casuccio

G.S. Casuccio
V. President

C: R. Cash