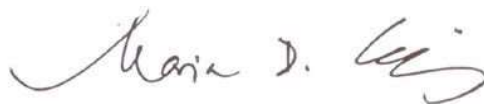


Wind Tunnel Testing Report
for LabWorks Shrouded Probes
(RF-2-111, RF-2-112)

(SERVICES/TESTING AGREEMENT No. M1803253
between Texas A&M AgriLife Research and LabWorks Inc.)

Oct. 18, 2018

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Prepared for
LabWorks Inc.
under SERVICES/TESTING
AGREEMENT No. MI803253

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1. OBJECTIVES

This work was performed by Texas A&M University (TAMU) as Project of Wind Tunnel Testing for LabWorks Shrouded Probes (RF-2-111, RF-2-112) under Agreement No. M1803253 between Texas A&M AgriLife Research and LabWorks Inc.

The ANSI/HPS N13.1-1999 standard states that at least 50% of the 10 μm aerodynamic diameter (AD) particles present in the stack free stream must be delivered to the sample collector. For this purpose, a sampling nozzle shall have an aerosol transmission ratio within the range of 0.80 to 1.30 over the anticipated range of normal or anticipated accident operational conditions for an aerosol particle size of 10 μm AD, or for the range of sizes that could be encountered in normal operating or accident conditions if those sizes are greater than 10 μm AD. Also, the aspiration ratio of a sampling nozzle shall be within the range of 0.80 to 1.50 for the anticipated range of operating conditions and the previously noted particle size or sizes. Compliance shall be demonstrated with liquid aerosol particles, which will provide conservative transmission values in comparison with solid particles because liquid particles adhere to walls, while solid particles may rebound or be reentrained from a surface.¹⁾

This study is report for evaluation of the performance for LabWorks Inc. commercial shrouded probes (Model : RF-2-111, RF-2-112). Performance tests were conducted by TAMU Wind Tunnel for several conditions of flow such as using 10 micron liquid particles at 5, 10, 15 m/sec free stream velocity for RF-2-112 and 10, 15, 20 m/sec free stream velocity for Model RF-2-111, respectively.

2. EXPERIMENTAL METHODS

2.1 Materials and Methods

2.1.1 Shrouded Probes

LabWorks Inc's commercial shrouded probes Model A (RF-2-111) and Model B (RF-2-112) as shown in **Fig. 1** were mounted inside an aerodynamic wind tunnel at the angle of zero degrees relative to the flow. The wind tunnel dimensions are 2 ft x 2 ft x 16 ft, with an elliptical nozzle insert in the middle as shown in **Fig. 2**. Flow field data such as velocity and turbulence intensities were measured with the hot film anemometer.

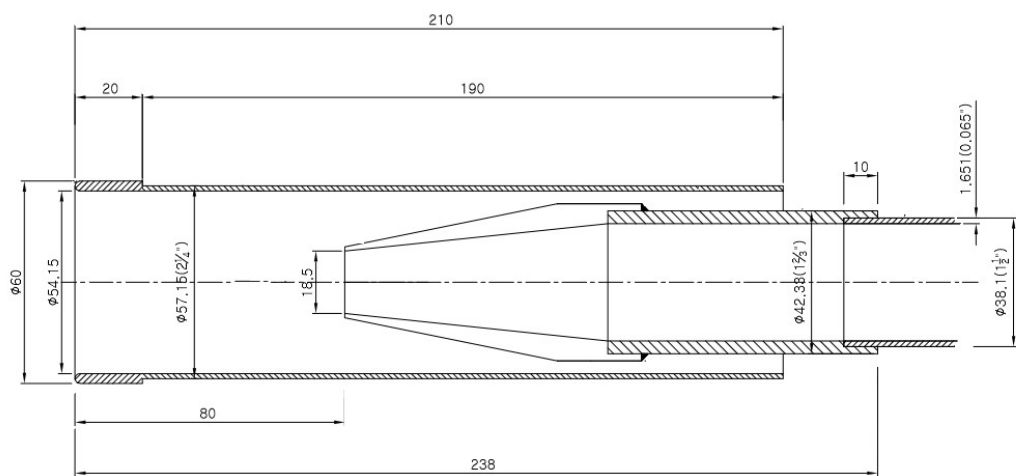
The shrouded probes were mounted isoaxially at the exit of the elliptical nozzle in the mid-section of the wind tunnel and velocity profiles at the entrance of the probe were determined with the hot film anemometer.

The 7.6 mm isokinetic probe RF ISO 1 and the 13.4 mm isokinetic probe RF ISO 2 were used at different flow rates (**Table 1**). The shrouded probe Model A and Model B (LabWorks) were tested at 57 L/min.

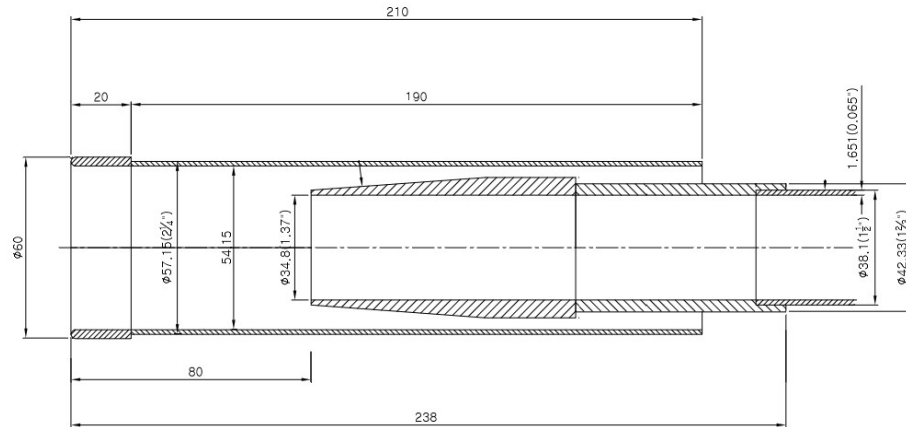




(b) Front View



(c) Model A (RF-2-111) Drawing



(d) Model B (RF-2-112) Drawing

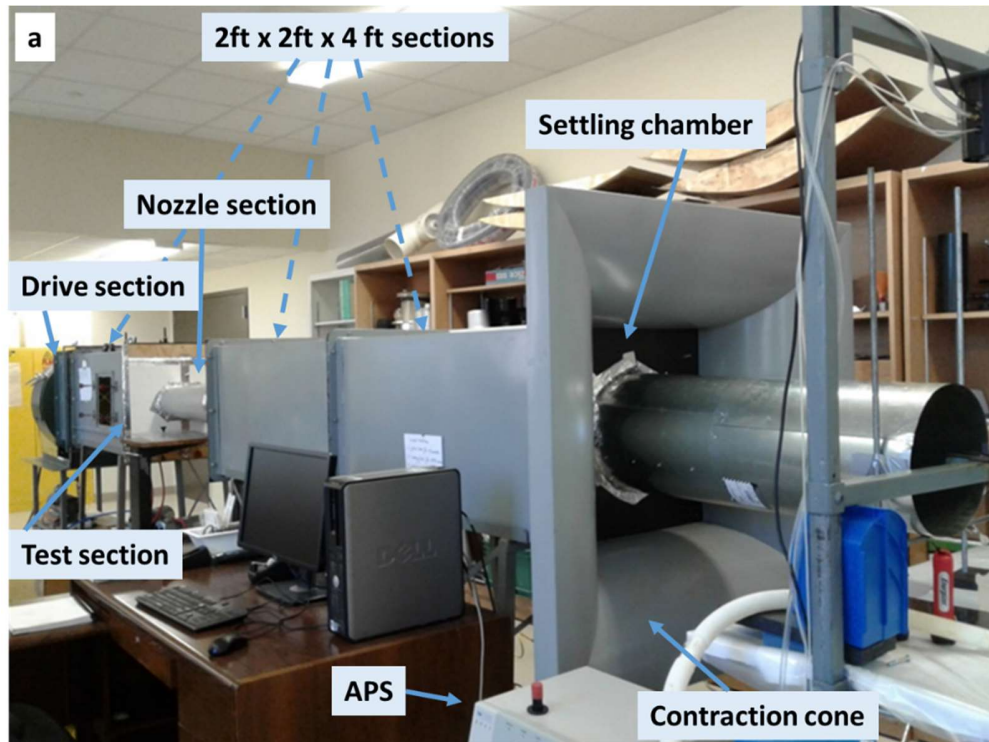
Figure 1 (a)-(d). Pictures and Drawings of Two (2) Shrouded Probes for Performance Tests

Table 1. The shrouded and isokinetic probes tested in the study

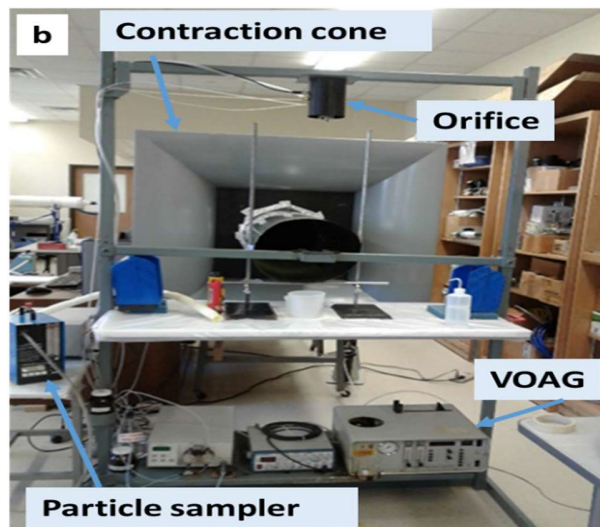
Probe	Model A (RF-2-111)			Model B (RF-2-112)		
Identification	RF-2-111(SUS316L)			RF-2-112(SUS316L)		
Flow Velocity	(10 m/s)	(15 m/s)	(20 m/s)	(5 m/s)	(10 m/s)	(15 m/s)
7.6 mm ISO	27.3 m/s	41.1 m/s	54.2 m/s		41 m/s	27.2 m/s
13.4 mm ISO				42.5 m/s		

2.1.2 Test Facilities

Figure 2 (a) shows general layout of the test facilities at Department of Biological and Agricultural Engineering (BAEN) in Texas A&M University. The wind tunnel has three long sections, each is a 2 ft x 2 ft x 4 ft rectangular unit, with a nozzle section in the middle; Figure 2 (b) shows the inlet of the wind tunnel with the VOAG unit on the lower shelf and the orifice above the inlet. A general purpose fan (F03792; NYB, The New York Blower Company) was used for the air flow as a driving component in wind tunnel.



(a) General layout of the Test Facilities (BAEN, Texas A&M University)



(b) The inlet of the wind tunnel with the VOAG unit on the lower shelf and the orifice above the inlet

Figure 2. General layout of the Test Facilities and Inlet Section of the Wind Tunnel (BAEN, Texas A&M University)

Experiments were performed with monodisperse liquid oleic acid aerosol particles with sodium fluorescent tracer generated by the Vibrating Orifice Aerosol Generator (VOAG, Model 3450, TSI Inc., Burnsville, MN) and introduced into the wind tunnel flow for conservative evaluation purpose. A particle sampler was used to collect liquid particles onto a NyBar treated glass slide for particle sizing (**Fig. 2b**).

2.2 Generation of liquid oleic acid particles with the VOAG

2.2.1 Preparation and generation of liquid oleic acid - uranine aerosol

The calculated masses of uranine (Fluorescein sodium salt $C_{20}H_{10}Na_2O_5$, TCI-F0096-500G) powder (prepared from TCI Inc. New Brunswick, NJ 08901-3605) and oleic acid (Octadecenoic acid $C_{18}H_{34}O_2$, prepared from Spectrum Chemical Manufacturing Corp., Gardena, CA 90248) for making solution of 10 μm weighed by an analytical balance ($\pm 0.00001 g$ precision, Mettler Toledo, Columbus, OH, USA).

In order to generate the 10 μm liquid particles, a HPLC pump (High Performance Liquid Chromatography, Series 1500, ChromTech, Inc., Apple Valley, MN, USA) transferred the uranine solution to the nozzle of a vibrating orifice aerosol generator (VOAG; model 3450, TSI, Inc., Shoreview, MN, USA) at a constant flow rate (0.225 mL/min) after the system was primed and washed with pure ethanol. The streamline resulted from the nozzle of VOAG directed to a Krypton-85 Aerosol Neutralizer (Model 54-0024, TSI Inc., Shoreview, MN, USA) to eliminate electrostatic charges possibly created between aerosols. The ionized uranine particles were discharged due to the interaction with ionized air. After the generated aerosols passed this stage and prior to introduction into the wind tunnel, they directed into APS (Aerodynamic Particle Sizer) Model 3321 (TSI, Inc., Shoreview, MN, USA) to verify the sizes of generated particles for 60 sec periods.

2.2.2 Correlation between the generated and aerosolized oleic acid particle diameters

Equation 1 (Berglund and Liu, 1973) describes the relationship between the particle diameters (measured by APS) and the parameters used to produce the particles in the wind tunnel.

$$Dp_a = Dp_p \sqrt{\frac{\rho_p}{\rho_w}} \quad (1)$$

where, Dp_a = aerodynamic particle diameter (μm), Dp_p = physical particle diameter (μm), ρ_w = water density = 1 g/cm³ and ρ_p = particle density = 0.9325 g/cm³.

Equation 2 (Berglund and Liu, 1973) shows how to calculate the physical diameter and density of uranine particles, respectively.

$$Dp_p = \left(\frac{6 Q C}{\pi f} \right)^{1/3} \quad (2)$$

where, Q = solution flow rate (ml/s), C = volumetric concentration of aerosol material in the solution (dimensionless), and f = vibrating orifice aerosol generator (VOAG) frequency (Hz)

2.2.3 Verification of the homogenous distribution in the wind tunnel

First the homogenous distribution of the particles in the wind tunnel was verified by two identical 7.6 mm isokinetic probes. The 7.6 mm isokinetic probes RF ISO 1 were used at 41 m/s flow rate. The positions of the two isokinetic probes were interchanged to mitigate any effect of radial aerosol concentration variation that may be present in the wind tunnel flow, and, the same tests were repeated. It was observed that the aerosol concentration differences between the two sampling points, each of which was radially 20 cm apart between the two probes, was typically less than 10% of the average value.

Then the shrouded probe and the isokinetic probe were mounted side-by-side, 20 cm apart at the exit of the nozzle in the wind tunnel, while the free stream velocity of the wind tunnel was set at 15 m/sec. The shrouded probe Model B (RF-2-112; LabWorks) was tested at 57 L/min. Particles penetrating through each of the probes were collected at the exit of the probes by means of 47 mm A/D glass fiber filters (Pall Inc., Waltham, MA). Such runs were conducted for a fixed time (for the 15 m/s tests for 120 minutes). This consisted of one set of experiment. A total of five replicate sets were tested. After each such set, the inner walls of both probes were thoroughly washed with measured amounts of ethyl alcohol and distilled water and the solutions were analyzed. Similarly, the fluorescein from the filters was also eluted in measured amount of ethyl alcohol and water and the resulting solutions were analyzed with the help of a Barnstead fluorometer to measure the Fluorescent Intensity Unit (FIU) values.

2.2.4 Measurement of fluorescent intensity unit (FIU) of oleic acid/uranine particles deposited on filters and lost inside walls of isokinetic and shrouded air samplers

After completing each replicate of different experiments, the filter of each air sampler was transferred to a small Nalgene jar with lid. The remaining particles adhered to the inner wall surface of the isokinetic nozzle and probe of shrouded air samplers were removed with a delicate task wiper and transferred again to small Nalgene jars with lids. The collected filters and delicate task wipers were mixed with 0.01N NaOH solution, closed, and shaken at room temperature for at least 30 min. Later ~10 mL of each solution along with blank (pure 0.01N NaOH) were transferred

to a specific test tube and its fluorescein intensity units (FIU) measured by the Calibrated Quantech Digital Filter Fluorometer (Model No. FM109515, Barnstead /Thermolyne Corp., Dubuque, IA, USA). The two filters (NB and SC) of Fluorometer had 490 and 515 wavelengths respectively for primary excitation and secondary emission of fluorescein solution. This Fluorometer leads light in 340-750 wavelength through a narrow band light-passing filter to measure the light absorption of fluorescein in liquid sample. In order to measure the standard deviation of measured FIU, the reading of each sample (including blank) was repeated for three times.

The fluorescein concentration was then determined from

$$C = \frac{FV}{\theta Q} \quad (3)$$

where,

F= fluorometer (G. K. Turner and associates, Palo Alto, CA) numerical reading,

V= measured solution liquid volume,

θ = testing time for each filter, and

Q= aerosol flow rate.

Transmission ratios (T), aspiration ratios (A) and wall losses (WL) for both types of probes (shrouded and isokinetic probes) were defined as follows:

$$T = \frac{C_{f,spr}}{C_{f,iso} + C_{w,iso}} \quad (4)$$

$$A = \frac{C_{f,spr} + C_{w,spr}}{C_{f,iso} + C_{w,iso}} \quad (5)$$

$$WL = \frac{C_{w,spr}}{C_{f,spr} + C_{w,spr}} \quad (6)$$

where,

C_f = aerosol concentration determined from the filters of shrouded/isokinetic probe.

C_w = aerosol concentration determined from the wall wash of shrouded/isokinetic probe.

Subscripts 'spr' and 'iso' are used for shrouded and isokinetic probes respectively.

Transmission ratio, aspiration ratio and wall losses of both the probes were calculated for that particular free stream velocity and particle size. Tests were conducted at free stream mean velocity of 10, 15 and 20 m/s (Model A, RF-2-111) and 5, 10, 15 m/s (Model B, RF-2-112). The particle size tested was 10 μm AED.

3. TEST RESULTS

Tables A.1~A.6 in Appendix A show the collected Fluorescent Intensity Unit (FIU) values, the calculated concentrations and the transmission and aspiration ratios for Model A(RF-2-111) and B (RF-2-112) at the relevant velocities. The whole data is attached at Appendix A.

The COV in Table is defined as Coefficient of Variation which a statistic that is the ratio of the standard deviation of a variable to the mean value of that variable. It is usually expressed as a percentage.1)

The summarized results for both shrouded probe RF-2-111 (Model A) and RF-2-112 (Model B) are shown in **Table 2** and on **Figs. 3~5**.

Table 2. Summary of the shrouded probe Model A (RF-2-111) and Model B (RF-2-112) testing at all velocities with 10 μm liquid particles.

RF-2-111 (10 μm)									
Airspeed (m/s)	Transmission Ratio			Aspiration Ratio			Wall Loss Ratio		
	Ratio	SD	95% CI	Ratio	SD	95% CI	Ratio	SD	95% CI
10	81.2%	4.91%	0.043	90.8%	5.60%	0.0491	10.5%	2.42%	0.0213
15	96.6%	7.30%	0.064	112.5%	6.67%	0.0585	14.2%	2.82%	0.0247
20	100.8%	4.87%	0.0427	131.1%	9.55%	0.0838	23.0%	3.40%	0.0298
RF-2-112 (10 μm)									
Airspeed (m/s)	Transmission Ratio			Aspiration Ratio			Wall Loss Ratio		
	Ratio	SD	95% CI	Ratio	SD	95% CI	Ratio	SD	95% CI
5	90.9%	9.07%	0.0795	98.6%	9.87%	0.0865	7.8%	0.94%	0.0083
10	94.0%	6.17%	0.0541	107.4%	5.57%	0.0488	12.5%	1.89%	0.0166
15	105.6%	7.17%	0.0628	126.1%	10.01%	0.0877	16.2%	1.84%	0.0161

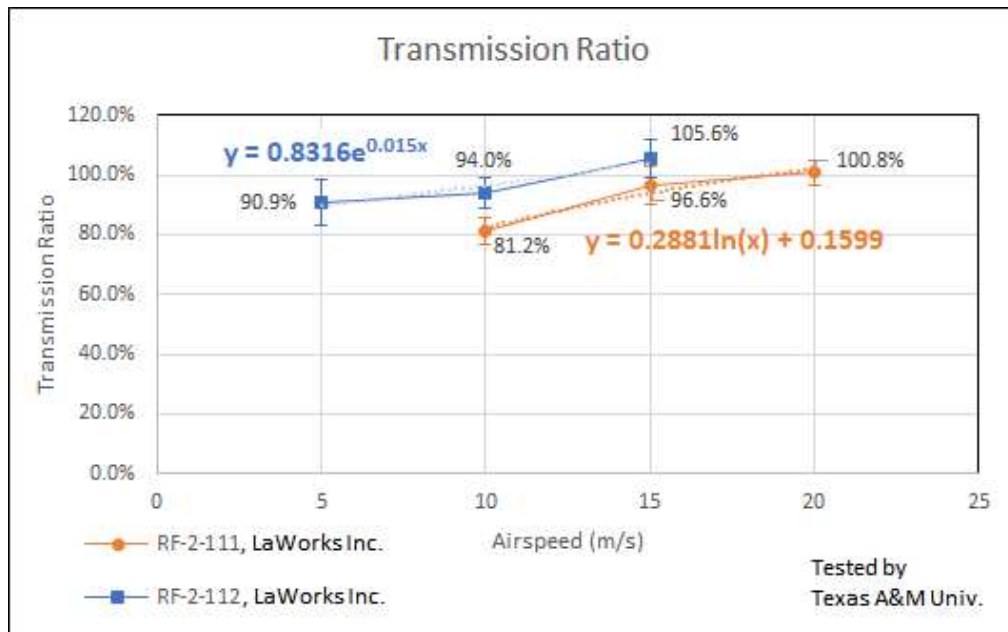


Figure 3. Summary of the Transmission Ratio values for shrouded probes RF-2-111 (Model A) and RF-2-112 (Model B) (dot line shows each empirical correlation)

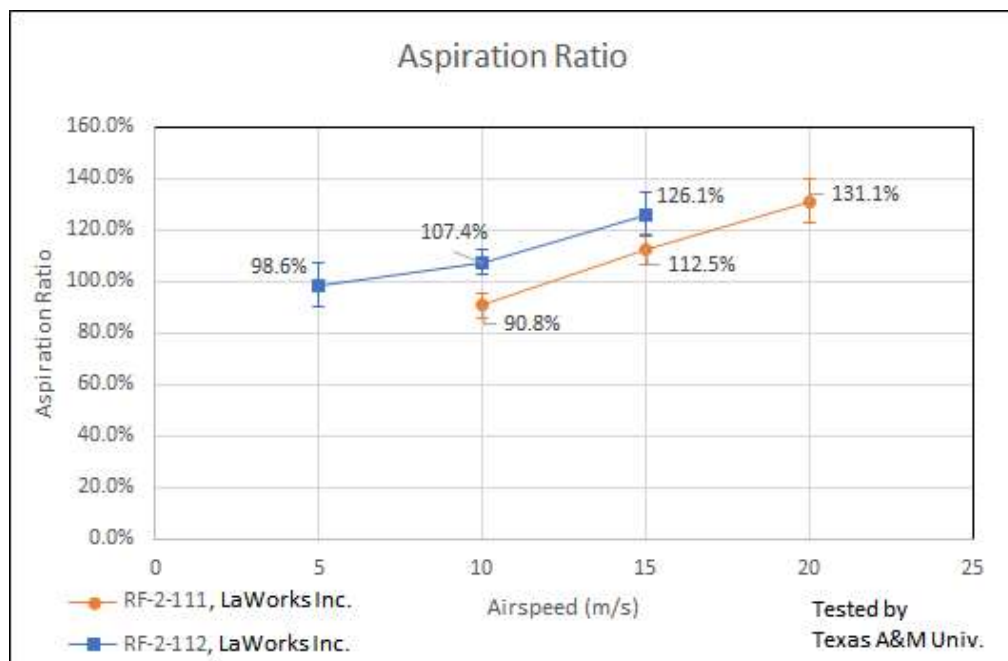


Figure 4. Summary of the Aspiration Ratio values for shrouded probes RF-2-111 (Model A) and RF-2-112 (Model B)

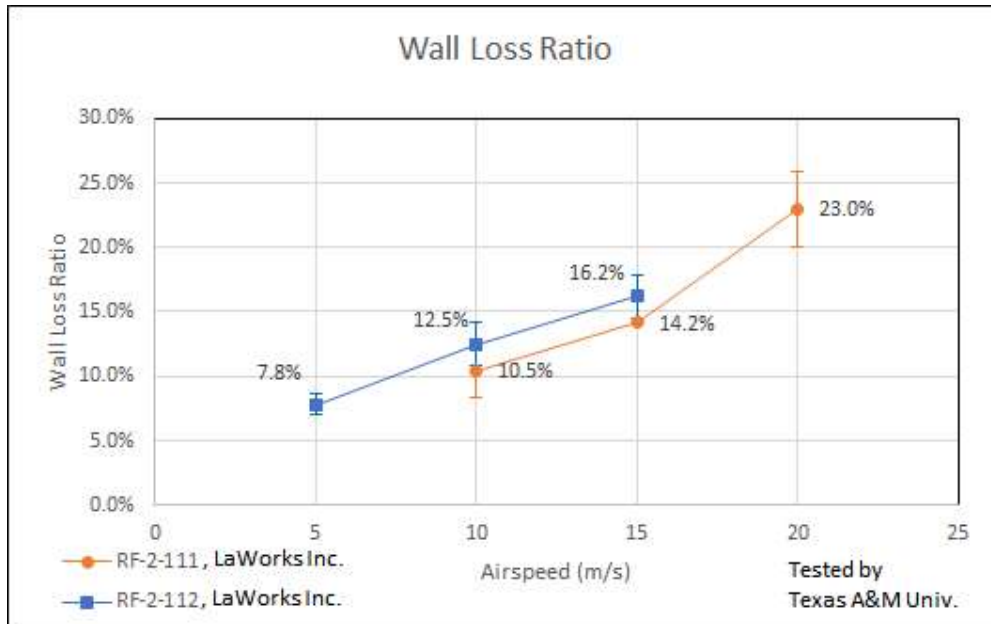


Figure 5. Summary of the Wall Loss Ratio values
for shrouded probes RF-2-111 (Model A) and RF-2-112 (Model B)

4. CONCLUSIONS

Test results show that LabWorks Inc's commercial shrouded probes (namely shroud nozzle) Model A (RF-2-111) and Model B (RF-2-112) meet acceptance criteria for the performance in accordance with ANSH/HPS N13.1-1999 requirements.

The Aspiration ratios for RF-2-111 and RF-2-112 are in the range of 80 ~ 150% while the Transmission ratios are in the range of 80 ~ 130%, respectively.

The measured whole data shows COV is lower than twenty (20) % of its allowable limits.

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Appendix A. *The results of shroud probes testing with 10 μm liquid particles*

Table A.1 The results of the Model A (RF-2-111) shrouded probe testing
at 10 m/s with 10 μm liquid particles
(Test Date: Aug. 20 & 30 (sample #5), 2018)

	Iso Filter FIU	Iso Wall FIU	Shr Filter FIU	Shr Wall FIU	Flow A (L/min)	Flow B (L/min)
Sample 1	86.7	60.3	233.0	36.0	27.3	57.1
Sample 2	88.7	56.3	240.0	26.3	27.4	57
Sample 3	84.3	45.7	240.0	33.3	27.3	57.1
Sample 4	78.0	43.3	200.3	21.7	27.1	56.9
Sample 5	79.7	39.3	208.7	16.0	27.3	57
	Iso Filter conc	Iso Wall conc	Shr Filter conc	Shr Wall conc	Duration (hr)	Airspeed (m/s)
Sample 1	42.3	29.5	54.4	8.4	1.5	10
Sample 2	43.1	27.4	56.1	6.2	1.5	10
Sample 3	41.2	22.3	56.0	7.8	1.5	10
Sample 4	38.4	21.3	46.9	5.1	1.5	10
Sample 5	38.9	19.2	48.8	3.7	1.5	10
	Transmission Ratio	Aspiration Ratio	Wall Loss Ratio			
Sample 1	75.78%	87.49%	13.38%			
Sample 2	79.56%	88.29%	9.89%			
Sample 3	88.27%	100.53%	12.20%			
Sample 4	78.64%	87.14%	9.76%			
Sample 5	83.98%	90.42%	7.12%			
Average	81.2%	90.8%	10.5%			
STDev	4.91%	5.60%				
COV	6.04%	6.17%				
	Transmission Ratio	Aspiration Ratio				
Acceptance Criteria	80 ~ 130%	80 ~ 150%				
Pass/Fail	PASS	PASS				

Table A.2 The results of the Model A (RF-2-111) shrouded probe testing
at 15 m/s with 10 μm liquid particles
(Test Date: Sep. 3-4, 2018)

	Iso Filter FIU	Iso Wall FIU	Shr Filter FIU	Shr Wall FIU	Flow A (L/min)	Flow B (L/min)
Sample 1	87.7	60.7	188.0	33.0	41.1	57
Sample 2	90.7	52.0	207.0	21.3	41.1	57.1
Sample 3	72.7	55.3	156.3	29.0	41.01	57.06
Sample 4	82.3	59.0	190.0	37.7	40.9	57.2
Sample 5	33.3	19.3	76.0	12.7	40.9	57.06
	Iso Filter conc	Iso Wall conc	Shr Filter conc	Shr Wall conc	Duration (hr)	Airspeed (m/s)
Sample 1	21.3	14.8	33.0	5.8	2	0
Sample 2	22.1	12.7	36.3	3.7	2	0
Sample 3	17.7	13.5	27.4	5.1	2	0
Sample 4	20.1	14.4	33.2	6.6	2	0
Sample 5	8.1	4.7	13.3	2.2	2	0
	Transmission Ratio	Aspiration Ratio	Wall Loss Ratio			
Sample 1	91.39%	107.43%	14.93%			
Sample 2	104.44%	115.20%	9.34%			
Sample 3	87.78%	104.06%	15.65%			
Sample 4	96.12%	115.18%	16.54%			
Sample 5	103.44%	120.67%	14.29%			
Average	96.6%	112.5%	14.2%			
STDev	7.30%	6.67%				
COV	7.56%	5.93%				
	Transmission Ratio	Aspiration Ratio				
Acceptance Criteria	80 ~ 130%	80 ~ 150%				
Pass/Fail	PASS	PASS				

Table A.3 The results of the Model A (RF-2-111) shrouded probe testing
at 20 m/s with 10 μm liquid particles
(Test Date: Aug. 16-17, 2018)

	Iso Filter FIU	Iso Wall FIU	Shr Filter FIU	Shr Wall FIU	Flow A (L/min)	Flow B (L/min)
Sample 1	121.0	101.3	227.3	66.7	54.2	57
Sample 2	83.0	49.0	142.0	57.7	54.7	57
Sample 3	100.3	58.3	176.3	47.7	54.5	57
Sample 4	116.0	77.3	190.0	52.0	54.7	57
Sample 5	124.0	81.7	220.0	56.7	54.7	56.9
	Iso Filter conc	Iso Wall conc	Shr Filter conc	Shr Wall conc	Duration (hr)	Airspeed (m/s)
Sample 1	17.9	15.0	31.9	9.4	2.5	0
Sample 2	12.1	7.2	19.9	8.1	2.5	0
Sample 3	14.7	8.6	24.7	6.7	2.5	0
Sample 4	17.0	11.3	26.7	7.3	2.5	0
Sample 5	18.1	11.9	30.9	8.0	2.5	0
	Transmission Ratio	Aspiration Ratio	Wall Loss Ratio			
Sample 1	97.23%	125.74%	22.68%			
Sample 2	103.23%	145.16%	28.88%			
Sample 3	106.26%	134.98%	21.28%			
Sample 4	94.31%	120.12%	21.49%			
Sample 5	102.83%	129.32%	20.48%			
Average	100.8%	131.1%	23.0%			
STDev	4.87%	9.55%				
COV	4.83%	7.29%				
	Transmission Ratio	Aspiration Ratio				
Acceptance Criteria	80 ~ 130%	80 ~ 150%				
Pass/Fail	PASS	PASS				

Table A.4 The results of the Model B (RF-2-112) shrouded probe testing
at 5 m/s with 10 µm liquid particles
(Test Date: Aug. 15, 2018)

	Iso Filter FIU	Iso Wall FIU	Shr Filter FIU	Shr Wall FIU	Flow A (L/min)	Flow B (L/min)
Sample 1	156.0	67.3	227.3	19.0	42.5	57
Sample 2	156.0	39.0	242.0	16.7	42.6	57
Sample 3	125.0	28.3	187.3	18.7	42.5	57.1
Sample 4	101.0	23.0	158.3	14.0	42.2	57
Sample 5	102.3	21.0	167.0	14.0	42.2	57
	Iso Filter conc	Iso Wall conc	Shr Filter conc	Shr Wall conc	Duration (hr)	Airspeed (m/s)
Sample 1	73.4	31.7	79.8	6.7	1	5
Sample 2	73.2	18.3	84.9	5.8	1	5
Sample 3	58.8	13.3	65.6	6.5	1	5
Sample 4	47.9	10.9	55.6	4.9	1	5
Sample 5	48.5	10.0	58.6	4.9	1	5
	Transmission Ratio	Aspiration Ratio	Wall Loss Ratio			
Sample 1	75.90%	82.24%	7.71%			
Sample 2	92.75%	99.14%	6.44%			
Sample 3	90.94%	100.00%	9.06%			
Sample 4	94.53%	102.89%	8.12%			
Sample 5	100.25%	108.65%	7.73%			
Average	90.9%	98.6%	7.8%			
STDev	9.07%	9.87%				
COV	9.98%	10.01%				
	Transmission Ratio	Aspiration Ratio				
Acceptance Criteria	80 ~ 130%	80 ~ 150%				
Pass/Fail	PASS	PASS				

Table A.5 The results of the Model B (RF-2-112) shrouded probe testing
at 10 m/s with 10 μm liquid particles
(Test Date: Aug. 22 & 30 (sample #5), 2018)

	Iso Filter FIU	Iso Wall FIU	Shr Filter FIU	Shr Wall FIU	Flow A (L/min)	Flow B (L/min)
Sample 1	93.3	70.3	345.7	41.7	27.2	57.1
Sample 2	70.3	47.0	247.0	32.0	27.36	57.09
Sample 3	87.0	57.3	267.0	49.7	27.34	57.05
Sample 4	85.0	75.3	307.0	43.3	27.21	57.28
Sample 5	70.3	53.3	230.3	32.0	27.32	57.08
	Iso Filter conc	Iso Wall conc	Shr Filter conc	Shr Wall conc	Duration (hr)	Airspeed (m/s)
Sample 1	45.8	34.5	80.7	9.7	1.5	10
Sample 2	34.3	22.9	57.7	7.5	1.5	10
Sample 3	42.4	28.0	62.4	11.6	1.5	10
Sample 4	41.7	36.9	71.5	10.1	1.5	10
Sample 5	34.3	26.0	53.8	7.5	1.5	10
	Transmission Ratio	Aspiration Ratio	Wall Loss Ratio			
Sample 1	100.61%	112.73%	10.76%			
Sample 2	100.89%	113.96%	11.47%			
Sample 3	88.65%	105.14%	15.68%			
Sample 4	90.96%	103.80%	12.37%			
Sample 5	89.15%	101.53%	12.20%			
Average	94.0%	107.4%	12.5%			
STDev	6.17%	5.57%				
COV	6.56%	5.18%				
	Transmission Ratio	Aspiration Ratio				
Acceptance Criteria	80 ~ 130%	80 ~ 150%				
Pass/Fail	PASS	PASS				

Table A.6 The results of the Model B (RF-2-112) shrouded probe testing
at 15 m/s with 10 μm liquid particles
(Test Date: Aug. 21-22, 2018)

	Iso Filter FIU	Iso Wall FIU	Shr Filter FIU	Shr Wall FIU	Flow A (L/min)	Flow B (L/min)
Sample 1	106.0	85.7	264.7	46.3	41.02	57.2
Sample 2	105.0	95.7	285.3	45.0	41.1	57.2
Sample 3	101.7	86.0	299.3	61.3	41.1	57.1
Sample 4	107.3	85.3	298.0	62.3	41.1	56.9
Sample 5	91.0	71.0	226.0	49.7	41.12	57.2
	Iso Filter conc	Iso Wall conc	Shr Filter conc	Shr Wall conc	Duration (hr)	Airspeed (m/s)
Sample 1	25.8	20.9	46.3	8.1	2	15
Sample 2	25.5	23.3	49.9	7.9	2	15
Sample 3	24.7	20.9	52.4	10.7	2	15
Sample 4	26.1	20.8	52.4	11.0	2	15
Sample 5	22.1	17.3	39.5	8.7	2	15
	Transmission Ratio	Aspiration Ratio	Wall Loss Ratio			
Sample 1	99.03%	116.36%	14.90%			
Sample 2	102.17%	118.28%	13.62%			
Sample 3	114.81%	138.33%	17.01%			
Sample 4	111.72%	135.09%	17.30%			
Sample 5	100.29%	122.33%	18.02%			
Average	105.6%	126.1%	16.2%			
STDev	7.17%	10.01%				
COV	6.79%	7.94%				
	Transmission Ratio	Aspiration Ratio				
Acceptance Criteria	80 ~ 130%	80 ~ 150%				
Pass/Fail	PASS	PASS				

Appendix B. Research works of Aerosol Testing Laboratory (ATL) in TAMU

History of ATL

The Aerosol Technology Laboratory (ATL) is an independent University research laboratory at the Department of Biological and Agricultural Engineering in Scoates Hall at Texas A&M University that was established under the direction of Dr. Andrew R. McFarland, Wyatt Professor of Mechanical Engineering, and has been serving for over thirty-five years as a center for aerosol research for both private and public sector interests.



1. A robust engineering and research environment, the Aerosol Technology Laboratory has produced dozens of M.S. and Ph.D. graduates at Texas A&M University, many of whom have gone on to lead research efforts at prestigious research facilities such as Los Alamos National Laboratory, Sandia National Laboratories, HI-Q Environmental Products Company (HI-Q) and Ohio State University.
2. The Aerosol Technology Laboratory operates from laboratory facilities within at Texas A&M University, as well as a large-scale wind tunnel facility located on the main campus at the Hobgood building as well as a round wind tunnel off campus in the University Services Building (USB). Capabilities of the Aerosol Technology Laboratory include :

Static bench-top testing of aerosol devices with inert monodisperse aerosol (liquid or solid particles with imbedded fluorescent tracer) as well as with non-pathogenic bacteria spores; fluorometric analysis, and imaging of test aerosol particles; culturing of bacteria spores for quantitative analysis; and wind-tunnel testing of aerosol sampling equipment with either inert aerosol particles or non-pathogenic bacteria spores.

3. Specific accomplishments of past Aerosol Technology Laboratory research include :

- A. The design and patenting of a Shrouded Probe for representative sampling of aerosols at a constant flow rate and high wind speeds.
- B. Development of American National Standards Institute Standard 13.1-1999 describing the method and application of single-point representative sampling from stacks and ducts.
- C. Design of the Generic Mixing Plenum for low power mixing of duct effluent to satisfy single-point representative sampling criteria.
- D. Design of a Continuous Air Monitor for detection of airborne alpha-emitting particles (Alpha Sentry System, Canberra Industries Inc., Meriden, CT).
- E. Design of a Continuous PM10 Particulate Monitor for real-time measurement of dust emissions from a corrosive stack environment.

4. Design (patented) of a Circumferential Slot Virtual Impactor for low power concentration of aerosols

5. Specific Design (patented) of the Wetted Wall Cyclone (WWC) for low power collection and concentration of bioaerosols and nanoaerosols.

Appendix C. CVs of participants

Prof. Maria D. King

Prof. John S. Haglund

Dr. Ahmad Kalbasi-Ashtari

MARIA DOBOZI KING

Department of. Biological and Agricultural Engineering, Texas A&M University
MS 2117, 333 Spence St., College Station, TX, 77843
Ph: 979-845-2251, Email: mdking@tamu.edu

A. Professional Preparation

Degrees held

Budapest University of Technology and Economics, Hungary	Biological and Chemical Engineering
B.S., 1979	
Budapest University of Technology and Economics, Hungary	Biochemistry and Food Technology
M.S., 1985	
Academy of Sciences, Berlin, Germany	Biotechnology / Chemistry
Ph.D., 1986	

Postdoctoral research

Rutgers University (New Brunswick, NJ), Recombinant fungal systems,	1989-1990
Int. Centre for Genetic Engineering and Biotechnology (Trieste, Italy),	1990-1991
Cornell University (Ithaca, NY), Regulation of ACC synthase gene,	1992-1993

B. Appointments

Assistant Professor, Dept. Biological and Agricultural Eng, TAMU, September 2017-present.
Research Associate Professor, Aerosol Technology Laboratory, Dept. Mech. Eng, TAMU, 2014 – 2017.
Research Associate Engineer, Aerosol Technology Laboratory, Dept. Mech. Eng, TAMU, 2005 – 2014.
Senior Research Scientist, Dept. Biochemistry and Biophysics, TAMU, TX, 2002 – 2005.
Senior Research Associate, Dept. Agronomy and Range Science, UC Davis, CA, 2000 – 2002.
Research Associate, Biotechnology, Seminis Vegetable Seed Research Center, CA, 1996 – 2000.
Head of Dept. Biochemistry, Central Food Research Institute (CFRI), Budapest, 1993 – 1996.
Senior Scientist, Head of Immunology Laboratory, Dept. Biochemistry, CFRI, 1986 – 1993.
Research Scientist, Dept. Enzymology, Central Food Research Institute, Budapest, 1979 – 1986.

C. Products (61 peer reviewed journal papers, 3 book chapters, 2 patents)

1. Development of novel biosensing and bacterial diagnostic technologies

- Li, R., Goswami, U., King, M.D. and Rentzepis, P.M. (2018). In-situ detection of live/dead bacteria: A synchronous fluorescence, PCA study. PNAS, 115 (4) 668-673.
- Kish, L.B., Chang, H-C., King, M.D., Kwan, Ch. et al. (2011). Fluctuation-Enhanced Sensing for Biological Agent Detection and Identification. IEEE Transactions on Nanotechnology, 10(6): 1238-1242.
- Chang, H-C., Kish, L.B., King, M.D. and Kwan, Ch. (2009). Fluctuation-enhanced sensing of bacterium odors. Sensors and Actuators B (Chemical), 142, 429–434.
- Kish, L.B., Schmera, G., King, M.D., Cheng, M., Young, R. and Granqvist, C.G. (2008). Fluctuation-Enhanced Chemical/Biological Sensing and Prompt Identification of Bacteria by Sensing of Phage Triggered Ion Cascade (SEPTIC), Internat. J. High Speed Electronics and Systems. 18: 11-18.
- Dobozi-King, M., Seo, S., Kim, J.U., Young, R., Cheng, M. and Kish, L.B. (2005). Rapid nanoscale detection of bacteria: SEntensing of Phage-Triggered Ion Cascade (SEPTIC). J. Biol. Chem. Phys. 5: 3-7.

2. Development of the wetted wall cyclone collection technology

- Lauterbach, S., Wright, C., Zentkovich, M., Nelson, S., Lorbach, J., Bliss, N., Nolting, J., Pierson, R., King, M. and Bowman, A. (2018). Detection of influenza A virus from agricultural fair environment: air and surfaces. Preventive Veterinary Medicine, 153: 24-29.
- King, M.D. and A.R. McFarland. (2012). Bioaerosol Sampling with a Wetted Wall Cyclone: Cell Culturability and DNA Integrity of *Escherichia coli* Bacteria. Aerosol Science and Technology, 46: 82–93.

- c. King, M.D. and A.R. McFarland. (2012). Use of an Andersen Bioaerosol Sampler to Simultaneously Determine Culturable Particle and Culturable Organism Size Distributions. *Aerosol Science and Technology*, 46: 852–861.
- d. McFarland, A.R., Haglund, J.S., King, M.D., Hu, S., Phull, M.S., Moncla, B.W. and Seo, Y. (2010). Wetted Wall Cyclones for Bioaerosol Sampling. *Aerosol Science and Technology*, 44(4), 241-252.
- e. King, M.D., Thien, B.F., Tiirikainen, J.S. and McFarland, A.R. (2009). Collection characteristics of a batch-type wetted wall bioaerosol sampling cyclone. *Aerobiologia*, 25(4), 239-247.

3. Environmental bioaerosol – nanoaerosol collection, tracking and analysis

- a. Estrada-Perez, C.E., Kinney, K.A., Maestre, J.P., Hassan, Y.A. and King, M.D. (2018). Droplet Distribution and Airborne Bacteria in an Experimental Shower Unit. *Water Research*, 130: 47-57.
- b. Hoisington, A., Maestre, J.P., King, M.D., Siegel, J.A. and Kinney, K.A. (2014). Characterizing the Indoor Microbiome with Pyrosequencing: Impact of Sampler Selection. *Building & Environment*, 80: 1-9.
- c. Meng, F., King, M.D., Hassan, Y.A., and Ugaz, V.M. (2014). Localized fluorescent complexation enables rapid monitoring of airborne nanoparticles. *Environmental Science: Nano*, 1: 358-366.
- d. Kesavan, J., Schepers, D.R., Bottiger, J.R. King, M.D. and McFarland, A.R. (2013). Aerosolization of Bacterial Spores with Pressurized Medical Dose Inhalers. *Aerosol Science and Technol.*, 47(10): 1108-17.
- e. Kassab, A., Ugaz, V.M., King, M.D. and Hassan, Y.A. (2012). High Resolution Study of Micro- meter Particle Detachment on Different Surfaces. *Aerosol Science and Technology*, 47(4): 351-360.

D. Synergistic Activities

Education:

Teaching: Three graduate courses in Molecular Biotechnology at Texas A & M University.

Committee membership: 36 graduate and undergraduate students; Co-chair or member on 85 graduate committees, including 6 Ph.D. students. Graduate student internships (2) and directed studies (15).

Major professor for MS student graduated in May 2017.

Review activities:

Reviewer for 5 journals including *Aerosol Science and Technology (AS&T)*, *Journal of Applied Microbiology* and *Journal of Aerosol Science*.

Reviewer for funding agencies including the National Science Foundation, USDA and DTRA.

Guest Editor: "Environmental Nanotechnology" in *Journal of Nanomaterials and Biosensors*.

Services:

Serving on several professional committees at different levels and organizations such as the AAAR conference committee and the European Biochemists' Society. Chaired/co-chaired several sessions in national and international conferences. Principal Investigator of the Aerosol Technology Laboratory and Director of Bio-Chem Air Quality & Mold Analysis Laboratory, helping the community with air testing.

Selected Other Experience and Professional Memberships:

2006 Member, American Association of Aerosol Research (AAAR)

2017 Member, American Association for the Advancement of Science (AAAS)

Honors:

2005 Michele Costato Award, Best Conference Presentation, UpON Conference, Italy

2005 Science and Technology: Screening for screams; Bacteriology. *The Economist*. London, 2005. 375(8422):81.

2012 Guest Editor, *Biosensors*

2014 "Professor of the Year 2013-2014" Texas A&M University Award

2015 Appreciation of Dedicated Service to the Professional Program in Biotechnology, Texas A&M

2016 Guest Editor, Special Issue "Environmental Nanotechnology" in *Journal of Nanomaterials*

2017 Outstanding Reviewer Award, *Aerosol Science and Technology*



John S. Haglund, Ph.D.

Lecturer, Department of Mechanical Engineering

Texas A&M University, MS3123, College Station, TX 77843-3123

(979)739-9577, john.haglund@tamu.edu

PROFESSIONAL PREPARATION

Ph.D. Texas A&M University, Mechanical Engineering, 2003.

M.S. Texas A&M University, Mechanical Engineering, 2000.

B.S. Montana State University, Mechanical Engineering (Mathematics minor), 1995.

APPOINTMENTS

2010-present	Senior Lecturer/Research Associate, Department of Mechanical Engineering, The Texas Engineering Experiment Station and Agrilife Sciences, Texas A&M University.
2005-present	Lecturer/Research Associate, Department of Mechanical Engineering and Applied Research Laboratories, The University of Texas at Austin.
2003-2005	Research Associate, Department of Mechanical Engineering, Texas A&M University.
2003-present	Graduate Faculty, Texas A&M University.

5 RECENT RELEVANT PUBLICATIONS (of 9 total)

*=undergraduate students, **=graduate students, ***=postdocs or technicians

W.B Faulkner and **J.S. Haglund**. 2012. Flattening coefficients for oleic acid droplets on treated glass slides. *Aerosol Science and Technology*, 46:828:832.

J.A. Hubbard, **J.S. Haglund, O.A. Ezekoye, and A.R. McFarland. 2011. Liquid consumption of wetted wall bioaerosol sampling cyclones: characterization and control. *Aerosol Science and Technology*, 45:172:182.

A.R. McFarland, **J.S. Haglund**, M.D. King, **S.S. Hu, **M.S. Phull, **B.W. Moncla, **Y. Seo. 2010. Wetted wall cyclones for bioaerosol sampling. *Aerosol Science and Technology*, 44:241:252.

T. Han, **J.S. Haglund, ***S. Hari, and A.R. McFarland. 2009. Aerosol deposition on electroformed wire screens *Aerosol Science and Technology*, 43:112-119.

S.S. Hu, **Y. Seo, A.R. McFarland, **J.S. Haglund. 2008. Heat transfer study on a bioaerosol sampling cyclone. *Engineering Applications of Computational Fluid Mechanics*, 2:309-318.

RELEVANT PUBLICATIONS

J.S. Haglund and A.R. McFarland. 2004. A circumferential slot virtual impactor. *Aerosol Science and Technology*, 38:664-674.

J.S. Haglund, ***S. Chandra, and A.R. McFarland. 2002. Evaluation of a high volume aerosol concentrator. *Aerosol Science and Technology*, 36:690-696,



SCIENTIFIC COLLABORATORS OUTSIDE OF TEXAS A&M UNIVERSITY

Brent Blunt (Savannah River National Laboratory, ret.), Ofodike Ezekoye (University of Texas), Thomas Kiehne (University of Texas).

GRADUATE AND POST DOCTORAL ADVISORS

Andrew R. McFarland, M.S., Ph.D. and Postdoctoral Advisor (1998-2005, Texas A&M University)

Margaret Wooldridge, M.S. Advisor (1996-1998, Texas A&M University)

COMPLETED GRADUATE STUDENTS AND POSTDOCTORAL ADVISEES

Ph.D. Dissertation Advisor (n=1), M.S. Thesis Advisor (n=2)

H. Li co-advisee (2012-2013, now postdoc at Agrilife, Texas A&M University), J.A. Hubbard co-advisee (2006-2009, now at Sandia National Laboratory), E.E. Burton co-advisee (2005-2008, last at Bank of America, Charlotte N.C.)

Ahmad Kalbasi

akalbasi@ut.ac.ir

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Highlights of Qualifications

- Strong background in R&D techniques related to of Air Quality, Food and Agricultural Engineering.
- More than 20 years' academic experience (mainly research) in Science, Quality Control and Environmental Engineering.
- Industrial consultant on finding the appropriate technology for different separation, purification and characterization of aerosols and agricultural products.
- Working with various analytical, microbiological and plant design instruments successfully.

Professional Experience

- I. Research Scientist in Environmental and Agricultural Engineering**
Oct. 2011- Present time

Biological & Agricultural Engineering Department, Texas A&M University

Performed Research Project:

- *Working on different air quality projects to determine the effects particles size and air flow on particle concentrations of indoor and outdoor agricultural facilities.*
- *Designing of a practical and economically feasible method to scrub the Ammonia and Methane gases of poultry houses before releasing into the atmospheric air. Two manuscripts were published as a result this project.*
- *Writing different manuscripts to publish the research results obtained in different areas of food science and engineering.*
- *Preparing different proposals to CPS (Center for Produce Safety)*
 1. *“Preventing Cross Contamination of Mangoes during Post Harvest Operations and Quarantine Treatment by Using Antimicrobials”.*
 2. *“Efficacy of using Electrolyzed Water with Vibration for Disinfection of Cantaloupe Surfaces during Postharvest Washing”*
 3. *Assessment of bio-aerosols collected from three cattle feedlots in Texas and their antibiotic resistance evaluation*
- *Plant Study of the bio-aerosol internalization of Papaya during washing stage in fruit packing*

II. Associate Professor of Food Engineering in University of Tehran
Sept. 1984-Oct. 2011

Performed Academic Responsibilities:

- Taught courses in Food Engineering, Quality Control of Food and Water, Sensory Evaluation, and HACCP in the Water and Food Products.
- Supervised MS and PhD graduates' students involved with different research areas of food processing.
- Ordered instruments, machinery, and chemical compounds for laboratories and the pilot plant.
- Working as a consultant for different catering plants to obtain different ISO and HACCP Certificates.

Education & Training

- **Achieving a Certificate in a Practical Short Course on “Nutraceuticals & Functional Foods”**
Texas A&M University, College Station, Texas, July 2013.
- **Achieving a Certificate in a Complete Training of “Biological Safety (Level 2)”**
Texas A&M University, College Station, Texas, December 2011.
- **Achieving a Certificate in a Practical Short Course in “Developing and Implementing HACCP Plans for the Meat Industry”.** Texas A&M University, College Station, Texas, December 2002.
- **Achieving a Certificate in a Practical Short Course in “Aquaculture, Feed Preparation, Nutrition and Feed Management”.** Texas A&M University, College Station, Texas, August 2002.
- **Achieving a Certificate in a Practical Course of “Membrane Technology”**
Texas A&M University, College Station, Texas, March 2001
- **Ph.D. in Food Engineering**
Iowa State University, Ames, Iowa, 1980
- **M.S. in Food Technology**
Iowa State University, Ames, Iowa, 1976
- **B.S. in Agricultural Industries**
University of Tehran, Karaj, Iran, 1969

Selected Published Papers

- **Electrolyzed water spray scrubber for removing ammonia from air. 2015.** A. M. Samani Majd, [A. Kalbasi-Ashtari](#), G. L. Riskowski, S. Mukhtar, L. Y. Zhao, W. Fang. 2015. *Transactions of the ASABE*. 58(4): 1069-1078. DOI 10.13031/trans.58.10973.

- **Effects of air exchange rate, particle size and injection place on particle concentrations within a reduced-scale room. 2015.** W. B. Faulkner, F. Memarzadeh, G. Riskowski, [A. Kalbasi](#), A. Ching-Zu Chang. *Building and Environment*. 92: 246-255.
- **Removing ammonia from air with a constant pH, slightly acidic water spray wet scrubber using recycled scrubbing solution. 2016.** [A. Kalbasi Ashtari](#)¹, A. M. Samani Majd¹, G. L. Riskowski, S. Mukhtar, L. Zhao. *Front. Environ. Sci. Eng.* 10(6): 3. DOI 10.1007/s11783-016-0869-3
- **Effects of electron beam irradiation on the bacterial load and sensorial quality of sliced cantaloupe. . 2004.** M.P. Palekar, E. Cabrera-Diaz, [A. Kalbasi-Ashtari](#), J.E. Maxim, R.K. Miller, L. Cisneros-Zevallos, And A.Castillo. *Journal of Food Science. M: Food Microbiology and Safety*. 69 (9): 267-273.
- **Carcass composting for management of farm mortalities: a review. 2005.** [A. Kalbasi-Ashtari*](#), S. Mukhtar, S. E. Hawkins, and B. W. Auvermann. *Compost Science & Utilization*. 13(3):180-193.
- **Design, utilization, biosecurity, environmental and economic considerations of carcass composting. 2006.** [A. Kalbasi-Ashtari*](#), S. Mukhtar, S.E. Hawkins and B.W. Auvermann. *Compost Science & Utilization*. 14(2): 90-102.
- **Carcass rendering systems for farm mortalities: A review. 2008.** [A. Kalbasi-Ashtari](#), M. M. Schutz, and B. W. Auvermann. *J. Environmental Engineering and Science*. 7:199-211.
- **Fractionation of monomeric and polymeric anthocyanins from Concord Grape (Vitis labrusca L.) Juice by Membrane Filtration. 2007.** [A. Kalbasi-Ashtari](#) and L. Cisneros-Zevallos. *Journal of Agriculture and Food Chemistry*. 55:7036-7042.
- **Estimation of Moisture Sorption Isotherms in Kerman Pistachio Nuts. 2008.** H. Tavakolipour and [A. Kalbasi-Ashtari](#). *Journal of Food Process Engineering*. 31(4):564 – 582.
- **Storage Stability of Kerman Pistachio Nut. 2010.** H. Tavakolipour, M. Armin, and [A. Kalbasi-Ashtari](#). *International Journal of Food Engineering*. 6(4): 1-11.
- **Effect of process Conditions and Carrier Concentration for Improving Dryer Yield and Other Quality Attributes of Spray Dried Black Mulberry (Morus Nigra) Juice. 2011.** M. Fazaeli, Z. Emam-Djomeh, [A. Kalbasi-Ashtari](#), and M. Omid. *International Journal of Food Engineering*. 8(1):1-20.
- **Rheology of Selected Persian Honey. 2010.** H. Tavakolipour and [A. Kalbasi-Ashtari](#). *International Journal of Food Engineering*. 6 (3): 1-12 (Article 16).
- **Evaluation of Fouling Phenomenon in the membrane clarification of Black Mulberry Juice. 2011.** G. Hojatpanah, Z. Emam-Djomeh, [A. Kalbasi-Ashtari](#), H. Mirsaedghazi, and M. Omid. *International Journal of Food Science & Technology*. 46; 1538-1544.

- Effect of process conditions and carrier concentration for improving drying yield and other quality attributes of spray dried black mulberry (*Morus nigra*) juice. 2010. Mahboubeh Fazaeli, Zahra Emam-Djomeh, **A. Kalbasi-Ashtari**, and Mahmoud Omid. *International Journal of Food Engineering*. Manuscript 2023.1-23.
- Prediction of the Physicochemical Properties of Spray-Dried Black Mulberry (*Morus nigra*) Juice using Artificial Neural Networks. 2011. Mahboubeh Fazaeli, Zahra Emam-Djomeh, Mahmoud Omid and **A. Kalbasi-Ashtari**. *Food Bioprocess Technology*. July: DOI 10.1007/s11947-011-0648-x.
- Development and characterization of a novel biodegradable edible film obtained from psyllium seed (*Plantago ovata* Forsk). 2012. Reza Ahmadi, **A. Kalbasi-Ashtari**, Abdulrasoul Oromiehie, Mohammad-Saeed Yarmand and Forough Jahandideh. *Journal of Food Engineering*. 109:745-751.
- Physical properties of psyllium seed. 2012. R. Ahmadi, **A. Kalbasi-Ashtari** and S.M.T. Gharibzahedi. *International Agrophysics*. 26: 91-93. doi: 10.2478/v10247-012-0013-y.
- Effects of low and high acyl gellan gums on engineering properties of carrot juice. 2012. Marjan Sherafati, **A. Kalbasi-Ashtari** and Seyd Mohammad Ali Mousavi. *Journal of Food Process Engineering*. Article first published online: 2 May 2012. DOI: 10.1111/j.1745-4530.2012.00682.x.
- Effects of defatted soy flour, xanthan gum, and processing temperatures on quality criteria of spaghetti. 2013. A. Ansari1, **A. Kalbasi-Ashtari**, and A. Gerami. *J. Agr. Sci. Tech*. 15: 265-278.
- QTL analysis for Malt Quality in DH Lines of Barley (Steptoe × Morex) grown in sub-tropical zone of Iran. 2013. M. B. Sadeghi1*, W. A. Sarhadi, S. A. Peighambari, M. R. Naghavi, **A. Kalbasi Ashtari**. *Turkish Journal of Agriculture - Food Science and Technology*. 1(2): 56-61.
- Effects of storage time on compositional, micro-structural, rheological and sensory properties of low fat Iranian UF-Feta cheese fortified with fish oil or fish oil powder. 2013. Farzad Farbod, **A. Kalbasi**, Sohrab Moini, Zahra Emam-Djomeh, Hadi Razavi and Ali Mortazavi. *Journal of Food Sci. and Technol*. DOI 10.1007/s13197-013-1163-z.
- Optimization of Operational Parameters to Fortify Iranian UF-Feta Cheese with Fish Oil Using Response Surface Methodology. 2013. Farzad Farbod, **A. Kalbasi**, Sohrab Moini, Zahra Emam- Djomeh, Hadi Razavi and Ali Mortazavi. *Journal of Food Processing and Preservation*. doi:10.1111/jfpp.12162.
- Biocompatible nanotubes as potential carrier for curcumin as a model bioactive compound. 2013. R. Sadeghi, **A. Kalbasi**, Z. Emam-jomeh, S. H. Razavi, J. Kokini, A. A. Moosavi-Movahedi. *J. Nanopart Research*. 15:1-11. DOI 10.1007/s11051-013-1931-8.

- Effects of sulfur water extraction on anthocyanins properties of tepals in flower of Saffron (*Crocus Sativus* L). 2013. L. Lotfi, **A. Kalbasi-Ashtari***, M. Hamed and F. Ghorbani. *Journal of Food Science and Technology*. DOI 10.1007/s13197-013-1058-z.
- **26.** Effects of enzymatic extraction on anthocyanins yield of saffron tepals (*Crocus sativus*) along with its color properties and structural stability. 2015. Leila Lotfi, **Ahmad Kalbasi-Ashtari***, Manoochehr Hamed, Fereshteh Ghorbani. *Journal of Food and Drug Analysis* 23: 210-218.
- Characterization and sensory evaluation of a novel grapefruit beverage made with lactose-free demineralized milk permeate. 2015. Monireh Rahimi, **A. Kalbasi-Ashtari***, Mohsen Labafi, Michael longnecker and Faramarz Khodaian. *Journal of Food Process Engineering*. doi:10.1111/jfpe.12313.
- Lipid oxidation kinetics of pistachio powder during different storage conditions. 2016. Hamid Tavakolipour, Mohsen Mokhtarian and **A. Kalbasi-Ashtari**. *Journal of Food Process Engineering*. doi:10.1111/jfpe.12423.
- Effects of solar drying along with air recycling system on physicochemical and sensory properties of dehydrated pistachio nuts. 2017. Mohsen Mokhtarian, Hamid Tavakolipour and **A. Kalbasi Ashtari**. *LWT - Food Science and Technology* 75 (2017) 202-209.
- Energy and exergy analysis in solar drying of pistachio with air recycling system. 2015. Mohsen Mokhtarian, Hamid Tavakolipour, **A. Kalbasi-Ashtari***. *Drying Technology An International Journal*. DOI: 10.1080/07373937.2015.1129499.
- Inhibitory effects of cinnamon, clove and celak extracts on growth of *Aspergillus flavus* and its aflatoxins after spraying on pistachio nuts before cold storage. 2017. S. Khorasani M.H. Azizi, M. Barzegar, Z. Hamidi-Esfahani, **A. Kalbasi-Ashtari*** *J. of Food Safety* 37:e12383. <https://doi.org/10.1111/jfs.12383>
- **35.** Bleaching effects of massecuite on some properties of crystallized sugar beet and milk chocolate bars produced. 2018. F. Seyed Sadjadi, M. Honarvar, **A. Kalbasi-Ashtari***, P. Motaghian. *J. Food Science and Technology*. Doi.org/10.1007/s13197-017-3007-8.

References

- **Dr. Ronald Lacey**, Professor of Biological and Agricultural Engineering Department, Texas A&M University, College Station, Texas, 77843 <ron-lacey@tamu.edu> Phone: 979-845-3967.
- **Dr. Gary Riskowski**, P.E., Professor, 103 Price Hobgood, Texas A&M University, College Station, TX 77843-2711. <riskowski@tamu.edu>, Phone: 979-845-7619.
- **Dr. Steve Searcy**, Senior Professor and Department Head of Biological and Agricultural Engineering Department, Texas A&M University, College Station, Texas, 77843 <s-searcy@tamu.edu> Phone: 979-845-3940.
- **Dr. Alejandro Castillo**, Associate Professor of Food Science & Technology, Kleberg Center, Texas A&M University, College Station, TX 77843-2471 <a-castillo@tamu.edu>, Phone: 979-845-3565.

Appendix D. Test Procedure

- 1.** Wind Tunnel configured and proven for 40CFR53 Subpart D: Procedures for Testing Performance Characteristics of Methods for PM 10.
- 2.** Prepare of Fluorescein solution for testing
- 3.** Install for Shrouded probe and Isokinetic probe
- 4.** Wind Tunnel exhaust blower ON
- 5.** Measure flow velocity using hot film anemometer
- 6.** Generate monodispersed 10 μm AD liquid aerosol using VOAG and check aerosols size
- 7.** Adjust Shrouded probe Suction Flow
- 8.** Inject Aerosols into Wind Tunnel
- 9.** Check test time
- 10.** Stop suction pump
- 11.** Stop VOAG operation
- 12.** Disassemble Shrouded Probe and Isokinetic Probe
- 13.** Purge Wind Tunnel
- 14.** Wash nozzles wall and Fluorescein Analysis
- 15.** Calculate for Aspiration, Transmission Ratio and Wall Losses
- 16.** Repeat 3 to 15 for another test conditions
- 17.** Data Reduction
- 18.** Report Test Results