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Katlyn R. DeVoe
Iowa State University

Steven J. Hoff
Iowa State University, hoffer@iastate.edu

Yun Gao
Iowa State University

Brett C. Ramirez
Iowa State University, bramirez@iastate.edu

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Abstract

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Keywords

airflow, animal housing, efficiency, emissions, fans, sensors, ventilation

Disciplines

Agriculture | Animal Sciences | Bioresource and Agricultural Engineering | Poultry or Avian Science

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2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

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Commissioning of a Segmented Wand for Evaluating Airflow Performance of Fans in Livestock and Poultry Housing

Katlyn R. DeVoe[1], Graduate Research Assistant, **Steven J. Hoff[1],** Professor, **Yun Gao[1,2],** Visiting Scholar, **and Brett C. Ramirez[1],** Graduate Research Assistant

[1]Department of Agricultural and Biosystems Engineering, Iowa State University, Ames, IA USA

[2]College of Engineering Huazhong Agricultural University and the Cooperative Innovation Center for Sustainable Pig Production, Wuhan, China

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Abstract. *Ventilation rate estimates play an important role in evaluating the thermal environment and determining emission rates from livestock and poultry housing. Currently, the standard method to measure in situ ventilation rates is the Fan Assessment Numeration System (FANS). A similar sensing system is needed for extension personnel that eliminates the labor and set-up requirements of FANS. In order to efficiently and cost-effectively estimate ventilation rates, a Segmented Wand for Evaluating Airflow Performance (SWEAP) was developed. The objectives of this research were to: (i) design and construct a hand-held device capable of measuring in situ fan intake flowrate, (ii) evaluate SWEAP against a FANS unit, and (iii) assess the in-field applicability of SWEAP. Eight uniformly spaced Omnidirectional Thermal Anemometers (OTA) were heated above ambient temperature using Constant Temperature Anemometer (CTA) feedback methodology. The flowrate was determined by multiplying the cross sectional area associated with each OTA, with SWEAP placed at the intake of a tested fan. SWEAP was calibrated against a FANS unit (42-0002) for several flowrates and to accommodate typical agricultural-use fans. Several in situ fans ranging in diameters: 36 cm (14 in.), 61 cm (24 in.), 91 cm (36 in.), and 122 cm (48 in.), and capacity were tested with SWEAP to determine the feasibility of field applications. In-lab SWEAP traverse rates of 76 ±13, 127 ±13, 178 ±13, and 229 ±13 mm s^{-1} (3.0 ±0.5, 5.0 ±0.5, 7.0 ±0.5, and 9.0 ±0.5 in. s^{-1}) were tested with no significant difference found between the 76 ±13 mm s^{-1}, 127 ±13 mm s^{-1} rates. A nominal SWEAP traverse rate of 127 ±13 mm s^{-1} was used for subsequent in-field testing. Results showed that there was no significant difference ($p>0.05$) between SWEAP and FANS airflow means for the 36 cm fan, 61 cm fan, and the 91 cm fan. The average percent difference between SWEAP and FANS for all in-lab and in-field fans tested was less than 5.0%. SWEAP can be used by extension personnel to quickly and accurately evaluate airflow for multiple fans.*

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Introduction

The livestock and poultry industries have progressed from housing their animals in buildings with outside access towards housing their animals inside environmentally controlled barns. These modern facilities allow the producer to control the environment by increasing airflow through the summer months and using supplemental heat through the winter months in order to maximize animal performance and comfort. In order to properly control the environment, automatic forced ventilation systems are installed that responds to the animal's thermal and gas environment. These ventilation systems include multiple sized fans that either draw air through the building (negative pressure), or push air into the building (positive pressure) while maintaining an optimal pressure differential of between 10 to 25 Pa (0.04 to 0.10 in.H_2O; MWPS, 1990). In large poultry barns, the static pressure required to achieve the required air-jet throw is 25 to 37 Pa (0.10 to 0.15 in.H_2O; Casey et al., 2008). Knowing the desired static pressure differential helps determine the selected fans for a given system, which have a rated airflow rate at designed resistances.

Understanding ventilation rates and fan efficiencies can help producers optimize their system and reduce operation costs. Currently, many fans used in production facilities do not operate at their rated capacity and efficiency. Shutters typically reduce airflow and efficiency by 10% (intake shutters) to 25% (discharge shutters); with fan guards providing an additional 5% reduction (Ford, Riskowski, Christianson, & Funk, 1999). Fan performance is also impacted by accumulated debris on the blades and shutters, mechanical wear, and degree of maintenance (Casey et al., 2008). Accumulated debris on shutters can further reduce airflow by up to 40% (Ford et al., 1999). One study conducted on poultry barns showed ventilation performance of otherwise identical fans varied by up to 24% (Casey et al., 2008). Producers need to know how efficient their fans are in order to properly ventilate their building to maximize production.

There are several different devices and sensors currently used for evaluating airflow in livestock and poultry barns, which include Pitot tubes and mechanical or thermal-based anemometers. The Pitot tube, in conjunction with a suitable manometer or pressure transducer, provides a simple method of determining air velocity at a point in a flow field (*ASHRAE Handbook*, 2013). A device called averaging Pitot tube (APT) was developed that utilizes multiple Pitot tubes, which are constructed into a copper tube that is mounted on the intake side of a fan (Liang, Bautista, Dabhadkar, & Costello, 2013). APT is a light-weight, low-cost, instrument that measures airflow from wall mounted large agricultural exhaust fans (Liang et al., 2013), but was only designed to test one fan diameter per APT. Anemometers used to measure airspeeds include vane, propeller, cup, hot-wire, and thermal techniques. An innovative Pit Exhaust Airflow Measurement Assembly (PEAMA) was developed to continuously measure the ventilation rates of pit fans utilizing an anemometer (Ni et al., 2016). PEAMA consists of a long flow straightener and a 4-blade helicoid impeller connected to an anemometer that has a generator, which produces a DC voltage signal when the generator is driven by the rotating blades (Ni et al., 2016). This device was developed for pit fan airflow and has not been tested with wall fans.

The current and most widely-adopted instrument for accurately evaluating *in situ* fan performance is the Fan Assessment Numeration System or FANS (Gates et al., 2002). The FANS unit is an aluminum box that utilizes a row of propeller anemometers, which traverse the inlet to measure the velocity profile of a ventilation fan (Sama, Gates, Adams, Day, & King, 2008). This unit is most often mounted on the upstream side of the fan being tested and is sealed properly forcing all incoming air to pass over the propeller anemometers before going through the fan. Approximately 1.8 million velocity readings are obtained as the anemometers traverse the flow field in 180 seconds while outputting an averaged air velocity and flow rate to the designated software (Casey et al., 2008). Researchers have been using the FANS unit for emissions studies (Lim, Heber, Ni, Gallien, & Xin, 2003), fan efficiency studies (Janni, Jacobson, Nicolai, Hetchler, & Johnson, 2005), and barn infiltration studies such as the one conducted looking at infiltration rates in various types of swine facilities (Jadhav, Hoff, Harmon, Jacobson, & Hetchler, 2015). The FANS unit is currently the most reliable tool with an uncertainty as low as ± 1% (Gates et al., 2002); however, FANS units are heavy with bulky design features that require good labor support and extensive time to position and seal (Wheeler et al., 2002), making it difficult to use in on-farm extension evaluations.

Animal production producers and extension personnel would benefit from a portable device that is quick and easy to use and could be used to assess *in situ* fan performance without the initial labor and transportation required for implementing FANS. An apparatus, the Segmented Wand to Evaluate Airflow Performance (SWEAP), was developed and commissioned to serve this need. The objectives to achieve these goals were to:

1. Design and construct a hand-held device (SWEAP) capable of measuring *in situ* fan intake flowrate,
2. Evaluate SWEAP against a FANS unit, and
3. Assess the in-field applicability of SWEAP.

Materials and Methods

Airspeed Sensor and Calibration

SWEAP utilized multiple omnidirectional thermal anemometers (OTA). Each OTA was a spherically-shaped, negative temperature coefficient (NTC) thermistor (nominal 470 Ω at 25°C, Model LC471F3K; U.S. Sensor Corp., Orange, CA, USA) heated above ambient temperature using constant temperature anemometer (CTA) feedback methodology. It has the ability to measure airspeeds typically found in livestock and poultry barns (Gao, Ramirez, & Hoff, 2016). They are low cost and simple, which makes OTA's well-suited for the purpose of this research. The NTC thermistors used in this design and all associated hardware and circuitry were developed in-house at Iowa State University. The CTA circuit is used to determine the voltage measured at the noninverting terminal of an operational amplifier and transistor emitter voltage. The measured voltages are then used to estimate the electrical power dissipated by the OTA as a function of airspeed, kinematic viscosity, and the thermal conductivity of the ambient air. The OTA was calibrated at different dry-bulb (t_{db}) temperatures ranging from approximately 16°C to 34°C and at airspeeds between 0 and 5.5 m s^{-1} to develop the dry bulb compensation relation as shown in equation 1. Detailed information regarding the sensor design, calibration, and dry bulb temperature compensation approach can be found elsewhere (Gao et al., 2016).

$$\frac{u'}{\nu} = d_1\left(\frac{\delta}{k}\right)^3 + d_2\left(\frac{\delta}{k}\right)^2 + d_3\frac{\delta}{k} + d_4 \quad (1)$$

Where

u' = predicted airspeed with t_{db} compensation (m s^{-1})

v = kinematic viscosity (m^2 s^{-1})

$d_1 - d_4$ = coefficients obtained from temperature compensation calibration regression

δ = heat dissipation factor (W $°C^{-1}$)

k = thermal conductivity at film temperature (W m^{-1} $°C^{-1}$)

The thermistors were calibrated against a known reference airspeed sensor (Model 8455-152; TSI, Inc., St. Paul, MN, USA) using the apparatus shown in Figure 1. The transmission pipe used was 10.16 cm inside diameter schedule 40 PVC pipe, 2.15 m long. Two exhaust variable speed 12 V_{DC} fans were connected in series in order to provide a maximum airspeed of 8 m s^{-1} through the pipe and to overcome the pressure loss of the entrance flow straighteners. The intake side of the pipe consisted of a precision nozzle (for flow entrance uniformity) and a honeycomb flow straightener was constructed of 0.6 cm diameter plastic drinking straws. The reference air velocity sensor was mounted at the pipe centerline with a cable grip. The developed OTAs were calibrated in groups of five at six airspeeds between 0.0 and 8.0 m s^{-1}. Three minutes was allotted between airspeed changes to allow the thermistor's temperature to stabilize before data was collected. A total of 1000 data points were collected at each airspeed. Linear regression equations were developed transforming measured OTA airspeed to the reference with an offset and gain.

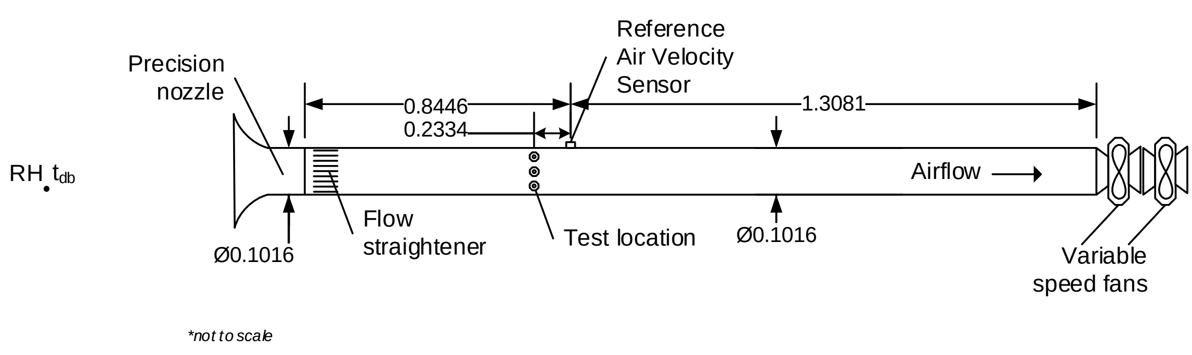


Figure 1. Schematic of custom wind tunnel standard tube used to calibrate the thermal anemometers. All units in meters.

SWEAP Design and Construction

Hardware

Each OTA was connected to its own circuit board that was designed in a CAD program (Eagle, Inc., Pembroke Pines, Florida, USA) to accommodate the thermistor circuitry and sequentially scanned using a 16-channel multiplexer (MUX). The common MUX output was monitored as a differential input to a 14-bit data acquisition system (Model 1408FS; Measurement Computing, Inc.) as shown in Figures 2 and 3a. Dry-bulb temperature (Model LM35; Texas Instruments, Inc.) and relative humidity (Model HIH4000; Honeywell, Inc.) sensors were added and placed near SWEAP to ultimately determine moist air properties required to calculate airspeed. A custom interface using visual basic for applications (VBA) was developed to record all monitored data.

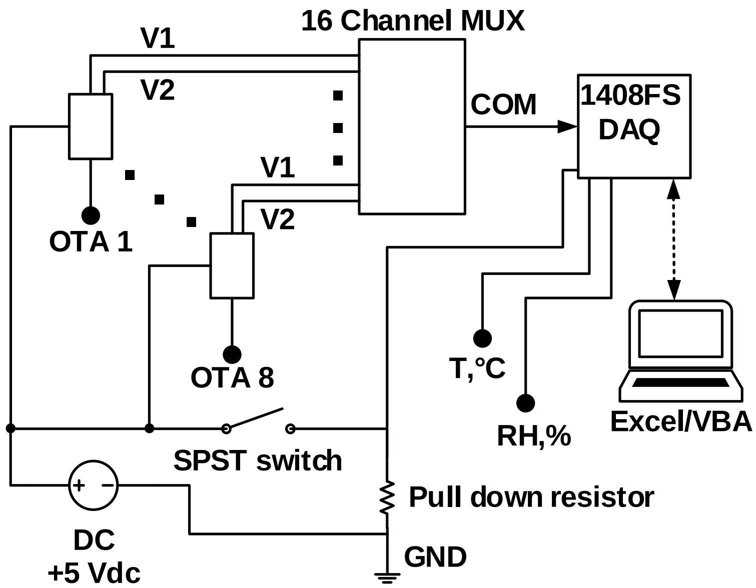


Figure 2. Schematic of instrumentation hardware. The 1408FS DAQ receives voltages from the T and RH sensors as well as the OTA's, which are then converted into the associated temperature, relative humidity, and airspeeds in VBA.

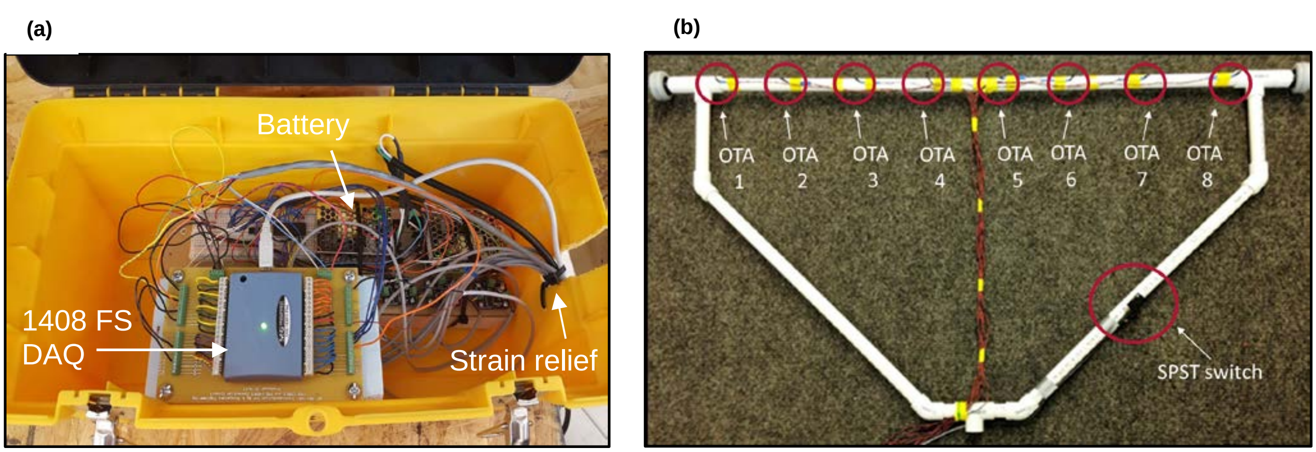


Figure 3. (a) Temporary housing for SWEAP hardware and (b) SWEAP measurement system.

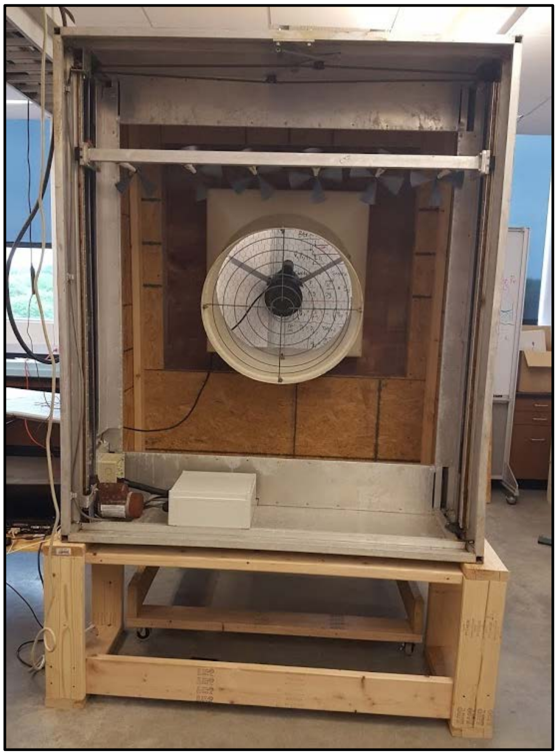
SWEAP Housing

Eight OTAs were selected for the version of SWEAP given in this paper. A light-weight PVC frame was constructed to support the eight OTAs as shown in Figure 3b. These OTAs were spaced at 127 mm (5 in.) on center with the end OTAs beginning 165 mm (6.5 in.) from the inside of the guide wheel. Small 50.8 mm (2 in.) diameter guide wheels were mounted on the ends to provide a smooth transition of the device over the fan. The total length of SWEAP from inner guide wheel to inner guide wheel is 1092.2 mm (43 in.). A single pole single throw (SPST) switch was used to start and stop data collection of SWEAP as it traversed the fan intake as well as time-stamping the SWEAP run.

Lab Testing against FANS

An apparatus was built to simultaneously measure airflow from FANS and SWEAP. FANS was placed on the exhaust side of a test fan, and a rigid foam board insulation (blue-board) frame was constructed on the intake side of the fan for directing air into the intake and allowing for easier SWEAP testing (Figure 4). The frame consisted of 5 cm blue-board with an inner width and length of 99 cm (39 in.) and 101.6 cm (40 in.), respectively. This blue board frame can accommodate fan sizes 61 cm (24 in.) and below. Both SWEAP guide wheels were placed on the outer edge of the blue-board frame to ensure horizontal tracking through the airflow region. For testing, SWEAP was placed at the top of the blue-board frame with the top of the OTA's parallel with the inner edge of the frame. A scan was initiated with the SPST limit switch depressed during the SWEAP traverse.

(a) Exhaust



(b) Intake

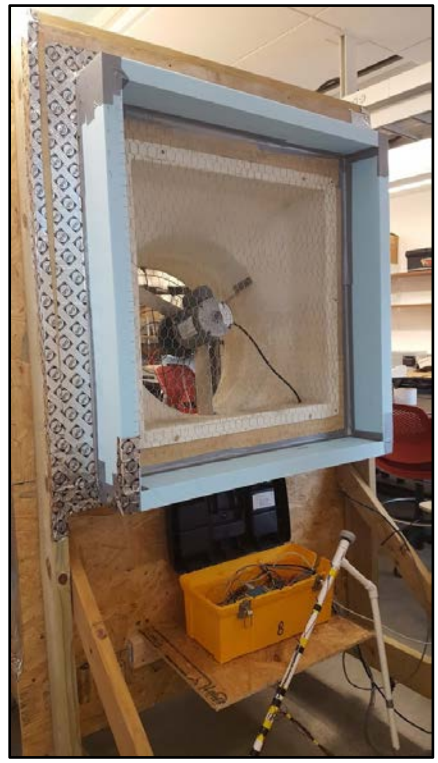


Figure 4. Measurement of airflow from a 61 cm (24 in.) fan with a discharge cone (a) FANS unit measuring exhaust airflow and (b) SWEAP measuring the intake airflow

Determing SWEAP Traverse Rate

Nominal SWEAP traverse rates (±target SWEAP traverse rate range) of 76 ±13 mm s^{-1}, 127 ±13 mm s^{-1}, 178 ±13 mm s^{-1}, and 229 ±13 mm s^{-1} were tested (3.0 ±0.5 in. s^{-1}, 5.0 ±0.5 in. s^{-1}, 7.0 ±0.5 in. s^{-1}, 9.0 ±0.5 in. s^{-1}). The SWEAP traverse rate is the average velocity that SWEAP traverses down the intake opening of the blue-board frame. A 61 cm fan with a discharge cone (Figure 4) was used for determining an optimal SWEAP traverse rate. The success of SWEAP relies on a uniform SWEAP traverse rate through the intake aperture, and this initial testing was conducted to test the influence of changes in SWEAP traverse rate. Data collected consisted of 12, 4 run averages at each SWEAP traverse rate (n=12). A run consists of traversing SWEAP from the top down. After four runs had been conducted, the average was taken to create one replicate. The overall mean of 12 replicates was compared to FANS at each SWEAP traverse rate. An individual run that did not fall in the specified SWEAP traverse rate range was discarded and a new run was conducted. In order to determine which SWEAP traverse rate had the closest relationship to FANS, a one-way ANOVA and Tukey's test were performed in JMP Pro 12 (*JMP*, 1989).

SWEAP Validation

Several fans of varying diameter and airflow capacity were tested in the lab including a 36 cm (14 in.) fan without a discharge cone, a 61 cm (24 in.) fan without a discharge cone, and a 61 cm (24 in.) fan with a discharge cone. The procedures explained above were followed to test each fan.

Field Testing against FANS

The lab calibration apparatus did not allow for fans larger than 61 cm in diameter to be tested. A cooperator's grow-finish swine facility was used to test *in situ* SWEAP performance with larger 91 cm and 122 cm diameter fans, as well as an existing 61 cm wall fan. All of the fans were located on the end walls of the facility. The fans were tested at free-air conditions. Each fan was first tested with FANS followed as close in time as possible with SWEAP. Like the lab calibration, a blue-board frame was constructed around the intake opening of the test fan and adhered to the wall with duct tape ensuring that all airflow passing through the fan first entered through the blue-board frame (Figure 5). Field testing used SWEAP traverse rates of 76 ±13 mm s^{-1} and 127 ±13 mm s^{-1}. SWEAP testing for the 91 cm and 122 cm fans required two SWEAPs to encompass the larger openings relative to the physical width limitation of SWEAP. A piece of thin plywood board was placed in the center of the blue board frame to ensure equal SWEAP areas (Figures 5b and 5c). SWEAP was flipped to measure the second half of the fan so that the same OTA's were active for both measurements. Both measurements were added to achieve a total airflow measurement through the fan.

(a) (b) (c)

Figure 5. Field testing: blue board frame encompassing a (a) 61 cm (24 in.) fan with a hood and (b) 91 cm (36 in.) fan with a cone (c) 122 (48 in.) fan with a cone

SWEAP Airspeed Profiles

During field testing, airspeed profiles were taken of SWEAP following the previous procedures for a SWEAP run. Data was collected at the 127 ±13 mm s^{-1} SWEAP traverse rate for the 61 cm and 91 cm fans. These profiles consist of the airspeeds for each OTA as it traversed down each fan. The airspeeds were only collected when the SPST switch had been activated. MATLAB (*Matlab*, 2015) was used to linearly interpolate data in-between OTA's to produce a contour plot for each fan.

Results and Discussion

Lab Testing against FANS

Determining SWEAP Traverse Rate

SWEAP traverse rates of 76 ±13 mm s^{-1} and 127 ±13 mm s^{-1} (±target SWEAP traverse rate range) were statically similar to FANS ($p>0.05$) while a SWEAP traverse rate of 178 ±13 mm s^{-1} and 229 ±13 mm s^{-1} were significantly different ($p<0.05$). Figure 6 shows the average SWEAP airflow measured at the tested SWEAP traverse rates and airflow measured from FANS for a 61 cm fan with a cone. A nominal SWEAP traverse rate of 127 ±13 mm s^{-1} was used for further testing because it was the easiest reproducible traverse rate to evaluate multiple fans quickly, and it had the closest relationship to FANS.

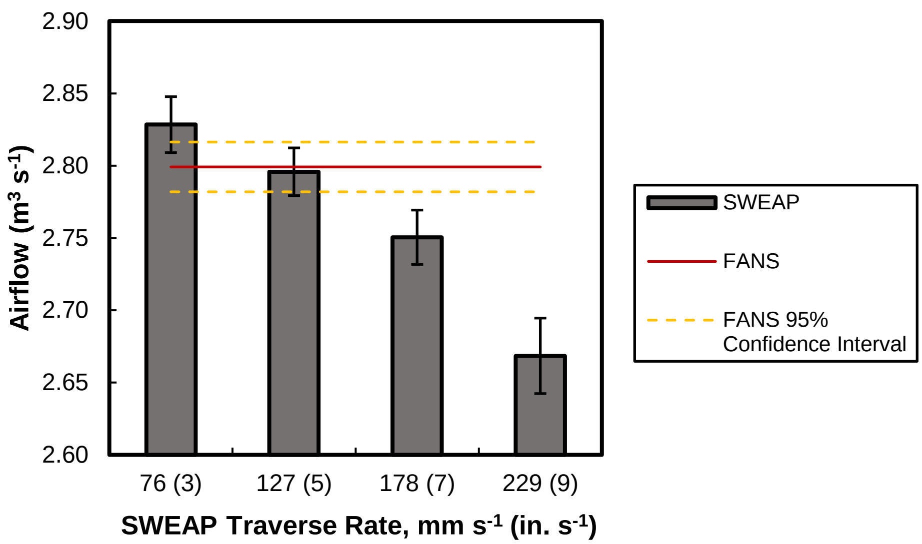


Figure 6. FANS vs SWEAP at selected SWEAP traverse rates

SWEAP Validation

The means between FANS and SWEAP showed no significant difference for the 36 cm (14 in.) fan without a cone and the 61 cm (24 in.) fan with a cone as shown in Tables 1 (SI units) and 2 (IP units). The average percent difference between the SWEAP and FANS means for in-lab testing was between 0.24% and 2.27% with the 61 cm fan with a cone having an average percent difference of less than 0.25%.

Table 1. Summary statistics table for fans analyzed at a nominal SWEAP traverse rate of 127 ±13 mm s^{-1} (SI Units).

	FANS				SWEAP				
Fan ID	n	Mean (m^3 s^{-1})	SD	±95% CI (m^3 s^{-1})	n	Mean (m^3 s^{-1})	SD	±95% CI (m^3 s^{-1})	Percent Difference (%)
36 cm w/o cone	8	1.73	0.030	(1.70, 1.75)	12	1.70	0.028	(1.68, 1.72)	1.45
61 cm w/o cone	8	3.35	0.053	(3.31, 3.40)	12	3.28	0.033	(3.25, 3.30)	2.27*
61 cm with cone	8	2.80	0.039	(2.77, 2.84)	12	2.80	0.026	(2.78, 2.81)	0.24

* significant difference ($p < 0.05$)

Table 2. Summary statistics table for fans analyzed at a nominal SWEAP traverse rate of 5 ±0.5 in. s^{-1} (IP Units).

	FANS				SWEAP				
Fan ID	n	Mean (cfm)	SD	±95% CI (cfm)	n	Mean (cfm)	SD	±95% CI (cfm)	Percent Difference (%)
14 in. w/o cone	8	3660	64.1	(3607, 3714)	12	3607	59.5	(3569, 3645)	1.45
24 in. w/o cone	8	7103	109.6	(7012, 7195)	12	6942	66.1	(6900, 6984)	2.27*
24 in. with cone	8	5938	84.0	(5868, 6008)	12	5924	57.2	(5888, 5960)	0.24

* significant difference ($p < 0.05$)

Field Testing against FANS

The means between FANS and SWEAP showed no significant difference for the 61 cm (24 in.) fan with a hood and the 91 cm (36 in.) fan with a cone as shown in Tables 3 (SI units) and 4 (IP units). The average percent difference between the SWEAP and FANS means for in-field testing was between 1.01% and 4.91% with the 61 cm and 91 cm fan having a percent difference of less than 1.5%.

Table 3. Summary statistics table for fans analyzed at a nominal SWEAP traverse rate of 127 ±13 mm s^{-1} (SI Units).

	FANS				SWEAP				
Fans ID	n	Mean ($m^3 s^{-1}$)	SD	±95% CI ($m^3 s^{-1}$)	n	Mean ($m^3 s^{-1}$)	SD	±95% CI ($m^3 s^{-1}$)	Percent Difference (%)
61 cm with hood	8	2.13	0.051	(2.08, 2.17)	11	2.15	0.047	(2.12, 2.18)	1.33
91 cm with cone	8	4.75	0.057	(4.70, 4.80)	3	4.70	0.042	(4.60, 4.81)	1.01
122 cm with cone	8	6.92	0.072	(6.85, 6.98)	3	7.26	0.136	(6.92, 7.60)	4.91*

* significant difference ($p < 0.05$)

Table 4. Summary statistics table for fans analyzed at a nominal SWEAP traverse rate of 5 ±0.5 in. s^{-1} (IP Units).

	FANS				SWEAP				
Fans ID	n	Mean (cfm)	SD	±95% CI (cfm)	n	Mean (cfm)	SD	±95% CI (cfm)	Percent Difference (%)
24 in. with hood	8	4501	108.4	(4410, 4592)	11	4561	98.3	(4495, 4627)	1.33
36 in. with cone	8	10066	121.1	(9964, 10167)	3	9964	89.5	(9742, 10187)	1.01
48 in. with cone	8	14654	148.9	(14529, 14778)	3	15374	289	(14656, 16092)	4.91*

* significant difference ($p < 0.05$)

A graph summarizing Tables 1 and 3 is shown in Figure 7. Only the airflow and percent difference is graphed for FANS and SWEAP for each fan. The fans on the left side of the dashed line were tested in the lab, whereas the fans on the right side of the dashed line were tested in the field.

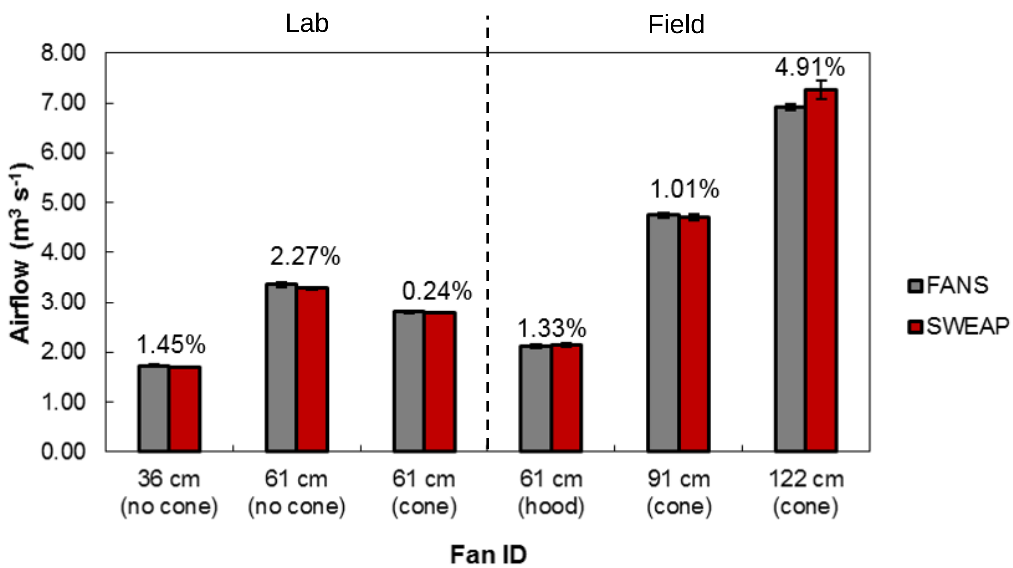


Figure 7. Visual summary of graphs

SWEAP Airspeed Profiles

Figures 8a,b outlines SWEAP's airspeed profile as it transitions from the top to bottom of the blue-board opening for the 61 cm and 91 cm fans, respectively. Each OTA is labeled and the path of the thermistors is denoted by the dotted line. The space in-between both OTA 4's for the 91 cm fan is where the thin plywood board was located to accommodate the required double sweep (see Figure 5b).

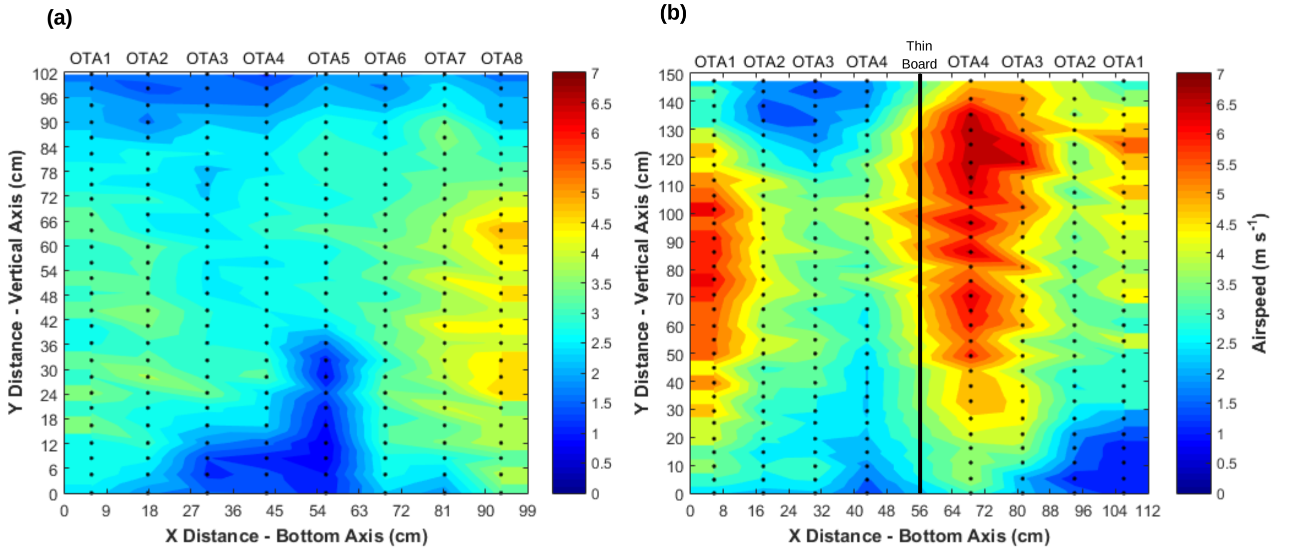
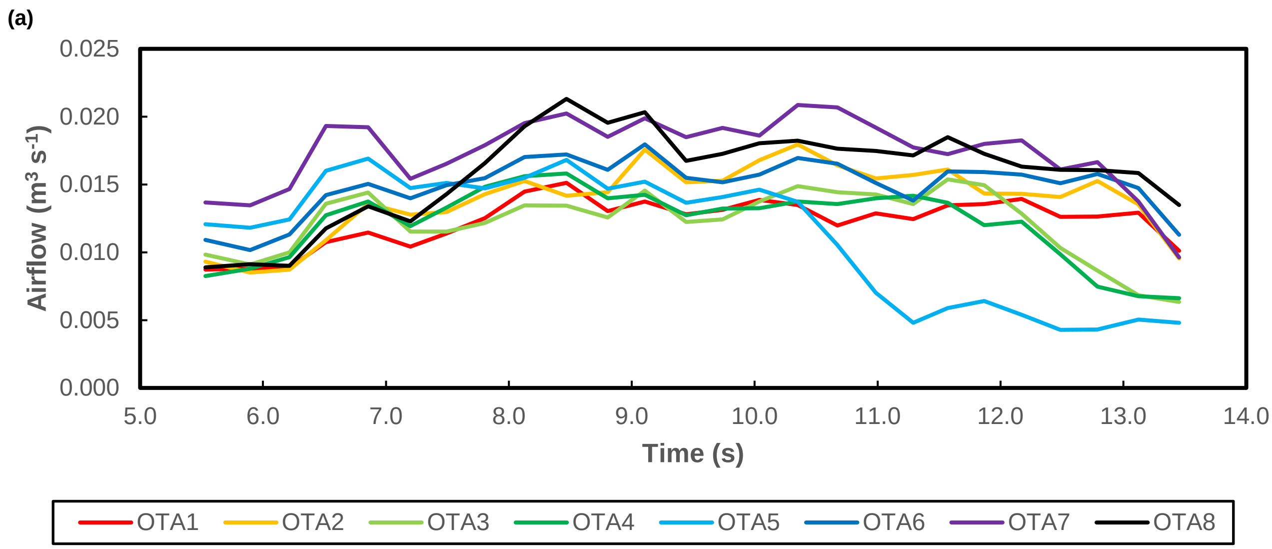


Figure 8. (a) airspeed profile in time for all 8 OTA's for one run at 127 ± 13 mm s^{-1} for the 61 cm fan with a cone and (b) airspeed profile in time for the first 4 OTA's for the double sweep runs at 127 ± 13 mm s^{-1} for the 91 cm fan with a cone

Figure 9a shows individual airspeeds versus time for the single-SWEAP 61 cm fan (with cone) at a SWEAP speed of 127±13 mm s^{-1}. The integrated airflow and airflow profile is shown in Figure 9b. The strip total in Figure 9b corresponds to the total airflow for all 8 OTA's as SWEAP traverses down the fan.



(b)

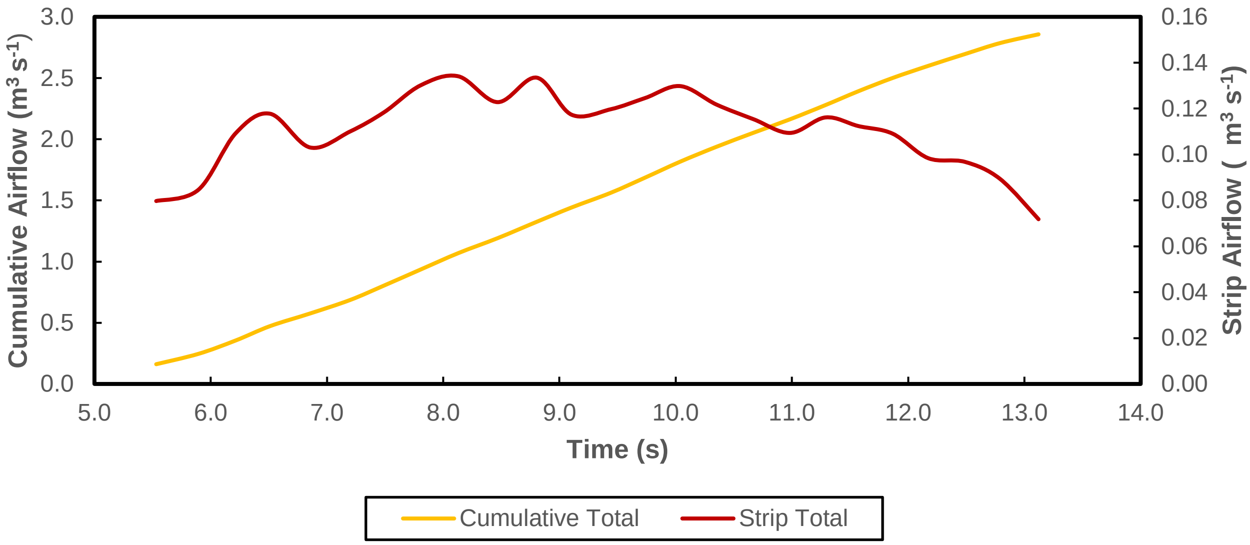


Figure 9. (a) Airspeed profile in time for all 8 OTA's for one run at 127 ± 13 mm s^{-1} for the 61 cm fan with a cone and (b) cumulative airflow for the fan.

SWEAP vs FANS

A linear regression of SWEAP against FANS was performed that resulted in a coefficient of determination (R^2) of 0.9975 and a root mean square error (RMSE) of 0.1144 m^3 s^{-1} (244 ft^3 min^{-1}). The shaded region in Figure 10 represents the 95% confidence interval for the SWEAP mean. All airflow data points are within this shaded region.

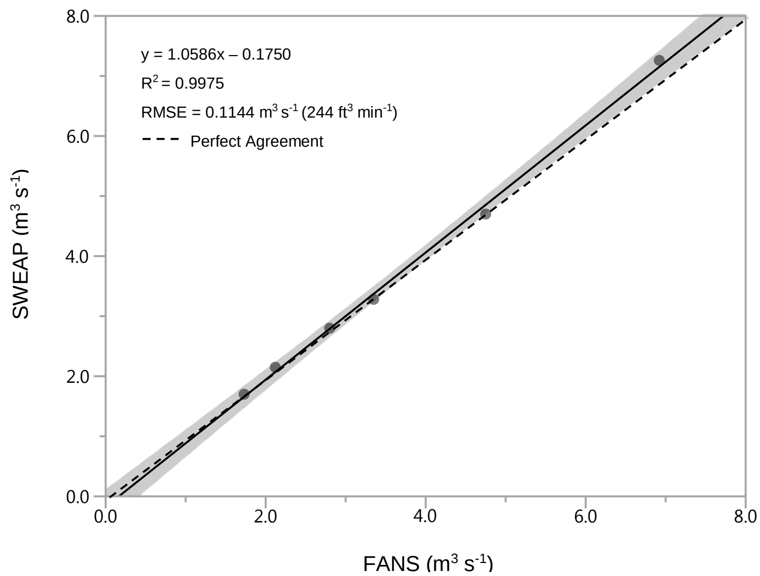


Figure 10. A linear regression of SWEAP vs FANS with a shaded 95% confidence interval for the mean value of SWEAP

Conclusion

A portable tool that extension personal could use to evaluate intake airflow for *in situ* fans was developed called SWEAP (Segmented Wand for Evaluating Airflow Performance). SWEAP utilizes eight OTA's to measure airspeed. SWEAP was evaluated against the FANS unit in a lab as well as tested in the field for several sized fans (36 cm, 61 cm, 91 cm, and 122 cm). The data showed that there was no significant difference between the means between SWEAP and FANS for the 36 cm fan, 61 cm fan with a cone, 61 cm fan with a hood, and the 91 cm fan. The average percent differences for each of these fans were less than 1.5%. For all in-lab and in-field testing, the maximum difference between SWEAP and FANS was 4.91%.

SWEAP can be used by extension personnel to quickly and accurately evaluate airflow for multiple fans. Further work to improve SWEAP is required in order to condense the circuit hardware into a smaller box that would be directly mounted onto SWEAP with a display screen that outputs the average SWEAP traverse rate as well as the airflow for that run. Also, increasing or decreasing the number of OTA's incorporated on SWEAP could be investigated, as well as traversing SWEAP horizontally. Higher capacity fans will also be tested and the influence of upstream operator obstruction will be investigated as well. SWEAP is another tool that researchers, producers, and extension specialists could use to assess *in situ* fan performance without the initial labor and transportation needs required for implementing FANS.

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Nomenclature

APT (Averaging Pitot Tube)
CTA (Constant Temperature Anemometer)
FANS (Fan Assessment Numeration System)
MUX (Multiplexer)
NTC (Negative Temperature Coefficient)
OTA (Omnidirectional Thermal Anemometer)
PEAMA (Pit Exhaust Airflow Measurement Assembly)
RMSE (Root Mean Square Error)
SD (Standard Deviation)
SPST (Single Pole Single Throw)
SWEAP (Segmented Wand for Evaluating Airflow Performance)
VBA (Visual Basic for Applications)