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Field Estimation of Ventilation Capacity Using FANS

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Abstract. Instrumentation and procedures have been developed to characterize mechanical ventilation system capacity as part of an evaluation of ammonia emissions from commercial poultry housing. A FANS anemometer array unit, developed at the Mississippi USDA center, built and refined at University of Kentucky, and calibrated at the BESS laboratory, was found to have repeatability in the range of about 1% between two traverse readings performed one after the other. The unit was used to measure broiler house fans under typical system static pressure differences. A hydraulic lift cart was fabricated to streamline FANS positioning and movement through the large poultry houses. Taping all gaps between the FANS unit and fan housing improved airflow measurements about 6% versus not taping. Using a duct to transition down to 36-inch fans resulted in a 2.5% improvement versus not using a duct. Fan manufacturer performance data was 2 to 13% higher than actual field performance.

Keywords. Broilers, protocol, rated data, static pressure.

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Introduction

In order to assess ammonia gas emissions from livestock facilities two simple, but difficult to measure, parameters are needed: the ammonia concentration in the exhaust air and the ventilation rate. Protocols and instrumentation for ammonia emission measurements for poultry housing are being developed as part of a multi-state and multi-disciplinary project funded by the USDA-IFAFS and are part of a second IFAFS-funded project that evaluates poultry in addition to other livestock species. Xin et al. (2002) reports on the ammonia instrumentation development and comparison to other ammonia detection equipment used on these projects.

Determination of ventilation rates of livestock facilities has never been straightforward due to the inherent variability of ventilation system installation and maintenance. Additionally, wind effects on ventilation system performance can be considerable. Mechanical ventilation systems that employ fans for air exchange offer an air exchange measurement advantage over natural ventilation systems since air is under relatively controlled discharge from the livestock facility. Measurement of airflow at each operating fan would allow calculation of ventilation system air exchange. An array of anemometers was developed by Simmons et al. (1998) to accurately measure livestock ventilation fan airflow capacity in the field. The instrument incorporates an array of anemometers that perform equal area traverse of the air flow entering fans up to 54-inches in diameter. This Fan Assessment Numeration System (FANS) was further refined, evaluated, and fabricated Gates et al. (2002) at the University of Kentucky for use at the various livestock facilities being evaluated by these projects. Calibration of each FANS unit was performed at the University of Illinois' BESS (Bioenvironmental and Structural Systems) Laboratory.

Objective

The objective of the protocol was to get accurate estimates of ventilation system capacity in the field. This needs to be completed in a reasonable time. Although the FANS tests were of individual fans, the capacity of each ventilation stage, which usually involves more than one fan, needs to be determined for use in emission estimates.

Methodology

Facility Description

FANS data were collected from two broiler farms, referred to as Farm B and Farm H, during four site visits in Spring 2002. The broiler houses, two at each site, were built by the same builder in 1999 and 2001 but under contract to two different integrated companies. Ventilation equipment in the houses was nearly identical. Each of the four houses was completely characterized as to dimensions, equipment, and ventilation management strategy in previous site visits. The houses used conventional sidewall ventilation with up to four 36-inch plus four 50-inch sidewall fans unless weather warmed enough to use tunnel ventilation. During hot weather, the conventional ceiling inlets were closed and the 36-fans shut off, then the ten 50-inch fans were used with inlet curtains on the opposite end of the house for tunnel ventilation.

FANS Procedures

The FANS was tested in the normal operating range of static pressure difference at each farm. At least four SP were tested: 0, slightly below normal range, within normal range, and slightly above normal range. For example, at Farm B, the manager always ran the SP from 0.05 to 0.10. The SP evaluated were 0, 0.03, 0.06, and 0.12. At Farm H, higher SP were sometimes used so a fifth test at 0.18 was added to the fan evaluation.

After the FANS was set into place at a chosen fan, a static pressure (SP) was set via the house control room Photohelic (Dwyer, MI) instrument, which is used for inlet opening control. The SP needles were set to within about 1mm of each other so that SP was kept in a very narrow range by the inlet controller. Once the SP stabilized, a FANS traverse was run. A second traverse was run right away. If the difference between the two runs differed by more than 3%, another pair of traverse was completed. All tests were done when the house had no birds present so that any ventilation condition could be evaluated without jeopardizing bird comfort and well-being.

Streamlining Data Collection

A secondary objective was to streamline the process so that more fans could be tested in a day. Once the crew was practiced at setting up and operating the FANS at different static pressures, the time needed for each fan test was as follows. About 7 minutes was needed for two consecutive FANS traverses plus data notation time. Changing and stabilizing each static pressure setting took on average about 2 minutes but with even minor complications this could easily range up to ten minutes. For example, end doors and all inlets need to be opened to get a zero SP reading and then closed again to get the other SP settings. These FANS traverses were preceded by 10 to 20 minutes of FANS positioning and almost 10 minutes of sealing the FANS to the fan housing. If a duct was used for a 36-inch fan, then 40 to 50 minutes was needed to assemble and seal a pre-cut duct between the FANS and the fan housing. More time was needed if the duct was fabricated from scratch. Therefore, for a complete evaluation of one fan at five static pressure settings, about 70 minutes was needed. The broiler houses under study had 14 or 15 fans while the layer houses had 60 fans. Clearly, only a portion of the fans can be evaluated in the layer houses. Evaluation of all fans in the broiler house would take about 16 hours of efficient, error-free work.

Results

Designs and Tests to Streamline FANS Data Collection

Several preliminary tests and designs were done in an attempt to streamline the FANS data collection process.

Lift Cart. A cart was needed to comfortably move the FANS unit down the length of a 500-foot long poultry house. A hydraulic lift was added to allow easy height adjustment of the 80-pound FANS unit to match the test fan height. The wheels had balloon tires for easy rolling over broiler house litter. With this lift cart, the FANS can be easily moved and the height adjusted by one person.

Communications. Walkie-talkie radios were used so that the person adjusting static pressure in the control room could easily talk with the person running the FANS unit. Often these two people are out of sight of each other in layer houses and/or 500 feet apart. The radios eliminated disruptive yelling and miscommunications. The FANS unit operator could tell the SP control person when tests were completed. Likewise, the SP control person could indicate when the test SP was adjusted and steady in order to start the test.

Repeatability of Traverse Reading. The repeatability of FANS readings was very good with about a 1% difference between two traverses. Table 1 shows results of paired traverses, one upward and one downward, on four different fans. Wind influenced repeatability, which is most often seen in the larger differences between traverses at 0 SP (Table 1). To get 0 SP the house endwall doors were opened. Part of the protocol is to only open the end door on the opposite end of the house from where a fan is being tested. This greatly reduced the wind gusting through an end door onto the FANS unit. The best repeatability was found in the normal fan operating range of 0.03 to 0.12 inches SP.

Static Pressure Recording. Part of the airflow difference between a pair of traverses and operation of the fan with and without its stage partners (presented later) can be attributed to variations in static pressure against which the fan operated during the three-minute FANS test. Wind had the most influence on varying SP during a test. A refinement to the protocol was to monitor SP at the FANS unit even though the poultry house control room SP instrument was used to set SP for the tests. A Magnehelic (Dwyer, MI) static pressure sensor with 4-20 mA signal output, for SP range of –0.05 to 0.25 inches water, was connected to a Hobo (Onset Corp. MA) mA datalogger for recording SP at 10-second intervals. These SP readings were averaged over the three-minute FANS data collection interval. The outside SP port consisted of a flexible plastic tube run outside the house through a gap in fan housing or end door with its end positioned out of the wind within a plastic jug. (note: The data presented in this paper include the nominal SP as adjusted on the control room SP instrument since the SP gage was made to order by the manufacturer and was not available for these earliest field evaluations.)

Sealing FANS to Fan Housing. Sealing the FANS to the wall and fan housing takes the bulk of the setup time in moving the FANS from one fan to the next. In an attempt to reduce this time and the fuss of duct taping all the gaps between the FANS and the wall, a foam insert and no seal were evaluated. The FANS was positioned as close to the fan as possible and the foam was inserted for the first test. The foam was closed-cell 2-inch square cross-section, three-foot long strips commonly used to seal around window air conditioners. The foam was used on three sides of the FANS while the top gap was sealed with a piece of cardboard laid on top of the unit (which was not as well sealed as the foam sealed sides but the gap was too wide for the foam to seal). Table 2 shows the results that the foam allowed about 1.2% more air leakage than the tape sealed unit. With careful installation of foam, which may take as long as taping, the error could be improved. Tape remains the seal of choice. Some gap seal is needed since about 6% of airflow is leaked through FANS gaps with no sealant.

Duct Transition to Smaller Fan. A lightweight collapsible duct (blue polystyrene R-3) was used to connect the FANS unit, with square opening of about 52-in, to 36-in fans. Gaps were sealed with duct tape. The duct was 48-inches long, which is about 1.3 fan diameters of the smaller fan, with one to two diameters length considered acceptable. Setup time for the duct was even longer than for simply taping the FANS unit against the housing of the larger fans. A test was run to see if the FANS taped against the housing and wall of a 36-inch fan was a suitable replacement for the duct. Table 3 shows that there was about a 2.5% difference between FANS tests with and without the duct. For comparison, in the same table, the difference between two identical fans, both tested with ducts, was 1.0%. Use of the transition duct is recommended if time and space allow.

Fan Data Comparison. The FANS measurements were compared to fan performance data supplied by the fan manufacturer. Tables 1 and 2 show that the 36-inch fans were within about 13% of manufacturer performance and the 50-inch fans were within 6%. All fans tested so far (ten fans) in the field have reduced airflow versus manufacturer performance data. The FANS unit imposes some flow penalty that depends on the particular fan being tested (2-10% in separate tests reported in Gates et al., 2002). Some of this discrepancy also appears to come from bare fan data being offered rather than performance data where the fan was outfitted with accessories (shutters, guard) it will use during installation. Using manufacturer data does not produce reliable airflow estimates unless the data come from a rated test from a laboratory where the fan was tested with accessories in place. For comparison, Figure 1 compares rated data from BESS laboratory to FANS evaluation. Data included the shutters and guard so fan field performance was within 2 to 5%. All the fans tested in this study were clean and in very good working order with most of the reported data from fans (Farm H) in operation less than one-year.

Full Ventilation System Characterization

Number of Fans to Test. Even with only 14 fans in a broiler house, it can take a long time to determine performance of over a range of four to five static pressures. For this reason, only about a third of the fans were evaluated. Since the houses under study are relatively new, the fans are virtually identical throughout the house, versus an older house where motors and other components are often replaced over time. During FANS evaluations, once two of the ten tunnel fans were tested, if data from those evaluations were similar (within about 3%), then it was concluded that the other tunnel fans would likewise be similar. Fans that potentially were most dissimilar were chosen for these initial tests. For example, with the tunnel ventilation fans, one tested fan was the most used of the group (runs during conventional and tunnel ventilation) while the second one was the least used (only used in last stage of tunnel ventilation on hottest days). Often fans were chosen on opposite sides of the house if outside variables had influence on fan performance (windward versus leeward side; free airflow versus fan discharge into obstructions, etc.). If these two fans, which were most dissimilar to each other, were reasonably close in performance, it was assumed the other fans would have similar performance. In layer houses where 60 or more fans may be found, similar logic would apply in testing a suitable number of fans.

Fan Alone versus with Other Fans in Stage. Fans should operate with similar performance whether evaluated alone or when tested with all the other fans that operate in its ventilation stage. There is preliminary evidence of slightly reduced airflow when a fan operates with it stage members versus when operated alone. A 50-inch fan delivered about 2% less airflow when with its other conventional ventilation stage members (figure 1) than when tested when operating alone. Within these two pairs of FANS tests, there was a 0.9 to 1.4% difference between a pair of traverses so the effect of staged fan operation versus operation alone seems to be rather small at about 1%. The location of each fan in figure 1 was second fan from the endwall of a sidewall bank of five tunnel fans. In figure 2, the results of two more fan evaluations show that the upstream-most tunnel fan was more affected by other fans running in its stage (or more affected by the FANS unit) than fans in a more downstream position along the same sidewall bank of tunnel fans. Future measurements will attempt to separate the effect of the FANS unit from the airflow measurement by taking data on the discharge side of these two fans. The downstream fan showed virtually no difference between operating alone versus with other fans in its stage.

Inlet Opening Measurement. To completely characterize a ventilation system, inlet opening area is needed at each static pressure difference of a ventilation stage. This information was gathered by measuring the opening of four box inlets, two on each sidewall of the broiler house, and both curtain openings during tunnel ventilation. These data will be used to develop ventilation characterization curves as found in Albright (1990) and in upcoming ASAE ventilation system performance standards.

Note Weather Conditions. During FANS tests the outside wind conditions are noted on data sheets. Wind will have an influence on fan performance and discrepancies between FANS runs can be partially explained if wind direction and speed are known. A hand held vane anemometer was used to note general wind conditions. A note as to sunshine and precipitation was quickly noted. None of the tests reported here were performed on windy days.

Conclusions

A Fan Assessment Numeration System (FANS) unit was used to measure broiler house fan performance under typical ventilation system static pressure differences. The FANS was found to have repeatability in the field of about 1% between two traverse readings performed one after the other. Fan manufacturer data was 2 to 13% higher than actual field performance, with the poorer performance primarily a function of bare fan data being provided by the fan manufacturer (via the builder), which does not account for the airflow reduction associated with fan shutters and guard. There was evidence of some tunnel ventilation fans exhibiting decreased performance when operating with other fans in it stage versus when operating alone.

In an attempt to refine the protocol and speed data collection, a hydraulic lift cart was fabricated to streamline FANS positioning and movement through the large poultry houses. Taping all gaps between the FANS unit and fan housing must be continued since secure sealing improved airflow measurements about 6% versus not taping. Using a duct to transition down to 36-inch fans resulted in a 2.5% improvement versus not using a duct.

Acknowledgements

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Table 1. Repeatability of FANS tests on four different fans. Fan airflow as determined and then test repeated.

Fans tested at Farm H; all tested alone with no other fans running.

Static Pressure Difference	50-inch fan #5			50-inch fan #1			36-inch fan #3			36-inch fan #5		
inch water	*cfm*	*cfm repeat*	*% difference*	*cfm*	*cfm*	*% difference*	*cfm*	*cfm*	*% difference*	*cfm*	*cfm*	*% difference*
0	17200	17087	0.7	18115	17796	1.8	9174	9107	0.7	9107	9329	2.4
0.03	16759	16592	1.0	16886	16896	0.1	8899	8858	0.5	8647	8796	1.7
0.06	15764	15608	1.0	16212	16105	0.7	8542	8521	0.2	8511	8542	0.4
0.12	13422	13615	1.4	13941	13969	0.2	7332	7390	0.8	7336	7182	2.1
0.18	10929	10903	0.2	11327	11275	0.5	6206	6359	2.4	6330	6151	2.9
Average Difference			0.9%			0.6%			0.9%			1.9%

Table 2. FANS Installation where gap between fan wall and FANS housing was secured with tape, closed cell-foam, and no sealant.

	50-inch fan #1 (Farm H)						
Static Pressure Difference	**with tape seal[1]**	**with foam seal[1]**	**with NO seal[1]**	**Manufacturer Data for Bare Fan[2]**	**Difference between taped fan and Manuf. Data**	**Airflow reduction using foam seal versus tape seal**	**Airflow reduction using NO seal versus tape seal**
inch water	*cfm*	*cfm*	*cfm*	*cfm*	*%*	*%*	*%*
0	17956	17617	16599	20861	-13.9	-1.9	-7.6
0.03	16891	16808	15904	20036	-15.7	-0.5	-5.8
0.06	16159	15843	15257	19203	-15.9	-2.0	-5.6
0.12	13955	13915	13330	17442	-20.0	-0.3	-4.5
0.18	11301	11161	10537	N/A	N/A	-1.3	-6.8
				Average Difference	-16.4	-1.2	-6.0

[1]Data represent average of two FANS traverses

[2]Manufacturer data of bare fan was supplied by fan manufacturer via builder

The tested fans were GSI Group CGBB5021 belt drive fans with split, gravity shutters on intake and 1x2-inch mesh guard on discharge; fans were clean and less than one year old.

Table 3. FANS comparison of two identical fans and the use of a duct attachment to a 36-inch fan.

	36-inch Fans (Farm H)						
Static Pressure Difference Setpoint	**Fan #3 with Duct[1]**	**Fan #5 with Duct[1]**	**Fan #5 NO Duct[1]**	**Difference Fan with and without Duct**	**Difference between Fan #3 and #5**	**Manufacturer Data for Bare Fan[2]**	**Difference from Manuf. Data[3]**
inch water	*cfm*	*cfm*	*cfm*	*%*	*%*	*cfm*	*%*
0	9141	9218	9047	-1.9	-0.8	10428	-12.7
0.03	8879	8722	8876	1.8	1.8	10042	-13.2
0.06	8532	8527	8483	-0.5	0.1	9651	-11.8
0.12	7361	7259	N/A	N/A	1.4	8843	-17.9
0.18	6283	6241	5875	-5.9	0.7	N/A	N/A
			Average difference	-1.6%	0.6%		-13.3%
			Average using absolute value of differences	2.5%	1.0%		

[1]Data represent average of two FANS traverses.
[2]Manufacturer data of bare fan was supplied by fan manufacturer via builder
The tested fans were GSI Group CGBB3614 belt drive fans with split, gravity shutters on intake and 1x2-inch mesh guard on discharge; fans were clean and less than one year old.
[3]Difference from manufacturer data is for fan #5 with duct

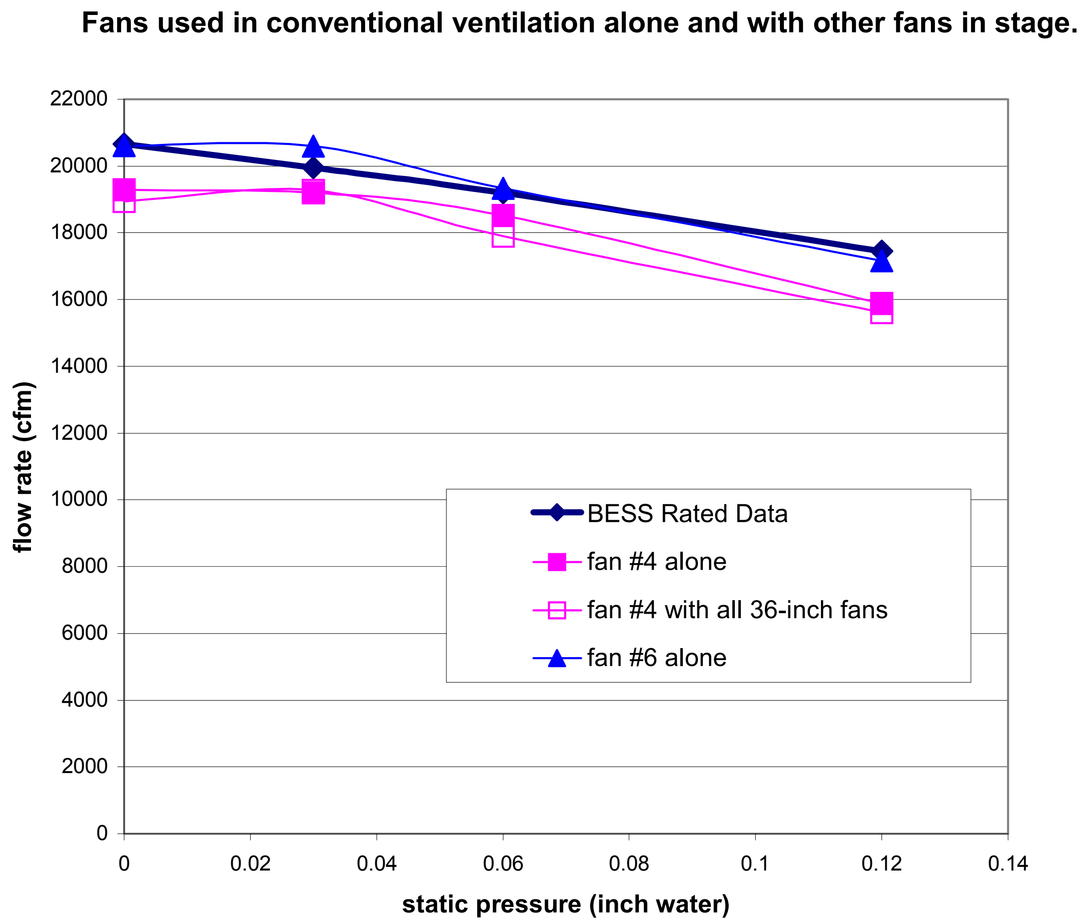

Figure 1. Comparison of two 50-inch fans at Farm B. One fan was tested with all the 36-inch fans running, which would be one of the final stages of conventional ventilation.

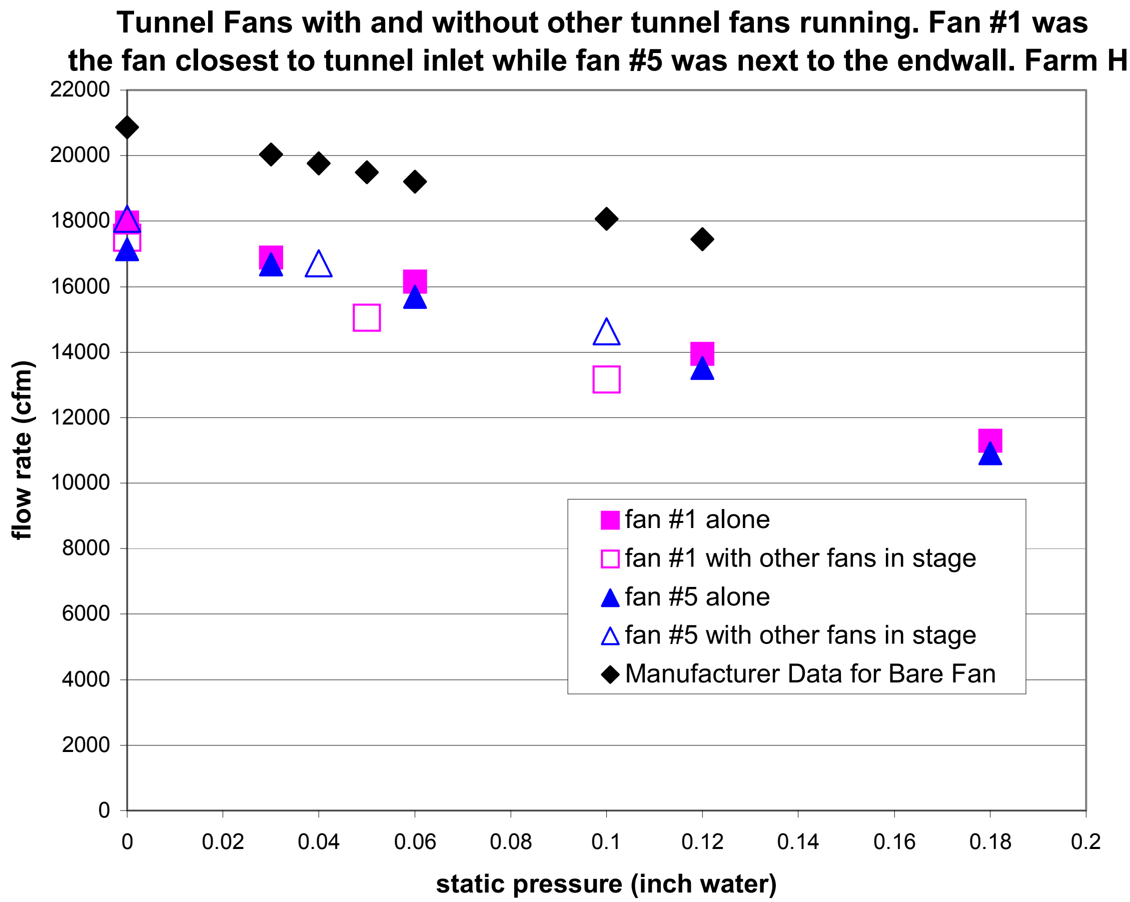

Figure 2. Comparison of fan field performance to data supplied by manufacturer. Difference in performance of tunnel ventilation fans with and without other tunnel fans operating.