6-2009

Downstream Placement of FANS to Determine Fan Performance in Situ

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Abstract

Accurate ventilation rate data are essential to maximizing the quality of aerial emission measurements. The fan assessment numeration system (FANS) devices have been widely used by U.S. researchers in measuring aerial emissions from mechanically ventilated livestock and poultry confinement. It is used to conduct in-situ calibration of building ventilation fans and thus development of the fan performance curve under the field operation conditions. The FANS device was originally intended to be placed in the upstream of the fan under in-situ calibration. However, certain field situations make it impractical to apply the FANS device as such. This study assessed the possible use of the FANS in the downstream of a ventilation fan, with the gaps between the FANS device and the discharge cone of the exhaust fan sealed by non-permeable fabric. Nine exhaust fans (1.22 - 1.32 m diameter) in laying-hen and turkey houses were tested with the FANS placed in upstream or downstream for a building static pressure range of 10 to 40 Pa. The results revealed that downstream placement of FANS device yielded 0.44 to 3.1% higher ventilation rate when compared to its upstream placement. This discrepancy is considered acceptable for in-situ fan calibration.

Keywords

Aerial emissions, building ventilation rate, fan assessment numeration system (FANS), in-situ fan calibration

Disciplines

Bioresource and Agricultural Engineering

Comments

This is an ASABE Meeting Presentation, Paper No. 095886.

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An ASABE Meeting Presentation
Paper Number: 095886

Downstream Placement of FANS to Determine Fan Performance *in Situ*

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Written for presentation at the
2009 ASABE Annual International Meeting
Sponsored by ASABE
Grand Sierra Resort and Casino
Reno, Nevada
June 21 – June 24, 2009

Abstract. *Accurate ventilation rate data are essential to maximizing the quality of aerial emission measurements. The fan assessment numeration system (FANS) devices have been widely used by U.S. researchers in measuring aerial emissions from mechanically ventilated livestock and poultry confinement. It is used to conduct in-situ calibration of building ventilation fans and thus development of the fan performance curve under the field operation conditions. The FANS device was originally intended to be placed in the upstream of the fan under in-situ calibration. However, certain field situations make it impractical to apply the FANS device as such. This study assessed the possible use of the FANS in the downstream of a ventilation fan, with the gaps between the FANS device and the discharge cone of the exhaust fan sealed by non-permeable fabric. Nine exhaust fans (1.22 - 1.32 m diameter) in laying-hen and turkey houses were tested with the FANS placed in upstream or downstream for a building static pressure range of 10 to 40 Pa. The results revealed that downstream placement of FANS device yielded 0.44 to 3.1% higher ventilation rate when compared to its upstream placement. This discrepancy is considered acceptable for in-situ fan calibration.*

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Downstream Placement of FANS to Determine Fan Performance *in Situ*

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Introduction

Concentration difference of an aerial constituent (gases or particulate matter) between the outlet and inlet air streams and the corresponding air exchange or ventilation rate (VR) through the source or sink are the two essential elements for determining aerial emission of the source. Of the two key elements, continuous VR quantification with good certainty is generally more difficult. A recent uncertainty analysis of aerial emission rate by Gates et al (2009) revealed that unless VR uncertainty can be controlled within 10%, a concentration uncertainty of 2% or 5% makes little difference on the emission result. To improve the certainty of VR measurement in mechanically-ventilated animal confinement, a portable anemometer-array system (Simmons et al., 1998), also known as the Fan Assessment Numeration System (FANS) (Gates et al., 2004), has been developed and is being widely used in air emission studies in the United States. The portable FANS device allows *in situ* measurement of airflow rate of the exhaust fans and thus development of fan performance (flow rate vs. static pressure or SP) under field conditions. Compared with the more traditional, traverse VR measurement method (i.e., use of velocity grid in the fan airflow cross section), the FANS method provides much improved accuracy. The FANS device is originally designed to be placed in the upstream of the fan to be *in situ* calibrated. However, it is not always practical to place the FANS device in the upstream location (inside the barn), such as high-rise laying-hen houses with large amount of manure accumulation. Then, a question naturally arose: How would the FANS device perform if used in the downstream (or discharge side) of the fan? A positive answer would allow the flexibility of using the device on the outside and thus better environment for the operators too.

The objective of this study was to assess the performance of the FANS device when used upstream *vs.* downstream of the ventilation fans to be calibrated *in situ*.

Materials and Methods

Four 1.32-m diameter exhaust fans in a turkey house and five 1.22-m diameter exhaust fans in a high-rise laying-hen house were randomly selected and used in this evaluation. Each fan was tested and performance curve developed at the normal barn operating SP of 10, 20, 30, and 40 Pa. For the upstream tests, the FANS device was placed against the wall and the gaps between the wall and FANS frame were sealed to prevent air leakage. For the downstream tests, a non-permeable fabric was used to cover the gaps between the fan discharge cone and the FANS frame (fig. 1). At each SP, the FANS device was run twice (array of anemometers traveling up and down). If the difference in VR between the two runs was greater than 2%, the process was repeated until the difference was within 2%. The sequence of running upstream or downstream tests was randomized, with the two following each other for a given calibrated fan. The exhaust fans were spaced at least 5 m apart for the layer house, whereas the discharge cones were touching each other for some of the tunnel-ventilated fans in the turkey house. Hence, the exhaust fans of the turkey house were calibrated while operating alone or in combination with the neighboring fans.

Difference in VR between the upstream and downstream placements was calculated with VR from the upstream placement as the reference, of the following form,

$$Difference[\%] = \frac{(VR_{Downstream} - VR_{Upstream})}{VR_{Upstream}} \times 100\% \qquad [1]$$

Upstream placement of FANS at the turkey site

Downstream placement of FANS at turkey site

Upstream placement of FANS at the layer site

Downstream placement of FANS at the layer site

Figure 1. Upstream or downstream placement of FANS device for in-situ fan calibration.

Results and Discussion

The individual fan curves for the upstream or downstream tests and the VR differences between the two approaches are presented in Figure 2. The VR difference ranged from -2.82 to 6.52%. The difference tended to increase with SP except for two fans (S6-52" and H6-36-48"; where "S" stands for stage, "H" stands for house). With the pooled data, a linear regression was developed to relate the difference and SP (fig. 3). The difference for the tested fans averaged 0.44 to 3.1% for the SP range of 10 to 40 Pa.

Comparisons of the fan curves with or without operation of the neighboring fans are shown in Figure 4. The VR difference averaged -1.81 to 4.42% for the SP range of 10 to 40 Pa (fig. 5). The relationship between the VR difference and SP was not significant ($P=0.14$).

Under field operational conditions, ventilation fans undergo inevitable conditions such as dust accumulation on the blades and/or shutter, reduced belt tension (for belt-driven fans), and reduced motor performance over time. All these conditions or factors contribute to degradation of the fan performance. Consequently, certain tolerance to temporal shift in fan performance is allowed during the periodic fan calibrations of a given fan. A tolerance of 5~10% shift may be considered reasonable. Therefore, the VR differences (mostly <5%) arising from upstream vs. downstream placement of the FANS device are considered tolerable. This outcome provides a great flexibility for performing more frequent and convenient *in-situ* fan calibrations.

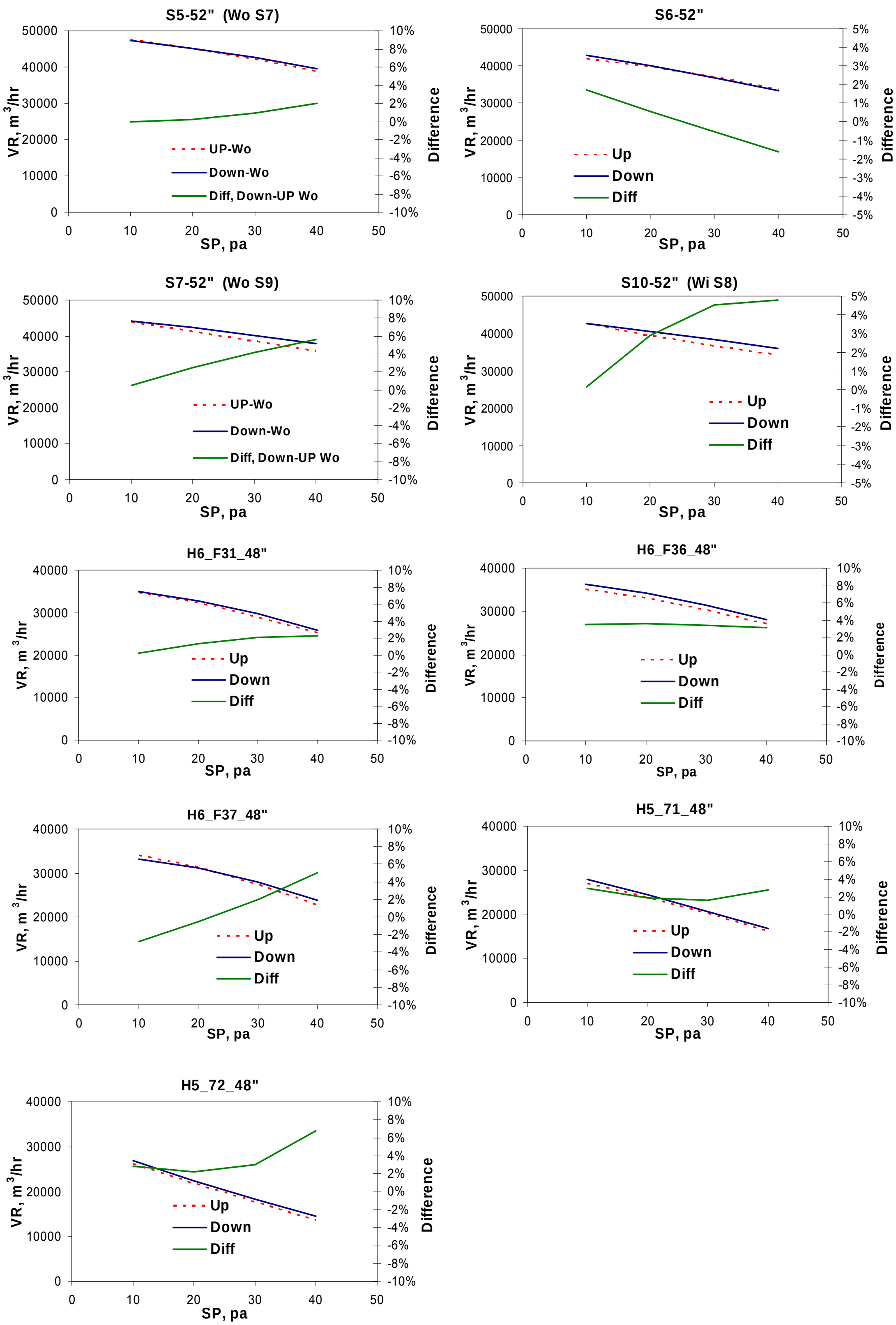

Figure 2. Comparison of in-situ fan performance obtained with upstream vs. downstream placement of the FANS device (Wo = without; S = stage; H = house; F = fan; SP = static pressure)

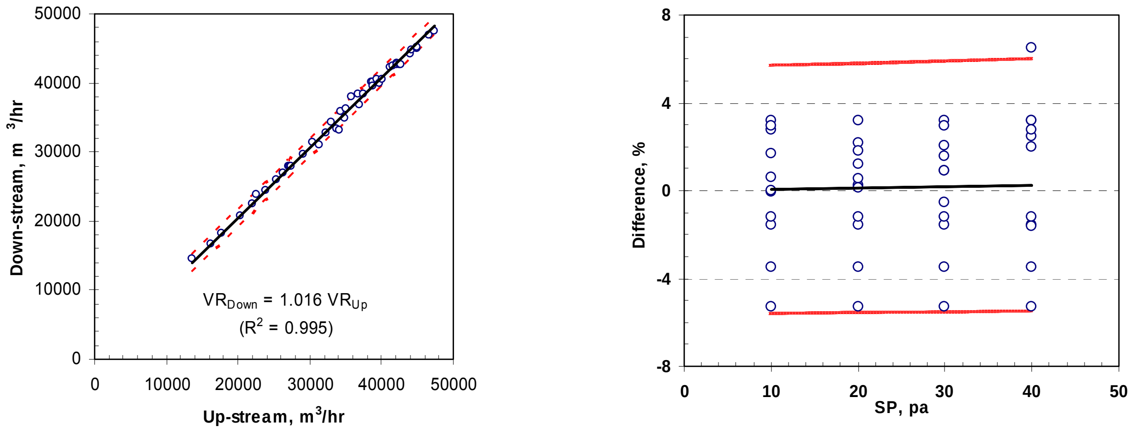

Figure 3. Downstream vs. upstream ventilation rate (VR) and VR difference vs. static pressure (SP).

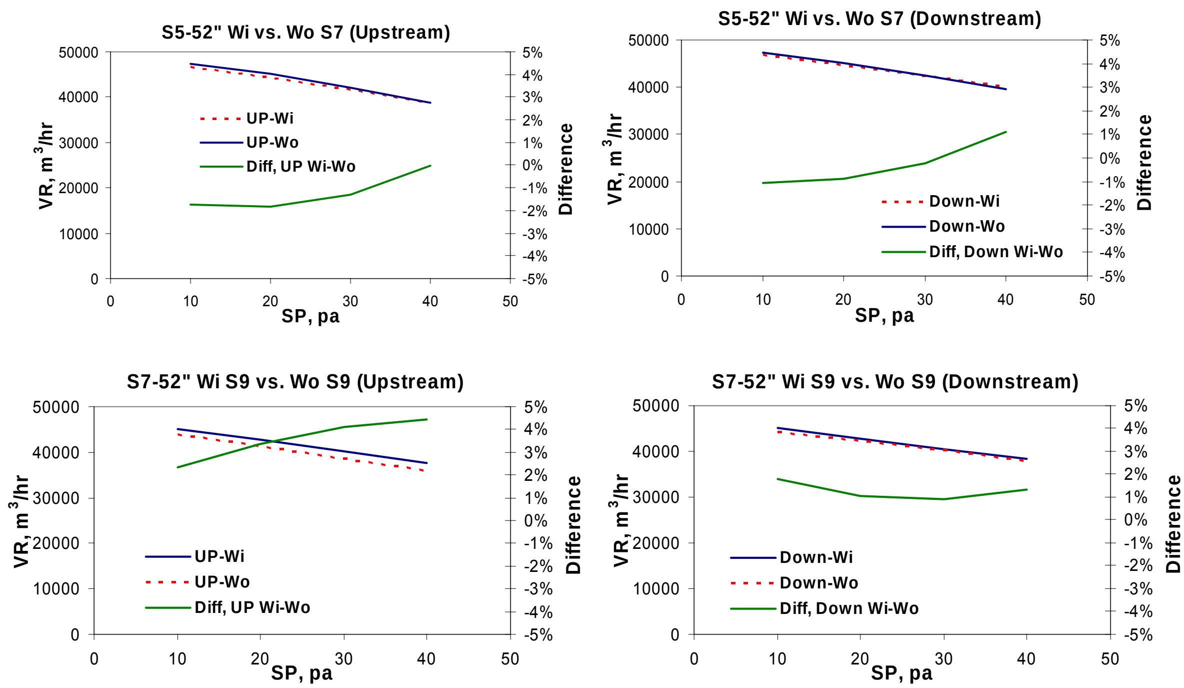

Figure 4. Fan performance curves with (Wi) or without (Wo) operation of the neighboring fans (VR = ventilation rate, SP = static pressure, S = stage).

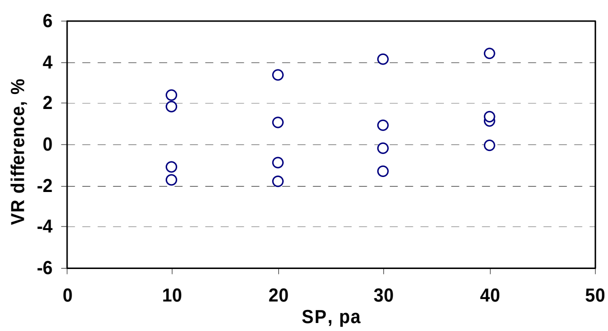

Figure 5. Fan curve difference between with and without operation of the neighboring fans (VR = ventilation rate, SP = static pressure).

Conclusions

Downstream sealed placement of FANS device for *in-situ* fan calibration leads to 0.44 to 3.1% higher VR when compared to upstream sealed placement of the FANS device at a static pressure range of 10 to 40 Pa. Hence, FANS device may be used in downstream of the ventilation fan for *in-situ* calibration. This flexibility will prove conducive to the use of the FANS device for initial calibration and frequent subsequent check or recalibration of ventilation fans. The operational status of the neighboring fans seems to have no appreciable impact on the performance of the operating fan.

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