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# DESIGN AND CONSTRUCTION OF A TEST BED FOR PERFORMANCE EVALUATION OF FANS

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## ABSTRACT

Optimization of energy consumption is an important consideration in the design and production of residential ventilation fans. We have designed and constructed a test bed for performance evaluation of residential ventilation fans. The test bed can provide accurate measurement of air flow rate, fan energy efficiency, and other air flow parameters, which can be useful for performance evaluation and improvement of design of residential ventilation fans constructed in this country. Presently, the test bed is being used in an on going project for compilation of standards for consumption and energy labeling of fans in Iran.

**Keywords:** Ventilation fans, Ventilation Efficiency Ratio, Air flow rate, Energy efficiency, CFD.

## 1. INTRODUCTION

The residential ventilation fans consume a significant portion of energy in the residential ventilation sector. Hence, optimization of energy consumption is an important consideration in the design and production of this class of fans. A standard test bed is an important facility for this purpose. The test bed not only provides a platform for performance evaluation of commercially available fans, but also assists the researches in their quest for development of new and more energy efficient fans.

Li and Heber [1] studied motors and controllers for variable speed fans. Ford et al. [2] studied performance parameters of fans, having variable frequency prime movers. There were other efforts around the world directed towards the development of standard test procedures and test facilities. In Denmark, Storm and Pedersen [3] evaluated the performance of 122 residential exhaust fans, having diameter ranging from 600 to 650 mm. Their results, for 1978 to 1992 period, show that the energy consumption of fans of 5000 $m^3$/hr capacity reduced by 51%, while energy consumption of fans of 10,000 $m^3$/hr capacity showed a reduction of about 43%. Ford and co-workers [2, 4-6] at Illinois Univ. (USA), performed tests on fans of 0.91 m diameter. Their results show that the performance of fans, designed and constructed in North America during 1991 to 2003 period, increased appreciably. They have shown that the average air flow rate, measured at 25 Pa (0.10 in. of water), and the Ventilation Efficiency Ratio (VER), expressed as $m^3$/h/W, increased by 14% and 19%, respectively. Similarly, the performance of fans of 1.22 m diameter increased by 16%, while their Ventilation Efficiency Ratio (VER) increased by 22%.

In this paper we present our work on design and construction of a standard fan test bed. The bed is presently being used in an on going project for compilation of standards for consumption and energy labeling of fans in Iran.

## 2. THE TEST BED

The test bed is capable of measuring flow rates of up to 7600 $m^3$/hr (4500 CFM). The nozzle measurement method, presented in ANSI/AMCA210-99 and ANSI/ASHRAE51-1999 standards [7-8], which is fast and can be designed to measure a wide range of flow rates, has been followed for the design of this test bed. Additionally, the inlet chamber condition, in which the test chamber is situated at the suction side of the fan being tested, has been selected. Figure 1 shows the schematic sketch of the chamber.

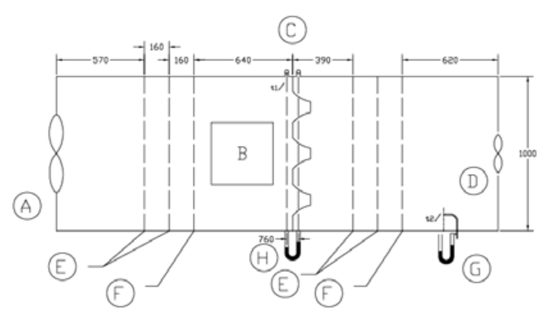

Fig 1: The schematic of the test chamber

The various sections in the above figure are:

A = variable flow rate auxiliary fan,
B = access door to the nozzles,
C = nozzles installation plate,
D = the test section with the fan being tested
E = stainless steel screens (50% open area)
F = stainless steel screen (40% open area)
G = static pressure measurement
H = differential pressure measurement tab

A total of 13 nozzles have been designed in accordance with ANSI/AMCA210-99 and ANSI/ASHRAE51-1999 standards. Of these, 9 nozzles have throat diameters of 87 mm, while the remaining 4 are of 40 mm throat diameter. The smaller diameter nozzles can be used for measuring very low air flow rates of up to 68m$^3$/h (for example in low flow rate ventilation fan applications). Figures 2 and 3 show two photographs of the same test bed. Figure 4 shows the distances of nozzles from their support plate, and also from one another. Figures 5 and 6 are photographs, showing the front and rear views of the set of nozzles, installed in their support plate.

Fig 2: Photograph of the test bed, showing the instrumentation and data acquisition system

Fig 3: Photograph showing the installed test fan

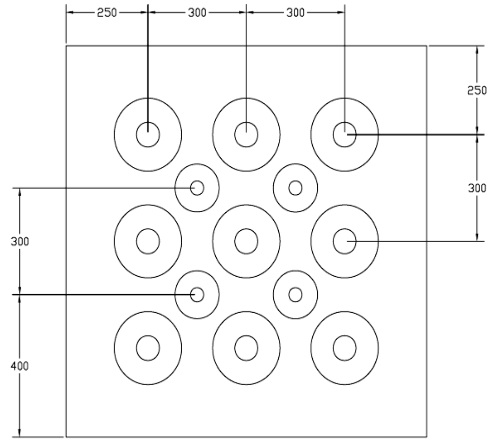


Fig 4: The nozzle support plate

Fig 5: Photograph showing the front view of the set of nozzles in the test bed

Fig 6: Photograph showing the back view of the set of nozzles in the test bed

## 2.1. Instrumentation

The piezometer rings pressure difference, upstream and downstream the nozzles, and fan static pressure, are measured using an electronic pressure transducer, having an accuracy of 1% of the measured pressure value. A psychrometer and a barometer are used to measure ambient conditions during the test. In addition, rotational speed and electric power consumption of the fan under test is measured using a digital tachometer and an AC power analyzer. Refer to Figs. 2 and 3.

## 3. CFD ANALYSIS

Stainless steel screens, placed at the top and bottom of the nozzle set, have been used to make the air velocity uniform across the test bed. Two sets of three stainless steel screens of 50%, 50%, 40%, and 60%, 60%, 40% open area have been used. Applying the recommendations in the Standards [7], the maximum air velocity after the last screen, and prior to its entrance to nozzles, at a distance equal to 0.1 times the hydraulic diameter ($D_h$) of the bed section, should not exceed 1.25 times the average air velocity at that section. CFD analysis has been used to model the air flow distribution in presence of the screens. Figures 7 and 8 present the air velocity distributions after the screens (placed before and after the nozzles).

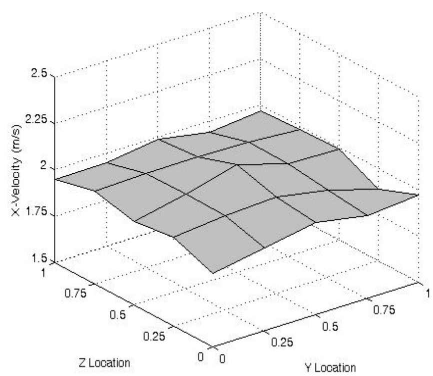


Fig 7: Air velocity distribution after the screens (placed before the nozzles)

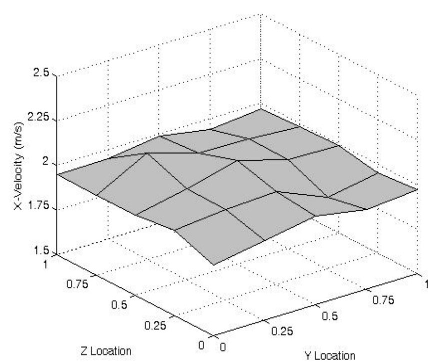


Fig 8: Air velocity distribution after the screens (placed after the nozzles)

To simplify the analysis, the first compartment of the bed, prior to entrance to the nozzles has been considered. Figures 9 and 10 show the air velocity contours across the bed with two sets of three screens of 50%, 50%, 40%, and 60%, 60%, 40% open area.

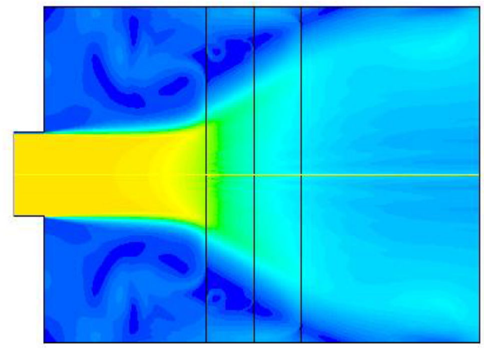

Fig 9: Velocity contours produced due to the existence of three screens of 40%, 60%, 60% open area

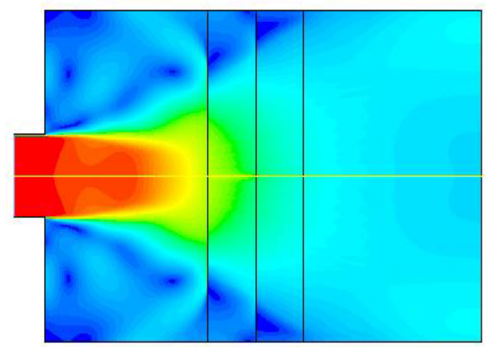

Fig 10: Velocity contours produced due to the existence of the three screens of 50%, 50%, 40% open area

Figures 11 and 12 present the air velocity distribution as function of the distance of the three screens. Due to the symmetry of the air flow across the bed, the air velocity distribution has been shown for half of the section. The average velocity across the test bed is 2 m/s. These figures show that the best air velocity distribution is obtained with screens having 50%, 50%, 40% open area. Under this condition, the maximum air velocity exceeds the average velocity by only 13%.

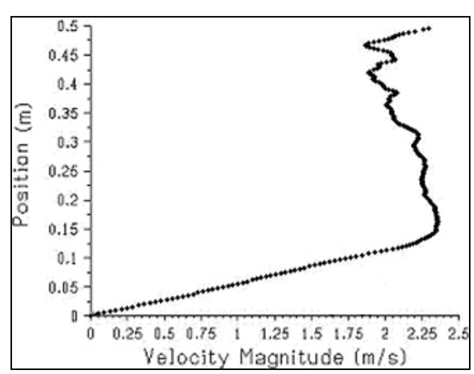


Fig 11: Air velocity in the bed section with three screens of 40%, 60% and 60% open area

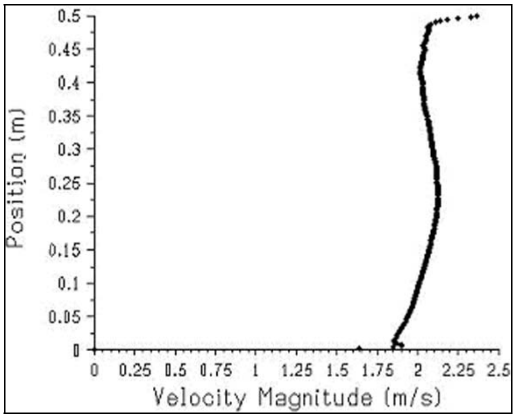


Fig 12: Air velocity in the bed section with three screens of 50%, 50% and 40% open area

## 4. LEAK TESTING

Two sets of leak tests, one for the nozzle support plate, and another for the entire test chamber, have been performed to check the test bed for any possible leaks (Figures 13 and 14). For measuring leaks in nozzle plate, an axial fan of 7600 $m^3$/h and 280 Pa gauge pressure has been installed at the entrance of the test bed. When all the nozzle openings were blocked, no pressure difference was observed. To measure the leak in the entire test bed, outlet of the test chamber and openings of all nozzles, except one of the 4 cm diameter nozzles, were blocked. The measured flow rate through the nozzle was 14.5 $m^3$/h, when the static pressure before the nozzle was 280 Pa.

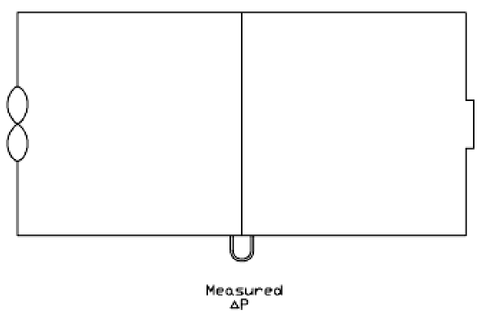


Fig 13: Nozzle wall leak test

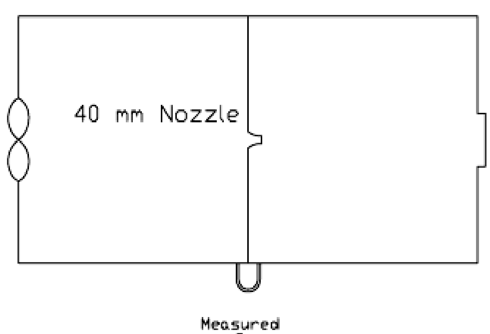


Fig 14: Chamber leak Test

## 5. CONCLUSIONS

A bed for testing fans of up to 7600 $m^3$/hr capacity has been designed and constructed. The leak tests and air velocity distribution measurements across the bed show acceptable results. The test bed uses suitable measurement instruments to achieve high measurement accuracy. An auxiliary fan is used, which is equipped with a frequency control to increase the applicability of the test bed for all measurement ranges. The results of CFD analysis show that application of the three screens of 50%, 50%, 40% open area, and consideration of a distance of 16 cm between the screens, results in the optimum air flow distribution across the test bed.

## 6. REFERENCES


1. Li, J. and Heber, A. J., 1992, "Optimizing Performance of Variable Speed Fans", Transactions of the ASAE 35(5).
2. Ford, S. E., T. L. Funk, G. L. Riskowski and A. M. Zhivov, 1998, "Evaluation of Variable Frequency Drives for Agricultural Ventilation Fan Speed Control", ASAE Paper No. 984041.
3. Pedersen, S. and J. S. Storm, 1992, "Testing of Complete Ventilation Units", ASAE Paper No. 924506.
4. Ford, S. E., L. L. Christianson, A. J. Muehling and G. L. Riskowski, 1991, Agricultural Ventilation Fans, Performance and Efficiencies, Urbana, III, Univ. of Illinois, Department of Agricultural Eng.
5. Ford, S. E., Y. Zhang, L. L. Christianson, and T. L. Funk, 2003, "Agricultural Ventilation Fans, Performance and Efficiencies", Department of Agricultural Engineering, publication #UILU-ENG 2003-7001, Urbana, III., Univ. of Illinois.
6. Guul-Simonsen, F. and P. Madsen, 2000, "Laboratory Measurements of Noise from Livestock Ventilation Units", Applied Engineering in Agriculture, 16(1).
7. "Laboratory methods of testing fans for aerodynamic performance rating", 1999, ANSI/AMCA210-99/ANSI/ASHRAE 51-1999.
8. ASHRAE Handbook, 2005, *Fundamentals*, Atlanta, Ga.: American Society of Heating, Refrigeration and Conditioning Engineers, Inc.