

# A mobile test rig for determining the air leakage characteristics of farm buildings

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Massé, D.I., Munroe, J.A. and Jackson, H.A. 1994. A mobile test rig for determining the air leakage characteristics of farm buildings. *Can. Agric. Eng.* 36:185-188. A mobile test rig to determine the air leakage characteristics of farm buildings was developed, constructed, and tested. This rig consisted of a trailer mounted 1.2 m diameter vane axial fan with a rated capacity of 14 m<sup>3</sup>/s at a static pressure of 60 Pa and an adjustable duct-to-building adapter. Air flow was measured using 20 Pitot tubes located in the duct. Initial tests on two dairy barns indicated air leakage rates in the order of 5 and 11 air changes per hour at a pressure differential across the building envelopes of 20 Pa.

Un appareil mobile pour évaluer l'étanchéité des bâtiments agricoles d'élevage a été élaboré, construit et testé. Cet appareil comprend une remorque sur laquelle est montée un ventilateur hélicoïdale à vitesse variable, ainsi qu'un conduit d'air avec un adaptateur ajustable pour relier le ventilateur au bâtiment. Le ventilateur a un débit de 14 m<sup>3</sup>/s à une pression statique de 60 Pa. Le débit d'air est mesuré avec l'aide de 20 tubes de Pitot localisés à l'intérieur du conduit d'air. Des tests préliminaires sur deux étables laitières ont indiqué des infiltrations d'air équivalentes à 5 et 11 changements d'air par heure lorsque la pression statique à travers l'enveloppe du bâtiment était de 20 Pa.

## INTRODUCTION

Air infiltration through the building envelope of farm structures can induce poor temperature control within the building and hinder development of good airflow patterns and air mixing. As well, such infiltration can result in unwanted and uncontrolled drafts that can affect animal comfort, health, and performance. Excessive air infiltration can greatly interfere with the original design purpose of the ventilation system including planned air inlets. This note describes a mobile fan test rig that was developed to allow on site determination of the air leakage characteristics of farm building envelopes and the effect of different construction practices on air leakage. The fan pressurization method can also be used in conjunction with smoke tests, thermographic surveys, or acoustic tests to identify the air leakage paths across the farm building envelope. The contribution of a specific air path to the overall air leakage rate can also be determined using the fan pressurization method if the particular air path can be sealed.

## BACKGROUND

The steady state pressurization test has been widely used to measure air leakage characteristics of commercial buildings

and residential housing. Shaw and Tamura (1980), Kronvall (1978), Hunt (1978) and several others have made use of this method. Typically, a fan is used to develop a pressure difference between the interior and exterior of the building. The air flow rate through the fan at different pressure differences is then measured to determine the air leakage characteristic of the building envelope. This type of test rig will not determine the actual air infiltration rate of a building since wind pressures have an influence and are generally not uniform around the building, but it will give a good estimation. It is thus very useful in assessing the construction quality and performance of the building envelope. It can also be used to compare the relative air tightness of buildings having different shapes or built according to different construction practices.

## MATERIAL AND METHODS

### Description of apparatus

Schematic drawings of the test rig are shown in Figs. 1 and 2. Figure 3 shows the test rig installed at a farm building for an air leakage test. This mobile rig, required for large buildings, was somewhat similar to that developed for small buildings by other researchers (Orr and Figley 1980). The fan selected for the depressurization of the building was a vane axial fan manufactured by CML Northern Blower, Winnipeg, MB. The fan had a diameter of 1.2 m and a rated capacity of 14 m<sup>3</sup>/s at a static pressure of 60 Pa. The fan was driven by a 13.4 kW Kohler gasoline engine. Fan speed varied according to engine speed and could therefore be adjusted to obtain different air flow rates.

### Ducting from fan to building

The ducting consisted of three sections, each with a diameter and length of 1200 mm, plus a duct-to-building adaptor. Each section had flanges at both ends to allow joining together and had a mass of about 60 kg. These sections were attached to the axial fan housing with foam rubber gasket material used between the flanges to obtain an air tight seal. The duct section nearest the building contained a honeycomb air flow straightener. The duct-to-building adaptor was a transition element ending in a rectangular frame which was aligned with and sealed against a doorway of the building to be tested. This frame could be adjusted to accommodate different door sizes.

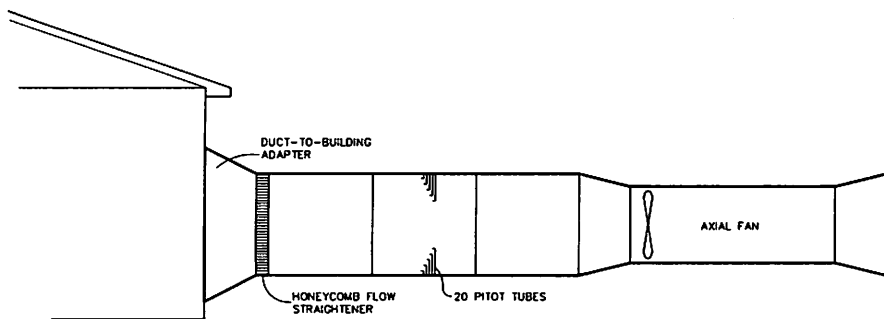


Fig. 1. Schematic of the test rig.

**Air flow measurement**

The fan pressurization technique induces a pressure difference across the building envelope. The resulting air flow through the envelope is then estimated by a power law equation:

$$Q = a (\Delta p)^b \tag{1}$$

where:

- $Q$  = flow rate through the envelope ( $m^3/s$ ),
- $\Delta p$  = pressure difference (Pa),
- $a$  = leakage coefficient, and
- $b$  = flow exponent.

Due to the size of the fan and duct, the Pitot tube method was considered the best method to determine air flow in the duct. This permits using a shorter duct which is a benefit when transporting and setting up on site. Velocity in the duct was measured using four Pitot tubes in each of five concentric rings of equal area (ASHRAE 1985) for a total of 20 Pitot tubes. The average velocity pressure of the Pitot tubes in each ring was converted to velocity using a Shortridge Instruments, Air Data Multimeter ADM-870 (Scottsdale, AZ). This instrument measures the velocity with an accuracy of  $\pm 3\%$ . Air flow was then determined by multiplying the area of each ring by the average velocity within the ring.

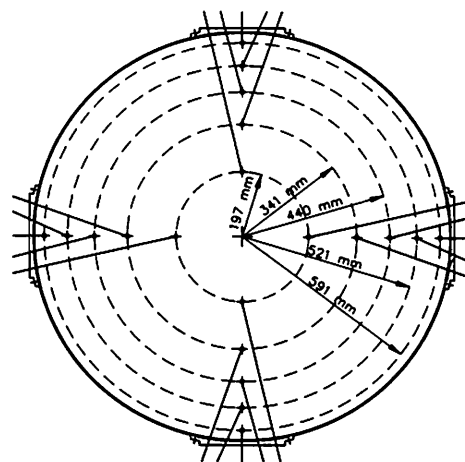
Because of the limited speed range of the gasoline engine, three different restriction panels were fabricated for insertion in the duct. For a given fan speed, a restriction panel permitted smaller air flows through the building envelope which is typical of tighter buildings. Through trial and error, a suitable panel was chosen to obtain a range of pressure differentials across the building envelope between approximately 10 and 100 Pa.

For a given barn test, the air flow versus the pressure difference across the building envelope was plotted on log-log paper along with the regression of the log of air flow versus the log of pressure difference. A typical plot of test data for two barns is shown in Fig. 4. Barn A was 12.2 x 36.6 m, 14-year old steel frame dairy barn with cathedral ceiling while Barn B was a 17 x 49 m wood stud frame dairy barn with flat ceiling. Although generally accepted to be well built, significant air leakage is apparent. Further study with this test rig would allow establishing what are the primary

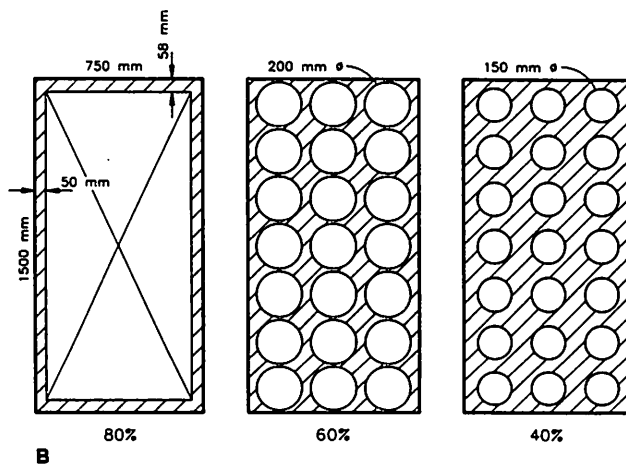
factors that contribute to and affect this air leakage and how they differ for each building. Initially several tests were run at the same pressure difference; however, due to the excellent repeatability of results achieved, the average of two runs was thereafter considered adequate. This only applied during periods of very low wind. As a result, all tests reported were only carried out during calm or very low wind speed conditions.

The standard practice for small buildings is to express air leakage in terms of air changes per hour at 50 Pa pressure difference. For large buildings air leakage is expressed in terms of litres per second per square meter of building surface area at a pressure difference of 75 Pa. Another parameter that is useful when considering farm buildings is leakage measured as air changes per hour at a pressure difference of 15 Pa. This pressure difference, or greater, across the building envelope

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A



B

Fig. 2. a) Location of Pitot tubes. b) Restriction panels to accommodate smaller air flows of tighter buildings.

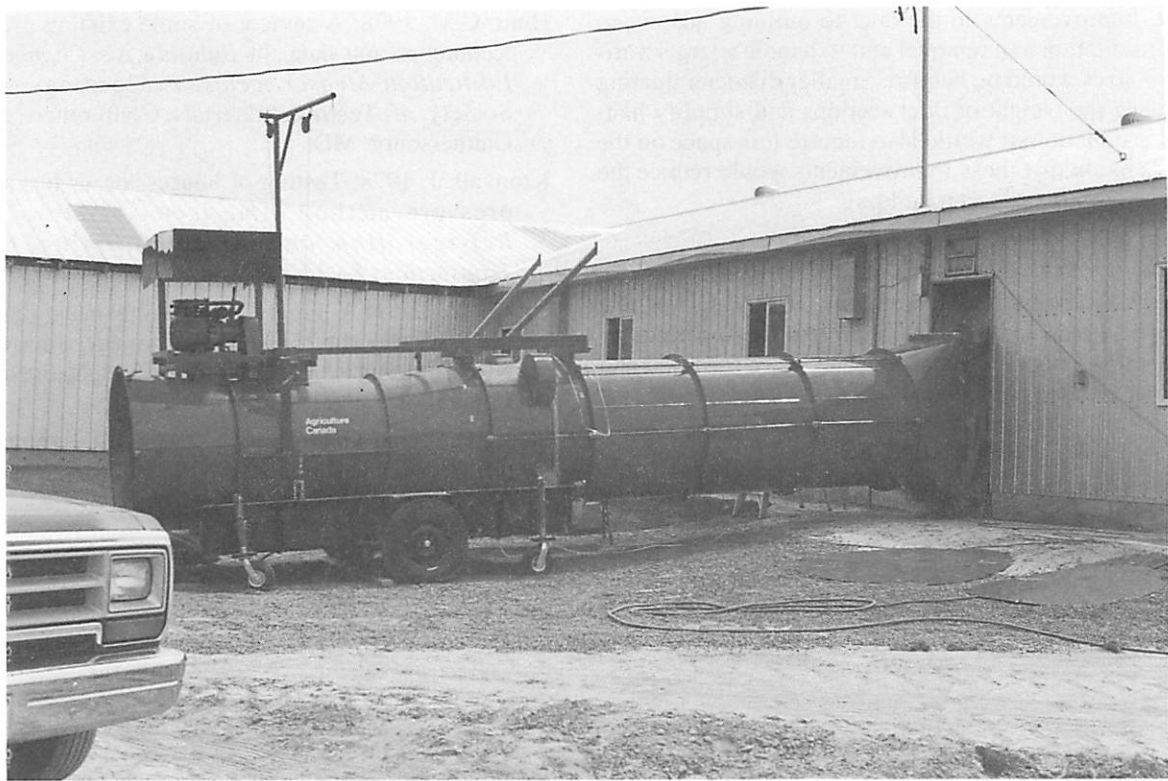


Fig. 3. Photograph of the air leakage test rig installed for an air leakage test on a farm building.

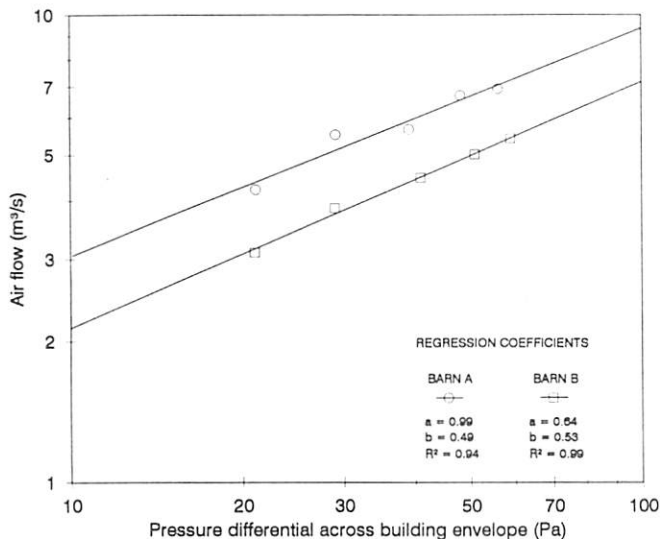


Fig. 4. Air leakage characteristics for two barns.  
One air change per hour is equivalent to 0.35 and 0.64 m<sup>3</sup>/s for barns A and B, respectively.

of a farm building is desirable for winter ventilation in order to get high enough velocities at air inlets to promote good air mixing. The air leakage rate at this pressure difference indicates the portion of the ventilation air that will enter the room due to leakage as opposed to through the air inlet. It is important to confirm which units are being used when comparing results of various research studies.

#### EXPERIENCE WITH THE MOBILE TEST RIG

The equipment described in this technical note was successfully used to determine the air leakage rate of large farm buildings in the eastern Ontario region. The internal volume of the buildings tested ranged from 916 to 2300 m<sup>3</sup>. The fan had enough capacity to induce pressure differences of 10 to 60 Pa across the building envelopes. The fan flow rates required during these tests to reach a pressure difference of 60 Pa across the building envelope were in the range of 30 - 60% of the rated capacity of the fan. On this basis, the mobile test rig should be able to evaluate farm buildings with volumes up to about 4000 m<sup>3</sup>; however, this is quite dependent on the air tightness of the building envelope.

#### Testing apparatus performance

Two people were required to operate the test rig. A complete test could be carried out in less than five hours. The installation of the duct-to-building adaptor required about one hour, while it required another hour to fit the rest of the apparatus. A test run (approximately 30 min) consisted of measuring the air flow rate at pressure drops of 10, 20, 30, 40, 50, and 60 Pa across the building envelope. A minimum of two test runs should be carried out. The dismantling of equipment took one to one and one half hours. The test rig was noisy and created drafts within the building which might be a concern for some species due to stress, if tests occurred when the building was occupied.

#### Improvements recommended

An electric motor could replace the gas engine to drive the fan. This would provide a wider range of fan speed and possibly eliminate the need for using a restriction panel dur-

ing a test. Improvements to the duct-to-building adaptor to simplify installation and removal and to handle a larger variety of door sizes would be helpful. Smaller diameter ducting would reduce the weight of duct sections and simplify handling and installation; it would also require less space on the trailer. It is likely that these improvements would reduce the overall time required to test a building.

#### ACKNOWLEDGEMENTS

The technical support by M. Lemieux and A. Olson, the artwork by R. Pella, and the construction of the apparatus by the Engineering Laboratory staff of the Centre for Food and Animal Research are appreciated.

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