Design and Development of Natural Ventilation Products and Associated Improvement of Indoor Environment Quality.

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Summary

The Australian / New Zealand Standard, 4740 (2000) *Natural Ventilators- Classification and Performance,* is discussed in this paper. It has provided an ideal platform to standardise and make accurate comparative analysis of natural ventilators exhaust flow rates.

Experiments with various manufacturers' ventilators were undertaken, comparing them to, the relative performance of an unimpeded 300mm diameter opening; the methodology employed and the results of this testing are disclosed in this paper.

New advanced ventilation designs and test procedures are also described in this paper, such as the long volume turbines and improved wind directional vanes, with increased exhaust flow rates.

Product innovation and improved performance and test results utilising the test facility developed for the Australian / NZ ventilation standard has led to the commercialisation of new products such as the Wind Directional Skylight Ventilator and the roof siphon that utilises the hot air in the roof space to further drive the natural ventilation process.

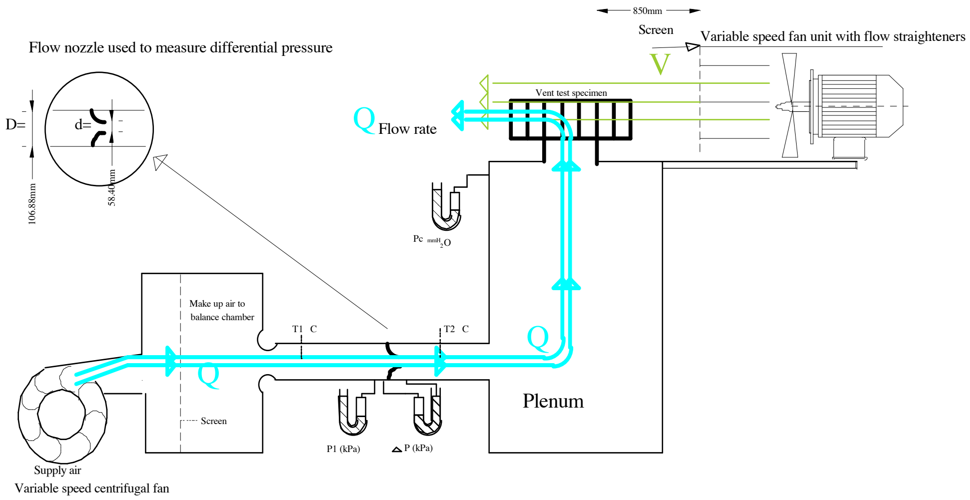
The paper concludes with discussion on the detailed product design of the unique Wind Directional Skylight Ventilator, its measured exhaust flow rates, ability to reduce condensation and improve indoor environmental air quality via natural ventilation and daylight.

1. Introduction

An initial approach by the Australian Consumers' Association (CHOICE) and a leading ventilator manufacturing company to see if low wind speed testing was achievable at the University of Technology, Sydney aerodynamics laboratory, developed into a very successful industry and cross Faculty collaboration. The research outcomes have significantly advanced the understanding of wind driven turbine ventilators and natural ventilation in general.

Following exhaustive trials, a suitable test rig was developed, (please refer to figure No.1.) and a comparative analysis undertaken of most of the ventilators on the Australian market supported by the Australian Consumers' Association.

Following the results of the testing and comments submitted to Standards Australia/New Zealand regarding a draft Standard on Natural Ventilators, the author was invited to join the Standards Committee on Natural Ventilators
This work has resulted in the Australian/New Zealand Standard AS/NZ 4740 2000 Natural ventilators- Classification and performance.



UTS pressure differential ventilation test rig

Figure No.1. The UTS pressure differential ventilation test rig later adopted as the test method for Australian / New Zealand Standard AS 4740.

Several wind siphonage test configurations were evaluated at the UTS aerodynamics laboratory, with reference to results achieved by other testing facilities and to manufacturers published performance. From these attempts at finding the best test methodology to employ, an appropriate testing standard was sought.

No official standard was available so, guidelines were established following trials including variables such as:

Air flow to be measured using a flow metering device as described in AS 2360.1.1 1993 *Measurement of fluid flow in closed conduits.*

A controlled airconditioned environment was considered essential to allow for consistent result which would have otherwise been affected by pressure and temperature differentials, as each ventilator would be required to be mounted on a stack and the pressure and temperature needed to be controlled within the stack, to allow for consistent results, as a decrease or increase in temperature will affect density and subsequent flow rate measurements.

It was assessed that a variable wind speed would be required to be applied as Free Field (unbounded fluid flow field) instead of a closed test station such as a wind tunnel, which would lead to blockage effects. And subsequently each ventilator should be mounted on a stack / plenum chamber and the pressure and temperature controlled within the plenum chamber

It was a requirement to make the testing procedure as realistic as possible to field applications so the results obtained from these tests would establish the relative performance of several ventilators measured to the control- (300mm diameter open pipe 200mm high) as depicted in Figure No.1.

2. Methodology

To test ventilators performance a comparative analysis was undertaken, utilising the developed pressure differential facility. A suitable fan produced the required wind velocity over the ventilator, opening or wind directional vane, giving rise to suction, drafting air out of the plenum chamber. Air pressure is balanced by an input supply fan to achieve ambient air pressure and this in turn is measured applying Bernoulli's principle across a flow metering nozzle as shown in Figure.1 and mathematically expressed, to derive the appropriate flow rate formula:

3. Results

3.1 Comparative analysis of ventilators performance

Ventilators tested were those that are sold commonly in the Sydney market and experimental designs aimed at increasing performance. A fair analysis was sought to compare the ventilators performance at Sydney's average wind speed of 12km/hr.

Ventilators on the market had a range of manufacturers performance and options such as fans (refer to figure No 2.) stated as improving exhaust performance. In fact throat restrictions in the case of some fans actually impeded performance.

Figure No 2. 380mmm throat vent with fan blade fitted.

A significant result of the comparative performance was the effect that throat area had on the flow rate. Comparing a 250mm throat diameter to a 300mm throat diameter,(0.049m^2 and 0.071m^2 respectively) showed a 30% increase in throat area but there is not a proportional association i.e. as the throat increases in diameter the flow rate does not increase proportionally, but increases by an extra15% over the 30% throat increase giving a 45%

increase in flow rate. In experimental designs the limitation of throat diameter was recognised and the ability to increase the blade height was also assessed as being a possible variable affecting exhaust flow. In other words the throat area remains constant but the vent lengthens in blade height to increase its volume, hence the term, long volume turbines (refer to figure No.3).

Figure No. 3. Variable blade height / Long Volume Turbines (LVT's)

In this experiment, keeping the uniform 300mm throat and allowing only the blade height as a variable showed the poor performance of the 170mm blade height model, which only had half the exhaust performance of the 340mm blade height model, which also corresponded to a 25% increase in the blade height over the normal 250mm model and correspondingly increased the exhaust flow by 15%.

The 50% blade height was not manufactured correctly and a 50% increase on the standard 250 should have been 375mm not 340mm, however the hypothesis was proven correct and results were scientifically unique. Blade separation, shape and reduced bearing drag were other factors that were shown to contribute to exhaust efficiencies.

4. New Product development-Wind Directional Skylight Vent

With the on going energy reduction / greenhouse emission campaigns and in line with ESD principles the relevance of stack effect and wind siphonage to provide energy neutral effective ventilation is now gaining the attention of building designers around the world.

Experimentation and extensive CFD analysis with new designs resulted in a unique omni directional aerodynamic foil that ventilates by rotating into the wind and generating negative pressure to extract efficiently and at the same time provides daylight as a vertical light pipe. The Wind Directional Skylight Vent (WDSV) was a product designed to incorporate cost efficient componentry and was laboratory tested to the Australian/New Zealand Standard AS/NZ 4740 2000 requirements. The product is a clear aerofoil skylight that ventilates by turning as an omni directional vane into the wind, giving rise to increased air extraction flow rates, (as seen in Figure No 4 below)

Figure No 4. 300mmm throat Wind Directional Skylight Vent.

The WDSV product will be particularly useful in New Zealand, which has condensation problems. The WDSV has been demonstrated to ventilate at twice the air changes per hour (ACH) compared to the 250mm rotary vent. Another useful feature for local conditions is the purported benefits of daylight into attic spaces discouraging possums and vermin that being nocturnal like to sleep during the day, in the darkened roof space.

Another major benefit of the vent is the ability to locate it over sources of moisture to remove hot and moist air at ceiling height via a tube to the outside (please refer to Figure No.7). As inside temperatures rise, the ability for air to hold moisture rises, which is usually exasperated by warm humid sources such as showers, kitchen sink, clothes dryers etc.

Above the point of the moisture source is an ideal location to have a ceiling vent that will via light tube and WDSV, extract the humid air to the outside environment saving potential dew / condensation forming inside the house as would be the case if warm humid air touches cool windows or walls and results in mould issues leading to asthma and material decay.

The results shown in figure No 5 were all tested at the UTS aerodynamics laboratory, under AS/NZ 4740 requirements, those in yellow by the author on the 20.7.05 and those in red by (Low 2006).

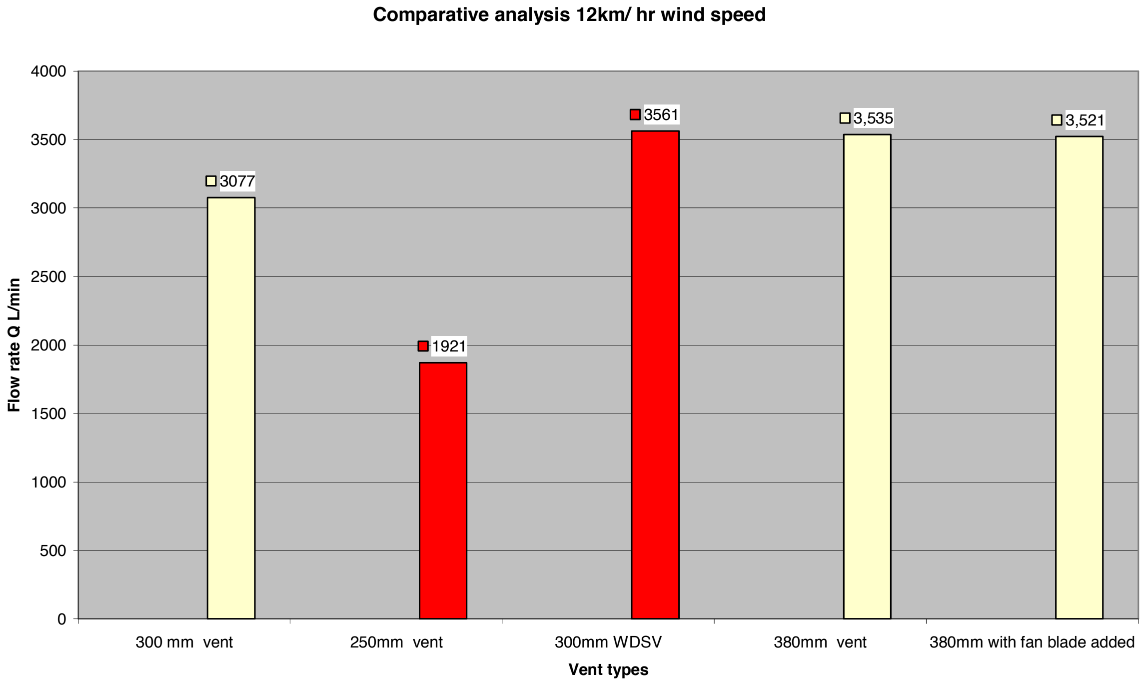


Figure No. 5 Vents tested, 300 mm throat, 250mm throat, WDSV 300mm throat, 380mm throat with and without fan.

The efficiency of the WDSV having a smaller throat size than the 380 mm throat vent but better performance is a notable experimental result as is the slight reduction in flow rate caused by blockage to the throat of the 380mmm throat fitted with a fan blade compared to the relative performance of the same vent with the fan removed.

5. Condensation- IAQ Health Issues

Indoor Air Quality is well known and growing concern and reports have consistently shown that indoor air pollution may be twice or up to five times worse than outside air (Hess-Kosa, 2002). Breathing trapped polluted air, is one definition that could be used to describe the indoor air quality that occupants may be subjected to in some buildings. Even in airconditioned buildings, contrary to the name "conditioned", implying improved air quality; the internal air may have poor filtration and have less than 15% fresh air intake, (Australian Standard 1668 Pt 2 1991, recommends offices to have a ventilation rate of 10 litres per second per person.) leaving the internal air space full of contaminants.

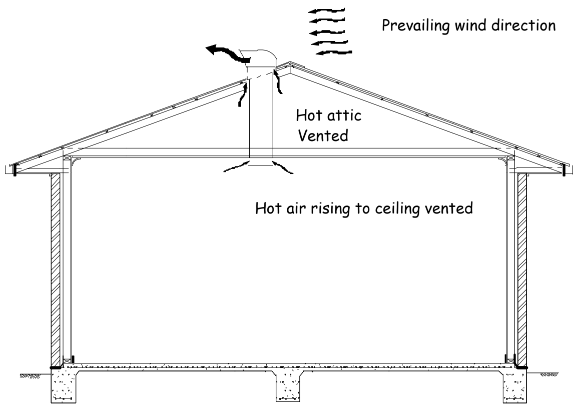
The value of increased ventilation and desired removal at ceiling levels above sources has been identified in several studies such as (Li & Delsante 1997) where range hoods and direct bathroom exhaust ceiling extractor efficiencies were measured. This study showed the efficiency and ability to reduce the spread of moisture and contaminants were best achieved at source before dispersal throughout the building.

The need to further increase and induce air movement in bathrooms and kitchens of Malaysian houses was expressed by (Zain –Ahmed Et al 2005).

Many mould issues associated with bathrooms and carpets having high moisture content have also been shown to have higher dust mite concentrations. In New Zealand studies have suggested that higher ventilation rates are required to overcome the situation of tighter houses requiring greater drying ventilation to reduce moisture content. (Cunningham et al 2001) suggested the need to alter bio climatic conditions and reduce humidity levels to reduce mould growth and associated micro organism proliferation.

The WDSV's ability of reducing moisture laden air at its source over shower recesses is combined with an energy free operation that allows for ventilation to continue unabated and provide a suitable outlet that is required for tight buildings that operate with roof ventilation supply systems that push drier air from the roof attic space or outside into the house, relying on the moist inside air finding seepage out of the building via ill fitting doors etc..

The effectiveness of reducing the moisture at the source, providing daylight to further reduce mould growth and the ability to ventilate at ceiling level are the features incorporated with the WDSV operation that enhances the anti condensation pressure systems by providing a flow path of air to the outside that is capable of greater exhaust than a rotating cowl by also utilising attic pressure, better wind siphonage, and internal stack pressures as shown in figure No 6.



This system has three way extraction: Stack effect, wind assisted, attic siphonage

This arrangement ventilates the room space and the attic space, whilst providing daylight to both the room and attic space.

Roof Siphon

Figure No 6. The Wind Directional Skylight Vent operating as a ceiling daylight and vent combination.

6. Conclusion

The testing procedure developed at UTS and incorporated into the Australian / New Zealand Standard 4740 has provided an ideal platform to standardise and make accurate comparative analysis of natural ventilators exhaust flow rates.

The need to provide ventilation, reduce or dissipate heat and moisture levels inside buildings to improve health and comfort conditions and hence productivity is desirable. However, the costs associated with redesigning, air conditioning and insulation may be prohibitive and simple cost effective natural ventilation methods are now being considered as more sustainable options.

In the experiments conducted, advanced aerodynamic designs have been shown to have increased exhaust flow rates and improved ventilation rates for stack flow and wind siphonage. The increased flow rate will in turn provide reduce heat load and moisture by increasing the air exchange rate. The WDSV's application into ceiling fixtures in conjunction with attic exhaust will assist in reducing mould growth conditions associated with bathrooms and laundries, by exhausting warm moisture laden air to the outside of the building envelope, helping in turn to improve IAQ.

Further to these advances, the development of WDSV technology described in this paper will make another contribution to improving energy efficient building operations, cleaner / healthier internal environments by providing a cost efficiency saving in the product design. Cost efficiency (economic sustainability) needs to be considered in sustainably designed products, in the case of the WDSV by simplifying and reducing the need for expensive mechanical ventilation, and reducing artificial lighting it is a straight forward design that does the role currently of two or three products associated with higher energy demand.

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