

Air Filtration in Swine Buildings



Introduction

This fact sheet presents a summary of certain potentially interesting key information on air filtration in swine buildings. For more information on the various topics dealt with in this document, please refer to these:

- Canadian Swine Buildings and Inlet Air Filtration Systems-Technical Guide, available at <http://www.swinehealth.ca>
- Economics Fact Sheet: Case Study
- Minimum Standards for Swine Buildings with Air Filtration System-Engineering and Biosecurity
- Analysis of Findings and Recommendations to Minimize Risks of Contamination in Canadian Buildings with Air Filtration Systems
- Air Filtration in Swine Barns: Overview of the current situation-Literature review

Pathogens can be Airborne

Many bacteria and viruses can be spread by aerosol transmission from one site to another. PRRS virus (PRRSV) and *Mycoplasma hyopneumoniae* (*M. hyo*) can be spread through airborne transmission over a distance of up to 9.2 km^{1,2}. Little information is available on the airborne transmission of swine influenza in pigs³. Even though data on this virus is rare, the airborne transmission of swine influenza in pigs is considered important⁴. A field study showed that populations of pigs acutely infected with influenza A generate viable particles that can be spread through the air outside the building⁵. One phase of this study (currently underway, but with results unavailable at the time of writing) is specifically concerned with the detection of the virus at specific distances from the building.

Regarding survival of the pathogens; *M. hyo* can remain viable for four to eight days in dry air at room temperature⁶, while the swine influenza virus survives up to 15 hours at 15% relative humidity and a temperature of 21°C³.

Several Routes of Infection: the Importance of Biosecurity and Air Filtration

Airborne transmission (aerosols) is not the only mode of transmission of the PRRSV (Figure 1). Several transmission routes feature in the list, of which among others⁷:

- Inanimate objects (boots, clothing, supplies and equipment)
- Human beings
- Transport vehicles
- Semen
- Manure
- Water
- Insects

Maintaining a biosecurity program is essential to effectively protect the operation by preventing the introduction of PRRSV. While not eliminating the risk completely, a good program can greatly slow the downward spiral of a herd's health.

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In the building with no biosecurity protocol, animals were infected from different sources (14 times out of 21) while in the building with medium biosecurity, aerosol transmission was identified as the source of animal infection (eight times out of 26)⁹. In 26 repetitions, no infection was observed in the building with high level biosecurity⁹. Implementation of a biosecurity protocol significantly reduced the risk of introduction of PRRSV in the herd and the air filtration system provided crucial extra protection.

The capacity of commercial air filters to protect herds against airborne transmission of PRRSV and *Mycoplasma hyopneumoniae* (*M. hyo.*) was evaluated over a four-year period, also from the University of Minnesota's experimental farm, representing a model of regional production¹⁰. Contamination of naive farms (PRRSV) was able to be simulated, involving four buildings: Building 1 was the source of bioaerosols (pigs contaminated with PRRSV and *M. hyo*) and was located 120 m from other buildings (Figure 2). All the other buildings contained naive pigs also with PRRSV. Building 2, serving as a control, was not filtered but had a Danish entry, while Buildings 3 and 4 were filtered using different types of filters (mechanical and antimicrobial) and also equipped with a Danish entry. Airborne transmission of PRRSV and *M. hyo.* was found in respectively 43% and 34% of the repetitions performed in Building 2 (unfiltered). However, no infection was found in Buildings 3 and 4, irrespective of the type of filter used (Table 2). All the filter types tested reduced the risk of airborne transmission of these pathogens in equal measure.

Table 2 Summary of events according to pathogen and type of filter used over the four-year study

| Pathogen | No filtration | Filter Type | | | | |
|---------------|---------------|-------------|---------|---------------|---------------------|---------------|
| | | MERV 16 | MERV 14 | Antimicrobial | Used Antimicrobial* | Electrostatic |
| PRRSV | 28/65 | 0/39 | 0/13 | 0/13 | 0/13 | 0/13 |
| <i>M. hyo</i> | 17/39 | 0/13 | 0/13 | 0/13 | 0/13 | 0/13 |

* Used for two years on commercial pig farm

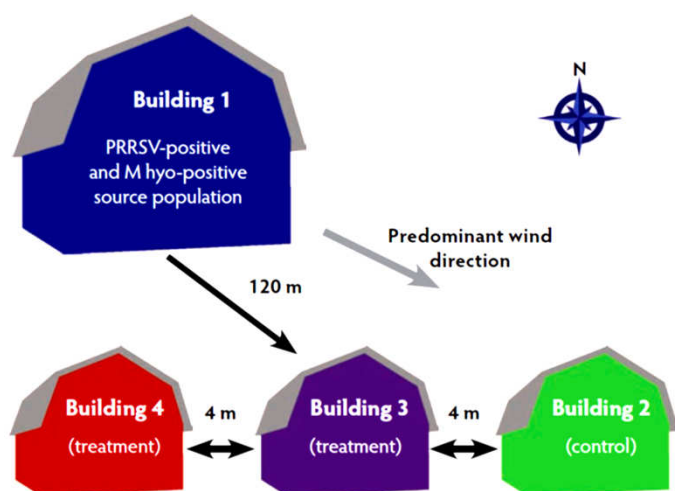


Figure 2 Layout of buildings on the University of Minnesota's experimental farm, representing a regional production model
Source : Dee et al., 2011

And so, the results of these two research projects clearly demonstrate the effectiveness of combining a biosecurity protocol with air filtration. It should be noted that these projects were carried out in a controlled research environment and on a small scale. The following sections feature information on commercial production settings.

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Number of Commercial Swine Buildings with Filtered Air in North America

Currently (2013) there are around 30 barns in Canada equipped with air filtration systems and in the United States in 2012, the number was approx. 98 (Table 3). The first commercial sites to be equipped with filters in North America, were in Quebec in 2003.

Table 3 Number of farms equipped with air filtration systems in Canada and the United States

| | Number of farms (estimations) | |
|-----------------|-------------------------------|--|
| Canada | 30* | 13 board studs 3 farrow-to-finish sites 9 farrowing facilities 3 gilt development units 2 quarantine units |
| United States** | 98 | 62 farrowing facilities 26 boar studs 10 others (quarantine units, gilt development units, etc.) |

* The majority of farms are found in Quebec province

** Reicks, 2012, personal communication

Types of Filters Available and Tested for the Swine Sector

Mechanical Filters

Mechanical filters capture airborne particles when they come into contact with the filter media and adhere to its fibres. There are currently two manufacturers of mechanical filters for swine barn installations: Camfil Farr and AirGuard® who developed V-box pleated filters (Figure 3). Different levels of filtration efficiency from MERV 14 to MERV 16 were tested and found effective enough for use in swine applications. Since these mechanical filters are not washable and represent a significant portion of the investment outlay, an efficient upstream prefilter (minimum MERV 8) should be used to block the larger particles and increase filter lifespan.



Figure 3 V-Box pleated filter

Antimicrobial Filters

Noveko's antimicrobial filter (Figure 4) is composed of polypropylene fibers with embedded antimicrobial agents that are designed to render viruses inactive upon contact. Different levels of filtration efficiency, from 10 to 20 layers of antimicrobial membranes, were tested and found effective enough for use in swine applications. Installation of filters with at least 15-layers is recommended based on laboratory tests by Dr. Scott Dee from the University of Minnesota. Although this filter is washable, installation of a prefilter is recommended to reduce filter clogging and to facilitate the effectiveness of the antimicrobial agents.



Figure 4 Dome-type antimicrobial filter

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Filter Lifespan

The lifespan of a filter depends on the progression of its clogging and its resistance to air flow. Filter lifespan can vary from three to five years. Prefilters are usually cleaned or replaced every six or twelve months. That is why installation of pressure gauges to measure the static pressure is recommended, it being a good indicator of the level of clogging of the air filtration system so as to determine when it is necessary to replace the prefilters and/or filters and so enable control of the pressure drop that they cause¹¹. To optimize the overall cost of the lifespan of a mechanical filter, it should not exceed the moment at which it reached twice its initial pressure drop or three quarters of the distance between the initial pressure drop and final pressure drop indicated for replacement¹¹. Even so, to minimize unfiltered air infiltration, it is recommended the system not exceed a static pressure in the building of 0.2 inches of water.

Impact of an air Filtration System on the Ventilation System and Air Quality Inside the Building

When well designed, with sufficient filter surface based on a given airflow, to meet the generally accepted standards, the addition of an air filtration system does not require the addition of extra fans, and air quality and the inside atmosphere is not compromised in both summer and winter (it is advisable to work with an engineer specialised in this field).

Filter Installation Methods According to Air Inlet Type

The installation method for the air filtration system will be geared to the type of air inlet. In Canada, there are different types of buildings and ventilation systems, and so there will be different ways to install filtration systems. In general, building retrofits and installation of filters can be done without too many complications. The level of complexity depends on the type of air inlet already in place and the building's initial tightness. What follows is a summary of the installation methods according to the air inlet types most frequently encountered. These methods are for information purposes only and are by no means exhaustive.

Lateral Air Inlet (continuous wall or ceiling opening)

Air intake is through a continuous linear sidewall or ceiling opening in the building and subsequently into the room. Stale air is expelled by exhaust fans located on the opposite wall.

To install V-box pleated filters on this type of air inlet, the recommended method is to build an annex onto the existing building to house the filters and prefilters (Figure 5). The air first enters this annex through the wall, where the opening is managed by a curtain and an actuator according to the airflow, and then passes through the prefilters and filters layers. The filtered air then flows toward the opening in the room wall before being expelled by the exhaust fans on the other side of the building. When the air inlet opening is located in the ceiling, it is preferable to seal it off and create an opening in the wall so as to reduce the risk of potentially contaminated air entry from the attic (construction of an airtight duct between the roof trusses is complicated).

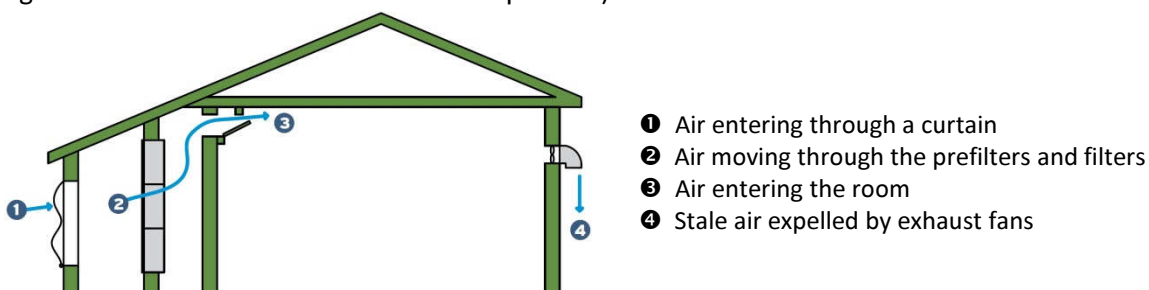
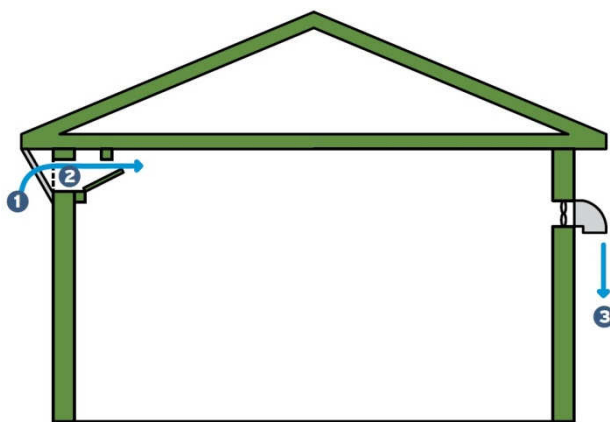


Figure 5 Installation of V-box pleated filters for continuous lateral air inlet

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The curtain-type antimicrobial filter can be installed according to manufacturer recommendations under the eaves outside the building (Figure 6 and Figure 7). The size of the eaves must be large enough to accommodate the height of the filter. If a duct is serving as a plenum, it must be removed so as to install the filters as close as possible to the air intake to reduce the risk of contaminated air entry and allow increased clearance between the filters and the ground to prevent them from being blocked by snow build-up. When the filters are installed under the eaves, the air passes through the prefilters and filters and flows towards the room wall opening and be expelled by the exhaust fans. For the same reasons when installing box filters on the lateral air inlets located in the ceiling, it is best to seal them off and create a wall opening.



- 1 Air moving through the prefilters and filters
- 2 Air entering the room
- 3 Stale air expelled by exhaust fans

Figure 6 Installation of antimicrobial curtain filters for continuous lateral air inlet



Figure 7 Buildings equipped with a curtain-type antimicrobial air filtration system

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Modular Ceiling Air Inlet (attic)

Air intake takes place through many separate attic openings along the ceiling. Air enters through the eaves on both sides of the building to move towards modular diffusers in the ceiling. The filters are mounted above the diffusers. Stale air is expelled by exhaust fans on both sides of the building (Figure 8).

The V-box pleated filters and prefilters are installed inside wooden, Coroplast or galvanized steel cases that are to be fixed over the modular air inlets (Figure 9) (all box joints must be sealed to prevent the infiltration of contaminated air).

As for the antimicrobial filter, on this type of air inlets, the cube-type filter (Figure 10) covered with a prefilter is the preferred choice. It is designed to be installed directly on the diffusers with a plastic casing to keep the filter in place and provide a seal between the filter and the diffuser (the casing joints must be sealed to prevent the infiltration of contaminated air). The dome-type antimicrobial filter can also be installed on this type of air inlet (Figure 11).

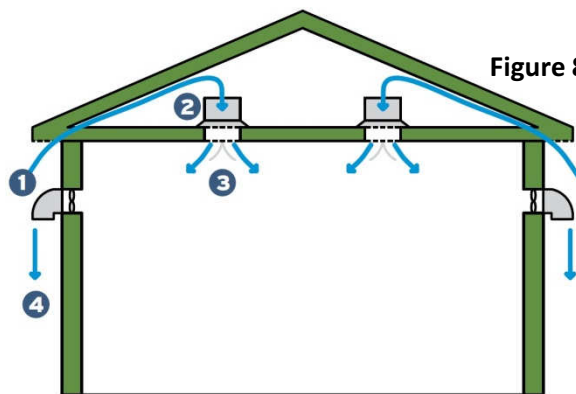


Figure 8 Installation of box and antimicrobial filters for modular air inlet

- 1 Air entering through the eaves
- 2 Air moving through the prefilters and filters
- 3 Air entering the room through the modular diffusers
- 4 Stale air expelled by the exhaust fans



Figure 9 Filter boxes of mechanical filters installed on modular air inlets



Figure 10
Cube-type antimicrobial filters installed on modular air inlets

Figure 11
Dome-type antimicrobial filters with prefilters installed on modular air inlets



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Continuous Linear Air Inlet (attic)

The air intake is through continuous linear openings in the attic. Air enters through the eaves on both sides of the building, moves towards the ceiling air inlet, above which are installed filters. Stale air is expelled by exhaust fans on both sides of the building (Figure 12).

The installation of the V-box pleated filters (Figure 13) depends on the presence or absence of obstacles, such as roof trusses, spanning the air inlet. In the event that no obstacle is encountered, the V-box filters are installed inside wooden, Coroplast or galvanized steel cases (all joints around the case must be sealed) to be set side by side on the air inlet. If the air intake is obstructed by trusses, the installation method is similar to that of the modular air inlets.

If no obstacle is encountered, the installation of a curtain-type antimicrobial filter is suggested, but a cube- or dome-type filter can also be installed (Figure 14). If the air intake is obstructed by trusses, the installation method is similar to that of modular air inlets with cube-type filters.

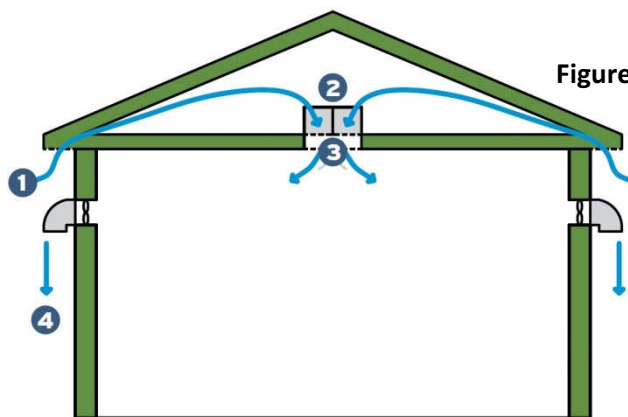


Figure 12 Installation of box and antimicrobial filter for a continuous linear air inlet

- 1 Air entering through the eaves
- 2 Air moving through the prefilters and filters
- 3 Air entering the room through ceiling air inlet
- 4 Stale air expelled by exhaust fans



Figure 13 Mechanical filters installed on a continuous linear air inlet

Photo: Dr Stephen Pohl



Figure 14 Dome-type antimicrobial filters installed on a continuous air inlet

Photo: Noveko

Air Filtration in Swine Buildings



Factors to Consider when Selecting a Filtration System

1. Filtration efficiency
2. Ease of installation of filter models on the air inlets
3. Air resistance of the filter, i.e. the pressure drop caused by the filter, because it has a direct influence on the efficiency of the fans and the number of filters required for a static pressure and a given flow of air
 - a. In the case of mechanical filters, at constant airflow, the resistance and filtration efficiency increase as the filter becomes clogged
 - b. To avoid creating too high a static pressure in the building for a given airflow, sufficient surface area of filters must be set up
4. Total cost overall of a filter's lifespan (including the initial investment for the purchase and installation as well as the amounts invested in energy, maintenance and disposal)

Efficiency of Commercial Farm Buildings with Filtered Air in North America

In the Midwest of the United States, it is reported that, when compared to farms equipped with an air filtration system, the probability of a new PRRSV outbreak occurring in an unfiltered farm located in a high pig density area, is about eight times higher¹².

At the end of 2011, some 16 American farms equipped with air filtration systems were infected within five to six weeks. Possible causes of infection were targeted: the long duration of filter lifespan, viral load, the construction of or finishing of buildings with inadequate airtightness, or backdrafting through the fans (Reicks, 2012, personal communication). So it is that infection of a herd lies not only with air filtration efficiency, but rather goes hand in hand with biosecurity measures and how the building has been finished. Therefore, special attention must also be paid to all the openings made in the building exterior (ceilings, walls and foundation) to check for the presence of contaminated air entry.

According to Dr. Darwin Reicks (2012, personal communication), in the United States, in September 2012, for all types of production, the infection rate for 98 American farms was 61% before implementation of air filtration and it dropped to 13% following the introduction of air filtration. Targeting only 62 farrowing facilities, the annual rate of infection dropped from 80% to 25% after the introduction of air filtration.

In February 2013, the annual contamination rate in Canada for 14 investigated farms with air filtration systems for the past 5 to 50 months was 37%.

- Excluding the contaminations from sources known to be other than aerosol, the rate decreases to 28%.
- Excluding the contaminations from sources known to be other than aerosol and avoidable cases of aerosol contamination, the rate decreases to 12%.

As can be seen, air filtration inside a building ventilated under negative pressure should be regarded as a risk management tool, one that, unfortunately, cannot guarantee protection against any eventual infection. However, given that there have been no documented cases of infection in farms filtered under positive pressure, and that it is now possible to reduce the cost of this type of installation, looking into this option is strongly recommended.

Listed below are the main findings for improvement that could be realised on most Canadian farms monitored in this project between 2012 and 2013:

1. Biosecurity protocols could be improved and more rigorously applied
2. Relatively major unfiltered air leakages observed around the building
3. Training for producers regarding the ventilation and air filtration was insufficient
4. No maintenance protocol for both the building and the air filtration system
5. Producers were not sufficiently aware of the importance of operating a building with filtered air with attention to detail and stringent discipline
6. No existing regular internal or external audit process

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Air Filtration Costs

The costs of implementing air filtration may vary depending among other things, on changes made to the building and the level of filtration that is wanted. The return on investment will vary considerably from case to case, depending on the frequency and intensity of crises/outbreaks as well as the farm's productivity.

Installation of an air filtration system in a farrowing facility costs from \$250 to \$450 per place over 10 years, with filter changes every three years. Costs amount to \$185 to \$345 per place over 10 years, if filter changes are required only every five years. Thus, depending on the frequency of filter changes, installation of an air filtration system would be profitable if it prevents 1.5 to 4 outbreaks over a 10 year period. In addition, the payback period (excluding funding) would be 9 to 10.5 months, according to whether the filters are changed after five or three years.

Table 4 provides a summary of the order of magnitude of the capital outlay and maintenance costs for an air filtration system in Canada, for three types of swine operations :

- 4 farrowing facilities (1,400 to 2,600 sows)
- 2 gilt development units (560 to 1,200 places)
- 1 farrowing-to-finish facility

Table 4 Estimate of Costs for an Air Filtration System

| | Gilt Development Unit | | Farrowing Facility | | Farrow-to-Finish | |
|---|-----------------------|---------|--------------------|---------|------------------|---------|
| Capital outlay costs per place * | \$12–78 | | \$46–98 | | \$217\$ | |
| Annuities per place** | \$2–11 | | \$6–13 | | \$30 | |
| Frequency of filter changes | 3 years | 5 years | 3 years | 5 years | 3 years | 5 years |
| Maintenance costs per place per year | \$13–15 | \$9 | \$18–31 | \$12–21 | \$63 | \$41 |
| Total annual operating costs | \$15–25 | \$10–20 | \$25–45 | \$18–35 | \$93 | \$72 |

* Does not include initial and replacement filters and prefilters. These are included in maintenance costs.

** For a 10-year loan with an annual interest rate of 6.5%

In the United States, the costs of filtration vary from \$120 US to \$170 US per sow in inventory, with an average cost of \$150 per sow in inventory^{a,13}. It should be noted that the investment cost here includes the initial purchase cost of filters and prefilters, something which is not the case in Canada shown in Table 4.

^a Estimations based on 33 farrowing facilities or 116,000 places (AgStar clients), and conventional ventilation, i.e. ceiling air inlets only, installation of MERV 14 and MERV 15 mechanical filters and air filtration in all four seasons.

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Control of Contaminated Air Infiltration

In a building with filtered air and ventilated under negative pressure (exhaust fans take up the stale indoor air and push it outside), the main challenge is to prevent the entry of unfiltered air that poses a potential risk of infection for the herd. When the exhaust fans expel air outside, it creates a vacuum in the building, letting fresh air enter through the air inlets, but also by all other openings (door and window frames, building joints, shutter frames on fans, etc.) (Figure 15).

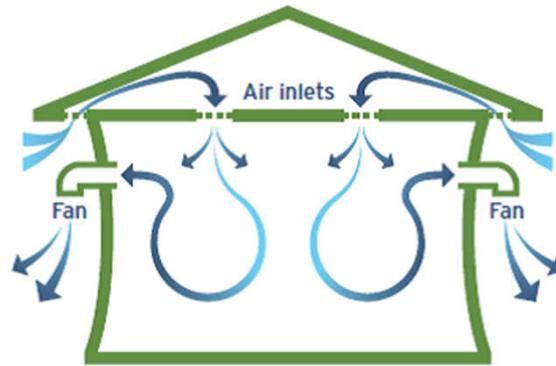


Figure 15 Negative pressure ventilation

The whole envelope of a building using filtered air becomes a barrier against the entry of viruses and should be as tight as possible, because the efficiency of a building with filtered air depends not only on the efficiency of the filtration system, but also on building tightness. There are a multitude of items to check to ensure airtightness, some of which are:

- Wall lining
 - Plywood lining is generally more airtight than corrugated plastic lining (Figure 16).
- Exterior doors
 - Door frames of unused doors let drafts in and must be repaired if split or broken (Figure 17).
 - Unused doors must be sealed.
 - Polythene sheet attached to the wall with slats around the perimeter^b (Figure 18). In the event that the animals might tear the polythene sheet, additional protection may be added at the bottom of the door (e.g. a hinged plywood sheet, easily removable in emergencies). Any system put into place must allow fast opening of the door in an emergency.
 - Thick grease could be applied as an alternative sealant to the outside perimeter of the doors^b, to ensure the airtightness of the door (solution recommended from the point of view of safety).
- Fans
 - Sealant is applied around the perimeter of all fan enclosures from inside the building (Figure 19) to prevent air infiltration.
- Perimeters of feed lines
 - Smoke tests have shown that air infiltration can occur when the foam is used to seal the perimeters of the feed lines (Figure 20).

^b It is the breeder's responsibility to ensure compliance with the prescribed safety rules concerning fire or other issues relating to access to the doors.

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Figure 16 Breaks in corrugated plastic allowing air infiltration
Photos: Darwin Reicks



Figure 17 Non-airtight door frame lets air infiltrate and has to be replaced



Figure 18 Door made airtight using polythene and slats around the perimeter to prevent air infiltration



Figure 19 Perimeter of a fan housing sealed to prevent air infiltration



Figure 20 Smoke test done on the perimeter of a feed line sealed with foam to check for possible air infiltration

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The Centre de développement du porc du Québec inc. (CDPQ) showed that traditional fan shutters are not tight enough, but that it is possible to effectively reduce the air leakage by installing an adequate anti-backdrafting system. Two systems stood out for their effectiveness in reducing air infiltration: the air chute (home made) (Figure 21) and the No BackDraft damper (Figure 22) developed by Conception Ro-Main inc.

Blower door tests on a test bench verified the airtightness of different anti-backdrafting devices. At a static pressure of 0.1 inches of water, the air chute and the No BackDraft damper, in combination with traditional shutters for dual protection, reduced air infiltration by 84% and 96% respectively compared with traditional shutters alone.

For airflow restriction, the combination of air chute and traditional shutters (recommended dual protection) showed the most airflow restriction, i.e. a reduction of 23%, compared to a fan with traditional shutters alone, whereas the No BackDraft damper under identical dual protection conditions showed a decrease of 15%.

For more information, consult the document “Filtration d’air à la ferme : des moyens efficaces pour réduire les infiltrations d’air par les ventilateurs en arrêt”, available online at <http://www.cdpq.ca/recherche-et-developpement/projets-de-recherche/projet-187.aspx>



Figure 21 Air chute



Figure 22 No BackDraft damper

Photo: Conception Ro-Main inc.

Conclusion

This document is a reference tool on the primary information that may interest you with regard to the air filtration in swine buildings.

The tools, results, findings and recommendations resulting from this project will be disseminated through the Technology Transfer Program led by the Prairie Swine Centre Inc. (PSCI). All deliverables will be available on the following websites:

Canadian Swine Health Board : www.swinehealth.ca

Centre de développement du porc du Québec inc. : www.cdpq.ca

Prairie Swine Centre Inc. : www.prairieswine.ca

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