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CANADIAN SWINE BUILDINGS AND INLET AIR FILTRATION SYSTEMS

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TABLE OF CONTENTS

FOREWORD

This guide offers a technical introduction to inlet air filtration systems for use in swine barns with **negative pressure ventilation systems** and is not intended to provide an exhaustive analysis of ventilation and air filtration design. Producers should consult an expert before implementing a negative-pressure ventilation system.

This guide focuses only on the technical aspects of inlet air filtration systems. It does not include installation and operating costs and the necessary biosecurity parameters that must be taken into account in the development and implementation of inlet air filtration systems. Before investing in these systems, producers should consult a veterinarian with specific expertise in biosecurity issues for filtered barns to ensure compliance with recognized biosecurity protocols.

The information contained in this guide is as current as possible. Products, equipment and techniques tend to change quickly, thus producers should ensure that their data are up to date.

WHY SHOULD ONE CONSIDER AIR FILTRATION?

PRRS: A COSTLY DISEASE

Porcine reproductive and respiratory syndrome (PRRS) causes major economic losses each year. This disease is the most costly in the North-American pork industry. In Canada, losses reach approximately $150 million per year (FVM, 2007). A single Canadian hog producer can incur losses between $250 and $460 per sow per year if a herd is infected by chronic PRRS or affected by a new acute infection (Mussel, 2010).

AIRBORNE TRANSMISSION OF PATHOGENS

The possibility of airborne PRRS virus transmission has been the subject of controversy for many years (Cho and Dee, 2006). However, it has now been confirmed that many pathogens that cause significant economic loss, including PRRS virus, influenza and *Mycoplasma hyopneumoniae*, can be a result of airborne transmission from one production site to another (Desrosiers, 2004) carried by dust particles or other bioaerosols. Studies have shown that the PRRS virus and *Mycoplasma hyopneumoniae* can be transmitted by air over distances of up to 9.1 km (Dee *et al*., 2009a; Otake *et al*., 2010).

BIOSECURITY AND FILTRATION: EFFICIENT SYNERGY

A number of studies have shown that different types of filters can reduce airborne transmission within a herd (Dee *et al*., 2006a, b, 2010; Pitkin *et al*., 2009; Batista *et al*., 2008; Batista *et al*., 2009); viruses such as PRRS virus, however, are not limited to airborne transmission. A reliable biosecurity program used in conjunction with an air filtration system is critical to reduce the contamination risk. In a study by Pitkin *et al*. (2008) comparing three levels of biosecurity, the contamination level in an operation with no biosecurity measures was 66%, and dropped to 30% in a building with biosecurity measures. By comparison, over the study's same two-year period, a barn with a filtration system and a biosecurity program experienced no herd issues with PRRS. Moreover, it seems that in high-density swine areas, PRRS outbreaks cannot be prevented by conventional biosecurity protocols alone.

AIR FILTRATION IN SWINE BARNS

EARLY INSTALLATIONS OF AIR FILTRATION IN SWINE BARNS

The first hog farms to install air filtration systems were insemination centres in Brittany, France. These barns were equipped with HEPA (High Efficiency Particulate Absorbing) filter systems. Given the significant pressure drops associated with HEPA systems, these buildings had to be ventilated under a positive pressure. Toward the end of the 1990s, farrow-to-finish producers began to introduce positive-pressure HEPA systems (Coudé, 2004).

In North America swine barns, the first air filtration systems appeared in Canada, and specifically in Quebec, in 2003. Two artificial insemination centre sites are equipped with HEPA filters and ventilated under positive pressure. Today, HEPA filters are used in almost all major artificial insemination centres in Quebec and, in 2004, a farrow-to-finish producer also adopted a HEPA system.

Beginning in 2005, the high costs of HEPA systems resulted in negative-pressure ventilation research and development initiatives in the United States and Canada. To reduce costs, research focused on negative-pressure ventilation to facilitate retrofits. Since 2008, approximately 10 to 15 commercial hog farms in Canada use inlet air filtration systems under negative pressure and, since 2006, approximately 50 units have been installed in the United States.

FILTER CLASSIFICATION

In North America, the American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc. (ASHRAE) has published filter efficiency standards. Among the methods developed, the ASHRAE gravimetric technique measures the efficiency of medium-efficiency filters generally used as coarse-particle pre-filters. The ASHRAE opacimetric method rates high-efficiency filters including those generally used in the hog industry. With this type of evaluation, air filter effectiveness is rated on a scale from 1 to 16 referred to as the Minimum Efficiency Reporting Value (MERV). The higher the MERV value, the greater the effectiveness of a filter in trapping fine particulate matter. Thus, a MERV 14 filter is greater than 75% but less than 85% effective in capturing particles from 0.3 to 1 μm in diameter, while a MERV 16-rated filter can capture up to 95% (Allergy Clean Environments, 2010). Finally, the ASHRAE dioctylphtalate (DOP) test assesses extremely high-efficiency filters such as HEPA filters.

Note that the ASHRAE classification is based only on mechanical filtration and does not take into account the antimicrobial properties of some filters. There is no standard rating for antimicrobial or antiviral filtration.

AIR FILTRATION IN SWINE BARNS

MANY MODELS AVAILABLE... BUT NOT ALL EFFICIENT

One can assume that all inlet air filters can prevent the transmission of PRRS viruses to a herd; however, the level of success rests largely on the filter type. Filters are not equally effective (or not at all) against the removal of PRRS viruses. Dee *et al*. (2006a, b) evaluated several low-cost filters that were potentially effective against PRRS virus and found, among other things, that a screen (pre-filter) system in combination with a fibreglass furnace filter (MERV 4) or an electrostatic furnace filter (MERV 12) proved significantly less effective than a HEPA or a MERV 16 filter.

Furthermore, Dee *et al*. (2009b) demonstrated that the MERV rating was not the only criterion necessary for assessing the effectiveness of viral filtration. For instance, four mechanical filter models, each with a MERV 16 rating, were not equally effective in removing the PRRS virus. The authors tested the efficiency of the 10, 15 and 20-layer antimicrobial filters in preventing the transmission of viable viruses. Thus, they demonstrated the importance of basing filter selection on their effectiveness, specifically against PRRS viruses or other targeted pathogens. Selecting a filter designed for durable performance in agricultural conditions (humidity, low pressure, corrosion, etc.) also is an important consideration.

FILTER SELECTION

Zero risk of contamination is not possible; however, inlet air filtration systems help to manage the risk. The higher the risk of aerosol contamination on a farm, the higher the MERV rating required for mechanical filters. A MERV 14 to MERV 15 filter is recommended for lower risk farms, while higher risk farms should select filters with ratings of MERV 16 or higher. Note than these recommendations refer only to a filter's MERV rating, since the filtration capacity of the pre-filter and filter are not cumulative (for instance, a MERV 4 pre-filter combined with a MERV 12 filter do not have the same filtration capacity as a MERV 16 filter).

With a higher contamination risk, it is recommended that filters be selected with a higher number of antimicrobial membranes, thus increasing contact between pathogens and the antimicrobial / antiviral agents. These are integrated with the membrane fibres, ultimately increasing the effectiveness of mechanical filtration. Lower risk farms could use filters with 10 antimicrobial membranes, while higher risk farms should select filters with 15 or more membranes.

AIR FILTRATION IN SWINE BARNS

Furthermore, with risk levels being equal, operations with more value added (e.g.: nucleus herds) should use higher efficiency filtration systems. It is recommended that producers consult a veterinarian and an air filtration specialist to determine the level of filtration most appropriate to their operations.

Air filtration efficiency and impact on air restriction

The higher the level of filtration, the greater the restriction to the inlet airflow. The increase of the filter efficiency will increase the energy required to maintain airflow. To maintain a given static pressure, higher efficiency filtration systems will require a greater number of filters, which in turn will increase pre-filter and filter purchase and replacement costs, as well as the installation space required. It is possible to reduce filter costs by reducing the number of filters, but such a reduction would lead to higher interior static pressure and therefore increase the risk of introducing unfiltered air in negative-pressure buildings.

VENTILATION AND AIR FILTRATION DESIGNS

Ventilation system types: mechanical, natural and hybrid

Three most common types of ventilation systems encountered in Canada are: mechanical, natural, and hybrid ventilation.

Natural ventilation systems do not use fans to move air through the building. Airflow into and through a building is controlled by the adjustment of chimneys to ensure minimum airflow during cold weather conditions, and the adjustment of sidewall vents to control wind-induced airflow during hot weather conditions. Natural ventilation is most often used in gestation and growing facilities. During the past few years, many buildings that were using natural ventilation have been converted to hybrid ventilation systems. A hybrid system relies on mechanical ventilation during cold weather, moving air by means of chimneys fans and ceiling intakes. During warm weather conditions, airflow is maintained by the force of wind passing through wall inlets. Both natural and hybrid systems will require modifications in order to draw the incoming air through a filtration system.

In a mechanical ventilation system, air is most commonly drawn through inlets into the building by negative pressure created by the exhaust fans mounted on the wall across from the inlets. However, the ventilation system can be designed to create positive, negative or neutral pressure within the building.

Positive-pressure ventilation

In a positive-pressure system (figure 1), fans blow fresh air into the barn, and the air is exhausted through outlet openings.

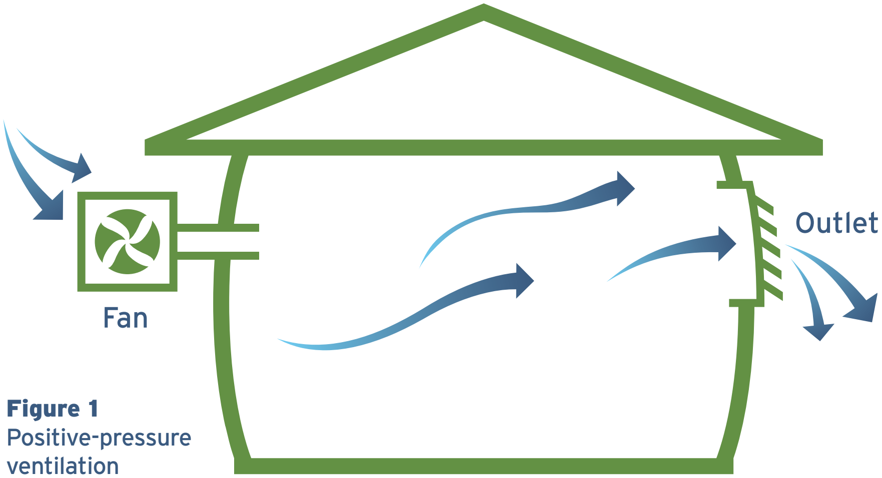


Figure 1
Positive-pressure ventilation

Positive-pressure ventilation is used in some barns in North America and in France with HEPA filters. Because air is forced out of the buildings, positive-pressure ventilation significantly reduces the risk of unfiltered air being introduced through unplanned openings. This major benefit of positive-pressure ventilation, however, comes with an added cost. To maintain an interior static pressure of up to 0.2 inH_2O (inch of water), the building must be airtight, otherwise leakage will increase cold season heating costs.

VENTILATION AND AIR FILTRATION DESIGNS

Vapour barriers are also essential in positive-pressure systems to prevent contaminated air or moisture from condensing inside the walls during cold weather conditions and causing structural damage. With a conventional HEPA system, fans in a positive-pressure system must be able to operate at over 1 inH_2O in order to provide the required airflow rate through the filters, thus requiring a significant amount of energy. Trials with less restrictive filters have yielded promising results against PRRS virus transmission. Pressure drops can be significantly reduced in positive-pressure systems with these filters.

Despite its advantages, positive-pressure ventilation systems can be more complex to implement, because most buildings operate under negative pressure and would require major building and ventilation system retrofits. The biggest challenge in designing positive-pressure ventilation systems in existing buildings is the efficient, simple and cost-effective location of air intakes throughout the building. Their location must allow uniform distribution of fresh air to all rooms with good control of air drafts at the animal level. While positive-pressure systems offer many compelling advantages, the negative-pressure systems is considered to offer the easiest alternative to integrating filters with the ventilation system. Consequently, this guide provides an overview of only negative-pressure systems.

Negative-pressure ventilation

Negative pressure ventilation systems are the most frequently used in Canadian barns where fans exhaust air from the building (figure 2).

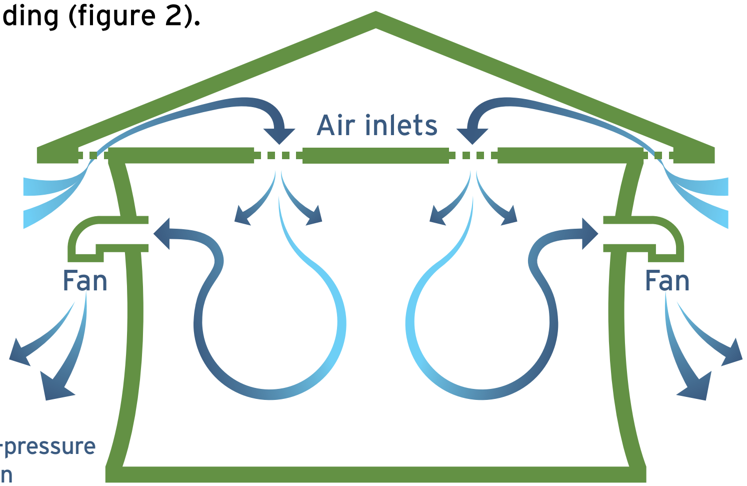


Figure 2
Negative-pressure ventilation

The main drawback of negative-pressure systems is the potential for hard-to-control leaks from doors, louvers, cracks and so on (unplanned openings). To limit leakage and maintain optimal fan performance, the total pressure drop should not exceed 0.15 inH_2O (which has far lower energy requirements than HEPA systems). Negative-pressure and air filtration building design tend to be more popular since the filters are easier to install and because of the relatively low retrofitting cost.

TYPES OF FILTERS FOR THE SWINE INDUSTRY

The mechanical and antimicrobial filters described below have been assessed by researchers for their effectiveness in preventing airborne contamination of swine by PRRS virus and by Mycoplasma. For more information on the trials and results, please see Dee *et al.*, 2006a, 2010; Batista *et al.*, 2008; Batista *et al.*, 2009.

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®.

Camfil Farr[1] and AirGuard®[2] have developed V-box pleated filters (figure 3). Both companies' filters have similar shapes and sizes (approximately 24 in. by 24 in. or 20 in. by 24 in. for the front opening surface, and 12 inches in height). A chart detailing the air flow according to the static pressure generated by a filter is available from the manufacturers to assist producers in calculating the number of filters required for a given airflow and static pressure. The calculations also take into account losses caused by the pre-filter and filter.

Figure 3
V-box pleated filter

For swine barns, Camfil Farr offers its "Pathogen-Barrier" filter, available in L6 (MERV 14) and L9 (MERV 16). The L9 offers the best level of protection, while the L6 can be used in lower-risk situations.

AirGuard® also makes a V-box filter, the "Vari+Plus® AG," which has a MERV 15 rating.

[1] Camfill Farr dealer website: http://www.automatedproduction.com/

[2] Airguard technical support: 1-866-247-4827 or http://www.airguard.com/international.htm

TYPES OF FILTERS FOR THE SWINE INDUSTRY

These mechanical filters are not washable, and the use of an upstream pre-filter (figures 4 and 5) is necessary to eliminate the coarse particles and extend the life span of the filter. When a pre-filter is installed on a filter frame, make sure it is airtight to protect the filter from unwanted particles. These filters must also be protected from adverse weather (rain and snow). Also, the filter media should not be handled directly to avoid affecting the filters' efficiency or piercing the filter media (Pitkin and Dee, 2010).

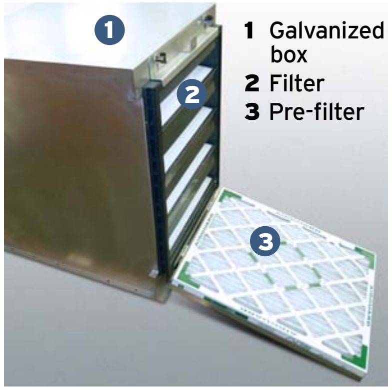


Figure 4
V-shaped filter installed in a galvanized box

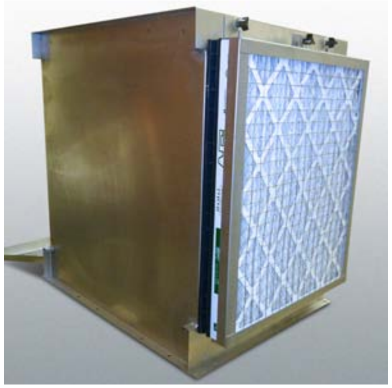


Figure 5
Filter box

Figure 6
Antimicrobial cube filter

ANTIMICROBIAL FILTERS

The Noveko[3] antimicrobial filter is made from polypropylene fibres in which the antimicrobial agents are integrated into the media fibre. This filter has several antimicrobial membrane layers allowing for mechanical filtration combined with antimicrobial action of agents integrated within the media fibre. These antimicrobial agents render viruses and bacteria inactive upon contact with them.

This filter was developed specifically to adapt to existing agricultural structures more easily. It is available in two levels of protection, with 10 or 15 layers (the number of layers can also vary according to need). Also, two models are offered with a different capacity and shape: a cube filter (figure 6) for use with ceiling inlets, and a curtain filter (figure 7) for use with exterior linear wall inlet vents or in ceiling inlets.

[3] For more information on Noveko products, visit http://www.noveko.com or call 1-877-874-0606.

TYPES OF FILTERS FOR THE SWINE INDUSTRY

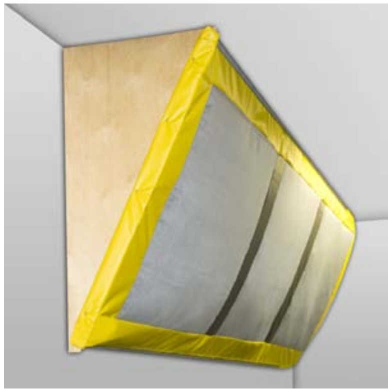


Figure 7
Antimicrobial curtain filter

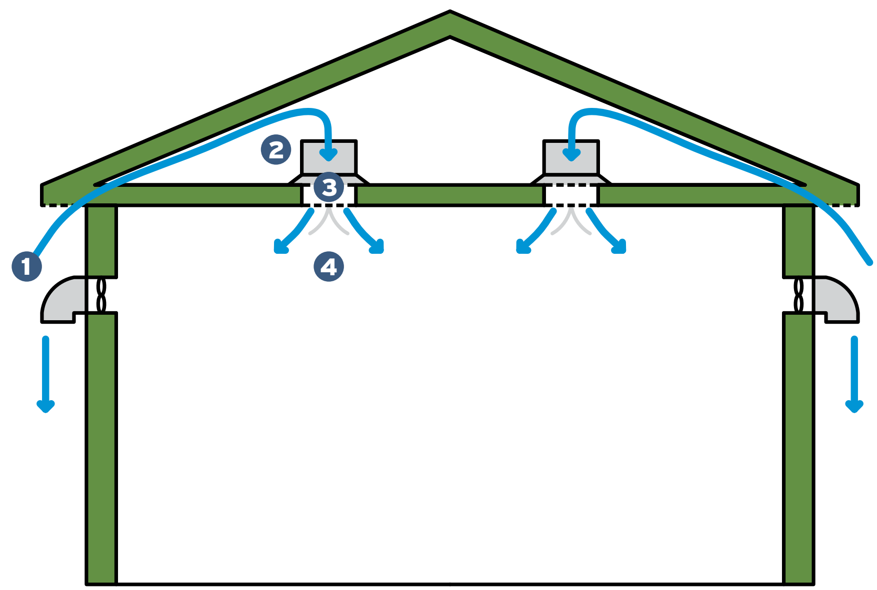
The 15-layer filter offers a higher level of protection than the 10-layer filter, which is recommended for lower risk situations. This filter is washable, however, the manufacturer recommends the use of a pre-filter (figure 8) to limit filter clogging and reduce the washing frequency. A pre-filter also helps maintain clean filter fibres, making the filter's antimicrobial agents more effective. As with other filters, manufacturers can provide a static pressure chart based on airflow through the pre-filter and filter.

Figure 8
Pre-filter installed on a cube filter

PRESSURE DROP, STATIC PRESSURE AND FAN PERFORMANCE

Resistance to airflow is referred to as pressure drop. A pressure drop can be caused by the widening or narrowing of the air passage by physical obstacles such as filters, fan shutters, air intake shutters, etc. These losses reduce the performance and output of fans. Pressure drops are cumulative, which is to say that losses accumulate when air moves from the outside to the inside the building (figure 9). For instance, in a ceiling-inlet system, losses will accumulate as the air passes through the eaves (1), inlet filters (2), ceiling inlets (3) and ceiling inlet baffles (4). An engineer can calculate the total cumulative pressure drop. He will design the filtration system and air inlets, taking into account, not only the pressure losses caused by filters, but the total cumulative loss between the air entering and leaving the building. Note that it is preferable to increase the air inlet surface area (e.g.: eaves, ceiling inlets, etc.) rather than compensating by adding filters.

Figure 9
Cumulative pressure drops



Losses in pressure are measured by the difference in pressure drop between two given points, in this case inside and outside the building. The difference in pressure can be measured by a manometer, in inch(es) of water (inH_2O) or in pascal(s) (Pa). The higher the pressure differential, the more fan energy necessary to overcome the resistance to move the ventilation air through the building.

Without filters, ventilation systems in agricultural buildings function under negative static pressure of approximately 0.05 to 0.10 inH_2O. With a filtration system in place, it is recommended that the pressure differential be 0.15 inH_2O across the building. Note that the higher the interior negative pressure, the higher the chance of unplanned infiltration.

PRESSURE DROP, STATIC PRESSURE AND FAN PERFORMANCE

It is important to ensure that air inlets be adjusted to maintain the desired airflow. To avoid excessive negative pressure, the use of automatic controllers is recommended. For a given air inlet opening, an increase in airflow will lead to an increase in interior static pressure.

Static pressure affects fan output as measured in cubic feet per minute (ft^3/min or CFM) or in litres per second (l/s). Data from recognized organizations such as the University of Illinois BioEnvironmental and Structural Systems Laboratory[4] (BESS Lab) should be used to determine fan output under different static pressures. In situations where the fan model has not been tested by an accredited organization, producers should request data with equivalent precision from the manufacturer, since fan output significantly affects the design of a filtration system.

[4] Website: http://bess.illinois.edu/

AIR QUALITY AND TEMPERATURE

With a well-designed and well-maintained filtration and ventilation system, adding filters should not cause airflow problems for pressures lower than 0.15 inH_2O. With adequate airflow, standard system specifications and sufficiently large, well distributed and well calibrated air inlets, inlet air filters can simply be added to maintain the total recommended static pressure to avoid having to reduce the fan output and increase the incidence of air leaks. Note, however, that inadequate ventilation or air intake components may have to be modified prior to installing a filtration system. A qualified engineer should be consulted.

The objective of a filter is to capture particles that accumulate over time. Pre-filters and filters can simply be washed or changed as necessary. Build-up on pre-filters and filters increases the overall pressure drop and reduces airflow, thus a regular maintenance schedule of pre-filters and filters is crucial.

IMPORTANT SWINE BARN FILTRATION DESIGN AND OPERATION PARAMETERS

What follows is a checklist of the main considerations before, during and after installing an air filtration system. Note that the system should be designed by an engineer.

BEFORE INSTALLING THE FILTERS

Note: It is important to ensure an adequate level of biosecurity before investing in an air filtration system.

Necessary information for an inlet air filtration system design

- ☐ A drawing of the plan and cross-sectional view of all air inlet and exhaust fan locations
- ☐ A plan of all buildings, noting:
  - ☐ The dimensions of each room
  - ☐ The number of fans, the diameter and model of each fan in each room
  - ☐ The dimensions of the different openings of air flowing from outside to inside the building
  - ☐ The number and type of animals for each production stage as well as the minimum and maximum weight range

Prior to undertaking the air filtration system design

- ☐ During warm weather conditions, the maximum airflow rate for each room must be based on generally accepted standards
- ☐ The static pressure at maximum airflow rate must be lower than 0.05 inH_2O when inlets are fully open
- ☐ Where incoming air is introduced through the attic, the roof should be insulated to prevent solar preheating of the air during the summer
- ☐ The possibility of adopting a cooling system to reduce the ventilation rate and the number of filters should be evaluated
- ☐ Any necessary structural modifications necessary for the decided level of biosecurity must be taken into account

Designing the air filtration system

- ☐ Determine the number of filters required to maintain less than 0.15 inH_2O (moving the ventilation air including filters)
- ☐ Determine the filter installation method based on the air inlet type(s)
- ☐ Ensure that filter installation is feasible and that filters will be easily accessible
- ☐ Ensure that the air ducting downstream from the filters are airtight to prevent leaks
- ☐ Ensure that there are no backdrafts from exhaust fans towards filters that could prematurely clog the filters

IMPORTANT SWINE BARN VENTILATION DESIGN AND OPERATION FACTORS

Leak management

- ☐ Seal all unplanned inlets, i.e., spaces around doors and windows, around grain auger, slurry disposal pipes, etc.
  Note: certain types of wall and ceiling coverings are not airtight (e.g. corrugated plastic)
- ☐ Organize the building layout to reduce leaks through exterior doors with double-door systems (SAS)
  Note: these SASs should ideally be under positive pressure in order for air to exit the building when doors are open. Air velocity should be at least 200 to 300 ft / min. If the SAS is under negative pressure, allow at least three changes of filtered air following the closure of the exterior door before opening the interior door.
- ☐ Plan for an exterior, enclosed, loading area that hold all animals during loading / unloading that is ventilated with filtered air
- ☐ Install airtight backdraft dampers on all fans, since traditional shutters are not sufficiently airtight
  Note: multi-stage ventilation control can be adjusted to reduce the number of fans by using variable-speed fans with larger diameters with increased higher air flow at stages two and up, reducing the need for backdraft dampers

FILTER INSTALLATION AND BUILDING RENOVATION

Filter installation

- ☐ Hire meticulous installers and carpenters who are committed to reduce the risk of leaks
- ☐ Ensure the installer has been trained in air filtration system installation
- ☐ Hold a preliminary meeting to provide the installer and carpenter with adequate instructions and ensure the manufacturer and design engineer specifications are met
- ☐ Install a manometer in each room to allow regular assessment of the filtration system's cleanliness
- ☐ Install filters and boxes on the air intakes, ensuring an airtight seal
  Note: v-box pleated filters should be sheltered from adverse weather (water and snow) and should be handled carefully to avoid perforating the filter media
- ☐ Ensure that filters and pre-filters are easily accessible for regular maintenance
- ☐ Allow for at least three visits by the design engineer to oversee the installation

IMPORTANT SWINE BARN VENTILATION DESIGN AND OPERATION FACTORS

Prior to the operation of the air filtration system

- ☐ With the design engineer, inspect the air filtration system to ensure compliance with standards and specifications
- ☐ With the design engineer, conduct a structural inspection of all buildings to ensure all leaks have been sealed
- ☐ With the veterinarian, inspect all building infrastructure to ensure that the desired level of biosecurity is in compliance

Commissioning a ventilation system; operation and calibration

- ☐ Adjust air inlets to maintain an interior static pressure of less than 0.15 inH_2O that will create the necessary airflow patterns to ensure animal well-being
- ☐ Verify electronic controllers are programmed as specified
- ☐ Verify that static pressure is as per design standards

Operator and employee training

- ☐ The design engineer should train operators on the use, adjustments, maintenance and verifications of the ventilation / filtration system
- ☐ The veterinarian or other competent persons should train employees on the necessary biosecurity measures

FOLLOWING FILTER INSTALLATION

Anticipated maintenance and repair schedules

- ☐ With the design engineer, determine the maximum pressure at which filters and pre-filters should be cleaned or replaced

  Note: the frequency of filter and pre-filter cleaning, washing or replacement will depend on the location of the building (near a road, a woodlot, a pollen source, etc.)
- ☐ Keep a weekly log of the static pressure in each room at maximum ventilation to assess build-up on the pre-filters and filters

  Note: excessive build-up can impede the optimal operation of the ventilation system and cause pressure drops and leakage
- ☐ Every day, note down minimum and maximum room temperatures to detect abnormal low and high temperatures and clogging problems
- ☐ Conduct regular inspections of filters and pre-filters to ensure they are not damaged

  Note: these inspections are important since filters can be damaged by rodents, etc.
- ☐ Replace filters and pre-filters according to manufacturer recommendations
- ☐ The design engineer should conduct annual inspections of the ventilation / filtration system

FILTER INSTALLATION METHODS BASED ON AIR INLET DESIGN

ADAPTING FILTER DESIGNS TO EXISTING STRUCTURES

It is necessary to consider the adaptability of animal structures to air filtration systems, since renovations can affect costs and feasibility. In Canada, with different types of buildings and ventilation systems in existence, various methods need to be considered to install air filtration systems. There are several common difficulties to the installation of air inlet filters. These include roof trusses, restricted space and narrow eaves. Good planning will help ensure optimal system efficiency and cost effectiveness.

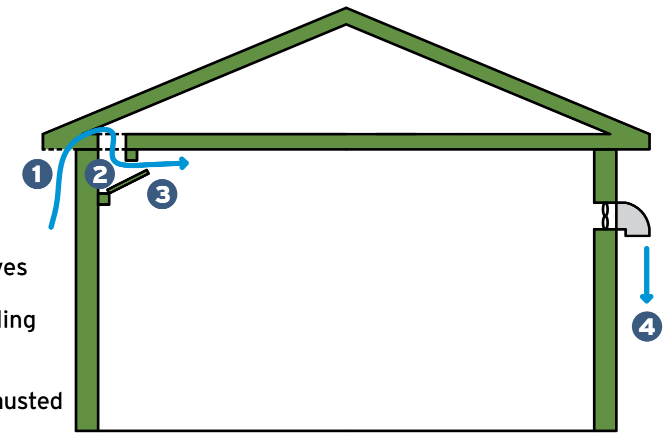
INSTALLATION METHODS ACCORDING TO AIR INTAKE

Possible installation methods for the most common air intakes are presented below, as examples only, and are not intended to be exhaustive. The designer and installer are responsible for ensuring that filters are installed as per industry standards and in compliance with the manufacturer's specifications. Any modifications to roof trusses must be approved by the manufacturer.

Lateral inlets (ceiling or wall)

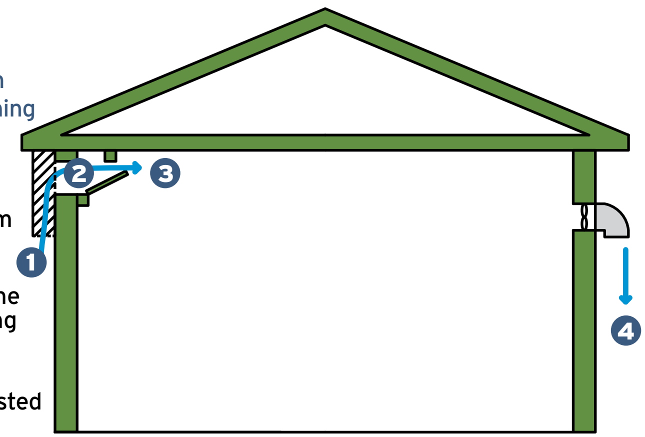
Lateral-air inlet ventilation systems use a continuous linear opening at the ceiling level (figure 10) or along the wall (figure 11). The air then passes into and through the building (figure 12) before being exhausted by fans mounted on the opposite wall.

Figure 10
Lateral air inlet with continuous ceiling opening (without filters)



1 Air entering through the eaves
2 Air entering through the ceiling
3 Air entering the barn
4 Building air exhausted by the fans

Figure 11
Lateral air inlet with continuous wall opening (without filters)



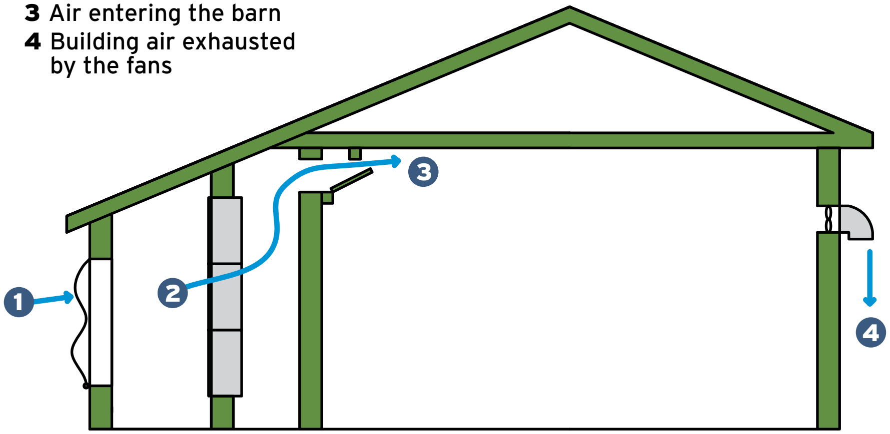
1 Air entering through the plenum
2 Air entering by the continuous linear intake on the side of the building
3 Air entering the barn
4 Building air exhausted by the fans

FILTER INSTALLATION METHODS BASED ON AIR INLET DESIGN

Figure 12
Interior view of an inlet with a continuous wall opening

Figure 13
Installation of V-box pleated filter for continuous lateral air inlet

1 Air entering through a curtain
2 Air passing through the filters and pre-filters
3 Air entering the barn
4 Building air exhausted by the fans



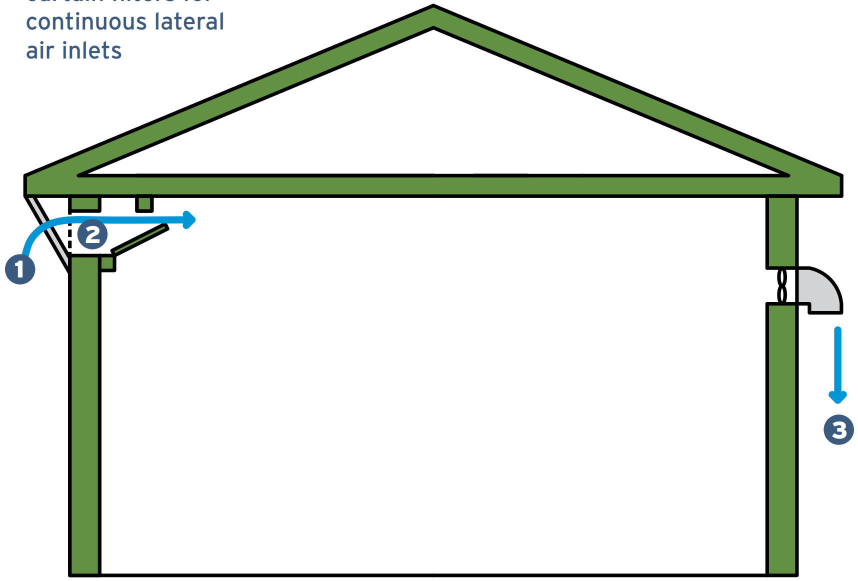
V-box pleated filter

Because this type of filter must be protected from weather and requires significant surface area and volume, the best installation method is to build a structural addition to house the filters (figure 13). There should be enough space to allow access for filter servicing or replacement. The air enters the addition through the wall, from which the opening is managed by a curtain and an actuator (1) according to airflow, and flow through the pre-filters and filters (2). The filtered air is then directed to the wall inlet (3) and into the barn. The air is exhausted by the fans mounted on the opposite wall of the building (4). When an inlet is located in the ceiling (figure 10), it is preferable to seal it and create an access opening in the wall to reduce the risk of leaks through the attic. Building an airtight duct through the roof trusses is extremely complex.

FILTER INSTALLATION METHODS BASED ON AIR INLET DESIGN

Figure 14
First-generation antimicrobial filters (a)
and new generation of antimicrobial curtain filters (b)

Figure 15
Installation of antimicrobial curtain filters for continuous lateral air inlets



Antimicrobial curtain filter

Recommended curtain-type filters are the new generation of antimicrobial filter (figure 14b). This type of filter requires minimal protection from the weather. It can be installed outside the building under the eaves according to manufacturer specifications (figure 15). The size of the eaves must be sufficient to accommodate the height of the filter. If a duct is serving as a plenum, it must be removed in order to install the filters as close to the intake as possible. This will reduce leakage and allow space between the filters and the ground to prevent obstruction by accumulated snow. Once filters are installed under the eaves, the air passes through the pre-filters and filters (1) and flows towards the wall inlet (2) before being exhausted by fans (3). As with box filters, it is preferable to seal any lateral ceiling inlets and install an access opening in the wall. As well, it is important to ensure there are no leaks downstream from the filters. Corrugated metal sheet cladding installed on the outside wall can be a source of leakage.

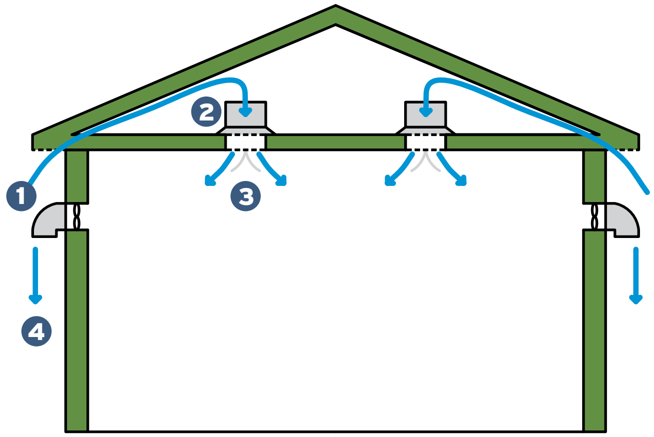
FILTER INSTALLATION METHODS BASED ON AIR INLET DESIGN

Figure 16
Modular air inlet without filter

MODULAR AIR INLET (ATTIC)

In modular air inlet systems, the inlets in the barn consist of multiple separate openings in the attic, distributed along the ceiling (figure 16). The air enters through the eaves on either side of the building (1), flows through filters (2) and diffusers (3), and is exhausted by fans at either side of the building (4) (figure 17). In some cases, the exhaust air can re-enter the barn through the eave intakes, which can cause an increased build-up on the filters. In such cases, either the eave intakes or the fans must be relocated. In addition, under roof insulation is recommended to limit increases in temperature resulting from solar radiation. With less preheating, less airflow is required during the warm season.

Figure 17
Installation of box and antimicrobial filters for modular air inlet



V-box pleated filter

Filter ducts (2) fitted in wood or galvanized steel boxes are mounted on the modular air inlets (3) (figures 4 and 5). To avoid leaks, all box joints must be sealed and caulked. If their dimensions vary, ducts can contain from 1 to 6 filters and pre-filters depending on maximum airflow. The distance between trusses (24 or 48 in.) is an important design factor to consider in selecting a filter model, dimensions and the maximum number of filters to install per air inlet (figure 18). Truss spacing of 48 in. allow more flexibility than 24-inch truss spacing. A narrower distance may require the use of 20 in. by 24 in. filters (V-box filters) if the trusses obstruct the installation of the filters. Note that with smaller filters, the flow of air through the filter will be lower and a higher number of filters will be necessary.

Figure 18
Filter ducts installed in an attic with trusses 48″ apart

FILTER INSTALLATION METHODS BASED ON AIR INLET DESIGN

Figure 19
Cube filter and pre-filter installed in an attic with trusses 24″ apart

Antimicrobial cube filter

Cube filters (figure 19) are a better choice than curtain filters for attic intakes. Cube filters (2) are designed to be installed directly on the diffusers (3) with a plastic duct holding the filter in place and providing an airtight seal. The shape and size of the duct can vary as needed. To avoid leaks, all duct joints must be sealed and caulked. This type of filter / pre-filter can vary in size based on the airflow required per diffuser, the desired pressure and the space available. Generally, ducts can hold one or two filters, depending on the maximal airflow.

Since the filter material is flexible, it can be shaped differently. The space between trusses becomes less problematic and the filters can be shaped to fit around trusses if necessary.

CONTINUOUS LINEAR AIR INLET (ATTIC)

Continuous linear air inlets allow air to enter the barn through openings in the attic (figure 20). The air passes through the eaves on either side of the building (1), flows through the filters (2) fitted over the ceiling inlets (3), and building air is exhausted by fans at either side of the building (4). As with modular air inlets, adjustments may be required if foul air re-enters the attic through the eave openings.

Figure 20
Continuous linear air inlet without filter

FILTER INSTALLATION METHODS BASED ON AIR INLET DESIGN

V-box pleated filter

The installation of filters will depend on whether or not there are any obstacles (e.g. trusses) spanning the air inlet (figure 20). If there are no obstacles, the V-box filters (2) are installed in wood or galvanized steel ducts placed side by side on the air inlets (3) (figures 21 and 22). To avoid leaks, all duct joints must be sealed and caulked. The duct dimensions can vary, and ducts can contain filters on one to three sides depending on the maximum airflow. If the intakes are obstructed by trusses, the installation method will be similar to that for modular air inlets.

Antimicrobial curtain or cube filter

The installation of curtain filters is suggested for linear air inlets that are not spanned by trusses (figure 23). Cube filters can also be installed. This type of filter (2) is designed to be installed directly on the air inlet (3) with a plastic duct holding the filter in place. Antimicrobial curtain or cube filters used with pre-filters can vary in size according to the airflow required per diffuser, the desired pressure and the space available. If the air inlet is obstructed by trusses, the installation method will be similar to that for cube filters.

NATURAL AND HYBRID VENTILATION

Based on the knowledge currently available, the installation of filters in natural or hybrid systems is possible, but would require structural modifications to implement mechanical ventilation. Given the different possible barn layouts, and the many possible ventilation systems, retrofits for natural or hybrid ventilation systems are not covered in this guide.

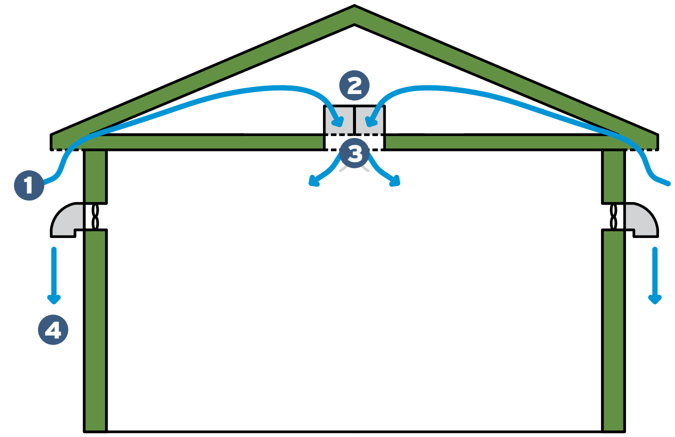


Figure 21
Installation of box and antimicrobial filters in a continuous linear intake

Figure 22
Filter box installed on a continuous linear air inlet

Figure 23
First-generation antimicrobial filter installed on a continuous linear air inlet

AIRTIGHT STRUCTURES AND EQUIPMENT

INSTALLATION BASICS

The governing principle of air filtration systems is that all the ventilation air is passed through the filters with no unplanned openings (leaks). Leak management can be a challenge in negative-pressure ventilation systems. When filters are installed, the building itself becomes a structural barrier against airborne pathogen contamination.

Several important design elements will help to reduce leaks in air filtered barns:

- Ensure the air ducting downstream from the filters is airtight;
- Install filters on intakes located as close as possible to the animal rooms;
- Avoid high static pressure in these rooms (less than 0.15 inH_2O);
- Manage unfiltered air entering the building when opening exterior doors;
- Seal other unplanned inlet openings (e.g.: fan shutters, cracks in the walls, etc.).

MAIN SOURCES OF CONTAMINATED AIR LEAKS

In a building under negative pressure, the structure must be as airtight as possible to reduce the risk of herd contamination through air leaks. Likely leaks include:

- The shutters of fans that stop functioning;
- Exterior doors (main entrance, loading dock, manure deep pit access, etc.);
- Walls (grain auger holes, cracks, etc.);
- Door and window frames;
- Leaks around the fan housing;
- Slurry disposal pipes;
- Leakage around the filter housing;
- Air conditioning units.

AIRTIGHT STRUCTURES AND EQUIPMENT

To reduce leaks:

- Install well-sealed backdraft shutters on any fans (maintain regularly throughout the year);
- Calibrate air inlets to avoid excessive interior pressure (less than 0.15 inH_2O);
- Regularly record static pressure inside the building with a manometer;
- Use a double-door system (SAS) for exterior doors;
- Build a loading area with double doors;
- Install a positive-pressure ventilation system in the loading dock and for the exterior double-door systems;

- Install backdraft shutter in slurry disposal pipes;
- Seal any openings in the walls (fan edges, grain auger holes, etc.);
- Regularly check filters for damage.

FACTORS TO CONSIDER IN CHOOSING AN AIR FILTRATION SYSTEM

There are several key factors to consider in evaluating air filtration systems. To make an informed decision, comparisons must be made based on the same variables. The airflow per room and total static pressure (inlet and filter pressure drop) must be considered, as well as the life span of the filters. These three factors will have a significant impact on filter and energy costs, and affect the performance of the ventilation system and therefore the air quality. The service quality provided by the suppliers, design engineer and installer will also be a tremendous asset throughout the design, installation, commissioning and follow-up. The table below provides the breakdown necessary to compare three different options.

ELEMENTS	OPTION 1	OPTION 2	OPTION 3
Technical Data			
Total site air flow (CFM)			
Static pressure generated by filters alone (inH_2O)			
Total static pressure (inlet plus filter pressure drop) (inH_2O)			
Type of filter (mechanical or antimicrobial)			
Filter efficiency (MERV or number of antimicrobial layers)			
Type of pre-filter (mechanical or antimicrobial)			
Pre-filter efficiency (MERV or number of antimicrobial layers)			
Washable filter (y / n)			
Washable pre-filter (y / n)			
Estimated filter lifespan (yr)			
Estimated pre-filter lifespan (mo)			
Sufficient space for filter installation (y / n)			
Ease of filter installation (easy, medium, difficult)			
Structural renovation costs (low, medium, high)			
Air flow vs. a static pressure chart is available (y / n)			
Designer's experience in the hog industry (low, medium, high)			

FACTORS TO CONSIDER IN CHOOSING AN AIR FILTRATION SYSTEM

ELEMENTS	OPTION 1	OPTION 2	OPTION 3
Initial Investment			
Filters (including delivery) ($)			
Pre-filters (including delivery) ($)			
Filter installation (parts and labour) ($)			
Building renovation (parts and labour) ($)			
Annuities and annual operating and replacement costs			
1 - Capital and interest payments ($ / yr)			
2 - Maintenance and repairs (parts and labour) ($ / yr)			
3 - Replacement filters ($ / yr)			
4 - Replacement pre-filters ($ / yr)			
5 - Added energy costs ($ / yr)			
6 - Disposal costs ($ / yr)			
TOTAL COST ($ / YEAR)			

FUTURE WORK

DEVELOPMENT OF AIRTIGHT, SIMPLE AND COST-EFFECTIVE BACKDRAFT SHUTTERS

In a negative pressure system, there can be significant unfiltered backdraft through the fan shutters when the fans are not operating. The amount of unfiltered air entering the barn becomes a substantial risk of airborne contamination to the animals. Airtight, motorized mechanical shutters do exist, but they are expensive and require maintenance. The challenge is the development of simple and economical shutters. A 2011 research and development project will assess several promising airtight backdraft shutter designs. A maintenance schedule is recommended.

TRUCK AND TRANSPORTATION AIR FILTRATION

Filtration in trucks transporting breeding animals or transferring them from one filtered building to another must be considered. Trucks equipped with filtration systems would help reduce herd contamination resulting from the introduction of animals contaminated during transport. To our knowledge, although a prototype of a small trailer with a filtration system has been developed, and although a few are in use in France, there are no animal transport trucks in Canada equipped with filtration system.

POSITIVE-PRESSURE AIR FILTRATION

Since 2005, positive-pressure air filtration systems have been more or less abandoned by researchers and designers of commercial breeding buildings. However, with the advancement of knowledge on low-restriction filter efficiency, positive-pressure systems may have to be reconsidered, given their advantages in controlling unfiltered air leakage.

USE FILTERS AT THE EXHAUST FANS

Two Canadian producers recently participated in a pilot project to test a new approach to air filtration. The approach was noteworthy because of the installation of washable antimicrobial filters downstream from the exhaust fans, to avoid contaminating neighbouring buildings after a PRRSV infection. The goal was to reduce or avoid airborne transmission beyond the infected building. Both projects are currently underway, and no results are yet available. Although this filtration technique remains in its early stages, further development will offer a new tool to avoid inter-farm contamination.

FUTURE WORK

COST REDUCTION

There are several possible ways to reduce the costs associated with air filtration systems. A solution should be found to reduce the maximum (summer) ventilation rate, without affecting animal performance, in order to reduce the number of filters necessary and the cost of purchasing and replacing filters. As well, more broadly adaptable filters should be developed to reduce the costs associated with retrofitting existing structures. Finally, new building concepts should be developed to more easily integrate air filtration systems.

CREATING A QUARANTINE UNIT IN AN EXISTING FARROWING BARN

The ability to filter air entering and exiting from buildings also raises the option of developing quarantine areas within a farrowing barn using filtration and by laying out the building accordingly. This would benefit many Canadian farms by allowing low-cost quarantine sections to be set up within existing structures.

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