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Engineering air filtration systems of swine facilities

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Introduction

Filtration systems were designed for four 200 to 250 head boar studs and a 2800 breeding/gestation facility. The goal for installing these systems was to reduce the possibilities of transmission of the Porcine reproductive and respiratory syndrome virus (PRRS) by aerosol. The filtration systems for these facilities were set up to filter all incoming air during cold, mild, and hot weather conditions. The ultimate in filtration systems would be to use high efficiency particulate air (HEPA) filters. However, costs associated with this method and the effect on traditional negative pressure ventilation systems would make it very difficult to adopt this method of filtration for large scale units. Filter selection for these projects was based on research conducted by Scott Dee, et. al... They found that when comparing different filtration systems to the control group with no filtration, infection was not observed in any of the 76 HEPA-filtration replicates but was observed in 2 of the 76 95% dioctylphthalete (DOP), 0.3-μm filtration systems and 42 out of 50 control replicates. The 95%-DOP, 0.3-μm-filtration system used in this study was a pleat-in-pleat V-bank disposal filter with a 95% efficiency rating for particles 0.3-μm or greater in diameter and ratings of Eurovent 9 EU9 and minimum efficiency reporting value (MERV) of 15. Dee, et. al. concluded whether the 95% DOP-0.3-μm can be considered an acceptable substitute when compared to HEPA filtration depends on the cost of implementation, compatibility with the existing ventilation system, and the level of risk that the producer is willing to accept when comparing the superior performance of the HEPA system.

Boar studs

Three boar stud sites having capacities ranging from 200 to 250 per room were setup with filtration systems. One of the boar studs had a PRRS outbreak in 2005. A suspect finishing unit with PRRS was located approximately 1.25 kilometers (km) away south east from one of the sites. The unit was depopulated and inquiries were made on how a majority of the fresh air entering the units could be filtered.

Objectives of the project were:

- Filter all incoming air through the air inlets
- Provide adequate ventilation (convert natural cross ventilated to full mechanical ventilation)
- Provide approximately 0.12 cubic meters per second (m^3/sec.) or 250 cubic feet per minute (cfm) or per boar of airflow during hot weather conditions
- Maintain boar comfort and productivity
- Maintain worker comfort and productivity
- Seal all unplanned openings

Problems to overcome included:

- The high static pressures created by the filters on fan performance
- Present ceiling air inlets not compatible with a full mechanical ventilation system
- Existing fans not providing enough airflow with the higher static pressures
- Sealing all unplanned openings including non-operating fans and pit covers
- Filtration box construction and installation
- Hot weather cooling

Since the boar studs were set up initially to be a naturally cross ventilated facility during warm and hot weather conditions, initial fan capacity was limited to cold and mild and a portion of warm weather ventilation. All of the units needed additional fans and some of the existing fans needed to be replaced because of poor airflow output at the higher operating static pressures greater than 50 Pascal's (0.20 inches). Additional fans selected for the projects included 61 centimeters (cm) and 91.4 cm (24 and 36 inch) units. These fans had an airflow ratio [airflow at 50 Pascal's (0.2 inches) divided by airflow 12.5 Pascal's (0.05 inches) of static pressure] of 0.89. Fan airflow performance data was obtained from the Bioenvironmental and Structural Systems Laboratory (BESS Labs).

Providing air inlet filtration was set up by installing two Camfil Farr 1511-MV16 61 x 61 cm. (24" x 24") filters for each air inlet. These filters are capable of delivering approximately 0.93 m^3/sec (2000 cfm) at 200 Pascal's (0.80 inches) of static pressure. Since 200 Pascal's (0.80 inches) of static pressure is not practical for a conventionally ventilated facility which typically operates at a maximum rate of 31 Pascal's (0.125 inches) of pressure, the amount of airflow allowed for each filter was decreased. At 0.28

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m^3/sec (600 cfm) per filter the pressure resistance is approximately 50 Pascal's (0.2 inches) and at 0.19 m^3/sec (400 cfm) the pressure resistance is approximately 31 Pascal's (0.125 inches). In order to extend the life of the MERV-16 filter a pre-filter is recommended. At 0.19 m^3/sec (400 cfm) per 61 × 61 cm. (24" × 24") pre-filter (Camfil-Farr 5 cm. (2") deep Aeropleat IV, MERV 6) the pressure resistance from the 5 cm. (2") deep pre-filter is minimal and is recommended over the 2.54 cm. (1") pre-filter. For this application, a minimum gap of 15 cm. (6") is needed between the bottom of the Durafil filter and the top of the insulation stop for the air inlets. A 61 cm. (24") high surround for the filters should provide enough height for the filters, a 15 cm. (6") gap, and a 15 cm. (6") high insulation stop. The insulation is important to prevent condensation of the surfaces between the filter holding surround and the intake for the air inlets. For this project all of the 4-way air inlets where eliminated and replaced with 0.56 m^3/sec (1200 cfm) bi-flo air inlets. With two 61 × 61 cm. (24" × 24") filters per 0.61 meter (m) x 1.2 m (2 × 4 foot) box it was estimated that between 0.37 to 0.47 m^3/sec (800 to 1000 cfm) of airflow could be delivered per inlet.

Summary

After the filtration system was installed and additional fans added, the ventilation rate per boar was approximately 0.10 m^3/sec (220 cfm) per housed boar. Even though a ventilation rate of 0.12 m^3/sec (250 cfm) per boar was not achieved, the high pressure atomizer cooling system that was added keeps the stud at satisfactory temperatures during hot weather conditions.

At this point in time there has been no reoccurrence of PRRS in any of these boar stud facilities. Overall, the ventilation system has performed satisfactorily with the addition of filtration. Boar comfort and productivity has been maintained as well as worker comfort.

2800 sow unit

Objectives of the project included:

- Filter all of the air entering the breeding/gestation, farrowing, and isolation rooms from the air inlets and cool cells
- Keep airflow rates to less than 0.06 m^3/sec (125 cfm) per square foot of filter area
- Keep cool cell flow rate at 0.18 m^3/sec (375 cfm) per square feet at maximum fan output
- Keep the maximum static pressure the fan sees to around 50 Pascal's (0.20 inches) w.g.
- Seal all entry possible points
- Minimize costs if possible.

Gestation facility filtration

The filtration system for the gestation facility was based on 2600 sows, forty four 2.0 m^3/sec (4300 cfm) ceiling inlets, twelve 61 cm. (24-inch) pit fans (Aerotech AT24CZP), four 66 cm. (26-inch) wall fans (Aerotech VX26F1CR), and eighteen 130 cm. (51-inch) fans (Aerotech VX511F1CR). The total ventilation capacity (**Table 1**) of these fans without filtration at 25 Pascal's (0.10 inches) w.g. is 253.6 m^3/sec (543,400 cfm). With filtration at 50 Pascal's (0.20 inches) of static pressure, the ventilation rate will be cut to 198.7 m^3/sec (420,000 cfm). This would be the equivalent of cutting out 5 of the 6 fans in the final stage, fan bank 6. Endwall cool cells included a 1.8 x 20.7 meter (6' × 68') and 22 m. (72') units and sidewall cool cells included two 1.5 m. (5') × 7.9 m. (26') and 9.2 m. (30') units.

The initial phase of this project was to provide air inlet filtration during cold and mild weather operation. Eight 61 x 61 cm. (24" x 24") filters for 3 square meters (32 square feet) of filter area were needed to provide 1.9 m^3/sec. (4000 cfm) of capacity per inlet. Since the trusses are 1.2 meters (4') on center, there was a need to cut back on filter area by using 50.8 x 61 cm. (20" x 24") filters on one side to make sure the box fits between the trusses. This reduced inlet capacity to 1.7 m^3/sec (3670 cfm). Total ventilation capacity through the ceiling air inlets at 50 Pascal's (0.20 inches) became 75 m^3/sec (161,480 cfm) or approximately 0.28 m^3/sec (60 cfm) per sow. What this meant was airflow through the cool cells at lower outdoor temperatures. The advantage of pulling air through the cool cells is it optimizes the lower stages fan performance by reducing static pressure. The disadvantage is the sows on each end could be chilled.

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Table 1: Stages of fan operation

Static pressure	25 Pascal's (0.10 in.)	37 Pascal's (0.15 in.)	50 Pascal's (0.20 in.)
Stage1:12-61 cm. fans	31.4 m^3/sec. (67,200 cfm)	29.1 m^3/sec. (62,400 cfm)	26.7 m^3/sec. (57,120 cfm)
Stage 2: 4-66 cm. fans	13.1(28,000)	11.6 (24,880)	10.0 (21,360)
Stage 3: 2-130 cm. fans	23.2 (49,800)	20.8 (44,600)	18.6 (39,800)
Stage 4: 4-130 cm. fans	46.5 (99,600)	41.6 (89,200)	35.8 (76,800)
Stage 5: 6-130 cm. fans	69.7 (149,400)	62.4 (133,800)	53.8 (115,200)
Stage 6: 6-130 cm. fans	69.7 (149,200)	62.4 (133,800)	53.8 (115,200)
Total Ventilation	253.6 (543, 200)	227.9 (488,680)	198.7 (425,480)

Filtering the gestation building cool cells

A number of options were considered for this part of the project. Option one was to only filter part of the air until outdoor temperature reaches a certain point where the PRRS virus is not as viable and by-pass the filter system with some sort of air intake system. The problem with this method is we don't know what that temperature is and if it was worth the risk. Option 2 was to add push fans to compensate for the additional static pressure the filters created. If the designed filter area created 0.50 inches of pressure which would reduce the number of filters needed by one half, the number of push fans necessary to generate 233 m^3/sec (500,000 cfm) of airflow would be fourteen 7.5 hp 122 cm. (48-inch) fans (Greenheck). This option was not chosen because the service would not be able to handle the number of fans and horsepower required. Option three was to filter all of the air entering the unit and this was the option chosen for this project.

Adding the up the amount of area for the 6 cool cells came to a total area of 130.2 square meters (m^2) [1400 square feet (ft^2)]. At 0.18 m^3/sec (375 cfm) per 0.093 m^2 (1.0 ft^2) of cool cell the total ventilation rate is 245 m^3/sec (525,000 cfm), which did not match up with the total overall fan capacity at 50 Pascal's (0.20 inches) of static pressure. At the 0.18 m^3/sec (375 cfm) rate a 1.8 m. (6') high cool cell will require a minimum of 6.1 m. (20 linear feet) of filter length based on a m^3/sec rate of 0.53 m^3/sec (112.5 cfm) per 0.093 m^2 (1.0 ft^2) of filter area. A 1.5 m. (5') cool cell will require 4.9 m. (16 linear feet) of filter per 0.305 m. (1') of cool cell.

Farrowing units

The farrowing filtration system was based on 16 rooms of 30 crates each, seven 0.56 m^3/sec (1200 cfm) air inlets in each room, one 40.6 cm. (16-inch) fan (Aerotech AT16Z) and three 61 cm. (24-inch) fans (Aerotech AT24ZCP). Each air inlet was to be filtered with two 61 × 61 cm (24" × 24") filters at 0.23 m^3/sec (500 cfm) per filter for a box size of 0.61 × 1.2 m. (2' × 4'). At 50 Pascal's (0.20 inches) each inlet should deliver approximately 0.47 m^3/sec (1000 cfm) of air flow or 0.11 m^3/sec (233 cfm) per sow for the seven inlets. The rooms were evaporative cooled with four 1.2 × 15.9 m. (4' × 52') cool cells. Total ventilation rate per room at 25 Pascal's (0.10 inches) was 9.2 m^3/sec (19,720 cfm) or 0.31 m^3/sec (657 cfm) per sow. Having 4 rooms on each cool cell resulted in a flow rate of 0.18 m^3/sec (379) cfm per 0.093 m^2 (1sq. ft.) of cool cell. Using that number also resulted in a flow rate of approximately 0.7 m^3/sec (1500 cfm) per 0.305 m. (1') of cool cell. Adding 4.3 m. (14 ft.) of filter area per running foot of cool cell will have a delivering rate of 0.05 m^3/sec (107 cfm) per 0.093 m^2 (1 sq. ft.) of filter. In the case of the farrowing rooms there are three pressure points, the filters, cool cell, and the through the wall inlets. If the static pressure is at 50 Pascal's (0.20 inches), fan capacity drops to 7.8 m^3/sec (16,770 cfm).

Summary

Overall, the gestation facility required a total of 1500 filters and pre-filters with frames and 484 m^2 (5200 square feet) of building extensions beyond the cool cells. The farrowing facility required 952 filters and pre-filters and 321 m^2 (3456 square feet) of building extensions. The isolation unit required 264 filter assemblies and 90 m^2 (972 square feet) of extensions beyond the cool cells. The total cost of this project to provide complete air filtration came to approximately $650,000. It was decided by the Board of Directors not to pursue filtration at this time.

References

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