THE DESIGN OF A PRESSURE VENTILATION SYSTEM FOR THE NUTRITION PIGGERY BARN

Report of Project for Course 336-490D

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TABLE OF CONTENTS

LIST OF APPENDIX I FIGURES

LIST OF APPENDIX II TABLES AND GRAPHS

LIST OF ABBREVIATIONS

A	area
Btu	British thermal unit
cfm	cubic feet per minute
cp	specific heat of air
cu.ft.	cubic feet
ft^2	square feet
ft	feet
°F	degree fahrenheit
hp	horsepower
hr	hour
in	inch
lbs	pounds
Ma	Q/V
min	minute
ph	measure of hydrogen ion concentration
Q	ventilation rate
qs	sensible heat
R	insulation value
RH	relative humidity
Δt	temperature differential
V	specific volume of dry air
W	specific humidity
%	percentage

GLOSSARY OF TERMS

Ambient Temperature: The temperature of the medium surrounding a body or system.

Condensation of Vapour: Change of vapour into liquid. Takes place when the pressure of the vapour becomes equal to the maximum vapour pressure of the liquid at that temperature.

Conduction: Heat transfer between bodies in direct contact, because of a temperature difference, and without gross movement of the material.

Convection: Heat transfer which occurs when particles of a fluid mix with lower or higher temperature particles. Natural or free convection may result from differences of density caused by temperature differences.

Dry Bulb Temperature: Temperature measured with a common thermometer or thermocouple.

Enthalpy: The heat energy content of an air-vapour mixture.

Metabolic Heat Production: The minimum rate of heat production

GLOSSARY OF TERMS (contd)..

	while an animal is fasting and resting and subjected to effective environmental temperatures in the thermoneutrality zone.
Latent Heat:	The heat required or released when a material changes phase without a change in temperature.
Radiation:	The exchange of thermal energy between objects by electromagnetic waves. The rate depends upon their temperature and the nature of their surfaces.
Relative Humidity:	The ratio of the actual water vapour pressure to the vapour pressure of saturated air at the same temperature.
Specific Humidity:	The weight of water vapour in lb/lb of dry air. The base of one pound of dry air is constant for any change of condition, making calculations easier.

GLOSSARY OF TERMS (contd)..

Specific Volume:	The specific volume of a gas or mixture is the space occupied by a given mass. The volume is in cubic feet of mixture per pound of dry air. The base of one pound of dry air is used because the pounds of dry air entering and leaving an air-conditioning unit in a given time are constant after steady-state flow is established.
Sensible Heat:	A measure of the energy which accompanies a temperature change.
Total Heat Production:	The heat production from animals in two forms: sensible heat, transferred by conduction, convection and radiation; and latent heat transferred by evaporation of moisture from lungs and body surfaces.
Wet Bulb Temperature:	Temperature measured with a common mercury thermometer, with the bulb or junction covered with a water-moistened wick and in a moving stream

GLOSSARY OF TERMS (contd)..

of ambient air. Evaporation of water cools the bulb; the drier the surrounding air the greater the rate of evaporation and the lower the wet bulb temperature.

ABSTRACT

~~Evaluation of~~ the pressure ventilation system in the nutrition piggery barn was ~~made~~ evaluated to check for moisture, dust and odour problems. Ventilation requirements, fan capacities and location for distribution were verified.

Recommendations were made to improve dust and moisture control. This includes the building and relocation of a new fan-jet distribution channel.

No constructive measures have been specified for odour control. Pending construction of the fan-jet system, tests should be performed to study air circulation and odour problems.

abstract should contain "what was done" material only.

INTRODUCTION

With the trend towards reducing labour and increasing profits by mass producing in confined areas, ventilation equipment has become of premier importance to the swine grower. The best possible controlled environment is needed to adjust the feed conversion rate or rate of gain to optimum value because feed costs for hogs are by far the largest part of the maintenance expense. The feed costs are roughly 80% of the total cost of growing swine.

The primary consideration ~~of~~ m a winter ventilation control system is to conserve heat while removing moisture and objectionable odours. What is needed is a comfortable and healthy climate during the day and night. The system must be capable of maintaining the desired uniform temperature and relative humidity, with no drafts and no sudden changes in temperature.

REVIEW OF LITERATURE

Due to the industrialization of agriculture in the past several ~~years~~ decades, much research has been done to increase the feed efficiency of animals. The basic justification of the animal shelter is to increase growth, production and health. Many different types of shelters have been designed to balance economy and production but this has been greatly improved with the introduction of ventilation to control the environment.

Three basic requirements for conditioning air are; an insulated structure, a controlled fan system to move the right amount of air, and an inlet system of appropriate size and location to give reasonable distribution of air. These facilities can be arranged to operate by two different methods known as a positive or negative pressure system. Under the positive pressure system, air is drawn into the building by an intake fan and exits through outlets due to a positive indoor pressure. ~~Just the opposite,~~ Conversely, under the negative system, air is drawn out of the building by an exhaust fan and enters freely through inlets due to negative indoor pressure. Once the pressure convention is determined, ventilation control systems can vary in the amount of control provided to accommodate the extreme range of duirnal and seasonal climate. But usually a system is designed to operate under winter or summer conditions. The system can differ in number of fans that run either continuously or intermittently under variable speeds.

There are many factors which must be considered (theoretically and practically) in ventilation design. The following will be a brief discussion on each of the major individual factors to give an indication of the previous work done concerning them.

Temperature.

Air temperature is acknowledged to be the single most important environmental factor in heat loss. Increasing temperature, decreases feed consumption and reduces the rate of gain, but not necessarily the feed efficiency above 70°F. If the temperature drops below 48°F, however, the reduction in daily gain becomes significant. The optimum temperature for feed efficiency is 70°F, but the difference between 60°F and 70°F is not pronounced enough to warrant conditioning of the environment for optimum temperature. And, as with average daily gain, the difference in feed efficiency between 50°F and 60°F is highly significant. This is true for all animal sizes. Thus swine housed at colder air temperatures utilize more energy for body temperature regulation than that used at 60°F.

Bond et al[7] studied the effect of ambient temperature on hogs of different weights, (from 40°F to 100°F). - put in separate short sentence. Relative humidity was kept at 50% and air velocity at 20-30 ft/min. The weights and temperatures were correlated on a graph to give total heat lost from hogs in Btu/hr.

Beckett[7] constructed a partitional heat loss diagram based on air temperature, skin temperature and amount of air exhaled by the lungs. The relative humidity was again held at 50% but the temperature varied ~~at a high range~~ between high values: 80°F to 100°F. From this diagram, the five different types of heat loss can be estimated. These are radiant, conductive, convective, perspiration (skin latent heat loss), and lung heat loss. The overall heat balance equation under steady state conditions is as follows:-

Total heat lost = skin latent heat loss ± convection loss ± conduction loss ± radiation loss ± lung heat loss.

how ±? heat loss can only be +.

Swine effective temperature and the amount of air breathed with time indicate animal discomfort regardless of how it is produced. Skin temperature and total metabolic heat production also increase with rising temperatures but the respiration rate only increases above 70°F.

In general, temperature increases cause higher ventilation rates, oxygen consumption, and heart rate than any other environment factor increase.

Humidity.

Animals produce moisture through perspiration, breathing, wastes and spilled water. In addition to the effect on production, this moisture hampers the buildings operation and the control of disease. As with temperature, increased humidity decreases feed consumption but not necessarily feed efficiency at high temperatures. Relative humidity has little effect on swine effective temperature at 80° F but above 90° F, its effect is pronounced.

In winter, a minimum continuous ventilation rate should operate for the removal of moisture from the building.

Materials and Insulation.

The materials used in construction and insulation are crucial for the effective preforarnce of an air conditioning system. Inside surfaces of walls and ceilings are kept warmer so condensation will not occur. This condition for no condensation is influenced by the outdoor temperature, indoor temperature, and indoor relative humidity.

Insulation reduces the heat flow through walls and ceilings and thus, higher temperatures are maintained in the building. As an indirect effect, more air can be moved through the building to lower the moisture and odour levels.

If intake air enters through porous insulation and ceilings are equipped with a porous permeable material, heat loss is reduced and moisture is effectively dissipated. Vapour barriers are also used to prevent vapour from moving through walls. This prevents condensation from occuring in the insulation, an undesirable condition, because moisture ~~will~~ lessens a material's insulating value.

Fans and Inlets.

Low air velocities in agricultural structures lead to confusion about air movement and difficulty in ventilation design. Both the fans and the inlets must function simultaneously to achieve the desired effect within the building.

Fans should be selected, with the dealer's guarantee of ~~perforance~~ performance, to operate at one-eighth inch of water pressure. This is approximately two-thirds to three-quarters of the free air delivery. They should be placed in the upper one-third of the wall on the leeward side. Shutters can be installed to prevent back drafting. Hoods enable air to be exhausted more efficiently into prevailing winds and prevent freeze-ups in winter. The fans should be cleaned and serviced regularly.

Inlets must be adequate in size and location. They should be larger in summer and smaller in winter. Drafts can be avoided when located properly. Air is usually deflected downward in summer to allow the fresh, cooler air to reach the animals as quickly as possible with a minimum of mixing. In the winter, the air is deflected along the ceiling to allow mixing with warmer air before coming in contact with the animals. Attic inlets can also be considered, allowing ~~to allow~~ recapture of heat lost through the ceiling in winter. This should be accompanied, however, by continuous air exhaust to prevent back drafting of warm, moist air to the attic. Another criteria, for the proper placement of inlets to ensure even air distribution, is that their location should ~~be considered to~~ prevent outside wind pressure from affecting the amount of air entering the building. This can also be accomplished by the indirect entry of air through the attic.

Fans and inlets must be designed and installed in order to control air velocity in the structure. Bond _et al_[8] have concluded that as the air velocity is lowered, the animals' weight will increase on less feed. There is also, no advantage in using more than the minimum air flow over an animal if the air temperature is lower than 96°F in the building.

Of the different modes of heat transfer, increased air velocities affect radiation and convection ~~the most~~, but pulse and respiration rates have been shown not to be affected at all.

In general, varying of the air velocity causes errors in the use of published swine heat and moisture data.

Controls.

~~The~~ Controls are essential to the succesful operation of the system. They govern the ventilation rate under a variety of conditions ranging from severe, to normal, to mild. The controls should allow a minimum amount of air to be moved in the winter. The procedure for this is to run a small fan of approximately one-quarter the winter ventilation rate continuously. The other fans turn off when the inside temperature drops below a minimum level and turn on when the inside temperature reaches approximately 65°F. The fan and heater controls must be interlocked to prevent exhausting supplemental heat in winter or producing extra heat in summer.

Louvers or timers can be used to regulate the air flow, or an intake control can be used that automatically adjusts the opening according to negative pressure. The most common control is the thermostat. It can control both the heater and the fans quite simply. A heating and cooling thermostat should be obtained with a built-in differential. The differential is usually about 2 degrees fahrenheit.

Placement of the thermostat must be carefully considered to allow it to sense the average temperature, free from possible physical damage. It is usually placed in the middle of a building (up to 30ft wide), midway between floor and ceiling and free of all incoming air inlets.

The protection of the control from corrosion is another problem that researchers are attempting to solve. It must have access to the ventilated air in order to determine the average temperature, and must also be ventilated ~~for~~ heat and moisture. Heat and moisture ~~problems are~~ worst in control boxes. But the controls must be sufficiently enclosed to keep insects and dust out. Thermostats are preferred over humidistats because of their reliability, low cost, and ruggedness.

<u>Dust</u>.

Dust particles are not only harmful to the sense organs of humans and animals but also cause problems in operating commercial cooling or heating equipment in a severely dust-ladened atmosphere.

A gel is formed from the condensation organic substance secreted by swine, when combined with dust and water which contains ammonia absorbed from the air in the hog environment. This gel has a high ph and corrodes aluminium fins on fans or humidifier coils, causing restricted air flows.

Fin space can also become plugged by the accumulation dirt.

Tests have been conducted on air filters and electronic air cleaners to eliminate the dust. If there is ammonia in the air, it is a wise practice not to recycle it over coils if possible.

In most piggerys, however, the moisture ventilation rate is assumed to be sufficient to control dust. This does not always produce the desired results.

Enthalpy.

Attempts have been made to combine temperature and humidity into one variable, enthalph. This would simplify calculations because there is a linear relationship between air enthalpy and heat loss. Heat removed by the lungs is equal to the difference between enthalpy of exhaled air and inhaled air.

Water sprinklers.

Water sprinklers have been used during the summer months and in warmer climates to reduce the discomfort level of swine at high temperature. It has been shown that hogs in hot atmospheres showed marked reductions in respiration rates when cooled by skin wetting.

Floors.

Floor types have a major effect on ventilation. The ventilation rate for slotted floors can be reduced below that required to prevent condensation in a concrete floor house, because of reduction in evaporation of moisture from the slotted floors as compared to concrete floors. Slotted floors require approximately 40% less ventilation for moisture than concrete floors. In general, the reduction of moisture to be removed is directly proportional to the amount of floor slotted.

Slotted floors also improve the cleanliness of animals and pens.

Heated floors do not alter production significantly, especially when bedding is used. With no bedding used, between 40°F and 60°F, heat lost by conduction, mainly to the floor is approximately 12%.

The preceding has been a summary of the major points of past work concerning the environmental factors involved in livestock ventilation design. These must be interelated with non-environmental factors, such as animal activity, quantity and type of feed, body weight and age of animal, in the actual design.

OBJECTIVE & SCOPE

The purpose of the report is to design a pressure ventilation system to recommend alterations to the existing system in the nutrition piggery barn.

The scope of the project is to rectify the moisture and odor problems. From observations at the piggery, the moisture problem would appear to be confined to the entrance of the Fan-Jet ventilation tube and not to the floor, ceiling, or walls (except at inlets during very cold weather). Also, a solution must be found for the dust accumulation in the Fan-Jet tube.

PROCEDURE & CALCULATIONS

Number of finishing swine = 250

Average weight per swine = 120 lbs.

Inside conditions desired (75% R.H.
(60° F

Outside temperature varies from -10° F to 40° F

Outside R.H. = 100%

Latent heat = 200 Btu/hr-hog

Total heat = 504 Btu/hr-hog

sensible heat = Total heat - latent heat

= 504 - 200

= 304 Btu/hr-hog

Moisture Calculations

$$\text{Moisture (from swine)} = \frac{200 \text{ Btu/hr latent heat}}{1036}$$ per hog ?

$$= 0.19305 \frac{\text{lbs water}}{\text{hr - hog}}$$

$$= 48.26 \frac{\text{lbs water}}{\text{hr}}$$

The value 235 Btu/hr is for solid concrete floors so no additional allowance is needed for water being evaporated.

Sample calculation: (ventilation rate at 50° F)

at 40° F, 100% RH outside, W_1 = 0.0053 lbs water/lbs dry air

at 60° F, 75% RH inside, W_2 = 0.0084 lbs water/lbs dry air at 60°F, 75% RH inside, V = 13.55 cu ft/lbs dry air

$$Q = \frac{V}{60} \times \frac{W}{W_z - W_1}$$

$$= \frac{13.55}{60} \times \frac{48.26}{0.0084 - 0.0053}$$

$$= 3516 \text{ cfm}$$

Similar calculations for other outside temperatures yield the following data:

Temperature	Ventilation Rate (moisture)
40°F	3516 cfm
30°F	2224 "
20°F	1758 "
10°F	1557 "
0°F	1434 "
-10°F	1380 "

Heat Calculations

Heat (from swine) = (304 Btu/hr sensible heat) x (250 head)

$$= 76{,}000 \ \frac{\text{Btu}}{\text{hr}}$$

Building dimensions

Length	= 116 ft
Width	= 32 ft
Wall height	= 7.5 ft
Linear feet of wall	= 296 ft
Ceiling area	= 3712 ft^2
Wall area	= 2220 ft^2

Ceiling area + Wall area: Total area = 5932 ft^2

Insulation material (ceiling)	Thickness (inches)	R value
Glass fiber insulation	3	11.10
Asbestos board	1/8	0.03
Plastic vapor barrier		0.90
Inside surface condition		0.61
Outside surface condition		0.17
Total R value for ceiling		= 12.81

Insulation material (walls)		
Slag block	8	1.73
Portland cement mortar	$\frac{1}{4}$	0.02
Polystyrene foam insulation (Styrospan)	$1\frac{1}{2}$	6.63
Portland cement plaster	3/4	0.53
Inside surface condition		0.68
Outside surface condition		0.17
Total R value for walls		= 9.76

Assume no heat lost through inlet is zero.

R total for building = 22.57

$$\frac{A}{R} = \frac{5932}{22.57} = 262.8 \text{ Btu/hr - }^{\circ}F$$

Sample calculation: (ventilation rate for heat at $40^{\circ}F$)

$$Q = \frac{V}{14.4\ (\ t)} \quad qs - \frac{A}{R}\ (\ t)$$

$$= \frac{13.55}{14.4\ (60-40)} \quad 76{,}000 - 262.8\ (60-40)$$

$$= 3328 \text{ cfm}$$

Similar calculations for other outside temperatures yield the following data;

Temperature	Ventilation Rate (heat)
$40^{o}F$	3328 cfm
$30^{o}F$	2137 "
$20^{o}F$	1541 "
$10^{o}F$	1183 "
$0^{o}F$	945 "
$-10^{o}F$	774 "

The actual ventilation rate must meet the maximum demand, which is the moisture removal requirements within the range $-10^{o}F$ to $40^{o}F$. (See Figure (1)0. Since the curves for heat and moisture do not intersect for this temperature range, supplemental heat is required continually.

<u>Calculation of Supplemental Heat Required</u>

At $-10^{o}F$ outside, 1380 cfm of outside ventilation air is heated from $-10^{o}F$ to $60^{o}F$. The hog sensible heat warms 774 of the 1380 cfm to $60^{o}F$; supplemental heat warms the other 701 cfm.

Specific volume = V = 11.33 cu ft/lb

q = amount of supplemental heat needed

$$q = Ma\ Cp\ \ t = \frac{Q}{V}\ cp\ \ t = \frac{701\ ft^3}{min} \times \frac{lb}{11.33\ ft^3} \times \frac{0.24\ Btu}{lb^{o}F} \times (60-(-10))^{o}$$

$$= 1040\ Btu/min$$

$$= \underline{62,366}\ Btu/hr\ \text{ at } -10^{o}F \text{ outside}$$

The heating system in piggery consists of two Peerless propane gas heaters. One heater is located on the east end of the piggery and the other on the west end. They are capable of supplying 60,000 and 52,500 Btu/hr of output heat respectively.

Therefore, the requirement of supplemental heat can be easily met by the combined capacity of both heaters.

The higher capacity heater is in the east end, because the wall at that end is directly exposed to the atmosphere, whereas on the west end there is an extension of the barn for feed storage and slaughtering facilities. The east end is also cooler because of air entering around the two doors and that which comes in through the exhaust outlet when the fan is not running. This has led to the closing of the inlet along the wall nearest these openings.

Fan Capacity

Once the amount of ventilation required has been determined, the capacity of the fans in the piggery must be checked to ensure functionality of the system. 'if the system will operate according to design'?

There are three small exhaust fans of 12 inch diameter located along the south wall. Each of these fans has a capacity of 1100 cfm. Their total combined capacity of 3300 cfm is sufficient for the ventilation rate up to approximately 40°F.

There is also a Jamesway air distribution system, consisting of a motorized inlet shutter, weather hood, a six-bladed fan of 18 inches in diameter, directly driven by a $\frac{1}{4}$ horsepower electric motor, and a 99 foot long by 18 inch diameter distribution tube with 3 inch holes in both sides at intervals of 3 feet. The intake capacity of this fan-jet system is 3120 cfm at 1/8 inch static pressure. The exhaust fan connected to the fan-jet system is run by a $\frac{1}{2}$ horsepower electric motor and is 24 inches in diameter. Its capacity is 4725 cfm. (All above mentioned capacaties are at 1/8 inch static pressure). Therefore, the capacity of the fan system in the nutrition piggery barn have obviously been designed for the higher summer ventilation requirements, and,using the proper controls, could be adapted to the winter ventilation rates.

DISCUSSION

Since the barn is almost completely separated by an insulated wall, the fans in each section should operate to remove one-half of the moisture in the building.

Let both fans run continuously in the west end of the piggery until the temperature drops to approximately 30°F. Then turn fan Number 2 off. (See Figure 3). This is done manually.

In the east end, the small 12 inch fan should be run continuously, and the large exhaust fan should be set to turn on by thermostatic control at 30°F. When this large exhaust fan goes on, the inlet shutters open and fresh air is blown through the tube. Otherwise, when the fresh air is not entering, the fan-jet system runs continually to circulate the air within the barn. This is also the method used to circulate the supplemental heat produced by the gas heaters at both ends of the barn. The heaters can be controlled by the same thermostat as the fan-jet exhaust fan, and will turn off as the exhaust fan is turned on at 30°F. Although, Figure (1), supplemental heat is needed up to 40°F, the amount becomes quite small after 30°F. Also, it is very expensive to heat the building when the large exhaust fan is on.

The minimum continuous flow is necessary because when none of the fans are operating, air comes in the inlets and moisture vapor in the air condenses and freezes, clogging the inlets. Then, when the fans come back on, velocities are too high. This causes severe turbulence which is not desired during the winter.

There are a total of thirty-one inlets located on the north and south walls. These inlets are 4 feet long and 1 inch high. The configuration is as shown in Figure (2). The inlets are the key to good air distribution because they supply the air uniformly in the building, to be circulated by the fan-jet.

The nutrition piggery barn has a combination of both positive and negative pressure systems. The small, continuously running fans are an example of a negative pressure system and the fan-jet is a positive pressure unit. This is a suitable arrangement to ventilate and circulate air except that the exhaust fan on the fan-jet unit is located within a few feet of the intake fan. This allows the air with a high moisture content, which has just been expelled, to re-enter the building. This could be an additional factor in causing excess moisture at the intake fan. If the fan-jet intake were located at the other end of the building, on the ceiling, it would reduce the effect of high moisture containing air being drawn in and would also help to recapture some of the heat lost through the ceiling. This method has further justification when considering literature which recommends an R value for the ceiling of 10 to 20. The piggery's ceiling R value has been calculated at 12.81. The attic receives ventilation air through the slot inlets along the north and south walls and through 2 large inlets on the east and west ends.

The problem of dust accumulation in the tube is difficult to eliminate but the removal of the intake to the west end will reduce the problem. The cleaning of the tube is a difficult task at the moment because it must be disconnected to remove the dust. If a rectangular plywood air channel were constructed, with hinged openings on the bottom, the dust could be quickly and efficiently removed. With this alteration the accumulation of dust in the wooded air channel and the recirculation of some of it back into the piggery could be controlled.

The plywood air channel could be constructed with the same length and volume dimensions as the plastic tube. Three inch holes on each side, at three foot intervals, could be drilled. The air channel should be insulated to eliminate the moisture condensation at the entrance completely.

The odor problem in the piggery is mainly due to a large defecation area used by the pigs in each pen. The gutter is midway between the wall and the front of the pen leaving one-half of it continually wet with wastes and spilled water. Without time consuming removal of these wastes, the odor is hard to control on a solid concrete floor. The rearrangement of the fan-jet system, eliminating the recirculation of expelled air, should improve this problem. At the moment, I recommend no construction be undertaken to alter the floor in the pens until the effect of the new fan-jet system can be evaluated.

The exhaust fan-jet capacity must be less than the intake fan-jet capacity. Since this is not the case in the nutrition piggery, the exhaust fan is thermostatically controlled. This system helps to control and balance the enviroment by circulating air without cold drafts. It is also not affected by outside wind pressure. For a better understanding of the air distribution patterns, see Figure (4).

CONCLUSIONS

1. Install new plywood air channel, with hinged openings at the bottom. Locate the intake fan's access to incoming air through the attic on the west end of the piggery.
2. Insulate the plywood channel.
3. Close the former intake entrance at the east end permanently.
4. No measures should be taken for odor control at this time.

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APPENDIX I

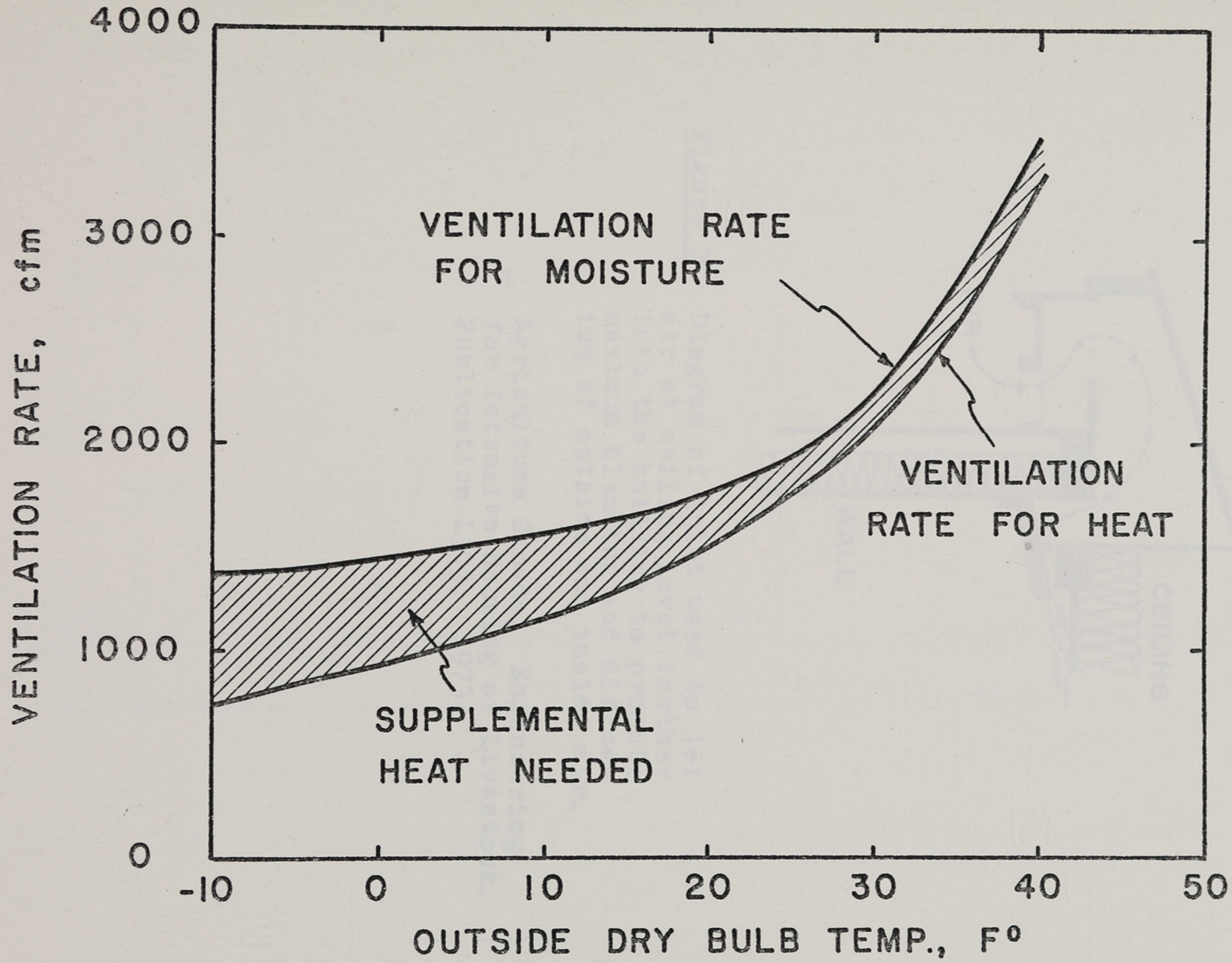

Fig. 1 Ventilation Curves

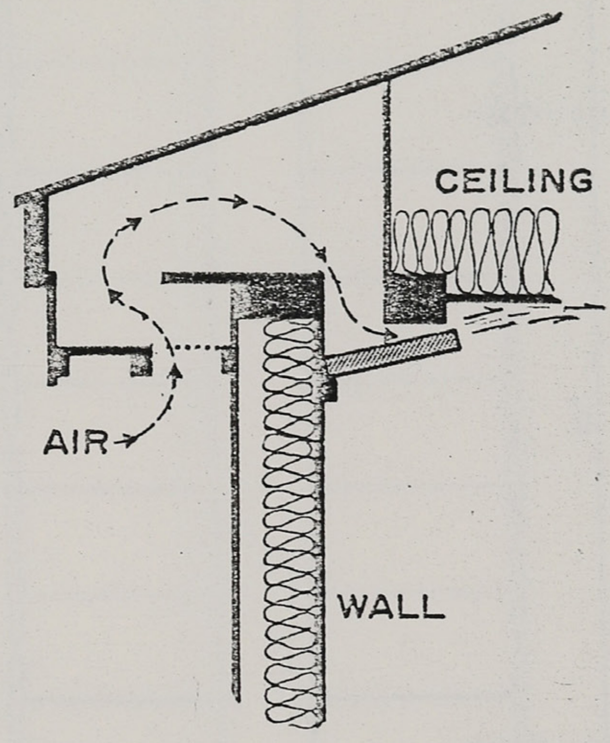

Figure 2 Diagram of inlet used to jet air at ceiling level farther into the building to promote maximum blending and diffusion of outside and inside air.

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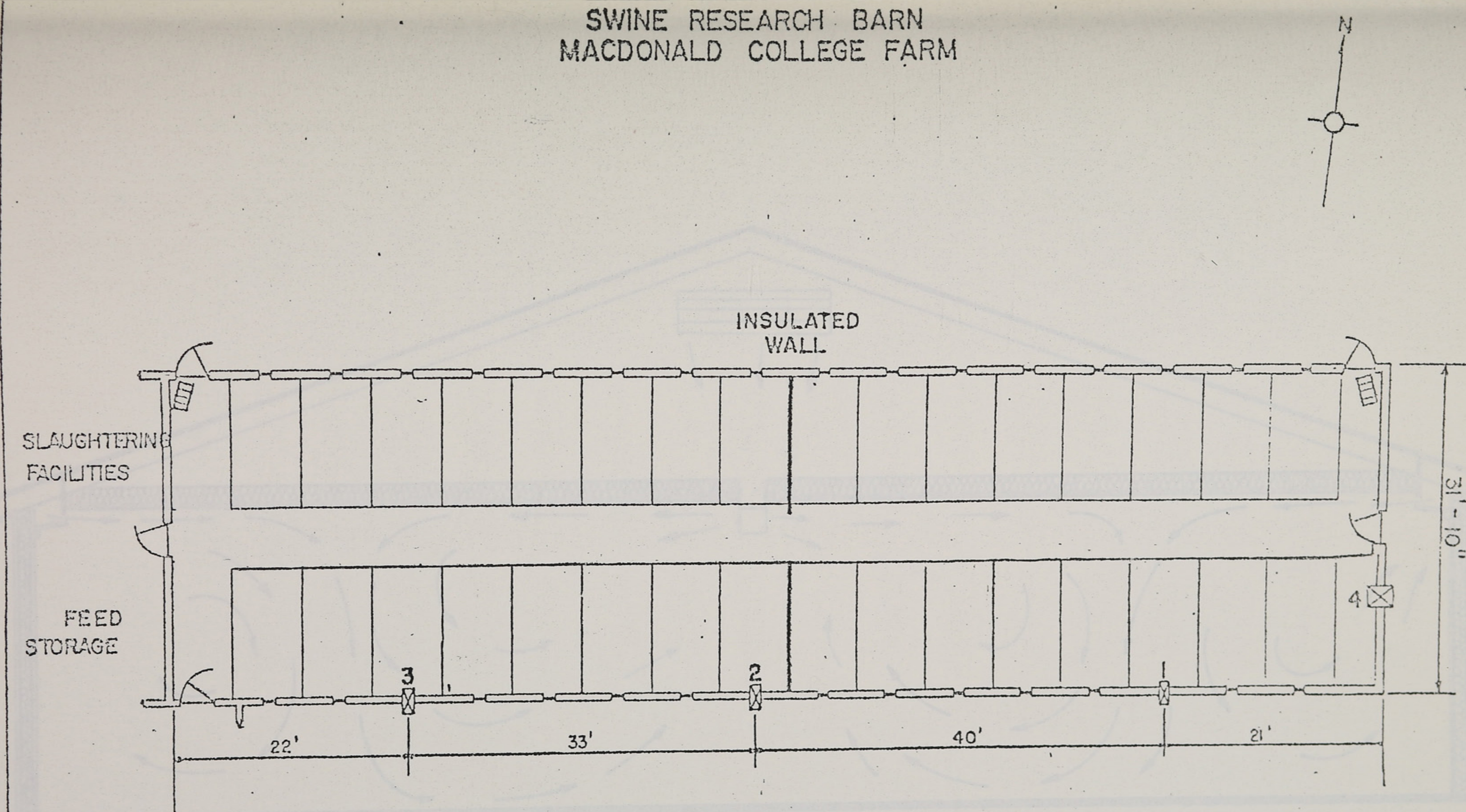


Figure 3 Floor plan of nutrrition piggery barn and exhaust fan location diagram.

— Marquis, Alfred, and Ogilvie, J. R., and Sabourin, H. , Experimental Study of Constant-Rate Winter Ventilation for Growing-Finishing Swine, CSAE paper no. 75-213.

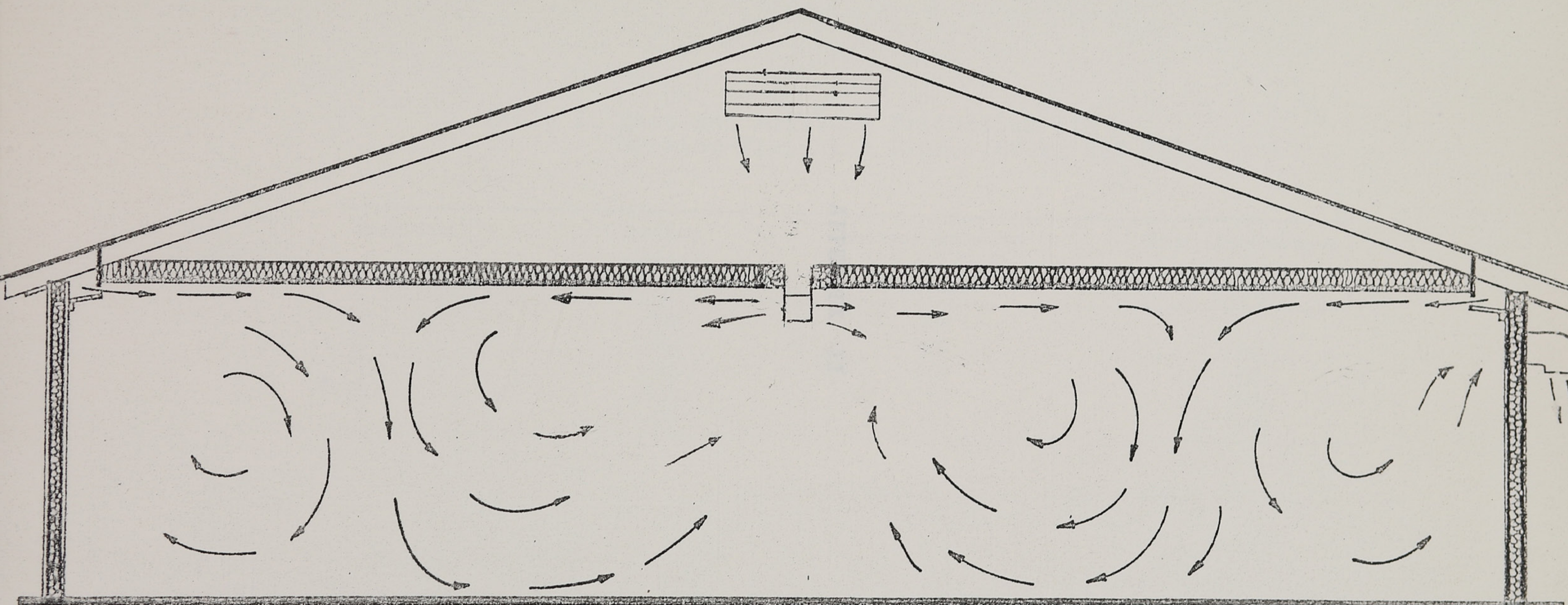


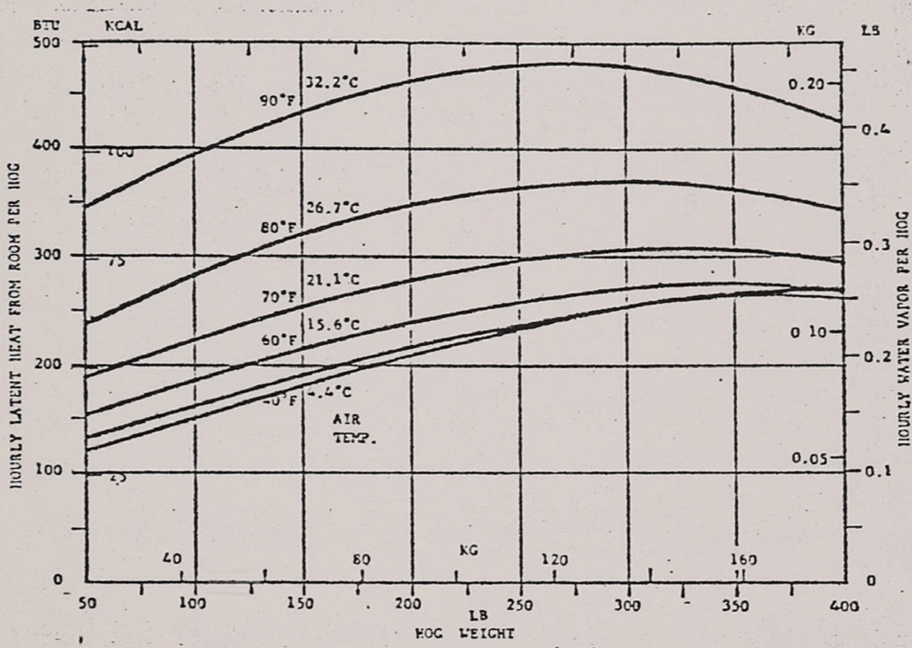
Figure 4 General Air Circulation Pattern.

APPENDIX II

Table I Heat and Moisture Production of Growing-Finishing Pigs. (AV WT I20 LB)

Room temp. (°F)	Total heat production (BTU/pig/hr)	Water vapor production with solid floors (lb/pig/hr)	Water vapor with floors 35% slotted (lb/pig/hr)
90	480	.396	
80	462	.285	.265
70	473	.222	.185
60	504	.186	.156
50	575	.165	.148

– Agriculture Canada, Confinement Swine Housing, Publication I451, I971.



Graph I Total Room Latent Heat From a Hog House with Solid Concrete Floors.

_ Esmay, Merle L., Principles of Animal Environment, The AVI Publishing Company Inc., Wesport, Connecticut, 1969.