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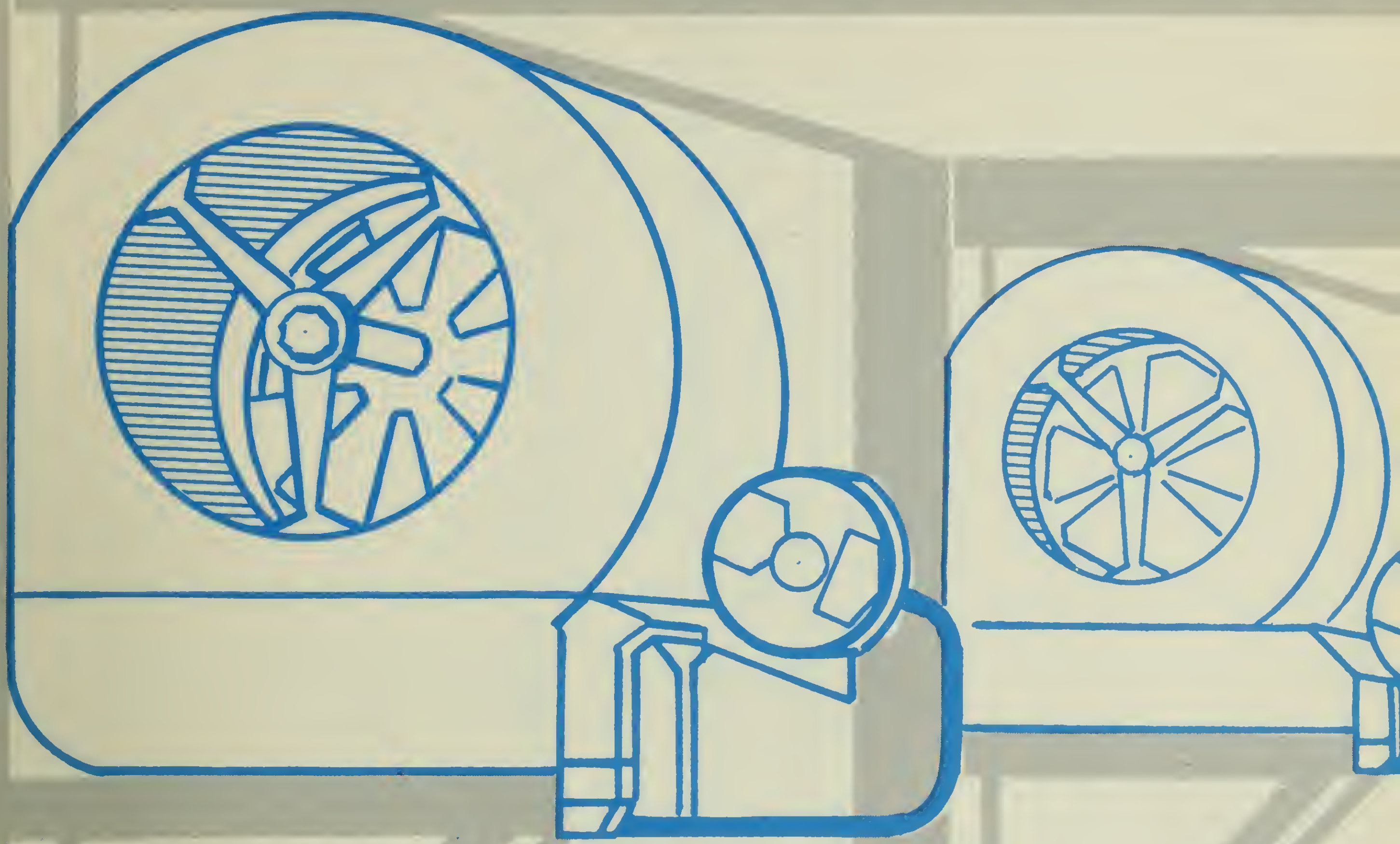



# Ventilation of Dairy, Poultry and Pig Buildings

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# VENTILATION of DAIRY, POULTRY and PIG BUILDINGS

Compiled by
C. G. E. DOWNING
Engineering Science Department
Ontario Agricultural College
and
W. R. MILNE
Agricultural Engineering Extension Service
Ontario Department of Agriculture

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## FOREWORD

In livestock buildings, proper ventilation and insulation can mean the difference between substantial profit and loss. Suitable practices are especially important to poultry or pig producers because they affect feed conversion, disease and cleanliness of eggs. Although the buildings are more expensive, the savings in feed alone can quickly pay for the extra cost.

Ventilation removes the water vapor produced by the livestock, reduces fluctuations in temperature, provides a fairly continuous supply of fresh air and makes the building last longer. Dairy cattle give off much water vapor in their breath, but they also produce a large amount of heat. You can use the heat to keep the stable warm and yet provide enough fresh air for ventilation during winter. Poultry and pigs produce little heat in relation to the space they occupy. Therefore, for poultry and pigs it is much more difficult to provide proper ventilation and to keep the temperature satisfactory unless you insulate the buildings well or provide supplemental heat.

Buildings lose heat through walls, ceilings, doors, and windows and in the ventilating air. Well-insulated ceilings and walls with properly installed vapor barriers are essential.

The amount of air needed for proper ventilation depends on the outside temperature, when the inside temperature is kept constant—the colder the outside temperature, the less air needed.

The best ventilating system for medium-sized to large units is a small fan and one or more larger ones. The small fan runs continuously and supplies as much air as is needed during coldest weather. The largest fans operate on a thermostat and keep inside temperature from fluctuating too much.

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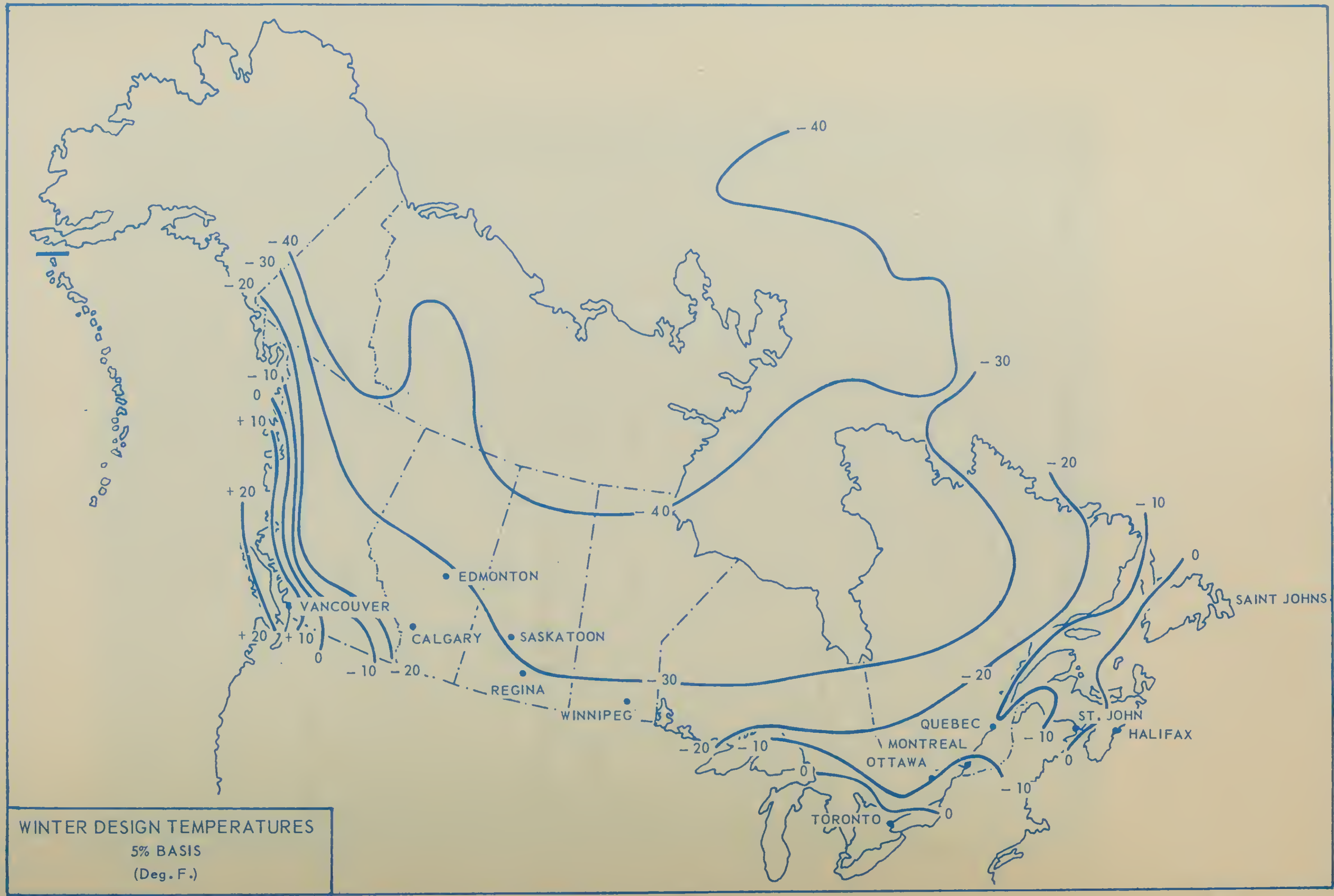



Climatic-zone map of Canada. Low winter temperatures in various areas of Canada.

## INTRODUCTION

This publication explains the principles of ventilation for livestock buildings, and provides information for designing ventilating systems. The sections on ventilation, insulation, and fans, air inlets and systems give general information on ventilating all types of livestock structures. Read these to gain a basic understanding of the problem. The sections on cattle, poultry and pigs give details on the ventilating systems and the recommended rates of ventilation for various outside temperatures. The map of Canada, opposite, shows minimum winter temperatures in the various climatic zones. When designing a ventilating system, check this map for the temperature conditions which exist in your area. Tables and examples of calculations are given in the appendix to guide you in making calculations for a specific installation.

There is no section on beef cattle. It is now common practice to house beef cattle in open-front sheds, in which a mechanical ventilation system is not normally needed. You may use the section on dairy cattle if you plan to house beef cattle in closed barns.

Because natural-draft ventilating systems are not efficient and are difficult to regulate, this publication deals only with fan ventilation. The widespread use of electricity on farms makes fan ventilation practical in almost every livestock area in Canada.

## VENTILATION

The interiors of many livestock buildings are hot and oppressive in spring and fall, and damp and cold in winter. Ventilation overcomes this by:

- Removing water vapor.

Figure 1. A beam in a dairy barn showing the effects of continual exposure to dampness.

- Reducing fluctuations in temperatures.
- Providing an adequate supply of fresh air.

A cow's breath, for example, is about 95° F. and is 90 percent saturated with water vapor. Unless this vapor is removed as it is produced, it condenses when it strikes a cooler surface. Frost on a window pane is a form of frozen condensation.

More important, perhaps, is the vapor that finds its way into the building materials and causes them to rot. Damp conditions in a barn may also contribute to wet litter, dirty eggs, pneumonia in calves, higher disease rates and many other problems.

Some buildings ventilate themselves because air passing through cracks in the buildings carries some moisture with it. However, the temperature then fluctuates almost as much inside as outside. Livestock production is affected by fluctuating temperatures as well as by high or low temperatures. Therefore, it is important to keep the air in a closed livestock building moderate and as uniform as possible.

Livestock need fresh air. When the air becomes stuffy because of high humidity, and contaminated with stale odors and ammonia, production drops. Ventilation supplies the fresh air necessary to overcome these conditions. A controlled ventilating system with proper air inlets maintains the inside temperature automatically.

Proper ventilation should be based on the moisture and heat produced by the livestock, the outside and inside temperatures and relative humidities, the type of building, and the amount of insulation and type of air inlets in the building.

The basic problem in ventilation is to hold enough heat in the building to keep the temperature uniform and warm up incoming fresh air, while exhausting the moisture-laden air. Normally, the only source of heat is that given off by the livestock.

This makes insulation most important, especially in pig and poultry buildings where the amount of heat produced by the livestock is small in relation to the space they occupy. In cold areas, you need to add considerable insulation to these buildings to have good ventilation.

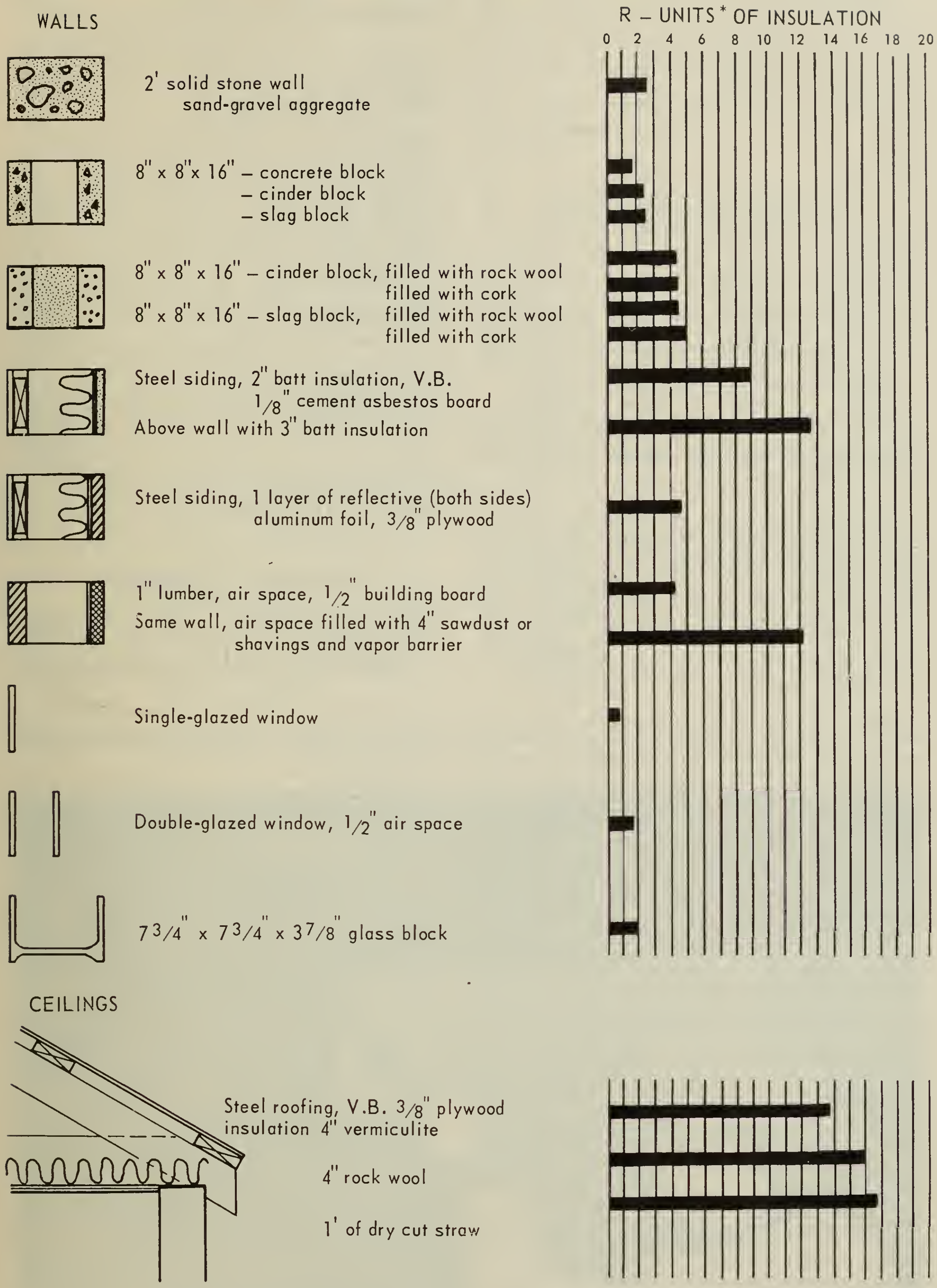
## INSULATION

Heat is lost from a building in many ways, but primarily by conduction through the walls and ceilings. To insulate a building properly, you must select the right insulating materials.

Chart 1 gives the units of insulation provided by various types of walls and ceilings. In the sections of the text on ventilating dairy-barns, pig-buildings,

Figure 2. A broiler house in which insulation was added to the roof to permit better ventilation.

Chart 1. — —Insulation Provided by Various Types of Walls and Ceilings




* See appendix for definition of R.

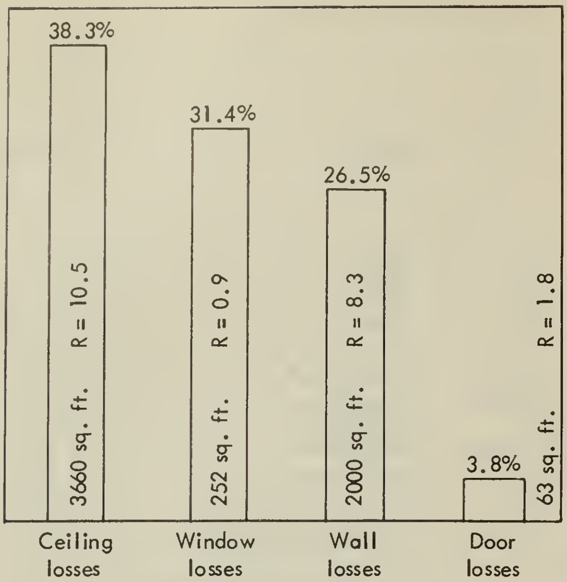



Chart 2. Total heat lost by conduction through various parts of an insulated laying house, 36 feet by 108 feet by 8 feet.

and poultry-houses, the units of insulation required are given. If a particular wall or ceiling is not included in the chart, you may calculate the value by using the equation for *R* in Appendix I.

Heat also escapes from a building through cracks around windows, doors and eaves. You can retain this heat by caulking and weatherstripping the cracks and openings.

Much heat is lost through windows. As shown in Chart 2, more heat is lost through 252 square feet of glass (single-glazed) than through 2,000 square feet of insulated wall. If the windows are double-glazed only half as much is lost, and in a windowless house most of it is kept. Therefore, keep the window area to a minimum and use either storm sash or double glazing. Many poultry and some pig producers are now building windowless houses.

## VAPOR BARRIERS

The insulating value of any material is reduced when the material is wet. In

Figure 3. Installing an insulated ceiling in a pig barn. The vapor barrier of polyethylene plastic is placed on the warm side of the insulation, between it and the interior sheathing.

fact, more heat may pass through a wall containing wet insulation than one with no insulation at all.

The water vapor in the air exerts a pressure. When more vapor is present in the air on one side of a wall than on the other, the vapor tends to travel through the wall from the wetter side to the drier side. This is the case in livestock buildings, where the inside air is very moist. The air cools as it passes through the wall, and the vapor condenses in the insulation.

A wet wall also shortens the life of a building, because the structure rots quickly.

You can stop moisture from entering the wall by placing a vapor barrier on the warm side (the inside) of the wall. Batts and blanket-type insulation already have vapor barriers, but since these are inadequate you should use a continuous vapor barrier over them.

Though some building papers are impervious to moisture, most are not. For this reason, do not use asphalt or tar building paper as a vapor barrier; use polyethylene plastic or aluminum foil instead.

If building paper is to be placed next to the outside sheathing, use a breather type of paper. If you use an impervious paper on the cold side of the insulation, any moisture in the wall cannot escape to the outside and will condense in the insulation during cold weather.

"Brick" siding of the roll or board types, when used as an exterior covering, acts as a vapor barrier and traps moisture and frost in the wall. To let this moisture escape, you must vent the stud space by drilling small holes at the bases of the studs. Otherwise, the wall will rot badly.

One of the major problems with materials such as rigid fiberboards is to prevent moisture from entering them and reducing their insulating value. Painting this type of material with two coats of aluminum paint is a great help but does not guarantee complete protection.

## VENTILATING SYSTEMS

Often the effect of a good ventilating system is lessened by the improper choice and location of a fan. Keep two points in mind when selecting a fan:

1. Select it on the basis of its capacity in cubic feet per minute (c.f.m.) rather than on its diameter. Two 16-inch fans powered by motors of the same size may vary in capacity by as much as 25 percent. The output depends on the pitch and diameter of the blade and the distance between the tips of the blades and the cowling.

2. The c.f.m. ratings should be based on a minimum of $\frac{1}{8}$-inch static pressure rather than on free air delivery (output when no resistance is offered to the flow of air). Fans usually work against pressure created by shutters, wind or a

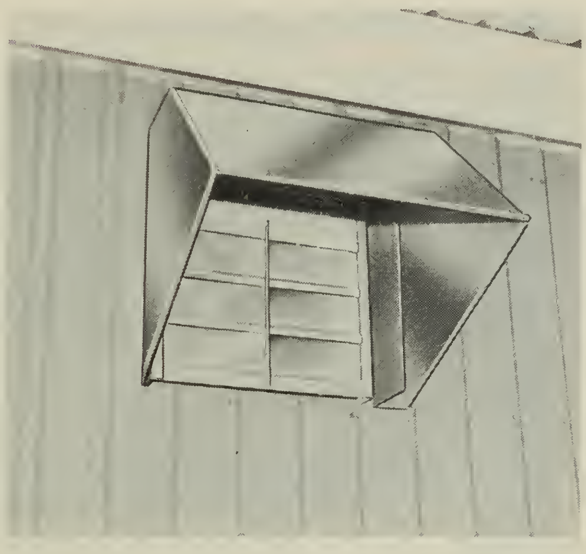


Figure 4. A hood to protect an exhaust fan from prevailing winds and a shutter to prevent backdrafting.

slight vacuum in the building, and must maintain the required output under these conditions. Literature on fans often gives the output at free air delivery, and these ratings may be as much as 25 percent higher than at $\frac{1}{8}$-inch static pressure.

Install the fans on the leeward side of the building if you can. However, if it is necessary to put them on the side facing the prevailing winds, protect them with hoods extending down over the fan openings. Always provide shutters to prevent back-drafting when the fans are not operating.

## TYPES OF FANS

The two main types used for ventilating systems are propeller and centrifugal fans. Each type has its particular advantages and disadvantages.

*Propeller type.*—Small-diameter, high-speed fans have a number of blades mounted on the shaft of an electric motor (Figure 5). They are easily installed and take little space. The chief

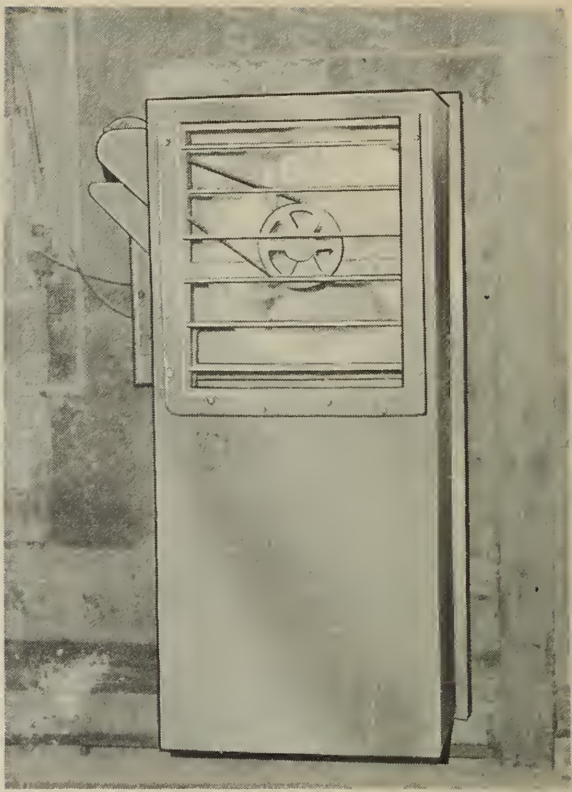


Figure 6. A large-diameter, slow-speed fan exhausting air from a broiler pen.

Figure 5. A small-diameter propeller fan ventilating a laying house.

Figure 7. Centrifugal fans ventilating a turkey broiler pen.

disadvantage, apart from noise, is that the output in c.f.m. falls off considerably if the fans must exhaust into a wind.

High-speed fans should be protected by wire grills. The cowlings should be smooth and streamlined around the tips of the blades.

Large-diameter, slow-speed fans are commonly used in poultry houses. Most are belt-driven and are housed in a cabinet. Air is drawn from floor level at a slow, continuous rate or from near the ceiling at a higher rate.

These fans are quiet and need less horsepower per cubic foot of air moved than high-speed fans. However, installed in a cabinet, the fans take up space inside the building, a disadvantage if they are placed over a passageway.

*Centrifugal type.*—Centrifugal fans have a number of small narrow blades around a central shaft and encased in a housing. They are generally belt-driven (Figure 7). Thus, the output may be changed by varying the size of the pulley. They give ventilation with very little reduction in output at the static pressures usually encountered, and so are good for duct work. They are very quiet.

Centrifugal fans are bulky, a disadvantage if placed over a passage. They also need slightly higher horsepower per c.f.m. than other fans. In poultry houses, dust collects in the fan motor and you must clean it often.

Electric motors driving fans should:

- Be totally enclosed to keep dust, dirt and moisture from entering the windings and bearings.
- Have overload protection, either a thermal overload device or a two-element fuse in the disconnect switch, in case the shutters should freeze or the fans overload.
- Be of the "split phase" or "capacitor start" type.
- Have the fan housing and metal boxes safely grounded.
- Be made by a reliable manufacturer and be installed by a qualified electrician.

NOTE: All electrical equipment and controls used should carry the stamped approval of the Canadian Standards Association (C.S.A.).

## FAN CONTROLS

Use a special corrosion-resistant thermostat (Figure 8) designed for farm buildings. Ordinary house thermostats are not satisfactory.

Under average conditions, place the thermostat 2 to 3 feet down from the ceiling and in a central location. Never



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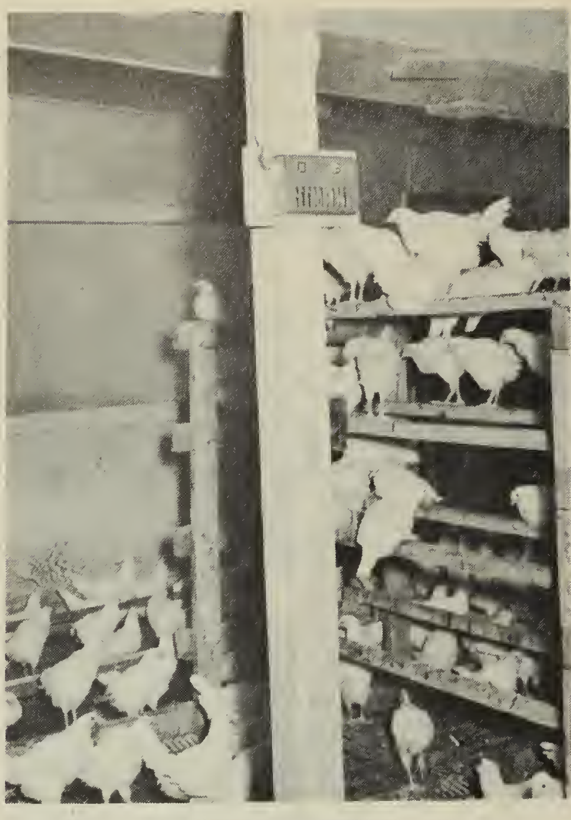


Figure 8. A ventilation thermostat.

place it near feed or silo chutes, doorways or any other place where it will be affected by drafts.

Humidistats, for control of humidity, are unreliable because dust and moisture collect on the hairs that control them.

## AIR INLETS AND SYSTEMS

### DAIRY BARNS

In most older barns, air inlets are not necessary. Enough air enters through cracks, especially around doors and windows. Never use feed or silo chutes, or windows, for inlets during cold weather.

In new two-storey barns with a vapor barrier in the walls and ceiling, an inlet is needed. Cut a continuous slot or drill a series of 1-inch holes through the ceiling along the perimeter of the barn. This allows air to enter the stable from the upstairs.

In new one-storey barns, use inlets of the type recommended for poultry and pig buildings.

Figure 9. A windowless laying house showing a louver that lets air into the attic.

## POULTRY AND PIG BUILDINGS

*Buildings up to 40 feet wide.*—For a single-storey building with truss-type roof, a louver in the attic wall (Figure 9) provides a good air inlet. The heat that passes through the ceiling insulation into the attic space helps to warm the incoming air, and some heat from the sun is picked up through the roof. The incoming air may be 5° F. warmer than the outside air.

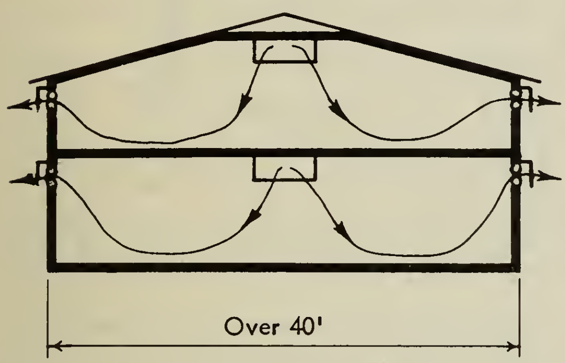



Figure 10. Flow of air in an attic-intake and continuous-slot ventilating system.

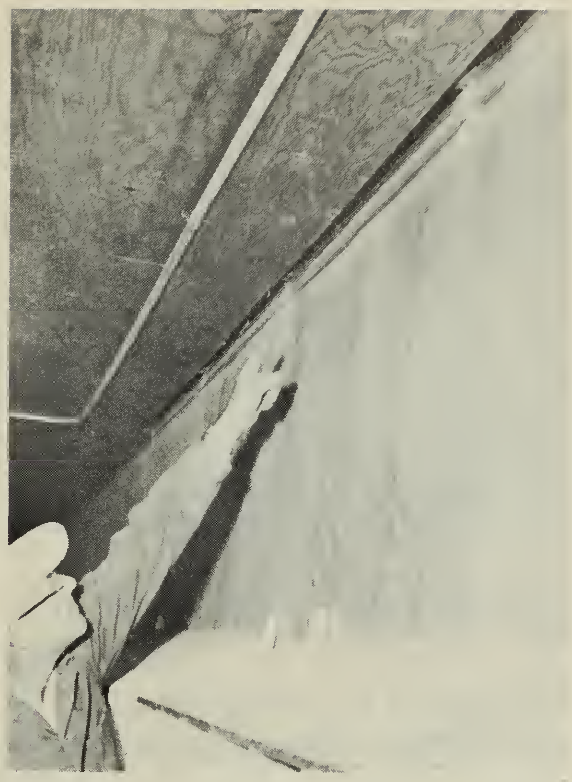
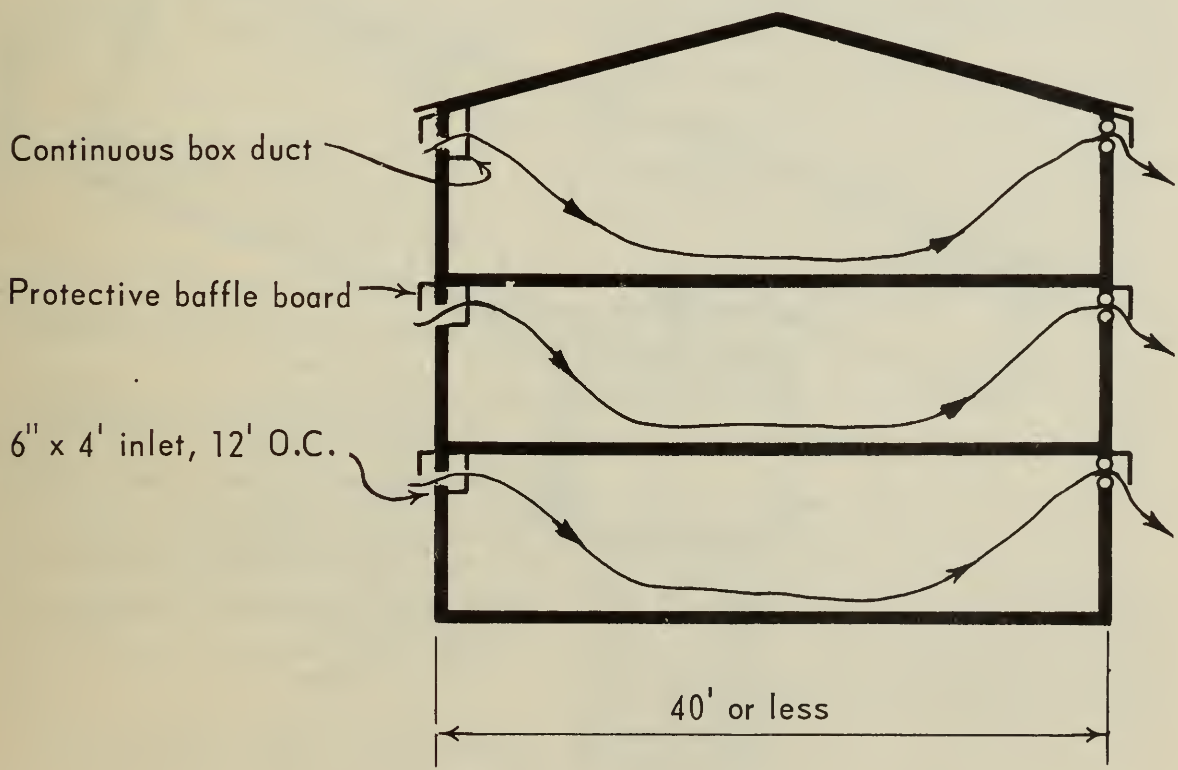


Figure 11. A continuous-slot air inlet along the perimeter of a windowless laying house.

The air comes down from the attic through a continuous slot along the

Figure 12. Flow of air with box-duct air inlets in a multistory building.



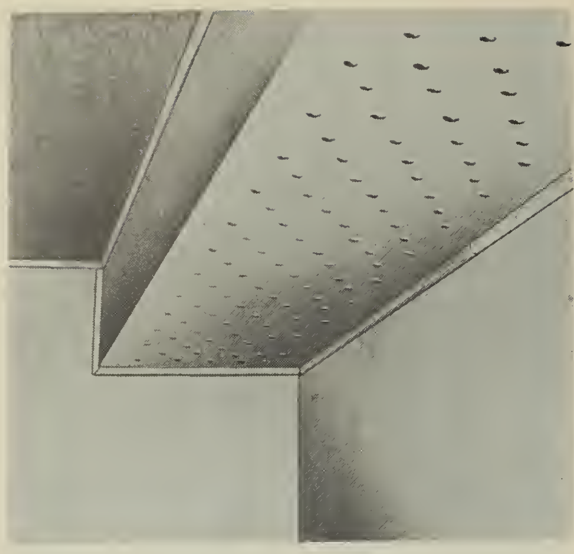


Figure 13. A continuous box duct running the length of a building to ensure even distribution of incoming air.

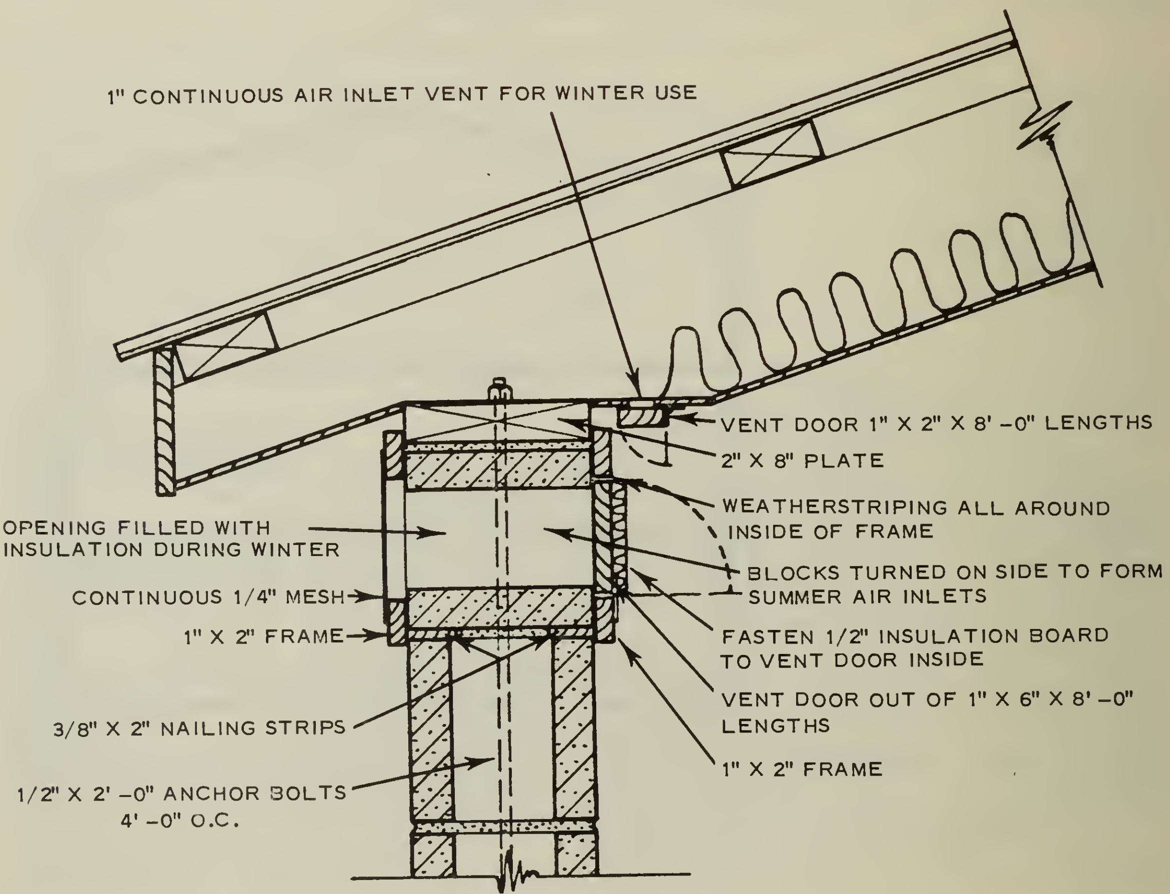
perimeter of the ceiling, except at the end of the building where the fans are located. The air coming through the slot forms a curtain of fresh air along the walls and helps to prevent condensation on them.

With pole construction, the space above the windows is open between the purlins to the attic. You can use a slot over each window for an inlet. In the summer close the slots and use the windows for inlets. You need 40 feet of continuous slot, 2 inches wide, for each 4,000 c.f.m. of fan capacity.

In multi-storey, quonset and one-storey buildings without attics, admit air through a plywood box duct drilled with $\frac{3}{4}$- to 1-inch holes on the side or bottom. Outside air is admitted into the duct through openings, 6 inches by 4 feet, every 12 feet along the wall. Protect these with a baffle board and a screen.

If the walls are built of concrete or other insulated blocks, turn some of the blocks on the top row on edge to provide openings, and fit these with box-type baffles.

Figure 14. An air inlet in a block-wall building.



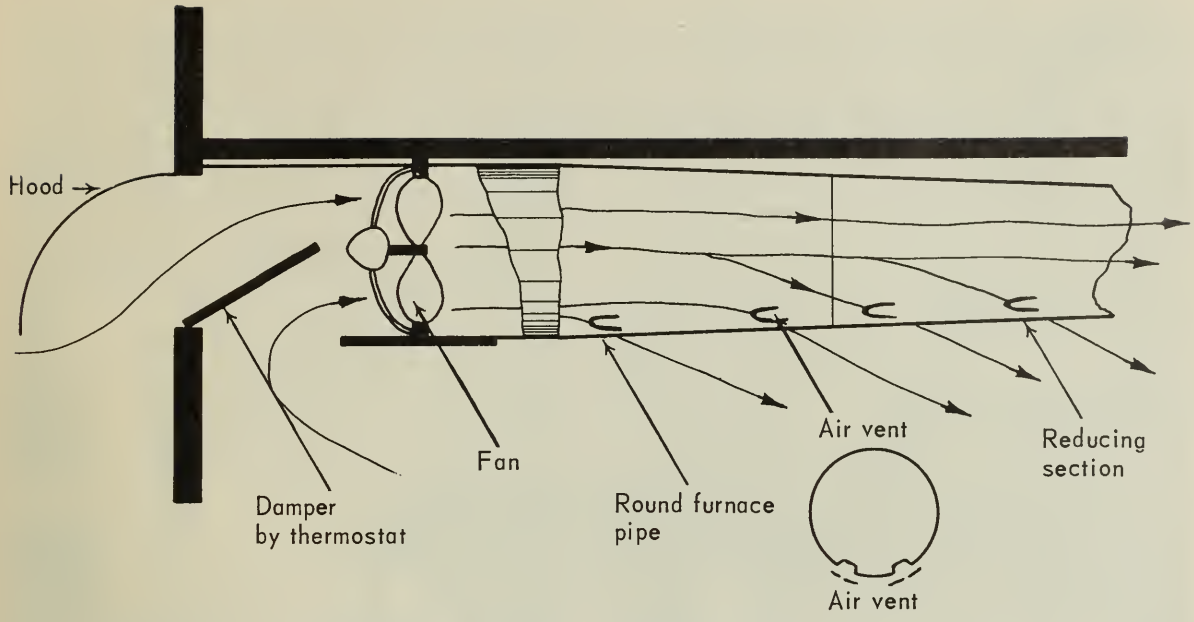



**Figure 15. Diagram of a forced intake recirculating ventilating system.**

A forced intake-recirculating system (Figure 15) allows fans to run almost continuously as warm air from the pen is automatically mixed with the cold incoming air. The exhaust air escapes through small outlets located around the outside wall.

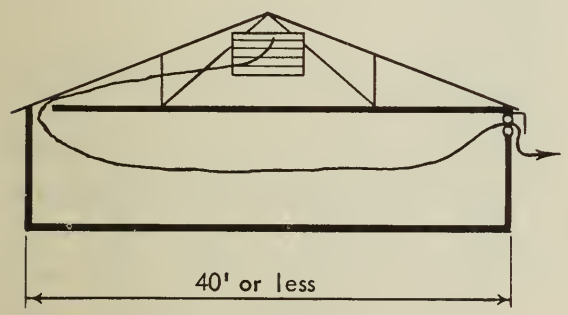



**Figure 16. Flow of air in a poultry house with a central air-intake duct and exhaust fans on either side.**

*Buildings over 40 feet wide.*—Buildings less than 200 feet long need a central inlet duct running from end to end, with fans on both sides of the building drawing air from it. The duct opens to the outside at the ends. Always protect the duct from the wind by a hood or louver.

Build the duct of plywood, and drill $\frac{3}{4}$- to 1-inch holes in the bottom. The total area of the holes should be at least four times as great as the fan outlet area. Often, reversible fans are used with this system. They are useful for summer cooling when reversed.

In a building over 200 feet long, a single central duct is not practical because of its size. Use a system of lateral exhaust ducts that do not require a central duct. The loss from friction, which depends on the material used in the duct, is a big factor. You must force air through the ducts with a centrifugal fan to ensure satisfactory results.

You can get detailed plans for various ventilation inlets through the Canadian Farm Building Plan Service. Ask your agricultural representative for information about this service.

## DAIRY-BARN VENTILATION

A cow gives off 18 to 30 pounds of water vapor in her breath in a day, and a herd of 30 gives off 540 to 900 pounds, or 54 to 90 gallons. If this moisture is not removed, it condenses, causes the

Figure 17. A central air-intake duct in a laying house.

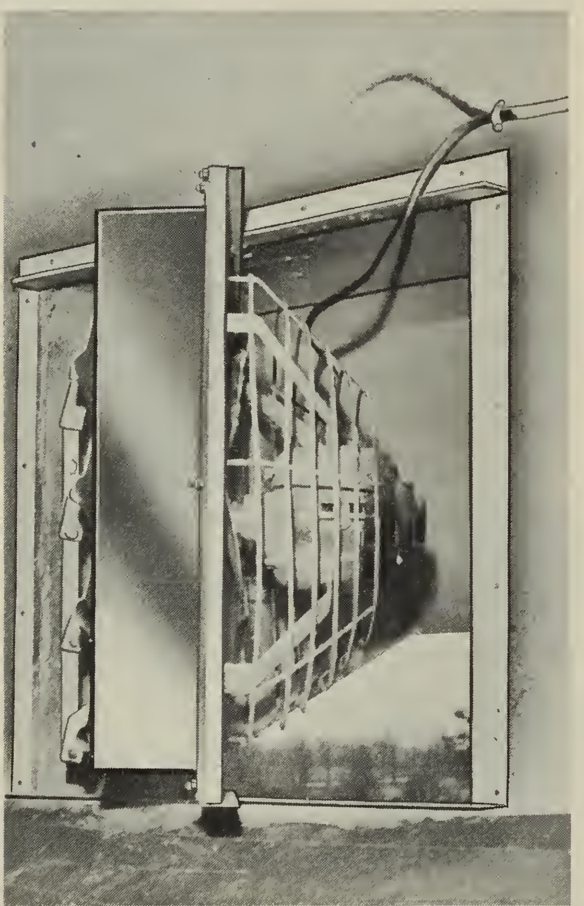


Figure 18. A reversible fan that exhausts air during cold weather and forces air into the building during hot weather.

barn to deteriorate, frosts windows heavily, and makes the air wet and unhealthy.

Ventilation must satisfy the following conditions:

- It should keep the stable dry. If the water vapor produced by the animals is not continually removed it either penetrates the walls and ceiling or condenses on them. You can see this in many barns where sills and joists are partly rotted.
- It should remove stale air and odors. Many of the "off" flavors found in milk are caused when these odors or flavors enter the milk through the cow's body or are picked up by the milk as it is handled in the stable. This means you must keep your dairy stable as free of odors as possible.
- It should bring in fresh air. Fresh air should enter without causing

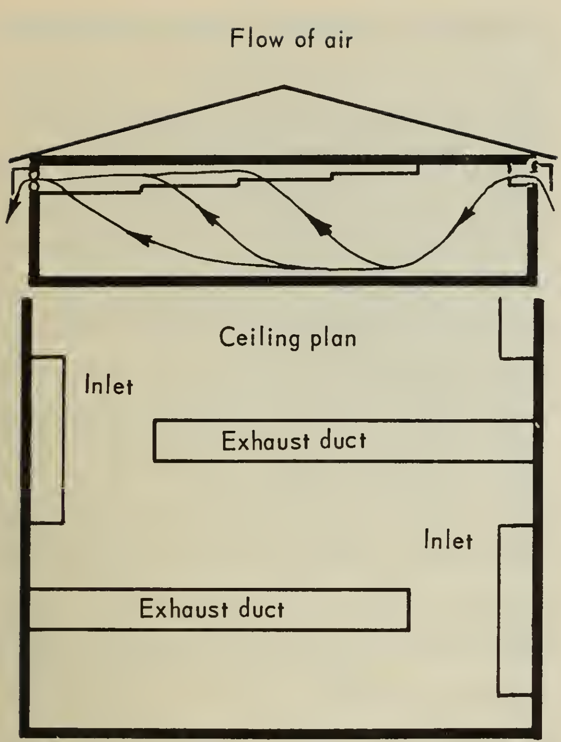



Figure 19. A ventilating system with alternate exhaust ducts and air-inlets.

Figure 20. A lateral exhaust duct in a broiler house 60 feet by 365 feet. Note the air inlet slots in the duct.

drafts or lowering the stable temperature too much. As a cow breathes, she takes a certain amount of oxygen from the air and replaces it with carbon dioxide and water vapor. If she breathes the same air over and over again it soon becomes saturated with water vapor. When this happens the cow becomes sluggish, loses her appetite and gives less milk.

- It should reduce fluctuations in barn temperature. The inside temperature of an uninsulated, unventilated barn fluctuates considerably with the outside temperatures. Since cows produce heat as well as moisture, the stable often becomes hot and oppressive during the day and cool during the night, or vice versa. Fluctuating temperatures may affect milk production as much as either constant high temperatures of 70° F. and higher or constant low temperatures of 30° F. or lower. Cows produce most efficiently at constant temperatures within the 40° to 65° F. range.

For ventilation in cold weather it is better to keep the stable temperature as low as possible. At low temperatures cows produce less moisture and more heat than at higher temperatures. Thus, enough air must be circulated during warm weather to remove the excess heat, water vapor and stale air, and during cold periods only enough air change is needed to remove the water vapor and stale air.

Though you may prefer a temperature that is comfortable for yourself, a lower limit of 45° to 50° F. is generally recommended. In very cold regions 40° F. is more practical.

Consider relative humidities, insulation and the lowest winter temperature for your area when you design a ventilating system. Refer to the temperature-zone map (page 4) to determine the temperature zone in which you live. In areas where the winter design temperatures go lower than 0° F., insulation is extremely important to keep enough heat in the building for ventilation.

Almost every stable contains heifers, calves and cows of various sizes. To calculate the ventilation needs of any stable, use a measure called *animal unit*. An animal unit equals 1,000 pounds of animal. Divide the total weight of all your animals (in pounds) by 1,000 to get the number of animal units.

It is practically impossible to make recommendations for all the combinations of temperatures and relative humidities that occur across Canada. Relative humidities, however, are largely constant for a given range of temperatures; Table 1 gives recommendations based on various outside temperatures representative of Canada. Near lakes and oceans where humidities are very high or in areas where extreme temperatures occur, make calculations for the ventilation and insulation needed, using the sample calculation in the appendix.

Table 1 is based on the assumption that the ceiling is covered with 4 feet of straw or hay or its insulating equivalent. In one-storey barns make calculations taking into account the amount of heat lost through the ceiling (Check the walls against Chart 1 in the section on insulation to see if they are insulated enough to give the necessary *R* value stated in Table 1).

At very low temperatures the ventilating rate should be 30 c.f.m. or less per animal unit. Because cattle produce moisture continuously you should ventilate continuously at the minimum rate. In warm weather, a rate of 130 c.f.m. per animal unit may be needed. Therefore, a combination of two or more fans is best: one running continuously to supply the minimum of 30 c.f.m. (or less) per animal unit, and the others with thermostats set at 45°-50° F. When the outside temperature reaches 50° F. or higher, open windows and doors to allow natural cross-ventilation.

TABLE 1. Ventilating rates and insulation for dairy barns

| Outside | | Inside | | C.F.M. needed per animal unit to remove water vapor | *R*[1] units needed for walls |
|---|---|---|---|---|---|
| Temp., ° F. | R.H., % | Temp., ° F. | R.H., % | | |
| −20 | 90 | 50 | 75 | See note | 18 |
| −20 | 90 | 40 | 75 | 30 | 18 |
| −10 | 90 | 50 | 75 | 32 | 12.5 |
| 0 | 80 | 50 | 75 | 33 | 3.7 |
| 10 | 80 | 50 | 75 | 37 | 2.0 |
| 20 | 80 | 50 | 75 | 44 | 1.2 |
| 30 | 70 | 50 | 75 | 54 | 1.2 |
| 40 | 70 | 50 | 75 | 88 | 1.2 |
| 45 | 70 | 50 | 75 | 130 | 1.2 |

[1]*See* Appendix IV.

NOTE: It is impossible to maintain an inside temperature of 50° F. when the outside temperature is −20° F. at 90 percent R.H. without adding heat because all the animal heat is lost through the walls. You must tolerate either a lower stable temperature (40° F.) or an accumulation of moisture.

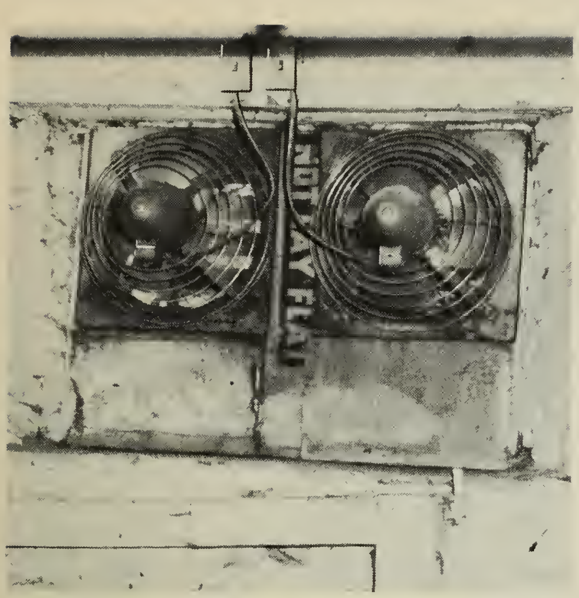


Figure 21. Two exhaust fans, one exhausting continuously and the second controlled by a thermostat in the center section of the stable.

## FAN LOCATION

When installing two or more fans, put them in the same wall, preferably on the leeward side of the barn and as close to the ceiling as possible. This prevents the fans from working against high winds and also helps keep the shutters from freezing. If the fans have to face the prevailing winds, protect them with a hood extending 6 inches below the fan opening (Figure 4). Generally, you should place the fans on the side of the barn where the calves are penned. This helps to keep the stable temperature nearly uniform, especially in the calf-pen area.

If you pen the calves on the cold side of the barn, the heat from the cows will be drawn over them. However, additional insulation must sometimes be placed in this wall or excess condensation will form as the warm moist air strikes it.

If you need more than one thermostatically controlled fan in addition to the continuously operating fan, space them evenly along the same wall.

Keep the fans at least 20 feet from doors or windows. Fans installed near

Figure 22. Exhaust fans over calf pens.

TABLE 2. Guide for choosing size and number of fans for various numbers of animal units

| No. of animal units | Capacity, c.f.m. Cold weather | Warm weather | Total | No. of fans | No. of thermostats | No. of fans | Size of fan c.f.m. |
|---|---|---|---|---|---|---|---|
| 20 | 600 | 2000 | 2000 | 1 | 1 | 1 | 2000 (T) |
| 30 | 900 | 3000 | 3900 | 2 | 1 | 1 | 900 (c) |
| | | | | | | 1 | 3000 (T) |
| 40 | 1200 | 4000 | 5200 | 2 | 1 | 1 | 1200 (c) |
| | | | | | | 1 | 4000 (T) |
| 50 | 1500 | 5000 | 6500 | 3 | 1 | 1 | 1500 (c) |
| | | | | | | 2 | 2500 (T) |
| 60 | 1800 | 6000 | 8700 | 3 | 1 or 2 | 1 | 1800 (c) |
| | | | | | | 2 | 3000 (T) |
| 75 | 2250 | 7500 | 9750 | 3 | 2 | 1 | 2250 (c) |
| | | | | | | 2 | 3750 (T) |
| 90 | 2700 | 9000 | 11700 | 4 | 2 or 3 | 1 | 2750 (c) |
| | | | | | | 3 | 3000 (T) |

An animal unit is a 1000-lb. cow or its equivalent.
T—Fan on thermostat control; c—Fan on continuous operation.
Fans should deliver the above capacities at ⅛-inch static pressure.

openings draw air directly from them and reduce the ventilation. If the fans are installed in a window frame, make the frame as nearly airtight as possible.

### THERMOSTATS

Thermostats should be placed centrally and about 2 feet from the ceiling. Take care that they are not in the path of drafts from doors, chutes, or other openings, and that they are well protected from the animals. Set the thermostats at 45° to 55° F. depending on outside temperature conditions and the number of thermostats. The small continuous fan should be controlled either by an additional thermostat set at 40° F. or by a manual wall switch. If it is wired to a wall switch, turn it off at night during extremely cold weather (less than −20° F.).

### INLETS

In most older barns, inlets are not necessary. Enough air enters through cracks, especially around doors and windows. Keep feed and silo chutes closed; do not use these as air inlets.

In new barns that have vapor barriers and very tight construction, some type of inlet is needed.

Read the sections on ventilating systems and air inlets and systems for more information on inlets and fans.

## POULTRY-HOUSE VENTILATION

Each poultryman has his own particular production problems, such as disease control, poor feed conversion, or mortality. Yet when we analyze any one of these problems we always find that poor ventilation is one of the causes.

Tremendous advances have been made in poultry-house ventilation and poultry housing in recent years. Poultry were once housed in cold, damp, poorly constructed buildings; the hens practically stopped laying during the winter and ate great quantities of feed just to keep up their body heat.

The introduction of the broiler industry and the subsequent housing of more hens in less space has stressed the problem of ventilation. Production of both broilers and eggs now continues throughout the year. This means that the effects of cold weather and fluctuating temperatures have to be reduced.

Birds that have a constant supply of fresh air, and are protected from fluctuating temperatures and dampness, use feed more efficiently and are less susceptible to many diseases.

The ventilating system should do the following:

- It should keep the litter dry. One of the main problems in the poultry industry is wet litter. It contributes to dirty eggs, disease and death of birds. Wet litter results when the relative humidity is over 80 percent.
- It should keep the temperature uniform. Poultry do not readily adjust to changing temperatures. When it is hot they produce less than when the temperature is right; when it is cold they also produce less and eat more feed. Keep the temperature close to 50° F. during cold weather.
- It should prevent condensation and dripping. This helps keep litter dry, eggs clean, and the building sound. You need both adequate insulation and good ventilation.
- It should remove odors. Too much ammonia harms the birds.
- It should control temperatures automatically and at the proper rate of ventilation according to the outside temperature.

A poultry house that is not properly insulated cannot be properly ventilated. It is the heat not lost from the building that determines how much ventilation is possible.

## FACTORS AFFECTING DESIGN

*Temperature.*—Winter design temperatures in Canada vary from −40° F. to 20° F. Check page 4 to see in which zone you live. A 50° F. inside temperature is best, except in areas where −10° F. to −20° F. weather persists for long periods. In these areas an inside temperature of 40° F. is more practical unless the building is heated.

*Relative humidity.*—Relative humidities are nearly constant at any given temperature across Canada. They are also rather high in the main poultry-raising areas. This means that the outside air is already very moist before it enters the building. This air must be heated considerably so that it can pick up more moisture from the pen.

*Moisture removal.*—A hen produces little heat in relation to the space it occupies. In cold weather it is not possible to keep enough of this heat to remove all the moisture; much is lost with the ventilating air and through the walls and ceiling. However, the ventilating system must at least remove the water vapor produced by the birds when the outside temperature is 0° F. or lower. When the outside temperature is above 0° F., the moisture in the feces not deposited in the dropping pits should also be removed by ventilation.

*Type of building.*—The design of the building and ventilating system is not as critical for broilers as for laying hens, since a source of heat is always available for brooding and, if necessary, this may be used for ventilation.

*Poultry-house management.*—Good management adds greatly to the value of a ventilating system. Having waterers

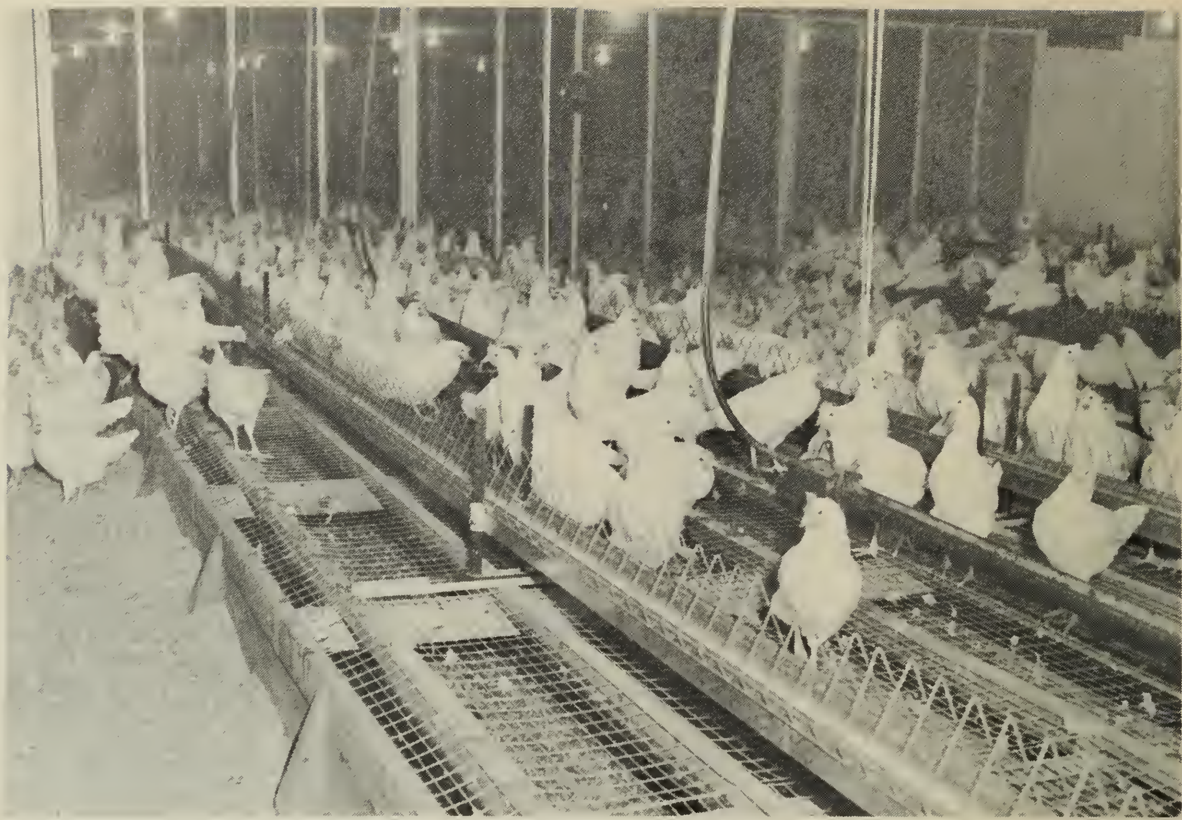


Figure 23. Water and feed are provided over dropping pits. A pit cleaner in the pits also helps ventilation. Note the dryness of the litter.

at the proper heights to prevent spilling, keeping enough litter in the house, arranging feeders and waterers to avoid heavily travelled areas and many other things are important. Ventilation does not replace good management but complements it.

*Litter dropping pits and pit cleaners.*— Wet litter tends to cake or pack and forms a seal over its surface. This seal prevents the ventilating air from penetrating the litter and very little moisture is removed.

TABLE 3. Ventilating rates and building insulation needed for poultry houses

| Outside | | Inside | | C.F.M.[1] needed to remove water vapor | Necessary $R^2$ value (units) of walls |
|---|---|---|---|---|---|
| Temp., ° F. | R.H., % | Temp., ° F. | R.H., % | | |
| −20[3] | 90 | 40 | 60 | 45 | 24 |
| −10 | 90 | 40 | 60 | 48 | 18.3 |
| 0 | 80 | 40 | 60 | 52 | 9.1 |
| 10 | 80 | 50 | 60 | 54 | 9.9 |
| 20 | 80 | 50 | 60 | 67 | 6.1 |
| 30 | 80 | 50 | 60 | 110 | 4.5 |
| 55 | 60 | 60 | 60 | 404 (for heat removal) | 4.5 |

[1]The C.F.M. figures are based on units of 100 3½-pound hens housed at 1.5 square feet of floor area each.

[2]*See* Appendix IV.

[3]Supplemental heat is required at this temperature.

Figure 24. A laying house ventilated by a continuously operating small fan and a larger fan controlled by a thermostat. Note the feed and water over the dropping pits.

Put the water and feed over the dropping pits to keep litter dry. You can then expect two thirds to three quarters of the feces to be dropped in the pits, leaving only a small amount in the rest of the poultry house. Pit cleaners remove the moisture in the feces regularly and so aid ventilation as well as save labor.

Table 3 shows the c.f.m. needed to remove the moisture from 100 birds and the necessary units of insulation to accomplish this at various temperatures and humidities. Along lakes and oceans where humidities are extremely high and in areas of extreme temperature, make calculations by following the sample calculation in the Appendix I.

In areas where winter temperatures are continually −20° F. and lower, you must add more insulation, reduce the floor area per bird and use either storm windows or additional heat. If you do not, ventilation cannot take place and moisture will accumulate. The more insulation the building has, the less heat will be needed. Because warm air rises and because there is more ceiling area per square foot of floor space than there is wall area, insulation is more important in the ceiling than in the walls. Install $1\frac{1}{2}$ times as much insulation in the ceiling as in the walls.

## RECOMMENDED RATES

*Laying hens.*—Since poultry produce moisture continuously it is necessary to ventilate continuously. Continuous ventilation at $\frac{1}{2}$ c.f.m. for each $3\frac{1}{2}$- to 4-pound bird removes the moisture during cold weather. This rate is too low for summer, so two rates are necessary. To provide this, have a small fan operating continuously at $\frac{1}{2}$ c.f.m. per bird, and one or more larger ones, controlled by thermostats, rated at 3 c.f.m. per bird; or have two-speed fans that exhaust the smaller amount at the temperature set on the thermostat and then automatically increase the rate when the pen temperature starts to rise.

When the outside temperature rises above 55° F., open windows and doors to allow natural ventilation.

*Turkey and chicken broilers.*—Rates of ventilation per pound of bird are the same for turkey as for chicken broilers. A two-level ventilating rate is a distinct advantage in broiler raising since the minimum rate can be used during the brooding period.

In tight buildings used for brooding the minimum rate ensures a continuous supply of fresh air to give the birds enough oxygen.

Some growers preheat the ventilating air. Though this is effective it is also expensive. It is better to have more insulation and if necessary use the heat source for brooding.

A rate of $\frac{1}{8}$ c.f.m. per pound of bird should be provided continuously. An additional capacity of $\frac{3}{4}$ c.f.m. should be provided in the spring, summer and fall. For 1,000 four-pound birds this is 500 c.f.m. continuously and an additional 3,000 c.f.m. in summer.

## POULTRY-HOUSE COOLING

When it is hot, egg production falls and laying hens may even die. To overcome these problems, practice the following:

*Insulation.*—It is best to have 12-16 units of insulation in the ceiling. Insulation delays heat transmission, and by the time the peak temperature is reached in the building the outside temperature has usually dropped. The heat is then dissipated by the cooler evening air coming through the ventilating system.

Figure 25. A broiler house in which tempered air is brought from a hot-air furnace and distributed through round pipes to aid ventilation.

Steel roofing painted with white or aluminum paint absorbs less heat than darker ones.

*Air flow.*—The problem in using exhaust systems in hot weather is that it is practically impossible to get the ventilating air moving around the birds. It tends to go straight from the inlet to the fan, leaving stale air around the hens.

Reverse the exhaust fan to blow air in when temperatures reach 80°-85° F. This creates much more turbulence in the building. The incoming air reaches the hens and cools them. As the body temperature of a hen is 107° F., even air at 90°-100° F. has a cooling effect. Hens in moving air are less likely to suffer heat prostration than those in still air at the same temperature.

*Fogging.*—Applying a mist spray to the inside of the poultry house dampens the birds and cools them by evaporation. The air is also cooled to some extent. The fogging system should be automatically controlled by a thermostat set at 90° F. Fogging is most effective in areas where relative humidities are 50 percent or under; it is useless above 75 percent. Take care that too much moisture is not added to the house, or the litter will become wet and add to the problem of dirty eggs. For this reason, do not begin fogging until 2 or 3 o'clock in the afternoon. Foggers use about 60 gallons of water per 1,000 square feet of floor area per day.

*Evaporative cooling.*—In this system, incoming air is drawn through water-soaked pads of jute or plastic fibers and thus is cooled by evaporating moisture. The relative humidity must be less than 75 percent for evaporative cooling to be effective. It is possible to cool the air in the pen by as much as 10° F. when the relative humidity is 65 percent or lower. However, if air is drawn a distance of 100 feet or more after being cooled, it will warm up to the original temperature again.

Pads with water dripping onto them are placed on either a side or an end of the building and the incoming air is drawn through them. If the fans are in one end of the building, the door at the other end is usually covered with water-soaked jute. Along the side of the building a number of smaller pads are usually used. Water drips down the pads from a piece of eavestroughing drilled with small holes.

About 90 gallons of water per 1,000 square feet of floor area are needed a day.

Installing an evaporative cooling system costs about 60 cents per bird.

*Effectiveness of foggers and evaporative cooling.*—Light-weight hens do not lay any more eggs when they are cooled by these methods, although fewer die.

The results are usually better for heavy hens. Production may increase by as much as 10 percent when outside temperatures approach 100° F. Fertility is also higher and mortality lower.

Fogging or evaporative cooling may be justified as a short-term emergency setup, but is generally not recommended, as the humidity across Canada averages 75 percent or higher during the hot summer months. Also, the fans needed must have a capacity far greater than normally needed, especially during the winter.

Instead, for best results, install plenty of insulation and use a fan with a capacity of 1 c.f.m. per pound of bird, or enough to provide an air change every 3 minutes, whichever is the greater. Have the fans blow in during the hot weather.

## PIG-BUILDING VENTILATION

For efficient pig production you must have dry conditions and temperatures between 50° and 60° F. A pig is somewhat like a chicken; it produces a relatively small amount of heat in relation to the space it occupies. Until recently, most pigs were raised in barns with other livestock, which supplied much of the heat necessary for ventilation. However, when pigs are housed by themselves the building becomes cold and damp in winter. This contributes to disease and poor feed conversion. A well-insulated and ventilated building is the solution.

The ventilating system should:

- Keep temperatures at 60° F. The average winter-design temperature varies in different locations in Canada from −40° F. to +20° F. Check the map (page 4) to see the proper temperatures for your ventilating system.
- Keep the building dry, with the relative humidity below 75 percent. This helps to keep the building from deteriorating.
- Change air often enough to remove the moisture without causing a draft on any of the pigs.
- Meet the requirements for cold weather but have enough capacity for summer. If the building is not insulated well enough, then proper ventilation is impossible. It is the heat in excess of the building losses that determines the amount of ventilation possible. Table 4 shows that a continuous rate of ventilation of 10 c.f.m. or less per 125-pound pig is necessary in cold weather, and 30 c.f.m. in mild weather.

In areas where the winter design temperature is −10° F. or lower, you must provide heat to maintain dry conditions. Pigs do not produce enough heat to replace that lost in the ventilating air at these temperatures. If heat is not provided, proper ventilation is impossible and the building will get damp.

Where winter temperatures are often at 0° to −10° F. it is more practical to keep the inside temperature at 40° F. by reducing the amount of ventilation and allowing some moisture and odor to build up. You can remove these during warmer periods.

Even storm windows lose much heat, so keep the window area to a minimum.

TABLE 4. Ventilating rates and building insulation needed for pig houses

| Outside | | Inside | | C.F.M.[1] needed to remove water vapor | Necessary $R$[2] value (units) of walls |
|---|---|---|---|---|---|
| Temp., ° F. | R.H., % | Temp., ° F. | R.H., % | | |
| −20[3] | 90 | 40 | 75 | 9 | 24 |
| −10 | 90 | 40 | 75 | 10 | 18 |
| 0 | 80 | 40 | 75 | 10 | 13.5 |
| 10 | 80 | 50 | 75 | 7½ | 5 |
| 20 | 80 | 50 | 75 | 9 | 2.5 |
| 30 | 70 | 50 | 75 | 11 | 2.0 |
| 60 | | | | 30 (to remove heat) | |

[1]C.F.M. figures are based on pigs weighing 125 pounds.
[2]*See* Appendix IV.
[3]Supplemental heat is required at this temperature.

## VENTILATING SYSTEMS

You may use fans that have a variable capacity, or a combination of a small and a large fan. The combination system is more common and more easily adapted to the rates needed.

Pigs do not sweat. In hot weather they lose heat by radiation and respiration. This makes air movement around the pigs necessary to remove the heat. A rate of 25 to 30 c.f.m. per pig is recommended for warm weather. Occasionally spraying the pigs with water by means of a perforated hose helps to cool them in extremely hot weather. The continuous fan exhausting at 8-10 c.f.m. per pig should be controlled by a wall switch. The larger fan exhausting at 20 c.f.m. per pig should be controlled by a thermostat set at the desired inside temperature. When more than the minimum rate is needed the larger fan will run intermittently.

When pigs are subjected to drafts they often succumb to some type of sickness, usually pneumonia. Therefore, inlets must distribute the incoming air evenly. Small inlets that admit air at high velocity often cause drafts and are not satisfactory; do not use these. Also, do not use windows as inlets during cold weather.

Because drafts are a problem, exhaust systems are better than forced-intake systems in cold weather. However, forced intake, usually accomplished by turning the fans to blow air in, has definite advantages during hot spells in summer.

For the recommended types of inlets, air distribution systems and fans see the main section on ventilating systems.

## CONTROLS

Set thermostats at 50° F. to 60° F. for as much of the time as possible. During

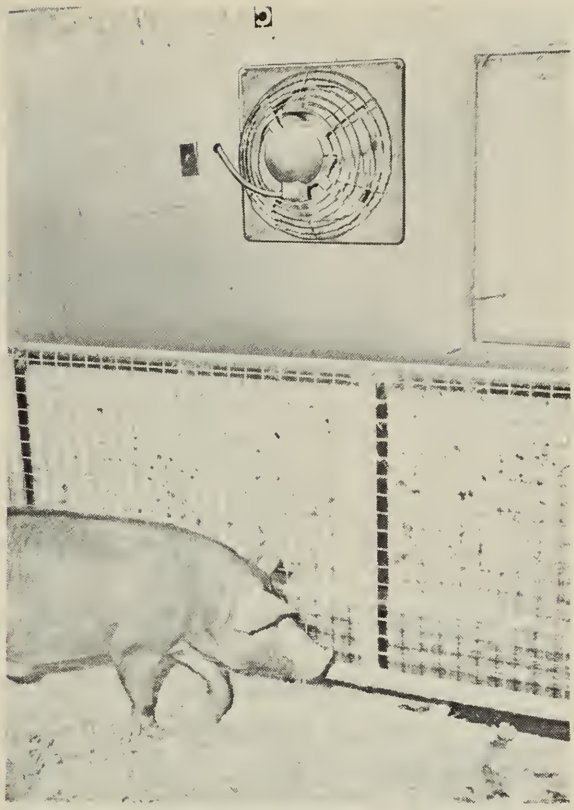


Figure 26. A propeller exhaust fan ventilating a pig building. Note that the wire partition on the front of the pen allows air circulation through the pen. Use solid partitions between pens.

the very cold weather, turn them down to 40° and 45° F.

If heat is added to the building the fan thermostats tend to buck the air-heating equipment thermostats; they may operate continuously and remove too much heat. An alternative system is to use a time clock on the ventilating fan, so that the fan operates at regular intervals. This way the fan does not remove the heat being added to the building but only runs long enough to take out the moisture.

## FARROWING HOUSES

Though a farrowing house must have a high, uniform temperature you need some ventilation to remove moisture and provide fresh air in the winter. In the summer much more air is needed to help cool the sow. The recommended rates are: winter, — 30 c.f.m. per sow and litter; summer,—200 c.f.m. per sow and litter.

Use two fans: a small fan for winter and a larger one for summer. Because the difference in volume between the two is so great, shut off the small fan during the summer and run only the larger one.

## APPENDIX I

Formula for calculation of heat transfer through a composite type of construction:

$$U = \frac{1}{\frac{1}{fi} + \frac{x_1}{k_1} + \frac{1}{C} + \frac{1}{a} + \frac{x_2}{k_2} + \frac{1}{fo}},$$

where $R = \frac{1}{U}$.

*U* is the over-all coefficient of heat transmission—expressed in British thermal units (B.T.U.'s) per hour per square foot per degree Fahrenheit difference in temperature. The *U* value applies to the combination of materials in a wall or roof and to single materials such as glass, but it always includes the surface conductances on both sides.

*k* is the coefficient of conductivity, or the measure of the ability of a particular material to conduct heat. It is expressed as the number of B.T.U.'s transmitted per hour per square foot per degree difference in temperature between the two surfaces of a homogeneous material 1 inch thick. The lower the *k* value of a material, the better its insulating qualities.

*x* is the thickness of material in inches. All the tables give values of *k* per inch of thickness. To find the total conductance for a certain thickness of material, divide the value of *k* by the thickness of the material in inches.

*C* is the conductance, or the number of B.T.U.'s transmitted per hour per square foot per degree difference in temperature through a stated thickness of a wall, roof, or non-homogeneous material. For example, the *k* value of concrete is given per inch of thickness, but the *C* values are given for 4-, 8-, and 12-inch concrete masonry units.

*f* if the film or surface conductance—the measure of radiation, conduction and convection for a unit area of a surface. It is expressed in B.T.U.'s per hour per square foot per degree difference in temperature between surfaces of film. The inside surface conductance is designated by *fi* and the outside surface conductance by *fo*.

*a* is the conductance of an air space expressed in B.T.U.'s per hour per square feet per degree difference in temperature between extremities of air space.

*R* is the resistance, or the insulating value, and is the reciprocal of the heat transmission coefficient. For example, a wall with a *U* value of 0.25 has a resistance value of $\frac{1}{0.25} = 4$ units.

## APPENDIX II

The relative humidity (R.H.) of air is the ratio of the amount of moisture in a cubic foot to the maximum amount it can hold at the same temperature. The maximum amounts of moisture a cubic foot of air can hold at various temperatures are:

| Temperature, ° F. | Grains of moisture[1] per cubic foot of air |
|---|---|
| −20 | 0.166 |
| −10 | 0.284 |
| 0 | 0.475 |
| +10 | 0.774 |
| 20 | 1.238 |
| 30 | 1.94 |
| 40 | 2.86 |
| 45 | 3.44 |
| 50 | 4.11 |
| 55 | 4.89 |
| 60 | 5.79 |
| 70 | 8.05 |

[1] 1 pound = 7000 grains.

For example, 1 cubic foot of air at 80 percent relative humidity at 0° F. contains $\frac{80}{100} \times 0.475 = 0.380$ grains of moisture per cubic foot.

## APPENDIX III

Heat and Water Vapor Produced by Livestock

| Type of Livestock | Building temperature ° F. | Sensible heat produced ($H$) B.T.U./hr. | Water vapor produced ($Wa$) lb./hr. |
|---|---|---|---|
| 1000-lb. dairy cow | 40 | 2750 | 0.50 |
| 1000-lb. dairy cow | 50 | 2600 | 0.75 |
| 1000-lb. dairy cow | 65 | 2450 | 1.04 |
| $3\frac{1}{2}$-lb. hen | 50 | 33 | 0.006 |
| 125-lb. pig | 50 | 500 | 0.15 |

# APPENDIX IV

## Equations Necessary for Design Calculations

1. The air flow ($V$) necessary for removal of the moisture produced per animal unit (ventilating rate) is obtained by the equation:

$$V = \frac{Wa}{(gi-go)\,60},$$

where $V$ = ventilating rate necessary per animal unit in cubic feet of air per minute (c.f.m.),

$Wa$ = moisture (produced by one animal unit) to be removed in (grains/hr.),

$gi-go$ = amount of moisture held in 1 cubic foot of the inside air minus the amount of moisture held in 1 cubic foot of the outside air at their respective temperatures and relative humidities (grains).

2. The amount of heat lost per animal unit in the ventilating air is obtained from the equation:

$$Qv = 0.018\ V\,(ti-to)\ 60,$$

where $Qv$ = loss in ventilating air per animal unit (B.T.U./hr.),

0.018 = heat required to raise the temperature of one cubic foot of air 1° F. (B.T.U.),

$V$ = air flow necessary to remove moisture (c.f.m.),

$ti-to$ = difference between the outside and inside temperatures (° F.).

3. The heat lost through a window, wall or ceiling per animal unit is obtained by the following equation.

$$Qwi,\ Qw \text{ or } Qc = U\,A\,(ti\text{-}to),$$

where $U = \dfrac{1}{\dfrac{1}{fi} + \dfrac{x_1}{k_1} + \dfrac{x_2}{k_2} + \dfrac{1}{fo}}$ (*see* Appendix I),

$Qwi$ = heat loss through window, $Qw$ = heat loss through wall, $Qc$ = heat loss through ceiling,

$A$ = area of window, wall or ceiling in square feet per animal unit,

$(ti-to)$ = difference between the inside and outside temperatures.

4. The $U$ value of the wall necessary to retain sufficient heat to maintain a desired ventilating rate ($V$) is obtained by the equation:

$$\text{Necessary } U \text{ value for wall} = \frac{Qw}{A\,(ti-to)},$$

where $Qw = H - Qc - Qwi - Qv$ [heat produced per animal unit (*see* Appendix III) minus the heat lost through the ceiling, windows and ventilating air per animal unit],

$A$ = exposed wall area in square feet per animal unit,

$ti-to$ = difference between the inside and outside temperatures.

5. The number of units of insulation necessary to allow the ventilating rate ($V$) required is obtained from $R = \frac{1}{U}$ = units of insulation.

As an example let us take a dairy herd consisting of 30 animal units where
$to$ (winter design temperature) = 0° F.,
$ti$ = 50° F.,
$RHo$ = 80%,
$RHi$ = 75%,
Exposed area of ceiling = 60 sq. ft. per animal unit—assume covered with 4 ft. of straw,
Exposed area in glass = 4 sq. ft. per animal unit,
Exposed area of wall = 40 sq. ft. per animal unit.
Using equation (1) to find the ventilating rate:

$$V = \frac{Wa}{(gi - go)\,60}, \qquad Wa \text{ from Appendix III}, \quad gi, go \text{ from Appendix II}$$

$$V = \frac{.75 \times 7000}{(.75 \times 4.11 - .80 \times .475)\,60} = 33.3 \text{ c.f.m. per animal unit.}$$

Therefore the small continuous fan for this 30 animal unit herd should have a capacity of 30 × 33.3 = 1000 c.f.m.

From equation (2) the heat lost in the ventilating air is

$$Qv = 0.018\, V\, (ti - to)\, 60,$$
$$= 0.018 \times 33.3 \times 50 \times 60 = 1800 \text{ B.T.U. per hr. per animal unit.}$$

From equation (3) the heat lost through 60 square feet of ceiling covered with 4 ft. of straw,

$$Qc = \frac{1}{\frac{1}{fi} + \frac{x}{k_1} + \frac{1}{fo}} \times A\,(ti - to),$$

$$= \frac{1}{\frac{1}{1.63} + \frac{48}{.70} + \frac{1}{6.0}} \times 60 \times 50 = 39.3 \text{ B.T.U. per animal unit.}$$

The heat lost through 4 sq. ft. of glass,

$$Qwi = \frac{1}{\frac{1}{1.63} + \frac{1}{10} + \frac{1}{6.0}} \times 4 \times 50 = 226 \text{ B.T.U. per animal unit.}$$

$$\therefore Qw = 2600 - (1800 + 39.3 + 226) = 534.7 \text{ B.T.U. per hr. per animal unit.}$$

From equation (4) the necessary $U$ value of the wall is:

$$U \text{ wall} = \frac{Qw}{A\,(ti - to)},$$

$$= \frac{534.7}{40 \times 50} = .267 \text{ B.T.U. per hr.}$$

Therefore, from equation (5) the number of units of insulation needed in the wall are:

$$R = \frac{1}{U} = \frac{1}{.267} = 3.7 \text{ units.}$$

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