PENNSTATE

College of Agricultural Sciences Cooperative Extension

Agricultural and Biological Engineering

G-91

Inlets for Mechanical Ventilation Systems in Animal Housing

Eileen Fabian Wheeler, Assistant Professor, Agricultural Engineering

Ventilation is important in animal structures for temperature and relative humidity control and for removal of gases, dust, odors, and pathogens. Ventilation has two simple goals: air exchange and air distribution. Air exchange is simply fresh air in, stale air out. Air distribution provides fresh air delivery to all animals and mixing of fresh air with stale air prior to removal from the building (Figure 1). Ventilation system components such as fans, inlets, and controls need to function well together.

Inlets are critical to the success of the ventilation system. Inlets require thoughtful sizing, placement, and control.

The air inlet is the most important part of the ventilation system. The air inlet is responsible for providing good air distribution and movement throughout the structure. To the credit of agricultural fan manufacturers, there are many good fans which will provide the desired air exchange. To many people, ventilation is "a fan" and solutions to ventilation problems are solved by the addition of more fans. Additional fan capacity may be justified in some problem situations but more often the cause of poor air quality in animal structures is improper inlet design and/or function.

Inlet design and operation demand that some technical aspects of air flow be understood. In addition, there is an "art" to inlet operation that comes with experience. The art and experience aspects are what make inlet design adjustment unique to each application and often provides hurdles in diagnosing and solving ventilation problems. The purpose of this fact sheet is to provide explanation of the technical side of inlet design and function while providing a glimpse of the art involved in inlet adjustment. Negative pressure or exhaust ventilation is common in animal housing and will be described here.

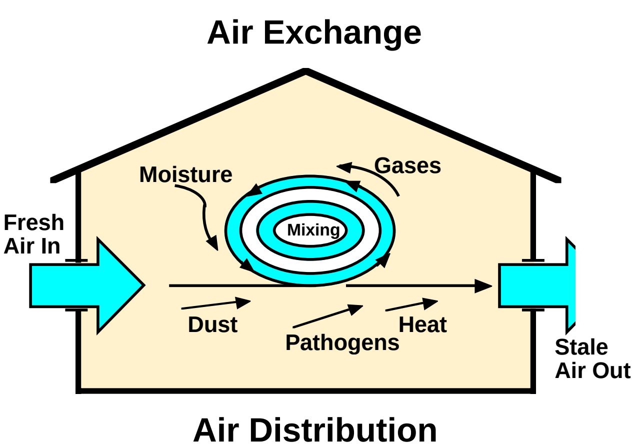

Figure 1. Ventilation has two simple functions: air exchange and air distribution.

Fan Creates Static Pressure Difference

The fan is the air pump. It is important as it creates the static pressure difference which drives air flow. An exhaust fan creates a slight vacuum within the structure compared to outside static pressure. Air moves in response to a pressure difference from a region of higher pressure to lower pressure. The static pressure difference required to ventilate a building is very small: on the order of 0.05-inch water (pressure is often measured as a depth of liquid in a column). To visualize this, it is the amount of suction needed to draw water up a straw 5/100th of an inch. This does not seem like a lot of suction but it is enough to create sufficient air flow to properly ventilate a building. It's enough to make you have to gently tug open the entry door to a properly ventilated building. Air will enter the building through any opening in response to this pressure difference...including that entry door you just left open. Proportionately more air will enter through the opening(s) which offer the least resistance to air flow, such as that open door, compared to movement through higher resistance openings such as the inlets you carefully designed. Requiring all inlet air to flow through your planned inlets helps assure that all parts of the building are supplied with fresh air.

Creating a static pressure difference, that slight vacuum, between the inside and outside of a building requires relatively tight building construction. Most modern animal agriculture buildings meet this criteria. Mechanically ventilated buildings need to have a static pressure gauge (manometer) so the operator can verify that desired static pressure (0.02 to 0.07-inch water) is being maintained. Static pressure should be maintained within this reasonably constant range.

So the basics of mechanical ventilation are that a fan (or fans) exhausts air from the building and the resistance to this air flow at the air entrance to the building, creates a static pressure difference between the interior of the building and outside conditions. Fans provide air exchange by exhausting stale air and causing fresh air to enter the structure. Air inlets are designed and located in the structure to supply air at a desirable direction, speed, and condition.

Inlets

Inlets come in many shapes and sizes with varying levels of usefulness. Inlet types are categorized in Figure 2. Open windows can be adequate inlets but they are inconvenient to control. Most modern animal buildings use openings specifically designed to be inlets to a mechanical ventilation system. Examples are shown in Figure 3. Inlets used for managing cold-weather minimum ventilation often have different requirements than those used for the large air volume needed during summer ventilation.

Good inlets are easily adjusted so that as conditions change within and outside the building, the inlet size can be changed. Some inlets respond passively to changing conditions, for example, by a free-swinging, top-hinged baffle which moves in response to static pressure differences and air flow. Other inlets work with mechanical controllers which adjust opening size in order to maintain a relatively constant static pressure within the building. Inlets are most often positioned high in the structure, such as at the eave juncture of sidewall and ceiling, to allow incoming air to mix with room air before dropping into the animal occupied area.

Functions of an air inlet.
1. Provide fresh air throughout the building.
2. Control direction of air flow.
3. Maintain sufficient inlet air velocity.

If these three functions are not achieved, then poor air distribution, uneven temperatures, and drafts are the result.

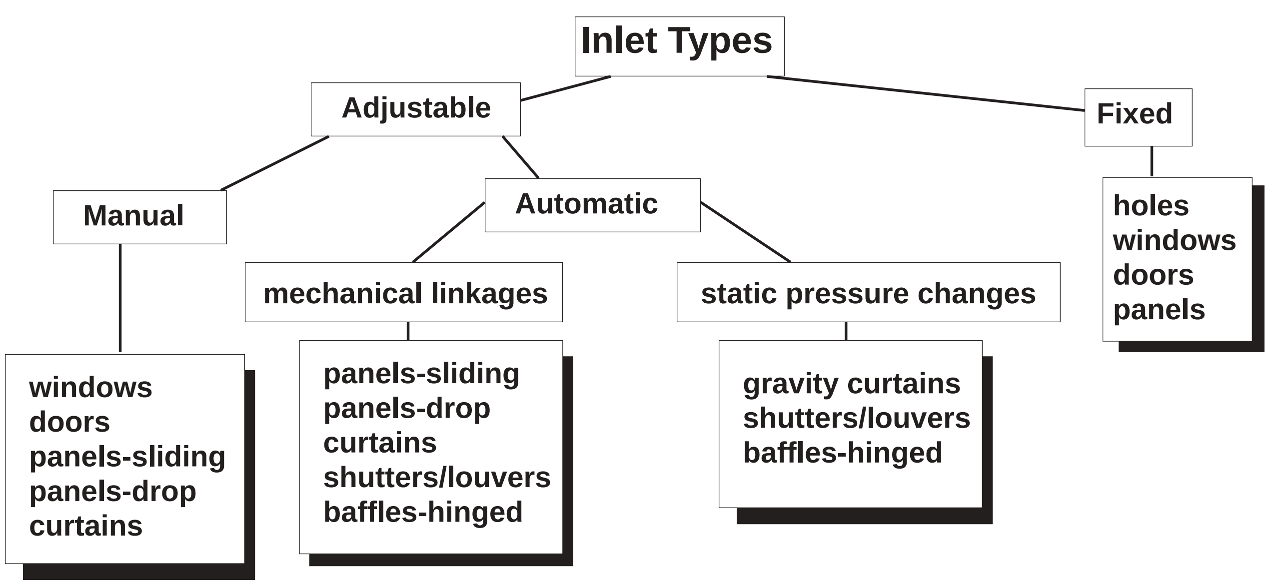

Figure 2. Types of inlets commonly used in animal housing.

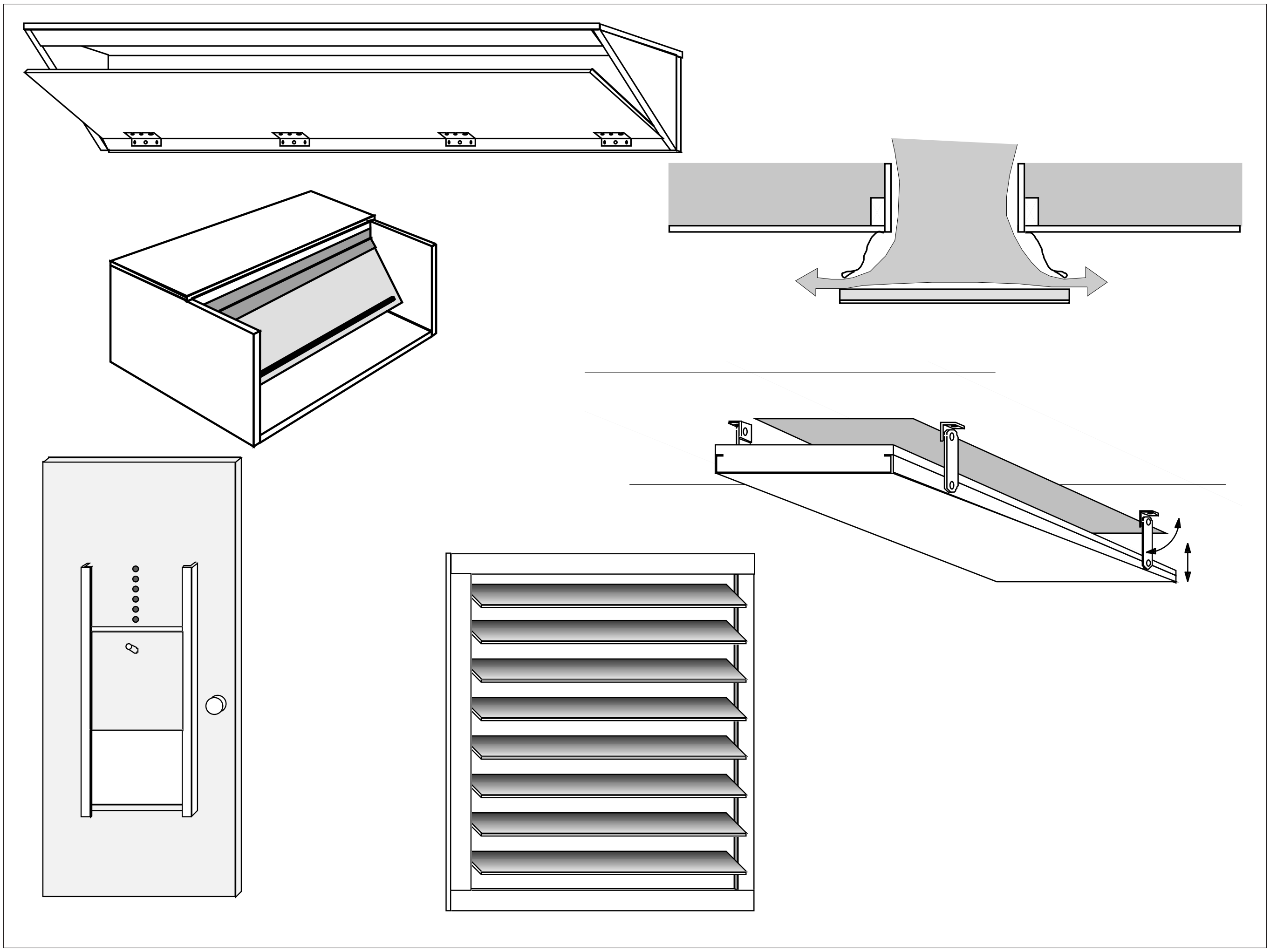

Figure 3. Examples of inlets (clockwise from top). Top left: sidewall slot inlet with baffle. Top right: center ceiling slot inlet with baffle. Middle right: adjustable ceiling drop inlet. Bottom center: louvers. Bottom left: door with adjustable panel. Middle left: box inlet with baffle.

Provide fresh air throughout the building.
Since air is needed in all parts of the building it is necessary to have inlets in all parts of the building... or a distribution mechanism to get air to places where there are no inlets. Two methods commonly used to do this are either by providing inlets around most of the building perimeter (Figure 4) or by bringing air in at one point and distributing it throughout the building using a duct (Figure 5). If air is brought in at only one point, and ducts are not used to distribute the fresh air, then animals near the fan are breathing stale air while animals nearer the inlet benefit from fresh air. In addition, air movement near the inlet is more predictable and less prone to dead air zones than near the fans where the inlet's control over air direction has been dissipated.

Control direction of air flow.
Direction of inlet air flow is either horizontally along a ceiling or vertically down a wall. Inlet air jets have an affinity for traveling along building surfaces. In fact, an inlet air jet that is protected by a surface from mixing with room air will travel farther across a room than a free air jet. One goal of inlet direction is to cause air to mix with the air already in the room before it enters areas where the animals are located. In most animal housing, air is directed across the ceiling. During warm summer conditions, it is often desirable to have air moving over animals as a breeze to enhance convective cooling. Inlets can direct air onto the animals. Changing the size of the inlet opening or the type of inlet allows us to accommodate winter and summer air direction needs.

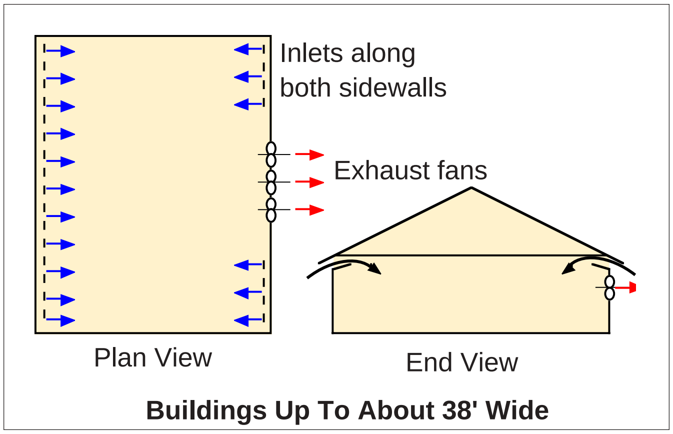

Figure 4. In an effort to provide fresh air throughout the building, inlets are recommended throughout the building. Fresh air may be brought in directly from outside or after traveling through the attic.

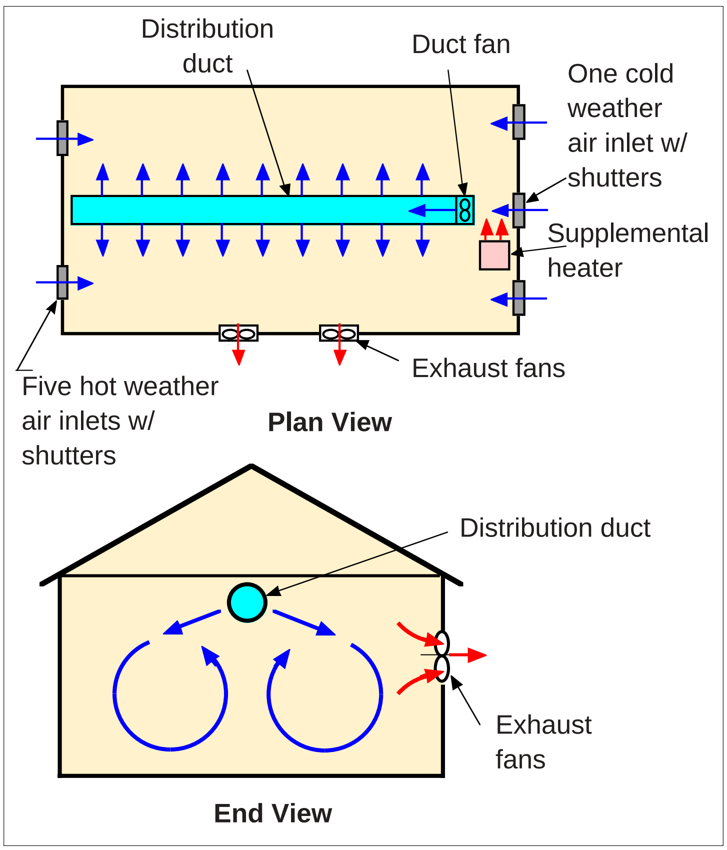

Figure 5. Fresh air may be ducted throughout the building when inlets are available in limited locations.

A DRAFT is cool air moving over animals. Due to its heavier density, cool air drops when entering a warm space. Warm air moving over animals usually does not constitute a draft.

Maintain fast inlet air velocity.

Fast inlet air speed of 700 to 1000 feet per minute (fpm) provides for air mixing, or entrainment, and air distribution, or throw (Figure 6). When an inlet, such as that shown in Figure 6a, is adjusted correctly, high velocity cool air sweeps the ceiling and mixes with warm air in the building. When an inlet is open too wide, a slow moving stream of cool air sinks to the floor without mixing with warm room air and causes drafts as shown in Figure 6b. Inlet size must be adjusted to maintain correct static pressure and create the fast air velocity.

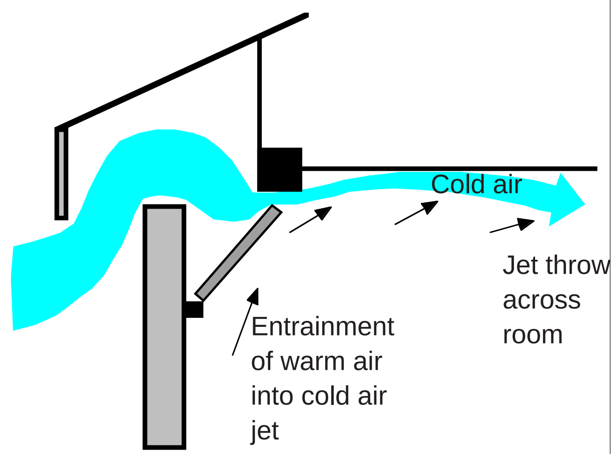

Figure 6a. With an inlet adjusted correctly, high-velocity cold air sweeps the ceiling and mixes with warmer room air.

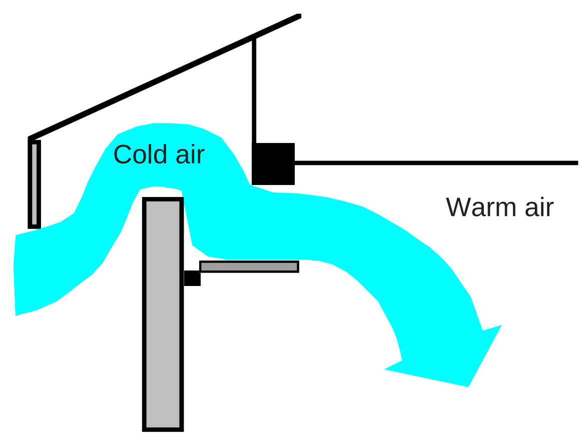

Figure 6b. When an inlet is open too wide, a lazy, low-velocity stream of cold air sinks to the floor causing a draft.

Unplanned inlets are undesirable because we cannot adjust opening size and hence, static pressure. Unplanned inlets include big openings such as doors and windows that were not originally designed to be part of the ventilation system. Openings often forgotten are things like haychutes, manure handling openings, or conveyors. Small openings, such as cracks in the structure and those around doors, windows, and fans, can cause drafts and poor control of air distribution. Ironically, in the past, in traditional barns with natural (no fans) ventilation, the small cracks around board and batten siding, for example, provided hundreds of feet of narrow slot inlets for air exchange in the barn. For fan ventilation, tighten up the building and bring air in through carefully designed and placed inlets for more control over ventilation air distribution.

How big should inlets be?

When air flows through most openings, the cross sectional area of the air jet is reduced to 60-80% of the total free area of the opening. This vena contracta is shown in Figure 7. Nearly all inlet sizing recommendations already account for this reduced effective area of air flow. Provide at least 1.7 sq. ft. of inlet area per 1000 cubic feet per minute (cfm) of air exchange fan capacity. For continuous slotted inlets, providing 2 sq. ft. per 1000 cfm is recommended. Stay within the 1.7 to 2.0 range of inlet size. A smaller inlet creates a faster inlet jet velocity but increases resistance to air flow which can overload fans. Larger inlets allow air speed to slow below desirable level which causes drafts and dead air zones in the building by not mixing and distributing air properly.

The control point on an inlet is where the smallest cross-sectional area occurs in the travel of air flow. Controllers are used to adjust inlet opening size. Inlet opening size is adjusted each time the fan exhaust rate changes to maintain a reasonably constant static pressure in the building while providing high inlet jet velocities.

Fast inlet air velocity is essential for providing air mixing and desirable circulation patterns

Inlet Design

Restrictions to air flow before or after the inlet must be avoided because they reduce volumetric air flow without creating an air jet in the room. The control point of the inlet should be where air enters the animal room. Typically, some sort of baffled opening is used to provide air direction and velocity at this control point. Restrictions before this point will cause an undesirable resistance to air flow which lowers air speed. The smallest upstream restriction should be at least twice the baffled inlet's size (Figure 8). Obstructions after the inlet can deflect air into undesirable drafts and destroy good air circulation (Figure 9). In many ways, air is like water. In fact they are both fluids with one being a gas and the other a liquid fluid. Air has a lot of similarities to water flow in its movement over obstructions, through restrictions, and as affected by thermal buoyancy (hot air rises). When it is difficult to "see" what air is doing, sometimes it is useful to visualize what water might do under similar circumstances.

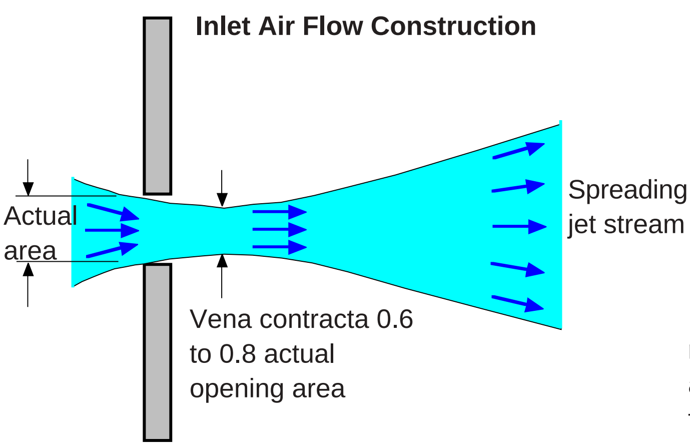

Figure 7. Air flowing fast through any inlet, from the smallest holes in a window screen to an open window, has a vena contracta effect which makes the effective area of air flow about 60% of the apparent (measured) free area of air flow. Recommendations for 1.7 to 2.0 sq. ft. of inlet area per 1000 cfm take the vena contracta into account.

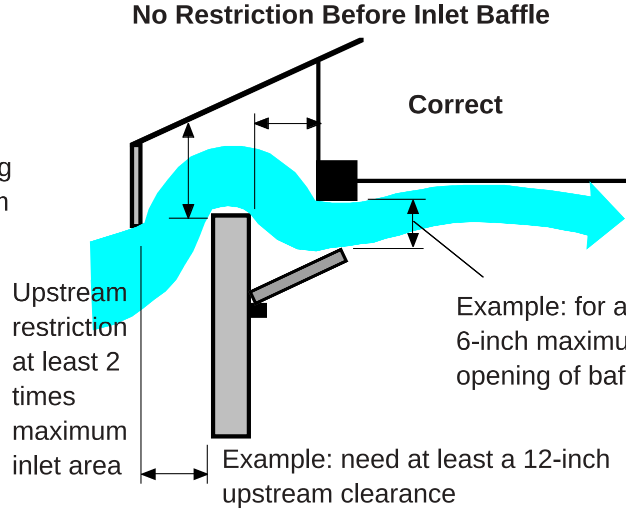

Figure 8a. Upstream of the inlet control baffle there should be little resistance to airflow so the air speed and direction control point is at the baffle.

Restriction Before Inlet Baffle is Undesirable

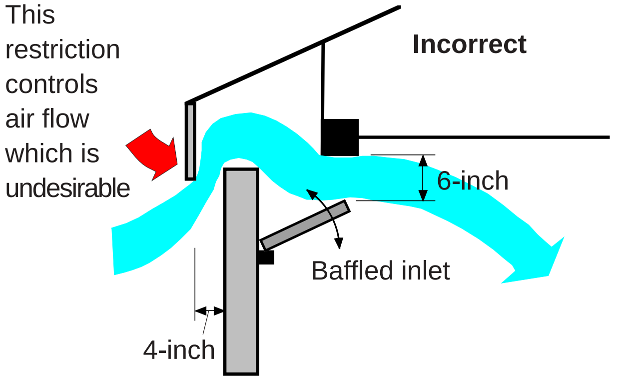

Figure 8b. When upstream restrictions inhibit proper air flow, control is lost at the inlet control point.

Obstruction After Inlet is Undesirable

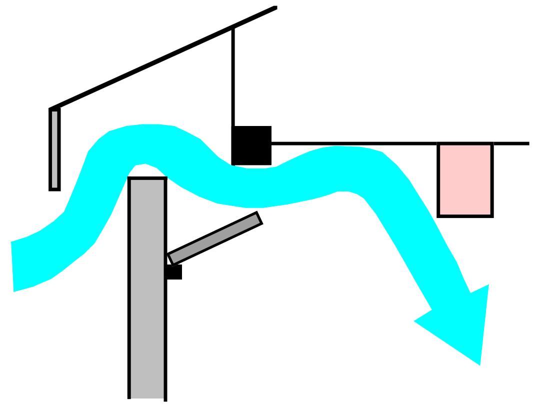

Figure 9. Obstructions, such as barn beams or fluorescent light fixtures, can deflect inlet air jets into undesirable locations.

Inlet Checklist

Refer to Figures 10, 11 and 12.

♦ **Building width**
For buildings up to 38-feet wide, place continuous slots at the ceiling along both sidewalls. For wider buildings, add one or more interior ceiling slot or box inlets.

♦ **Maximum distance**
The maximum distance between fan and inlet should be limited to 75-feet. Air moving this far in most confinement livestock barns has picked up enough moisture, odor, dust, and/or heat to be considered stale air and should be discharged from the building.

♦ **Near fans**
Close inlets within 6 to 8 feet of each side of a fan during cold weather to prevent fresh air from short circuiting out the fan.

♦ **Sectional inlets**
Inlets should be installed in sections so that optimal slot opening and air distribution can be effectively controlled. Some buildings have sections which are not used for part of a production cycle, such as during partial-house brooding of broiler chickens, so only the populated half of the house has functional inlets. Box inlets, which are spaced rather than continuous, can provide control over air distribution as building animal population changes. An example is where one box inlet is provided per farrowing stall.

♦ Provide 1.7 to 2.0 square feet of inlet area per 1000 cfm fan capacity. Provide at least double this area upstream of contol point of inlet.

♦ **Cold weather inlets**
Controlled inlets are essential to direct incoming cold air and to provide mixing (Figure 11). Inlets are placed high on the sidewalls so that air can be tempered with room air before it reaches the animals. The attic often has the advantage of being a wind-protected air inlet. This prevents wind and driven precipitation from entering the building. Often only a portion of the building inlets are used in the winter. For example, every other section of a continuous baffle inlet may be closed for the winter while the remaining sections are controlled to provide ventilation inlet area. This allows half the inlets to be open one-half inch rather than trying to keep all the inlets open one-quarter inch. Generally, construction irregularities will prevent uniform openings less than one-half inch wide.

♦ **Hot weather inlets**
It is best to bring fresh air directly from outdoors (Figure 12). Roof insulation reduces sun warming of the building and is required if using attic ventilation in hot weather. Outdoor air can be blown directly onto older or adult animals (not recommended for very young stock) to create a breeze for enhanced cooling. Hot weather inlets need to be sized to provide a large amount of air without restriction to flow following the 1.7-2.0 ft^2/1000 cfm guideline.

♦ **Inlet screen**
Screen the intake at the building exterior with three-quarter inch hardware cloth or bird netting. Do not use residential window screening or soffit vents as air flow will be too low.

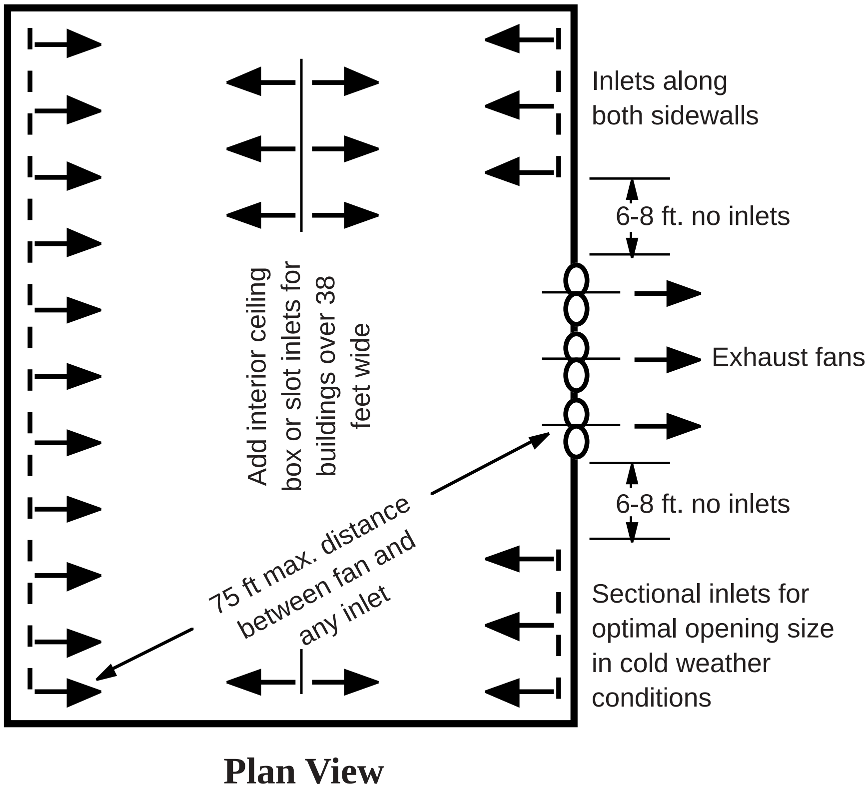

Figure 10. Inlet location checklist.

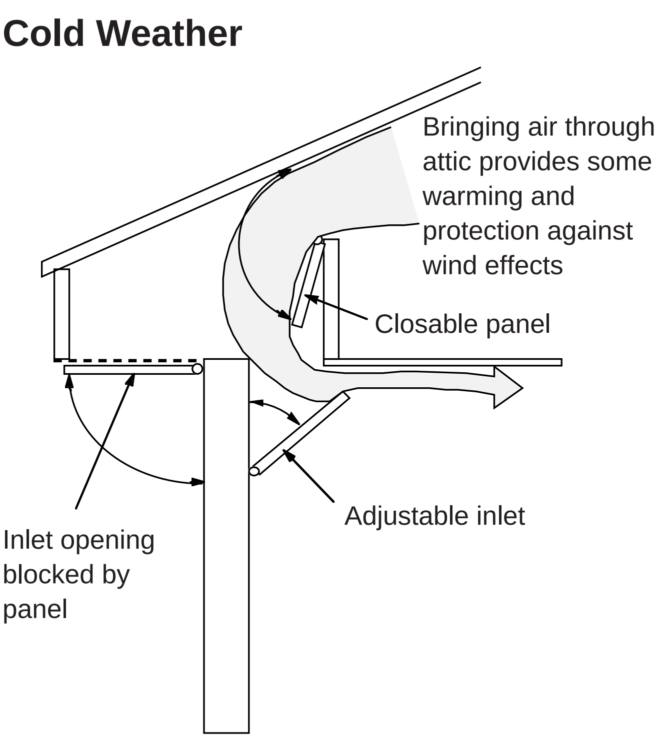

Figure 11. Cold weather ventilation inlet option.

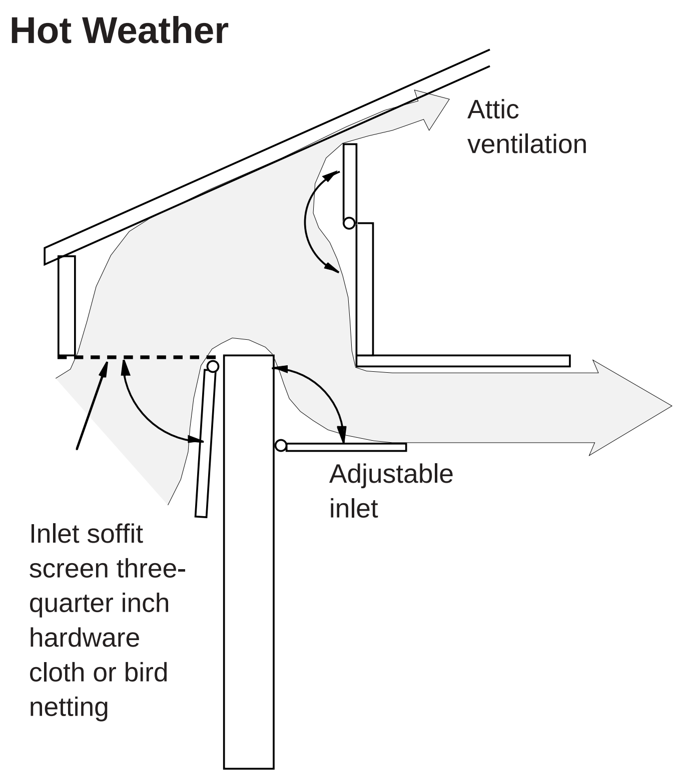

Figure 12. Hot weather ventilation inlet option.

A System

It is important to remember that ventilation is a **system**. The inlets, fans, controls, and a building's structure (such as insulation level, layout, etc.) are components which must function together to provide air exchange and distribution (Figure 13). Careful attention to proper inlet design and location will enhance air distribution within the animal zone. Control of inlet size is needed as conditions change. Remember to check inlet area, air speed, and air direction when ventilation and air quality problems are found.

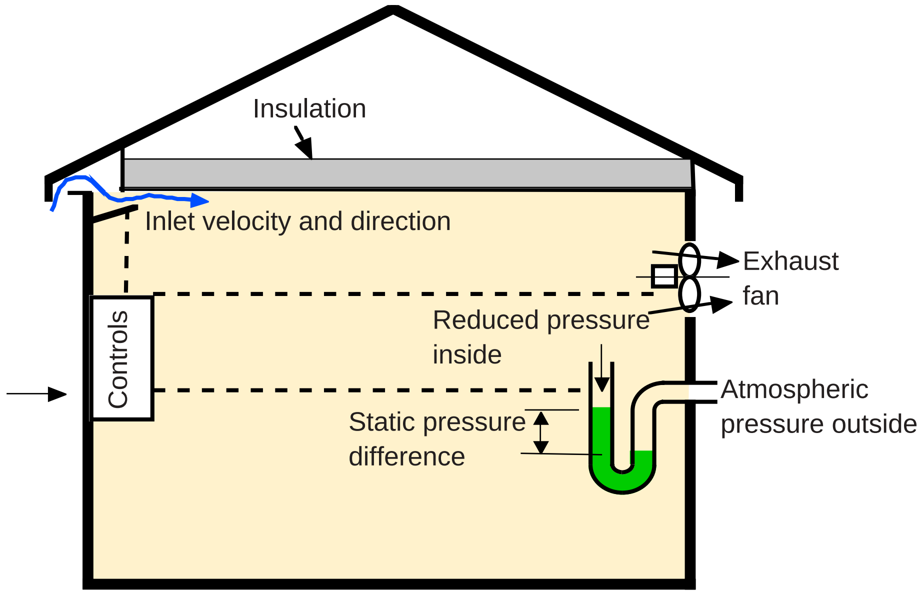

Figure 13. A ventilation system includes fans, inlets, controls, sensors, and often building insulation for proper environmental control.

Additional References

G-80, *Principles of Measuring Air Quality*
G-81, *Instruments for Measuring Air Quality*
G-82, *Evaluating Mechanical Ventilation Systems*
G-83, *Psychrometric Chart Use*
G-85, *Selecting Rated Ventilation Fans*
MWPS-32, *Mechanical Ventilating Systems for Livestock Housing*

For a copy of our Fact Sheet listing contact:
Agricultural and Biological Engineering Extension
246 Agricultural Engineering Building
University Park, PA 16802.
Phone (814) 865-7685; FAX (814) 863-1031
email agbioeng@psu.edu   www http://engrabe.cedcc.psu.edu

PSU 9/97