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Ventilation System Design Parameters for Greenhouses for Tobacco Production

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INTRODUCTION: Methods for germination and initial growth of tobacco have changed rapidly in recent years, moving from outside float beds into double-layer plastic greenhouses. Typically, these "tobacco greenhouses" consist of sidewall curtains, which run the entire length of both sides of the house. They may also have modest mechanical ventilation.

Ventilation of greenhouse structures is a mature field, with engineering practices for proper design given by numerous organizations including ASAE. In this article we briefly outline the important features of ventilation of concern to tobacco greenhouse operators

WHY VENTILATE? Ventilation provides three major functions: temperature control, moisture control and elimination of other indoor pollutants. For tobacco greenhouses with vented gas-fired heaters the ventilation requirements for eliminating pollutants are small compared to the need to remove excess moisture.

Tobacco greenhouse ventilation design thus involves ventilation for temperature control, and ventilation for moisture control. At any time during the day or night, one of these two ventilation requirements is larger than the other, and it is this larger requirement that must be met with a properly designed ventilation system. Ventilation is measured with volume of air moved in a time interval, typically cubic feet per minute (cfm).

For example, during a sunny day the inside temperature will rise quickly. To limit the temperature rise, additional ventilation is needed. This is ventilation for temperature control.

Likewise, during night hours with little need for ventilation for temperature control, condensation occurs on the inner surfaces of the greenhouse.

This is an indication that there is more moisture being put into the greenhouse than is being removed. This situation calls for ventilation for moisture control.

VENTILATION METHODS: There are two principal means for supplying ventilation in tobacco greenhouses:

1. Natural ventilation – produced by wind-induced flow across a building with curtains open. Another significant source of natural ventilation can be the "chimney effect" in buildings with ridge vents.

2. Mechanical ventilation – the use of fans to provide ventilation requirements, typically by adding additional ventilation as interior temperature rises above a thermostat setting.

Many tobacco greenhouses in use are a hybrid of natural and mechanical ventilation systems.

VENTILATION REQUIREMENTS: Two ventilation requirements are computed to cover the two ventilation modes (temperature and moisture control). These are maximum ventilation and minimum ventilation. Maximum values for two greenhouse sizes are given in Table 1.

Table 1: Example building maximum and minimum ventilation rates

Building size	Maximum Ventilation	Minimum Ventilation
30' x 100'	30,000 cfm	500 cfm
35' x 150'	52,500 cfm	875 cfm

Maximum ventilation - This is the amount of airflow available to limit temperature rise. During warm and/or sunny conditions, as outside air comes into the greenhouse it is warmed. This temperature rise is limited by constantly replenishing interior air with outside air. For greenhouses, one complete exchange of the air in a building each minute (1 air change per minute) is generally recommended.

To figure maximum, simply multiply the building floor area by 8 (average height). For example, a house 150' by 35' has a floor area of:

$$35' \times 150' = 5{,}250 \text{ ft}^2$$

One air change per minute is thus about:

$$5{,}250 \times 8 = 42{,}000 \text{ cfm.}$$

Note: A multiplier of 10 for taller greenhouses, rather than 8, may be used. In this example, the maximum ventilation would then be 52,500 cfm.

Minimum ventilation – This is the amount of airflow continuously available to limit moisture levels in the building. It may be provided by a small fan, a large fan with a timer, or a partially opened curtain. In some buildings it may be provided simply by leakage. A reasonable value for minimum ventilation for moisture control is 1 air change per hour. Minimum ventilation rate can be computed by dividing maximum ventilation rate by 60 (1 air change/hr).

Double wall plastic greenhouses have a leakage rate of about 1 air change per hour. However, this can vary widely with construction and age of the building. New buildings with flashing over all curtain edges may have leakage rates of 0.6 air changes per hour or lower, and leaky buildings on a windy day may experience 5-10 air changes per hour.

Factors affecting leakage rate, and hence the uncontrolled minimum ventilation, include outside wind velocity and direction, tightness of the building, and the difference between inside and outside temperature.

Minimum ventilation needs vary with crop stage of development. During germination it is critical that moisture be controlled to levels low enough that condensation does not drip off interior surfaces and splash seeds out of trays. Once germinated, higher moisture levels may be tolerated but standing water on plant surfaces and continuous values of relative humidity above 70% will promote disease and mold.

MECHANICAL VENTILATION INLETS: If fans are used for ventilation, it is important to provide enough inlet area. Motorized shutter inlets are typically provided for this purpose, and are located on the opposite end wall from the fans.

Too few inlets result in a large pressure difference between inside and outside the house. Exhaust fans pull a suction on the inside of the house, and must work harder to provide air flow if there are insufficient inlets. The greater the pressure difference, the less the air flow rate actually provided by the fan.

To determine the number of inlets needed, use certified fan manufacturers' airflow data, tested at 0.05" or 0.1" static pressure. This ventilation rate should be divided by a design inlet velocity of 720 feet per minute (fpm) to find the gross inlet area needed. For example, a 48" fan rated to provide 22,000 cfm at 0.1" static pressure requires:

$$22{,}000/720 = 30.5 \text{ ft}^2$$

From Table 2, this could be provided by any combination of inlets that give at least 30.5 ft^2; for example: one 60" shutter and one 36" shutter, or three 42" shutters.

Table 2: Typical inlet shutters

Nominal Size	Frame Dimensions	Free Area
15"	15"x18.25"	1.45 ft^2
24"	24"x27.25"	3.72 ft^2
30"	30"x33.25"	5.8 ft^2
36"	36"x39.25"	8.37 ft^2
39"	39"x42.25"	9.82 ft^2
42"	42"x45.25"	11.39 ft^2
60"	60"x63.25"	23.25 ft^2

It is generally best to provide more, rather than less, inlet area because many fans' performance drops rapidly as static pressure increases. But, too much inlet area (e.g. curtains open and fans running) should also be avoided.

MECHANICAL MINIMUM VENTILATION: A simple method to provide minimum ventilation is by using a small fan that runs continuously and blows into the greenhouse. It is important to blow air into the greenhouse so that exhaust fumes are not pulled into the house. Consider using fans of 9" to 10" diameter controlled with a percentage timer. These fans are available which provide about 1000 cfm at 0.1" static pressure. If only 500 cfm were needed on a cold day for minimum ventilation then the timer could be set to operate the an 50% of the time.

CURTAIN-SIDED MINIMUM VENTILATION: For houses with curtains, a simple method to provide minimum ventilation is to slightly open the leeward curtain. The opening does not need to be large, and ventilation occurs primarily by the temperature difference between inside and outside inducing leakage. Adjustment can be made by visual inspection of the degree of condensation.

COST OF MOISTURE CONTROL: It is crucial to understand that ventilation for moisture control has an energy cost. Drier outside air is brought in to replace moist warm inside air. This outside air typically must be heated to the desired inside temperature. During cloudy conditions or at night, the source of heat for this colder outside air must be from the heating system.

Consequently, over-ventilating for moisture control can result in excessive heating costs. Using a percentage cycle timer to reduce the minimum ventilation rate during periods when less is needed can provide a cost effective operation.

EXAMPLE MECHANICAL VENTILATION SYSTEMS: Table 3 lists example mechanical ventilation for two greenhouses. Note: Not all fans deliver the same air flow.

Table 3: Example mechanical ventilation systems. *Assumed fan capacity at 0.1" static pressure: 36" fan is 9,000 cfm; 48" fan is 19,000 cfm*.

Building size	Number of Fans	Number of Inlets
30' x 100'	1 x 36" 1 x 48"	4 x 39"
35' x 150'	1 x 36" 2 x 48"	2 x 39" 2 x 60"

Be sure to check the performance characteristics (flow vs pressure, cfm/watt) before purchasing any fan.

EXAMPLE CURTAIN-SIDED VENTILATION:
Table 4 lists approximate ventilation rates for two greenhouses, assuming 1 mph wind perpendicular to the opening.

Table 4: Example curtain-sided ventilation rates. *Assumed 0.6 opening effectiveness coefficient, equal curtain openings, 1mph wind velocity, 30' building width.*

Curtain Opening	100' Building (cfm)	150' Building (cfm)
1 inch	450	660
1 ft	5,000	7,500
2 ft	10,500	15,800
4 ft	21,000	31,500

Note that these ventilation rates assume near still-air conditions. A 5 mph wind perpendicular to the curtain openings will give approximately a five-fold increase in ventilation rate.

The ventilation rate through a partially open curtain depends on building width, but not on building length. A wider greenhouse will in general require more curtain opening to achieve one air change per minute. Because of this, wide buildings with short curtains can experience problems on hot, still days. A general rule of thumb is to provide one foot of curtain opening for each 10 feet of building width.

COMPARISON: Table 5 compares the mechanical and curtain sided ventilation systems for two building sizes. NOTE: A wind velocity of about 3 miles per hour is sufficient to realize maximum ventilation for temperature control in a curtain-sided house with the curtain open 2 ft.

Table 5. Comparison between mechanical and curtain sided ventilation.

Building Size	Maximum Ventilation Required	Number Fans	Required Wind Speed (2‘ opening)
30' x 100'	30,000 cfm	1 x 36" 1 x 48"	3
35' x 150'	52,500 cfm	1 x 36" 2 x 48"	3.3

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