H o r t i c u l t u r a l   E n g i n e e r i n g

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Website: www.cook.rutgers.edu/~roberts/

Website Technology

There were several who wrote or sent an e-mail indicating that they had located the Horticultural Engineering Newsletters on the webpage and indicated that it wouldn't be necessary to mail a hard copy to them. I don't know how large the response will be but we appreciate those who desire to take this route.

www.cook.rutgers.edu/~roberts/

The use of the website seems to be a growing desire among growers and researchers alike. It may never replace the printed page but it provides an excellent opportunity to review a particular subject, relatively quickly and effortlessly and in most cases economically. Watch the popular greenhouse publications for listings of helpful websites.

Horticultural Engineers Graduate

Three bright young people have recently completed their studies in Horticultural Engineering. Evaluating their senior design project gives me great courage and hopefulness for the future of young people working with horticultural engineering degrees in the Controlled Environment Agriculture arena. The program continues to grow under the excellent leadership of Dr. Gene Giacomelli. If you know of young people who would like to study engineering and plant science and build a career in horticultural

Website of Interest

This Issue of Horticultural Engineering like previous ones is available on the web at:

www.cook.rutgers.edu/~roberts/

Our hope is that many of you will want to make use of the website and eliminate the need for us to send you a hard copy.

Please let us know so that we can save the duplicating, postage and handling costs in our department, *ment,* *Bill Roberts*

Rutgers Research Open Roof Greenhouse nearing operation

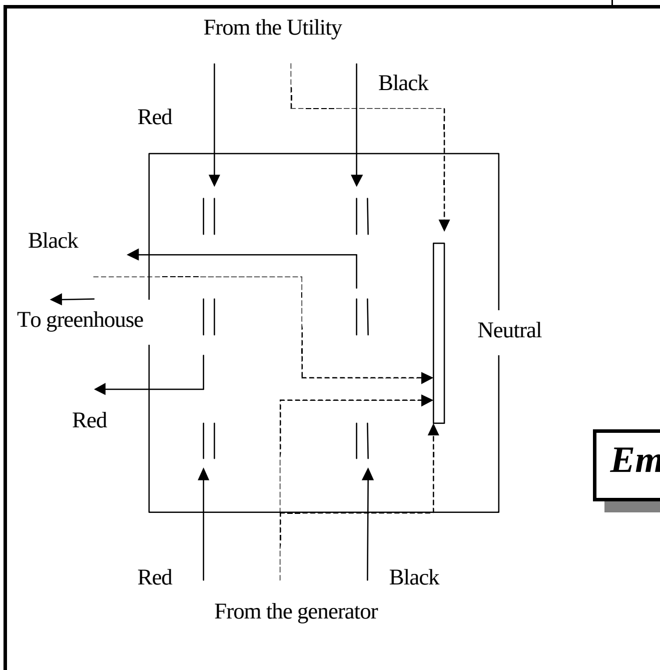
The MXII open-roof greenhouse has been completed and the equipment is being installed. The 58 (with the 5 foot wide sidewalls) by 60 feet long greenhouse is covered with double poly. The 4 moving-roof sections are controlled by an Argus computer and four gear motors.

Page 8 gives a view of the greenhouse during construction. Your editor knows much more about these designs than when he became a member of a small construction team.

Commercial growers using this type of design have had an excellent spring season. Visiting one recently it was noted that the temperature inside was the same as outside in the open roof design and in an adjacent conventional greenhouse the temperature was 8°F above outside. Excellent plant quality was evident throughout the section.

Use Caution with Emergency Generators

With the concerns for Y2K everywhere the use of emergency generators is getting much attention. The most critical concern for the installation of emergency generators is to make sure that they are isolated from the utilities lines for very important safety reasons. If a lineman is working on the repair of a line, he knows that the power is off from the utility generator but if the lines are being fed from emergency generator somewhere on the system he can be in grave danger.



Emergency Generator System Switch Diagram
Double pole – Double throw switch*
Neutral lines go to a common bond.
If three phase power is used, triple pole- double throw switch

Specifically, the emergency generator must be installed with a double throw switch. The lines from the utility are installed on one side of the switch and the lines to the generator are installed on the other side of the switch and the lines to the greenhouse are installed on the middle set of connectors. In this fashion, energy is going to the greenhouse from the emergency generator or from the utility lines. The emergency generator can never then be connected to the utility line and cause a problem. The diagram indicates how this is done.

Another concern is for the safety of the emergency generator operation. Never refuel the generator while it is operating. Always shut down the system during this time. Make sure that the combustion gases from the generator or from the tractor driving the generator through the PTO are vented to the outside to avoid any dangers of carbon monoxide poisoning.

A recent communication from my local utility indicated that customers who improperly install, operate or maintain a generator are responsible for any injury or damage suffered by themselves, their neighbors and the Utility. Words of wisdom. The most important thing of course is not to injure a linesman risking their lives working on the pole during a storm or other emergency situation.

Emergency Generators are a necessity

It's a good idea to have a competent licensed electrician install the generator switch and another good idea is to run the generator often during the season so that when it is needed it will start and be ready to function. Automatic switching equipment is available but quite expensive. In the absence of such a switching system emergency alarms are needed to alert personnel that power is off. This can be done with a system which dials up to three phone numbers in sequence and relays a message that the system is down. Regardless of the time, day or night someone is alerted to come look over the situation and start the generator if needed and avoid a serious problem, particularly on a very cold windy night.

Managing the Greenhouse Environment for Ventilation and Cooling

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Many of the principles for air movement for heating systems also apply to ventilation systems. The National Greenhouse Manufacturing Association has developed excellent standards for ventilating and cooling greenhouses. These include recommendations and designs affecting site elevation, sunlight intensity, orientation and shape of the greenhouse and crops being grown. The following is a discussion of systems and requirements.

Greenhouse ventilation is required to control temperature and moisture levels and provide CO_2 for good crop production. There are two basic ventilation systems used in greenhouse production systems, natural and mechanical ventilation systems. Natural ventilation depends upon normal air movement created by wind pressures or by gradients induced by differences in air temperatures between the growing area and outside the greenhouse. Mechanical ventilation is air movement created by fans that bring air into the growing area through controlled entrances built into the greenhouse area and exhaust it through the fan assembly. The ability to change the size of inlets is important to the design of good mechanical ventilation systems. Fan ventilation is normally controlled by thermostats and in some cases by humidity-sensing devices when relative humidity is the controlling factor for disease control.

NATURAL VENTILATION

Natural ventilation is driven by temperature differences or wind conditions. Natural ventilation occurs when there is a temperature difference between the inside and the outside of the greenhouse and a vent is opened to allow the warmer air to leave and cooler replacement air to enter. The greatest potential for natural ventilation is during the winter, when the temperature difference between inside the greenhouse and outside is the greatest. Unfortunately, this occurs when the need for ventilation is the least. On excessively hot summer days, the outside temperature may be only slightly cooler than the inside temperature. The ventilation potential is practically nonexistent when the need is the greatest. Adequate ventilation during warm and hot summer periods must be wind-driven and is often site-specific. Areas of naturally occurring breezes provide the best opportunities for warm weather ventilation.

Naturally occurring breezes with proper greenhouse orientation can provide excellent ventilation at some sites. The wind in some areas is often unpredictable, however, and adequate temperature control is very difficult to achieve. Meteorological information about the proposed site is essential in designing a natural ventilation system.

Natural ventilation system designs include roll-up sides, either hand or automatically operated, and ridge vents constructed as an integral part of the greenhouse structure. Although difficult to install, ridge vents in polyethylene-glazed structures can provide good options for natural ventilation. In gutter-connected or ridge-and-furrow greenhouses, ridge vents perform better than the vents that open at the gutter. Although the gutter units are easier to recover and construct, they do not perform as well as ridge systems. Time required for attention each day and the loss of control, particularly during cold weather, are the most often mentioned complainsts of natural ventilation systems using roll-up sides.. Most glass greenhouses are ventilated naturally using ridge and side ventilators. These are usually automated systems, but are still limited by the factors listed above.

Several newer greenhouse designs for warmer climates feature greenhouse structures with no glazing. These are designed with retractable thermal screens and provide opportunity for excellent environmental control during warmer weather. Site selection is important for heating considerations when growing throughout the year. Some growers use them for increasing growing space and hardening off areas in the spring. Another design features articulating roof sections where the entire roof opens giving more than 90% opening. One design hinges at the gutter and opens at the ridge. The other design hinges at one gutter and the ridge and opens at the gutter. Figure 1 illustrates these two types of structures. These are superior to the sliding thermal screen type because they have all the attributes of conventional greenhouses. When the roof is closed sunlight enters as it would in a normal greenhouse. When the roof is open natural light reaches the plants without having to pass through the glazing. Orientation of North-South is important to ensure that the shadow pattern moves throughout the greenhouse during the day.

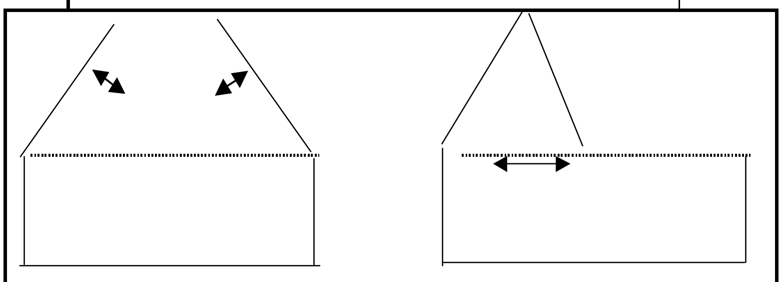

Figure 1. Diagram on left illustrates design which hinges at the gutter and opens at the ridge and the diagram on the right indicates the design which hinges at the gutter and ridge and opens at the gutter.

MECHANICAL VENTILATION

Fan ventilation systems with properly designed inlets can provide excellent temperature control in all seasons. The most desirable feature is the ability to easily automate the entire system. This has become increasingly true with the use of computer based control. This feature is especially useful to growers with other responsibilities who may be away from the greenhouse during the day and who have difficulty obtaining labor on the weekends. The negative aspects of mechanical ventilation systems are the higher installation and operating costs.

Fan systems are designed to provide approximately one air change per minute for the growing area. Recommendations vary but generally 7-10 cfm per square foot is used as a design parameter. If thermal screens are used for summer shading, 7 cfm/sq. ft is the preferable design parameter. It is generally desirable to provide this ventilation capacity with two fans, unless the greenhouse is very small and costs for installation would become too high. The use of multiple fans provides an easy opportunity for using more than one ventilation stage, a feature very desirable in cooler times of the growing season.

In any ventilation system the size and location of the inlets are the most important design consideration. Air entering the greenhouse is always cooler than the inside temperature during colder weather. It is important to obtain proper mixing of the inlet air with the ambient greenhouse air, so that local cold spots or unequal temperatures are not experienced throughout the growing area. Figure 2 illustrates the action of air moving through a restricted opening and the resultant distribution pattern. The high-velocity air moving through the opening causes significant mixing of the cold incoming air with the ambient greenhouse air. It is similar to using a jet of water coming from a hose to mix the liquid in a barrel.

Another similarity is the human nose. We exhale CO_2 from our lungs and inhale O_2. The reason we do not inhale the breath that we just exhaled is because of the mixing action of the tiny jets of air created by our lungs when we exhale. The action of these jets mixes the CO_2 with the ambient air so that when we inhale we get a proper mixture of air.

In ventilation systems the location of the inlets is of paramount importance. It is desirable to keep the length of air travel to approximately 100 feet in free-standing houses. The upper limit for gutter-connected greenhouses appears to be 200 feet. Fans are usually mounted in one end of the house and air inlets on the other end.

Design cfm = (length) (width)(7) or (10)

A: 30 x 96 x 7 = 20,160 cfm *B*: 30 x 96 x 10 = 28,800 cfm

For a two-fan installation: *A* select 2 fans @ 10,000
B select 2 fans @ 15,000

The fans would be rated at 0.1 inch static pressure and have an electric motor capable of delivering 15,000 to 20,000 cfm per horsepower.

If one of the fans selected were a two-speed fan, three levels of ventilation could be provided. If the higher air exchange rate were desired, the ventilation rates would be (1) 7500 cfm, (2) 15,000 cfm and (3) 30,000 cfm. This provides the opportunity for better and more uniform environmental control.

Observations taken in a double- glazed polyethylene greenhouse, 72 x 210 feet on a bright January day, revealed that the first fan stage was cycling and ventilation was taking place when the outside temperature was 0^oF and the inside temperature 75^oF. Thorough mixing was occurring without any damage to the crop adjacent to the window because the air was coming through the window inlet at high velocity and directed upward as indicated in Figure 2. The fans were operating in cycles of about 2 minutes during these conditions.

Fans should be provided with gravity shutters and safety wire screens and have the fan motors protected locally with proper electrical protection and an on-off switch to protect workers when servicing the fans. Inlet shutters should be motorized. Gravity-type shutters have been used, but are subject to wind action in adverse weather and are not suitable for winter operation.

Inlets should be sized to provide an apparent velocity of 700 feet per minute or 1.4 square feet of inlet per 1000 CFM of installed fan capacity. The cross-sectional area can be determined by dividing the air capacity of the fan in cfm by the inlet pre-determined design velocity in fpm, which gives excellent mixing. An example for calculating areas required is given in the box on page 6.

Motorized shutters can be a problem during the colder part of the year. The inlets direct a large volume of air to the crop directly in front of the opening and can cause reduced temperatures at that location. If the velocity of air moving through the shutter is low, then the cold air tends to settle without mixing and move across the greenhouse to the fan and be exhausted, having had no impact on the control thermostat located usually at the 6-ft level. The fan continues to operate because the thermostat cannot sense the cold temperatures at the floor level. It would be desirable to open the shutters in stages to match the number of fans operating. Because of this, continuous window vents with openings that can be regulated are very popular. The manufacturer often provides continuous aluminum extrusions that serve as hinges, making the windows essentially maintenance free. They are often glazed with acrylic or polycarbonate panels.

The following example illustrates how a design might be carried out for a gutter connected greenhouse using a continuous vent window rather than a series of motorized shutters. The table indicates how the fans and the window would be staged to achieve three levels of ventilation to provide uniform conditions in the greenhouse regardless of the outside conditions.

In the example cited earlier, a 30'by 96' greenhouse with two 15,000 cfm fans would require the following inlet area.

Area = cfm/velocity, Square feet = cubic feet per min/feet per min

2 x 15,000 = 30,000/700 = 43 square feet. Providing two 48" by 48" motorized inlet shutters and one 42" by 42" motorized shutter would provide 44 square feet of opening.

Continued on the next page

PLASTICULTURE 2000

28th National Agricultural Plastics Congress and the 15th International Congress for Plastics in Agriculture

September 23-27, 2000
Hershey Lodge and Convention Center
Hershey Pennsylvania USA

A special feature of this landmark meeting will be the three-four day tour through Pennsylvania and New Jersey prior to the opening of the conference. The tour is designed to accommodate international attendees who will be entering our country at the New York City airports. The tour will include visits to production agriculture farms utilizing drip irrigation in conjunction with plastic film mulch as well as the latest in greenhouse technology with visits to a 14 acre site as well as a one acre greenhouse tomato production facility which utilizes methane gas for heating as well as electrical production from a co-generation unit. The tour will include stops in the historic Philadelphia area and additional visits to eastern Pennsylvania growers as the group moves directly to Hershey for the Congress. The tours will be hosted by Rutgers University and arranged by Gene Giacomelli and several New Jersey county agricultural agents.

Congress co-chairs are Michael Orzolek and Bill Lamont Jr. of Penn State University who is the host for the Congress.

Additional up-to-date details of the meeting are available on the ASP website: http://www.plasticulture.org. Registration materials will be available in the spring of the year 2000.

For example, a greenhouse which is 84 by 150 feet would have an installed fan capacity from 90,000 cfm to 126,000 cfm. If six 20,000 cfm fans were installed in the house, a total window inlet of 168 square feet would be required. This would require 10, motorized 48 by 48 inch motorized shutters. Another way to provide the inlet area required would be the use of a continuous vent window on the side of the greenhouse opposite the fans. Since 168 square feet is required, and the greenhouse is 84 feet long, a maximum continuous opening of only 24 inches would be required. The window can be opened in stages to match the number of fans operating.

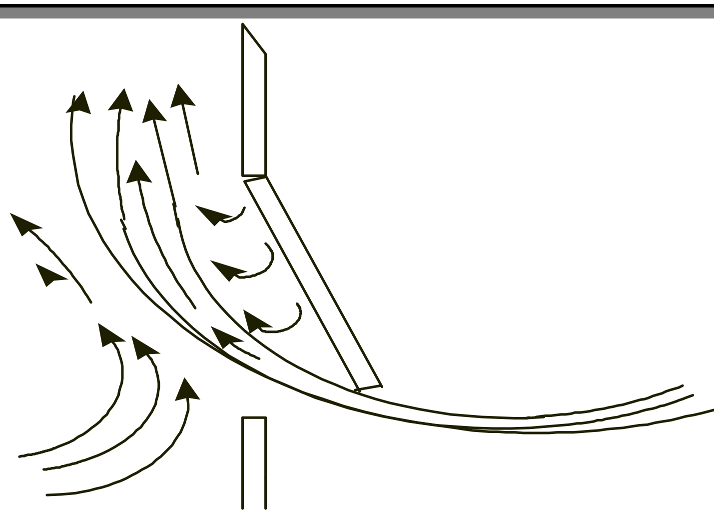

Figure 2 This diagram illustrates the mixing action which occurs when cold air coming into the greenhouse through a controlled window vent opening mixes with warm ambient greenhouse air.

In the example, the design calls for six fans. A suggested control strategy would be to use three stages. If the fans were aligned along one wall, fan number 3 could operate as stage number 1. Fans 1 and 6 could be turned on for the second stage, and fans 2, 4 and 5 could be turned on for the final stage of ventilation. The table indicates the three fan stages, the ventilation volume being delivered and the window opening required to provide a apparent velocity of 700 fpm through the opening and good mixing of the incoming air. Computer-based systems provide excellent control by staging the inlet window opening depending upon the number of fans operating, based on desired temperature settings recorded in the computer program.

Fan Staging Scenario

Fan operating	CFM	Area Opening	Width opening
T1 stage 1 fan 3	20,000	28	4”
T2 stage 2 fans 3,1,6	60,000	84	8”
T3 stage 3 fans 3,1,6,2,4,5	120,000	168	24”

Article To be continued in the September 1999 Horticultural Engineering

View of MXII greenhouse when superstructure was erected in March 1999

View of Greenhouse during covering in April 1999

View of Greenhouse nearly completely covered May 5, 1999

COOPERATIVE EXTENSION
COOK COLLEGE
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We cannot direct the wind, but we can adjust our sails. SPeaking of sails and wind, minds are like parachutes, they only function when open.

HORTICULTURAL ENGINEERING

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Special CCEA Conference
ACESYS III
"From Protected Cultivation to Phytomation"
Friday July 23, 1999
Cook College Rutgers University
New Brunswick, NJ USA

Conference Chair Dr. Gene Giacomelli
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The Conference will include a Phytomation Special Lectures Forum, comprised of an outstanding international field of experts in controlled environment agriculture, and chaired by Dr Tadashi Takakura of Nagasaki University and Dr. K.C. Ting, Chair of the Bioresource Engineering Department of Rutgers University.

The morning Forum will provide a foundation for the day's program, offering a firm background and promoting the discussion for visioning of Phytomation which will follow in an afternoon program. The Forum will be open to include growers, research, industry and interested academics.

The special CCEA afternoon session will also include several speakers and a discussion session. The entire conference should be of especial interest to those interested in planning the future of Phytomation as it develops from controlled environment agriculture.

The day will conclude with an evening retirement banquet in honor of