Horticultural Engineering

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

Roberts Hangs it Up

After 41 years on the faculty, I'm retiring. I came to Rutgers as a student 50 years ago and except for two years in the military service I have been here at Rutgers University. As difficult as it is to believe these numbers the time has come to let younger minds and energies carry on the important work of supporting food, fiber and horticultural production, particularly in controlled environment agriculture applications. I'm confident that our faculty and staff will carry on this very important and timely program. Although my official date is September 1, 1999, I will continue on until the end of the year and into early next year in a modest part-time role. During this time I hope to carry on some of the research activity of our new open-roof greenhouse, continue as editor of the Horticultural Engineering Newsletter and conduct our annual Greenhouse Design and Environmental Control Short Course to be held on January 10 and 11, 2000. Depending upon the filling of my position I will also help acclimate the new Horticultural Engineer.

There is not enough ink in the cartridge to adequately thank all those who have made this enjoyable and challenging career possible. Dottie, my wife is at the head of the list. For 45 years she has been a faithful encourager and one who has held me accountable. Ruth Novak, a trusted colleague and friend has been of inestimable help to me. She has kept me from large pitfalls and helped me out when I couldn't avoid them. Many have commented over the years, don't let Ruth slip away. She is always friendly and unquestionably most helpful in answering our questions and supplying the necessary information.

Thanks to all. I have enjoyed the trip and look forward to God's continued blessing in the new challenges of retirement. Bill Roberts

Baton Passes to Giacomelli

Dr Gene Giacomelli assumed leadership of CCEA at the ACE-SYS III conference on July 23, 1999 The ceremonial passing of the baton took place during the annual CCEA meeting held in conjunction with the Symposium.

Gene is no stranger to CCEA Partners and Scientific Advisory Board members. He has been active in CCEA and has produced two highly successful workshops and was the prime mover with Dr. KC Ting of ACE-SYS III. As Director, Gene will assume duties of day to day operations of CCEA and be responsible for its long range vision and mission.

I will continue for a short time as Editor of the CCEA Newsletter and assist Gene in minor administrative and operational duties. These are exciting days and we are very optimistic about the role of CCEA in the next century.

COMBINATION HEATING AND PARTIAL VENTILATION SYSTEM

(Continued from H. Eng'g Volume 14 # 4)

Some growers have had good success with a design that provides both heating and partial ventilation maximizing the use of the system, Figure 3.

The purpose of this type of system is to minimize the effect of the fans operating at the same time as the hot air heaters. Separated combustion units have eliminated the problem of working the heating system and fan system simultaneously because of the separate air paths for the combustion air and the greenhouse air being heated by passing through the heat exchanger.

A horizontally fired unit is used, which is connected directly to the polyethylene heating tube located along the exterior wall of the greenhouse. Directly above the furnace is a plywood chamber, approximately the same size as the furnace. This chamber has one inlet from the greenhouse and one from the outside, each controlled by a motorized shutter. The position of the motorized shutters dictate the movement of the air being moved by the blower.

ENVIRONMENTAL CONTROL

Controls are an important part of any heating and ventilating system. Capillary bulb-type thermostats are the most durable for greenhouse use. Home-use thermostats are usually more accurate but are also more subject to deterioration and malfunctioning caused by the greenhouse atmosphere. Mercury-type thermostats are often affected by vibration, which occurs in strong winds, and should not be attached to the greenhouse structure. Aspiration, or passing air over

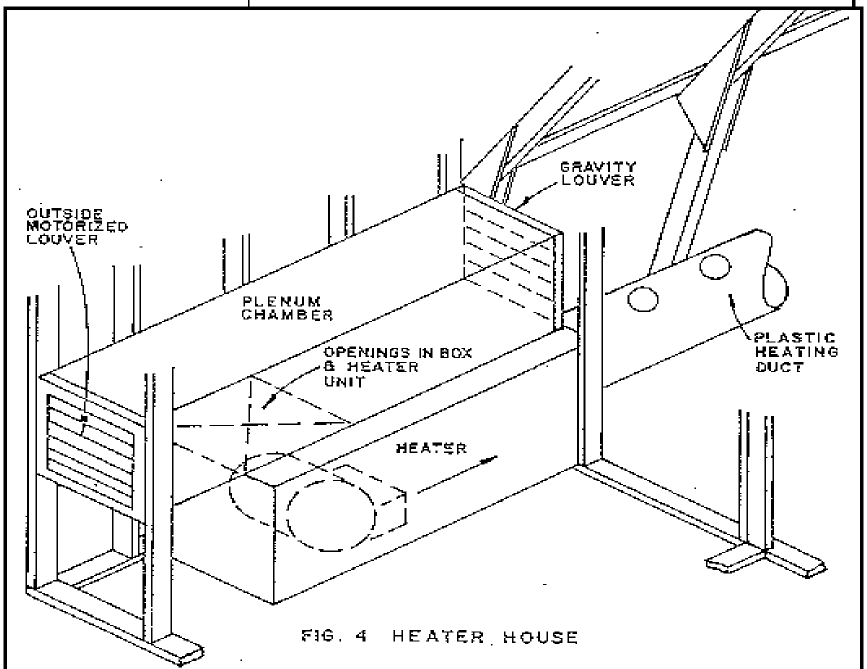

Figure 3.
A system designed many years ago and used successfully by both flower and vegetable growers who were trying to eliminate the pollution effects caused by heating units located within the greenhouse.

thermostats or computer sensors, is mandatory for good environmental control. Figure 4 indicates a method to construct an aspirated chamber containing a small blower or fan that draws air over the thermostat sensing units of the thermostats. Figure 5 indicates test results obtained by simply blowing air on a traditional capillary bulb thermostat. This can produce increased productivity by allowing the grower to more closely manage the crop based on the best known day and night growing temperatures. Totaling all the time that the air temperature is over the set point will give an idea of the energy required for heating being wasted with a thermostat that is not aspirated. The benefit to the plants is also important

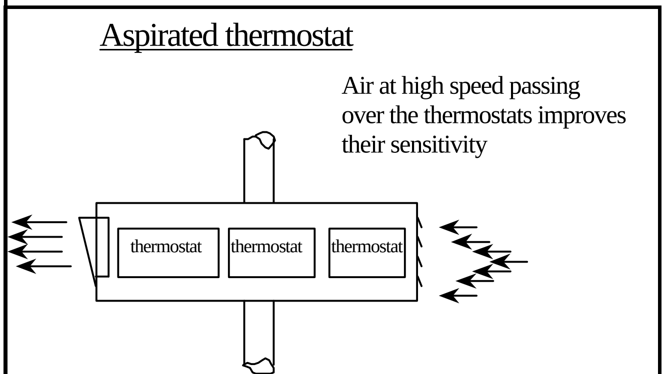

Figure 4.
Wooden housing for aspirated thermostats with a small fan mounted in one end drawing air through a screened inlet causing it to pass over the capillary bulb of the thermostats.

The diagram in figure 5 indicates the variability of about 8°F between the on-off cycle of the heater. At the point the thermostat was aspirated this variability decreased to about 2°F. After the daytime hours the fan

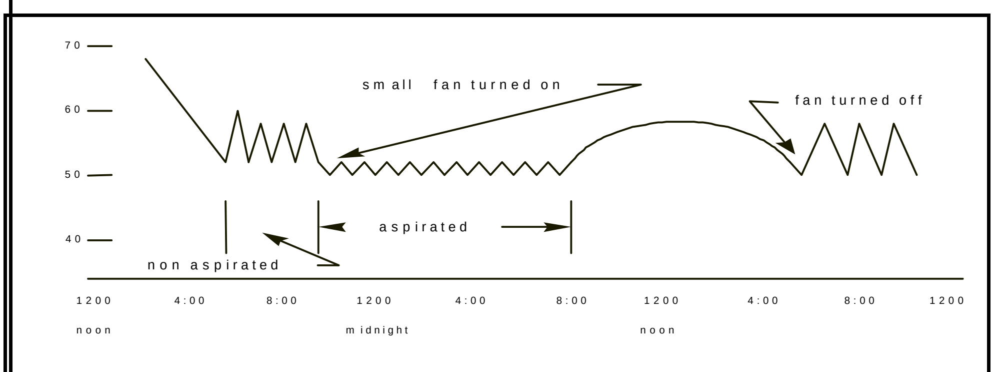

Figure 5
Diagram illustrates the effect of air moving swiftly over a conventional capillary bulb thermostat.

was disconnected and the 8°F temperature difference between on and off was again observed.

Sophisticated environmental control units now being marketed have the distinct advantage of providing temperature information throughout the day. The data-acquisition feature of these computer-based systems is the most attractive aspect for the grower. They provide various stages of heating and ventilation control for time of day applications, can integrate light sensing equipment into the system and control the operation of the thermal screen.

Computer-based systems should be used only to control a well-engineered heating and ventilating system. A heating or ventilation system that is poorly designed cannot be improved simply by installing a better control system. The control system works best with a properly engineered heating and ventilation system.

SCREENING

Screens have been used for insect control in dwellings and the work place for many years. Insect screens limit air movement and provide an engineering challenge to exclude insects and not decrease the efficacy of the installed mechanical ventilation system. Fans used for greenhouse cooling are typically of low pressure design with a normal operating range up to 0.125 inches of water static pressure. These highly efficient large diameter low-pressure fans are designed for moving up to 20,000 CFM per horsepower at low static pressures but are unable to move air at higher pressure differences and exhibit a phenomenon known as slip. Air tends to move off the blades at the tip. When the static pressure between inside and outside the greenhouse increases the air has a tendency to return to the greenhouse through the center of the fan. This is why higher pressure fans have the characteristic large hub to eliminate this condition and are able to perform at higher static pressures.

Dr. James Bethke of the University of California and Dr. James Baker of North Carolina State University have determined the size of screening which various insects can penetrate. Several publications describe their research and are listed in the bibliography. Thrips and white fly are common insects which greenhouse vegetable growers would like to exclude.

Table 1 is a summary of some research work and lists size of aperture of screening and the insects which can be excluded.

Table 1

Insect pests	micron	inches	mesh
leafminers	640	0.025	40
whiteflies	462	0.018	52
aphids	340	0.013	78
flower thrips	192	0.0075	132

Unfortunately screening is currently limited to mechanically ventilated greenhouses at this house. Naturally ventilated greenhouses present special problems for screening. Results of tests conducted in the Netherlands on two glasshouses growing greenhouse vegetables illustrated the difficulty of screening naturally ventilated greenhouses. Both of these houses were 40 feet wide with large 5' wide ridge vents. One greenhouse was equipped with a screen material to limit pests entering the greenhouse through the vents and the other was not screened. The temperature on clear days in the screened house was on the average 9°F above the unscreened greenhouse. To overcome this problem Dutch engineers have designed accordion type units to fit into the vents to increase the screen surface area. These increase the screen area without limiting ventilation but tend to be expensive and difficult to maintain.

Air flow characteristics of fans are determined by their design. Propeller fans used for ventilating greenhouses have low pressure characteristics and move large quantities of air at low static pressures of approximately 0.1" to 0.15" inches of water. The design static pressure used for most systems is 0.10".

Using this criteria the following design procedure seems appropriate. Approximately 30% to 50% of the total pressure drop allowable which the fan will experience should be attributed to the screening. This leaves the remaining 50% to 70% available for the normal pressure losses in the total ventilation system including, automatic fan shutters and the window vent openings. This allowance also provides for insect and debris buildup on the screening before cleaning is required. In practice this design procedure has proven to be effective and efficient with no adverse affect on the ventilation system. As indicated earlier, the normal design calls for 8 - 10 cfm of ventilation for each square foot of greenhouse area.

Dr. James Baker and Mr. Ed Shearin of North Carolina State University have developed a computer model, programmed in QBasic to help designers calculate the area of screening required for a particular screening material being selected by the grower to exclude pests from their operation. This model requires for input parameters, the size of the greenhouse, the number, type and manufacturer of the fans being used, the static pressure of the building when all the fans are operating and all the vents are open, the physical characteristics of the window vents and the screening being selected. The program's output is the required area of screen for several different materials.

The design procedure using the computer program for a vegetable production greenhouse which is 30' by 84' feet, equipped with insect screening would be as follows. Greenhouse data, the type and number of fans and area of inlet would be entered into the program. Table 2 indicates the area of screening that is required for four types of commercial screening compared to the allowable pressure drop through the screening.

Table 2

Allowable SP drop	Econet T*	Flybarr *	Bugbed 123*	No thrips*
Square feet of screening required for a 30' by 84' greenhouse				
.03	130	127	104	
328				
.04	103	99	83	254
.05	87	82	69	211
.06	76	70	60	181

**Reference to commercial products or trade names is made with the understanding that no discrimination or endorsement is intended or implied.*

For instance, the no thrips material would require 254 square feet of screening if an allowable pressure drop of 0.04" was the design parameter for the screen. This would leave .06" pressure drop available for the rest of the ventilation system. By allowing a pressure drop of .06" through the screen only 181 square feet of screening is required with only 0.04" available for the rest of the system including insect and debris buildup on the screening.

By selecting another material such as Econet T, 103 square feet of screening and 76 square feet of screening would be required under the same conditions as stated above.

This information can be used in several ways. For a typical free-standing greenhouse which uses fans on one end and motorized shutters on the other Figure 6 indicates a means of calculating the area needed for enclosures to be built over the motorized shutter ventilation inlets. This design leaves the integrity of the motorized shutter in tact so that no changes are required in the operation of the ventilation system throughout the year. If screening is installed as a substitute for the glazing in the end of the greenhouse it is easy to have large areas of screening and a minimum of effect on the ventilation system. However, provisions for closing the end of the greenhouse by either covering over the screen or reglazing with the covering is required for the greater part of the operating season.

A 30' by 84' greenhouse equipped with a continuous vent as indicated in Figure 3 for the same conditions would require a similar screened inlet area. This type of ventilation window permits a grower to design for a lower pressure drop through the screening because the ventilation inlet area of the continuous vent window is usually much larger than for a similar greenhouse equipped with two motorized shutters. If allowing a pressure drop of .04”, then 103 square feet of screening is required. The greenhouse is 30 feet wide so the area of screening required per foot of width of the greenhouse is approximately 40 inches. If the screening material is available in 48 inch widths then the pressure drop through the system would be about 0.03" which is predicted for a 48 inch wide screen. In each case it is wise to go to the widest material suitable for the window. If attaching it as in figure 7 there must be enough clearance to keep the screen off the soil.

Growers who have installed screening are excited and optimistic about its performance. We have been testing several screens for many years. One grower reduced total sprays for white fly protection from 13 to 3 over a two year period and used only 8 spot sprays on the locations indicated by the yellow sticky indicator cards. Although there are yearly differences, these data indicate the screening effectiveness.

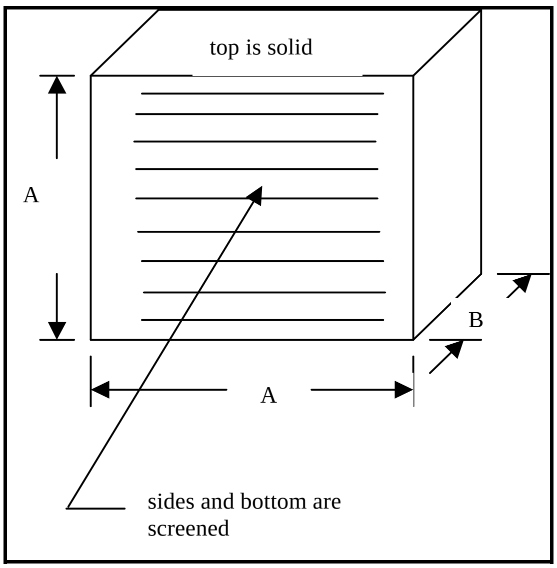

Figure 6 Enclosure for screened inlet (A=AxA + 3AB)

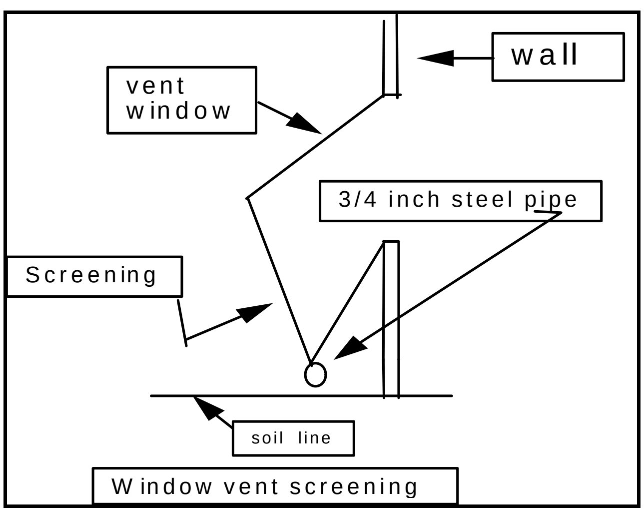

Figure 7.
Window vent screening detail for continuous vent window.

Nieswand Assumes Chair

Dr George Nieswand recently became chair of the Bioresource Engineering Department. He succeeds Dr. KC Ting who served for 6 years and has returned to the faculty to continue his noteworthy and world acclaimed research and teaching duties.

George Nieswand graduated from the Agricultural Engineering program many years ago and has invested most of his career at Cook in the Department of Environmental Resources. He has served as Dean of Cook College and is noted for his intense and brilliant mind. The Department eagerly looks forward to his leadership and wit.

Greenhouse Construction Trends

NGMA, the National Greenhouse Manufacturers Association surveys the amount of new construction each year among its members. In the last 10-year period, they reported new construction was more than 22.7 million square feet in 1986 and 22.5 million square feet in 1994. The growth curve has recovered and in 1996 new construction topped 25 million squre feet.

During this ten year time period new construction accounted for $49 million dollars in 1986 and $96 million dollars in 1996 of the gross sales of the reporting companies.

NGMA is located at 7800 South Elati, Suite 113, Littleton CO 80120.

*****The People's Republic of China**

The plastic covered quonset type greenhouse area of the PROC now exceeds 450,000 Ha, up from 100,000 Ha just a few years ago.

ACESYS III FORUM

A very successful symposium was held on July 23rd, 1999 at the Cook College Center of Rutgers University. The forum entitled "From Protected Cultivation to Phytomation," was sponsored by CCEA, the Center for Controlled Environment Agriculture and was dedicated to Bill Roberts upon the occasion of his retirement.

Following is an epilogue presented at the Conference by Dr. David Mears of the Bioresource Engineering department describing some of the major points made by the celebrated world class researchers who are truly outstanding in their field.

Complete proceedings are available from CCEA at the Department of Bioresource Engineering, 20 Ag Extension Way in New Brunswick, New Jersey or from your editor.

Epilogue

Dr David Mears

Dr. Merle Jensen Associate Dean, University of Arizona

In his paper on the role of plant culture in protected cultivation**, Dr. Merle Jensen** discusses the development of the NFT system in England, rockwool culture in Denmark and perlite culture in Ireland, all in the late 1960's. He did not write about his own work in that period that was done here at Rutgers University in collaboration with Bill Roberts. In that same era they developed the plans for the "Rutgers 700" tomato production greenhouse system. The wood frame, polyethylene covered greenhouse could accommodate 700 tomato plants growing in an "artificial" media irrigated with nutrient solution.

Since that time great progress has been made in realizing the potential of soilless culture systems. Providing plants with the water and nutrients required for growth without ties to the natural soil requires that one understands all of the plant needs and provide for them. As the natural soil systems are far more complex than manufactured cultural media they can provide for a variety of plant requirements without the grower necessarily being aware that it is occurring. With a hydroponic system there is the potential to provide exactly what the plant requires and virtually eliminate discharge to the environment of surplus nutrients. To accomplish this one must have essentially complete knowledge of the plant requirements over time and establish precise control of the nutrient delivery system.

The control of light continues to evolve as a major aspect of environmental control. Historically greenhouses attempted to incorporate designs that would maximize the transmission of natural light. Seasonal summer shade was used to limit incoming radiation in hot summer weather. Movable shade systems provide more control of incoming light and supplemental light is often provided to increase plant growth when extra growth can justify the cost. While shading can reduce the amount of light coming into the greenhouse, additives to the glazing can filter out specific wavebands of incoming or outgoing radiation. With polyethylene film, additives to absorb long wave infra red radiation have the primary benefit of reducing heat loss at night in cold climates. Recently efforts have been undertaken to incorporate additives that absorb specific wavebands not needed for photosynthesis but that do effect crop growth, pest activity. and/ or disease development.

Dr. Lou Albright Agricultural Engineer, Cornell University

Environmental control strategies are evolving at an accelerated pace as **Dr. Lou Albright** indicates in his discussion. Computers offer the possibility to optimize environmental parameters. Temperature control with thermostats and time clocks enabled one to achieve far more control over temperature at any time than could be dreamed of in open field conditions. Minimum crop temperatures can be maintained with well-designed heating systems with very good spatial uniformity and relatively good temporal response. Uniformity of cooling and adherence to a prescribed temperature under conditions of high ambient temperature and solar gain is substantially more difficult to achieve in practice. Computer control of temperature control systems using sophisticated algorithms can do a more precise job of control than simple thermostats.

Computer control strategies are being applied in a much more creative way than simply keeping individual environmental parameters at or near prescribed setpoints. By incorporating sensors for several parameters and information on the crop condition and state of development one can compute appropriate setpoints for each in real time. One example is the optimization of the combined control of light and CO_2 described by **Dr. Albright**. Another is the control of lighting based on crop development and accumulated light history to schedule the development of a crop. As sensors and sensing systems, such as computer vision analysis, become more sophisticated the ability of the grower to optimize combinations of inputs such as heat, light, CO_2, water and nutrients will be substantially increased assuming we can continue to learn more about the plant's requirements.

Dr. Toyoki Kozai Dean College of Agriculture, Chiba University, Tokyo Japan

In his discussion of transplant production in closed systems, **Dr. Toyoki Kozai** explains how artificial light sources can be very efficient in that they have the potential to provide only the wavelengths of light actually required by the plant under cultivation and at the levels of intensity needed. His discussion points out the differences in working with natural sunlight where one has the option of perhaps filtering out some of what is coming in, and producing light according to a prescribed recipe. In this discussion he points out that the word "artificial" carries a connotation in the language that is generally regarded negatively relative to "natural". Photons from light sources other than the sun are identical to photons from the sun of the same wavelength so it would be helpful to have another term for light from non-solar sources, such as supplemental without the negative connotation associated with the word "artificial".

Plug seedling transplanting is one operation falling into this category. Fixed automation systems have been developed which can transfer seedlings from plug trays into growing flats for specified tray and flat geometries. If a mechanical transplanter must detect the quality of the plug seedling and select only certain minimal quality plugs greater sophistication is needed. Flexible automation systems are needed to satisfy these requirements.

Dr Naoshi Kondo Professor of Okayama University, Okayama Japan
(*has written a textbook on robotics with Dr. KC Ting of Rutgers University)*

Dr. Naoshi Kondo describes several flexible automation systems using robotic components and sensors to determine the key characteristic of each plant or plant part being dealt with. When planting chrysanthemum cuttings far greater discrimination of the important attributes of each unit is needed than when planting seeds

In addition, the actions of cutting, leaf trimming and sticking are far more complex than the action of placing a seed at a specific location. Similarly, the harvest of ripe strawberries and the evaluation of cut flower quality each require that the robotic system be capable of modifying the action taken on each unit according to information acquired by a sensing system.

The wide variety of plant material further complicate the challenge of achieving a high degree of automation for greenhouse crops. General categories of crops produced in greenhouses include cut flowers, cut ornamental greens, seedlings for transplant, potted plants and increasingly, an ever-expanding variety of food crops. Within each category, there are many individual species to be produced and each may require a different characteristic depending upon the market for which it is destined. Thus the protected cultivation industry has need for a very large selection of relatively complex automated equipment with low volumes of potential application for each system.

ADVANCED LIFE SUPPORT
Dr. John C. Sager Manager Advanced Life Support Program, Kennedy Space Center

Development of an advanced life support system (ALS) is essential if humans are to explore the universie and establish bases on the lunar surface, Mars, and other extraterrestrial bodies. Technology requirements for development of a bioregenerative A:LS system include: enclosure type, HVAC, atmospheric constituents, irradiance (lighting), nutrient/water delivery system, environmental sensors, mechanization and materials handling, data management, autonomous control, and high reliability. Emphasis is placed on developing the technologies with maximum impact on reliability and autonomy in space applications.. All the technologies are critical to controlled environment crop production, but these four were selected as highest priority. All these technologies have commercial development potential.

Dr Haruhiko Murase Osaka University Osaka Japan

The prospect of mankind undertaking long term travels in space and/or establishing long term colonies on the moon or Mars presents a tremendous challenge in the further development of controlled environment plant production systems. This challenge may represent the best opportunity imaginable for the realization of the potential of phytomation engineering. **Dr. Haruhiko Murase** points out the importance of modeling in developing decision support systems for more demanding phytomation systems. The evolution of controlled environment plant production systems is being driven, in part, by the realization that sustainability of a system is essential.

Dr David Mears Distinguished Professor Cook College, Rutgers University

Summary remarks concerning Controlled Environment Agriculture production.

Commercial greenhouse production is becoming more concerned with the issues related to long term sustainability and this is reflected in several ways. Major efforts are underway to reduce pollutants including discharge of unused nutrients or pesticide residues to the environment. As production moves from open field agriculture to greenhouse to plant factory to space missions the boundary around the production system becomes smaller. Also, the cost in both economic and environmental terms of transporting new inputs in and waste products out increases dramatically. In space travel and settlement the ecosystem supporting man will be highly constrained in many ways so it is essential for sustainability that virtually all resources be recycled. All waste products from one cycle of production must serve as the source of raw materials for the next. The economic and environmental costs to dump non-recyclable wastes and import new raw materials are extremely high.

In space as on earth, a primary means of utilizing energy to upgrade the quality and utility of materials is photosynthesis. In open field agriculture and commercial greenhouses natural sunlight is the energy source with some supplementation of sunlight in greenhouses. In plant factories light sources other than natural sunlight are becoming the dominant energy source for photosynthesis. For a variety of sound reasons plant growing in space will focus on the use of lamps in confined spaces in the near future.

In space one must provide the gas environment around the plant as well as water, nutrients, light and care. If human beings are at all involved in plant care the gas environment must also be able to support humans as well as plants if people are to work without space suits. If all processes could be completely automated one can consider the minimum gas environment that will support plant growth.

Other speakers included:

Dr. KC Ting Bioresource Engineering Dept. Rutgers Universiy.

Dr.Irwin Chu CEO Taiwan Flower Biotechnology Co. Ltd., Taiwan

Dr. Gene Giacomelli Bioresource Engineering Dept. Rutgers Universiy.

Dr. Gene Giacomelli arranged for the program and the entire day's activities which included an evening banquet for **Bill Roberts** retiring CCEA Director,

Y2K Preparations

The Year 2000 problem has two faces, remediation and liability. Businesses must concern themselves with remediation of their own systems to ensure their ability to function through all critical Y2K dates. However the question of whether the power will fail or the water be drinkable raises the issue of the liability of third parties to fulfill their obligations.

Both businesses and consumers must be concerned about liability issues. The first step to addressing this issue is for the consumer (be it business or a private individual) to send a compliance letter to all major suppliers to make them go on record with respect to their Y2K compliance.

The following is a sample compliance letter developed by the National Institute for Standards and Technology. It is intended for use by businesses but can easily be adapted for use by consumers.

Sample Compliance Letter

Date

Supplier Contact Person
Name Of Supplier
SupplierAddress City State Zip
Dear Supplier Contact Person:

As part of our Year 2000 (Y2K) Project, we are contacting all of our suppliers and service providers to identify any possible disruptions to our operations due to an interruption in these services.

Since we are dependent upon you for the provision of (***Specify Service Or Product),*** we are writing to seek assurance from you that: You are aware of the Year 2000 problem and have a Year 2000 Project Plan in place that:

- You are using all due diligence to ensure that no disruption of services will occur due to Year 2000 problems;
- that you are contacting business partners that you, in turn, are dependent upon; and that
- You are preparing contingency plans in case some of your suppliers and processes have unanticipated Year 2000 problems.

Please respond to (***Company Contact Person)*** with answers posed to questions in this letter which affect our livelihood.

Thank you for your prompt attention to this matter. Please direct any questions you might have about this request to (***Company Contact Person.***)

Sincerely, ______________,

Recycling Program Extended

The NJDA Greenhouse and Nursery Film Recycling Program has reclaimed more than one million pounds of film used in the industry over the last three years. Secretary Art Brown recently stated, “New Jersey is a front runner in recycling greenhouse and nursery film.”

East Coast Recycling, a private recycling center in Millville, NJ has agreed to growers’ requests and will continue to accept NJ grower’s film, possibly through November. East Coast will waive the tipping fee for growers.

East Coast recycling is located in the Millville Industrial Park at 1801 Eden Road. The facility is open from 7:30 AM to 4:00 PM and growers should check with them at 609 327 8888 to make sure film is still being accepted.

Secretary Brown is evaluating this years program and funding availability before announcing the 2000 program. Further info is available at 609 984 2506.

COOPERATIVE EXTENSION
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HORTICULTURAL ENGINEERING

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Preventing Back-Siphoning

The contamination of a water source is a serious matter. The use of safe operating systems for handling fertilizers and pesticides is worth the trouble, time and effort.

Back-siphoning is the reverse flow of a solution from a holding tank or pump into the source of fill water. This situation can create a potential source of contamination for wells, ponds, streams and other valuable natural water resources. Understanding why back-siphoning occurs and how to prevent it can greatly reduce this problem.

Back-siphoning occurs when the delivery hose being used to fill a tank is below the surface level of the solution in the tank. If the source of fill water is shut off while this situation exists, the solution can be pulled back through the delivery hose and into the source of water, either a pond or well.

This can also occur when fertilizers and pesticides are being applied through an irrigation system and a sudden loss of pump pressure occurs. Back-flow protection devices, required by law, can properly protect against other potential back-siphoning possibilities.

Always leave an air gap between the end of the delivery hose and the fertilizer/pesticide solution in the tank.

Do not leave the delivery hose unattended while filling the tank. Work above the tank and water and secure the hose so that it cannot be below the surface of the liquid.

Taken from "Water Management Guidelines for the Greenhouse Industry." Texas A&M Agricultural Extension Publication B5016
Dr Don Wilkerson et.al