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TECHNICAL PROGRESS IN GREENHOUSE CLIMATE CONTROL

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Greenhouse climate control is the principal means by which profit is earned. As in overhauling an engine, good tools make the job easier, cheaper, and usually the end result is better. In research, as well as commercially, well designed computer systems, used intelligently, offer a major technological improvement.

The interest in computers that has swept the U.S. in recent years has finally reached the point where we felt it vitally necessary to undertake a major step. We have installed and developed a system representing one of the more significant technological advances in the past 20 years. It is unfortunate that we have not done it sooner. Some of our foreign competitors are much further along. Playing catch-up is a hard way to win. There are very few companies in the U.S. that sell, and install, computerized climate control systems and, unfortunately, being proprietary, seldom publish much documentation on what can be done, how well it is done, or all the other factors a greenhouse operator must consider if he is not to buy a "pig-in-the-poke."

One of the most apparent factors that has impressed us in developing software for computers to control climate, is the ability to easily, rapidly and accurately measure the environment, allowing the investigator to monitor, record and plot nearly everything influencing a particular experiment. At first peek, this may not seem very important to a greenhouse operator, struggling to make ends meet. On the contrary, it is a major advance which makes most reports in the literature, including our own from CSU, completely and irrefutably old hat. A research project should not be conducted without some idea of the environmental conditions which occurred. Computer systems provide the capability of:

1. Providing average, maximum and minimum plant and air temperatures for the entire experiment.
2. Totalizing energy utilized from the sun and from fossil fuels.
3. Average, maximum and minimums for humidity in the greenhouse for the entire experiment.
4. Average, maximum and minimum CO_2 concentration for the entire period.

Additional information obtained in these systems include the number of irrigations, air temperatures at more than one location in the greenhouse, and the ability to control shade, irrigation frequency, and nutrition. The grower, with similar system capability can now provide his operation with climatic data for precision timing of the crop. He should be able to compare crop performance just as he measures profitability or calculates a liquidity ratio, based upon history, and to adjust the environment to meet timing and quality requirements. Almost all greenhouse research, due to the limitations imposed by local climate, assume an "average" year — whatever that may be. The fact that it was a "warm" year, a "cloudy period", etc. can be documented on a few pages — provided, of course, that what goes into the machine is reliable. Precision timing is not all that far off with good systems.

Development at CSU has been to obtain available equipment **(Fig. 1),** fit it into an existing system **(Figures 2 and 3),** and write the software required to do what we feel is necessary. This is a backdoor approach to modeling, and in the process, we have created a model which can be used to fine-tune yield and quality of any greenhouse crop. Several people have been instrumental in providing support for this effort, chiefly Hewlett-Packard who loaned us much of the early equipment on which we learned. The present system was purchased with the aid of the Colorado Rose Growers, Gloeckner Foundation and Roses, Inc. with assistance from several businesses which include Wadsworth Controls, Reznor, Devor Nurseries, Dupont, and Siemens-Allis.

These systems are not cheap. The hardware was in excess of $20,000, and **Fig. 4** suggests the additional materials in cabling, electrical parts and the labor required to connect it together. Assuredly, a package system would be much neater than our own efforts which may leave some things to be desired. On our small scale, this much investment would not be warranted commercially, but these and similar systems are capable of operating any size range. You will not find any pay-back figures to be trusted. On the other

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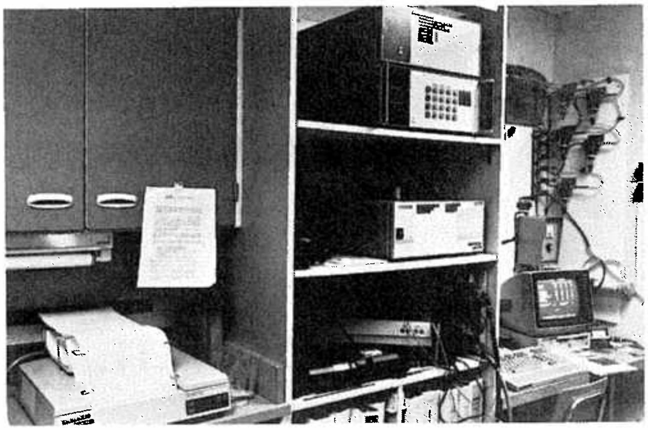

Fig. 1: Computer system for controlling four greenhouses. The two units on the upper shelf are the digital acquisition/control system, operated by the box computer located below them. To the left is a thermal printer, and a plotter to its left. To the right is the video monitor and keyboard.

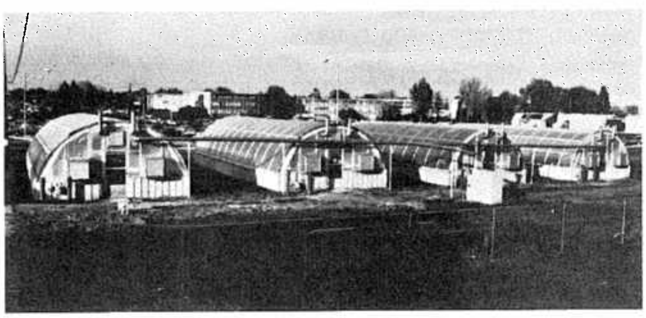

Fig. 2: The CSU Heat Houses, employed for several years for cover evaluations. Each house is identical with the exception of the covers. Roses were planted in March, 1985, and automatic shading is expected for two of the houses shortly.

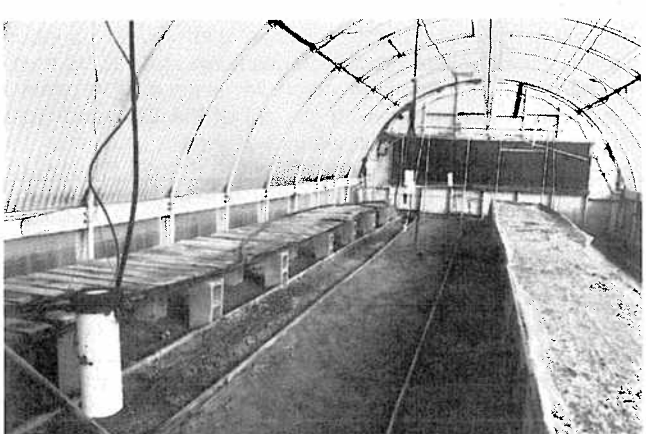

Fig. 3: Wide angle interior view of one of the four houses, showing the three aspirated thermosensor shelters. The control system measures temperature, accumulating each value for the day or night period, determines maximum and minimum temperatures, and calculates the average for all three locations.

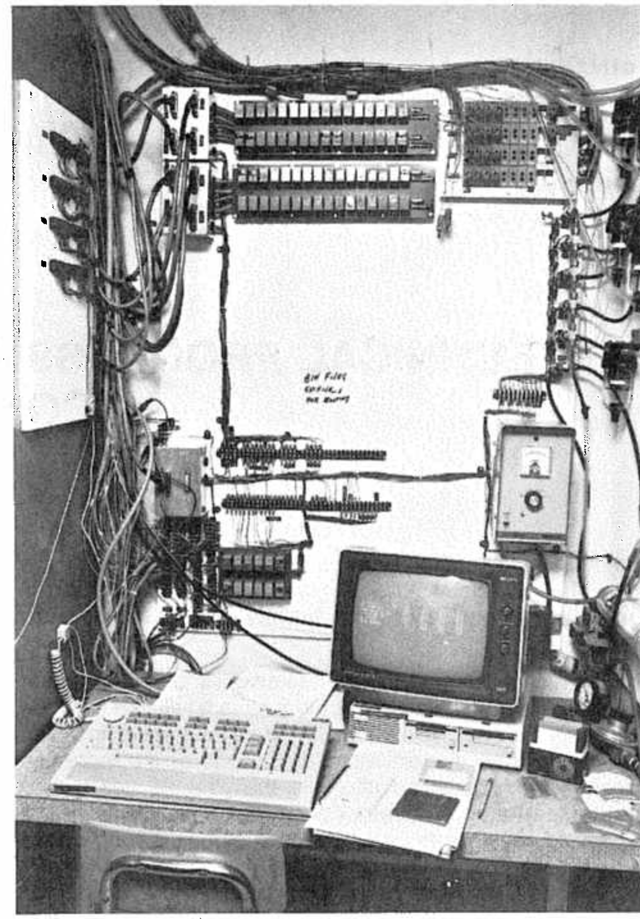

Fig. 4: Main interface control board. On the left wall is the CO_2 sampling system with a small infrared gas analyzer just above the CRT. In the top center are low voltage relays for the control system, while the remaining terminals on the lower right and right wall are connections for the sensor inputs, interruption devices, etc. The large space is for future expansion.

hand, there are things that can be done with computers that are not feasible any other way. In terms of information, one possibility has been suggested.

There are a number of problems that should be addressed in this computerization process. One is the requirement that the measuring devices used are reliable and accurate. As one noted biologist has said: "A temperature sensor (thermometer or whatever) only tells you what **its** temperature is. It is up to you to interpret it properly." This means proper mounting, shielding, etc. as indicated by **Fig. 5.** It also means investigating new measurement methods and comparing them with previous systems. Secondly, these systems require a degree of technical competence beyond what we furnish in most of our training programs, and is generally unavailable in the industry. Fortunately, the requirement to master volumes of documentation **(Fig. 6)** won't be necessary. But, existing computers are idiots, and despite the best efforts of brilliant programmers, the operator must have some training to use these devices intelligently.

On the basis of what we have done to date, what should a grower look for when he decides to investigate computer

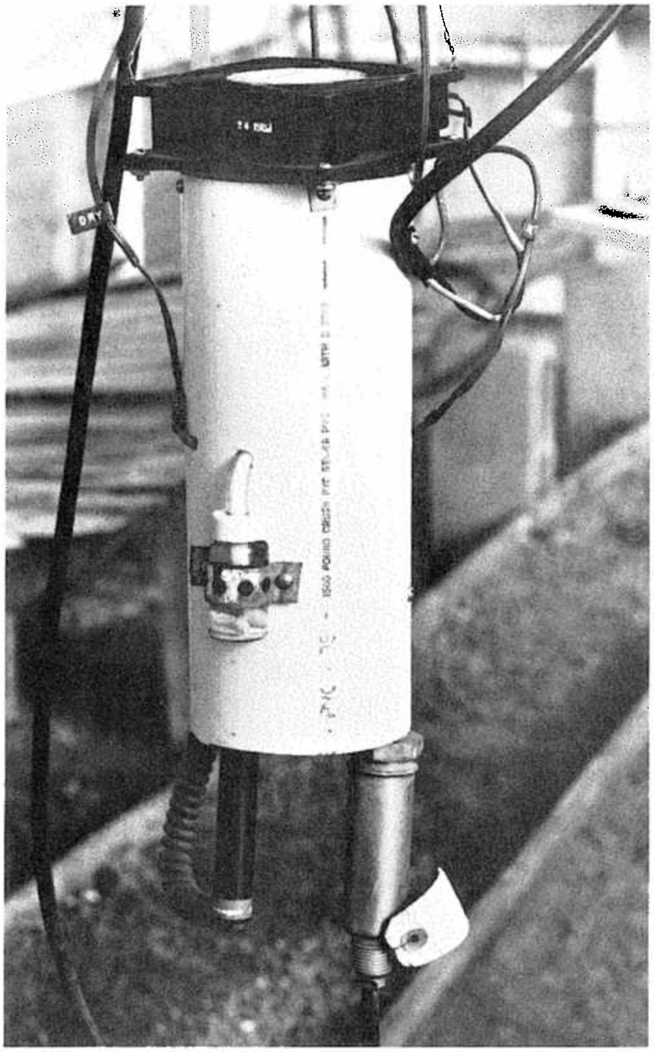

Fig. 5: One of three aspirated thermosensor shelters in each house. The small glass vial contains distilled water for a wet bulb temperature sensor, used as one means to measure humidity. The tube with the coiled lead, projecting below the shelter is a capacitive humidity probe while the other, metallic probe is a temperature detector, recording continuously at a remote location.

Fig. 6: Hewlett-Packard provides thorough documentation for their systems as evidenced by the number of notebooks.

climate control? Any system can measure a temperature and give you a fancy display calculated to impress the novice and extract money. If all you have in your greenhouse are two stages of heating or cooling — forget it. A computer in such a situation is like the British used to say: "Bringing coals to Newcastle." With all the possibilities inherent in climate control systems, a grower will get what he pays for, and can get taken to the cleaners if he has forgotten to look at the horse's teeth.

The first thing, is the history and performance of the firm touting the equipment. How long have they been in the business? Is their equipment reliable and trouble-free? Ask for examples of other installations, and investigate what kind, if any, service is available. Can you get help quickly, and how much does **that** cost? Will you have adequate documentation and will the company provide training? Computer programmers generally write for other programmers, and unless the company uses great diligence, their documentation is likely to be incomprehensible to a practicing Ph.D. As mentioned in other articles, greenhouses are incredibly noisy electronically, as well as nasty environments for delicate equipment. How does the company get around these problems? Will it be necessary for you to retrofit your heating and cooling equipment? Do not invest in a computer system if your implementation equipment leaves anything to be desired.

Once we have got around these initial questions, we can begin to ask: "What does the system do?" In my estimation, a reasonable computer system should:

1. Measure temperature accurately and rapidly in at least two, preferably more, locations, and those sensors should be adequately ventilated and shielded.
2. Provide a measurement of total energy, not just "light" from the sun.
3. Provide a good measurement of humidity, using some of the newer capacitance probes now available on the market. Wet bulbs are problems.
4. Provide a system for CO_2 measurement.
5. Measure outside radiation, outside temperature, outside wind velocity and perhaps outside CO_2 and humidity.

Depending upon the sophistication of the system, one may wish to measure fuel consumption.

6. A large range will almost invariably require "zoning", and the system should be capable of doing this. Also in large areas, what are the means to get the signals to the computer?

Once we have got all this information, what should be done with it?

1. This information should be stored, updated and accumulated at regular intervals for later summary at the operator's request.
2. The most important information should be displayed in an easily read manner, which is "refreshed" at a rate controllable by the operator. This should include, the temperature actually measured, used by the system for comparisons, the heating setpoints and the cooling setpoints for each location or zone.
3. The system should be capable of automatic switching from day to night, and the set-up in the morning should be capable of being controlled as to its rate of temperature increase.
4. Any system should provide automatic temperature resetting based upon outside conditions of temperature, radiation and wind.

5. Humidity should be controllable.
6. CO_2 level should be controllable, based upon radiation available.
7. Shade and thermal screens should be controllable with staged opening.

Other systems may include misting, irrigation frequency, pesticide vaporization, nutrition control, etc.

The system should be capable of re-establishing itself in the event of a power failure, and suitable alarms for temperature and error included. The operator must be able to easily change any constant in the program. By constants, we mean setpoints, numbers that regulate operations, etc. Nearly half of the software code will go to this aspect. A grower should ask, and get, some idea of how constants in the program operate, and what is likely to happen if he changes them.

Lastly, the system should be capable of expansion, with provision for updating.

In the next decade, we are going to see remarkable advances in greenhouse climate control. Those hoping to profit will, as most professionals must do, go back to school.