A Rutgers solar greenhouse heating system has been successfully demonstrated in a 1.3 acre greenhouse at Kube Pak in Allentown, N.J. The greenhouse is gutter connected with ten 20-foot bays, each 290 feet long.

Two layers of 4 mil polyethylene film separated by a small inflation blower are used to cover the greenhouse.

Heart of the system is the floor, which serves as warm water storage and primary heat exchanger. The water is contained by a 20 mil biocide treated vinyl swimming pool liner, which is filled with approximately 9 inches of ¾-inch gravel or stone and capped with a 3-inch layer of porous concrete.

The floor composite is capable of holding a maximum of 4 gallons per cubic foot in the area between the vinyl liner and the lower edge of the
porous concrete cap. Storage capacity of the greenhouse floor is about 100,000 gallons.

Porous concrete has been used by commercial growers for many years when they are producing crops directly on the floor of the greenhouse. This provides a solid weed-free surface which allows excess irrigation water to pass through it, eliminating low wet spots which would seriously damage the crop at that location.

The concrete is made by mixing 2,700 pounds of .375 aggregate, 5.5 bags of cement, and 22 gallons of water per cubic yard. It is handled the same as regular concrete except that it is only screeded and not troweled. Principal difference is the absence of sand in the mix.

Water is pumped from the storage pumping pit to the collectors through 6-inch PVC pipe which is connected to each of the five collectors through two 1.5-inch headers drilled with 7/32 holes spaced on 6-inch centers.

Water flows down over the surface of the black plastic layer and is collected in a gutter at the bottom of the collector. The gutters drain into a covered flume and the water flows by gravity back to the greenhouse floor and is distributed throughout the greenhouse.

The 7.5 horsepower pump is controlled by a sensing device located in the solar collector which measures temperature difference between water in the floor storage and the collector. When the temperature difference is greater than 10°F, the pump starts. When the temperature difference falls to 4°F, the pump stops, and water in the collectors drains back into the storage so there is no freezing problem.

The solar collectors operate in the 40 to 60 percent efficiency range at temperatures of 68°F to 85°F. The high efficiency is realized because the collectors operate at low temperatures and losses from the collector are minimized. Data recorded indicates that on a good day the equivalent of 80 to 90 gallons of oil are collected (from the 10,000 square feet of solar collectors) and stored in the floor.

When insufficient solar energy is available to warm the floor, the auxiliary heating system is activated. Two 60 horsepower boilers provide hot water to the heat exchanger located in the return flume. Water is pumped through the floor system and heated as it passes over the heat exchanger in the return flume. This process is controlled by a capillary bulb thermostat located in the rock-water section of the floor.
The boilers also supply hot water to a pipe loop located under the greenhouse gutters to provide maximum snow melting potential in extreme snow situations. The gutters must be kept ice and snow free in this type of structure. The pipe loops also provide the last stage of heating for the greenhouse in extreme cold weather.

A system previously designed for greenhouses to control day length for chrysanthemum production has been modified and is being used as an energy saving system.

A horizontal blanket is drawn across the greenhouse at night to enclose the crop and the floor heating system. Temperature measurements indicate that the aluminized blanket will reduce heat loss from the greenhouse by a factor of two. In the morning, the blanket is withdrawn and stored in a narrow band parallel to the gutters to minimize shading in the greenhouse. The blanket is automated and operated by a time clock.

The blanket is supported by a series of monofilament plastic cables and powered by a steel cable system which is spaced 10 feet on centers. As the blanket is closed in the evening, the leading edge intercepts a hanging section of the curtain in an adjacent bay to form an airtight seal.

Several blanketing materials have been tested and a woven polyester fabric, which is aluminized on one side, has been the most successful to date. This woven fabric allows condensation — which forms on the roof of the greenhouse and drips on the closed blanket — to pass through. Earlier materials, which were solid, did not allow this to happen and large pools of water formed on the blanket which was not acceptable.

Crop response to date has been very favorable. Five crops have been grown in the solar heated section — three spring bedding plant crops and two fall poinsettia crops. Effect of the warm floor has been dramatic in crop response and in reducing energy requirements.

Temperature at Night Cut by 10 Degrees

It has been possible to reduce the night ambient temperature as much as 10°F with some bedding plants with no decrease in plant response or timeliness. The warm floor maintains the proper root temperature without having to maintain the entire greenhouse at an elevated temperature. The floor heating system also maintained a higher temperature at the poinsettia plant canopy than at the 6-foot level.

It was also learned that spring bedding plants could be planted as much as three weeks later and
still be ready for sale because the crop responded so well to the warm soil temperature.

Effect of root temperature on flowering plants has not been determined, but response from most vegetative growth has been dramatic. This is not altogether unexpected since plants grown on greenhouse benches equipped with under-bench heat have shown the same response. Heretofore, growers in greenhouses with no benches, growing on the floor, have had to maintain higher night temperatures than necessary to ensure that root temperatures would be adequate.

The demonstration project has been very successful. Growers are happy with the results and have applied several of the developed and tested to the remainder of their facility.

The combination of the blanketing system, the advantage of the warm floor, and the solar collector has reduced energy consumption by 70 percent compared to a similar greenhouse without any of these features. These are average results for the overall project.

Specific data for the fall 1979 poinsettia crop indicated that 640 million British thermal units (Btu’s) were required for the season. Of this 640 million Btu’s, 340 million Btu’s were supplied by the solar system. Projected use for a similar section without the features mentioned would be 2,280 million Btu’s. With the solar system, the fossil fuel requirement would be only 300 million Btu’s or a savings of 87 percent.
The greatest saving is in the blanketing system and in the strategic use of the warm floor. The solar system provided about half of the energy required.

Present costs of the installation of this solar system indicate a payback of about six years. The blanketing system will pay for itself in less than two years and should be a consideration for every greenhouse producer.

The warm floor concept is valid for crops requiring very little or no hand labor. Crops which require hand operations should be grown on elevated movable benches to reduce labor requirements and increase growing space within the greenhouse.

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**Rock Storage Solar System Saves Greenhouse Energy**

By R. Scaffidi and C. Vinten-Johanson

Several years ago labor was the most costly input to grow greenhouse crops. And, of course, the main interest became automation to replace labor. Now fuel costs have surpassed labor costs and attention has switched to reducing those fuel costs.

This chapter describes a small commercial nursery located in the Washington, D.C., area featuring a solar energy air collection system and a rock storage unit used to both heat and cool. The authors designed and supervised building of the "heat sink" greenhouse.

Objective of the project was to design a simple active heating system to supply a substantial amount of the annual heating load without economic penalties resulting from oversizing the building.

Several modes of operation were incorporated in the system to determine minimum design standards

RICKY SCAFFIDI, who has a B.S. in ecology, is project designer, builder, and part owner of the solar greenhouse described here. Christian Vinten-Johanson has a B.S. in agricultural engineering, and is now attending graduate school at Penn State. He was involved in setting design criteria and predicting performance of the greenhouse.