greatly reduced. We make more efficient use of seed which is in short supply, such as our strain of *Pinus mugo* (ENCI). Crops which are not hardy in our area can be grown and sold in markets further south. Plants with low pH requirements can now be grown. Our transplanting work-load has been spread over the entire summer rather than concentrated in the busy spring months. Survivability is consistently excellent and predictable. Quality is improved through grading standards at the time of the initial transplanting and carries on into the field production. Finally, the Gro-Plus® system is replacing a considerable amount of our seed bed production and bare-root transplanting.

RALPH SHUGERT: Can you put *Taxus cuspidata* through this system?

THOMAS PINNEY: Yes. The key is getting good seed.

GREENHOUSES HEATED FROM POWER STATIONS[1]

RUSSELL STANSFIELD

Northern States Power Co.
414 Nicollet Mall
Minneapolis, Minnesota 55401

In the early 1970's, Northern States Power Company (NSP) began to explore methods of utilizing for beneficial purposes the large amounts of heat rejected by the condensers of electric generating plants. At that time all of NSP's plants had cooling systems which were designed for "once-through" cooling, that is, water was taken into the plant from a river, used to condense steam, and then was returned to the river. Minimum temperatures of condenser discharge water at plants designed for this type of cooling range from 50°F to 60°F.

Since it would be extremely costly to remove significant amounts of heat from water of this temperature, it was not until a "closed cycle" cooling system, such as the one designed for the Sherburne County plant (SherCo), came into the picture that the Company could seriously consider developing beneficial uses of power plant cooling water. Minimum temperature of SherCo's condenser discharge water is 85.F. Sometimes the temperature during the heating season can be as high as 95° to 100°F. In a closed cycle system, cooling water is circulated from the power plant condenser through cooling towers, where the heat is removed by evaporative cooling. The cooled water is returned to the condenser where the cycle is repeated.

[1] Editor's Note: the paper by Russell Stansfield was presented by Dr. Harold Pellett, University of Minnesota, St. Paul, Minnesota.

Most modern electric generating plants are 35 to 37 percent efficient. This means that for every three units of energy input from coal, natural gas, oil or nuclear fuel, only one unit is actually converted into electric energy. By using a portion of the wasted energy for beneficial purposes, such as heating of greenhouses, a more efficient use of natural resources can be realized.

Cooling water leaves the condensers of the power plant, where it is pumped to the cooling towers. The temperature is lowered 29°F, in the case of SherCo, with the cooled water returned to the plant. Prior to entering the cooling tower, a small protion of warm water is diverted to greenhouse structures where the heat is removed for a beneficial purpose — heating the greenhouse — after which the cooled water is returned to the power plant.

The plot plan of the Sherburne County generating plant is located in the village of Becker on U.S. Highways 10 and 52, 45 miles northwest of the Twin Cities. A 65 acre sludge pond has been built. The warm water greenhouse complex is located approximately 1,500 feet south of the Unit II cooling tower.

The 340 acre tract just west of Becker and north of the generating plant site is owned by NSP. This acreage has been made available to the University of Minnesota for a long-term, no-cost lease for the location of the Sand Plain Agricultural Experiment Station. The Agricultural Experiment Station and NSP were joined by the United States Environmental Protection Agency in the Warm Water Greenhouse Research and Demonstration Project. Construction of the greenhouse began in the fall of 1975.

The type of greenhouse selected for the project is a pipe-supported, gutter-connected double-polyethylene structure, manufactured by the X.S. Smith Company. Structures similar to this were introduced in the United States by a Dutch greenhouse operator, Aart Van Wingerden. Since that time, many acres of this type of structure have been built in this country. The bows of the roof, connected at the gutters, are covered with a double-layer of 6 mil polyethylene. The layers are separated by air from a blower powered by a tiny electric motor. The resulting air space provides an insulating effect. In fact, double-layer greenhouses have 30 percent less heat loss than single-pane glass structures. NSP workmen built the structure which consists of 14 bays, each 17' × 96', for a total of more than 22,000 square feet, or slightly more than one-half acre.

In the north end of each bay, a centrifugal air handling unit has been installed. These heat exchangers are manufactured by Trane, of La Crosse, Wisconsin. This equipment is readily available from Trane, McQuay, and other manufacturers. The heat transfer from warm water to air is accomplished by drawing air across finned-tube coils. Thirty-foot polyethylene perforated tubes distributed the warmed air throughout the structure.

Another facet of the heating system involves soil warming. The soil heating system consists of 1" polyethylene pipes buried 12" below the soil surface on 2' centers. Warm water is circulated through this network of pipes to warm the soil and enhance crop growth. Power plant warm water is not used for irrigation purposes. The soil warming system is a closed loop, as are the finned tube heat exchangers. The water in the heating systems is returned to the power plant. The control center, specifically designed to aid in trouble shooting is located in the headhouse.

University of Minnesota scientists in the fields of plant pathology, horticulture, soil science and agricultural engineering provided expertise to solve problems and to keep the greenhouse productive. The warm water heating system is designed to provide all of the heat for the greenhouse, even on the coldest winter days. Minimum temperature at night can be maintained at 60°F. The coldest day during the project was on January 9, 1977, when the outside temperature dipped to −42.6°F. Inside the greenhouse satisfactory temperature was higher than design.

The greenhouse atmosphere was enriched by the use of CO_2 generators. Burning propane to create CO_2 increases yield and quality of both vegetables and flowers.

Since the project was started before the power plant was completed, warm water was simulated with electric boilers. These are now used for standby purposes.

SherCo Unit I went on line in April, 1976. Each unit of SherCo produces 680 megawatts. Each unit has its own cooling tower which functions independently, with no connection to the other unit. Work began in connecting the greenhouse to the power plant in the fall of 1976. PVC irrigation type pipe (12″) was used to conduct the warm water from the power plant to the greenhouse with a second 12″ line to return the cooled water to the plant. The tap for the warm water supply was made in one of the cooling tower risers. One-way distance from the Unit I cooling tower to the greenhouse is 3,500′.

Above grade construction of the 12″ line is steel; the transition to plastic is made just a few feet from the cooling tower. The pipeline is buried at a nominal depth of 5′. Water is returned from the greenhouse to the basin at the bottom of the tower.

The first commercial greenhouse operator, Tom Hermes, built his own greenhouse on NSP property during the summer of 1977. He is presently buying waste heat from NSP, with rates based on the cost of building and maintaining the pipeline plus pumping charges.

Hermes liked the soil warming system that he saw demonstrated in the research greenhouse so he installed it throughout his own structure. The warm water heat exchangers are very similar to those in the SherCo greenhouse, with some improvements and refinements added. Herme's 1½ acre building is being used to grow roses.

The second commercial operator, again building and financing his own greenhouse, is Tom Lange. Lange grows vegetables, tomatoes, spinach, lettuce and cucumbers in his ½ acre unit, using the nutrient film (hydroponic) technique.

The Company has reserved approximately 50 acres adjacent to the power plant for warm water greenhouse development. With construction for 1980 completed, there are 2.5 acres of greenhouses at SherCo, with more scheduled for 1981. In fact, Tom Hermes has an additional 1.5 acres under construction at the present time. Fifty acres is enough land to support 14 to 15 acres of greenhouses. A pipeline has been built to connect Unit II to the complex, which gives operators two-unit realiability. The Company is pleased with the results of the waste heat project and feels that as the cost of natural gas, propane, and fuel oil continues to rise, the alternative energy in the form of waste warm water will look increasingly attractive.

KEN MUDGE: I was wondering how the cost compares to standard methods of heating.

HAROLD PELLETT: I am not sure of the exact cost; however it is considerably lower than common methods.

KURT TRAMPOSCH: What would happen if you have all those greenhouses tied into this system and it goes down for 6 weeks in February?

HAROLD PELLETT: The first 3 greenhouses built had backup heating systems, so your initial costs are greater. The SherCo system has 2 separate power units so now if one goes down the other can supply the needed hot water.

GRAFTING APPLES

STANLEY M. FOSTER

Greenleaf Nursery Company
Park Hill, Oklahoma 74451

Greenleaf Nursery Company is headquartered approximately 90 miles southeast of Tulsa, Oklahoma, at Park Hill. Our Texas division is located in south Texas approximatley 70 miles southwest of Houston at El Campo. Both nurseries are exclusively