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DESIGN AND OPERATION OF GREENHOUSE COOLING SYSTEMS

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Design and Operation of Greenhouse Cooling Systems

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Cooling plastic and glass covered greenhouses is a common and necessary practice among successful Texas growers. Natural ventilation may cool greenhouses adequately in areas where there is sufficient air movement and where artificial shading can be used to reduce heat from solar radiation. However, with natural ventilation alone temperatures can never be reduced below outside air temperatures, and will quite often be 5 to 10 degrees F higher. When outside temperatures are high, the relative humidity is usually low enough to allow additional cooling with evaporative cooling systems. With evaporative cooling, water is evaporated into an air stream, increasing its relative humidity and reducing its temperature. The maximum temperature reduction possible is equal to the difference between the dry bulb and the wet bulb temperatures of the air. Under most practical conditions only about 80 to 85 percent of this difference can be achieved. A sling psychrometer, available from heating and air conditioning equipment suppliers, is used to determine wet bulb temperature.

Design

Evaporative cooling can be accomplished in several ways. One method is to spray an extremely fine mist of water into an air stream. This is normally done within an enclosed chamber of sufficient length to allow water to evaporate before it is carried out of the chamber. A second method uses a material which can be kept moist so that air flowing through it will evaporate the moisture and be cooled. Suitable materials must have a large contact surface, such as aspen shavings, rock, manufactured cellular material or filter-type materials. Aspen pads have been used for many years because they have little resistance to air flow when used in thicknesses of 2 inches or less.

Since aspen pads have become more difficult to find and frequent replacement (every year or two) is necessary, there has been a recent trend toward the use of other materials. Rounded gravel or lightweight aggregate has been used successfully as an evaporative surface in many installations. These pads are constructed horizontally so that the aggregate can be supported with a single layer of hardware cloth. The aggregate should be round, uniform in size (about 5/8 to 1/2 inch in diameter) and used in a layer no more than 1 1/2 inches thick. Using thicker or non-uniform size aggregate tremendously increases the power required to operate the ventilating fans.

A resin-impregnated paper pad in a honeycomb design is available. One trade name for this product is "Cel-Deck." It has been used for commercial saturation devices and provides a highly efficient evaporative surface with little resistance to air flow. The useful life of this material in greenhouse applications is still under evaluation. Present experience indicates that it may last 5 years or more.

A cement-coated fiber pad has been used to some extent as an evaporative surface. This material is very durable, but also very heavy and requires much more support than aspen pads. These pads generally are available in a 2-inch thickness.

For best evaporating efficiency, install materials so that the air velocity at the pad surface (cubic feet per minute [cfm] divided by square feet of pad) does not exceed 150 feet per minute. The pad area can be reduced if materials have been adequately tested and proven to have high evaporative efficiencies at higher air velocities. Check with the manufacturer for velocity recommendations.

Figure 1 shows a typical vertical evaporative pad system using excelsior or aspen wall pads. Water can be distributed through a gutter or a 2-inch PVC pipe with 1/8-inch holes drilled at 2-inch centers. Cement-coated fiber pads and "Cel-Deck" pads also can be mounted vertically and kept wet in the same manner.

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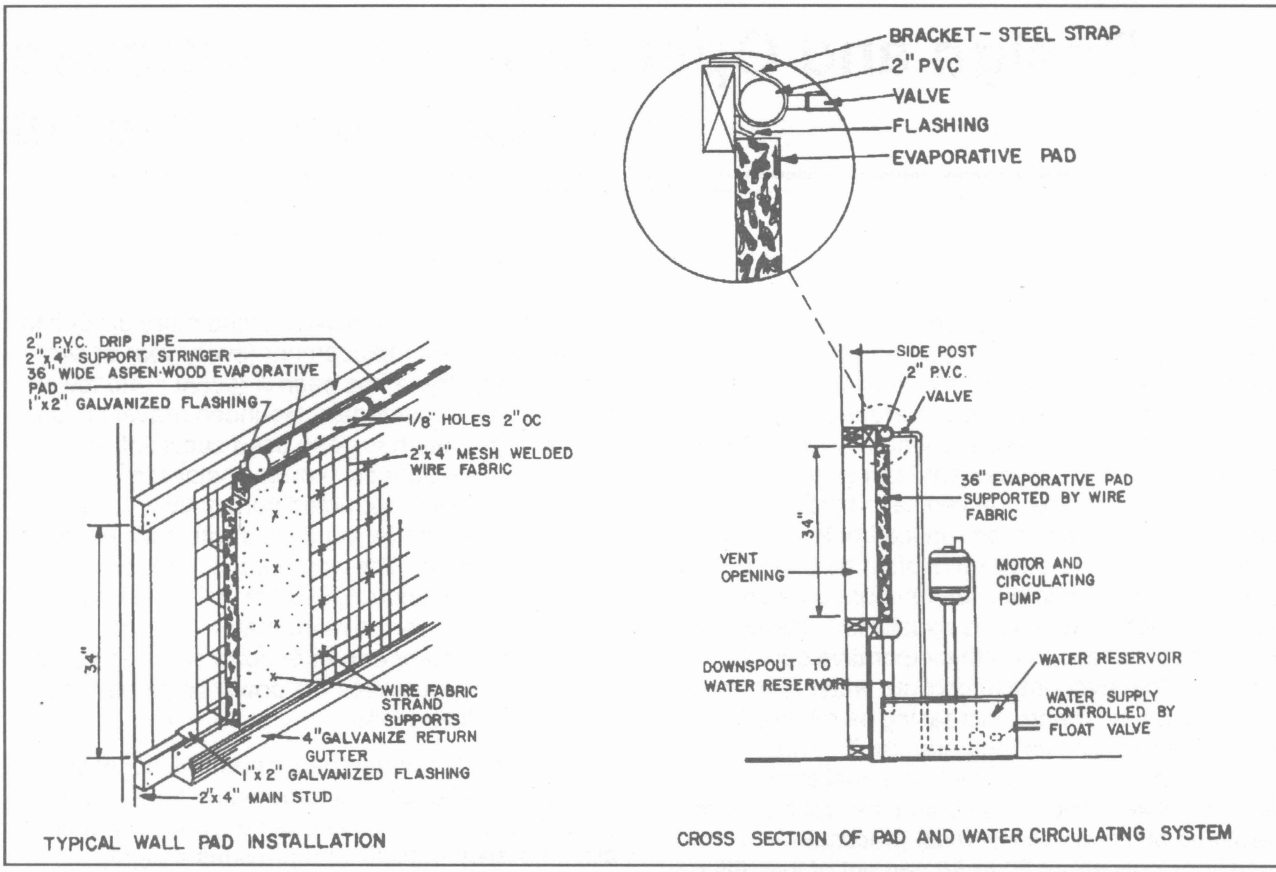

Figure 1. Typical vertical evaporative pad system, showing pad installation and water distribution system. Recirculation reservoir should hold 0.3 gallons of water per square foot of pad area.

Figure 2 shows a typical horizontal pad system. Sprinklers are required to wet the pad uniformly. The system pressure should be low so that the water doesn't atomize into fine droplets which may be carried away by the wind or pass through the pad without contacting the pad surface, thus creating a messy, wet area just inside the greenhouse.

Water Requirements

Vertical pads require approximately 0.11 gallon of water per minute (gpm) per square foot of pad to keep the pad wet and allow for evaporation. It is important to keep the pad thoroughly and uniformly wet for effective cooling.

Horizontal pad systems are constructed with either single or multiple pads (stacked two or three high, one above the other). For single-layer horizontal pads, the water must be distributed uniformly over the entire pad area. The multi-layer pad systems are usually installed with a sprinkler above the uppermost pad. Excess water is pumped so that drip from the upper pad wets the lower pad or pads. Experience in Arizona with three-tier pad systems indicates that a water supply of 0.4 gpm per 1,000 cfm of fan capacity, or approximately 0.06 gpm per square foot of pad area, is ample. All of the water is sprinkled on the top pad and allowed to drip through the lower pads.

Design the distribution system for an operating pressure to match the nozzle selected to provide the correct flow rate. Normal operating pressures are in the range of 8 to 12 psi. A low pressure provides a coarse droplet size and less wind drift. Distribution piping for the horizontal pad system is most often of PVC, because it can be worked without special tools. Select a pipe size which provides the flow rate required at a velocity of no more than 5 feet per second, which is equivalent to flow rates of 3, 12 and 48 gpm for 1/2-, 1- and 2- inch pipe, respectively.

Table 1 shows the equivalent length of pipe for various types of fittings. (a) After completing the pipe layout, including valves, couplings and elbows, determine the total equivalent pipe length. (b) Determine the friction loss for the pipe size used, in feet of head, from Table 2, adding the height the water is lifted from the sump to the distribution nozzle. (c) Multiply the operating nozzle

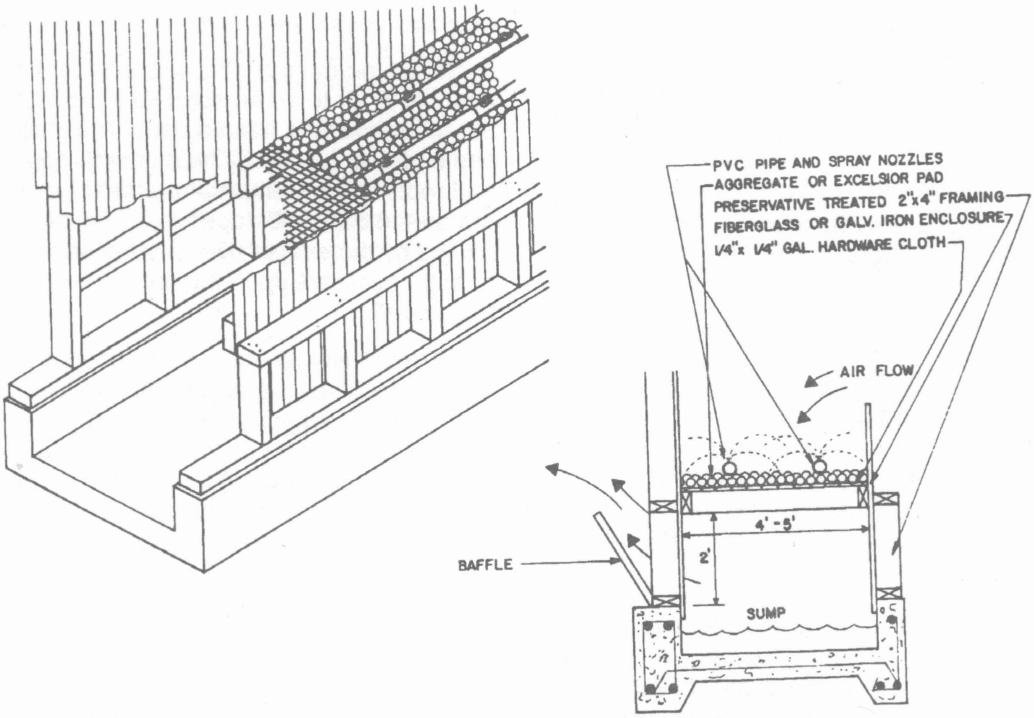

Figure 2. Typical single-layer horizontal pad system.

Table 1. Friction head loss in equivalent feet of pipe per fitting.*

Fitting type	Equivalent length in feet for nominal size – inches			
	1	1.25	1.5	2.0
Coupling	3	3	3	3
Union	3	3	3	3
90 degree ell	6	7	8	9
Tee	9	12	13	17
Check valve	7	9	11	13
Globe valve	25	35	45	55

*Data from MWPS-14.

Table 2. Friction head loss in feet per 100 feet of plastic pipe.*

Pipe diameter, inches	Flow rate in gpm							
	5	10	15	20	30	40	50	60
	Friction loss in feet							
1.0	1.8	6.3	14.0	**	**	**	**	**
1.25		1.7	3.5	6.0	13.0	**	**	**
1.5				2.8	6.0	10.2	15.0	**
2.0						3.0	4.6	6.5

* Data from MWPS-14.
**Excessive velocity.

pressure in psi by a factor of 2.31 and add to the feet of head in (b). The sum in (c) will be the total head in feet against which the pump must deliver the required gpm. With this information your pump supplier can then provide the proper pump model.

Figure 3 shows a typical pump and piping layout for a vertical pad system. Filters in the suction line or pump outlet are necessary to reduce nozzle plugging.

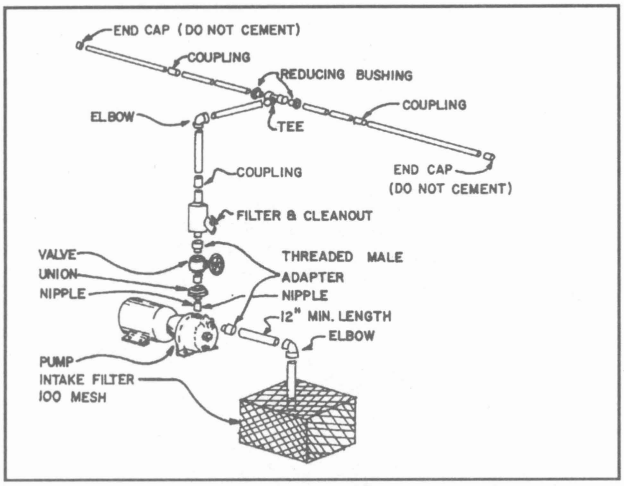

Figure 3. Pump and piping system for vertical pad system with drip pipe.

Fan Selection

Several types of fans may be used for evaporative cooling systems, including the propeller type and centrifugal type. Most pad and fan installations use the propeller or disk bladed fan as shown in Figure 4, since it performs well against low static pressures. Static pressure is the resistance to air flow by air inlets and outlets or ducts, and it influences the motor and fan size required for a given air flow.

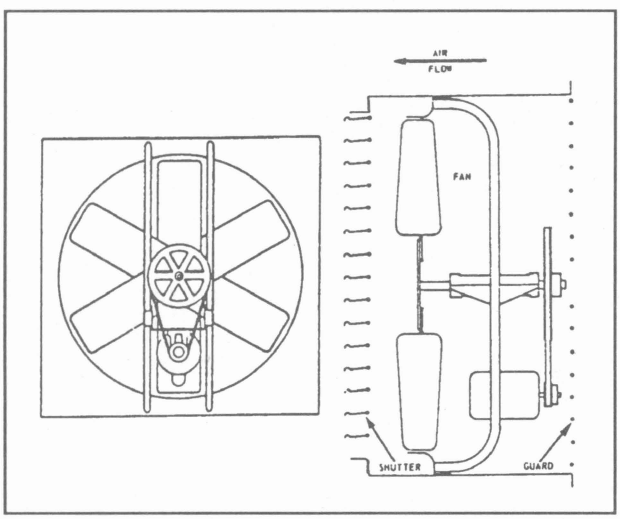

Figure 4. Belted venturi-type exhaust fan.

Belted, low speed fans are generally more efficient than high speed fans. Also, a large diameter fan usually will deliver air flow more efficiently than a small fan. However, these are general guidelines and one should always compare the power requirements of various fans delivering the same air flow against the same static pressure. A more efficient fan may cost more, but the lower operating cost may soon pay for the difference.

Select the fan size that will provide the proper quantity of air to do an adequate cooling job. Air in the greenhouse is heated primarily by solar radiation and secondarily by heat gain through the walls and roof. The air temperature maintained inside the greenhouse will depend on how much the air is cooled by the evaporative system and how much heat the air picks up in the greenhouse before it is exhausted.

Greenhouses should be designed to provide the lowest practical temperature during the hottest part of the day. Shading will reduce solar heat gain, but shading may not be desirable when maximum sunlight is needed for plant growth. Experience has shown that an air flow rate of 8 to 12 cfm per square foot of floor area is required. Air flow rates as high as 15 to 16 cfm per square foot of floor area may be necessary when shading cannot be used.

Excelsior pads, as used in pad-and-fan cooling systems, usually create a static pressure of about 0.125 inches of water. Aggregate pads 1 to 1 1/2 inches thick create a static pressure of about 0.20 to 0.25 inches of water. The "cement" cooler pad or the "Cel-Deck" pad creates a static pressure of about 0.10 to 0.12 inches or less. These values are based on an air flow velocity of 150 to 200 feet per minute through the pad.

When selecting fans, remember that less air flow will be required during cooler periods of the year and at night. Therefore, it is most efficient to use several fans to provide the maximum capacity needed and turn some of them off during cooler periods. It is good practice to use at least two fans, and preferably three or more in large greenhouses. The smallest fan should be adequate to provide proper ventilation during the winter.

Pad and Fan Location

Proper operation of cooling and ventilating systems requires that the pad and the fans be located correctly in the greenhouse. Always install the pad on the side of the greenhouse that will catch the prevailing wind during the period when maximum cooling is needed. For most areas of Texas, the pad should be placed on the south side. The fans will then be located on the opposite side of the house.

However, greenhouses are frequently oriented so that the ridge runs north to south, providing better distribution of sunlight to plants in early morning or late afternoon. If air velocity through the greenhouse needs to be kept low and the house is long and narrow, it is better to locate the pads on one side of the house and pull air across the house.

Where several houses are built close together, maintain a clear distance of 50 to 100 feet between houses to provide better air circulation. Closer spacing may cause the exhausted air from one house to enter the next house, thus reducing the cooling effectiveness.

Controls

Controls for the fans and pump can be automatic or manual, depending on the desires of the owner. A range of operating conditions can be established by using thermostats to stage the fans and the water supply pump. This allows the grower to adjust the system according to changing outside conditions. A thermostat is better for controlling the water supply pump than a humidistat, because humidistats require considerable maintenance and are difficult to keep calibrated.

Set thermostats to provide additional fan capacity at temperature intervals of 5 to 10 degrees F. When the temperature reaches 75 to 80 degrees F, all fans should come on. An additional 5- to 10-degree F rise should cause the water pump to start for evaporative cooling.

In addition to fan control, the discharge sides of exhaust fans should have automatic louvers which open when the fans start and close when the fans stop to prevent short circuiting of ventilating air.

Fan operating pressure and cost will be reduced if small motors are used to operate the louvers. Louvers should be kept clean and free of obstructions.

Place thermostat-sensing bulbs or thermistors in the air stream and shade them from the sun. Thermostats or thermistors may need to be moved or adjusted to provide the best operation in a particular house. Check temperatures manually in various parts of the greenhouse to determine if changes are needed for a more effective job.

Figure 5 shows a simple control system which might be used for greenhouse ventilation and cooling. This system involves two fans with motor-operated louvers and a pump for the evaporative system. Three thermostats are used to provide maximum system flexibility. Thermostat T1 could be set to start fan number 1 when the temperature rises to 65 degrees F. Thermostat T2 would be set to start fan number 2 if the temperature increases to 75 degrees F. The pump control thermostat (T3) would be set to start evaporative cooling at 85 degrees F. The control system shown uses 120-volt AC motors and 24-volt thermostats. Any system can be designed to handle multiple speed motors, incorporate time clocks, control winter heating and switch over from winter to summer. Watering systems, fertilizing systems and other components can be controlled automatically as well as manually.

Control systems should follow the National Electrical Code requirements for motor controls. Have a qualified engineer or electrical contractor check your system for safety and proper operation.

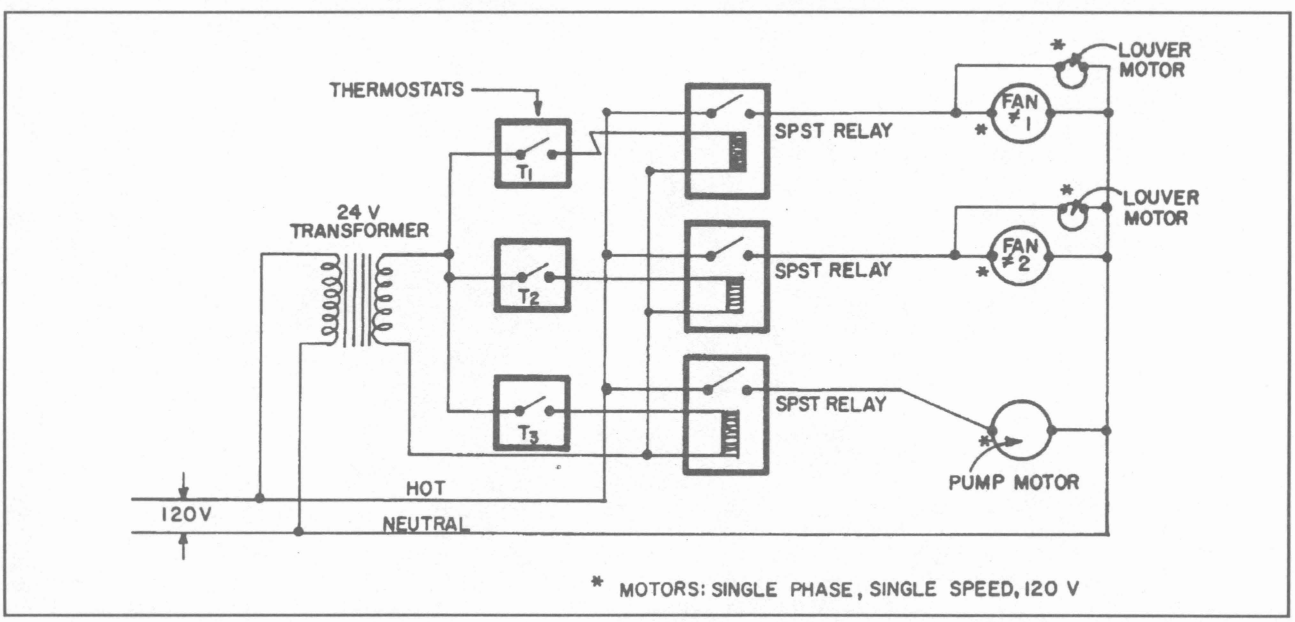

Figure 5. Low voltage control for greenhouse cooling system.

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