AN INTERMITTENT MIST SYSTEM WITH PRESSURE BOOSTED BY CONTINUOUS PUMPING

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Abstract. A mist system with line pressure boosted by a continuously running pump has advantages of design, operation, and cost over a system in which the pump runs intermittently. Between misting periods, the water is recycled at reduced pressure to a storage tank. Operation and safety features of the pump system are discussed schematically. The cost efficiency of the system makes it readily adaptable for large-scale expansion.

Fifty years of experience have established that misting leafy or green cuttings improves their survival and rooting (5). But too much mist can be deleterious (2,6). Therefore, intermittent misting has replaced the earlier practice of continuous misting (3).

The intermittent mist system described here operates with a continuously running pump that creates a misting pressure of 140 psi. The system is installed in a 9 ft by 12 ft propagation greenhouse at Berkeley, California, and has been in continuous use since 1981. The "fail safe" design ensures continued misting in case of power outage or failure of various system components.

DESIGN AND OPERATION

Any mist system is composed of two integral subunits: the "water distribution network," or mist lines; and the "water transmission system" that transmits the water into the mist lines.

Water Distribution Network. Mist is generated through nozzles rated at 2.0 gallons per hour at 100 psi. These nozzles point downward, are spaced 20 in. apart, and interconnect with ⅜-in OD copper tubing. Two such mist lines are mounted 18 in. apart 3 ft above each of two 3 ft by 12 ft benches. Fifteen nozzles are staggered in the two lines. Water left in the lines at the end of a mist period could drip from the nozzles and is therefore dumped to a floor drain by a lower-pressure relief valve that opens at the end of each mist period. A hand valve is installed in each mist line for line shutdown as needed. Three-inch-deep sand covers heating cable that lines the floor of each bench.

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Water Transmission System. After considering two intermittent pumping systems, we designed and built a system that, except for night shutdown, has continuous pumping, with water recycled to a storage tank between mist periods.

Operation of the system can be followed by focusing on pump P, solenoid valves SV_1 and SV_2, and tank T (Figure 1A). (For the moment, ignore hand valves HV_7, HV_8, HV_9, and HV_{10}.) During each mist period, which here is 12 seconds every 3 minutes, neither SV_1 (normally open) nor SV_2 (normally closed) is energized, and water from the pump flows through SV_1 to the mist lines. During recycle (non-mist) periods, solenoids for both valves are energized, closing SV_1, opening SV_2, and routing water from the pump back to the tank.

In daytime, the 6-min. time switch controls the solenoid valves and thus the alternating mist and recycle periods. At night, when misting is unnecessary, the 24-hour time switch and the relay (Figure 1B) leave the pump switched off and SV_1 energized. Thus, both SV_1 and SV_2 are closed at night.

When the water level in tank T lowers, float valve FV opens and the tank refills with water from the supply line. Check valves CV_1 and CV_4, and for an added margin of safety, swing check valve SCV prevent a backflow of water from the system into the supply line. (Local codes have different requirements for preventing potential backflow into supply lines.)

Pressure gauge PG indicates the pressure in the system — about 140 psi during each daytime mist period and 60 psi during each recycle period. Misting pressure is regulated by adjusting hand valve HV_5, at a time when the system is misting, allowing some of the water to recycle, the amount depending on the misting pressure desired. During recycle periods when water is recycled to the storage tank and flow is not restricted by the tiny nozzle orifices, pressure drops, reducing both pump load and energy consumption. Pressure in the system when water is recycling, set during a recycle period by adjusting hand valve HV_{10}, is kept slightly above supply line pressure. Any unusual surge of pressure that could damage system components is released by pressure relief valve RV.

The hand valves — all of ball-valve design — are for operational convenience. Exceptions are HV_5 and HV_{10} which regulate pressure as described, and HV_3 which flushes strainers S when opened. By opening hand valve HV_6 and closing HV_7 and HV_8, for example, mist can be maintained while solenoid valve SV_1 is removed for repair. (Union joints, common in the system to faciliate repair or replacement of components, are on either side of each solenoid valve). Hand valve

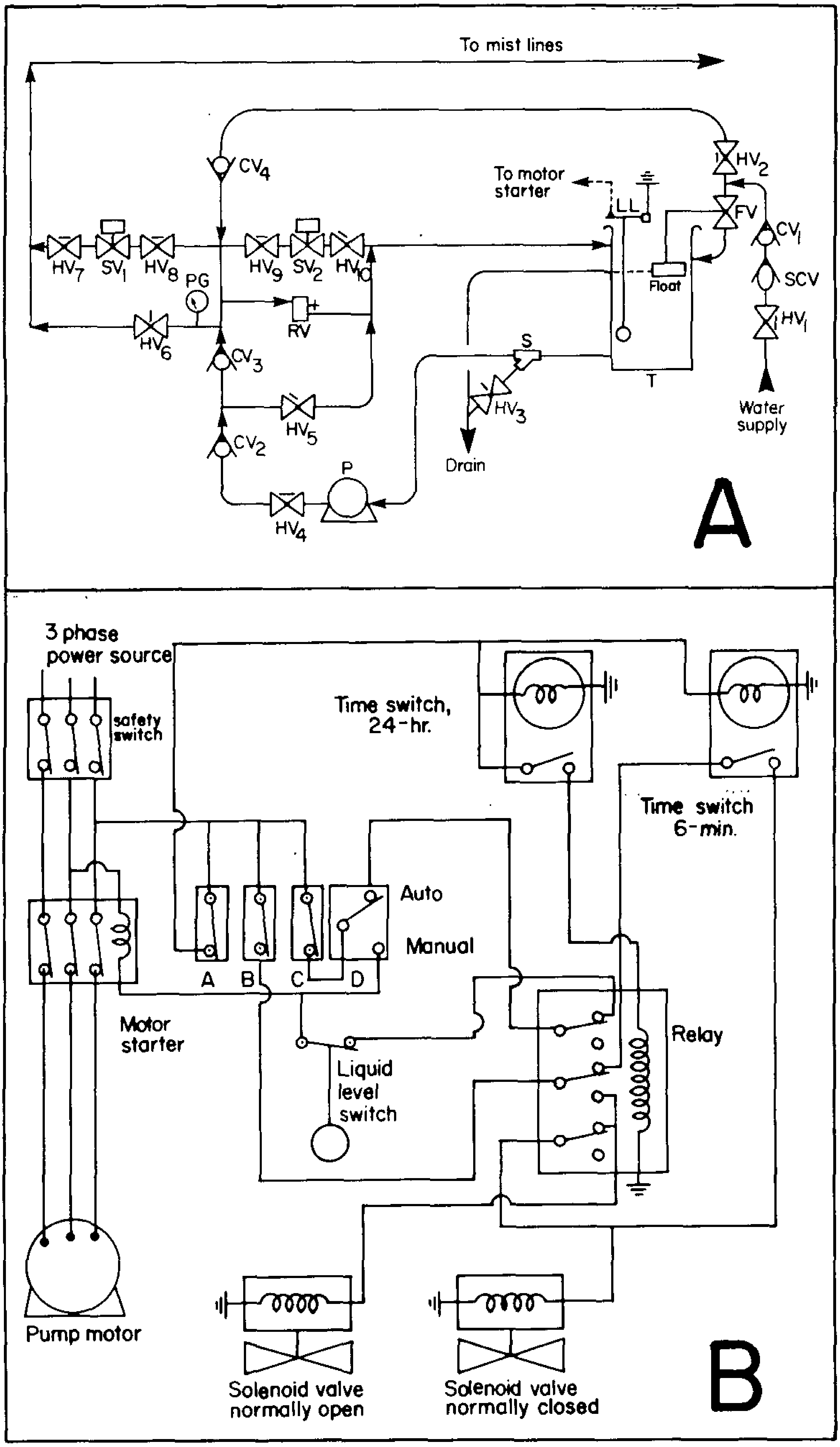

Figure 1. Schematic diagrams for the water transmission system: (A). Hydraulic or flow diagram; (B). Electronic diagram depicting normal, daytime, mist-period operation.

HV_1 shuts off water to the entire system. An appropriately oriented bar drawn next to each hand valve symbol (Figure 1A) indicates whether, during normal operation of the system, the valve is open (bar parallel to piping), closed (perpendicular to piping), or partly open (45 degrees to piping).

An emergency flow route from the water supply line to the mist lines passes through hand valve HV_2, check valve CV_4, solenoid valve SV_1, and hand valves HV_7 and HV_8. The emergency flow, at supply line pressure, is either continuous or intermittent, depending on whether a failure in the water transmission system involves loss of electrical power or only pumping. If power fails, the pump stops running, pressure within the system drops below that of the water supply, and water flows through the emergency flow route to the mist lines. Check valve CV_3 prevents backflow of water through the pump into the tank. Because solenoid valve SV_1 is normally open, water flows through it to produce continuous mist at supply line pressure, although the mist output per unit of time is less and the mist droplets are larger than at the normal misting pressure. If electrical power remains on but pumping stops because of pump failure or, for reasons mentioned below, tank emptying, misting at supply line pressure will be intermittent because solenoid valves SV_1 and SV_2 continue to open and close as controlled by the time switches (Figure 1B). In case water flows through SV_2 in excess of tank capacity it is dumped to a floor drain from the tank overflow outlet. Liquid level control switch LL shuts off power to the pump motor to prevent damage to the pump if the tank empties due to an unlikely event such as float valve malfunction, tank rupture, or lack of water in the supply line.

Electronics. The electrical circuitry of the water transmission system is shown in Figure 1B. Switches A, B, C, and D (all standard home wall switches) are for override purposes. Switch D switches the system between automatic and manual operation. The other switches cut off power to the time switches and relay (A), solenoids (B), and pump motor (C).

COSTS

Components of the mist system cost approximately $1500 when installed in 1981, excluding material for a 4 ft by 4 ft by 10 ft building to house the water transmission system and the heating cable installed in the benches. Numerous sources besides those in the specifications lists (Appendix) are available for each of these components.[2]

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[2] Trade names and commercial enterprises or products are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

Energy cost is the most significant operating expense and depends on many factors. We estimate energy consumption of the ½-horsepower motor of the close-coupled turbine pump to be between 3.8 and 4.8 kWh per 10-hour misting day for a cost of $0.30 to $0.38 per day at $0.08 per kWh. We mist two 3 ft by 12 ft propagation beds simultaneously, typically applying, as mentioned, 12 sec. of mist every three min. The system could mist a much larger area with only slightly increased energy costs.

DESIGN CONSIDERATIONS

The mist system has had only one unscheduled shutdown. A thumbscrew tripper on the 24-hour time switch loosened one night and the system consequently failed to switch on the next day. Several hours lapsed with no misting before the situation was noticed. A solid-state time switch or mechanical time switch with trippers securely anchored in position (e.g., pull out trippers) could avoid this specific problem. Although the system has a number of fail-safe features, daily monitoring is advisable.

The pump should be built for continuous operation and should be of sufficient capacity to discharge slightly more water during each mist period than the combined output of all nozzles. There is no way to compensate for an undersized pump that delivers too little water to maintain a desired misting pressure. Conversely, an oversized pump that recycles excessive amounts of water to the tank wastes energy.

If the mist propagation area is arranged with propagation benches or greenhouses of similar size, units can be misted serially rather than simultaneously. Solenoid valves can route the flow in turn to each unit. With serial misting, less water is recycled and less energy is used unproductively. For example, if a 15-station time switch and 14 more solenoid valves were added, this system could apply 12 sec. of mist every 3 min. to 15 greenhouses, with energy costs less than doubling.

The basic design of the system could be adapted to systems with pressures well above 140 psi and nozzles, such as those manufactured by Bete Fog Nozzle, Inc., Greenfield, Massachusetts 03102, that are designed to produce fog instead of mist. Fog preserves a humid environment around the cuttings whereas mist restores a thin film of water on the cuttings that is lost by evaporation. When fog is used it is circulated among the cuttings. either passively (1) or by forced air (4).

Acknowledgment. Appreciation is expressed to Four Winds Growers, Fremont, California, for consultation on the principles and merits of boosted pressure mist for plant propagation. Their mist system served as our original model, and we incorporated many of its features directly into our own.

We departed from their system primarily in the use of a continuously running pump to dispense with a pressure tank. Appreciation also is expressed to Stephen Jacobs, Coker Pump and Equipment Company, Oakland, California, who first suggested the framework of continuous pumping for an intermittent mist system. Our design developed from their inspiration.

APPENDIX

I. Specifications and manufacturers of piping components of the intermittent mist system.

Component	Specifications	Manufacturer	Model No.
Nozzle	Machined brass, 2.0 gph @ 100 psi, 120° hollow cone	Monarch Mfr. Works 2505 E. Ontario St. Philadelphia, PA 19134	F110C
Copper tubing and fittings	⅜″ for mist lines; 1⅛″, tank overflow to drain and tank to pump; ¾″ elsewhere	Unknown	
Polyethylene tank	18″ diameter, 40″ depth, 40-gal. capacity	Chem-tainer Industries 361 Neptune Ave. N. Babylon, NY 11704	None
Strainer	Y type, bronze, 1¼″ thread end 150 psi	Mueller Steam Speciality P.O. Box 1569 Lumberton, NC 28358	351
Turbine pump	2.4 gpm @ 150 psi, close-coupled to ½ horsepower, 3-phase motor	Burks Pumps P.O. Box 431 Decatur, IL 62525	35CT5M
Solenoid valve Open when *power is off)*	Normally open, ¾″ ips, 120 V AC	Automatic Switch Co. 56 Hanover Rd. *Florham Park, NJ 07932*	8210-C35
Solenoid valve (closed when power is off)	Normally closed, ¾″ ips, 120 V AC	Same as above	8210-B26
Pressure relief valve	¾″ ips, 5 to 300 psi	TEEL, Div. of W.W. Grainger, Inc. 5959 W. Howard St. Chicago, IL 60648	2P027
Float valve	¾″ ips	Robert Manufacturing Co. 10667 Jersey Blvd. Rancho Cucamonga, CA 91730	
Hand valve	Ball type, ¾″ ips, sweat end	Watts Regulator Co. 10 Enbankment St. Lawrence, MA 01842	B6001 400 WOG
Check valve	¾″ ips	Unknown	

II. Specifications and manufacturers of electronic components of the intermittent mist system.

Component	Specifications	Manufacturer	Model No.
Safety switch	30 A, 240 V AC, 3-pole knife, single throw	Square D Company 4335 Valley Blvd. Los Angeles, CA 90032	D321-NRB
Motor starter	NEMA size 00, 3 pole, 3 phase	Dayton Electric Manufacturing Co., W. W. Grainger, Inc. 5959 W. Howard St. Chicago, IL 60648	5X153B
Time switch	40 A, 240 V AC, 24-hr. repeating, single pole, single throw	Same as above	2E021
Time switch	20 A, 240 V AC, 6-min. repeating, 6-sec. increments	Tork 100 Grove Street Mount Vernon, NY 10550	8061
Relay	10 A, 120 V AC, 3-pole, double throw, 11-pin configuration	Cornell-Dubilier Electronics Corp. 1605 E. Rodney French Blvd. New Bedford, MA 02744	323A10-115
Liquid level control switch	120 V AC	Johnson Controls, Inc. 1250 E. Diehl Rd. Naperville, IL 60540	F59
Wall switch	15A, 120 V AC	Unknown	

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