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Constructing an Inexpensive Three-channel Reversible Peristaltic Pump

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Abstract. **Plans are presented for the construction of a three-channel reversible peristaltic pump that can operate at a rate of 45 ml/minute per channel. The cost of this peristaltic pump is about $84 compared to $620 for a commercially available peristaltic pump of similar design and capability. An electronic control scheme for pump operation is presented also.**

For several years our laboratory has conducted research to develop and refine an automated plant culture system (APCS) whereby long-term, large-scale micropropagation or plant development is achieved in a single culture chamber (Tisserat, 1990, 1991; Tisserat and Vandercook, 1985, 1986). In our system, the culture remains stationary while the medium is pumped in and out of the culture chamber. This eliminates many labor-intensive reculturing activities.

Alternating periods of medium immersion and aeration were found to be beneficial for plant tissue growth in culture (Tisserat, 1991; Tisserat and Vandercook, 1985, 1986). Early models of the APCS were gas-sterilized (Tisserat and Vandercook, 1985, 1986), while later versions were fully autoclavable (Tisserat, 1990, 1991). Contrasting sharply with impeller pumps, peristaltic pumps sterilely transfer medium—no moving parts directly contact the medium; thus, the potential for contamination is minimized. Multiple-channel peristaltic pumps are desirable to minimize control and pumping costs; however, they are expensive. For example, three- and five-channel pumps (Cole-Parmer Instrument Co., Chicago) cost $620 and $750 (1992 U.S. dollars), respectively. The cost of these commercially available multiple-channel peristaltic pumps preclude their mass use for laboratory research or commercial micropropagation practices.

In this paper, we present plans for an inexpensively constructed, multiple-channel peristaltic pump that significantly reduces the cost of using an APCS. Peristaltic pump design is essentially universal. Tubing is pinched periodically and rolled by the rotor's rotation to Facilitate liquid movement. Since only a few hundred milliliters of medium must be pumped, small, inexpensive motors are adequate (Table 1). The motor used for our pump is a 12-voltage direct current (VDC) gear motor equipped to run at 90 rpm with a 139-cm-kg starting torque and a 55 to 333-cm-kg running torque. A 12-VDC, 1-amp wall transformer is adequate for pumping. This multiple-channel peristaltic pump was constructed with off-the-shelf items (Table 1). Construction time is ≈15 rein/pump. The multiple-channel peristaltic pump is ≈50 cm long × 16 cm wide × 16 cm high, free standing, and handles 6.25-mm-outside diameter (OD) × 125-mm-inside diameter (ID) silicone rubber tubing rated at 50 ± 10 durometer.

Three aluminum channels and two zinc angles were cut with a hacksaw to dimensions given in Table 1. Holes in the channels were made with a 5.16-mm-diameter drill where designated in Fig. 1. A single 75-mm zinc slotted angle was attached with the 18.75-mm-long, 8-32 machine screws to support the motor. Motor and angle were secured to the wood platform with two 12.5-mm-long Philips wood screws (Figs. 1 and 2). The other zinc angle was attached to the opposite end of the motor with 18.75-mm-long 8-32 machine screws to support the channels (Figs. 1 and 2). Some additional trimming may be necessary to accommodate proper angle placement without interfering with the shaft. A 150-mm-long, 9.77 × 12.5 × 1.56-mm aluminum channel was attached to this angle by two 25-mm-long, 8-32 round-head machine screws, two no. 8 Society of American Engineering washers, and two 8-32 standard nuts. Silicone tape pieces (18.75 × 15.6 mm) were punched in the center with a no. 2 cork bore (5 mm in diameter). Silicone pieces were affixed to both sides of the central aluminum channel at the site of the drilled holes to provide a cushion for the silicone tubing (Fig. 1). Two 50-mm-long, 8-32 round-head machine screws and two 8-32 wing nuts attached the two 100-mm-long aluminum channels to the 150-mm-long channel as shown in Figs. 1 and 2. The three-channel tubing rotor was fastened to the steel shaft coupler at the 9.375-mm-diameter bore end, and the 6.25-mm-diameter bore end of the coupler was attached to the motor shaft. The shaft coupler set-screws were securely tightened with a 2.7-mm hexagonal key wrench. Tubes were attached by removing the outer 50-mm bolt and inserting silicone tubing between the channels and around the rotor. One 6.25-mm-OD × 3.125-mm-ID silicone tube was positioned in the center of each channel (Fig. 2). The outer bolt was reinserted and bolts and wing nuts were hand-tightened. Tubing rotated without any abnormal displacement; bolts should be tightened or loosened to effect optimum pumping. Once tubing was positioned correctly, no further adjustment was necessary (Fig. 2).

Two double-pull-double-through or four-pull-double-through relays controlled the DC motor (Fig. 3). Relay operation providing 12-VDC power to pump medium was controlled by two digital programmable plug-in timers (Intermatic Incorp., Chicago). One timer activates medium input and the second activates medium removal. Medium was introduced and evacuated from the culture chamber four equally spaced times a day and cultures were allowed to soak for 5 min each time.

Table 1. Materials required for constructing a peristaltic pump (1992 costs).

Item description	Model no.	Quantity	Cost ($)	Source[z]
Rotor, three-channel	RC3	1	25.00	1
Shaft coupling, 6.25 × 9.375 mm, steel	88019708	1	13.96	2
Motor, direct current, gear, 90 rpm	715-980156	1	34.62	3
Angle, slotted, zinc, 75 × 75 × 2.5 mm thick	---	2	0.45	4
Machine screws, round-head, zinc, 50 mm, 8-32	---	2	0.22	4
Machine screws, round-head, zinc, 25 mm, 8-32	---	2	0.17	4
Machine screws, round-head, zinc, 12.5 mm, 8-32	---	2	0.17	4
Washer, zinc, 8 Soc. Amer. Engineering, flat	---	6	0.03	4
Standard nut, zinc, 8-32	---	2	0.06	4
Wing nut, zinc, 8-32	---	2	0.17	4
Aluminum channels, 150 mm, 9.77 × 12.5 × 1.56 mm	---	1	0.66	4
Aluminum channels, 100 mm, 9.77 × 12.5 × 1.56 mm	---	2	0.44	4
Philips wood screws, 12.5 mm long	---	2	0.03	4
Plywood base, 112.5 × 87.5 × 12.5 mm	---	1	0.25	4
Wall transformer, 12 voltage direct current, 1 amp	DC1210	1	5.90	5
Rubber tape, silicone, 18.75 × 15.6 × 6.25 mm	---	4	0.06	6
Total			84.41	

[z]Source of items: 1 = De Novo, San Dimas, Calif.; 2 = MSC, Plainsview, N.Y.; 3 = Johnstone Supply, Portland, Ore.; 4 = local hardware store; 5 = Jameco Electronics Corp., Belmont, Calif.; 6 = Furon, CHR Div., New Haven, Conn.

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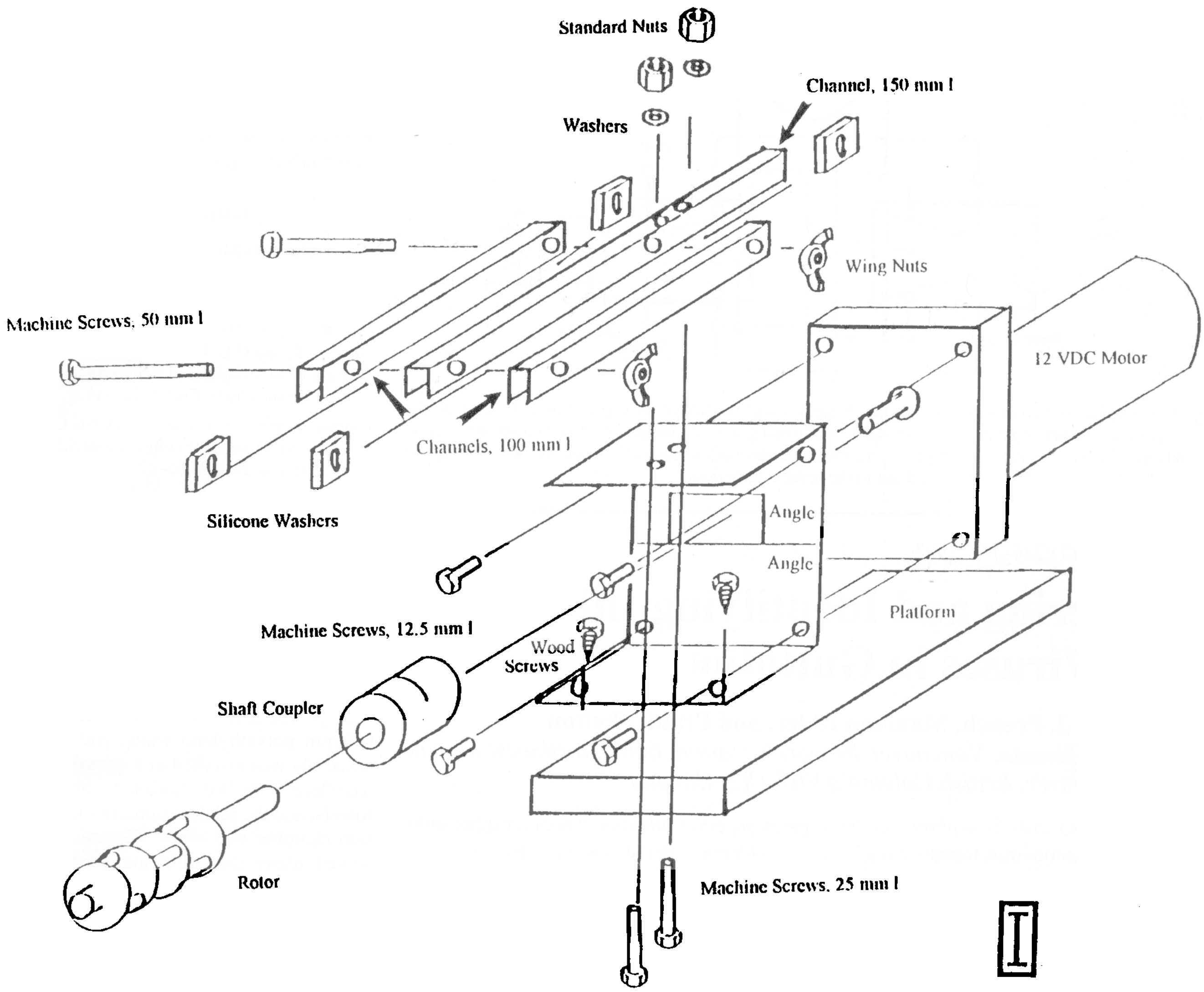

Fig. 1. Schematic representation of the components used to construct the three-channel peristaltic pump. Note: one angle attaches motor to base and the other angle supports the channels that secure the tubing during pumping. Bar = 1 cm.

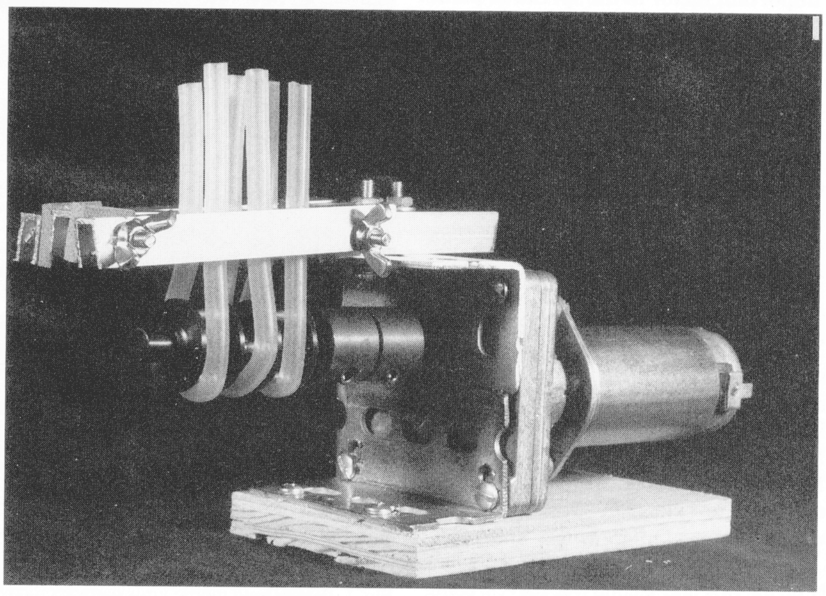

Fig. 2. Assembled three-channel peristaltic pump. Note: tightening and loosening the channels via the bolts and wing nuts allows for removal and insertion of silicone tubing and its correct placement on the rotor for optimum performance. Bar = 1 cm.

Experiments using three-channel peristaltic pumps showed that they were as effective as the more expensive commercial peristaltic pumps (e.g., Cole-Parmer three-channel pumps) for growing plants and cultures in the APCS. For example, when three 1-cm lengths of *Daucus carota* L. petiole pieces were grown in culture systems using a Cole-Parmer five-channel pump to circulate medium, 3.17 ± 0.38 g fresh weight of callus was obtained after 8 weeks. Our self-constructed system produced 3.47 ± 0.43 g fresh weight of callus. Pumps have been used continuously for up to 6 months without change in pumping capacity or other failure. Alternating exposures to air and submergence in medium four times daily is usually optimum for growing most cultures (e.g., *D. carota* callus) (Tisserat and Vandercook, 1985). Using these peristaltic pumps with 3.8-liter mason jars results in obtaining extremely large plants or culture populations in vitro (Tisserat, 1990, 1991). Total cost to assemble this system was about $84. Using 6.25-mm-OD × 3.125-mm-ID silicone tubing, this system pumps at a flow rate of 45 ml/min per channel. A variety of motors,

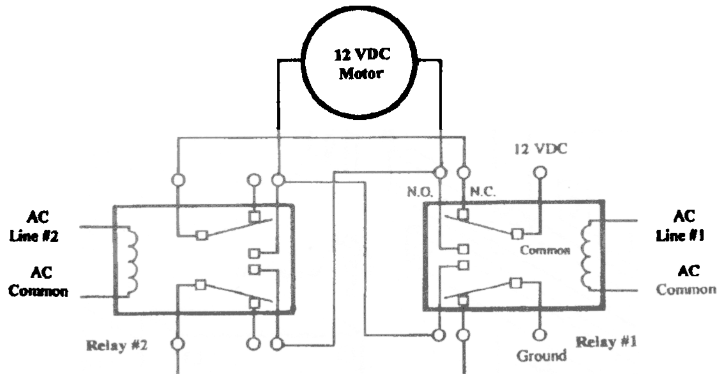

Fig. 3. Schematic of two double-pull-double-through relays controlled by digital timers to activate the forward and reverse operation of a peristaltic pump using one 12-voltage direct-current power source. When AC power is applied to relay no. 1, the motor pumps medium forward. When AC power is applied to relay no. 2, the motor pumps medium in the reverse direction.

rotors, couplers, and construction materials can be substituted for those presented to satisfy individual requirements. The low cost and simple construction techniques make this pump useful for a variety of activities performed in commercial nurseries, hydroponics, and research laboratories.

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