A LIQUID-DELIVERY UNIT FOR OPERANT SCHEDULES

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It has been found advantageous in this laboratory to approach the problem of scheduled delivery of various fluids on the basis of an unlimited quantity of the liquid presented for predetermined intervals. This technique has the notable advantage that when it is necessary to measure the temporal course of fluid intake, produced by such factors as drug effects and satiative changes in drive level, the subject has available all of the liquid it can drink for a prescribed period. In addition, a unit of this design tends to keep the subject in close spatial contiguity with the reward source since, following the operant response, liquid is continuously available during the feeding cycle.

We have designed and tested a light, rugged liquid-delivery unit which can be built with a minimum of tools and skill and requires little maintenance. It was designed for use with small animals (rat, hamster, guinea pig) and consists of an aluminum "Minibox" (4 in by 6 in by 2 in), a Synchron motor (8 rpm, 115 vac, 60 cycle, 5w), one DPDT relay (Potter-Brumfield, 5A, $\frac{1}{10}$ hp, 115 vac, 1 PH), an Amperite thermal delay relay (115N03T), a commercially available bar unit (Lehigh Valley Electronics), and three microswitches, together with associated Nylon and Teflon rod (Cadco Plastics) and rubber tubing.

To understand how the circuit operates, it is first necessary to understand the relationship of components in the assembly. The liquid-delivery unit, as seen from the open side, is shown in Fig. 1. Placement of the relays,

Fig. 1. Schematic of the liquid-delivery unit, with primary reservoir unit detached.

microswitches, motor, cam, linkage, plastic drinking tube, and sleeve is indicated.

At the start of the drinking cycle, with the unit in equilibrium, the inner (drinking) tube is completely retracted into its outer sleeve and the microswitch control rod is positioned in its rearmost traverse, holding Microswitch 1 firmly closed. When the bar (Microswitch 3) is depressed the motor rotates the cam 180 degrees from rear to front, transmitting a force vector simultaneously through the connector rod linkage to control rod and drinking tube. As rod and tube move forward, the rod disengages from Microswitch 1, opening it. When both rod and tube are fully extended, the rod closes Microswitch 2 and a small hole in the top of the drinking tube is exposed. This makes liquid available for a predetermined interval before the drinking tube retracts, again closing Microswitch 1 and completing the cycle.

Figure 2 is the circuit diagram for the internal wiring. At the start of the cycle, Microswitch 1 is held closed mechanically by the motor-driven rod through its "common" (C) and "normally open" (NO) contacts. When the bar (Microswitch 3) is closed, the relay coil is momentarily energized closing the two sets of relay contacts so that power becomes available through both sets through their C and

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Fig. 2. Circuit diagram for liquid-delivery unit.

NO contacts. The motor is activated through relay set 2.²

When the moving control rod releases Microswitch 1, the motor continues to run, obtaining power through the C and "normally closed" (NC) contacts of the same microswitch. The motor runs until the control rod closes Microswitch 2, cutting power from the other side of the line and stopping the motor. When Microswitch 2 is closed, its C and NO contacts are connected, bringing power to the heater (pins 1 and 6) of the thermal delay relay. When the heater warms sufficiently to close, contacts 3,4 (internally connected) are shorted to 8,9 (internally connected) thus supplying power again to the motor. The motor cam then retracts the control rod and drinking tube, disconnecting the C and NO contacts, while re-connecting the C and NC contacts of Microswitch 2, as well as cutting power to the heater of the thermal delay relay. When the control rod has traversed back to Microswitch 1, its C and NO contacts are re-connected, thus disconnecting power to the motor and terminating the cycle.

Two parts in this unit require some degree of care in fabrication. One is the cam-push-rod assembly, which connects the synchronous

motor with the drinking tube and also operates Microswitches 1 and 2 through the control rod during its traverse cycle. This assembly can be made from plastic or metal (cam and push-rod on our unit were machined from aluminum). The push-rod must be swiveled at each end so that one complete rotation of the cam drives the drinking tube outward and then back into its plastic sleeve. Perhaps the most difficult operation was the machining of the Nylon and Teflon. The latter was used for the inner sleeve because of its slippery, self-lubricating quality. Since plastic tubing was not available in the size required ($\frac{3}{4}$ " OD), a 4.5-in. piece of Nylon rod was drilled to an ID of $\frac{5}{8}$ -in. and machined a 7- $\frac{1}{4}$ -in. length of $\frac{3}{4}$ -in. Teflon rod to the desired OD of $\frac{5}{8}$ -in. An ovoid hole large enough to permit a rat to lap liquid with an unhampered motion was cut at the anterior end of the Teflon core. One-quarter inch from the opposite end of the core, another hole was drilled through the top and a plastic coupler glued to it to permit attachment of a length of rubber tubing from it to a larger reservoir. The reservoir, when filled with fluid and overturned, gravity-feeds continuously into the drinking tube without flooding. Another small hole drilled just anterior to the rubber tube connector prevents surging of liquid from primary to secondary.

The units may be "plugged" into the face of an operant conditioning apparatus, or even into a home cage and held in place on a supporting surface with bolts and wing nuts. The basic design can be modified for larger animals (cat, dog, monkey) by scaling up the size of box, linkage, and tubing, and adding a motor gearbox for greater torque. The time cycle of the unit may be modified by interchanging thermal delay relays or by replacing the motor with others of different speeds. It can also be modified for different reinforcement schedules by adding a stepping relay to the motor circuit (for FR) or by adding a timer (for FI).

²The bar must be held closed long enough for the rod to open Microswitch 1.

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