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A POSITIVE-FEED FLUID PUMP WITH VARIABLE FLOW RATE

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Although designed to feed a nutrient solution to a continuously growing microbial culture, the two-cylinder reciprocation pump described here can be used as well for other purposes which require a continuous liquid flow that is accurately maintained at a relatively low flow rate. With a driving motor geared to 1 rpm, the pump affords flow rates between 1.8 and 7 ml per hr. Other ranges are obtained when interchangeable driving motors of different speeds are used.

The essential features are shown in the photograph, Fig. 1. At the upper left corner is shown a synchronous motor (Bodine KYC-22) which turns a 0.5-in. -diam., 10-in. -long, 40-pitch screw. A split nut, driven by the screw, works one end of a crossarm, the other end of which terminates at a small cart between two 10-ml hypodermic syringes. The crossarm's fulcrum may be positioned along the slot in the base plate by a 20-pitch screw located beneath the base plate and passing through a threaded part of the fulcrum mount. Operation of the screw is by the hand crank on the front panel (bottom of photo). Connected to the orifice ends of the two syringe cylinders are two three-way solenoid valves (Skinner V5-100ST) which have their inlets and outlets joined by 0.25-in. copper tubing.

In operation, one syringe is filling while the other is discharging, and a limit switch, which reverses the synchronous motor, releases one valve, and actuates the other, operates at the extremes of travel to make the flow continuous.

Sturdy construction and elimination of play are essential in order to minimize liquid-flow error at reversal. To this end the 40-pitch screw is supported at the left end by ball bearings and at the right end by an adjustable point bearing consisting of a pointed 1/4-28 screw bearing on a center-drilled hole. The split nut is fitted by means of shims for free movement and no play; the crossarm pivots from point bearings at the split nut and passes through bearing carriers mounted on point bearings at the fulcrum and syringe cart, the bearing carriers, which are also shown in the end views of fulcrum and syringe cart, have three ball bearings (New Departure R-2), one of them spring-loaded,

mounted between two plates so as to roll along the crossarm. The cart runs along a track on three bearing wheels (also R-2), one spring-loaded. As a result of this construction the pause in fluid flow at reversal is only approximately 0.02 ml.

As mentioned above, the flow rate is varied by shifting the crossarm's fulcrum. The range of motion is such that flow rates from 1.8 to 7 cc/hr are obtainable. In order to obtain higher flow rates, the synchronous motor is arranged for easy exchange; 1.4, 2, 5, and 10 rpm are available as well as the 1 rpm normally used. The two 10-ml matched syringes were selected so that the plungers were interchangeable. The difference in diameter that satisfies this condition is approximately 0.0001 in. This corresponds to a maximum of 0.04% difference in volume and hence a corresponding difference in fluid-flow rate between the two directions of movement. The actual flow rates were calculated from measurements of syringe diameter and crossarm length by the use of a micrometer and vernier caliper. Errors may reasonably be assumed to be of the order of 0.0002 in. on micrometer measurements and 0.002 in. on caliper measurements; then the error in the flow rate may be of the order of 0.1 to 0.2%, depending on fulcrum position. Relative values of flow rate, however, do not share this error, and depend only on the accuracy of the screws and of the frequency of the ac supply that drives the synchronous motor.

This pump has performed very satisfactorily for several years in a system for feeding nutrient to yeast cultures, where individual experiments ran continuously for several weeks. Sterile solutions were required and, in order to avoid having to sterilize the pump, the system was arranged so that water could be pumped into a closed flask which also contained a rubber bag of sterile nutrient with an outlet to the culture tube.

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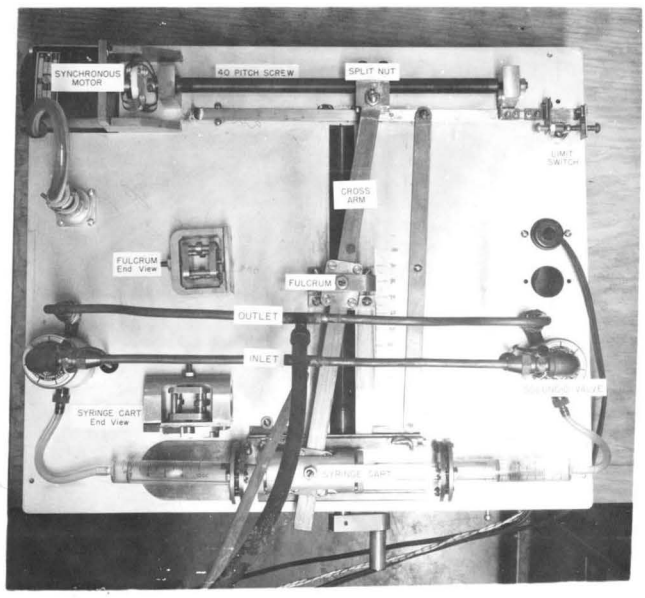

Fig. 1. Positive-feed, variable-flow-rate fluid pump (from above).