An Infusion Pump for Arterial Pressure Recording. (20568)

ROBERT A. LEHMAN.
From the Research Laboratories, Campbell Pharmaceutical Co., New York City.

The purpose of this communication is to describe an infusion pump which will make possible the continuous recording of blood pressure over long periods without an anticoagulant using high frequency recorders of the Hamilton, Sanborn, or Statham type. The principal requirements for such a pump are as follows: 1) it must deliver saline smoothly at a very slow constant rate into the artery from which the pressure recording is being taken; 2) it must not alter the magnitude of the pressure recorded but it must build up and sustain a pressure exceeding arterial by a small increment; 3) it must be provided with a device which will protect the artery and the pump in case of obstruction of the outlet because of a blood clot or for any other reason; 4) it must not introduce mechanical damping which would impair the frequency response of the manometer. The pump described below appears to meet these specifications.

In Fig. 1 is shown a schematic plan of the pump. The syringe holder and plunger drive assembly, which may be obtained commercially,* is mounted on any convenient base. It consists in a spur gear (not visible) which runs inside block A and drives rack B; this, in turn, drives a 50 cc standard syringe which is held in clamp C. It is necessary to ream the threaded hole in block A at the arrow to fit a piece of ¼″ drill rod D. This rod passes through the spur gear to which it is attached by a pin and terminates in a radio dial knob at E. The other end of the drill rod goes through a standard ¼″ radio panel bearing assembly in a vertical partition of masonite F, and terminates in spur gear G which meshes with spur gear H on the reduction box. Spring J enables one to disengage the spur gear in block A from rack B by pulling on knob E so as to quickly empty or refill the syringe by hand. The syringe may be emptied by 2 revolutions of knob E. In providing a drive mechanism a pair of Selsyn control transformers† have been inserted between the geared head motor and the reduction box in order to provide a variable torque slip clutch which will protect the syringe, gear train or blood vessel in case of obstruction of the outlet. These are connected in conventional fashion as indicated in Fig. 1 but are operated on 60 cycle current. When supplied with 15 volts from any suitable transformer they draw about 200 milliamperes. Under these conditions they will maintain exact synchronization and the pump will deliver saline against any pressure up to about 500 mm of mercury. When the pressure developed in the pump system exceeds this value, synchronization will break and the driven Selsyn will slip backwards and lock at a new angle of rotation. When this happens the pressure falls abruptly and then builds up again as before. This process will be repeated indefinitely until the high back pressure or obstruction is relieved. In Fig. 2 is shown the slow build-up of pressure and break of synchronization when the syringe outlet is purposely obstructed. Just before the slip occurs the current rises sharply which can serve as warning to the observer. Alternatively a relay operated buzzer or pilot light might be used for this purpose. A certain amount of adjustment in "slip" pressure may be obtained by varying the voltage applied to the Selsyn transformers. However, the electrical constants are not exactly reproducible because of inevitable variations in frictional resistance and small leaks.

It appears from the blood pressure tracing in Fig. 2 that neither the magnitude of the pressure recorded nor the frequency response of the manometer has been affected by introduction of the pump into the system. Probably flow occurs only during diastole but this has not been determined. For successful operation it is essential that leaks in the system be kept to a minimum since the flow rate

* Syringe Holder for Sodium Pentothal Anesthesia, Foregger Co., New York.

† General Electric Model No. 2J1G1.

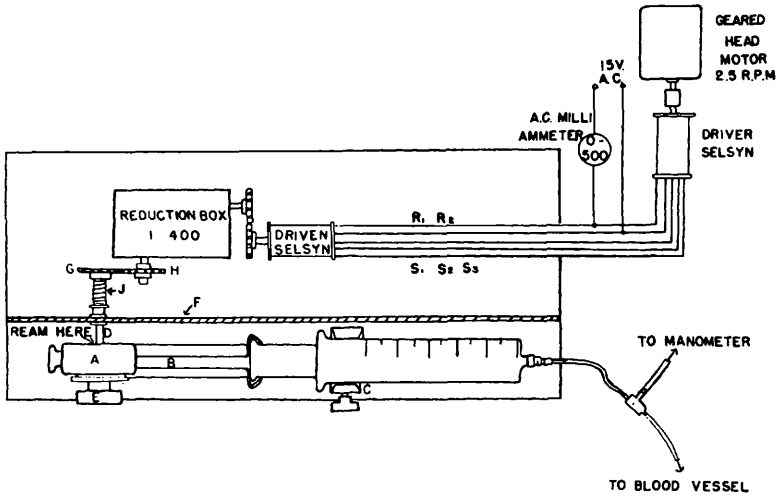

FIG. 1. Schematic plan of infusion pump. Explanation in text.

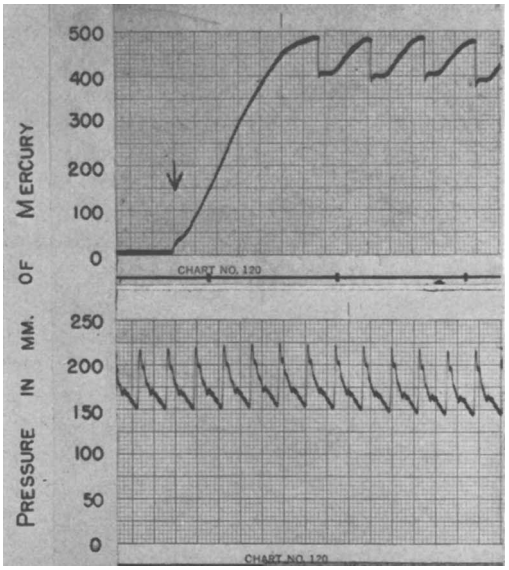

FIG. 2 (Above). Pressure recording with the outflow of the pump obstructed at the arrow. Time, 20 sec/cm. (Below) Blood pressure in femoral artery of an anesthetized cat. Time, 0.4 sec/cm. The pump was connected to the system at the signal. Note that no alteration of the high frequency components of the pressure waves occurs.

is very small and the saline will follow the course of least resistance. The syringe must be lubricated to prevent back seepage between the barrel and the wall. For this purpose a wettable grease is necessary to avoid trapping of air bubbles and polyethylene glycol 1500 has been found to be satisfactory. Luer-Lok fittings to polyethylene tubing were used for connection to animal and manometer. Luer stopcocks frequently caused leakage and were avoided.

As set up in Fig. 1, the delivery of the syringe will be:

$$\frac{(2.5 \text{ r.p.m.}) \times (25 \text{ cc/rev. of spur gear in block A})}{400} \times 60 = 9.4 \text{ cc/hr.}$$

This rate has been found to be sufficient to prevent clotting without heparin while recording blood pressure with the Sanborn Electromanometer continuously for 5 to 6 hours. In order to increase the delivery rate at the same "slip" pressure a faster motor may be used. For intravenous infusion at a high rate and low "slip" pressure the reduction box may have a smaller ratio. Exact control of the volume of infusion fluid is possible if a synchronous motor is used to rotate the driven Selsyn. Any convenient gear shift mechanism could be added to increase flexibility.

Although several infusion pumps are available commercially‡ it was felt that the pump described above might be of interest because of the protective mechanism, the freedom from damping and because it can be assembled from relatively inexpensive standard components with a negligible amount of shop work.

‡ Phipps and Bird, Richmond, Va.; Sanborn Co., Cambridge, Mass.; Metro Industries, L. I. City, N. Y.

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