# Section of Anæsthetics

President—I. W. MAGILL, M.B.

[*December* 3, 1937]

## The Errors of Flow-meters and the Advantages of a New Type of Constriction

By R. K. SCHOFIELD, M.A., Ph.D.

*Rothamsted Experimental Station, Harpenden*

IF the closed (carbon-dioxide-absorption) method of administering anæsthetic gases is to be used to full advantage, flow-meters are needed that can register rates as low as 10 c.c. per minute with a fair degree of accuracy. The purpose of this paper is to survey very briefly the problems which must be solved in the production of such instruments, to indicate the errors to which the various types are prone, and to point out the advantages of a new type of constriction.

In all flow-meters the gas generates a pressure difference between the two sides of a constriction through which it is made to pass. The instruments fall into two main groups—the fixed-pressure type and the fixed-constriction type.

*The fixed-pressure type.*—In this, the pressure difference is fixed, and the size of the constriction varies with the flow rate. The constriction may, for instance, be the clearance between a bobbin and the wall of a tapering tube, in which case the fixed-pressure difference is due to the weight of the bobbin. There are several alternative arrangements embodying essentially the same idea. The problems that arise are :—

(1) How to eliminate friction that would make the pressure difference greater for rising than for falling flow rates ;

(2) How to prevent an enlargement in the clearance, due to wear, permitting an increasing flow to pass in excess of that registered.

Great ingenuity in design and care in manufacture are required to solve both problems simultaneously. It is doubtful whether there is any instrument yet available in this group of which it may confidently be said that when it registers 50 c.c. per minute one may be sure that not more than 60 c.c. and not less than 40 c.c. is actually passing. The best may perhaps do this when new, but we do not know how great the error may be after they have been in use for some time. Some of the instruments in use at the present time can only be described as dangerously inaccurate.[1]

*The fixed-constriction type.*—In this group, the constriction is fixed and the pressure difference is measured. Here the problems are :—

(1) To choose a suitable constriction and reduce to a minimum the risk of its properties being altered (e.g. by dirt, moisture, or corrosion).

(2) To provide a convenient and sufficiently accurate means for measuring the pressure difference.

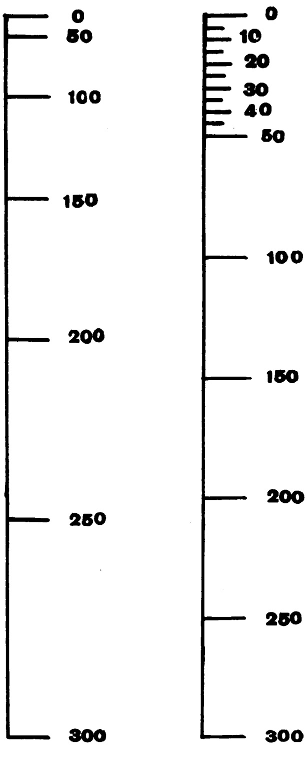
Again the difficulty is the *simultaneous* solution of the two problems. A Bourdon pressure gauge is convenient and sufficiently accurate, provided the pressures are high enough, but the very fine constrictions which have been used to obtain the necessary pressure differences have proved to be undesirably susceptible to partial blockage. A water depression manometer is much more sensitive and so permits the use of wider constrictions, but as hitherto constructed it is larger and more troublesome to transport and also less easy to read. It is quite possible, however, that these drawbacks which have hitherto made " wet " flow-meters unpopular may be considerably reduced by improvements in design.

*A new type of constriction.*—With the fixed constrictions hitherto employed the pressure difference varies roughly as the square of the flow rate. Thus in a water

[1] Errors amounting to several hundreds per cent. have been reported, and the author has been informed that cyclopropane "dissolves" vulcanite bobbins.

depression flow-meter the depression increases nearly fourfold for a twofold rise in flow rate. Consequently the markings for the smallest flow rates are crowded against the zero, as shown on one side of the figure. It is, however, possible to get an evenly spaced scale, such as that shown on the other, by using as constriction a set of long capillaries arranged in parallel. The gas passes through a constriction of this kind in " stream-line " motion, and the pressure difference, which is controlled by the viscosity of the gas, is directly proportional to the flow rate (very nearly). The motion through a hole or jet is " turbulent ", and the pressure difference is due mostly to the necessity of giving a high kinetic energy to the gas as it rushes through the constriction ; hence its dependence on the density and the square of the velocity.

By using a constriction that gives direct proportionality between pressure difference and flow rate, in conjunction with a water manometer, full use can be made of




the fact that a manometer has a true zero. With this arrangement the smallest flow rate gives a proportional movement of the liquid surface from the zero mark. With dry flow-meters there is always " threshold " flow below which the instrument does not register. In the fixed-pressure type this tends to increase with wear, and is a serious source of error.

It is a comparatively simple matter to make an accurate manometer flow-meter, using a set of parallel tubes as constriction, since Nature has provided such a constriction ready made in a stick of cane (not bamboo but " solid " cane). A piece about the size of a pencil can be selected to give a water depression of 2 in. for 100 c.c. per minute. Thus a 6-in. depression tube will register flows up to 300 c.c. per minute and will give one-tenth of an inch depression for 5 c.c. per minute. One depression tube could be given two scales, one for high and one for low sensitivity if two canes, one of which would be cut out for high sensitivity, were connected in parallel. In this way the scale could be extended to, say, 6 litres per minute, without lengthening the instrument or generating excessive pressure differences. There would be no real difficulty in making an instrument on this principle that would give an error not exceeding $\pm$ 5 c.c. per minute below 100 c.c. per minute, or $\pm$ 5% for higher readings. Blockage of the cane is the only possible source of error. The risk of this seems to be very slight in view of the many hundreds of channels through which the gas may pass, but it is a point that will have to be checked under practical conditions.

An instrument using a cane or equivalent system of metal tubes and a manometer of improved design seems most likely to combine the needed accuracy with moderate cost, as no highly specialized technique is involved in its construction. The possibility must not, however, be overlooked that a similar constriction might prove satisfactory in conjunction with a sensitive Bourdon gauge.

*Need for frequent checking.*—In conclusion it should be stressed that *all* flow-meters that are used in closed circuit work should be periodically checked. It is to be hoped that instruments will soon be available that are of such proved dependability that the checking need only be done at long intervals, but as matters stand at present the checking should be frequently done. Testing apparatus is cheap to assemble and comparatively easy to use.

## The Continuous-Flow Administration of Cyclopropane

By LAWRENCE H. MORRIS

THE method of continuous-flow administration of cyclopropane was excellently described by Burford in 1936.

An anæsthetic apparatus capable of measuring very small flows of gas is essential, but there are no flow-meters which measure accurately flows below 100 c.c. per minute down to about 10 c.c. per minute. A special apparatus was therefore constructed.

*Apparatus.*—The apparatus is composed of three parts—a footpiece, an upright rod, and a head ; these fix together by means of male and female joints and also fit into a small box container. The head has three yokes to take nitrous oxide, oxygen, and cyclopropane cylinders. Nitrous oxide flows at the rate of 1–10 litres per minute, oxygen at 100 c.c. - 1 litre per minute, and cyclopropane at 10–300 c.c. per minute. The flows are measured by means of calibrated gauges, which are, in fact, pressure gauges with a fixed restriction valve at the outlet. When the pressure is increased, the flow of gas increases and it is really this pressure, which is calibrated, and not the actual flow of gas.

*Disadvantage.*—This restriction type of flow-meter appears to have one disadvantage, in that the rate of flow of the gases falls (it never increases), and so does not correspond to the reading shown on the dial. This occurs gradually after some hours of use and for no accountable reason, although it may be due to very small particles of dirt or moisture from the gauges and the gases clogging the restriction valves, but there is no definite proof of this. The restriction valve must therefore be reset from time to time in order to overcome this disadvantage. As this apparatus is purely experimental, no emergency valves for a fast flow of oxygen have been fitted, but I have always had an oxygen cylinder at hand and have, so far, not had cause to use it.

*Technique.*—In conjunction with this apparatus I use a Waters to-and-fro soda-lime canister.

To induce, I start oxygen flowing alone at 1 litre per minute. After fixing the face-mask, and with the bag only slightly distended, I set cyclopropane flowing immediately at 300 c.c. per minute, which is the highest limit of flow at my disposal. I feel, however, that it would make induction easier and quicker in certain cases, if this limit was higher, say 400 or 500 c.c. per minute—but not more—for in most cases 300 c.c. suffices. After enough of the mixture has passed into the bag to prevent it from collapsing completely at the end of an inspiration, the rate of oxygen flow is reduced to 350–400 c.c. per minute, cyclopropane remaining at 250–300 c.c. per minute. When the desired level of anæsthesia is reached, cyclopropane is then cut