A SPIROGRAPH FOR SMALL LABORATORY ANIMALS

S. B. Daniyarov, Yu. M. Lanskii, and E. M. Bebinov

UDC 615.471.03:616.24-008.4-092.9-073.96

KEY WORDS: pulmonary ventilation; laboratory animals; spirograph; "piston in cylinder: system; impulse recording; electromagnetic valves

Instruments produced by Soviet industry for the study of the human respiratory system are mainly of the type which directly measure the quantity of inspired and expired air filling the space within a hollow cylinder (sector) immersed in water or a moving dry siphon (the bellows principle). The error of measurements obtained by these apparatuses is comparatively small when considered against the background of characteristic values for the depth of human respiration [2]. The absence of Soviet-produced or imported spirographs for small laboratory animals compels the research worker to resort to various, often indirect, methods of recording ventilation parameters. These methods are based on the principle of transformation of parameters of the external respiratory system (pressure differences in the air passages, air flow temperature, lung impedance, plethysmographic characteristics, and so on) into respiratory volumes. Values of lung ventilation obtained by apparatuses working on the indirect measurement principle are less accurate than data obtained by spirographs working on the principle of direct measurement of lung volumes [3]. All indirect measurement systems must also be calibrated, i.e., the values obtained must be compared with characteristics obtained by the use of direct measurement apparatuses. Incidentally, in experimental respiratory physiology even specialists in leading laboratories are forced to use the classical model of Krogh's spirograph [1] (because of the absence of any more accurate or reliable methods). However, during work with small laboratory animals, whose respiration rate is high, all the known methods of measuring volumes inside a cylinder or sector immersed in water are unsuitable because of inertia of the system.

When given the task of creating a spirograph with improved characteristics, we used several approaches, modifying the principles of operation of the apparatus. Our aim was to reduce to a minimum the resistance to breathing, to make an accurate measurement of the respiratory volumes, to record the depth of inspiration in pulsed form synchronously on the trace with other parameters of respiration and other systems. Another advantage of the apparatus was the replaceability of one of the components of the stationary cylinder and piston system (described below), for which an injection syringe was used. By using syringes of different volumes, without losing any accuracy of measurement, it was possible to record the respiratory volumes of animals which differed considerably in body weight, size, and lung volume (for example, rats of different ages weighing from 50 to 300 g).

The spirograph is used in experiments as follows (Fig. 1). The anesthetized animal is connected by means of a tracheotomy tube or breathing mask 1 to the gas-distributing box 2. During inspiration the rubber membrane 8 of the respiratory phase transducer 7 bends because of the small (0.1-0.5 mm water) vacuum, and the light-obstructing shutter 9, connected mechanically with the membrane, allows the beam of light from the photodiode 10 to fall on the photoelectric cell 11. The signal from the photoelectric cell 11 is led through the unit controlling the electromagnetic valves 24, and closes valve 12 and opens valve 13. The gas mixture, under the influence of the piston 16 of the syringe 3, which moves downward freely, enters the gas-distributing chamber 2 and passes through the mask (or tracheotomy tube) into the animals' lungs. The gas mixture enters the animal's lungs without any excess pressure, for the force of the pressure created by the falling piston of the syringe is balanced by the resistance of the air passages. Within the short time interval between inspiration and expiration the pressure is equalized in the chamber of

Department of Normal Physiology, Kirghiz Medical Institute, Frunze. (Presented by Academician of the Academy of Medical Sciences of the USSR G. N. Kryzhanovskii.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 102, No. 10, pp. 499-501, October, 1986. Original article submitted December 13, 1985.

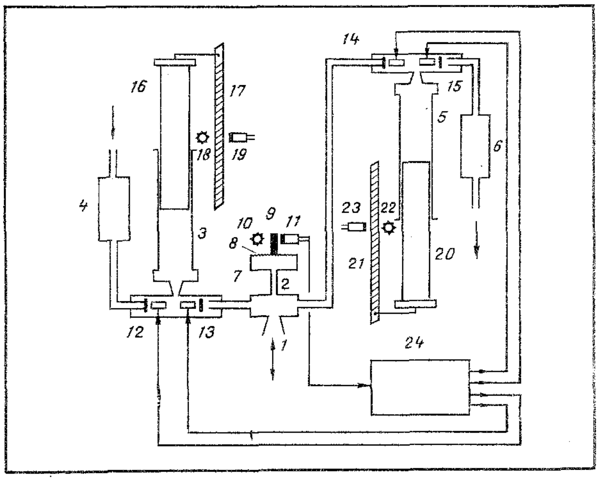

Fig. 1. Diagram of the spirograph.

the respiration phase transducer 7, the light-obstructing shutter 9 returns to its original state, which is recorded by the photoelectric cell 11, the signal from which, passing through the unit controlling the electromagnetic valves 24, closes valves 13 and 15 and opens valves 12 and 14. The expired gas mixture passes through the mask 1, the gas-distributing box 2, and valve 14 into the cylinder 5, whose volume is increased by the downward moving piston 20. In the dry spirograph, because of the high-quality polishing of the glass surfaces of the cylinders and pistons, airtightness and free movement of the pistons are ensured. During expiration the cylinder 3 is filled with the gas mixture by means of the microcompressor 4 with valve 12 open. During inspiration the mciropump 6 pumps the gas mixture through the open valve 15 from the cylinder 5. The design of the apparatus incorporates volumes of gas mixture are measured by a system ot photoelectric converters, consisting of measuring rules 17 and 21, marked with divisions, the light-diodes 18 and 22, and the photoelectric cells 19 and 23. The measuring rule is located between the light diode and photodiode, and is connected mechanically to the piston. During movement of the rule, the photodiode counts divisions marked on it, and signals from it can be recorded as impulses on the automatic recorder or by means of a digital counter. One division on the measuring rule (or one impulse) corresponds to 0.05 cm^3 of inspired or expired air if a 5-cm^3 syringe is used. The use of a syringe of smaller volume when working with the same animal increases the accuracy of measurement.

During the work a number of new opportunities for use of the instrument and its components was discovered. For instance, by using a syringe of greater volume in the system of the stationary and moving cylinders, respiratory volumes of larger animals (rabbits, cats) can be recorded. The spirograph is not only suitable for experiments in which the respiratory system is exposed to various influences at a normal barometric pressure, but it has also justified itself well for work in a pressure chamber, and for fault-free operation under conditions of increasing barometric pressure. Values of the respiratory parameters obtained with the aid of the apparatus on the tape of the automatic writer or digital printer and on an electronic digital signal panel enables exhaustive information to be obtained about the breathing pattern of the laboratory animal within a few minutes after the measurements are made.

LITERATURE CITED

1. É. A. Konza and V. P. Frolova, Fiziol. Zh. SSSR, 64, No. 6, 878 (1978).
2. L. L. Shik and N. N. Kanaev (eds.), Textbook of Clinical Physiology of Respiration [in Russian] (1980).
3. S. Jennett, Pharm. Ther., 2, 683 (1976).