amounts, has occurred at 10 seconds or promptly thereafter. This rapid recirculation is undoubtedly due to the increase in blood flow through the lungs occasioned by the deep rapid breathing of the procedure. The increased blood flow is also indicated by the volumes of O_2[4] and C_2H_2 removed from the lungs during the first 10 seconds before recirculation begins. There can be no doubt that recirculation occurs in the Marshall-Grollman procedure not only before the test is over (23 seconds) but even before the first sample is drawn (at 15 seconds). The ability to obtain good checks with the Marshall-Grollman procedure (an ability which has differed widely in the hands of different workers) will depend on timing the samples in exactly the same way in repeated experiments so that the errors due to recirculation (which are partly compensated by the error due to abnormal quickening of the blood flow beyond the metabolic needs of the tissues with consequent increase in the O_2 content of the mixed venous blood) will be fairly constant. The writer has been gradually and unwillingly forced to the conclusion that the results of the Marshall-Grollman method are heavily weighted with errors which compensate each other to a varying degree under different conditions, rendering the absolute figures obtained sometimes correct but never completely reliable, and rendering the method insensitive to the detection of small differences, because the size of the errors involved may vary even more than the function to be measured.

8076 P

A Modified Foreign-Gas Method for Determination of Cardiac Output in Man.

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The application of the foreign-gas principle for the determination of the arteriovenous oxygen difference and cardiac output in man is beset by two difficulties; first, the attainment of a homogeneous mixture in the gaseous system with which the arterial blood is assumed to be in equilibrium; second, the termination of the pro-

4 Preceding publication.

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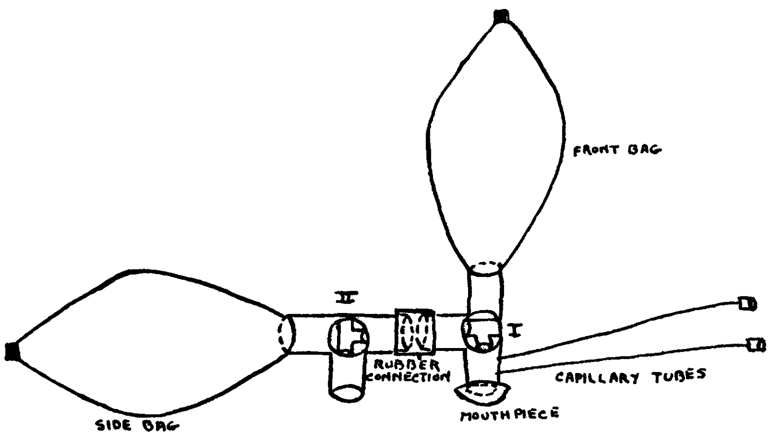
cedure before recirculation of blood takes place. The demonstration that the latter occurs within 10 seconds[1] renders unavailable the mixing technique of Marshall and Grollman[2] which requires 15 seconds, and *a fortiori* their rebreathing procedure which lasts for 23 seconds.

To restrict the procedure to the time available, the writer has introduced a method for attaining homogeneity of composition that can be finished in 3½ to 4 seconds, and is accomplished by dividing the inhaled foreign-gas mixture into 2 portions, such that the gas filling the dead space approximates in composition the alveolar contents, and further by washing out and discarding the contents of the dead space before the first alveolar sample is drawn.



The apparatus consists of 2 three-way aluminum valves (bore 2 cm.), 2 rubber breathing bags (capacity 4 liters) connected as shown in diagram. Lead tubes 15 cm. in length and of capillary (0.5 mm.) bore permit the drawing of samples from the mouth side of the valve into evacuated sampling tubes. Bag contents are

Front Bag		Side Bag
825 cc.	air	1300
55	CO_2	50
120	C_2H_2	500
	O_2	150
Total 1000		Total 2000

After the nose clip is applied, the subject expires to residual air, and then inspires the contents of the side bag followed by the contents of the front bag. The experimenter turns valve I so that

1 Preceding publication.

2 Marshall, E. K., and Grollman, A., *Am. J. Physiol.*, 1928, **86**, 117.

approximately the first liter of the ensuing expiration is discarded into the side bag, the rest of the expiration being directed into the empty front bag and at the end of this deep expiration the first sample is drawn. This preliminary period can be finished in 3½ to 4 seconds. Two more deep breaths requiring about 5 seconds are taken and the second sample is drawn at the end of the last breath, 8½ to 9 seconds after the beginning of the test.

The adequacy of the mixing procedure may be tested by drawing the first sample simultaneously at opposite ends of the rebreathing (front) bag and pairing each sample with the final sample for 2 separate calculations of the A-V difference. In 7 experiments (Table I) this double sampling has been done. The average dif-

TABLE I.
Effect on Different Individuals of Drawing First Alveolar Sample from Opposite Ends of Rebreathing Bag.

Pulse Rate per Min.	Blood Pressure Mm. of Hg.	O Consumption, cc. per Min.	Arteriovenous O Difference, cc. per L. of blood A	B	Difference between A and B	Cardiac Output Liters per Min. I	II
64	108/65	256	49.7	53.9	4.2	5.2	4.8
76	106/75	284	50.4	49.7	0.7	5.6	5.7
68	112/72	258	51.3	52.3	1.0	5.0	4.9
76	115/70	259	43.8	50.2	6.4	5.9	5.2
70	105/72	247	43.6	46.0	2.4	5.7	5.4
88	116/80	252	43.1	45.8	2.7	5.9	5.5
88	120/76	270	50.3	50.1	0.2	5.4	5.4
				Average	2.5	5.5	5.3

ference of about 5% may be attributed to errors of mixing and gas analysis. Since the latter alone may account for the variations observed, the error due to imperfect mixing is either negligible or absent.

In the gas analysis, to reduce the error due to absorption of C_2H_2 during removal of CO_2[3] the author has introduced for absorption of CO_2 a solution containing 40 gm. of NaOH and 6 gm. of NaCl per 100 cc. of solution.

The present technique is an application of the foreign-gas method, identical in principle and method of calculation with the nitrous oxide method of Krogh and Lindhard[4] but following more closely the rebreathing procedure of Marshall and Grollman. The essential features of the method described are the shortening of the technique to 8½ to 9 seconds, and the rapid mixing procedure (3½ to 4 seconds) which has made that shortening possible.

3 Gladstone, S. A., *Arch. Int. Med.*, 1935, **55**, 533.

4 Krogh, A., and Lindhard, J., *Skand. Arch. für Physiol.*, 1912, **27**, 100.