

# A high shear stress annular membrane oxygenator with tangential flow

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## 9-4 A HIGH SHEAR STRESS ANNULAR MEMBRANE OXYGENATOR WITH TANGENTIAL FLOW

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**PROBLEM.** All present membrane oxygenators may be divided into two types: a) oxygenators with laminar blood flow, b) oxygenators with secondary flows. The oxygenators with laminar flow are limited to gas transfer rates of 20 - 30 ccO<sub>2</sub>/min/m<sup>2</sup> membrane because of the diffusion of the gases in the blood layers.

Some increase in transfer can be accomplished by recirculation of the blood. In oxygenators with secondary flows the gas exchange can be enhanced up to the limits of permeability of 40μ thick silicone membranes. Bartlett and Drinker have shown that secondary flows can be achieved by oscillatory motion of a cylinder on which membrane tubes are wound. By introducing high shear rates in the thin blood layer of a Couette Oxygenator, Overcash and Keller demonstrated that cell rotation leads to augmentation of gas exchange. We have developed an oxygenator which combines cell rotation with recirculation (fig. 1.)

**METHOD.** Two membrane sheets with a total surface area of 0.03 m<sup>2</sup> are mounted over a smooth horizontal cylinder. Blood streams circumferentially in thin layers between the membranes and the cylinder surface. The turning cylinder introduces shear rate in the blood layers, which in turn determine the hydro-dynamic stability of film and membrane position. We were able to reach velocities of 1 m/sec at layer thicknesses between 50 and 300μ (this corresponds to average shear rates of 0.3\*10<sup>4</sup> - 2\*10<sup>4</sup>/sec.). At the top and bottom of the cylinder is a strong mixing of the blood. Recirculation is introduced (fig. 1) by the layer moving upwards. The net flow through the oxygenator is determined by means of a roller pump. A discoxygenator was used as deoxygenator through which a gas mixture of 95 % N<sub>2</sub> and 5 % CO<sub>2</sub> is blown. With the membrane lung a gas mixture of 95 % O<sub>2</sub> and 5 % CO<sub>2</sub> is used. The oxygen saturation of the blood before and after the membrane lung is continuously measured with a Philips Hb-Oximeter. At several fixed net flow rates the saturation increase in the oxygenator is measured as a function of the cylinder rotation rate. Typical results are shown in fig. 2.

**DISCUSSION.** The data presented indicates that enhancement of the O<sub>2</sub> - transfer can be realized by increasing the speed of the cylinder. Values of 120 ccO<sub>2</sub>/min/m<sup>2</sup> have been reached. This value is a factor of 5 greater than that of commercial membrane oxygenators operating under comparable conditions. It is not clear as yet how much of the enhancement is accomplished by cell rotation, by recirculation of the blood or by thinning of the blood layers. We note here that the max. capacity of the membrane used is approximately 272 ccO<sub>2</sub>/min/m<sup>2</sup>/atm. which implies that almost 50 % of the pO<sub>2</sub> difference between the gas atmosphere and the blood is needed for transfer of O<sub>2</sub> through the membranes. In the device presented here only one side of the blood layer has contact with membrane.

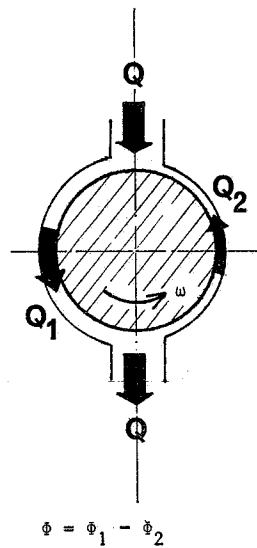


Fig.1  
Schematic of  
the oxygenator

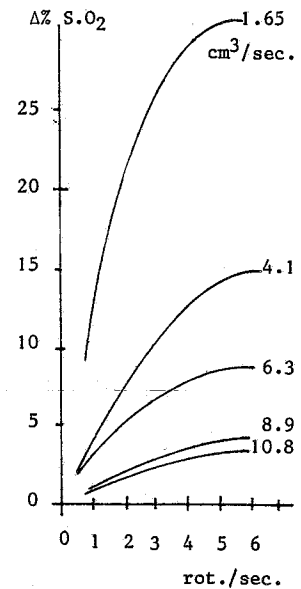


Fig.2  
Saturation increase across  
the oxygenator versus  
cylinder rotation rate

Thus the efficiency can be increased by using better membranes and inserting a membrane on the cylinder. Using this concept we believe that it may be possible to construct a membrane oxygenator for total bypass with a membrane area of less than 1 square meter.

### References:

- Bartlett, R.H., D. Kittredge, B.S. Noyes, R.H. Willard, P.A. Drinker. 1969, Development of a membrane oxygenator: Overcoming blood diffusion limitation. J. Thor. Card. Surg. 58:6, 795 - 800.  
Overcash, M.R. 1972, Couette Oxygenator. Ph.D. Thesis, University of Minnesota.