# A VOLUMETRIC-PUMP TYPE RESPIRATORY SIMULATOR

Gavril Iuliu Morariu
School of Kinesiology - Simon Fraser University
Burnaby, British Columbia, Canada V5A 1S6

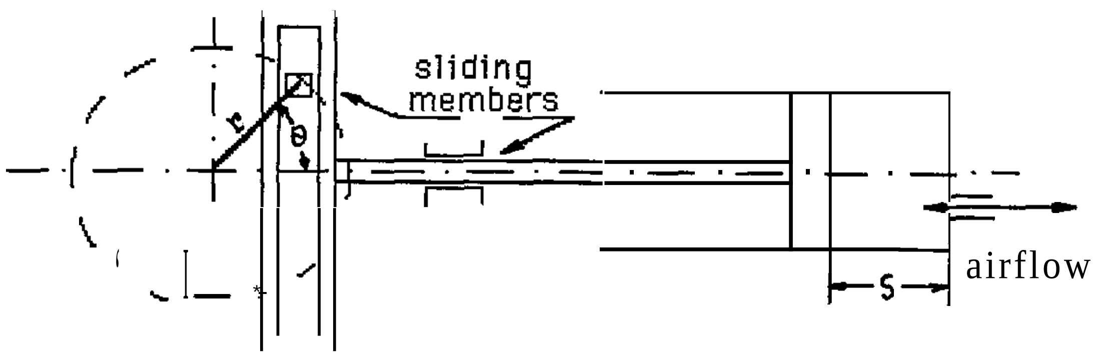
## INTRODUCTION

A versatile, accurate and reliable respiratory simulator has been developed for the purpose of testing breathing apparatus and life support systems. The device consists of a volumetric pump linked to a hydraulic motor through a harmonic motion generator. The motor takes its motive power from a hydraulic power unit, driven by an Adjustable Frequency A.C. Motor Speed Controller. The Combination allows the respiratory frequency of the simulator to be controlled continuously from 0 to 30 breaths/min. Tidal volume can be also varied (with the existing models) from 1.0 to 5.0 litres, in equal steps of 0.5 litres each, and measured by an analog displacement transducer. All data can be conditioned, recorded, stored or processed by computer, which eventually can control the entire experiment via a feedback loop.

## METHOD

### 1. Principle of apparatus

Mechanically the lung is passive, driven by outside forces. Part of the energy spent for inflating it is elastically stored, while the non recoverable part accounts for the lung's hysteresis. Several authors have sought mathematical expressions to accurately describe pulmonary volume-pressure relationship, but these are too complex and so far are thought to have only empirical value (1). However, during a normal breathing cycle the alveolar pressure and the flow rate through airways vary sinusoidally (2). To simulate similar ventilation patterns, the linkage between the driving motor and the pump (the actual lung simulator) is achieved by a harmonic motion generator. This is a four-bar mechanism which utilizes two sliding members (Fig. 1).



driving motor is hydraulic. Therefore the simulator can be immersed in water or [illegible] in hyp[illegible] [illegible] or short [illegible] as those encountered with electrically powered systems. In addition, less sophisticated through wall penetrations are acceptable as the more [illegible]ve, electrically insulated type become unnecessary. Any fault in the system will result in a small [illegible] easily detectable as pressure in the hydraulic circuits would be always higher than ambient. Consequently, defects [illegible] be eliminated quick[illegible] with [illegible] life or [illegible]

RESULTS

The simulator has been [illegible]d as an efficacious testing auxiliary during [illegible] studies.

In one case, seven open circuit demand regulators were tested in a hyperbaric chamber, down to 50 [illegible]t sea water equivalent depth, the simulator providing a wide range of ventilatory patterns. Comparison of [illegible] one regul[illegible] [illegible]d the ideal [illegible] test[illegible] [illegible] limitations, [illegible] regulators, at the point when the restricted air supply became independent of additional breathing effort. Innocuous to the sim[illegible], [illegible] would potentiate hypoventilation and [illegible] working at th limit of their equipment (4).

In another study, subj[illegible] were [illegible]lly ventilated by the breathing simulator in an attempt to evaluate the effects of breathing pressure compensation on airway resistance and the work of breathing during [illegible] Six different experimental [illegible] were established [illegible] were [illegible]d from 20 to 60 litres/min., in separate trials. Pressure and volume data were collected, which allowed for elastic [illegible] work, as well as respiratory resistance and dynamic compliance to be cal[illegible] (5).

More recently, the simulator was used to assess the endurance characteristics of the life support system designed for an atmospheric diving suit. The ventilation and carbon dioxide [illegible] were [illegible] [illegible] 4 °C water. Different diving scenarios included sequences of hard and moderate work, as well as periods of rest. S[illegible]ral [illegible]d tri[illegible] [illegible] up t[illegible] 70 h[illegible]s. [illegible] values for $PCO_2$ over a 72 hours survival period has demonstrated the need to improve scrubber performance before attempting any human endurance trials (6).

CONCLUSION

[illegible] simula[illegible] provides a [illegible] and [illegible] testing [illegible] for humans, especially valuable in hazardous [illegible] or [illegible]here the [illegible] makes their use [illegible] to its non-invasive [illegible] as a [illegible] ventilation [illegible] it has [illegible] proven to [illegible] a safe and useful research [illegible]ol.

ACKNOWLEDGEMENTS

Special thanks are due to Dr. J.B.Morrison who provided the material support necessary to build the pilot unit, and to Dr. I.B.Mekjavic for his invaluable support and encouragements as well as for making possible the second, improved version.

REFERENCES

1. West J.B. (ed) 1977, Bioengineering of the lung (Marcel Dekker, New York).
2. West J.B. 1985, Respiratory Physiology (Williams & Wilkin, Baltimore).
3. Tyson H.N. 1966, Kinematics (John Wiley & Sons, New York).
4. Morrison J.B., Morariu G.I. and Wood I. 1986, Performance characteristics of open circuit demand regulators from 0.5 to 50 metres seawater (abstract), The Ann. of Physio. Anthrop. 5,3, 169.
5. Jenks S.L. 1989, Measurement of respiratory work and resistance by artificial respiration under conditions of immersion and raised ambient pressures (M.Sc. Thesis, Simon Fraser University, Canada).
6. Mekjavic I.B., Isbister C. and Morariu G.I. 1992, Endurance of $CO_2$ scrubbing system in the "Newtsuit". Unpublished report