end tidal CO_2 % and four divers decreased (only one significantly) their minute ventilation during moderate work when the dead space decreased.

These results indicate that the free flow should not be reduced below 5-10 L/min to maintain a low dead space.

26 Development of ergonomic design standards for underwater breathing apparatus

J.B. Morrison, School of Kinesiology, Simon Fraser University, Burnaby, British Columbia, Canada

Although recent advances in the knowledge of pressure physiology have resulted in exposure of humans to 65 ATA within hyperbaric chambers, attempts to work underwater have been restricted to shallower depths. The transfer of diving technology from a simulated environment to the ocean is complicated by the remoteness of the worksite and the requirement of adequate life support systems. In particular the design and performance of underwater breathing apparatus is now recognised as a critical factor in underwater work. In order to design breathing equipment to satisfy the divers' needs, it is obvious that respiratory requirements must be identified and the effects of respiratory loading on physiological status must be carefully controlled. Human factors which are of concern to the designer include respiratory heat loss, work of breathing and physical work capacity. At depths greater than 20 meters respiratory heat losses can result in rapid core cooling and bronchial congestion in the absence of active heating of the breathing gas. Maximum ventilation decreases inversely with breathing gas density and may also be limited by breathing apparatus design, leading to respiratory insufficiency. Test procedures traditionally measure only the air flow resistance of the apparatus. Hydrostatic pressure imbalance within the lung-apparatus system can substantially alter internal airway resistance and pulmonary compliance resulting in major changes in the work of breathing. Research suggests that these factors ust be more carefully controlled to ensure safety and comfort of the diver.

In the development of ergonomic design standards for breathing apparatus, items to be specified include gas temperature, work of breathing, ventilation, hydrostatic breathing pressure, respiratory gas mixture and physical work capacity. A number of standards have been proposed, most of which are either concerned with surface breathing apparatus or are based on performance data collected at one atmosphere.Hence factors peculiar to the underwater environment are not addressed. Recently comprehensive guidelines for the performance requirements of underwater breathing apparatus have been published for use in British and Norwegian diving operations. Although testing suggests that it is possible for apparatus to comply with these guidelines, it is probable that only a few of the current products would be acceptable. This paper reviews the actual performance of existing apparatus in relationship to these guidelines and the physiological needs of the diver, and suggests improvements in ergonomic design.

27 Physiological limitations of human performance in hyperbaric environments

P.B. Bennett, F.G. Hall Laboratory, Duke University Medical Center, Durham, North Carolina, USA

Man has evolved to be able to live and work satisfactorily at one atmosphere absolute pressure and between narrow thermal constraints. The effects on human physiology of exposure to either hyperbaric or hypobaric pressures provide significant limitations to function and to life itself. Indeed it has been inferred that there is no practical working environment with a more severe and complex composite of physiological stresses than that encountered by the modern deep diver in the alien and hostile hyperbaric environment. Every phase of a man's compression, at pressure and decompression has numerous hazards which occur in three main areas: the basic life support systems, the physiological stresses of the special gases and pressure and the special medical factors to individuals who may be living in small confined pressure chambers for as much as 30 days or more and who will require much more time to