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

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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

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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 decompress to surface pressure than it takes an astronaut to return from the surface of the moon.

Life support factors necessary for maintenance of the body within safe physiological limits may include effective communications, correct humidity and temperature, monitoring and control of correct percentages of breathing gases, fire hazards due to high oxygen partial pressures, adequate nutrition and sleep, relaxation activities, showers and toilets. Medical stresses may involve procedures for diver selection with physicals and psychological screening. Infections and common medical and surgical illness can be extremely serious since there is little information on how drugs behave at increased pressure and surgical procedures are extremely difficult to undertake in such an isolated environment.

However, over and above all these difficulties are the physiological stresses. Most of the life support factors can be controlled by good engineering equipment and knowledge of the limitations imposed by pressure exposure. However, the physiological stresses of very deep diving are less amenable to solution and require careful and continual attention to compression profiles, gas mixtures, and decompression technology - mostly based on empirical data. This is because in spite of much research a clear understanding of the mechanisms and the means for prevention of these stresses remains elusive.

The stresses include oxygen toxicity, nitrogen or inert gas narcosis, respiratory embarrassment, temperature, decompression and post decompression sequalae. Any individual exposed to pressure is likely to experience more than one and possibly all in a given exposure.

Yet by understanding the limitations on human performance by these stresses, various means have been developed to elude many of the problems. Thus using a trimix breathing gas ($N_2/He/0_2$) and slow exponential compression rates over 7 days with stages for pressure adaptation, man has attained a pressure of 68 atmospheres or the equivalent of 2250 ft under the sea and been able to function appropriately and made a safe, if long at 31 days, decompression back to surface pressure.

However, much basic research is still required to understand the mechanisms of these problems so that more effective solutions may be achieved to these physiological limitations to man's exposure to high pressures and thus also to his conquest of the depths of the oceans.

28 Change of physiological parameters for divers in hyperbaric heliox environment of 31 ATA

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The hyperbaric environment at the pressure more than about 21 ATA (Atmosphere Absolute) causes high pressure nervous syndrome (HPNS) which generates physiological tremor and lowers the attention and the function of sensorimotor (Brauer et al., 1969). The detection of HPNS and its prevention have been an important problem to work safely in the sea-bed. It is the purpose of the present study to confirm the human security for the exploitation of natural resources in the bottom of open-sea around 300m which corresponds to the depth of the continental shelf in the neighboring waters of Japan.

The physiological parameters measured were the microvibration (MV), which is mechanical vibration on the skin surface, the eyelid and the thenar and the electroencephalogram (EEG) at T_4 site and O_2 were measured at various atmosphere conditions. MV was used to detect the omen of HPNS, and EEG was employed to check the lowering of the level of consciousness.