

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 sequelae. 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 ( $N_2/He/O_2$ ) 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**

*K. Sakamoto, K. Seki*<sup>1</sup> and *M. Yamasaki*<sup>2</sup> Department of Industrial Management Engineerings, The University of Electro-Communications, Chofugaoka, Chofu-City, Tokyo, <sup>1</sup>Japan Marine Science and Technology Center, Yokosuka, <sup>2</sup>Kumamoto University, Kumamoto, Japan

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<sub>4</sub> site and O<sub>2</sub> 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.

The period of the experiment was one month: the number of days required for pre-compression, compression, pressure holding, decompression, and post-compression were 6, 1, 7, 11, and 5 days, respectively. The compression rate was set at a slow rate of 25m/hr. The partial pressure of oxygen gas at pressure holding was 0.3ATA. The subjects were four males (28 to 33 years), of whom two were scientists and two were professional divers. MV and EEG were measured with MV pickup (MT-3T) and disk type electrode, in the supine position and with the eyes closed. The fast Fourier transform of the data during every ten second epoch was measured from a signal processor ATAC-450 and the square root of power spectrum was obtained in the frequency range from 3 to 30 Hz. The maximum peak frequency and the amplitude at the maximum peak frequency were evaluated from the power spectrum. The mean values of the peak frequency and of the amplitude for each subject in pre-compression (i.e., 1ATA) days were used as respective control values (i.e., 100%). The mean values for each of the other atmospheric conditions for each subject were represented as a percentage of the baseline control value.

The amplitude of MV increased after compression compared with the value at pre-compression, and this observation was emphasized in the eyelid MV post-compression (i.e., 1ATA), whereas the peak frequency of MV did not change significantly throughout the experiment. A remarkable hyperbaric effect was observed, however, in the EEG peak frequency. The peak frequency of the power spectrum was lowered during each phase of compression, pressure holding, and decompression respectively. As the high pressure nervous syndrome symptoms was not overtly recognized here, especially as might have been expected during compression, MV could not be an indicator of symptoms of HPNS. The MV amplitude of the eyelid, whose muscles are composed in greater part of fast twitch fibers, increased still more post-compression. Therefore, the influence of high pressure on skeletal muscle must be considered as a source of the observation, particularly the ballistocardiogram component of the MV. The EEG denoted a lowering in the level of consciousness during pressure holding, and is especially noteworthy for us as relevant to the safe operation of humans in a hyperbaric environment.

**29 Physiological reactions of the Rhesus monkey under high density gas hyperbaric environment (51 Bar, He-N<sub>2</sub>-O<sub>2</sub>, p=27g/l. BTPS)**

*K. Seki, Y. Taya, M. Nakano, Y. Mizushima, F. Shidara, and H. Nakayama<sup>1</sup>*  
Laboratory of Hyperbaric Physiology, Japan Marine Science and Technology Center (JAMSTEC), Natsushima-cho, Yokosuka-shi <sup>1</sup>Department of Hygiene, Tottori University, School of Medicine, Nishimachi, Yonago-shi, Japan

In 1981, Seki *et. al.* succeeded in bringing back cats alive to the surface after having exposed them for 72 hours to the high density He-N<sub>2</sub>-O<sub>2</sub> environment of 27 g/l BTPS which is equivalent to the depth of 500 m. In 1981 and 1983, within the framework of Franco-Japanese cooperation on oceanic development, Seki *et. al.* carried out further experiments at the Laboratory of hyperbaric physiology of CNRS - GIS in France to see the effects on cats of their exposure to the hyperbaric high density gas environment, and succeeded in making them survive in the environment of 67 g/l BTPS which is equivalent to the depth of 1200m. The results thus obtained turned out to be different from those of our past experiments.

The experiment at 51 bar with He-N<sub>2</sub>-O<sub>2</sub> was conducted under the following conditions: the ratio of He and N<sub>2</sub> was 3:2; PO<sub>2</sub> = 0.21 bar; ambient temperature at 34°C ± 1°C. On the first day of compression, due to the effects of N<sub>2</sub> narcosis, the behaviour of the cats was considerably restrained, but in time, their behavior became normal. The improvement of this ambient pressure diving method, which I tentatively named High Density Gas Hyperbaric Environment Diving Method will be rewarded with the following results: alleviation of high pressure nervous syndrome (HPNS); economy helium gas; the possibility of diving beyond the depths of 2,000m.