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# THE PROCEDURE BY EVALUATION OF DIVERS FOR THE DEEP DIVING

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**Rezumat.** *Când un scafandru este selectat pentru cursul de scufundări profunde, el trebuie să treacă un test medical şi să nu fie afectat de SNIP (Sindromul Nervos al Înaltelor Presiuni). Dacă el coboară foarte repede la adâncimi mai mari de 150 m, într-un mediu respirator de amestec heliu-oxigen, apar efecte neurologice şi psihomotorii care duc la scăderea performanţelor organismului uman. Testul de scufundări profunde constă în înregistrarea tremorului postural şi a electroencefalogramei la presiunea atmosferică şi la 180 m adâncime. Rezultatele obţinute la suprafaţă se compară cu cele de la adâncime şi se stabilesc limite procentuale de abatere a înregistrărilor făcute la presurizare cu cele de la suprafaţă.*

**Abstract.** *When a diver is selected to perform a deep diving course, he has to pass a medical test and isn't affected by the HPNS (High Pressure Nervous Syndrome). When a diver is selected to perform a deep diving course, he has to pass an evaluation stage in order to prove his ability to tolerate the compression speed accompanied by the helium - oxygen breathing mixture without encountering the HPNS effects. The deep diving test consists in postural tremor and the EEG registration, in both conditions: at the atmospheric pressure and at 180 m deep too. Then the results obtained at the surface percentage limits are fixed for the maximum deflection agreed between the values registration made under pressure and the atmospheric pressure (surface) values.*

**Keywords:** deep diving test, EEG waves, postural tremor

## 1. Introduction

Diving activity below 60 m, presumes the utilization of the synthetic breathing mixtures. These are made by oxygen diluted with an inert gas. The atmospheric air contains 21% of oxygen and 79% of nitrogen.

The narcotic effect of the nitrogen, which appears deeper 60 m, imposes to use another inert gaseous and the most appropriate is helium, due to his properties. This forms with the oxygen in various concentrations, the synthetic breathing mixture helium-oxygen, which has an indistinguishable narcotic effect.

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At diving below 150 m depth, have been observed in humans signs and symptoms by disturbances of the central nervous system (dizziness, nausea, vomiting, postural tremors, fatigue and somnolence, decrements in intellectual and psychomotor performance, increasing and decreasing of wave activity of the brain, as measured by an electroencephalogram). These symptoms are known as the HPNS (High Pressure Nervous Syndrome)

These disturbances begin at different profounder for various subjects, depending of our resistance. It is necessary to establish scales of aptitude to perform a deep diving course.
After Fructus [1], the symptoms are divided in two categories:

- clinical symptoms: tremor, dissymmetry, muscle convulsions, somnolence;
- EEG symptoms: EEG modifications, increase of Theta waves activity, depression of Alpha and Beta waves activity, sleeping perturbations.

Pathology HPNS (High Pressure Nervous Syndrome) is explicated by Hunter and Bennett through a series of factors indirect, like oxygen and carbon dioxide (both the minor role) and the temperature, especially hyperthermia and osmotic phenomenon [2].

## 2. Measuring procedures

Since1965, a comparative study of hydrostatic and gaseous breathing mixtures (helium, hydrogen, nitrogen) effects on animals first and then on humans, has significantly contributed to understanding causes, mechanism of production and prevention of HPNS (High Pressure Nervous Syndrome). Also amazing progress in the movement of the depth limits to diving has led first to the description of important HPNS symptoms, followed by preventive measures and finally by clarification and understanding of variable causes which they give rise. Very important roles in phenomenon study have Peter Bennet and collaborators [3].

The compressing of the diver with helium - oxygen to depth below 150 m, causes HPNS (High Pressure Nervous Syndrome) [5]. This syndrome is translated by:

- psychomotor disorders: tremor and dissymmetry, imprecision and gestures without coordination;
- decrease of the vigilance, decrements in intellectual performance fatigue and somnolence;
- modifications by increase of slow wave and decrease of fast wave activity of the brain, as measured by an electroencephalogram.

In general, it noted that tremor appears at diving below 150 m and it is characteristic at the extremities (hand fingers) and heightens with the profounder.

It was called "helium tremor", but appears in deep diving, with breathing helium-oxygen breathing mixture and hydrogen-oxygen too. The study of this phenomenon was made by Diving Center too, on hyperbaric complex of Diving Center, serviced by its team of qualified technicians (see Fig. 1).

**Fig. 1.** Hyperbaric Complex of Diving Center Constanta.

Two dive teams, by 3 divers selected for deep diving school, participated to the experiment. The test was made in a dry chamber, with 3 divers, without the tender diver. Before compression, were recorded for the three divers:

*Realisation of Electroencephalography procedure*, see Figure 2

**Fig. 2.** EEG registrations at 180 m.

Two diver teams by three subjects have participated at the experiment. It was made the electroencephalograms at surface, in the following conditions:

- open eyes,
- close eyes,
- at hyperventilation,
- after hyperventilation,

in supine position, without luminous stimulus. The discus silver electrodes were attached by the scalp with the conductive and adhesive paste. The electrical stimuli from different regions of the skull vault were take over and digital reproduced. Were recorded the Alpha rhythms, the Beta rhythms and the slow Delta activity.

*Realisation of the recording procedure of postural tremor*, see Figure 3.

**Fig. 3.** Postural tremor registrations at 180 m.

After EEG test, the six subjects were tested at postural tremor, at surface. The transducer for postural tremor was fixed on the median finger of the right hand, tensed on horizontal and were recorded the signals into a computer, during 20 seconds, 20 seconds pause and 20 seconds with the hand suspended near the body. For each subject were made by tow such recordings.

After finish of the surface recorders, the subjects were compressed very fast (10 m/s) at depth 180 m, in the dry chamber of the Hyperbaric Laboratory, with helium oxygen over the existing atmospheric gas. The divers stayed in repose

10 minutes, were resumed same EEG and postural tremor records like at atmospheric pressure. The total bottom diving time don't was over 60 minutes. At finalizing of the recordings was started decompression.

Decompression table used was OXY- HELIUM DIVING DECOMPRESSION TABLES from COMEX and decompression time was 38 hours.

Due to the air pressure existing in the caisson (nitrox mixture 79/21) were determined relations for calculating the variation of the partial pressure of the gases in the mixture based on the total pressure of the mixture to give:

$$p_{Ox} = \left(170.35525 \cdot 10^{-6} p^2 + 54.637571 \cdot p\right) / \left(3412.3224 \cdot 10^{-6} p + 0.56512\right) \quad (1)$$

$$p_{Ni} = \left(269.65994 p\right) / \left(3412.3224 \cdot 10^{-6} p + 0.56512\right) \quad (2)$$

$$p_{He} = \left(3239.6331 \cdot 10^{-6} p^2 + 323.96331 \cdot p\right) / \left(3412.3224 \cdot 10^{-6} p + 0.56512\right) \quad (3)$$

See figure 4 and Figure 5:

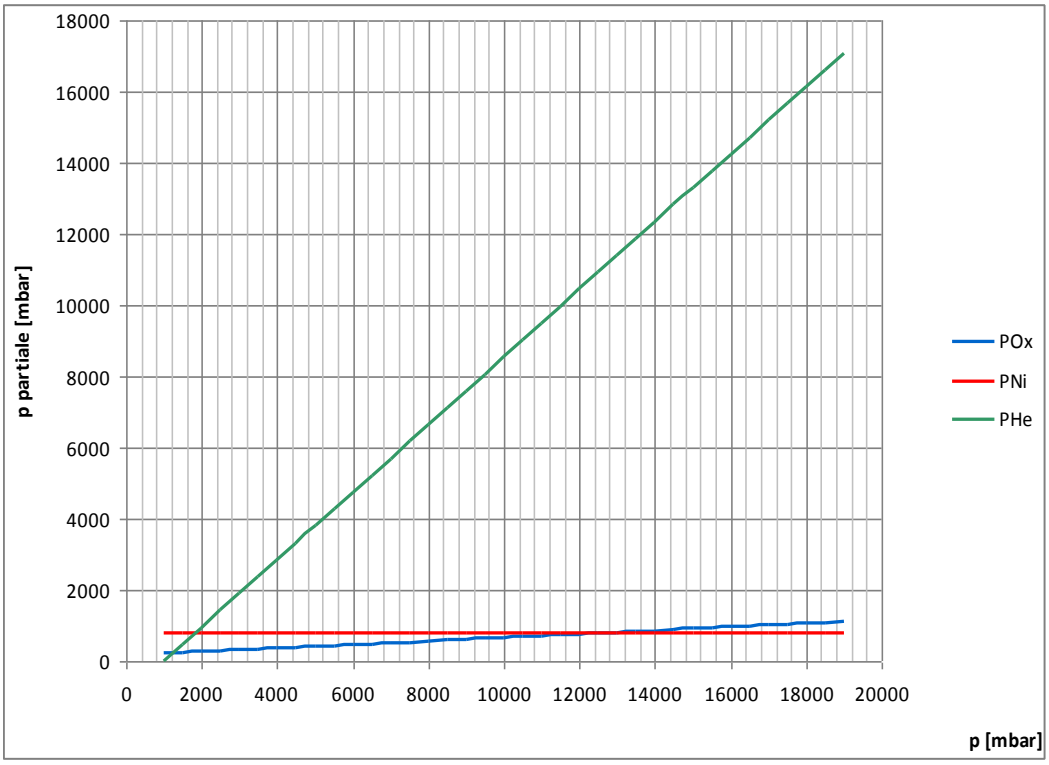


**Fig. 4.** Diagram representation of the partial pressures variation of gas mixture component from the hyperbaric chamber during the pressuring between 0 - 180 m, with Helium-oxygen (95/5) over the atmospheric pressure (Nitrogen-oxygen 79/21).

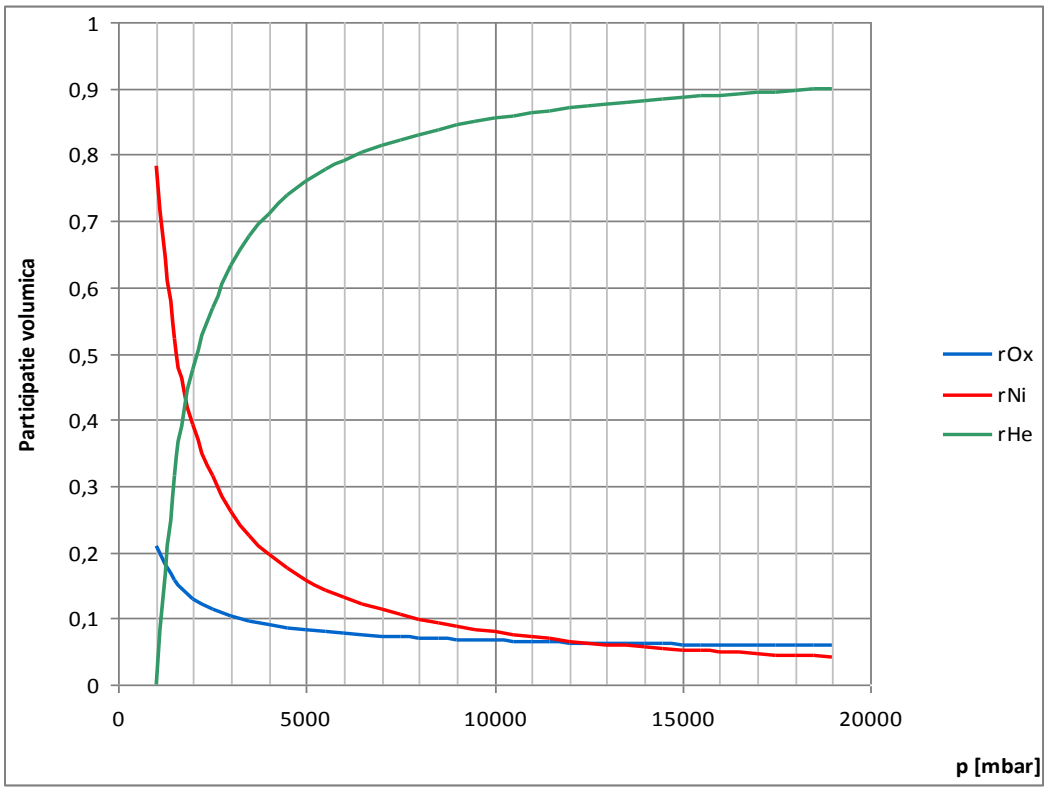


**Fig. 5.** Diagram representation of the partial volumes variation of gas mixture component from the hyperbaric chamber during the pressuring between 0 - 180 m, with Helium-oxygen (95/5) over the atmospheric pressure (Nitrogen-oxygen 79/21).

It's important to know these values during the diving, because increase of partial pressure of the oxygen $p_{ox}$, from the mixture, is limited, over a certain value can appear hyper - oxygen phenomenon.

The oxygen's partial pressure attends at finally 1.1 bar absolute, where the divers can't be exposed over 3 hours after NOOA and actually, less 3 hours after U.S. Navy.

The Nitrogen partial pressure remains constant $p_{Ni}$=790 mbar.

## 3. The equipment in use

Used kit is medical technique, provided by Naval Medicine Center (EEG apparatus) and completed with the technical equipment for the postural tremor, designed and adapted by the specialists of Diving Center.

EEG apparatus is a multifunctional computer system for neurology diagnosis "Neuron – Spectrum". See Figure 6:

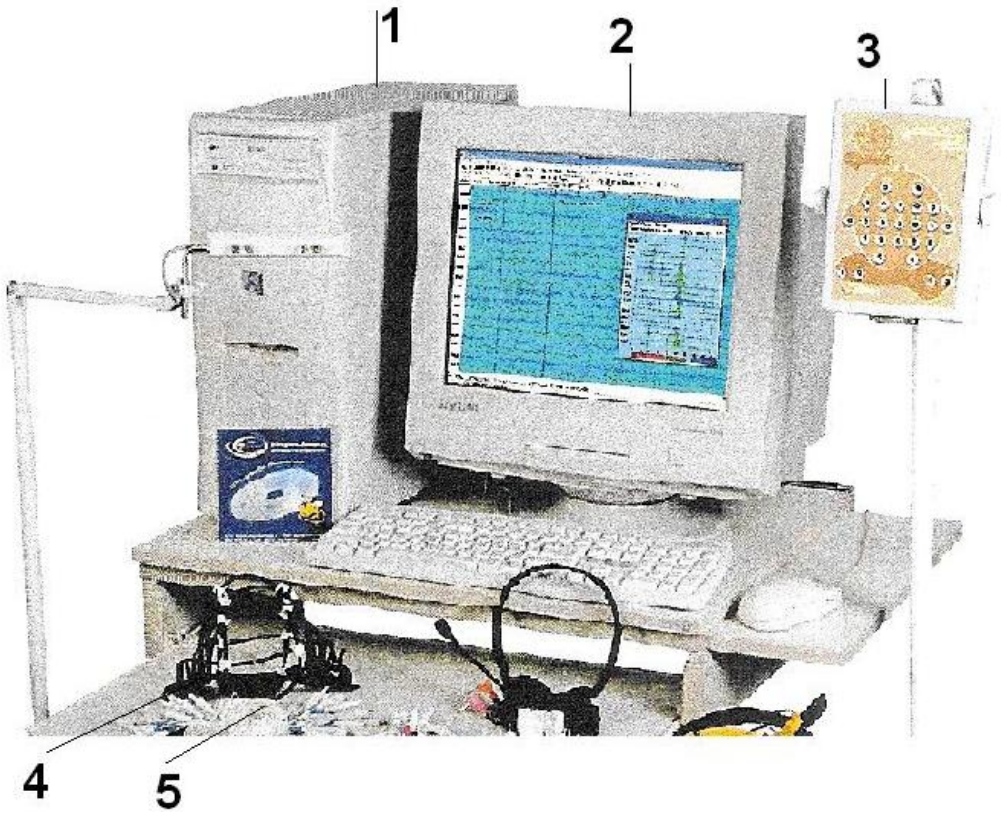


**Fig. 6** Computerized system for EEG record
1 PC, 2 display, 3 check panel, 4 head - electrode, 5 electrodes.

The signals were picked from patient with the electrodes located on:

- frontal – 2 electrodes
- occipital – 2 electrodes
- temporal – 2 electrodes
- central – 2 electrodes
- ear – 1 electrode

These were transmitted to the central processor which processed them with the programme "Neuron – Spectrum".

For postural tremor recording was made electronic equipment by registration of the subject's fingers oscillations and by transmission of electric signals to computer.

Equipment is made from accelerometer sensor, fixed on the median finger of the diver, which transmits the electric oscillations of a computer. The oscillations are recorded and then measure the frequency and amplitude. See Figure 7:

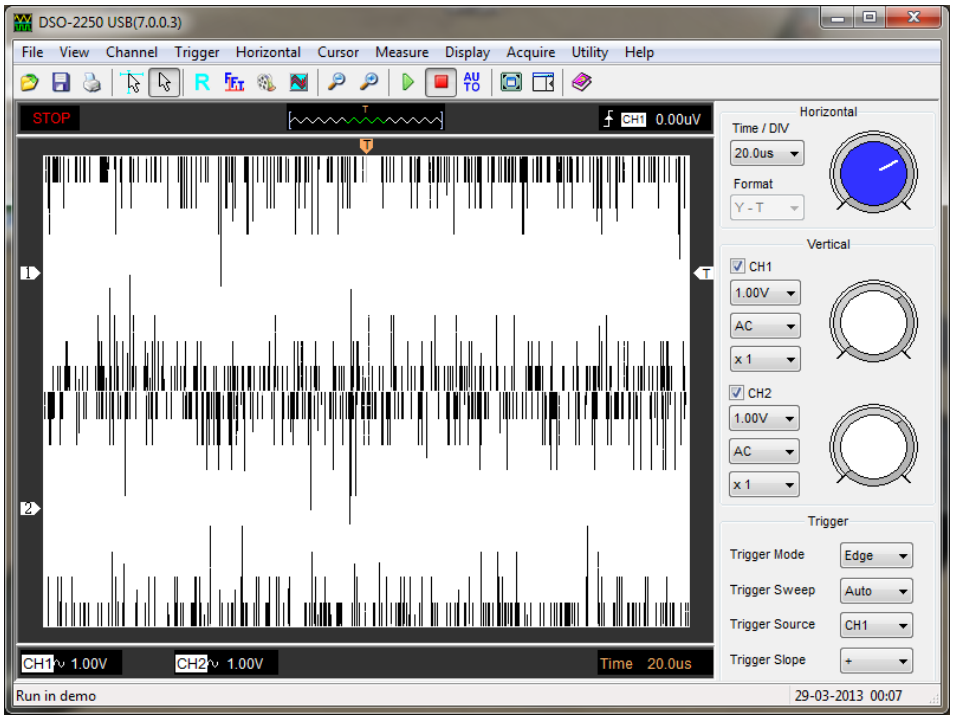


**Fig. 7.** Registration of postural tremor oscillation.

Both helmet with electrodes for EEG and transducer for postural tremor are connected to computers located outside by signal cables which cross the sealed hyperbaric chamber.

## 4. Interpretation of the results

*EEG results*

To establish the diving proficiency scale it considerate just the Alpha waves and slow Delta activity. The neurologist has analysed the entire cerebral activity of the subjects, respectively Alpha rhythms, Beta rhythms, slow Delta and Theta activity.

**Table 1.** EEG results

| *Subject* | *Surface* | | | *180 m* | | | *Surface* | *180 m* |
|---|---|---|---|---|---|---|---|---|
| | *Rhythm* $\alpha$ | | *Slow* $\Delta$ *waves* | *Rhythm* $\alpha$ | | *Slow* $\Delta$ *waves* | | |
| | *Average Amplitude* $\mu V$ | *Domin. Freq. Hz* | *Average Amplitude* $\mu V$ | *Average Amplitude* $\mu V$ | *Domin. Freq. Hz* | *Average Amplitude* $\mu V$ | | |
| S1 | 19 | 10 | 55 | 19 | 10 | 57 | 0% | 4% |
| S2 | 15 | 10 | 76 | 19 | 10 | - | 27% | - |
| S3 | 20 | 8.7 | 65 | 24 | 9.2 | 83 | 20% | 28% |
| S4 | 17 | 9.8 | - | 114 | 8.7 | 318 | 216% | +318 |
| S5 | 11 | 10.2 | 57 | 11 | 9.3 | 68 | 0% | 19% |
| S6 | 18 | 9.6 | - | 16 | 7.6 | - | -11% | - |

Alpha dominant frequency was 8 – 10 Hz. Slow Delta waves did not appear at surface, for the subjects S4 and S6. Diver S6 didn't present slow Delta waves neither after compressing. Subject S4 has presented a very large increase of Alpha waves at pressuring and have appear slow Delta waves, with large values. To establish the diving proficiency for every diver, it has calculated:

- Variation of Alpha waves average amplitude from 180 m depth, comparative with the surface value;
- Variation of slow Delta waves average amplitude from 180 m depth, comparative with the surface value.

*Postural tremor results*

**Table 2.** Postural tremor results

| *Subject* | *Surface* | | | *180 m* | | | *Increase of amplitude %* |
|---|---|---|---|---|---|---|---|
| | *Ampl. 1 mm* | *Ampl. 2 mm* | *Average Ampl.* | *Ampl. 1 mm* | *Ampl. 2 mm* | *Average Ampl.* | |
| S1 | 3 | 2.5 | 2.75 | 4.5 | 5 | 4.75 | 73 |
| S2 | 3.5 | 3 | 3.25 | 5 | 6 | 5.5 | 69 |
| S3 | 4 | 3.5 | 3.75 | 5.5 | 6.5 | 6 | 71 |
| S4 | 10 | 9 | 9.5 | 16 | 15 | 16.5 | 73 |
| S5 | 3.5 | 3 | 3.25 | 5.5 | 4.5 | 5 | 54 |
| S6 | 4.5 | 5 | 4.75 | 7 | 7.5 | 7.25 | 53 |

Depending on tremor's amplitude, which varied between 3–5 mm, appeared individual small variations recorded at atmospheric pressure. An exception was subject 4 with primary tremor's amplitude between 5–10 mm. Dominant frequency of the tremor was 8-10 Hz. After compression, didn't were found modifications of the tremor frequency. After the registration, the postural tremor's amplitude was calculated quantitative in millimetres and qualitative in percents, depending on the value obtained at atmospheric pressure. The amplitude has increased on average by 50 - 70%, with the pressure's increase.

## Conclusions

(1) During the experiment, were dignified psychomotor troubles, explicable by tremor's intensification, instability of sensitive performance and mental functions, affecting the memory. However, the symptoms are reversible at human.

(2) The depth where appear the symptoms, varies inversely the compressing speed and it is dependent by the genetic individuality. A characteristic phenomenon is the personal adaptability, when the symptoms decrease or disappear after a period of exposure on the pressure. HPSN (High Pressure Nervous Syndrome), symptomatic persuades long time. Inert gas can direct action by them molecular properties.

(3) Rapid pressurisation ($v > 8$ m/min) is only in extreme cases, limited time, rapid intervention, unplanned. To work under water at depths recommended or saturation diving unit. Moreover the causes of HPNS (High Pressure Nervous Syndrome) are not fully understood, experience has shown that it can be controlled by using a low speed pressuring.

(4) Considering the results of measurements obtained now and in the past years and the reaction of the tested divers, it settles the proficiency scale for deep divers:

- The increase of 1-10 Hz EEG waves over 35%,
- The increase of postural tremor's amplitude over 150%,
- Mathematical errors by over 50% compared to their solution to the surface.

These represent unsuitability criteria at deep diving bellow 150 m, with large compressing speeds ($v \geq 8\,\mathrm{m/min}$) [8]. The last condition has not been provided so far NODAS (Rules for the preparation, organization and safety in diving activity), but the criteria used hyperbaric centers tradition countries (USA, France).

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