

MONITORIZATION AND EVALUATION OF HPNS (HIGH PRESSURE NERVOUS SYNDROME)

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Abstract— HPNS (High Pressure Nervous Syndrome) is medical disorder connected with the diving activity. This syndrome occurs when a diver descent very fast below 150 m depth, in a breathing environment represented by a helium – oxygen mixture. The disorder consist in psychomotor and neurology type effects which represents in fact, the deep diving upper limit above which the human body decreases in performance.

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 (electroencephalography) 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— EEG (electroencephalography) waves, HPNS (High Pressure Nervous Syndrome), postural tremor.

I. SYMPTOMATHOLOGIE OF DEEP DIVING ACTIVITY

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.

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) and 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.

The symptoms are divided in two categories:

- 1) clinical symptoms: tremor, dissymmetry, muscle convulsions, somnolence;
- 2) EEG symptoms: EEG (electroencephalography) modifications, increase of Theta waves activity, depression of Alpha and Beta waves activity, sleeping perturbations [1].

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].

II. MEASURING PROCEDURES

Since 1965, 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 [2], [3].

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

- 1) psychomotor disorders: tremor and dissymmetry, imprecision and gestures without coordination;
- 2) decrease of the vigilance, decrements in intellectual performance fatigue and somnolence;
- 3) 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 [4], [5].

The studies of this phenomenon have been made to Diving Center too, on hyperbaric complex, serviced by its team of qualified technicians (see Fig. 1).



Fig. 1. Hyperbaric complex: two dry hyperbaric chambers and one wet hyperbaric chamber

Two dive teams, by 3 divers selected for deep diving course, participated to the experiment.

The hydrostatic pressure effects and the helium - oxygen effects at the divers were verified by HPNS (High Pressure Nervous Syndrome), according to NODAS (Normative for preparation, organization and labour protection) [6].

The test was made in a dry chamber, with 3 divers, without the tender diver. Before compression, were recorded the electroencephalography of the divers, in supine position, without luminous stimulus and postural tremor.

Electroencephalography represents the recorder of the electrical potential of the spontaneous activity of the cortical neurons, adding the electrodes fixed on the scalp [7].

Postural tremor represents the anomalous movement of the hand fingers, characterised by rhythmic and involuntary oscillations.

Pathology of the phenomenon isn't knower. Tremor is considered a sensitive symptom, determined by the hyperbaric stress, which may interfere with the nervous conduction and the metabolism too [8].

Realisation of Electroencephalography procedure

TABLE I
 FIRST TEAM – FEATURES OF SUBJECTS

S	Corporeal Pound (kg)	Hig (cm)	Thorax circumference (cm)	Age
1	94	180	115	45
2	93	173	121	30
3	128	194	125	40

Two diver teams with divers selected to perform a deep diving course have participated at the experiment. Every team was compound by three subjects.

First is made the test at the surface, into the hyperbaric dry chamber.

TABLE II
 SECOND TEAM – FEATURES OF SUBJECTS

S	Corporeal Pound (kg)	High (cm)	Thorax circumference (cm)	Age
4	84	178	110	42
5	68	168	92	39
6	94	191	115	39

The neurologist made the electroencephalogram for first team, at surface, in the following conditions:

- 1) open eyes;
- 2) close eyes;
- 3) at hyperventilation;
- 4) after hyperventilation;
- 5) in supine position;
- 6) 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.

After finish of the surface recorders, the subjects were compressed at depth 180 m, in the dry chamber of the Hyperbaric Laboratory, with helium – oxygen over the existing atmospheric gas and which has the following diving characteristics:

- 1) compressing mixture - HeO2 5/95 %;
- 2) respiratory mixture at life level - HeO2 5/95 %;
- 3) maximum depth – 180 m;
- 4) compression time - 18 minutes;
- 5) compression speed - 10 m/min;
- 6) stationary time at 180 m – 60 minutes maximal;
- 7) decompression time - 38,2 hours;
- 8) decompression table used is OXY - HELIUM DIVING DECOMPRESSION TABLES.

After 10 minutes pause, the tests were resumed at 180 m depth, in the same conditions.

Realisation of the recording procedure of postural tremor

After EEG test, the six subjects were tested at postural tremor, at surface and after very fast descent at 180 m.

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 recording: first amplitude A1 and second amplitude A2.

After 10 minutes pause at 180 m depth, 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.

III. CALCULATION RELATIONSHIPS FOR PARTIAL PRESSURES

For the variation of the partial pressure's gaseous from the mixture, relationships have been determined, depending on entire respiratory gas pressure, due to the

air existing in the hyperbaric chamber (nitrogen - oxygen 79/21), at the normal pressure. It was obtained:

$$p_{ox} = \frac{(170.35525 \cdot 10^{-6} p^2 + 54.637571 p)}{(3412.3224 \cdot 10^{-6} p + 0.56512)} \quad (1)$$

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

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

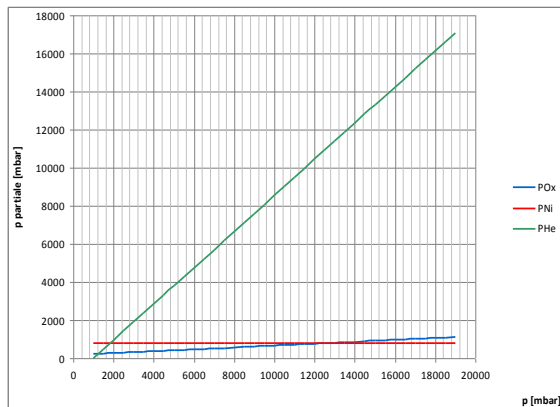


Fig. 2. Diagram representation of the partial pressures variation of gas mixture component from the hyperbaric chamber during the pressuring between 0 - 180 m, with Helium-oxygen (95/5) over the atmospheric pressure (Nitrogen-oxygen 79/21)

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 NOAA (National Oceanic and Atmospheric Administration) and actually, less 3 hours after U S Navy.

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

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

- 1) frontal - 2 electrodes
- 2) occipital - 2 electrodes
- 3) temporal - 2 electrodes
- 4) central - 2 electrodes
- 5) 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. 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. A new mobile data recording equipment will be purchased soon.

V. INTERPRETATION OF THE RESULTS

EEG results

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

TABLE III
SURFACE EEG RESULTS

S	Rhythm α		Slow Δ waves	
	Average Amplitude μV	Dominant Frequency Hz	Average Amplitude μV	
S1	19	10	55	
S2	15	10	76-	
S3	20	8.7	65	
S4	17	9.8	-	
S5	11	10.2	57	
S6	18	9.6	-	

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.

TABLE IV
180 m EEG RESULTS

S	Rhythm α		Slow Δ waves	
	Average Amplitude μV	Dominant Frequency Hz	Average Amplitude μV	
S1	19	10	57	
S2	19	10	-	
S3	24	9.2	83	
S4	114	8.7	318	
S5	11	9.3	68	
S6	16	7.6	-	

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 and variation of slow Delta waves average amplitude from 180 m depth, comparative with the surface value.

TABLE V
 INCREASING OF EEG WAVES

S	Increase of α waves	Increase of slow Δ waves
S1	0%	4%
S2	27%	-
S3	20%	28%
S4	216%	+318
S5	0%	19%
S6	-11%	-

Postural tremor results

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.

TABLE VI
 POSTURAL TREMOR RESULTS

S	Surface			180 m			Increase of amplitude %
	A1 mm	A2 mm	Average amplitude	A1 mm	A2 mm	Average amplitude	
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	15.5	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

VI. CONCLUSIONS

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.

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.

In case of saturation diving, the exposure of the human body at the ambient pressure does not depend than the pressure value, because exposure time to the pressure is sufficiently long for saturation of the all human tissues with the inert gas from the respiratory mixture.

Although the causes of HPNS (High Pressure Nervous Syndrome) are not completely understood, experience has shown that it can be controlled by using a slow rate of compression.

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:

- 1) The increase of 1-10 Hz EEG waves over 35%,
- 2) The increase of postural tremor's amplitude over 150%.

These represent unsuitability criteria at deep diving bellow 150 m, with large compressing speeds [6].

To monitor and evaluate HPNS (High Pressure Nervous Syndrome) in optimal conditions to follow:

- 1) Establishing an algorithm to perform the test for deep diving;
- 2) Realisation of the equipment;
- 3) Testing of deep diving in Hyperbaric Complex of Diving Center.



Fig. 3. EEG (electroencephalography) registrations under pressure into the hyperbaric chamber

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