[6] Kundiev Y.I., Nahorna A.M.: Occupational morbidity in Ukraine in long-term observation dynamics. *Ukr. zhurnal problem med. pratsi*. 2005, 1: 3-11 (in Ukrainian).
[7] Kundiev Y.I., Nahorna A.M.: Occupational health in Ukraine. Epidemiological analysis. Kyiv, Avicenna Publishing House, 2006; 316 p. (in Ukrainian).
[8] Kundiev Y.I., Nahorna A.M.: Occupational health in Ukraine. Epidemiological analysis. Kiev, Avicenna Publishing House. 2007; 396 p. (in Russian).
[9] Health of workers. Global plan of action. WHO document ERB 120/28. 02.05.2007, 1-9.
[10] Rates of health of the population and use of health protection resources in Ukraine in 2007-2008. Kyiv: Ministry of Health, 2008, 33-80 (in Ukrainian).
[11] Statistics year-book of Ukraine for 2008. Kyiv, Konsultant, 2008, 259 p. (in Ukrainian).
[12] Kundiev Y.I., Lysyuk M.O., Nahorna A.M., Romanenko N.V.: Industrial traumatism in Ukraine: hygienic, social, economic aspects. *Ukr. zhurnal problem med. pratsi,* 2006, 1: 3-9. (in Ukrainian).
[13] Kundiev Y.I., Lysyuk M.O., Nahorna A. M., Romanenko N.V.: The state of industrial traumatism and supervision over labor protection and safety in *Ukraine. Ukr. zhurnal problem med. pratsi.* 2008, 2: 4-9 (in Ukrainian).
[14] Information on the mortal industrial traumatism in subjects of the Russian Federation in 2001-2005 (by Federal Labor Inspection Data). *Okhrana truda i tekh. bezop. v stroitelstve,* 2006, 6: 36-37 (in Russian).

VALENTIN KALNYSH, ANDREY SHVETS
Institute for Occupational Health of NAMS of Ukraine, Kyiv
Research Institute of Military Medicine of Ukrainian Armed Forces, Irpin, Ukraine.

# Effect of strained work on operators' reliability in 24-hour shift work

## *Wpływ stresującej pracy na niezawodność operatorów w 24-godzinnym systemie zmianowym*

***Abstract:***
*Psychophysiological peculiarities of the effect of 24-hour shift work on psychophysiological indices of an operator's efficiency are considered. It is found that significant manifestations of the fatigue are developed in servicemen-operators as a result of daily shift-work. The informative psychophysiological characteristics, which can be used as reliable indicators of fatigue level, have been distinguished. A hypothesis has been proposed on the availability of several compensatory mechanisms in maintenance of the work capacity in operators in long-term shift work. An integral index of the reliability of operators' activity has bee developed, allowing to assess the quality of work, using a wide range of intensities of the proposed signals as well as to receive data on the overall possibilities of an operator to process information at the given level of reliability.*

***Streszczenie:***
*Badano psychofizjologiczne cechy wpływu 24-godzinnego zmianowego trybu pracy na psychofizjologiczne wskaźniki wydajności operatorów. Stwierdzono wyraźne oznaki zmęczenia u operatorów, wynikające z codziennej pracy zmianowej. Określono charakterystykę psychofizjologiczną, która może być wykorzystana jako rzetelna metoda określania stopnia zmęczenia. Zaproponowano hipotezę dotyczącą dostępności kilku mechanizmów kompensacyjnych, które można zastosować dla utrzymania pełnej zdolności pracy pracowników zatrudnionych na wielogodzinnych zmianach. Opracowano integralny wskaźnik niezawodności pracy operatorów z wykorzystaniem szerokiego zakresu intensywności proponowanych sygnałów jak również w celu uzyskania danych ogólnych na temat zdolności operatora do przetwarzania informacji na określonym poziomie niezawodności.*

***Keywords****: working capacity, occupational health, integral assessment of work reliability, simple and compound psychomotor reactions, functional mobility of nervous processes*

***Słowa kluczowe****: zdolność do pracy, zdrowie zawodowe, integralna ocena niezawodności pracy, proste i złożone reakcje psychomotoryczne, funkcjonalna mobilność procesów nerwowych*

In the modern society ever more and more people work by 'non-standard' work schedule, including shift and night work, which are being risk factors for health, safety and

✉ Valentin Kalnysh, Institute for Occupational Health of NAMS of Ukraine. 75, Saksaganski str., Kiev 01033, Ukraine

social well-being. Proper preventive and protection measures are needed to mitigate adverse effects and help a worker to overcome theme. Mainly, these measures should be based on organization of shift schedules by ergonomic criteria and proper medical surveillance. Occupational medicine, in the opinion of leading European scientists, should carefully consider several factors (psychophysiological, pathological and social), which can influence on the tolerance and/or inadequate adaptation to such type of occupational activity [1].

It is well known that a peculiar feature of modern operator's activity is a sharp raise of information volume, time limit for execution of professional tasks, sliding work schedule and other information factors, which, in their turn, cause strengthening of neuro-emotional strain and decrease the quality of occupational activity. There is a number of work environment factors, which affect negatively human work capacity and increase the work strain: low moving activity (hypodynamia); work monotony; long-term staying in the forced posture, leading to muscle tension in the neck, forearm and lumbar spine; information stress factors; significant fatigue in operators, causing the decrease of high mental activity (HMA), and others [2-4].

It is known that in regulatory processes, occurring in the human body, the central nervous system (CNS) plays a dominating role; so, when analyzing human state the degree of its functioning should be mostly assessed [5,6]. As a rule, psychophysiological indices of the visual analyzer are used as psychophysiological parameters, characterizing the state of the CNS, because the efficiency of work of many operator's professions, depends, first of all, on the level of its functioning [7].

At present, investigators of many countries pay much attention to studying the effect of shift work on operators' work. For examples, studies of operators have been conducted on the base of the «Control unit for crisis situations in the Russia Far East region» at 24-hour shift work. The following causes were mentioned, which had a negative effect in the work: first of all, fatigue of hand fingers (14,1%), muscles of spine and neck (17,4%), eyes (12,8%), attention decrease (10,2%) and sleepiness (8,0%) [8]. In the 24-hour shift work the presence of progressive fatigue has been recorded in near 90% respondents.

When studying the efficiency of operators at the commanding-measuring unit in the 24-hour shift work by Russian scientists there gave been found negative changes of psychophysiological functions. The number of errors in operators, in tests for assessing speed parameters of mental processes, as a result of a long-term work, increased. And in that, the durability and switching of attention worsened in 24 hours by 2,3-4,5 times [9].

European scientists have established some disorders in the state of health, developed due to the shift type of occupational activity. Cardio-vascular disfunctions were detected in 24,4% cases, worsening of sleep and wakefulness in 17,7%, metabolic changes in 13,3% [10-12]. In addition, the frequency of occurrence of selected types of tumors was noted [13,14].

Also, very few studies were devoted to the study of psychophysiological peculiarities of the effect of 24-hour work on operator's health and professional reliability. The results of literature analysis show that there is no index available able to adequately characterize the reliability of the human activity, covering the whole range of accessible loads [10,15,16]. As a rule, the reliability of the activity is assessed by the relation of the number of errors to the number of signals proposed for processing. There is a number of lacks in such estimation, because conditions, in which a mistake can occurs, are not taken into account in this case. Also, conditions can be very different. For example, a mistake can be made, when there is short of time or when there is quite sufficient time for taking a decision. Generally, these are quite different mistakes; however, in the formula for calculation of the reliability the mentioned detail is not taken into consideration, causing roughening of the mentioned estimation. On the other hand, if we record (make normative) any level of work reliability, satisfactory for production, then, in the case of a classic approach to estimation of the reliability it is principally impossible to learn, at what level of work intensity it is possible to reach such level of reliability. The mentioned facts points to the need of searching new approaches to assessment of an operator's reliability in the combined action of harmful factors of the work environment. So, studies of psychophysiological peculiarities for providing a high level of reliability in operator's work, based on development of a new approach to its assessment is an actual direction in studies of modern occupational health and physiology of work.

Purpose of the work was to define psychophysiological peculiarities of changes of work reliability in operators and, basing on this, to develop integral indicators for its assessment, taking a long-term 24-hour load, as a model.

## Materials and methods

A group of men, operators-radiotelegraphers, (40 persons), aged 18-23, was taken as a subject of the study, who executed their professional duties within 24 hours. Studies of psychophysiological characteristics of these individuals were conducted in the morning time (since $8^{00}$ to $9^{00}$ a.m.), before and after work.

Psychophysiological characteristics were recorded, using a special hardware-software unit, designed in Kharkov National University of Radioelectronics [17,18]. Methods for assessment of psychophysiological functions were

implemented with the use of protective non-transparent eye-glasses with built-in colored LEDs in order to provide with standard proposal of irritants and a proper contrast of the background and stimulus. The following psychophysiological characteristics of the visual analyzer functioning were determined (Table 1):

The diagnosis of the functional (FMNP) was made according to the modified M.V. Makarenko's method [19] with a feedback. The shortest exposure, using 200 conditioned visual irritants: red, green (exciting irritants) and blue (breaking irritant) of colors, in which a respondent differentiated these signals correctly, was FMNP index. In addition, the total time and effectiveness of a task execution were taken into account.

The effectiveness of the task execution (*E*) was calculated by the formula, developed for the assessment of the degree of the information value relatively to equiprobable responses [20].

$$E = \frac{0{,}5 - p}{1 - p};$$

where *p is a probability of an erroneous action*

The lability of nervous processes was determined by indices of the critical fusion frequency of red (CFFr) and green (CFFg) colors. The maximum frequency, at which a respondent records a moment of disappearance or appearance of light flickers, is considered to be the level of manifestation of this property [21]. It is considered that a higher is the frequency of irritation in these of those nervous structures in responses, the higher is lability of nervous processes, expressed in Hz. In order to determine the degree of fatigue by CFF parameters, an index of color asymmetry was calculated (*Ind*) [22] by the formula:

$$Ind = \frac{\mathrm{CFFr} - \mathrm{CFFg}}{\mathrm{CFFr} + \mathrm{CFFg}}.$$

For assessing other indices the results of testing of each respondent are described with the function, which adequately (significance $p<0{,}001$) characterizes a curve of exposure changes of irritants in time (*t*) in the regime of work with a feedback:

$$y = \mathrm{SNP} + \mathrm{INP}^{\times\,(-\mathrm{DNP}\times t)};$$

where «SNP» is interpreted as index of the strength of nervous processes, and «DNP» – as index of their dynamics [23], «INP» is index of inertance or stability of the studied processes [24,25].

The analysis of the results was conducted by methods of variation and nonparametric statistics (Spearman correlation criteria), cluster, logistical non-linear regression analyses, using the program package STATISTICA 6.0.

**Results and discussion**

The following indices of psychophysiological characteristics of operators have been obtained as a result of the investigations, which characterize CNS functioning before and after shift work (Table 2).

As it is seen in Table 2, as a result of the 24-hour shift work, characteristics of CNS functioning, according to indices FMNP, E, SNP, INP, worsen. In addition, the time for execution of the task on signal processing increased significantly. It is important to mention, that SVMR and CVMR have not changed significantly; however, the CIP value worsens significantly after work, pointing to the increase of the time for information processing in selected links of the CNS.

Peculiarity of CFF changes is in that CFFr was worsened more significantly as compared to CFFg. It is interesting to mention the dynamic of index of color asymmetry. The significance of its transformation is more essential in comparison with selected CFF indices. In our opinion it can be used as a more reliable indicator of fatigue in comparison with indices of responses to selected color irritants.

As a result of the analysis of distribution of psychophysiological characteristics the availability of their significant deviation from the normal law has been established, pointing to a definite heterogeneity of the group and the presence of individuals with different disorders among respondents before and after 24-hour shift work. So, it was important to distinguish homogenous subgroups for the further stage of investigation. For this purpose a cluster analysis was taken (a correlation coefficient between the rated differences of psychophysiological indices FMNP, SNP & Ind before and after work was taken as a criteria for clustering). As a result, two subgroups, similar by their psychophysiological parameters with different manifestations of shifts in work capacity, have been chosen. The first related to 57% respondents. The statistical indices have been calculated separately for the first and the second subgroups before and after work ($B_1$ – before work, $A_1$ – after work for the first group, and $B_2$ and $A_2$ – for the second, respectively).

Psychophysiological characteristics of these subgroups and their relative shifts by parameters of the visual analyzer are presented in Table 3.

It is seen in Table 3 that changes of psychophysiological indices after 24-hour shift work in the first group are more significant in comparison with the second, namely: CVMR, FMNP, SNP, INP, Tt, CFFr, Ind, CR, E. For the second subgroupo only significant changes in indices FMNP, SNP, Tt were specific as well as that of the color asymmetry index. We can state that in both subgroups by different values there are observed similar, but different by value, shifts in the level of work capacity.

If we consider the dynamics of changes in the signal exposure in the test in the feedback regime (in the case of a correct reaction to an irritant its exposure decreases, and in the case of an erroneous one - increases) we can note one interesting peculiarity. In long-term exposures of the assigned signal the number of erroneous actions is minimal, whereas in a boundary short-term exposures – it can reach 100%. Intermediate values of exposure duration cause the increase of the number of errors. The regularity of changes in the dependence of an error occurrence on the exposure duration for each respondent is very individual, however, the type of such regularity can be described with a definite precision, using a logistic curve. Thus, for each individual it is possible to calculate coefficients of the function: $p(\tau) = 1/(1 + t^{(a - b \times \tau)})$ , which adequately (with high level of significance $p<0,001$) describes the probability of an erroneous work «*p(τ)*» in the case of a signal exposure «*τ*» msec before and after 24-hour work. The obtained regularities have positive properties. The same as with the probit-analysis, applied in toxicology, it is possible to define by them a probability of an error occurrence for different levels of exposure of the given signal. And this makes possible to receive the integral information on the reliability of an operator's activity under information load, different by its intensity.

Group-average logistic functions, which making possible to assess the reliability of respondents' activity in the examined groups before and after shift work (B and A) in different intensities of the processed signals are presented in Fig 1.

Here, it is clearly seen the availability of the significant shift of the index «*p(τ)*» in individuals of the first subgroup before and after 24-hours work, proving likely more expressiveness of fatigue in comparison with the second subgroup. As far as the initial level of reliability of the work in both subgroups is approximately similar, we can suppose, that individuals of the first group have lesser level of functional reserves and, so, get tired more quickly.

For theoretical and practical purposes, it is always important to know, what level of reliability is inherent for an operator under the definite rate of the given processed signals. On the other hand, an inverse task for determination of the intensity of the executable work under given level of the reliability of the work is no less important. Such information is necessary in order to distinguish individuals, who can work with reliability, acceptable for practical purposes under defined rates of task statements. For the quantitative assessment of the reliability of an operator's work, exposure meanings of the given signals for 10, 30, 50, 70, 90, 99 and 99 percent levels of correctness in execution of a psychophysiologal test, have been defined. Group-average signal exposure assessments for each subgroup before and after work, depending on the definite level of work reliability, are presented below (Table 3).

Here we can clearly see the identity of initial exposure level characteristics of both subgroups. On the other hand, the resulting levels of the mentioned subgroups differ significantly, beginning with 50% work reliability, confirming our conclusions on the difference of mechanisms of fatigue development in the subgroups concerned.

The availability of the significant difference between indices of the intensity before and after work is likely to be a very significant result in solving the task of distinguishing operators with high level of reliability. If for the first subgroup such significant differences are defined at 99% level of erroneousness, for the second subgroup such difference at the level of high significance (95% and 99%) fails to be significant. Coming from the obtained data, we can make a conclusion that the second subgroup of operators (in comparison with the first one) processes information more effectively under smaller absolute values of the exposure at the end of the work shift. Also, to this contribute values of the relative shift of the examined functions. Under high values of erroneousness of work the relative shift in the first subgroup exceeds the same in the second subgroup (under 95% by 3,69 times, and under 99% by 3,44 times). Under the lowest values of the reliability (10%) this relation falls up to 1,49. It is interesting that the same relation of the traditional index of reliability ICR, when the speed of signal in the psychophysiological testing is not taken into consideration, reach the level 1,48; this is much lower than values of the majority of the proposed integral characteristics for high rates of work reliability. The thing is that the number of erroneous responses under low and mean exposures of a signal influences the ICR value to much extent. So, after work, a relative error in this case changes insignificantly – by 2-3%. At the same time, a value of the relative shift of the calculated integral indicator, even under such low reliability (10%), is 5 times more significant than relative shifts ICR for the first and the second subgroups. So, the proposed integral reliability indicator (IRI) demonstrates better changes in the level of errorless work in different operator's state. In addition, assigning a random level of an errorless activity (99, 95, 90, …%) with IRI, we can assess the level of a maximum intensity of the proposed signals for executing work with the fixed requirements to its reliability.

Current approaches to the analysis of the reliability of operators' activity include high requirements to sensitivity, objectivity and convenience in using indices of such characteristics. At present, a classic index of the reliability is used [26] as well as its modifications [27,28]. So, in this paper we propose a new index of reliability, using an idea of a probit-analysis. The obtaining reliability assessment

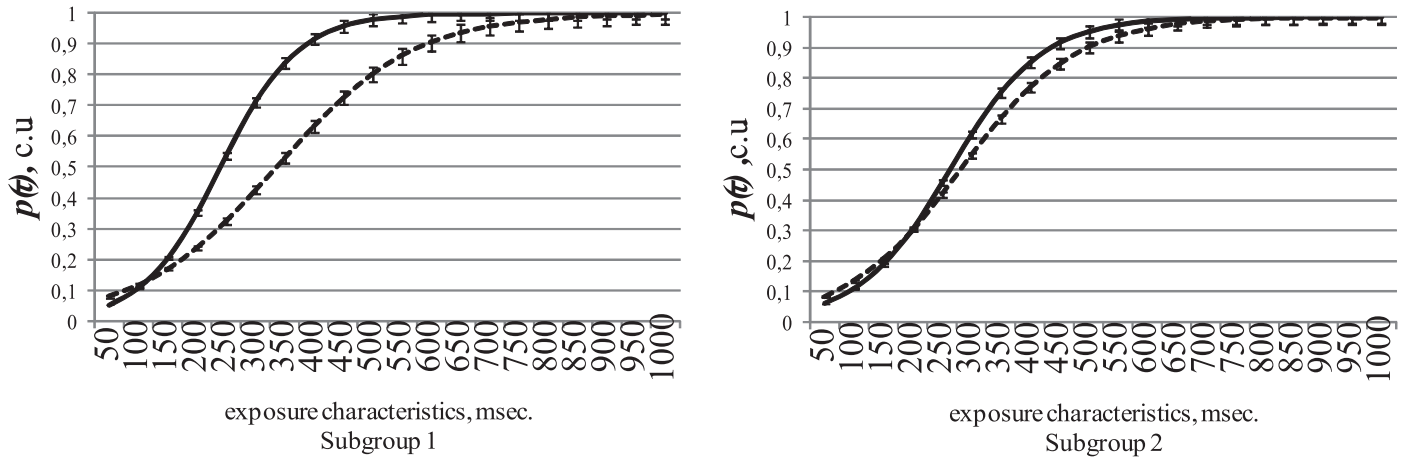


Fig. 1. Integral characteristics of the reliability of operators' work in the examined subgroups, depending on the exposure of the assigned signals. Note: — before shift work, - - - after shift work

Table 1. Assessment of psychophysiological characteristics

| | |
|---|---|
| Latent period of a complex visual-motor reaction (red light, 20 points) | CVMR, msec. |
| Latent period of a simple visual-motor reaction (red & green lights, 20 points) | SVMR, msec. |
| SPEED of central information processing (CIP = CVMR – SVMR) [19] | CIP, msec. |
| Function mobility of nervous processes | FMNP, msec. |
| Correct responses, quantity | CR, u. |
| Incorrect responses, percent | ICR, % |
| Effectiveness | E, c.u. |
| Strength of nervous processes | SNP, msec. |
| Inertness of nervous processes | INP, msec. |
| Dynamism of nervous processes | DNP, c.u. |
| Task's total time | Tt, sec. |
| Red light critical fusion frequency | CFFr, Hz. |
| Green light critical fusion frequency | CFFg, Hz. |
| Index of color asymmetry | Ind, c.u. |

Table 2. Operators' psychophysiological characteristics, M±m

| Indices | Before work | After work |
|---|---|---|
| SVMR, msec. | 210,26±4,44 | 211,21±5,71 |
| CVMR, msec. | 348,86±10,03 | 368,71±10,59 |
| CIP, msec. | 155,74±8,84* | 171,34±8,41 |
| FMNP, msec. | 176,08±3,99*** | 218,75±7,68 |
| Tt, sec. | 63,18±1,69** | 75,88±4,16 |
| E, c.u. | 0,13±0,001* | 0,11±0,01 |
| SNP, msec. | 227,12±7,95*** | 289,10±11,29 |
| INP, msec. | 940,01±18,76** | 866,78±17,13 |
| DNP, c.u. | 0,10±0,01 | 0,12±0,01 |
| CFFr , Hz | 56,26±0,84* | 54,30±0,46 |
| CFFg, Hz | 54,93±0,59 | 54,88±0,54 |
| Ind, c.u. | 0,018±0,006* | 0,001±0,005 |

Note: *, **, *** - statistical significant difference between groups by the Student's t-test corresponds to levels - p< 0,05, p < 0,01, p < 0,001.

Table 3. Psychophysiological characteristics of different operators' subgroups

| Task reliability | Subgroup 1 | | | Subgroup 2 | | |
|---|---|---|---|---|---|---|
| level, % | before work, M±m | after work, M±m | relative shear, % | before work, M±m | after work, M±m | relative shear, % |
| 10 | 93,24±7,28 | 108,47±9,52 | 16,34 | 92,29±8,07 | 102,38±7,46 | 10,93 |
| 30 | 183,24±6,50*** | 242,11±12,87 | 32,13 | 190,07±6,72* | 216,63±7,25 | 13,97 |
| 50 | 255,35±12,26*** | 348,71±17,90 | 36,56 | 260,92±8,63* | 294,88±9,25## | 13,01 |
| 70 | 321,59±17,94*** | 457,06±24,21 | 42,13 | 330,26±12,77** | 384,08±12,39## | 16,30 |
| 90 | 425,59±27,22*** | 629,88±35,69 | 48,00 | 442,13±20,14** | 529,21±18,41# | 19,70 |
| 95 | 436,06±30,49*** | 682,79±21,70 | 56,58 | 494,88±40,62 | 570,63±21,08### | 15,31 |
| 99 | 547,24±46,28*** | 876,21±34,23 | 60,12 | 623,08±43,15 | 732,08±35,29## | 17,49 |

Note: *, **, *** - statistical significance of the difference between subgroups by the Student's t-test corresponds to levels - p < 0,05, p < 0,01, p < 0,001.; # , ## , ### - statistical significance of the difference between subgroups by the Student's t-test corresponds to levels - p < 0,05, p < 0,01, p < 0,001

is an advantage of such approach, which is based on the whole range of intensities in information presentation, occurring in real conditions of productions. Basing on this, IRI index can be considered as an integral one. At the same time, when using the proposed approach it is possible to receive evidence on the limited intensity, when operators are still able to process information at the give level of reliability of their actions.

The assessment of fatigue development in operators, engaged in 24-hour shift work, has been made, based on the proposed approach. The use of IRI gave an opportunity to establish that the group of the examined operators was not similar and to assess the degree of fatigue formation in individuals with different mechanisms of adaptive reactions. The revealed peculiarities of transformation of different psychophysiological characteristics, which touch directly bases of the activity of the central nervous system (functional mobility, strength, dynamics, lability and inertness of nervous processes), point to the availability of generalized negative effect on the human body at long-term intensive work.

The obtained results have both theoretical and practical significance. In order to develop a theoretical aspect it is necessary to undertake further thorough studies, aiming to specify the mentioned mechanisms of the mutual compensation of psychophysiological functions in the development of a significant fatigue. From the practical point of view the distinguished informative psychophysiological functions enable to assess an individual reliability in execution of the task at different levels under unified information loads.

## Conclusion

1. It is found that in the process of uninterrupted 24-hour work significant fatigue is developing in operators, which can be identified by indices of the following psychophysiological functions: functional mobility, strength, lability and inertance of nervous processes.
2. The integral index of the reliability of an operator's work has been developed, enable to assess the quality of work, using a wide range of intensities of signal presentations as well as to receive the data on the overall possibilities of an operator to process information at the given level of reliability.
3. It is established that in the long-term 24-hour shift work the difference in psychophysiological characteristics has been defined in operators, pointing to the availability of several mechanisms of fatigue formation under a high information load.

REFERENCES:


[1] Costa G.: Shift work and occupational medicine: an overview. *Occup Med (Lond)* 2003; 53: 83–88.

[2] Bourdouxhe M.A., Quéinnec Y., Granger D., Baril R.H., Guertin S.C., Massicotte P.R., Levy M., Lemay F.L.: Aging and shiftwork: the effects of 20 years of rotating 12-hour shifts among petroleum refinery operators. *Exp Aging Res* 1999; 25: 323–329.

[3] Danev S., Dapov E., Pavlov E., Nikolova R.: The assessment of the general functional status and of the psychosomatic complaints of workers at hydroelectric power plants. *Probl Khig* 1992; 17: 63–70. [Article in Bulgarian].

[4] Olds J.: High functions of the nervous system. *Annu Rev Physiol* 1959; 21: 381–402.

[5] Pavlov I. P.: Conditioned Reflexes: An Investigation of the Physiological Activity of the Cerebral Cortex. Translated and Edited by G. V. Anrep. Oxford University Press, London 1927.

[6] Sirotskiĭ V.V., Kol'chenko N.V., Makarenko N.V., Voronovskaia V.I., Shcherbina P.K.: Role of individual-typological features of higher nervous activity and occupational choice. *Fiziologicheskiĭ zhurnal* 1980; 26: 505–511. [Article in Russian].

[7] Maslov N.B., Bloschinsky I.A., Maksimenko V.N.: Neurophysiological picture of the genesis of fatigue, chronic fatigue and overfatigue in a man-operator. *Fiziologiya cheloveka* 2003; 29: 123–133. [Article in Russian].

[8] Barmina O.S.: Peculiarities of operators' occupationally-applied physical preparation at communication mobile complexes. *Scientific remarks* 2009; 52: 13–16. [Article in Russian].

[9] Novikov V.S., Lustin S.I., Blaginin A.A., Kozlov V.P.: Change of operators' serviceability of the command-measuring complexes in shift work. *Voyenno Med. Zhurnal* 1997; 6: 55–59. [Article in Russian].

[10] Ekstedt M, Söderström M, Akerstedt T, Nilsson J, Søndergaard HP, Aleksander P.: Disturbed sleep and fatigue in occupational burnout. *Scand. J. Work Environ Health* 2006; 32: 121–131.

[11] Gemelli K.K., Hilleshein E.F., Lautert L.: The effect of shift work on the health of workers: a systematic review. *Rev Gaucha Enferm* 2008; 29: 639–646.

[12] Kaida K., Akerstedt T., Kecklund G., Nilsson Jens P., Axelsson J.: Use of subjective and physiological indicators of sleepiness to predict performance during a vigilance task. *Ind. Health* 2007; 45: 520–526.

[13] Akerstedt T., Wright K.P.: Sleep Loss and Fatigue in Shift Work and Shift Work Disorder. *Sleep Med Clin* 2009; 4: 257–271.

[14] Knutsson A.: Health disorders of shift workers. *Occup. Med* 2003; 53: 103–108.

[15] Burova K.: Effective cognitive work and individual response to external factors of activity. In: XXIX International Congress of Psychology 20-25 July 2008. Berlin, German 2008.

[16] Prochazka A.: Sensorimotor gain control: a basic strategy of motor systems. *Prog Neurobiol* 1989; 33: 281–307.

[17] Kochina M.L., Firsov A.G.: Information technology for the assessment of time and frequency indices in the human body. *Sistemy obrobky informatsi*i 2010; 83: 243–247. [Article in Russian].

[18] Kochina M.L., Firsov A.G. Multifunctional supply for psychophysiological investigations. *Applied radio electronics* 2010; 9: 260–265. [Article in Russian].

[19] Makarenko M.V., Lyzohub V.S.: The speed of central information processing in humans with different properties of basic nervous processes. *Fiziologicheskiĭ zhurnal* 2007; 53: 87–91. [Article in Ukrainian].

[20] Korogodin V.I.: Information and information phenomena. Academy of Science USSR, Puschino 1991. [Book in Russian].

[21] Makarenko N.V.: Speed of information processing as an criterion of property of nervous processes functional mobility. *Bulletin of National Military Academy of Ukraine* 2009; 10: 94–101. [Article in Ukrainian].

[22] Kim Su In, Bashkin V.M., Pavlova L.P.: Assessment method of human brain cortex function status. Patent Rus. Fed, Donetsk. RI of occupational medicine and pathology, RU2141244, SU1066533 A/6 A61 B3/06. 20.11.99, Bul.; 32.

[23] Makarenko N.V., Kalnysh V.V., Sytnik N.I.: Method of operators' occupational selection / A.C. № 1607777 SU. 04.07.88. № 4454516, Published. in Inf. Bul., 1990; 43. MKI A 61 B 5/16.

[24] Ilyin E.P.: Psychophysiology of human status. Piter, Sankt-Pietersburg 2005 [book in Russian].

[25] Latmanizova L.V.: Sketch of activation physiology. High School, Moscow 1972. [Book in Russian].

[26] Cuschieri A., Tang B.: Human reliability analysis (HRA) techniques and observational clinical HRA. *Minim Invasive Ther Allied Technol* 2010;19: 12–17.

[27] Podofillini L., Dang V., Zio E., Baraldi P., Librizzi M.: Using expert models in human reliability analysis - a dependence assessment method based on fuzzy logic. *Risk Anal* 2010; 8: 1277-1297.

[28] Kalnysh V., Shvets A., Levit Yo.: Gender peculiarities of operator's work reliability. *Zhurnal AMN Ukrajiny* 2009; 15: 755–768.