

## ЭКСПЕРИМЕНТАЛЬНОЕ ИЗУЧЕНИЕ ЭФФЕКТИВНОСТИ ПРОТИВОШУМОВ ДЛЯ ПРОФИЛАКТИКИ ИНТЕНСИВНОГО ШУМОВОГО ВОЗДЕЙСТВИЯ

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Профессиональная нейросенсорная тугоухость – одна из центральных проблем в медицине труда. Потеря слуха в связи с профессиональной деятельностью в структуре профессиональных заболеваний занимает первое место, и её удельный вес постоянно увеличивается. В очень шумных производствах рекомендовано использовать комбинацию противошумных вкладышей и наушников, а также регулярно контролировать состояния слухового анализатора, что в частности обусловило рост регулярного использования противошумных вкладышей в 3 раза. **Цель.** Проведение исследований по оценке эффективности заглушающей способности противошумов и их комбинаций в условиях воздействия интенсивных прерывистых и импульсных шумов. **Материалы и методы.** Изучено несколько типов противошумов отечественного и зарубежного производства: противошумные вкладыши: беруши (Россия) и EAR (Англия), – наушники ШЗО-1 (Россия), а также наушники, совмещенные с каской ККА (Россия). Исследования проводились в соответствии с положениями действующих стандартов и методических указаний в условиях лабораторного эксперимента и реального производства. В заглушенной акустической камере моделировалась шумовая экспозиция и затем в специальном помещении проводились аудиометрические исследования с испытуемыми. В условиях реального производства контролировалась размерность уровней и экспозиции шумового воздействия на рабочих местах и состояние слухового анализатора работающих. Для субъективной оценки конструкции и комфорта использованных противошумов и их комбинаций проведён анкетный опрос. **Результаты.** Итоги лабораторного эксперимента и исследований в условиях реального производства позволяют высказать предположение об идентичной и высокой эффективности оцениваемых противошумов и их комбинаций, и с учётом критерия сохранности слуха качество защиты слуха можно характеризовать как «хорошее». Анкетный опрос испытуемых показал высокую заглушающую способность и удобство испытанных противошумов и позволил составить банк данных по учету замечаний и предложений в плане удобства их использования и внесения конструктивных замечаний. **Выводы.** Лабораторные и производственные исследования показали высокую эффективность испытанных противошумов и возможного их практического использования в условиях реального производства при воздействии интенсивных импульсных шумов экстремальных уровней. Обязателен постоянный контроль правильности и своевременности их применения.

**Ключевые слова:** эксперимент, кузнечнопрессовое производство, экстремальность, интенсивный импульсный шум, эффективность противошумов, профилактика.



## EXPERIMENTAL STUDY OF EFFECTIVENESS OF EAR PROTECTION DEVICES FOR PREVENTION OF INTENSE NOISE EXPOSURE

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Occupational neurosensory deafness is one of central problems in the occupational medicine. Hearing loss associated with professional activity is the leading occupational disease with the permanently increasing share. In the industries with a very high level of noise it is recommended to use a combination of earplugs and earmuffs, and to control the condition of the ear analyzer, which provided a 3-fold increase in regular use of anti-noise earplugs. **Aim.** To evaluate effectiveness of sound damping capacity of ear protectors and of their combinations on exposure to intermittent and impulse noise. **Materials and Methods.** Several types of ear protectors of domestic and foreign manufacture were studied: earplugs of Berushi (Russia) and EAR (Great Britain) types, ShZO-1 earmuffs (Russia) and also earmuffs in conjunction with KKA helmet (Russia). The study was conducted in compliance with the rules and regulations of the effective standards and methodical instructions in the conditions of laboratory experiments and of real production. In the experiment, noise exposure was modeled in anechoic acoustic chamber, after which audiometric research was conducted on test subjects. In real industrial conditions, dimension of levels and noise exposure at the workplaces and the condition of the auditory analyzer of workers were controlled. For subjective evaluation of the design and comfort of the used ear protecting devices and their combinations, questionnaire-based survey was conducted. **Results.** The results of the laboratory experiment and research work in the conditions of the real production permit to suggest high effectiveness of the evaluated ear protectors and of their combinations, and, taking into the account the criterion of preservation of hearing, the quality of hearing protection can be characterized as «good». Questionnaire survey of test persons showed a high sound damping capacity and convenience of the tested ear protectors and permitted to compile the data bank of comments and proposals concerning convenience of their use and their design. **Conclusions.** Laboratory and industrial studies showed a high effectiveness of the tested ear protectors and the possibility of their practical use in the conditions of real production with exposure to extreme levels of intense impulse noise, with the obligatory permanent monitoring of correctness and timeliness of their application.

**Keywords:** *experiment, press forging production, extreme, intense impulse noise, effectiveness of ear protectors, prevention.*

In many industries it is practically impossible to reduce the level of noise to normative values by use of traditional technical means [1,2]. This is especially important for production technologies requiring equipment generating loud intermittent and impulse noises [3-5]. Today, the only effective preventive measure is use of means of individual protection (MIP) [6,7]. Taking into account

varieties of combinations and spectra of noise exposure, there are determined requirements to MIP for different kinds of noise including broadband impulse noise that act on workers during a prolonged period of the working shift [7-14]. Therefore, proposals for practical use of anti-noise MIP in certain industries should be based on scientifically substantiated recommendations taking into account the type

of technological process, parameters of the noise factor, subjective and objective characteristics of the convenience and effectiveness of a specific ear protector.

Thus, the *aim of study* was experimental study of the effectiveness of different types of ear protectors with different structural implementation for prevention of intense noise exposure in the conditions of laboratory experiments and real production.

### Materials and Methods

For study, three types of MIP were used: insert-type ear protectors: Berushi (Russia) and EAR (England) earplugs, ShZO-1 earmuffs, and also earmuffs in conjunction with KKA helmet (Russia). The study was conducted in compliance with the rules and regulations of the effective standards and methodical instructions in the conditions of laboratory experiments and real production [8-16].

In the process of two-factor experiment, test subjects were placed into the anechoic acoustic chamber of 25 m<sup>3</sup> volume for a specified time with different modeled noise exposures. Subsequent audiometric studies were conducted in the anechoic chamber of 5m<sup>3</sup> volume using MA-21 Parktronic audiometer (Germany) for control of the condition of the auditory analyzer on the basis of the temporary threshold shift (TTS) of hearing at 1000, 4000 and 6000 Hz frequencies. The dynamics of recovery of TTS of hearing was controlled during 2 hours.

In industrial conditions, the effectiveness of ear protectors was evaluated by difference between the hearing thresholds before and after use of ear protectors, by the method of the tonal threshold audiometry with use of clinical audiometer MA-31 Parktronic (Germany) [17]. Dimension and exposure of non-constant and impulse noise was controlled by precision noise-measuring apparatus – noise-meter and by individual noise dosimeters Brüel & Kjær (Denmark), RFT (Germany), Wärtsilä (Finland).

The tests were conducted in the production areas with the average noise levels

103.6±2.0 dB(A). The test group consisted of 10 young (the average age 27.0±1.6 years) workers with average job tenure 1.5±0.3 years. The study was conducted with each test subject within four days, for three of which he was working with MIP and one day without them. Noise exposure during the working shift was recorded daily using noise dosimeter. Effectiveness of ear protectors was determined by the difference of hearing thresholds with protected and unprotected ears. TTS of hearing was determined in compliance with the requirements of GOST 12.4.062-78 «Occupational Safety Standards System. Noise. Methods of Determination of Hearing Loss in Human» at the respective audiometric frequencies taking into account requirements to the acoustic environment in the rooms for research. The algorithm of research supposed determination of permanent threshold shift (PTS) before beginning of the working shift. After that the workers put on or inserted into the auditory canal the tested MIP according to the instruction and performed their professional work during the shift. In dinner break MIP were not used. In the end of the shift the levels of TTS of hearing and noise exposures were recorded by individual dosimeters.

Effectiveness of KKA earmuffs in combination with a helmet was studied at the workplaces of tool smiths, punchers and heaters in different production areas with different working conditions. Into the study 18 workers were included with the average age and job tenure 32.1±1.8 years and 7.4±1.4 years, respectively. The workers were divided into two comparable groups. One group was instructed in detail on correct fitting of earmuffs and on the rules of their wearing, and the second group performed these procedures independently without any instructions. Before the work each participant was taken PTS using audiometer. Then a worker put on a helmet with earmuffs after being instructed or by himself (depending on the group) and performed a production task during half the shift

(4 hours). After that TTS was taken in a special room. Noise exposure was simultaneously measured by the characteristics «slowly» and «impulse».

Upon completion of the study the participants were interviewed using the questionnaire that contained questions elaborated by us. Answers to these questions permitted to evaluate effectiveness of the sound-reducing capacity of the ear protectors, convenience of their use, and to create the data bank of comments and proposals.

Statistical processing of the results was carried out by standard methods of variation statistics with use of correlation analysis. Statistically significant were differences at  $p < 0.05$ .

### Results and Discussion

The choice of ear protectors for evaluation of their effectiveness in the conditions of press forging production with high levels of impulse noise was based on several principles: first, necessity of taking into account the spectrum of noise to be protected from; second, obligatory fixation of the ear protectors to the helmet (if they were earmuffs) required by safety measures; third, domestic manufacture of the devices.

At the same time, it was necessary to take into account the existing data about negative sides of MIP that are in some cases associated with discomfort and inconvenience of their long-term use in the conditions of heating microclimate, and also with reduction in the possibility of perception of signals carrying certain technological information and information concerning safety measures. All this determines importance and complexity of the problem of search for ear protection means that meet all the requirements.

In the laboratory experiment, ShZO-1 earmuffs and Berushi earplugs were evaluated. Test persons wearing the above mentioned ear protectors were exposed to 105-115 dB(A) noise within 5 to 50 min in a special chamber, with the total energy of noise exposure from 10 to 100 Pa<sup>2</sup>·h. Effectiveness of ear protection means was determined using audiometric method by TTS of hearing under action of modeled noises. The results of studies (Tab. 1) showed that on the basis of the used criterion (TTS below 5 dB) the quality of hearing protection with use of the mentioned ear protectors may be evaluated as «good».

Table 1

#### *Results of Evaluation of ShZO-1 Earmuffs and Berushi Earplugs Effectiveness in Experiment*

Ear Protection Means	Noise Exposure, Pa <sup>2</sup> ·h	TTS of Hearing, dB ( $\bar{x} \pm S_x$ )		
		1000 Hz	4000 Hz	6000 Hz
ShZO-1 earmuffs	10	1.0±2.2	4.0±4.1	1.0±4.1
	10	0	1.2±5.6	0
	10	0	1.0±4.7	2.5±2.8
	100	0	5.0±4.1	3.8±6.2
Berushi earplugs	10	0	3.3±2.1	0
	10	3.3±2.8*	5.0±8.6	1.6±6.5
	10	5.0±8.6	8.0±10.4	3.3±5.7
	100	1.6±2.8	3.3±5.5	1.6±2.8

Note: \* –  $p < 0.05$

With use of Berushi earplugs, higher values of TTS of hearing were noticed practically in all sessions, however, the differences were statistically insignificant ( $p > 0.05$ ), which can be explained by a low statistical power of the study ( $n$ ). Especially should be noted the quality of protection of ShZO-1 earmuffs and Berushi earplugs on noise exposure of  $100 \text{ Pa}^2 \cdot \text{h}$  energy.

Effectiveness of ShZo-1 earmuffs, KKA earmuffs combined with a helmet and

of EAR earplugs was evaluated in the conditions of real press forging production. The latter device was included into the study in view of the perspective use of earplugs made of plasticized polyvinyl chloride, and also due to the fact that earplugs are simple, convenient and cheap means of protection. The obtained results of alteration of the auditory sensitivity (Tab. 2) permit to suggest identical and high effectiveness of the evaluated ear protectors.

Table 2

***Results of Effectiveness of ShZO-1 Earmuffs and EAR Earplugs Based on Difference between TTS with and without Protection of Ears ( $\bar{x} \pm Sx$ ), dB***

Mean Geometric Frequency Bands, Hz	Ear Protector Type	
	ShZO-1 earmuffs	EAR earplugs
125	$8.7 \pm 5.0$	$8.1 \pm 4.1$
250	$11.2 \pm 7.2$	$10.2 \pm 5.8$
500	$13.2 \pm 5.8$	$11.3 \pm 4.0$
1000	$11.4 \pm 9.1$	$7.5 \pm 3.6$
2000	$17.3 \pm 9.7$	$13.4 \pm 7.4$
4000	$18.8 \pm 3.9$	$19.0 \pm 11.4$
6000	$15.7 \pm 6.1$	$8.4 \pm 9.0$
8000	$14.0 \pm 8.2$	$10.7 \pm 5.0$
Range of noise exposure, $\text{Pa}^2 \cdot \text{h}$	<b>13.1 – 69.3</b>	<b>29.5 – 100.7</b>

By results of the study, the quality of protection evaluated by the TTS values on the basis of the criterion of preservation of hearing, can be characterized as «good». On the basis of differences of TTS of hearing with protected and unprotected ears, a higher effectiveness of ShZO-1 earmuffs was noted in comparison with EAR earplugs, at frequencies of 2000 Hz, 8000 Hz and at 1000 Hz frequency that is considered to be an adequate parameter of the extent of noise exposure ( $p > 0.05$ ).

The recorded values of noise exposure ranged from  $13.1 \text{ Pa}^2 \cdot \text{h}$  to  $100.7 \text{ Pa}^2 \cdot \text{h}$  which determined the nonlinear character of relationship between TTS and exposures. The calculated values of the correlation coefficient «dose-effect» for TTS of hearing obtained

without use of MIP, showed a high positive and reliable relationship at speech frequencies and at 4000 Hz in test program for EAR earplugs and also a satisfactory and unreliable relationship at speech frequencies and at 4000 Hz in test program for ShZO-1 earmuffs (Tab. 3).

Taking into account the fact that the psychological stimulus and decisive factor for systematic use of ear protectors is their comfort, the participants were asked to answer a questionnaire for subjective evaluation of design and comfort of these ear protectors and of their combination with a helmet in press forging production.

Results of questioning of 31 workers of press forging areas showed a high muffling capacity and convenience of the tested ear protectors. A considerable part of workers



Table 3

**Values of Correlation Relationship between TTS of Hearing and Noise Exposure**  
( $\bar{x} \pm Sn / \sqrt{n}$ )

Test Program	Correlation Coefficient	
	TTS <sub>med.speech</sub> – E	4000 Hz – E
ShZO-1 earmuffs	0.02 ± 0.44	0.63 ± 0.26
EAR earplugs	0.79 ± 0.18*	0.74 ± 0.13*

Note: \* – p<0.05; E – noise exposure, Pa<sup>2</sup>·h

(90.3%) noted necessity to diminish their size and the force of pressure of earmuffs on the circumaural area. Besides, about 100% of workers noted excessive perspiration under the ear cups which caused discomfort and unpleasant sensations. A wish was formulated to change the design of the ear protector for possibility of fixation of ShZO-1 earmuffs to a helmet taking into account specificity of press forging production and observance of safety precautions. Alongside with that, all the tested

individuals noted convenience, hygienic aspect and effectiveness of EAR earplugs in terms of cushioning effect. However, it should be remembered that application of multiple-use earplugs requires special medical control.

Study of the effectiveness of KKA earmuffs in combination with a helmet at the workplaces of tool smiths, punchers and heaters (n=18) in different production areas with different production conditions, revealed the following tendencies (Tab. 4).

Table 4

**Noise Factor Parameters in Study of KKA Earmuffs**  
**Used by Instructed and Non-instructed Workers**

Group of Tested Individuals	Ranges of Noise Factor Parameters		
	E, Pa <sup>2</sup> ·h	dB A «slowly»	dB A «impulse»
Instructed group	41.6 – 138.8	112.0 – 118.0	120.0 – 129.0
Non-instructed group	29.3 – 80.2	108.0 – 116.0	118.0 – 125.0

The first group was subject to high intensity impulse noises with exposure 100 times the maximum permissible limit which characterizes the working conditions as extreme ones.

Using TTS of hearing as a parameter of alteration of the functional condition of the auditory analyzer it was found that the shift of the hearing threshold in the first group was below 5 dB, while in the second group it reached 9 dB. The obtained results show that even in the conditions of exposure to intense impulse noise, but with permanent control of correct use of MIP, the given earmuffs effectively protect the auditory analyzer, since the

alteration of TTS of hearing with them did not exceed the criterial level 5 dB. To prevent reduction in the effectiveness of these ear protectors in the conditions of press forging production (intense impulse noise in combination with the heating microclimate, hourly breaks with workers staying in the close proximity to the workplaces), it is recommended to use a combination of KKA earmuffs with a helmet and Berushi earplugs.

To study the effectiveness of ear protectors, questionnaire survey was conducted to evaluate acceptability and convenience of use of a combination of earmuffs with a helmet. For this, we elaborated a questionnaire that was

answered by 31 workers who were using KKA earmuffs in production conditions for more than 1 month. Before 87.0% of them were permanently using other types of ear protectors and could make a comparative evaluation. The main question «What is your evaluation of the given ear protectors?» received 42% of answers «I liked it», 32% of respondents found this question difficult to answer. Practically significant material was obtained from remarks, wishes and proposals concerning improvement of the given type of ear protectors. The main part of answers concerned changes in the design of the earmuffs and helmet.

### Conclusions

1. The result of the conducted laboratory studies of effectiveness of ShZO-1 earmuffs and Berushi earplugs taking into account the effective criterion (alteration of the temporary threshold shift by not more than 5

dB) showed that the quality of protection of hearing by these method may be evaluated as «good».

2. Production tests suggest a possibility of practical application of the tested ear protectors in conditions of exposure to intense impulse noise.

3. ShZO-1 earmuffs were noted to have higher effectiveness as compared to EAR earplugs at frequencies 2000 Hz, 8000 Hz and frequency 1000 Hz. However, the test participants noted convenience, hygienic advantage and high sound damping capacity of EAR earplugs.

4. On the basis of the results of study of effectiveness of KKA earmuffs in conjunction with a helmet, they are recommended for use in the conditions of press forging production with obligatory permanent control of their correct and timely application.

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