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INFRASOUND IN A VEHICLE COMPARTMENT RESEARCH RESULTS ACHIEVED IN RUSSIA

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Note: This document has been presented in order to exchanging of views of the GRB Experts about necessity and possibilities of development of international regulations in regards to setting the requirements for infrasound levels in automotive vehicles

1. Physical nature of infrasound. Physiological peculiarities of infrasonic influence

It is known fact that all sounds can be conventionally divided into three ranges. Infrasonic range - up to 20 Hz – cannot be heard by a human being, an audible range - from 20 to 20000 Hz, and ultrasonic range - from 20000 Hz and up – cannot be heard by a human being either. Such range division is significant not only because we can or cannot hear some sounds; the effects of these sound ranges on a human being are also different. Investigation methods and techniques for lowering sound pressure within these ranges also differ considerably.

It is worth mentioning that infrasound is not studied very well yet, although we live in its world unawares. Nevertheless, we may suffer from them or at the best case feel very uncomfortable. The point is, that some of the human's organs have their resonance vibration frequencies of 6–8 Hz that fall into the infrasonic frequency range. Even infrasound of low power painfully affects ears and makes human organs to vibrate. Obviously, there is an opinion that infrasound is the main reason of lasting weariness of the city people and workers of noisy factories. It has been found out that the people themselves are creating the most infrasonic sources. One of such sources is unfortunately an automotive vehicle, which is not only environmental pollutant in cities, but also a potential source of harmful influence on human beings.

It has been found out from the research that infrasound with level exceeding 100 dB, when influencing upon a human being for a long time, results in dysfunctions of human being bodily systems such as nervous, cardio-vascular, respiratory and endocrine, lead to loss of hearing and dulling of eyesight, deterioration of working capability and labor efficiency.

2. Results of infrasonic level measurements in vehicles

For the first time, the unpleasant effects of infrasound were noticed in Russia about 25 years ago, when the government officials complained that they felt uncomfortable while riding cars. The audible sound levels in the vehicles were very low but the noise of infrasonic range exceeded 120 dB. Investigations were carried out and it became clear that in particular driving conditions the roof and the floor of a vehicle body start oscillating in opposite phase, thus inducing infrasonic waves.

In 1980 NICIAMT Testing Center in collaboration with the N.E.Bauman Moscow State Technical University started collecting statistics as well as developing infrasonic measurement techniques in vehicles. As an example, Table 1 shows some results of infrasonic measurements at the driver's working place in different vehicles.

Table 1. Levels of infrasound at the driver's working place dB Lin

Car	Type of road surface	Travelling speed, km/h							
		30	**40**	**50**	**60**	**70**	**80**	**90**	**100**
1	Even stone-block pavement	113	113	112	113	113	112		
	Asphalt concrete	103	107	104	108	107	106	107	109
2	Even stone-block pavement	116	115	117	117	119	118	118	
	Asphalt concrete	107	108	109	113	115	116	114	
3	Even stone-block pavement	107	108	108	108	108	110	110	108
	Asphalt concrete	100	100	101	103	104	105	107	107
4	Even stone-block pavement	114	113	115	116	117	117		
	Asphalt concrete	103	103	105	105	107	107	109	110
5	Asphalt concrete				103	102	104	104	108
6	Asphalt concrete				112	113	114	115	
7	Asphalt concrete				111	111	111	111	112
8	Asphalt concrete				104	103	105	104	104
9	Asphalt concrete				104	105	104	105	107
10	Asphalt concrete				111	111	111		
11	Asphalt concrete				103	104	103		
12	Asphalt concrete				111	110			
13	Asphalt concrete				104	105	106		

It is clear that the levels of infrasound do not depend on the speed when driving along the even stone-block paved road. On the contrary, when driving along the asphalt concrete road, the levels of infrasound increase by 7 dB as average at the speed increasing from 30 to 100 km/h. Infrasonic compounds within frequency range from 4 to 16 Hz were dominate at that. The levels of infrasound are considerably higher when driving on the even stone-block paving, than those generated by driving on the asphalt concrete.

The position of side windows also significantly affects levels of infrasound inside the vehicle. The difference in the levels can be 10–17 dB and more. It can be supposed that when the side window is open it forms a resonant volume with a throat in the vehicle cab (like a sort of Helmholz resonator, where the vehicle compartment represents the volume and the opened window forms the throat). The resonator sucks in sonic energy. The carried out calculations shown that in the majority of cases such a resonator works at frequencies of 8–16 Hz). There were cases when the first response of a driver was a fear that something had happened with the car, although there were no reasons for that.

Table 2 shows the data on infrasound levels in the interior of one tested passenger car sample with various positions of the side windows.

Table 2. Infrasound levels in the interior of a passenger car

Car speed, km/h	Position of side windows	Levels of sound pressure in octave band 16 Hz	Overall sound pressure level, dB Lin.
70	All windows closed	**74**	**95.7**
70	Rear right window is ⅓ open, the rest are closed	**117.9**	**118**
70	Rear right window is ½ open, the rest are closed	**129.1**	**129.1**
70	Rear right window is fully open, the rest are closed	**130.5**	**130.5**
70	Rear left window is fully open, the rest are closed	**125.8**	**125.8**
70	Front left window is fully open, the rest are closed	**122.5**	**122.5**
80	All windows closed	**76.1**	**117.4**
80	Rear right window is fully open, the rest are closed	**132.2**	**132.2**
90	All windows closed	**77.6**	**112.9**
90	Rear right window is fully open, the rest are closed	**133.1**	**133.2**

It is possible to control noise of the audible frequency range using various available means, for example, sound insulating and sound absorbing materials. For the case of infrasound, the task becomes much more difficult. Control of infrasound in a vehicle represents a new complicated technical problem requiring thorough investigations.

Carrying out the model analysis, as well as experimental calculating investigations have allowed exposing the reasons of infrasound emergence in a vehicle. It has been determined that infrasonic compounds can be generated by a running engine, pulsations in air flow, a power plant suspension, unsprung masses and structural features as well. As a rule, such measures as toughening of the body framework elements, improvements of the power plant suspension, toughening of interior trimmings or glass, lead to reduction of infrasound levels.

3. Regulations related to infrasound

The results of carried out investigations were assumed as the basis for development of the "Sanitary Norms of Infrasound at the Working Places" No. 2274 in 1980, and the Sanitary Norms SN 2.2.4/2.1.8.583 "Infrasound at the Working Places, Habitable and Public Premises and at the Territories of Housing Estate" in 1996. To our knowledge, the norms for levels of infrasound have been only introduced in Russia at the present time. Tables 3 and 4 show the requirements set in both documents.

Table 3. Norms of Infrasound ("Sanitary Norms of Infrasound at the Working Places" No. 2274-80)

Levels of sound pressure in dB in octave bands with geometric mean frequencies in Hz					Overall level of sound pressure In dB Lin
2	4	8	16	31.5	
105	105	105	105	102	110

Table 4. Maximum Permissible Limits of Infrasound at the Working Places, Permissible Limits of Infrasound in Habitable and Public Premises and at the Territories of Housing Estate (Sanitary Norms SN 2.2.4/2.1.8.583-96)

Working activity	Levels of sound pressure in dB in octave bands with geometric mean frequencies in Hz				Overall level of sound pressure in dB Lin
	2	4	8	16	
Jobs with various degrees of laboriousness and intensity of working process in industrial premises and at territory of enterprise	100	95	90	85	100

As it can be seen from the Tables 3 and 4, the norms have become 2 – 3 times stricter. It is not easy to state to what extent they are substantiated, taking into account insufficient knowledge about effects of infrasonic radiation on a human being and what effects are more noticeable: frequency, intensity or duration.

Evidently, the levels of infrasound less than 110 dB are not very perceptible for a human being. At the same time, the levels of sound pressure in the tested vehicle interior (Table 2) that exceed the Sanitary Norms by 300 times, consequently can be injurious to health, create emergency situations on the road and so on.

Therefore setting the norms for levels of infrasound is undoubtedly important.

But it can be clear seen that for introduction of rather strict requirements for infrasound levels, the comprehensive study is necessary.