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OPERATION OF "RUSSIAN MAGLEV" TRANSPORT SYSTEM AND MEDICAL-BIOLOGICAL SAFETY ASPECTS

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Abstract: The article deals with the analysis of medical and biological safety of the results of work on the design and model-laboratory experiments of "Russian maglev" transport system.

Purpose. The purpose of the work is determination of location and level of field physical characteristics of national magnetic levitation system "Russian maglev", development of scientifically justified preventive-sanitary suggestions and recommendations necessary for design and application of the systems for protection, control and monitoring of hazardous effects of non-radiation physical fields on passengers, personnel and transported cargo and ecology.

Methodology. To achieve the set purpose a review of modern ideas on the influence of constant and low frequency magnetic fields on people was carried out, characteristics of main sources of EMF influence on people during "Russian maglev" technologies operation were studied and described. The obtained results were compared with technical documents on electromagnetic safety.

Results. As a result of this work, hygienic requirements for absolute levels and length of unfavourable factors impact on railway transport were determined, which are not mentioned in the active Sanitary Regulations and Instructions. Considering this, recommendations for the most safety placement of MF for people and safety means in crew vehicle were given.

Practical significance. The significance of this work is that the preliminary work for medical-biological studies in conditions of full-size model was carried out.

Keywords: magnetic levitation transport, permanent and alternating magnetic field, electromagnetic safety

Introduction

Now, in Russia several organisations are engaged in development of magnetic levitation (maglev) technologies: NIIEFA, PGUPS, St. Petersburg Polytechnic University, National Research Institute of Moscow Aviation Institute, and MIIT. But still, national elaborations have not left the stage of design and laboratory experiments.

There are several reasons for that. Let us highlight the most substantial ones: on the administrative and governmental regional levels, there are no confirmed actions and documents on development of maglev technologies, no maglev technologies have been singled out for realisation, no technical requirements base for most aspects has been worked out which are needed for commercial operation of projects, no source data on speed regimes of rolling stock have been determined, no technical and scientific studies are being carried out aimed at studying hazardous effects on passengers, staff and infrastructure workers, population in residential areas with where maglev lines are supposed to be lain.

In the books devoted to elaborations of national technologies and problems of Maglev, we did not succeed in finding convincing evaluations of compliance of calculated data of operation properties of this mode of transport with Russia's active Sanitary Regulations and Instructions, National Standards (GOST), Maximum permissible levels of power and physical parameters, other sanitary and technical data, prescribed in normative and technical documents. Thus, in the studies (2), just like in most similar ones, with the aim to prove operation safety of maglev transport, comparative evaluations of calculated intensities of magnetic fields (MF) and electromagnetic fields (EMF) in environments surrounding the future line of maglev with the current situation in big modern city's streets, urban transport, metro, residential houses and production buildings were presented. Without proper references, the values of intensities of emission of EMF by different working equipment and induction of the Earth's geomagnetic field (GMF). The work is abundant in inaccuracies, for example: the value of GMF is given which is equal to 0.5 μT, though it is a known fact that GMF value is not a constant parameter, but a space and time function, which depends on location of point of measurement on the surface of the Earth, and its value therefore varies from 42 to 70 μT (5). Further in the text, referring to the viewpoint of "Russian scientists" (without actually giving the names), it is maintained that maximum permissible levels of MF (permanent and alternating) for passengers equals 2 μT. This is also an unreliable statement because there are still no national requirements of maximum permissible levels of MF and EMF on transport, whereas in other country's requirements one could see different values of magnetic and electromagnetic safety provision (6, 7). This conflict of information about maglev transport ecological and hygienic impact on human organism is also seen in the works of other authors.

In most national publications, when estimating maximum permissible levels of MF on transport authors apply norms, specified in Russia's Sanitary Regulations and Instructions 2.2.4.3359-16 "Sanitary and epidemiological requirements to physical factors in working places", in which the confirmation of statement is seen, that impact of permanent and alternating physical fields on human organism is unequal and hence maximum permissible levels for different kinds of MF differ by gradation of zone of exposure and exposure dose are: for permanent MF the maximum threshold of exposure is limited to 10 μT, and the induction of EMF magnetic component of lower frequency (when electric and magnetic components are regard independently) is by two orders of magnitude smaller and equal to 0.2 μT.

Of course, during design of maglev transport in terms of power aspect, it would be based on energy-related analysis and calculation of electromagnetic phenomenon, but without correct ecological and hygienic calculations, which impose certain functional and constructive limits on the technology, the implementation of the new mode of transport is impossible.

During the previous maglev transport and systems-related conferences (Saint Petersburg, PGUPS) and in the literature (1 − 4), it was pointed at diversity of application and benefits of implementation of results of national project "Russian Maglev" − the elaborations of the technology designed for intercity passenger mainlines with speeds up to 600 km/h and for freight containers transportation with speeds up to 400 km/h.

For this transport technology, the levitation construction in the form of guideway was proposed. It consists of magnetic rails (MR), made of NdFeB permanent magnet blocks, assembled according to Halbach array and lain along the entire track; maglev bogies with similar onboard Halbach blocks (instead of permanent magnet blocks high-temperature superconductor blocks of 2nd generation can also be used); and traction system based on synchronous linear motor (SLM) with its working elements deployed in the guideway structure along the track and in the vehicle. The proposed system of EMS is based on interaction of currents of magnetic fields from permanent magnets (Halbach array), deployed onboard of vehicles and in MR. There are known variations of application of this technology, when instead of MR the acceleration systems and "reactive" elements of highly-conductive metals were used, deployed in the guideway structure.

In the works within the project "Russian Maglev" it is said about technical developments and experimental researches finding optimal constructive solutions, but approaches and plans of ecological and hygienic researches for evaluation of danger of the proposed constructive options are absent. There are also no specific results of this kind of researches in other countries' publications, dealing with analysis and results of commercial operations of different maglev technologies (6, 7).

The purpose of this work is determination of location and level of field physical characteristics of national magnetic levitation system "Russian maglev", development of scientifically justified preventive-sanitary suggestions and recommendations necessary for design and application of the systems for protection, control and monitoring of hazardous effects of non-radiation physical fields on passengers, personnel and transported cargo and ecology.

Today's ideas about methods of research of permanent and low-frequency magnetic fields on human organism

The lack of full-fledged ecological and medical researches of safe operation of maglev can be explained by a popular stereotype of adaptation of people to magnetic field impact: during the long course of evolution physiological functions of human body have adapted to GMF impact, sun and Earth's magnetic anomalies, man-caused MF, etc. Besides, in the early studies of MF and EMF impacts on living organisms, due to insufficiently developed instruments, the data were received, which stated that levels of permanent MF with induction of less than 2 T do not affect significantly functional systems of humans and animals. Therefore, it has been assumed for a long time, that artificial MF applied in industrial production, science and machinery, medical sphere and NMR and MRI diagnoses do not have any harmful effect (9, 10).

However, in other more modern sources (11, 12) it is said that pathological impact on humans is made not only by intense permanent ($B > 1,5$ T) magnetic fields, but also medium ones ($5*10^{-2}$- 1,5 T), weak ones (10^{-2} - $5*10^{-5}$ T), comparable to GMF, and superweak ones ($B<10^{-5}$ T), one of the mechanisms of performance of which is considered to be weakening of GMF in the biosystem considered.

There are also no common data in the studies of impact of structurally different types of MF (permanent, alternating, uniform, discrete, and gradient) on human and animal organisms.

Today's ideas of MF impact on humans consist in the following: despite human organism having no special magnetic receptors, sensors which react to MF, physiological systems of living organisms are extremely sensitive to permanent variables of MF in quite a wide range of amplitudes and frequencies.

As of today, we are aware of large number of publications with estimation and understanding of results of biological studies of functional impact and mechanisms of performance of MF on different physiological processes. They contain huge experimental material, which proves MF impact on humans in a wide range of intensities and frequencies, suggest reliable explanations of the phenomena surveyed on the level of organism, including informational, biomembrane and other hypotheses, but there is still no a widely accepted answer to the question of mechanisms of impact of MF on humans.

In this chapter, we will dwell upon intergrated results of the studies, carried out at large number of workers who operated in environment with magnetic fields of medium intensity (10^{-1}- 1 T).

It is assumed that, the most sensitive systems to this diapason are regulatory systems – neural, endocrine and cardiovascular. The syndromes of the exposure manifest themselves differently. Among them, the most frequent are: neurasthenic syndrome with autonomic dysfunctions and neurocirculatory disorders, the depth and duration of which are dependent upon exposure dose. A number of authorcardiologists have detected increase of systolic and diastolic blood pressures, heart rate variability, cardiac output, changes in ECG diagram, in full blood exam – decrease of concentration of erythrocytes, haemoglobin, and moderate leukocytosis.

As for the symptoms, headaches, increased fatigability, irritability, decrease of workability were most widespread. Among the latent consequences, there were development of oncological neoplasms, leukaemia, hormonal pathologies.

In several works, devoted to comparative study of low-frequency and permanent MF impact on human body, it is reported on high risk of development of above-mentioned pathologies under exposure of relatively less intense permanent MF.

Results of studies of properties of basic EMF sources in the technology ”Russian Maglev”

Almost all modern transport systems are equipped with complex power supply and information equipment that consumes and radiates electromagnetic energy.

On maglev transport apart from high-energy magnetic suspension facilities and traction motor, devices with electronic and electrotechnical elements of communication, control, automatics are widely used. Their operation is bound with EMF radiation of different intensity, frequency, and direction to the environment.

Thus, passengers, staff, technicians of maglev transport, who do repairs and preventive works on the line and infrastructure facilities, are exposed to non-ionising electromagnetic radiation, whose value and dose of exposure may significantly exceed maximum permissible level and dose of presence in hazardous zone, thus damaging human health.

General sources of permanent MF in “Russian Maglev” trains are Halbach arrays, which are part of the construction of levitation system. The arrays are located under bottom of vehicles and in guideway structure (MR).

Apart from them, work of powerful traction system of LSM, including active stator track winding located along the entire line, and rotor, magnet system made of Halbach blocks located in the vehicles, greatly contribute to the field load of vehicles and environment.

Track winding is a system of contours with phase currents shifted relatively to each other, lain in the track structure with a period τ. This system of contours creates a periodic sinusoidal distribution of currents along the track or track sections, finally resulting in a running MF.

Rotor, the onboard Halbach magnetic system, is assembled of NdFeB magnet blocks of size 50x50x500 mm and owing to interaction with running MF of stator ensures movement of vehicle at speed dependent on frequency of track winding power supply: $V = 2 \cdot f \cdot \tau$.

Other sources of EMF in the zone of maglev trains operation are radiations, created by vehicle equipment of control and communication, cables, switchboard buses, PC screens, and other devices. In our work, we would like to limit ourselves with studying field topography of permanent and alternating MF, generated by levitation and traction systems.

Levels of induction of permanent MF in a vehicle (Table 1) were evaluated in accordance with experimental data obtained during measurement of induction around Halbach blocks by virtue of Teslaampermeter F4354/1 (inaccuracy is from 2.5% till 10 %). Levels of induction of stator alternating MF (Table 2) were calculated theoretically by model of LSM, described in (2). At the same time, optimal constructive and power parameters of the LSM under design were set as follows:

- change of velocity of vehicles from 0 till 111 m/s (400 km/h);
- polar pitch $\tau = 0.5 \cdot \pi \cdot h = 0.2$ m, corresponds to obtaining maximum traction of motor and optimal levitation clearance h = 0.13 m;
- frequency of running MF $f = \frac{V}{2 \cdot \tau} = 2.5 \cdot V$ (Hz);
- location and power supply of the system of three-phase contours of stator winding (phase current power is $I = 2.5 \cdot 10^3$A) ensured sinusoidal running MF.

Table 1. Levels of induction of permanent MF dependent on the distance to the surface of Halbach block

z *, м	B, μT
0	800
0.1	40
0.2	5

*z – distance to the surface of Halbach blocks

Table 2. Levels of induction of alternating MF dependent on the distance to stator

Z, m	B, μT
0.1	300
0.2	180
0.3	61
0.4	13
0.5	3
0.7	~1

Comparing these two options, we come to conclusion that a more remote action of MF will be produced as a result of work of LSM. At the same time, if a maglev train runs in rapidly changing conditions (wind, falls, etc.) the work of the motor will not be the same. Consequently, the properties of MF will also vary.

The Table 3 shows changes of induction of MF dependent on current frequency.

Table 3. Control levels of alternating MF (root mean square values of MF)

Frequency range, Hz	Approximate velocity	Magnetic induction, μT
<1	<0,4 m/s	40
1–8	0,4 – 3,2 m/s	40–5
8–25	3,2 – 10 m/s	5–0,2
25–280	10 – 112 m/s	0,2–0,02

However, till nowadays the question of levels of human body tolerance and adaptation capabilities when placed in a zone of stochastic fickleness of alternating MF has not been solved yet. To solve this problem, experiments with characteristics similar to calculated characteristics of LSM for acceleration, maintenance of speed and braking are needed. Today, such “magnetic storm” have long-term exposure only drivers of transport with electric motors. For this category of workers, regular medical examinations, rehabilitation activities, etc. are envisaged. Bearing in mind construction features of maglev trains (small gap between MR and vehicle, construction of motor, etc.) we could assume that all passengers of these trains might be placed in these conditions. One of options of technical protection should be taken: construction methods, compensation, shielding, etc. It will become possible to recommend the most efficient method, when experimental studies have been carried out, since as of today there are few publications on MF impact on humans.

Practical significance of the work on improvement of normative and technical documents of electromagnetic safety provision

In Russia, usually hygienic regulation of MF and EMF is carried out according to threshold principle. According to this principle, the minimum intensity of field physical factor is taken as a harmful factor. When this factor occurs, organism suffers morphological and functional changes, going beyond limits of adaptation and compensation reactions of homeostasis. The presence of these changes is detected instrumentally or by means of laboratory and clinical methods while examining changes of functional changes of living organisms’ systems (humans and animals) both during exposure of the factor and after it. The Table 4 gives maximum permissible levels of permanent MF stipulated in the active Sanitary Regulations and Instructions 2.2.4.3359-16 “Sanitary and epidemiological requirements to physical factors in working places”, which should be abided by when constructing maglev trains.

Table 4. Maximum permissible levels (MPL) of MF at working places

Time of exposure per one working day, min	Conditions of exposure			
	Common		Local	
	MPL of excitation, кА/м	MPL of magnetic induction, μT	MPL of excitation, кА/м	MPL of magnetic induction, μT
10	24	30	40	50
11-60	16	20	24	30
61-480	8	10	12	15

Thus, comparing data of tables 1, 2 and 4 we come to conclusion that if the impact of a permanent magnet field on a passenger is supposed to meet the Sanitary Regulations and Instructions at time travel no less than one hour , the source of permanent magnetic field should be placed at a distance of at least 20 cm from a human. While the source of alternating magnetic field (stator) should be placed more than 40 cm away from human beings. And these are MPL for workers, not for passengers! People who are not engaged in production processes should be located at bigger distances with less time of exposure.

Plenty of hygienists consider the application of the threshold principle for the justification of hygienic standards as disputable, since the physiological sensitivity of individual elements of the structure of the functional system under study to external influences can vary significantly. Thus, for instance, in separate studies of behaviour of the central nervous system (CNS) and the autonomic nervous system (ANS) in weak and superweak MF and EMF with intensities of several orders of magnitude lower than those set by MPL, functional and polymorphic changes of regulatory and informational systems in the background of a favourable integrative index of the physiological norm of homeostasis were seen.

In this regard, in our opinion, in order to identify the disorders in the activity of the ANS, which is most sensitive to impact of unfavourable external factors, it is reasonable to use approved methods for determination of functional state of organism on a polysystematic level for identifying possible individual reactions to MF. To achieve this, monitoring systems of physiological, psychophysiological (a device for studying human psychomotor activity) and biochemical (laser correlation spectroscopy) indexes (13, 14) are used. This will make it possible to make more accurate recommendations for the design of the Maglev train in terms of medical and biological safety of both the staff and passengers.

Conclusion

The results of the works enabled making the following conclusions on medical and biological safety of people:

- The studies have demonstrated that the most severe impact on the nervous system is made by alternating magnetic field, which changed in a stochastic way.
- It is necessary to carry out experiments on impact of alternating EMF with calculated characteristics of maglev for different phases of traffic.
- Basing on the conducted studies, Sanitary Regulations and Instructions of impacts of non-radiation field characteristics on transport for passengers and staff should be worked out.
- Placement of means of protection from electromagnetic field in vehicles (construction, compensation, and shielding methods) should be recommended.

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