Engineering and Technical Solutions for Ensuring Security at Social Facilities

A V Zvyagintseva1, S A Sazonova2, A M Zaitsev2
1Department of Chemistry and Chemical Technology, Voronezh State Technical University, 84 October 20th Anniversary Street, Voronezh, 394006, Russia
2Department of Technosphere and Fire Safety, Voronezh State Technical University, 84 October 20th Anniversary Street, Voronezh, 394006, Russia

E-mail: zvygincevaav@mail.ru

Abstract. Engineering and technical solutions to ensure fire safety of the building and protection of people by deterministic factors have been installed. The object of research is a building of public social purpose. Constructive and planning solutions for preventing the spread of fire in the building of an object of class K0 for fire danger are diagnosed. The enclosing structures of the room must have a fire resistance index of at least REI 150. Technical solutions for evacuation routes and passageways, equipment that guarantees reliable protection from fires, communication in the building, ensuring procedures that implement the effective functioning of the fire Department to eliminate the source of fire have been formulated. Technical solutions for fire protection and communication systems of the building are justified in detail. Compensating measures are recommended for public buildings with an excess of the standard height and in the presence of six underground floors. It is specifically recommended to increase the fire resistance limits of load-bearing structures, stiffness cores – stair and elevator nodes and fire barriers to R/REI 180 and to provide the building with a type 5 warning system.

1. Providing procedures that implement the stability and protection of the object from fires.

Fixing the fire resistance rating of an object

In accordance with paragraph 44 of article 2 of Federal law No. 123-FZ, the degree of fire resistance of a building is determined by the fire resistance limits (P, min.) of its structures [1]. Fire resistance of the object should be recognized as guaranteed, provided that the fire protection regulations are implemented [2]:

\[ P \geq P_{req}, FSO \geq TSO, \]

\( P_r \) and \( P_{req} \) are the actual and prescribed limit indicators of object fire resistance, min.; \( FSO \) and \( TSO \) are the real (actual) and prescribed (required) indicators of fire resistance.

The required degree of fire resistance of a multifunctional shopping and office center depends on the height of the building and the maximum floor area of all its parts of various functional fire hazards.

Considering that the height of the building is more than 50 m, according to table 6.9 [3], we accept the required degree of fire resistance of the building as I. Analysis of the compliance of the architectural and construction part of the design with fire protection and the development of engineering and technical solutions to ensure safety at social facilities in the service sector, is
regulated by normative documents [1-11]. It should be noted that during the inspection, inventory of objects of the social, technical sphere of vital activity, the strategic component during their implementation, regulatory documents are recorded, for example SNiPs, GOSTs, standards, and so on, regardless of the object profile [12, 13, 14, 15].

We can note the studies in [16, 17, 18, 19, 20] devoted to the processing of mercury-containing waste and the development of environmental measures and rational consumption of water resources. In publications [21, 22, 23, 24, 25], designating an important branch of the technical sphere that has geopolitical significance, such as radio engineering and the radio-electronic industry, for example [26, 27, 28, 29, 30], when verifying complex functional blocks in CAD for microchips, deep submicron design standards are due to technological regulations for the required indicators of RTS for any purpose in further design. In [31, 32, 33, 34, 35] the development of automated control systems for monitoring the safety parameters of thermal power plants for thermal power plants is highlighted, and in [36, 37, 38, 39, 40] the regulation of technological risk by optimizing the equipment maintenance program is highlighted. You can also pay attention to [41, 42, 43, 44, 45] aimed at improving the technological regulations of the field of functioning, the ultimate goal of which is to ensure its fire safety. In [46, 47, 48, 49, 50] the variants of information technologies for the preventive guarantee of safety at life objects are shown. In [51, 52, 53] social support of citizens is positioned when they apply to state organisations.

In this regard in our study we carried out an examination of a specific object of the social sphere in accordance with the regulations and prescriptions.

2. Audit for verification of the fire protection regulations compliance

The results of the audit are presented in table 1.

| № | Structure name           | Accepted by the design P_f,min | Required by standards K_f | P_req, min | K_req | Conclusion on compliance |
|---|--------------------------|--------------------------------|---------------------------|------------|-------|--------------------------|
| 1 | Support walls            |                                |                           |            |       |                          |
| 1.1 | External                | R180                          | K0                        | R120       | K0    | conf.                    |
| 1.2 | Internal                 | R180                          | K0                        | R120       | K0    | conf.                    |
| 1.3 | Fireproof                | R180                          | K0                        | R120       | K0    | conf.                    |
| 2  | Columns                  | R180                          | K0                        | R120       | K0    | conf.                    |
| 3  | External bearing walls   | E60                           | K0                        | E30        | K0    | conf.                    |
| 4  | Internal walls of staircases | REI180                     | K0                        | REI120     | K0    | conf.                    |
| 5  | Flights and platforms of stairs | R60                          | K0                        | R60        | K0    | conf.                    |
| 6  | Floor elements           |                                |                           |            |       |                          |
| 6.1 | Interfloor and attic     | REI120                       | K0                        | REI60      | K0    | conf.                    |
| 6.2 | Fireproof                | REI180                       | K0                        | REI150     | K0    | conf.                    |
| 7  | Coating elements         |                                |                           |            |       |                          |
| 7.1 | Floorings                | RE30                         | K0                        | RE30       | K0    | conf.                    |
| 7.2 | Beams, crossbars, frames, trusses | R30                         | K0                        | R30        | K0    | conf.                    |

3. Results of verification of compliance with fire requirements

During the compliance check of the multifunctional shopping and office center, the following violations of the requirements of fire safety norms and rules were revealed:

- the height of the building exceeds the maximum allowable height for public buildings - 50 m (clause 6.6.1 table 6.9 set of rules (SP) 2.13130.2009) [3];
- the area of the fire compartment of the public part of the building exceeds 5000 m² (clause 6.8.1, table 6.11, note 2 SP 2.13130.2009) [3];
• the permissible number of floors in the underground parking lot (6 floors) has been exceeded (clause 6.3.1, table 6.5 SP 2.13130.2009) [3];
• the elevators that connect the underground and aboveground parts of the complex are provided for communication between the storage rooms of vehicles with premises for other purposes, (clause 6.11.7 SP 4.13130.2009) [5];
• in the isolated ramps of the underground parking there are no bulkhead rooms with air pressure in case of fire (clause 6.11.7 SP 4.13130.2009) [5];
• there are no platforms on the H1 type stairs in the building, which guarantee protection from smoke (clause 4.4.12 SP 1.13130.2009) [7];
• the building has staircases common for two fire compartments, including those for different functional purposes (clauses 4.4.6, 4.4.8 SP 1.13130.2009) [7];
• the staircases are provided without light openings (clause 4.4.7 SP 1.13130.2009) [7];
• the escalators (travelators), combining three levels of floors with public premises of functional fire hazard class F 3 with elevation from -4.80 to mark 4.80 are provided (p. 4.4.14, 4.4.15 SP 1.13130.2009) [7];
• 1 emergency exit is provided from the bank premises (area 475 m²) (clause 4.2.2 SP 1.13130.2009) [7];
• there are elevators in the building that descend below the first floor (clause 4.4.5 SP 1.13130.2009) [7];
• the size of the basic evacuation routes on the trading floors of the supermarket is not specified (clause 7.2.4 of SP 1.13130.2009) [7];
• there is no information about the height and width of evacuation exits (clause 4.2.5 SP 1.13130.2009) [7];
• there is no information about the size of stairs (clause 4.4.2 of SP 1.13130.2009) [7];
• there is no information about self-closing mechanisms and seals in door vestibules in the stairwells (clause 4.2.7 of SP1.13130.2009) [7];
• there are no external fire escapes (article 90, item 1 (item 2) of Federal law No. 123-FZ) [1];
• there is no access of fire equipment to each room outside the building (Article 90, clause 1of Federal law No. 123-FZ) [1];
• there is no information about the presence of the roof fencing (Article 90, item 16 of Federal law No. 123-FZ) [1].

According to the identified violations of fire protection requirements in the following sections of the explanatory note, engineering and compensating measures have been developed, as well as calculated justifications of fire protection systems have been performed.

4. Design and planning solutions to prevent the spread of fire in the building
1. The load-bearing elements of the building frame must serve as a guarantee of integrated aggregate fundamentality and inviolability, as well as topological non-deformability in geometric shape in the event of a fire.
2. In fire barriers, materials of the non-combustible group and building structures of class K0 for fire hazard should be used.
3. Heat and sound insulation of premises, equipment and pipelines should be provided from materials of non-combustible or low-combustible groups.
4. Use only non-combustible materials for finishing walls, ceilings and floors in the fire compartments of the parking lot.
5. The required limits of fire resistance of translucent structures of facades may be ensured by applying:
   • structures with the required fire resistance limit;
   • irrigation systems.
6. The use of hinged facade systems with a ventilated air gap is allowed if they have technical certificates for use in high-rise buildings. It is preferable to use a spider system with tempered glass or triplex filling.

7. The fire resistance limit of facade systems structures must be confirmed by references to fire test reports, regulatory documents or reference manuals in the field of design and construction, and in their absence - determined by calculation.

8. To protect the openings in the lift shafts for fire brigades transportation for the installation of type 1 (EI 60) fire-prevention two-rails in a smoke and gas tight design ensuring the resistance to smoke and gas penetration of at least 50,000 kg l\(^{-1}\) m\(^{-1}\) should be provided. To protect the openings of insulated ramps in the underground parking lot, provide for the protection of openings with fire gates with a fire resistance index of at least EI 60 with irrigation with deluge curtains in two strands with a flow rate of at least 1 l/s per running meter of curtain length.

9. To prevent the spread of fire along the facade, one of the following protection options must be provided:
   - arrangement of canopies and projections 60 cm wide, provided that an additional irrigation system for the inner perimeter of the glazing or fire curtains is performed;
   - protection of window openings of the floor above the fire-prevention ceiling with fire-prevention curtains.

10. Placement of explosive and fire hazardous premises belonging to categories A and B within the building is not allowed.

11. Placement of transformer substations (if necessary, such a design solution) is allowed only on the first above-ground or first underground floors with an exit from these premises directly outside. On technical floors it is allowed to install dry transformers with a capacity of up to 630 kVA.

12. The underground parking lot for fire hazard should be classified as category B for fire hazard. Separate boxes in the car park are not allowed.

13. When placing the premises of storey distribution boards in the cores of the building's stiffness, cable power grids to them must be laid in metal pipes or closed boxes and have incisions at the level of floor slabs.

14. Built-in transformer substations, generator, battery should be placed near the outer walls of the building, not lower than the 1st underground floor, allocating them to the fire compartments.

15. Built-in rechargeable batteries should be located near the outer walls of the building, providing for opening openings (windows) in them. The enclosing structures and exits from the built-in battery substations should be provided in accordance with the requirements. When designing a diesel generator set, ensure compliance with the requirements of the "Norms for technological design of diesel NTPD-90 power plants". If a diesel generator is used as an independent power supply source, it is allowed to install it in a built-in room. At the same time, the building envelope must have a fire resistance indicator of at least REI 150. The building must have a free exit outside of it. A tank (double-walled tank) with a fuel supply with a capacity of no more than 5 m\(^3\), it is allowed to be placed in a separate built-in room.

16. Premises for loading or delivering goods may have sliding or lift-and-slide doors and gates with non-standardized fire resistance in the openings of the outer walls, provided that evacuation is ensured bypassing these premises.

17. Pumping stations of fire extinguishing systems should be located no further than the 1st buried tier and have an exit to the staircase leading to the outside or directly to the outside.

5. Technical solutions to ensure procedures that implement the effective functioning of the fire department to eliminate the fire source

1. Entrances and driveways for fire ladders and car lifts should be provided as roads not lower than category IV according to SNiP 2.05.02-85 [11]. In places where automatic ladders and a car lift are installed, their slope should not be more than 60.
2. The distance from the facility to the nearby fire station should not exceed 2 km. If the specified distance is exceeded, provide for a fire-prevention group with round-the-clock duty at the facility, or provide for the construction of a fire station, the composition and fire-technical equipment in any case must be agreed with the State Fire Service of the Ministry of Emergency Situations of Russia in the Moscow region.

3. Water consumption for external fire extinguishing should be at least 100 l/sec, from fire hydrants on the ring network of the external water supply.

4. Hydrants should be located near building exits and parking exits. The building must be within a range (150 m) of at least four fire hydrants. The locations for the installation of hydrants are determined in accordance with the fire extinguishing plan, taking into account the location of the gas station.

5. In the building, provide for fire extinguishing support points (premises) - for the parking lot and for the high-rise part of the building, equipped with primary fire extinguishing means.

6. On each floor of the building from mark -4.80 to mark 63.30 fire shelters should be provided. Fire shelters should be provided near the elevators for fire departments. An elevator hall with an area of at least 20 m² with air pressure in case of fire can be used as a fire shelter. The area of fire shelters on the floor of the fire compartment should be designed for the number of people, which is at least 2.5% of the possible number of evacuees, based on the specific area per 1 m² rescued. Fire shelters should be provided with personal respiratory protection.

7. The distance from the outer walls to the parking lots and other buildings and structures (except for the attached gas station) should be provided in accordance with the requirements of the technical regulations.

8. Exit to the roof of the building should be provided by flights in the volume of two staircases.

9. It is recommended to organize a fire post at the facility. The staffing table and equipping the fire post with fire-technical equipment should be determined by the customer at the stage of detailed design and agreed with the State Administration of the State Fire Service of the Ministry of Emergency Situations of Russia for the Moscow region.

10. Sites for operational vehicles, including a helicopter landing site, should be provided by the order of the State Fire Service of the Ministry of Emergency Situations of Russia for the Moscow Region during the development of the general layout of the facility. Requirements for the arrangement of sites should be formed on the basis of an operational fire extinguishing plan developed by the beginning of work on the improvement of the site.

6. Development of compensating measures

1. Exceeding the standard height of a public building and the presence of six underground floors:
   - increasing the limits of fire resistance of load-bearing structures, stiffening cores - staircase-lift nodes and fire barriers up to R/REI 180;
   - providing each fire compartment of the building with lifts for fire departments transportation;
   - providing the building with a type 5 warning system;
   - providing each fire compartment of the building with a full range of fire protection systems.

2. Exceeding the maximum permissible size of the fire compartment area in the part of the building with public premises:
   - increasing the intensity of irrigation of the sprinkler fire extinguishing system up to 0.12 l/s.m²;
   - the protection of the opening for the installation of escalators in the interfloor ceiling is provided along the perimeter with a curtain that protects against smoke, in combination with a deluge barrier in two strips with a consolidated generalized consumption of at least 1 l/s per linear meter of the length of the barrier for 60 minutes.

3. Application for the evacuation of H2type stairwells without natural lighting:
   - equipping staircases with container devices for issuing respiratory protection equipment;
   - providing stairwells with constant artificial lighting, with the application of the requirements for the lighting wiring, as for the wiring of the fire protection system.
4. Organization of staircases common to two fire compartments, including those for different functional purposes: provision is made for the construction of corridors or bulkhead rooms with air pressure in case of fire in front of the floor entrances to the stairwells.

5. Lack of air-locks in isolated ramps of the underground parking:
   - allocation of ramps into independent fire compartments, provision of parking ramps with air pressurization systems in case of fire,
   - openings are protected by fire doors with a fire resistance index of at least EI 60 with irrigation with deluge curtains in two strands with a flow rate of at least 1 l/s per running meter of curtain length.

6. Arrangement of escalators uniting three levels of floors with public premises of functional fire hazard class F 3 from mark -4.80 to mark 4.80: the protection of the opening for the installation of escalators in the inter floor ceiling is provided along the perimeter with a curtain that protects against smoke, in combination with a deluge barrier in two strips with a consolidated generalized consumption of at least 1 l/s per linear meter of the barrier length for 60 minutes.

7. Lack of access for fire fighting equipment to every room outside the building due to solid facade glazing:
   - providing each fire compartment of the building with lifts for the transportation of fire departments;
   - all staircases are equipped with dry pipes, with the installation of connecting pipes on each floor.

8. Availability of lifts connecting the underground and aboveground parts of the complex: elevators providing communication between the underground and aboveground floors of the building are provided with binary vestibules - gateways in the underground part of the building.

7. Conclusion

1. When developing a comprehensive fire protection for a multifunctional shopping complex, the task was to apply the fire safety requirements contained in the current regulatory legal acts without fail.

2. In the course of the work an assessment of the design solutions compliance for the construction of a multifunctional shopping complex with fire safety requirements was made. As a result, a number of violations of the regulatory legal acts requirements, such as the absence of windows with pits in basements, a vestibule-gateway, a gap between flights of stairs, etc. were identified. In relation to the identified violations engineering, technical, organizational, operational and compensatory measures were developed.

3. It is recommended from the design and planning solutions:
   - In fire barriers, materials of the NG group and building structures of the K0 class for fire hazard should be used.
   - Heat and sound insulation of premises, equipment and pipelines should be provided from the materials of the group of combustibility of NG, G1.
   - To protect the openings in the Elevator shaft elevators for transportation of fire subsections to provide for the installation of fire doors of the 1st type (EI 60) in dymogazonepromitsaemye performed with providing resistance damage arising at least 50,000 kg·m⁻¹.

4. Recommended from the technical solutions:
   - Evacuation in the building should be carried out by non-smokable stairwells of type H2.
   - The alarms are fixed at intervals of height after a maximum of 6 m at a maximum of 300 mm from the top of the opening leading to the lobby in front of the elevator.

5. Compensating measures have been developed for social buildings, provided that the standard height of the building is exceeded and there are six underground floors:
   - Increasing the fire resistance limits of load-bearing structures, stiffness cores – stair and elevator nodes and fire barriers to R/REI 180.
   - Providing the building with a type 5 notification system.
5.3. If the maximum permissible size of the fire compartment area is exceeded in a part of the building with public premises, increase the irrigation intensity of the sprinkler fire extinguishing system to 0.12 l/s m².

5.4. These solutions include: the installation of an additional type 2 firewall and the installation of folding escape stairs.

8. References

[1] Federal Law of 22.07.2008 No 123-FZ Technical Regulations on Fire Safety Requirements
[2] GOST 12.1.004-91 Fire safety General requirements
[3] SP 2.131.30.2009 Fire protection systems. Ensuring fire resistance of protected objects
[4] Order of the Ministry of Emergency Situations of Russia No 382 On approval of the methodology for determining the calculated values of fire risk in buildings, structures of various classes of functional fire hazard
[5] SP 4.131.30.2009 Fire protection systems. Limiting the spread of fire at the objects of protection. Requirements for space-planning and structural solutions
[6] SP 12.131.30.2009 Definitions of categories of premises, buildings and outdoor installations for explosion and fire hazard
[7] SP 1.131.30.2009 Fire protection systems. Evacuation routes and exits
[8] SP 7.131.30.2009 Heating, ventilation and air conditioning. Fire safety requirements
[9] "AVOK" association of engineers recommendatons 5.5.1 2010 Calculation of the parameters of smoke protection of residential and public buildings 43
[10] Rules for electrical installations Edition 7 Access mode: https://tech-expo.ru/pue/
[11] SNiP 2.05.02-85 Highways
[12] Zvyagintseva A V, Tenkaeva A S and Mozgovoy N V 2015 Bulletin of the Samara Scientific Center of the Russian Academy of Sciences 17(5) 276-282
[13] Dolzhenkova V V and Zvyagintseva A V 2015 Bulletin of the Samara Scientific Center of the Russian Academy of Sciences 17(6) 70-81
[14] Zvyagintseva A V and Samofalova A S 2020 AIP Conference Proceedings 2313 060020
[15] Zvyagintseva A V 2020 Bulletin of the Russian Academy of Sciences: Physics 84 9 1097-9
[16] Zvyagintseva A V 2020 IOP Conference Series: Materials Science and Engineering 919 62054
[17] Zvyagintseva A V 2020 International Journal of Hydrogen Energy 45, 46 24991-25001
[18] Zvyagintseva A V and Kravtsova Y G 2007 NATO Security through Science Series A: Chemistry and Biology 661-4
[19] Zvyagintseva A V and Kravtsova Y G 2007 NATO Security through Science Series A: Chemistry and Biology 665-9
[20] Zvyagintseva A V, Sazonova S A, Kulneva V V, Asminin V F and Zyazina T V 2021 IOP Conference Series: Materials Science and Engineering 1047(1) 012192
[21] Manokhin V, Sazonova S, Nikolenko S and Zvyagintseva A 2020 Lecture Notes in Civil Engineering 70 37–53
[22] Sysoev D V, Sysoeva A A, Sazonova S A, Zvyagintseva A V and Mozgovoy N V 2021 IOP Conference Series: Materials Science and Engineering 1047(1) 012195
[23] Zvyagintseva A V, Sazonova S A and Kulneva V V 2020 IOP Conference Series: Earth and Environmental Science 459(5) 052047
[24] Zvyagintseva A V, Kulneva V V and Sazonova S A 2020 IOP Conference Series: Materials Science and Engineering 919(6) 062053
[25] Zvyagintseva A V, Samofalova A S, Sazonova S A and Kulneva V V 2020 Journal of Physics: Conference 1679(2) 022076
[26] Zvyagintseva A V, Sazonova S A, Kulneva V V and Panteleev I N 2020 IOP Conference Series: Materials Science and Engineering 919(6) 062034
[27] Zvyagintseva A V, Sazonova S A, Kulneva V V and Panteleev I N 2020 IOP Conference Series: Materials Science and Engineering 919(6) 062036
[28] Zvyagintseva A V, Sazonova S A and Kulneva V V 2020 IOP Conference Series: Materials Science and Engineering 962(4) 042045
[29] Zvyagintseva A V, Sazonova S A and Kulneva V V 2020 IOP Conference Series: Materials Science and Engineering 962(4) 042066
[30] Zvyagintseva A V, Sazonova S A and Kulneva V V 2020 IOP Conference Series: Materials Science and Engineering 962(4) 042067
[31] Kulneva V V, Zvyagintseva A V and Sazonova S A 2021 IOP Conference Series: Earth and Environmental Science 666(2) 022035
[32] Zvyagintseva A V, Sazonova S A and Kulneva V V 2021 IOP Conference Series: Earth and Environmental Science 666(2) 022036
[33] Kulneva V V, Zvyagintseva A V, Sazonova S A and Akamsina N V 2020 Journal of Physics Conference Series 1679(2) 022077
[34] Skripachev O V and others 2020 Remote Sensing Applications: Society and Environment 19 100328
[35] Skripachev O V and others 2020 Remote Sensing 12 371 1-31
[36] Mezhova L, Lugovskoy A, Gladkiy Yu, Glazyeva A, Sushkova O, Vampilova L, Sokolova A, Lugovskaya L 2020 South of Russia: ecology, development 14 98-110 10.18470/1992-1098-4-98-110
[37] Tereshchenko M A, Bychenok V I, Mozgovoi N V 2009 Thermal Engineering 56 6 522-5
[38] Zolnikov V K, Kryukov V P, Achkasov V N and Smerek V A 2011 Modeling of Systems and Processes 1-2 24-6
[39] Zolnikov V K 2012 Modeling of Systems and Processes 1 7-30
[40] Zvyagintseva A V Alternative Energy and Ecology 2017 16-18 (228-230) 89-103
[41] Yankov A I, Smerek V A, Kryukov V P and Zolnikov V K 2012 Modeling of Systems and Processes 1 92-5
[42] Kuzminov A, Sakharova L, Stryukov M and Zolnikov V K 2020 IOP Conference Series: Earth and Environmental Science 595(1) 012007
[43] Novikov A I, Zolnikov V K and Novikova T P 2021 Inventions 7 6(1) 1–11
[44] Sakharova L, Stryukov M and Zolnikov V K 2018 Journal of Physics: Conference Series 973(1) 012045
[45] Belokurov V P, Belokurov S V and Zolnikov V K 2018 Transportation Research Procedia 36 44-9
[46] Smolentseva T E, Sumin V I, Zolnikov V K and Lavlinsky V V 2018 Journal of Physics: Conference Series 973(1) 012045
[47] Belokurov S V, Belokurov V P, Zolnikov V K and Cherkasov O N 2017 Transportation Research Procedia 20 47-52
[48] Beskopylny A, Chukarin A and Isaev A 2019 Advances in Intelligent Systems and Computing 983 489–95
[49] Beskopylny A, Chukarin A, Meskhi B and Isaev A 2021 Transportation Research Procedia 54 39–46
[50] Litvinov A E, Novikov V V, Solod S A and Chukarin A N 2019 Russian Engineering Research 39(2) 158–9
[51] Chukarin A N, Beskopylny A N and Isaev A G 2019 Bezopasnost' Truda v Promyshlennosti 2019(11) 7–12
[52] Neklyudov L M, Morozov O M, Kulish V G, Zhurba V I, Khaimovich P A, Galitskiy A G 2011 International Journal of Hydrogen Energy 36 1 1192-1195
[53] Yaitsekov I and Chukarin A 2019 Akustika 32 92–6