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Noise protection from diesel generator units in a residential construction territory

Protección contra el ruido de las unidades generadoras de diésel en un territorio residencial de construcción

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ABSTRACT

Introduction: The article deals with the issues of protection against noise and vibrations of engineering equipment, which spread into the residential area through ventilation shafts, and the problems of bringing noise to standards during the operation of diesel generators. The purpose of this work was the development and implementation of methods and means to reduce the vibration levels of the walls of the technological room in which the diesel generator set was installed. **Materials and Methods**: The article presents studies using computational and graphical and resonance and statistical methods. Measurements of the noise level from the operation of a diesel generator located on the site of the residential buildings under consideration, as well as in residential premises, were carried out. **Results and Discussion**: The estimated calculation showed that the noise levels on the territory do not meet the requirements of sanitary standards. The results of measurements of the sound pressure level before and after noise protection measures for an individual living space gave an assessment of the qualitative and quantitative ratio of the accepted and new types of measures and materials. **Conclusions**: The effectiveness of vibration isolation of engineering equipment depends on the applied vibration isolation scheme; the wrong choice of vibration isolation scheme can lead to an uncontrolled increase in the amplitude of vibrations of the foundation of engineering equipment. To eliminate low frequencies, it is necessary to install vibration isolating supports under the foundation of the diesel generator set.

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INTRODUCTION

Ensuring a favorable environment in residential buildings is an urgent task of construction physics. Including a comfortable acoustic environment for buildings located in close proximity to engineering and technical equipment, which are a source of increased noise. What does this factor of discomfort - increased noise background, created by engineering equipment designed to maintain the specified parameters of the microclimate of the premises(1).

Experience shows that the task of reducing noise and vibration, as well as many other tasks of maintaining optimal life-support conditions, must be addressed from the earliest stages of design to the completion of equipment installation. One of the topical issues in individual residential construction is to provide the building with uninterrupted power supply, in this regard, there is a need for autonomous sources that operate independently of centralized electricity supply points. One of the best solutions is the use of diesel generator sets (DGS), which are able to provide electricity to buildings and construction sites, in accordance with the requirements of the relevant building regulations. When installing a DGU indoors, next to residential and public buildings, it is necessary to take into account a number of related installation and operation rules. This is not only about building structures that must withstand the load corresponding to the weight of the equipment, but also the design of premises, taking into account non-violation of optimal comfort conditions. The level of sound pressure produced by an open DGU at a distance of 1 m is 100-108 dB (A). Excessive exposure to noise can cause a serious, permanent condition known as noise-induced hearing loss. Some residents are more susceptible to higher noise exposure than others(2).

Ensuring acoustic comfort in residential buildings is an important task, the solution of which must be ensured at the design stage of the building in order to avoid complaints from the population(3). The research is devoted to the issues of noise protection in the use of diesel generators in residential construction, which generally refers to the issues of noise suppression of power equipment.

The reduction of noise impact, including in the energy sector, should be considered when solving a set of problems to prevent the growing environmental crisis of modern technogenic civilization. This problem of increased noise from equipment can be considered both in the medical aspect (sleep disturbances, fatigue and decreased performance, and as a result, the effect on the nervous and cardiovascular systems), as well as in the socio-economic aspect (large scale of excessive noise pollution in large cities, occupational diseases associated with noise exposure and liquidation costs). An increase in the noise level by 1-2 dBA leads to a decrease in labor productivity by 1% (at sound levels above 80 dBA). Noise from energy facilities can be a source of exceeding sanitary standards within a radius of several kilometers.

MATERIALS AND METHOD

Engineering equipment installed in residential, public and auxiliary buildings is a source of airborne noise and vibration. Airborne noise and vibrations, propagating along the building envelope, as well as through various communications (pipelines, walls of channels and shafts in the building), are radiated by them in the form of structural noise into adjacent premises and into the territory of residential development.

If the user of the generator will set intends to use an unsuitable room, then soundproofing will be more laborious and costly. Modern residential multi-storey buildings are equipped with a large amount of engineering equipment(4). Protection from structural noise should be carried out by methods of acoustic vibration isolation of engineering equipment and its communications.

Ways to solve the problems of noise from engineering equipment have been studied in general, although, of course, in each case, control measures are considered depending on the quantitative and qualitative characteristics of both equipment and materials and the type of enclosing structures. Any sound insulation is based on 4 principles: absorption, blocking, refraction, isolation(5).

The article presents studies using computational and graphical and resonance and statistical methods. The purpose of this work was the development and implementation of methods and means to reduce the vibration levels of the walls of the technological room in which the diesel generator set was installed. During the measurements the following results were obtained: the highest levels of floor vibration occur in the area of the nearest wall.

RESULTS AND DISCUSSION

In this article, we consider two different examples of a house (ILC-1 and ILC-2), where the standard values from the operation of a diesel generator set were exceeded. Measurements of the noise level from the operation of a diesel generator located on the site of the residential buildings under consideration, as well as in residential premises, were carried out.

Table 1. Values of measured SPL at night (23:00) in ILC-1.

Place of measurement	Sound pressure levels, dB in octave frequency bands with geometric mean frequencies, Hz									Sound levels, dBA	
	31.5	63	125	250	500	1000	2000	4000	8000	L_A eqv	L_A max
Permissible levels in the territory adjacent to a residential building	78	62	52	44	39	35	32	30	28	40	55
1 meter from the facade of the house ILC-1	58	85	68	62	54	53	51	45	38	62	64
Exceeding the permissible level	-	23	16	18	15	18	19	15	10	22	9
Permissible levels of living rooms of houses at night	67	50	39	30	24	20	17	15	13	25	40
Bedroom on the first floor of the house ILC-1	41	51	51	25	19	15	12	12	13	37	38
Exceeding the permissible level	-	1	12	-	-	-	-	-	-	12	-

Source: calculated by the authors.

The measured and permissible values of the sound pressure levels are given in Tables 1 and 2.

Table 2. Values of measured SPL at night (23:00) in ILC-2.

Place of measurement	Sound pressure levels, dB in octave frequency bands with geometric mean frequencies, Hz									Sound levels, dBA	
	31.5	63	125	250	500	1000	2000	4000	8000	L_A eqv	L_A max
Permissible levels in the territory adjacent to a residential building	78	62	52	44	39	35	32	30	28	40	55
1 meter from the facade of the house ILC-2	54	86	67	55	49	47	44	43	38	54	56
Exceeding the permissible level	-	24	15	11	10	12	12	13	10	14	1
Permissible levels of living rooms of houses at night	67	50	39	30	24	20	17	15	13	25	40
Bedroom on the first floor of the house ILC-2	41	71	40	25	22	12	11	10	9	40	42
Exceeding the permissible level	-	21	1	-	-	-	-	-	-	15	2

Source: calculated by the authors.

The measurements were carried out using a calibrated sound level meter "Multifunctional Acoustic Meter Ecophysics (version "Ecophysics - 110A" HF (White)) head. No. BF180661, year of manufacture of the device 2018 (see Figure 1). The measurements were taken at 23.00.

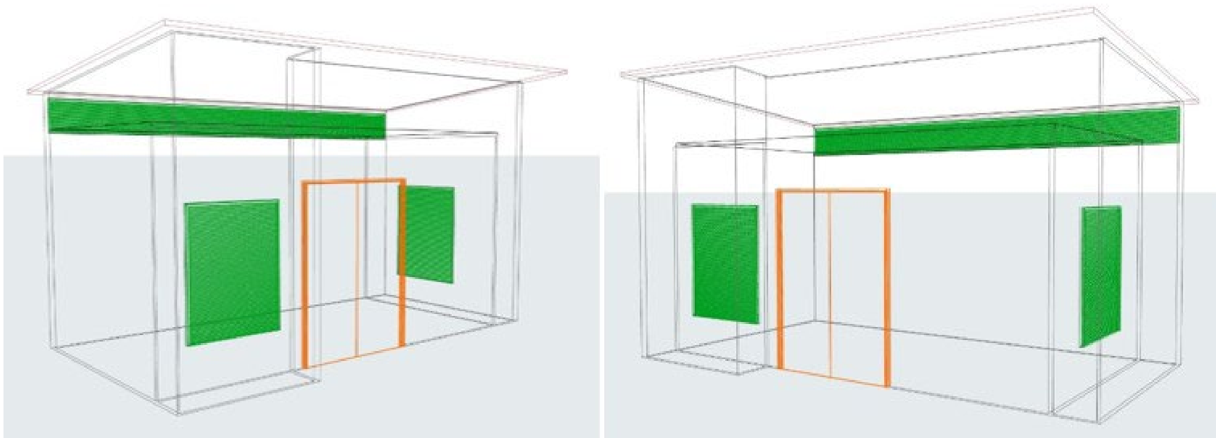
Figure 1. Appearance of the sound level meter "Ecophysics - 110A".

Source: LLC "AtomSnab" [6].

The purpose of the measurements is to identify non-compliance with the sanitary values of the sound pressure level in residential premises and in the territory adjacent to residential buildings from the operation of a diesel generator, and, if necessary, to justify the strengthening of protection against airborne and impact (structural) noise.
Normalized constant noise parameters are sound pressure levels L, dB, in octave bands with geometric mean frequencies of 31.5, 63, 125, 250500, 1000, 2000, 4000, 8000 Hz (octave sound pressure levels). For an approximate assessment, it is allowed to use sound levels LA, dBA. Sound pressure levels in octave frequency bands in dB, sound levels and equivalent sound levels in dBA for noise generated in rooms and in areas adjacent to buildings, air conditioning, air heating and ventilation systems should be taken at five dBA (five dB) below tabular (correction minus five dBA).
Thus, the assessment of noise levels in the territory of a residential building from the noise of a working diesel generator was made. The estimated calculation showed that the noise levels on the territory do not meet the requirements of sanitary standards[7] [8]. As a result of measurements, it was found that the noise levels in residential premises and in the territory adjacent to residential buildings from the operation of a diesel generator exceed the permissible values for the night time. To reduce the noise level from the operation of a diesel generator in residential premises of houses and in the adjacent territory to residential buildings, the following set of measures was taken:

- Vibration isolation of the base, to eliminate low frequencies: install vibration isolating supports under the foundation of the diesel generator set. As an elastic layer in the vibration isolating structure separating the "noisy" unit and the supporting structures, it is recommended to use a highly effective vibration isolating material of the Vibrofoam brand. The brand of material, dimensions and location of the supports are selected depending on the long-term static load acting on the elastic layer and the natural frequency of the equipment. The thickness of the elastic support is selected based on the required effectiveness of vibration isolation (the greater the thickness, the lower the natural frequency of the system). This solution is implemented only for ILC-1.
- Sound insulation: build a separate room for equipment (the dimensions of the room should be agreed with the designers to avoid equipment failure). The walls of the room are recommended to be made of solid brick with a thickness of 120 or more. The ceiling of the room is recommended to be made of a reinforced concrete slab with a surface density of at least that of the walls of the protected room (Figure 2).

Figure 2. General view of the premises of the diesel generator ILC-1.



Source: developed by the authors.

A general view of the ILC-1 diesel generator room is shown in Figures 2 and 3.

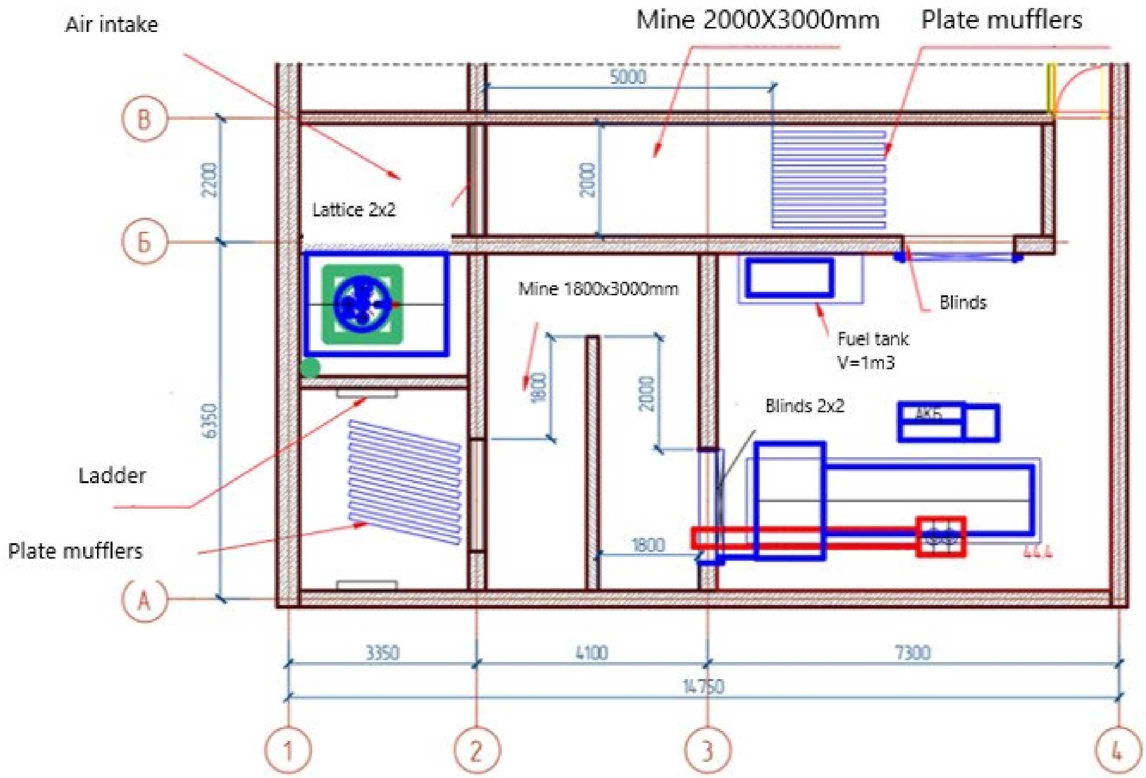
Figure 3. General view of the premises of the diesel generator ILC-1.

Source: developed by the authors.

Mount the duct silencer - build the design of the air outlet and air inlet chamber using a labyrinth-type circuit diagram (coordinate the dimensions of the chamber with the designers of the outdoor unit). The entrance door to the generator room is recommended to be installed with soundproofing properties. The sound insulation index of the door must be at least 40 dB. In ILC-2, to ensure the air exchange of the diesel generator, natural ventilation is provided with a separate ventilation shaft for air intake and hot air exhaust. The noise from the diesel generator spreads along these two shafts and is distributed over the area adjacent to the residential building. The general layout of the DGU premises is shown in Figure 2. Lamellar silencers are installed in the channel[8].

- Acoustic treatment: it is recommended to line the internal surfaces of the walls and ceiling of the diesel generator room and chambers with sound-absorbing boards 50 mm thick. In ILC-1, vibration isolation of the base was not made and plate silencers were not used.

Figure 4. General view of the premises of the diesel generator ILC-2.



Source: developed by the authors.

The measured values of sound pressure levels after soundproofing measures are given in tables 3 and tables 4.

Table 3. The values of the measured SPL at night (23:00) in ILC-1 after soundproofing measures.

Place of measurement	**Sound pressure levels, dB in octave frequency bands with geometric mean frequencies, Hz**									**Sound levels, dBA**	
	31,5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**L_A eqv**	**L_A max**
Permissible levels in the territory adjacent to a residential building	78	62	52	44	39	35	32	30	28	40	55
1 meter from the facade of the house ILC-1	57	55	49	47	45	39	31	24	23	45	45
Exceeding the permissible level	-	-	-	3	6	4	-	-	-	5	-
Noise reduction after soundproofing measures, dB	1	30	19	15	9	14	20	21	15	17	19
Permissible levels of living rooms of houses at night	67	50	39	30	24	20	17	15	13	25	40
Bedroom on the first floor of the house	31	34	31	25	19	15	12	12	13	25	30
ILC-1	-	-	-	-	-	-	-	-	-	-	-
Noise reduction after soundproofing measures, dB	10	17	20	-	-	-	-	-	-	12	8

Source: calculated by the authors.

Table 4. The values of the measured SPL at night (23:00) in ILC-2 after soundproofing measures.

Place of measurement	Sound pressure levels, dB in octave frequency bands with geometric mean frequencies, Hz									Sound levels, dBA	
	31.5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**L_A eqv**	**L_A max**
Permissible levels in the territory adjacent to a residential building	78	62	52	44	39	35	32	30	28	40	55
1 meter from the facade of the house ILC-2	52	51	44	40	32	22	21	25	19	38	39
Exceeding the permissible level	-	-	-	-	-	-	-	-	-	-	-
Noise reduction after soundproofing measures, dB	2	35	23	15	17	25	23	18	19	16	17
Permissible levels of living rooms of houses at night	67	50	39	30	24	20	17	15	13	25	40
Bedroom on the first floor of the house	29	40	30	23	20	12	11	10	9	24	27
ILC-2	-	-	-	-	-	-	-	-	-	-	-
Noise reduction after soundproofing measures, dB	12	31	10	2	2	-	-	-	-	16	15

Source: calculated by the authors.

For acoustic vibration isolation of diesel generator sets (DGU), it is recommended to pre-select the number of vibration isolators based on the dimensions (in plan) of the frame and the mass of the unit. The rigidity of the flexible connectors on the suction and discharge sides of the aggregate network can be neglected(9)(10).
To reduce structural noise from DGU units, flexible linen canvas inserts are used on the discharge and suction sides. Inserts of round cross-section up to 250 mm long are installed on the suction side, depending on the parameters of the diesel generator set, and inserts of rectangular cross-section of the same length are installed on the discharge side. Inserts are used at the temperature of the transported medium from - 50 to + 50 °C. Calculation of acoustic vibration isolation of a unit installed on a heavy reinforced concrete floor (surface density - 500 kg/m2) in a separate DGU building near a residential building.

Initial data: DGU engine speed - $f_{DGU.} = 25\text{ Hz}$ ($N = 1500\text{ min}^{-1}$); Unit weight - $M_A = 2175\ kg$; Mass of rotating parts (presumably, as no data) - $M_{vr.ch} = (300 \div 500)\ kg$; Base - Ceiling - a monolithic slab of heavy reinforced concrete.

The engine of the unit is dynamically balanced.

- The eccentricity of the rotating parts is taken equal to $\varepsilon = 0{,}3 \cdot 10^{-3}\, m = 0{,}3\, mm$ (achieved by dynamic balancing of the engine). Based on engine speed ($N = 1500\text{ min}^{-1}$) the maximum allowable amplitude of displacement of the center of mass of the unit is determined $a_{ДОП.}$ according to the Table 3(2).

$$a_{add.} = 0{,}07 \cdot 10^{-3}\, m, \qquad (1)$$

- The required efficiency of acoustic vibration isolation is determined according to Table 2 (Nor Afiah et al., 2016):

$$\Delta L_{TP.} = 26\ dB, \qquad (2)$$

- The permissible frequency of natural oscillations in the vertical direction of the vibration-isolated unit is determined $f_{Z\,add.}$ when placed on a heavy concrete floor

$$f_{Z\,add.} = 15/1{,}8 = 8{,}3\ Gc \quad , \tag{3}$$

- The total required mass of the vibration isolation unit is determined $M_{TP.}$

$$M_{TP.} \geq \frac{2{,}5 \cdot \varepsilon \cdot M_{vr.ch.}}{a_{add.}} = \frac{2{,}5 \cdot 0{,}3 \cdot 10^{-3} \cdot 300}{0{,}07 \cdot 10^{-3}} = 3215\ kg \quad , \tag{4}$$

- Since the mass of the unit $M_A = 2175\ kg$ less than required weight $M_{TP.} = 3215\ kg$, load weight is required. Load weight MP, kg, determined by the formula:

$$M_P = M_{TP.} - M_A = 3215 - 2175 = 1040\,kg \quad , \tag{5}$$

In the further calculation, the mass is taken as to reduce noise and vibration generated by units with a speed of 1500 min-1 or more, it is preferable to use rubber vibration isolators (or their analogues). Units with dynamic loads are recommended to be rigidly mounted on a reinforced concrete slab or a heavy metal frame, which must be supported by vibration isolators(5).

The vibration isolators should be positioned in such a way that the sum of the projections of the distances from the vertical axes of the vibration isolators to the center of mass of the unit on two mutually perpendicular axes located in the horizontal plane and passing through the center of mass of the unit is equal to zero, i.e. vibration isolators must be located symmetrically with respect to the center of mass of the unit. The total number of vibration isolators and their placement, i.e. the distance from the center of mass of the unit to the attachment points of the vibration isolators is determined by calculation, taking into account the need to ensure the stability of the unit(11).

Based on the rotational speed and mass of the unit, type-setting vibration isolators made of Sylomer material were selected. The number of vibration isolators is taken equal to $n = 8$.

- Determine the total cross-sectional area of all vibration isolators S, m², according to the formula:

$$S = \frac{M_{TP.} \cdot g}{\sigma} = \frac{3215\,kg \cdot 9{,}8\,m \cdot s^{-2}}{0{,}3 \cdot 10^{6}\ \Pi a} = 0{,}105\,m^2 \quad , \tag{6}$$

where σ - allowable static stress in rubber (for rubber with a hardness (Shore) up to 40, 0.1-0.3 MPa is taken, for rubber with a higher hardness - 0.3-0.5 MPa);

- Determine the cross-sectional area of one vibration isolator s, m², according to the formula:

$$s = \frac{S}{n} = \frac{0{,}105}{8} = 0{,}0131\ m^2 \quad , \tag{7}$$

- Determine the transverse dimension of one vibration isolator in the form of a parallelepiped of square section with a square side, δ, m:

$$\delta = \sqrt{s} = 0{,}12\ m \quad , \tag{8}$$

- Determine the required total stiffness of vibration isolators in the vertical direction $K_{Z\,TP.}$, Н/м, according to the formula (3):

$$K_{Z\,TP.} = 4 \cdot \pi^2 \cdot f_{Z\,\text{ad.}}^2 \cdot M_{TP.} = 8735225\ H/m, \tag{9}$$

- Calculate the working height of each vibration isolator H_P, m, according to the formula:

$$H_P = \frac{E_D \cdot S}{K_{Z\,TP.}} = 0{,}0721\ m, \tag{10}$$

where E_D - dynamic modulus of elasticity of rubber, Pa, determined tentatively according to the graph in Figure 3 (Nor Afiah et al., 2016)* depending on the hardness of the rubber ($E_D = 6 \cdot 10^6\ \Pi a$); S - cross-sectional area of all vibration isolators, m²; $K_{Z\,TP.}$ - required total stiffness of all vibration isolators, N/m;

Check compliance with the stability conditions, while it is necessary to comply with the inequalities, for vibration isolators in the form of cubes or square parallelepipeds

$$1{,}5 \cdot H_P \le \delta \le 8 \cdot H_P$$

$$1{,}5 \cdot 0{,}0721 = 0{,}11 \le 0{,}11 \le 8 \cdot 0{,}0721 = 0{,}58, \tag{11}$$

where H_P - operating height of the vibration isolator, m, determined according to the formula (14);

$$\delta = 0{,}11\ m., \tag{12}$$

If these conditions are not met, it is necessary to choose rubber with a different hardness or refuse rubber vibration isolators and opt for spring vibration isolators;

Because of this condition is done, then vibration isolators are selected from a material in the form of rubber squares from Sylomer with an elastic modulus $E_D = 2{,}54 \cdot 10^6\ \Pi a$. See Table 5 Standard range of materials Sylomer SR.

Table 5. Standard range of Sylomer SR.

Material type	SR11	SR18	SR28	SR42	SR55	SR110	SR220	SR450	SR850	SR1200
Color	Yellow	Orange	Blue	Pink	Green	Brown	Red	Grey	Turquoise	Purple
Ultimate static load, N/mm2*	0.011	0.018	0.028	0.042	0.055	0.110	0.220	0.450	0.850	1.200
Peak load, N/mm2 (maximum)*	0.5	0.75	1.0	2.0	2.0	3.0	4.0	5.0	6.0	6.0
Mechanical Loss Factor	0.25	0.23	0.21	0.16	0.17	0.13	0.13	0.11	0.12	0.09
Static shear modulus, N/mm2	0.03	0.05	0.07	0.08	0.13	0.22	0.35	0.58	0.8	0.9
Dynamic shear modulus, N/mm2	0.1	0.12	0.15	0.17	0.26	0.42	0.64	1.0	1.4	1.6
Abrasive wear, mm3	1400	400	1300	1200	1100	1100	1000	400	300	350
Static modulus of elasticity, N/mm2	0.061	0.097	0.166	0.282	0.367	0.87	1.44	3.30	7.2	10.4
Dynamic modulus of elasticity, N/mm2	0.172	0.280	0.437	0.611	0.753	1.36	2.54	5.04	11.1	16.4
Tensile strength at deformation 10%, N/mm2	0.12	0.020	0.031	0.047	0.061	0.12	0.22	0.42	0.86	1.08

Source: calculated by the authors.

Note: data are given for materials with a thickness of 25 mm

Determine the total height of the vibration isolator H , m, in the form of cubes and parallelepipeds of square section:

$$H = H_P + \frac{1}{8} \cdot \delta = 0{,}0721 + \frac{1 \cdot 0{,}11}{8} = 0{,}0859 \text{ m} \quad , \qquad (13)$$

- Determine the total stiffness of all rubber vibration isolators in the vertical direction K_Z , N/m, according to the formula:

$$K_Z = \frac{E_D \cdot S}{H_P} = \frac{2{,}54 \cdot 10^6 \cdot 0{,}105}{0{,}0721} = 3699029 \, \frac{H}{м} \quad , \qquad (14)$$

where E_D, S, H_P - same as in formula (14);

- Determine the natural vibration frequency of the vibration-isolated unit in the vertical direction f_Z , Hz, according to the formula:

$$f_Z = \frac{1}{2 \cdot \pi} \cdot \sqrt{\frac{K_Z}{M_{TP.}}} = \frac{1}{2 \cdot 3{,}14} \cdot \sqrt{\frac{3699029}{3215}} = 5{,}4 \text{ Hz} \quad , \qquad (15)$$

where K_Z - total stiffness of all vibration isolators in the vertical direction, determined by formula (17), N/m; $M_{TP.}$ - the total required mass of the vibration-isolated unit, kg;

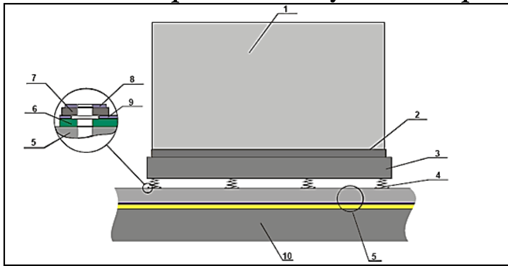
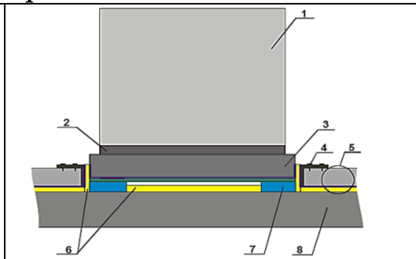
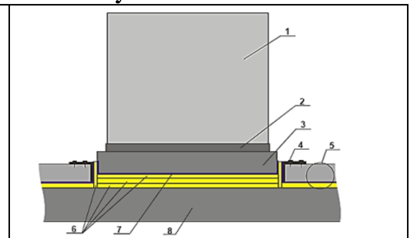
- Determine the effectiveness of acoustic vibration isolation ΔL, dB, provided by the selected vibration isolation system, according to the formula (1). Efficiency value ΔL , dB must not be less $\Delta L_{TP.}$, dB, defined in Table 1 (Table 2[2]).

$$\Delta L = 20 \cdot \lg\left(\frac{f^2}{f_Z^2} - 1\right) = 20 \cdot \lg\left(\frac{25^2}{5{,}4^2} - 1\right) = 26{,}2 \quad , \qquad (16)$$

$$\Delta L > \Delta L_{TP.} \quad , \qquad (17)$$

The necessary conditions are met. The selected vibration isolation provides the required acoustic efficiency. Currently, there are three different types of vibration isolating bases that are used in practice (Table 6).

Table 6. Comparative analysis of the principle schemes of vibration isolation of noisy units.

		
Unit #1 (Unit motor speed 750 rpm; Unit operating frequency f_Z, Hz, is 750/60 = 12.5 Hz)	Unit #2 (Unit motor speed 1500 rpm; Unit operating frequency f_Z, Hz, equal to 1500/60 = 25 Hz)	Unit #3 (Unit motor speed 3000 rpm; Unit operating frequency f_Z, Hz, equal to 3000/60 = 50 Hz)
Schematic diagram No. 1 - arrangement of a vibration isolating base using 8 spring vibration isolators of the VIP-44DO type and a floating floor structure	**Principal diagram No. 2 -** device of a vibration-isolating base using elastic elements made of Sylomer® material with a total thickness of 100 mm	**Schematic diagram No. 3 -** device of a vibration-isolating base using sound-proofing material "URSA P-60" with a total thickness of 60 mm
1 - unit; 2 - metal support frame; 3 - foundation plate with a thickness of 150 - 200 mm; 4 – spring vibration isolator VIP 44-DO; 5 - floating floor construction; 6 - rubber gasket 10 mm thick over the entire area of the base plate; 7 - rubber washer 10 mm thick and 40x40 mm in size; 8 - steel washer; 9 - steel bottom plate of the vibration isolator support; 10 - floor slab.	1 - unit; 2 - metal support frame; 3 - foundation plate with a thickness of 150 - 200 mm; 4 - metal corner (mounted if necessary); 5 - floating floor construction; 6 - sound-absorbing plates "URSA" with a thickness of 20-50 mm; 7 - vibration isolating element "Sylomer®R" with a size of 2300x200x50 mm; 8 - floor slab.	1 - unit; 2 - metal support frame; 3 - foundation plate 150 mm thick; 4 - metal corner (mounted if necessary); 5 - floating floor construction; 6 - sound-absorbing plates "URSA P-60" 20 mm thick; 7 - waterproofing layer of polyethylene; 8 - floor slab.

Source: calculated by the authors.

It follows from the results of the calculations that for the vibration isolation of the DGU, the most effective is the Principal Scheme No. 2

The necessary conditions are met. The selected vibration isolation provides the required acoustic efficiency.

1. The effectiveness of vibration isolation of engineering equipment (for example, DGU) depends on its operating frequency, on the applied vibration isolation scheme;
2. Incorrect choice of vibration isolation scheme can lead to an uncontrolled increase in the amplitude of vibrations of the engineering equipment foundation.

Table 7. The result of using various vibration isolating bases.

	Circuit Diagram #1,	**Circuit Diagram #2**	**Circuit Diagram #3**
Unit #1, f_Z = 12.5 Hz	foundation vibrations are reduced	resonance, a sharp increase in the vibrations of the foundation	foundation vibrations are not reduced
Unit #2, f_Z = 25 Hz	foundation vibrations are reduced	foundation vibrations are reduced	resonance, a sharp increase in the vibrations of the foundation
Unit #3, f_Z = 50 Hz	foundation vibrations are reduced	foundation vibrations are reduced	foundation vibrations are reduced

Source: calculated by the authors.

Analysis of the obtained measurement results showed the following:

It should be noted the importance of research and the possibility of application in architectural and construction design, in building physics and in life safety. The issues of environmental protection from the noise of power equipment were comprehensively considered, not only acquaintance with the problem, but the solution of a specific problem on the issues of noise suppression of power equipment. The results of measurements of the sound pressure

level before and after noise protection measures for an individual living space gave an assessment of the qualitative and quantitative ratio of the accepted and new types of measures and materials.
Noise protection measures ensured the required sound levels, reduced vibrations and created a favorable acoustic environment. Assessment of the risks of exposure to increased levels of noise and vibration will allow timely protection from the negative impact of adverse factors associated with the use of process power and thermal equipment.
The noise levels in the territory of a residential building and in the bedrooms from the noise of a working diesel generator were estimated at two projects ILC-1 and ILC-2 after soundproofing measures. In ILC-1, the sound pressure level in the residential area at some frequencies exceeds the permissible values, in residential premises - within the permissible values. In ILC-2, the level of sound pressure in the territory of residential development and in residential premises corresponds to the standard values.
As can be seen from the results of measurements in ILC-2 after the measures taken, it was revealed that the noise reduction is higher than in ILC-1.

CONCLUSIONS

Measures to reduce the noise level should be carried out comprehensively at the design stage, taking into account a clear algorithm, depending on the noise characteristics of the equipment in accordance with the current noise standards;
For the case of exceeding the level of 100 dB, it is necessary to provide for the creation of isolated rooms, special foundations for foundations. The effectiveness of vibration isolation of engineering equipment depends on the applied vibration isolation scheme; the wrong choice of vibration isolation scheme can lead to an uncontrolled increase in the amplitude of vibrations of the foundation of engineering equipment. To eliminate low frequencies: install vibration isolating supports under the foundation of the diesel generator set. As an elastic layer in the vibration isolating structure separating the "noisy" unit and the supporting structures, it is recommended to use a highly effective vibration isolating material of the Vibrofoam brand.
Mandatory installation of additional sound-absorbing material on the walls and ceiling of the room – a thin layer of fibrous material (URSA, ROCKWOOL, ISOVER, etc.) with a thickness of not more than 50 mm, covered with an air-transparent material – fiberglass or Yutadach type membrane; Implementation of additional soundproofing structures (soundproofing shells) of the walls and ceiling of the room, increasing the soundproofing capacity of building envelopes; Use of noise protection devices and partitions: blinds, mufflers, and casings.

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