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# Bench Studies of Sound Insulation Materials and Vacuum Sound Insulation Panel

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**Abstract.** There is a problem of protection from high-level sound of city residents, employees of enterprises; to a greater extent, in the workshops of machine-building factories, for example, during stamping, forging and other metalworking processes. Specialists and maintenance personnel are exposed to high-intensity noise near powerful agitators, pumps, engines and other power equipment. Due to these circumstances, it is necessary to constantly improve systems, devices, materials, coatings that reduce the negative impact of high noise levels on people. For this purpose, various soundproof walls, panels, screens, plates are being developed. One of the directions of modernizing sound-proofing fences is the method of using vacuum to design these protective devices. The article discusses the use of vacuum in special sound-insulating panels developed by the authors. The information about bench experimental studies of some sound-proofing materials is given, some results of testing of vacuum sound-proofing panels are presented. The research stand and research methodology are described. The features of the stand for the study of sound-proofing properties of flat samples of sound-proofing materials of the same size and thickness are given.

**Keywords:** sound insulation research, vacuum sound insulation, sound-proofing materials, panels, screens, experimental method, research automation, stand with software control.

## Introduction

Often, noises from machines, apparatuses and other equipment operating at enterprises or technological noises of production reach a level exceeding not only the norms of comfortable work for a person, but also legally permissible indicators. However, a relatively low noise level of 50-55 dBA negatively affects performance, causes faster fatigue of working people. As is known, the equivalent noise level for all types of work in workshops and on the territory of manufacturing enterprises is an acceptable noise level of 80 dBA, while the maximum level is 107 dBA. For concentrated work in rooms with noisy equipment, the maximum permissible noise level is 103 dBA, and the equivalent is 75 dBA. However, the requirements for the noise level at enterprises are not always met and often due to the lack of necessary means and sound insulation systems. Due to the high noise level, healthy people suffer and their ability to work decreases. Therefore, it is obvious that the task of improving sound-proofing structures and panels with effective sound insulation is urgent. The need for such developments is also explained by the fact that with the development of technology and technology, the intensity of machine work increases, the power of the equipment used increases and, as a result, the power of sound effects on humans increases [1].

In various industries, for example, in mechanical engineering, in light industry, problems with high noise levels in the area of human presence are very significant [2, 3]. And the solution of these problems is very relevant. This explains the relatively large number of publications in the field of noise abatement and the development of various methods and means of protecting people from industrial noise. In patent funds, for example in FIPS, a large number of patents for various methods and devices for noise control can be noted - engineers, scientists are actively trying to solve the problem under consideration [4 – 13].

From the wide variety of engineering solutions to the noise problem, we will single out several characteristic ones, close to the method of noise control by using soundproof fences in the form of walls, fences, panels, screens, etc.

## 1. Materials and Methods

The purpose of the research is to create effective sound insulation, taking into account the trends of its improvement. To achieve the goal, the analytical method of research, analysis of patent materials, planning and conducting experimental studies were used. Based on the results of the study of literary and patent materials, trends in the improvement of soundproof structures have been established.

This knowledge served as a basis for planning experimental studies. Taking into account the peculiarities of the research process of sound-insulating materials, a method of automated research of these materials is proposed and developed. A special automated stationary stand for experimental research was developed, and later the concept of robotization of some experimental works was formed. This concept is limited to those experimental studies in which the experimental plan includes a set of values of one or more parameters under study.

The experience of using such a stand has established its effectiveness with the "intelligent" control of the experimental program. When according to preliminary results, the program clarifies the experiment plan. In these studies, the frequency of sound emission and sound power were varied to determine sound reflection and sound absorption for various porous and fibrous materials. And also for various designs of soundproof panels.

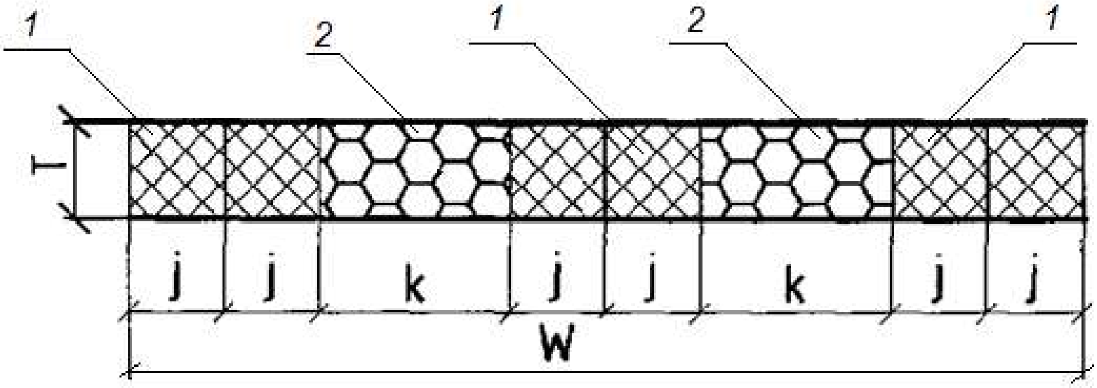
## 2. Results and discussion

A review of the methods of sound insulation, the designs of sound-proofing panels revealed some trends in their modernization. For example, the development of flexible sound insulation. As an example, we will give the device of a sound-proofing panel (Kalinin, 2019), which is made of upper and lower steel plates in the form of separate geometric shapes. The plates are fixed together on both sides on a flexible material. The panel is made of two layers of geometric shapes. In addition, the plates have a cutout h by an amount equal to half the thickness of the plate to ensure the flexibility of the panel during operation.

Another direction of creating sound-insulating fences is the creation of diverse sandwich panels, with elements to increase strength, durability, etc. It is necessary to single out developments in which both fibrous and porous materials are used simultaneously to solve the problems of sound insulation. When the directions of the fibers in the mineral wool insulation panels are combined.

For example, to solve the problems of sound insulation, a special construction sandwich panel has been developed (Kalinin, 2006), which uses two surface layers of metal and a central part made of pieces of mineral wool that make up longitudinal strips. The longitudinal axes of the pieces are parallel to the longitudinal axis of the panel, and the orientation of the fibers in the pieces is perpendicular to the plane of the surface layers, the ends of the pieces are displaced longitudinally with respect to each other. Between the strips of pieces of mineral wool, longitudinal strips of filler foam, polyurethane, etc. are additionally introduced), and they are introduced sequentially between groups of strips of mineral wool. The essence of such a combination is explained in Figure 1, by the layout of materials in the panel.

A heat and sound insulation honeycomb sandwich panel is also known [12], which includes two identical surface layers and an inner layer of equal area placed between them, which is honeycomb cells in the form of regular hollow prisms with hexagonal bases facing the surface layers. In this panel, hexagonal recesses are symmetrically made on the inner sides of the surface layers to form a base inside the layers, and the inner layer is made with holes that symmetrically coincide with the recesses and is shifted diagonally relative to the surface layers. Of course, interesting developments in which vacuum is used to improve sound insulation. For example, a sound–proofing structure is known - a "Sound-proofing element" in which sound insulation is provided by vacuuming the enclosed cavity with hemispherical surfaces [5].




1 - filled polyurethane foam, 2 - mineral (stone) wool

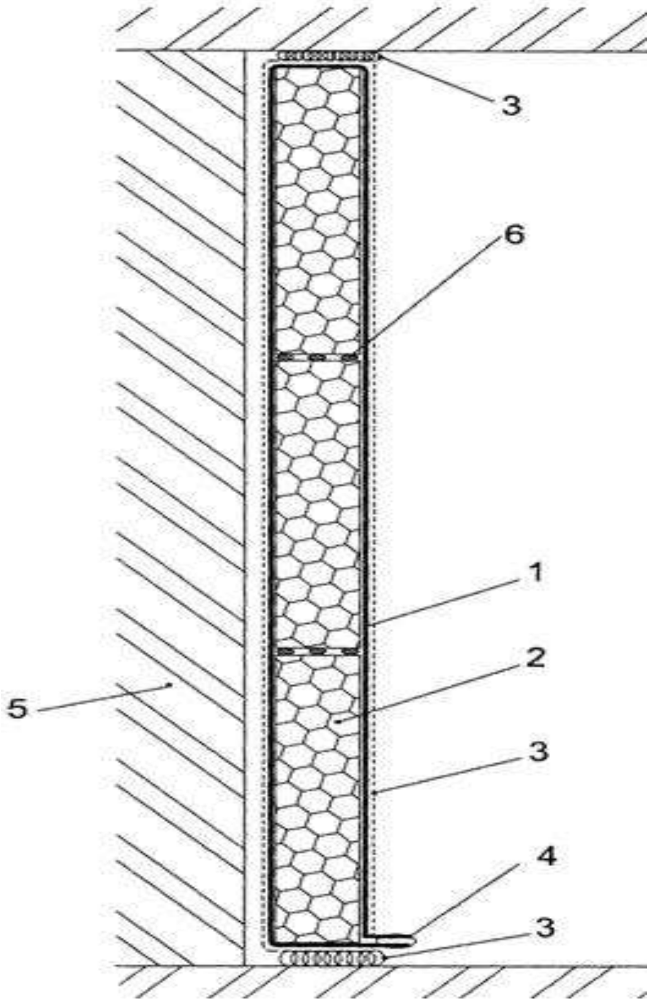
**Fig. 1.** - Layout of panel materials

There are also known designs of vacuum sound-proofing flat panels in which the evacuated cavity is filled with a form-forming and sound-proofing filler made of porous material. For example, a vacuum sound-proofing design according to the patent [11]. This flat panel is made in the form of a sound-proofing wall panel, which uses filler between the enclosing walls (Figure 2).

In the specified source, the evacuated panel contains a formative incompressible element with the formation of a porous internal space for its evacuation.

The sealed shell 1 is covered from the outside with a sound-absorbing material 3, a sealant, rubber or a rubber-like material (polyurethane, thiocol and others).

Metal foil 1, laminated with a polymer film, has flexibility and there are no cracks in it, it is technologically advanced in the assembly stage of the vacuum constructions. The tightness of the structure is provided by a welded or soldered joint 4.




1 – shell, 2 – filler, 3 – reflective coating, 4 – nipple, 5 – wall, 6 – partitions

**Fig. 2.** - Vacuum wall panel [11]

In other similar designs of sound-proofing panels, it is proposed to use flat, rigid covering sheets; between which plates of sound-proofing porous material are placed. At the same time, this material is used as a support for flat, rigid cover sheets.

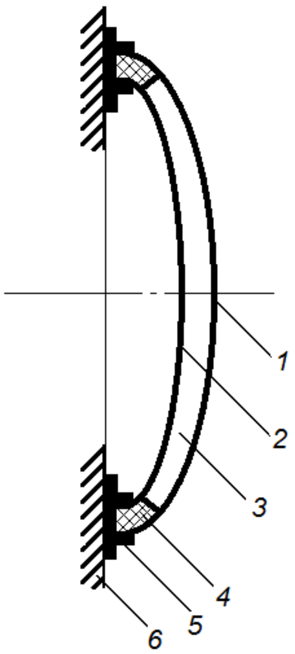
The application for the invention "Electrified Vacuum Panel" [4] describes a vacuum panel in which a porous filler is used as sound insulation, enclosed between two flat sheets connected at the edges of the vacuum panel. In such a design of a vacuum panel with rigid protective sheets, an intermittent or porous filling material is located between these sheets, which is also a conductor of sound vibrations and therefore the disadvantage of such a design is its relatively low sound-proofing ability.

We have developed a design of a vacuum sound-proofing panel [10], which has advantages in comparison with known similar vacuum sound-proofing panels (Figure 3).

In the developed design, two limiting walls are cylindrical in shape and oriented with bulges in one direction. At the same time, a connecting belt made of an elastic vacuum-dense material is located between the limiting walls along the perimeter, to which the limiting walls are firmly fixed, forming a closed vacuum cavity between them.

Another development of the authors is a vacuum sound-proofing panel in which stiffeners and coating layers are used [8]. Reinforcement of the covering sheets with ribs in the panel design provides rigidity of the limiting walls (covering sheets), since the stiffening ribs prevent the deflection of the limiting walls after vacuuming the cavity between them.

In this case, a "quasi-plate" is formed with a high deflection resistance. The membrane effect disappears and the proportion of energy of the reflected sound wave from the front surface facing the sound source increases significantly.

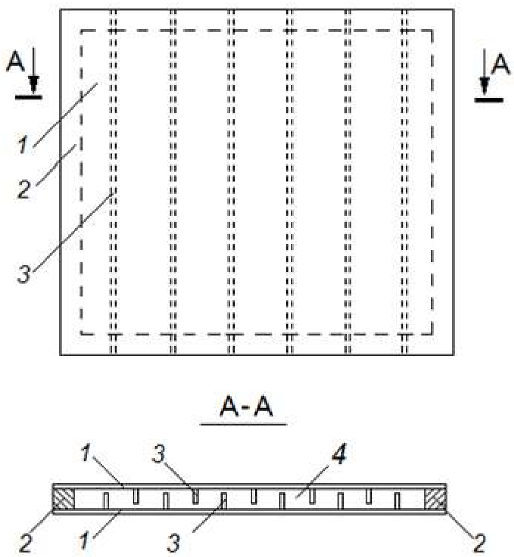



1,2 – limiting walls, 3 – vacuumed cavity, 4 – connecting belt, 5 – fasteners, 6 – panel support

**Fig. 3.** - Vacuum sound-proofing panel [10]

The disadvantage of such a panel is the ribbing of the front surface. We have also developed a sound-proofing panel with internal stiffeners [9], in which this disadvantage has been eliminated. And the sound-reflecting properties of the panel with internal ribs have been significantly increased, therefore, the sound-insulating characteristics of such a panel have been significantly improved.

Figure 4 shows a diagram of a panel with stiffeners inside the panel. The vacuum sound-proofing panel consists of two limiting walls 1, frame 2, stiffeners 3. The elements of the vacuum sound-proofing panel 1,2 form a closed vacuumed cavity 4 with the possibility of deep discharge up to 0.1...0.2 atm., while the elements 1,2 are interconnected motionlessly and vacuum-tight, and the stiffeners 3 are fixed along their entire length to the inner the surfaces of the bounding walls 1 are integral.




1 – covering sheets, 2 – spacer frame, 3 – stiffeners

**Fig. 4.** - Vacuum sound-proofing panel with internal stiffeners [9]

To evaluate ideas for improving sound-proofing structures, modeling or experiments are usually resorted. To test the effectiveness of vacuum sound insulation and compare the sound insulation performance of other known sound-insulating materials, experimental studies were conducted on a stationary stand. A research acoustic stand has been developed and used, allowing to study and compare various sound-proofing materials, including samples of a vacuum sound-proofing panel.

A stand has been developed with software control and with the possibility of autonomous individual experiments in the study of sound-insulating materials with varying sound frequency and sound pressure power, programmatically, without human participation.

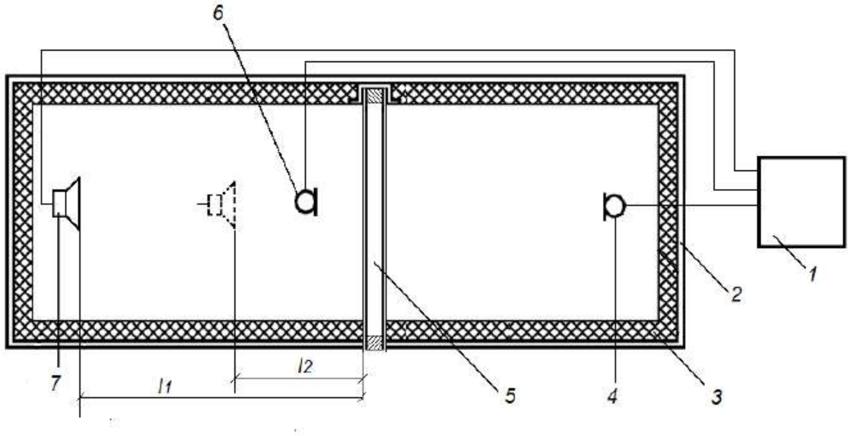
The scheme of the stand on which the research was carried out is shown in Figure 5.

The stand consists of: sensitive microphones – 4,6, a rigid body – 2, a soundproof coating – 3, a tray for installing the samples under study – 5, low-frequency and high-frequency speakers – 7. The stand is provided by: a system for changing the frequency and power of sound – 1. It includes a sound oscillator and an adjustable sound power amplifier, as well as a software controller for changing the frequency and power of the sound effect. To control the measurement algorithm of the parameters under study and record the measurement results, a personal computer is used, to which the microphone output is connected and which controls the operation of the controller for changing the frequency and power of the sound effect.

During experimental studies of sound-insulating materials on a stand with software control, a stable mono frequency and stable radiated sound power are established. According to the research plan, it is planned to generate different sound wave spectra and adjust their power (sound pressure) at different frequencies. The use of recording the noise of real machines for which sound insulation is being developed is provided.

Here are some research results obtained at the stand for various sound-insulating materials and for an experimental vacuum sound-insulating device. The experiments were carried out on samples in the form of flat panels with the same dimensions: 400x500 mm, 80 mm thick (Figure 5).

Table 1 shows the data of sound power measurements after a sound-proofing sample, under the same other measurement conditions.




1 – measurement unit, 2 – stand housing, 3 – sound insulation, 4 – microphone after sound insulation, 5 – test sample, 6 – microphone of reflected sound, 7 – sound emitters

**Fig. 5. -** Diagram of the stand for automated studies of sound insulation materials

As can be seen from Table 1, despite the different structure of sound-proofing materials and their physical and mechanical features, the materials studied differ markedly in sound-proofing properties. Along with this, the dependence of the degree of sound absorption of the studied materials on the frequency of the main sound wave is established. For better absorption of sound power with a large frequency range, it is obviously necessary to design multilayer fences made of various materials.

The camera without a partition, in Table 1, understands the mode when the maximum power of the sound source is measured at the installation site of the first microphone. In this case, the reflection of sound waves is equal to "0". So for acoustic felt, with a speaker power of 2 watts, the sound radiation power was 69.9 dBA, and the microphone measured the sound power after sound insulation equal to – 38.1 dBA. The sound power in front of the test sample, made of acoustic felt, on microphone 2 was 75.4 dBA, therefore, the reflected sound power for this experiment was 5.3 dBA. The greatest reflected sound power was found when measuring the sound-insulating properties of the vacuum panel, it was 28.5 dBA.

**Table 1.** Results of measurements of the sound-insulating properties of the materials under study at a generator frequency of 1000 Hz

| Material | Sound level on the microphone, dBA | | |
|---|---|---|---|
| | Gain 1 (P=2W) | Gain 2 (P=5W) | Gain 3 (P=10W) |
| Acoustic felt | 38.1 | 40.2 | 61.5 |
| Foam | 39.1 | 59.4 | 63.5 |
| Basalt cotton | 40.9 | 52.2 | 63.9 |
| Household felt | 44.7 | 54.0 | 68.5 |
| Isolon | 45.4 | 56.2 | 66.1 |
| Foam rubber (impregnated) | 46.7 | 66.3 | 68.6 |
| Corrugated cardboard | 48.1 | 64.4 | 65.7 |
| Wood chips | 41.6 | 54.1 | 68.0 |
| Sawdust | 49.4 | 59.9 | 67.0 |
| A camera without a partition | 69.9 | 80.9 | 85.6 |
| Vacuum panel | 34. 6 | 38.2 | 57.0 |

When analyzing the results of sound level measurements on the first microphone, after a sample of a sound-insulating material, at a frequency of 1000 Hz and a sound source power of 2, 5, 10 Watts, it was found that the materials have the best sound-insulating properties: acoustic felt, foam, basalt wool. Table 2 shows the values of these levels at those settings of the power amplifier of the stand, at 2, 5 and 10 watts. The levels are given as a percentage of the maximum level for each gain.

**Table 2.** The effect of sound level on the sound-insulating properties of the materials under study

| Amplifier power, watts | Materials under study | | | |
|---|---|---|---|---|
| | Foam | Basalt wool | Acoustic felt | Wood shavings |
| 2 | 56.0 % | 58.5 % | 64.0% | 59.5% |
| 5 | 73.0% | 64.5% | 66.7% | 66.8% |
| 10 | 74.0 % | 74.2% | 74.2% | 74.4% |

As can be seen from the data in Table 2, the greater the sound power, the less the sound insulation ability.

**Discussion**

In automated studies, the measurement results are recorded in the memory of a personal computer and can be transmitted for analysis remotely from the place of experiments. The developed and considered method of experimental research provides a significant simplification of the process of long-term multiparametric studies, reducing research costs, improving their quality. In addition, it becomes possible to automatically change the research program.

The possibility of conducting automated "intellectual research" using the criteria of a Student, Fisher, etc. is provided. "Intelligent research" is when the experiment plan can be adjusted based on the results of a certain amount of research already performed. For example, if there is an extremum in the studied range, the experiment control program can automatically increase the number of experiments in the critical area. In combination with software-controlled manipulators, it becomes possible to automatically change the test samples, and automatically change the experimental conditions, in a wide range and in working conditions with hazardous substances.

**Conclusions**

1) The developed research stand allows measuring the power transmitted through the sound-insulating material and the power of the sound reflected from the sound-insulating material.

2) Comparative characteristics of sound-proofing panel samples were obtained at different mono frequencies of the sound emitter and at three power levels of the sound source.

3) It was established that of the studied samples, the acoustic felt used for the noise insulation of automobiles has the best sound-insulating characteristics.

4) The study of the sound insulation properties of the vacuum panel showed results close to the properties of acoustic felt insulation.

5) The results of the study of the sound insulation vacuum panel turned out to be worse than expected, the authors will continue to research and improve the vacuum sound insulation structures from now on.

6) For experimental conditions, it was found that the sound permeability through sound-insulating materials increases with increasing power of the sound source.

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