Study of the acoustic efficiency of a plate silencer of the original design

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Abstract. Energy facilities are sources of noise impact. One of the most powerful sources of constant noise at such facilities is power boilers and draft machines, which emit noise into the surrounding area from air intakes and chimney mouths. To reduce noise from them, dissipative plate-type silencers are mainly used. In many cases, the installation in gas and air ducts of typical dissipative plate noise silencers consisting of plates with flat sidewalls does not provide the required acoustic efficiency with a limited length of the plates and the requirement for low aerodynamic resistance. In this regard, an urgent direction of scientific research is the development of new approaches to improve the acoustic characteristics of dissipative noise mufflers. The article presents the results of field tests of the acoustic efficiency of a dissipative plate noise muffler, consisting of patented noise suppression elements. The comparison of the obtained efficiency of the muffler from the proposed elements of noise suppression with the efficiency of the known designs of plate mufflers is carried out.

1. Introduction
One of the most powerful sources of constant noise at power facilities are power boilers and draft machines. The main ways of propagation of noise from such sources are surfaces of gas and air ducts, air intakes and chimney mouths. The most dangerous sources of noise are chimney mouths, since they are high-rise and affect long distances in the absence of noise shielding and the influence of the terrain. To reduce noise in gas paths of boilers, dissipative plate-type noise silencers are widely used in world practice. A typical plate silencer consists of parallel plates, consisting of cassettes with flat side perforated walls, which are installed in the channels of the gas-air ducts of boilers [1-2] (figure 1).

![Figure 1. Typical dissipative plate silencer.](image-url)
The problem of the negative noise impact from chimneys and air intakes of thermal power plants (TPP) on the residential areas of large cities located in the immediate vicinity is especially acute. Figure 2 shows a common case when a thermal power plant is located close to a residential area. In the absence of installed systems for noise suppression from equipment at TPPs, residents of the district are exposed to increased noise.

**Figure 2.** The close location of the TPP to the residential area.

Silencers are installed in the gas ducts of boilers behind the smoke exhausters in front of the chimneys. The advantages of dissipative silencers are broadband sound attenuation, simplicity of design, long service life and the absence of significant operating costs, as well as low cost of manufacturing and installation [3-8]. Sound attenuation in a plate noise damper can be determined by the formula [1], dB/m:

\[
\Delta L = 10 \log_{10} \left[ \frac{\alpha_{obl} S_{obl}}{2 S_{pr}} + 1 \right]
\]

where \( S_{obl} \) – sound absorption area, m\(^2\); \( S_{pr} \) – muffler free section, m\(^2\); \( \alpha_{obl} \) – sound absorption coefficient.

From formula (1) it follows that the increase in the efficiency of the plate noise mufflers is proportional to the increase in \( \alpha_{obl} \) and \( S_{obl} \).

The sound absorption coefficient \( \alpha_{obl} \) depends on the properties of the sound-absorbing material (ZPM) of the cassettes of the silencer plates. Certain requirements are imposed on ZPM: fire resistance, hydrophobicity, absence of shrinkage, low density. In the power industry, various types of mineral wool are used as RFPs for noise silencers: glass, stone (basalt) and slag, as well as expanded polystyrene and polyurethane foam.

Basalt wool, which meets the above requirements, is most widely used for stuffing noise-damping elements of dissipative noise mufflers. As the ratio increases \( \alpha_{obl} \) the sound attenuation increases. The use of a ZMP with a steel wire frame significantly extends the service life of the lamellar noise mufflers, ensuring a decrease in shrinkage.

Another way to increase the acoustic performance of silencers is to increase the sound absorption area. It is important not only to create a developed sound absorption surface, but also to select a surface shape that will be optimal in terms of production technology.

In work [9] it was shown that, the largest area of sound absorption of the side surfaces of the noise damping elements (cassettes of the NRU "MPEI") of the lamellar mufflers is achieved when using semi-cylindrical concavities.
2. Materials and methods
This article uses the method of experimental research. Full-scale bench acoustic tests of a dissipative noise muffler of an original design in several configurations were carried out.

3. Results
Bench tests were carried out to determine the acoustic performance of the original design of the dissipative silencer.

Figure 3 shows a diagram of a test bench for determining the effectiveness of plate noise mufflers made of original noise suppression elements (NRU "MPEI" cassettes) [10].

![Test bench layout diagram](image)

1 - end absorber; 2 - noise source; 3 - a prototype of a noise muffler; 4 - channel of the experimental stand

Figure 3. Test bench layout.

The test bench was a rectangular channel made of sheet steel with dimensions of 1000x1200 mm, from the outside the channel surface was wrapped with a sound-insulating shell, one channel end was plugged, the second channel end was open.

The joints of the stand channel are sealed with a sealant and tightened with a bolted joint. The outer surface is covered with soundproofing material, the joints are soundproofed.

A noise source was installed on one side of the channel; acoustic measurements were carried out at the opposite end of the channel, between them a prototype noise suppressor was installed, which is a parallel plate from the NRU "MPEI" cassette.

The test equipment included a two-channel signal analyzer LDViRTe 3000+ (LD3000 +) used as a noise generator, an acoustic cable, a noise emitter, a noise analyzer SIU Assistant of the 1st accuracy class, which was used for acoustic measurements. The LD3000 + Noise Spectrum Analyzer was used as a reference noise source that generated white noise. White noise is stationary noise, the spectral components of which are evenly distributed over the entire frequency range of the bands. The noise emitter converted the received signal from the LD3000 + into sound waves in the frequency range 50-20000 Hz. Measurements of sound levels (US) and sound pressure levels (SPL) were carried out at several control points with a noise analyzer in octave bands with geometric mean frequencies in the range of 31.5-8000 Hz.

Figure 4 shows the external view of the test bench with the investigated cassettes of the NRU "MPEI".

The tests were carried out in two stages:
• Noise levels were measured at control points when the noise source was operating in a channel without a noise suppressor;
• Noise levels were measured at control points when a noise source was operating in a duct with a noise suppressor in various combinations of location and number of cassettes.

The measurement points along the channel cross-section were chosen from the condition of equal area of the conditionally divided cross-section. The measurements were carried out at the same level of the noise emitter. According to the results of measurements for each arrangement of the muffler, the average values of the SPL were calculated.

The results of full-scale bench tests of the noise muffler are presented in Table 1.

**Figure 4. Test bench.**

**Table 1.** Results of full-scale tests of the acoustic efficiency of a prototype of a plate silencer in three configurations at different lengths.

| Length, m | Decrease in SPL, dB/m, in octave bands at geometric mean frequencies, Hz | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
|-----------|-------------------------------------------------|----|----|----|----|----|----|----|----|
| relative flow area 73% | | | | | | | | | |
| 1 m | 1,0 | 3,0 | 4,8 | 8,2 | 14,9 | 13,4 | 10,3 | 8,6 |
| 2 m | 1,5 | 4,4 | 9,5 | 14,6 | 24,7 | 19,2 | 12,2 | 10,2 |
| 3 m | 2 | 5,4 | 13,1 | 19,7 | 28,2 | 22,3 | 12,3 | 10,7 |
| relative flow area 60% | | | | | | | | | |
| 1 m | 1,4 | 4,1 | 8,2 | 14,8 | 20,3 | 21,1 | 15,7 | 13,0 |
| 2 m | 2,0 | 6,0 | 15,1 | 24,2 | 29,8 | 29,4 | 22,1 | 18,2 |
| relative flow area 47% | | | | | | | | | |
| 1 m | 1,4 | 5,3 | 12,0 | 20,4 | 22,9 | 23,0 | 21,4 | 19,7 |
| 2 m | 1,8 | 7,8 | 17,0 | 25,3 | 33,1 | 31,0 | 28,2 | 28,2 |

It can be seen from the results that with an increase in the length of the muffler, the decrease in noise in octave bands with geometric mean frequencies of 250-2000 Hz increases more intensively.

**4. Discussion**

To demonstrate the superiority of noise mufflers from MPEI cassettes over noise mufflers from standard cassettes, Figure 5 shows a comparison of noise reduction with the same number of plates, their length and distance between the plates.
Figure 5. Comparison of the acoustic performance of silencers of two types of cassettes:

a - thickness of cassettes - 200 mm, distance between plates - 400 mm
b - thickness of cassettes - 200 mm, distance between plates - 200 mm

The analysis of figure 5 shows that the acoustic efficiency of the plate noise muffler from the MPEI cassettes is superior to the noise muffler from standard cassettes with flat side walls in octave bands at geometric mean frequencies in the range of 500-8000 Hz, in the low frequency range the noise muffler from the NRU cassettes "MEI" either corresponds in efficiency to a noise muffler made from standard cassettes, or is slightly inferior within the measurement error.

The error in determining the acoustic efficiency of a noise muffler is the sum of the random error in the SPL measurement and the instrumental error, determined by the accuracy of the measuring equipment (noise analyzer).

The results of calculating errors in determining the acoustic efficiency of noise mufflers from cassettes of NRU "MPEI" are presented in table 2.

Additionally, the concavities of the MPEI cassettes contribute to an increase in the passage section of the noise silencer, which reduces the introduced aerodynamic resistance of the noise silencer.
Table 2. The error in determining the acoustic efficiency of a noise muffler from NRU "MPEI" cassettes in several configurations.

| Relative flow area, % | Name       | SPL, dB/m, in octave bands at geometric mean frequencies, Hz |
|----------------------|------------|-------------------------------------------------------------|
| 73                   | Acoustic efficiency | 1,0 3,0 4,8 8,2 14,9 13,4 10,3 8,6 |
|                      | Error      | ±1,7 ±1,5 ±2,2 ±2,2 ±2,1 ±1,4 ±1,4 ±1,9 |
| 60                   | Acoustic efficiency | 1,4 4,1 8,2 14,8 20,3 21,1 15,7 13,0 |
|                      | Error      | ±1,3 ±1,9 ±1,3 ±2,0 ±0,9 ±0,9 ±1,0 ±1,0 |

5. Conclusion
According to the results of bench tests of a dissipative plate noise muffler of the original design, its acoustic efficiency exceeded the efficiency of a noise muffler of a standard design in all similar configurations, especially in the range of medium and high geometric mean frequencies. The results of full-scale tests of the acoustic efficiency of an original design noise muffler, consisting of NRU "MPEI" cassettes, in various configurations are presented in table 1.

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