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NOISE ABATEMENT OF FORCED-DRAFT FANS USING ABSORPTIVE SILENCERS

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Absorptive silencers of different types for noise abatement of forced-draft fans, and the factors influencing the characteristics of silencers, are examined. A description is provided for the silencers developed and introduced by authors for noise abatement of induced-draft fans and fans. It is shown that silencers have specific characteristics and facilitate the provision of acoustic safety of the population of nearby residential areas.

Keywords: thermal power plants; noise abatement; silencers; induced-draft fan; forced-draft blower.

Forced-draft fans (FDF), including induced-draft fans and forced-draft blowers, are in many cases the primary sources for exceeding noise health regulations in the surrounding area [1 – 3]. In the development of measures for noise absorption of forced-draft fans, it is necessary to consider the following features of such sources of noise.

The first feature is that they are used in great numbers in power generation and in a number of other industries. Forced-draft fans provide the necessary pulling force on all steam and water-heating units. Radial machines with single or double intake are used as fans and induced-draft fans. Axial machines are used on units of 300 MW and above.

The second feature is that radiated noise depends strongly on the type of forced-draft fan. Other things being equal, the noise level for axial machines is more, by up to 15 dB. The basic characteristic of noise from an FDF is taken to be the sound power, which for modern axial machines is up to 150 dB and for centrifugal ones is up to 135 dB [1].

The third feature is that the noise radiated from FDF is of voice frequency. The maximum within the noise spectrum falls within the "blade frequency" and is defined as [1, 2]

$$f = Knz/60, \tag{1}$$

where $K = 1, 2, \ldots$ is the harmonic number; n is the frequency of rotation, min^{-1}; and z is the number of blades. With centrifugal machines, the maximum falls on the first harmonica ($K = 1$), for axial ones on the second and third ($K = 2$, $K = 3$). Noise abatement devices must take this feature into consideration without fail.

Fourth, when FDF operation deviates from the maximum efficiency mode, the level of radiated noise increases. This must be taken into consideration in use, since FDFs operate under decreased loads at night, when the strictest standards regarding noise level for housing developments territories are operative. At variable modes, the level of sound power L_{wn} is determined by the formula [1, 2]

$$L_{wn} = L_w + \Delta, \tag{2}$$

where L_w is the level of sound power of the FDF at nominal (maximum efficiency) mode, dB; and Δ, an adjustment that takes into account the operating mode, is found from η_{max}, the coefficient of efficiency at nominal load of the FDF (Table 1).

Hence in preparing recommendations regarding noise absorption, it is necessary to consider that characteristic operating mode of the forced-draft fan at which the greatest radiation of noise level occurs.

Fifth, it is necessary to consider the regional factor. Research [3] shows that, other things being equal, the sound level at a distance, for example, of 500 m from the station, can change up to 8 dBA due to temperature and humidity changes during the course of year for this region.

For close location of units with forced-draft fans relative to residential territory, the operative health standards for the noise factor are heightened [4].

TABLE 1. Dependence of Adjustment on Coefficient of Efficiency

η_{max}	1	0.9 – 1	0.8 – 0.9	0.8
Δ	0	2	4	5

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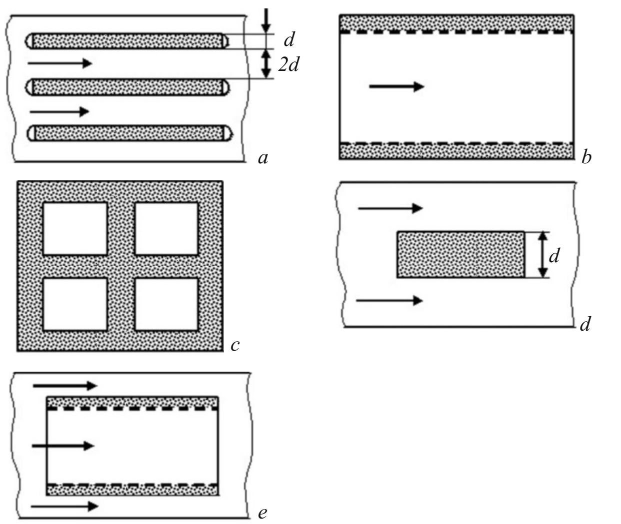

Fig. 1. Absorptive (dissipative) silencers: *a*, plate; *b*, tubular; *c*, cellular; *d*, rocker; *e*, cylindrical.

In this case, acoustic calculations according to this methodology [5] determine the required noise abatement from each of sources, taking into account the enumerated moments, including for forced-draft fans, and then develop and introduce facilities for their noise absorption. In order to reduce the effect of forced-draft fans on the environment, silencers are installed from the absorption side for fans and from the forcing side for induced-draft fans. Forced-draft fans of large-power thermal power plant can exceed health standards by 20 – 25 dBA [1].

An effective method of noise abatement of forced-draft fans is installation of absorptive (dissipative) silencers [1 – 3]. The ability to reduce noise in absorptive silencers is based on the transformation of sound energy to thermal when sound waves hit certain so-called sound-absorptive materials. Absorptive silencers differ from each other by the arrangement of sound-absorptive material by section of the channel. Figure 1 shows the main types of absorptive silencers: tubular, plate, cellular, rocker and cylindrical [2 – 4]. The sound-absorptive material is protected from blowout by the perforated sound-transmitting covering.

Plate thickness is selected by proceeding from the maximum sound in the range: the lower the frequency of the sound being dampened, the thicker the silencer plates. If the frequency characteristic of dampening does not coincide with the frequency characteristic of the silencer, then it is necessary to make the silencer in two or even three steps, each of which provides attenuation in its own range.

The use of one or another type of absorptive silencer depends on the following requirements:

1) necessary noise level abatement throughout the range, taking account of the specific nature of the noise emitted from the source;

2) minimum hydraulic resistance;

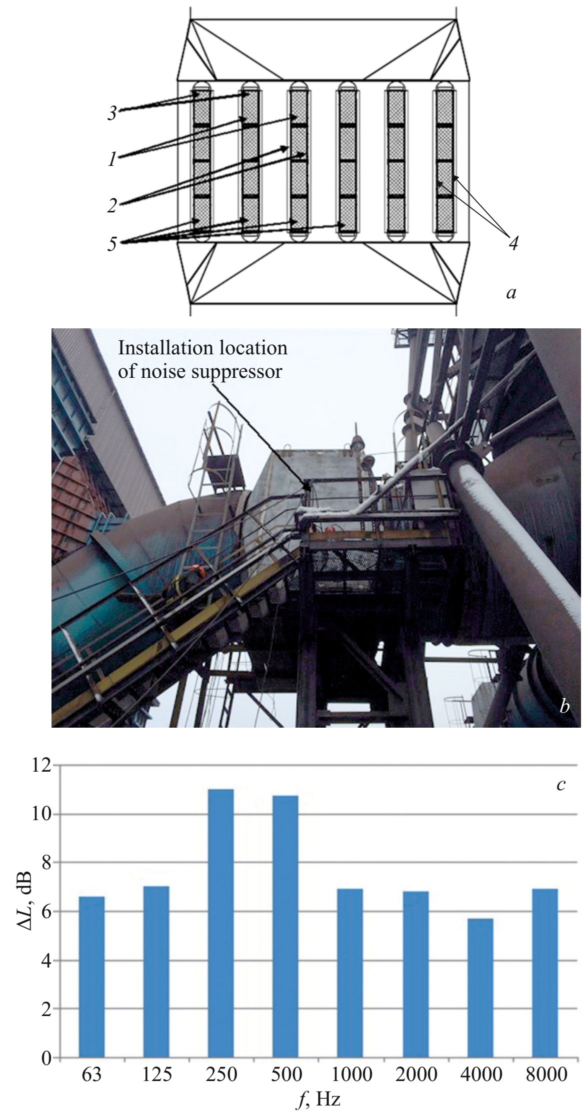

Fig. 2. Layout of plate silencer of an induced-draft fan (*a*), installation site of the noise suppressor (*b*), and the results of acoustic measurements of the efficiency of the silencer (*c*): *1*, sound-absorptive material; *2*, perforated sheet metal; *3*, round fairings; *4*, silencer casing; *5*, silencer plates.

3) eliable operation of silencers at relatively high temperatures and in the conditions of the possible occurrence of low-temperature corrosion;

4) minimal weight and overall dimensions, making it possible to position the silencer within existing structures;

5) convenience of assembly and operational checkup;

6) amounts of capital expenditure.

To the list of chief requirements shown for designs of noise suppressors for forced-draft fans, it is also necessary to add the necessity to preserve the operating characteristics of the equipment (such as thermal capacity or steam producing capacity).

The aerodynamic resistance of the absorptive silencer depends on many factors: fkiw velocity of the medium in the

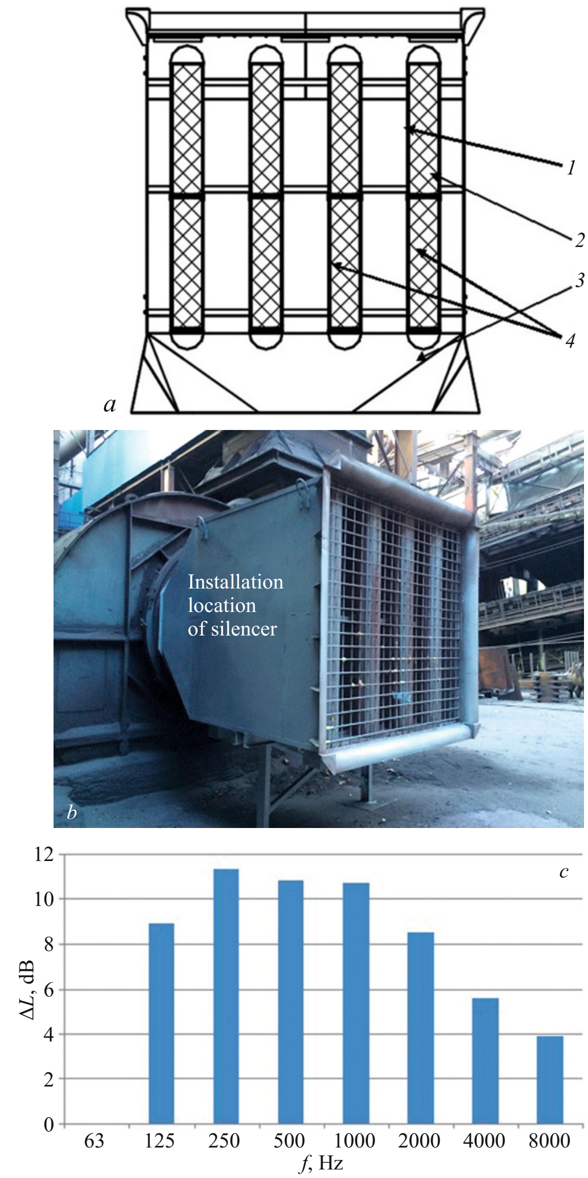

Fig. 3. Layout of plate silencer for air intake of the forced-draft blower (*a*), installation site of the sound suppressor (*b*), and the results of acoustic measurements of efficiency of the silencer (*c*): *1*, sound-absorptive material; *2*, perforated sheet metal; *3*, round fairings; *4*, silencer duct; *5*, silencer plates.

silencer, friction resistance, coefficients of resistance of the input and output section, and other factors [7].

Studies that have been done have shown [8] that the aerodynamic resistance of a complex section is affected by the placement of the silencer, more precisely the distances from the silencer stage before and after a bend.

Installation of an absorptive silencer of one or another design is a technical and economic problem [9]. The procedure for calculating plate lengths for stages with various plate thickness with the smallest discounted expenses is given in [10].

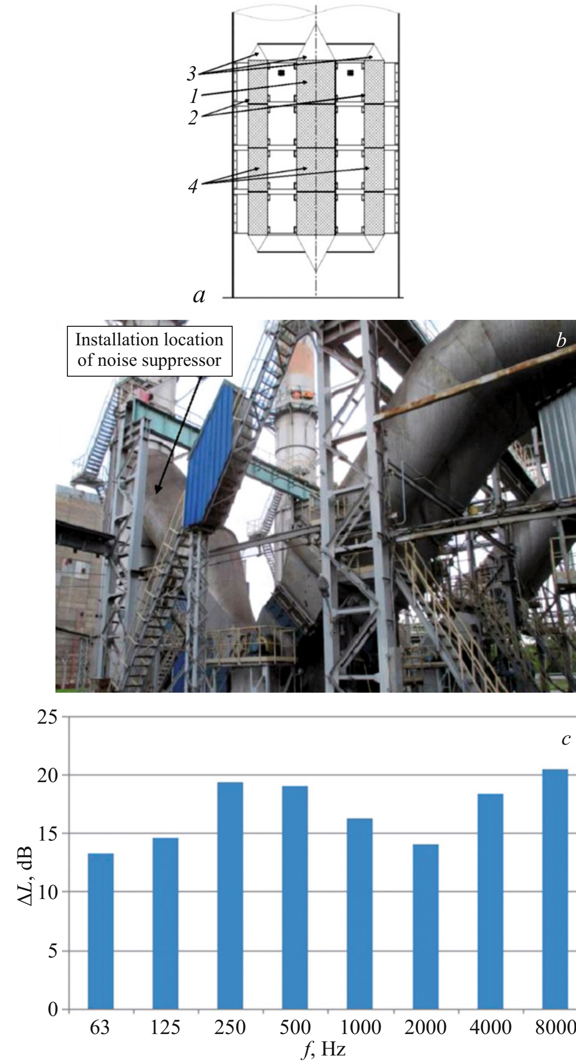

Fig. 4. Layout of the rocker-cylindrical silencer for an induced-draft fan (*a*), the installation site for the silencer for the induced-draft fan (*b*), and the results of acoustic measurements of the efficiency of the silencer (*c*): *1*, rocker; *2*, cylinder; *3*, fairing; *4*, sound-absorptive material.

The staff of the Scientific and Educational Center for Noise Abatement of Power-Generating Equipment of the National Research University MÉI (NIU MÉI) have been successfully developing and introducing for many years highly effective devices for noise abatement of forced-draft fans [1].

The absorptive silencers developed and introduced in 2015 for the following cases are further examined:

— the plate silencer for a horizontal gas duct after an induced-draft fan (Fig. 2);

— the plate silencer for a horizontal gas duct before the forced-draft blower (Fig. 3);

— the rocker-cylindrical silencer in a circular gas duct that is at an angle to the horizontal (Fig. 4);

— an overall set of devices where, in addition to a plate silencer for noise abatement, lining of turns and installation of sound-absorptive ramps (Fig. 5) is used.

Figure 2 shows the layout of a plate silencer for a horizontal gas duct after induced-draft fans, a photograph of the installation site of the silencer, and the results of measuring the acoustic efficiency of the silencer. It is clear from Fig. 2*c* that the acoustic efficiency of the silencer was 9 dBA and has a reserve to the value of the required decrease. The aerodynamic resistance of the silencer was 30.3 Pa (3.1 mm H_2O).

Figure 3 shows the layout of the plate silencer for a horizontal air line to the forced-draft blower, a photograph of the an air intake after reconstruction, and the results of measuring the acoustic efficiency. It is clear from Fig. 3*c* that the acoustic efficiency of the silencer was approximately 10 dBA. Improvement of the aerodynamic characteristics of the intake manifold due to change in its design made it possible to reduce aerodynamic resistance by 179 Pa (18.3 mm H_2O).

Figure 4 shows the layout of the rocker-cylindrical silencer in a circular gas duct which is at an angle to the horizontal, a photograph of the installation site of the silencer, and the results of measuring the acoustic efficiency of the silencer. The acoustic efficiency of this silencer is approximately 17 dBA (Fig. 4*d*) also has a reserve to the value of the required decrease. The aerodynamic resistance of the silencer was approximately 61 Pa.

Figure 5 shows the overall set of devices where in addition to a plate silencer (Fig. 5*a*), a lining of the bends and installation of sound-absorptive ramps are used there for noise abatement (Fig. 5*b*), as well as the results of measuring the acoustic efficiency of this set of devices.

The plate silencer is installed at a certain distance from the vertical mine. This step consists of six plates 200 mm thick with length 3000 mm (3200 mm together with fairings). The upper part of the vertical gas duct is lined with sound-absorptive panels. In order to improve the aerodynamics, a ramp (a slanting partition) is installed on the side opposite to the intake channel. In addition, immediately beneath the edge of the intake channel a special rounding made of metal is installed along the entire wall to reduce aerodynamic resistance. The lower part of the vertical gas duct is also lined with sound-absorptive panels.

Installation of the noise suppressor in the horizontal gas duct increases the aerodynamic resistance by 37.8 Pa (3.9 mm H_2O). Improvement of the aerodynamics of the gas path by installing ramps and special roundings reduces resistance of a gas path by 107 Pa (10.9 mm H_2O). As a result of the introduction of the entire set of actions, the general aerodynamic resistance of the gas path decreased by 69.29 Pa (7.1 mm H_2O). According to the results of acoustic measurements, acoustic efficiency was approximately 15.3 dBA.

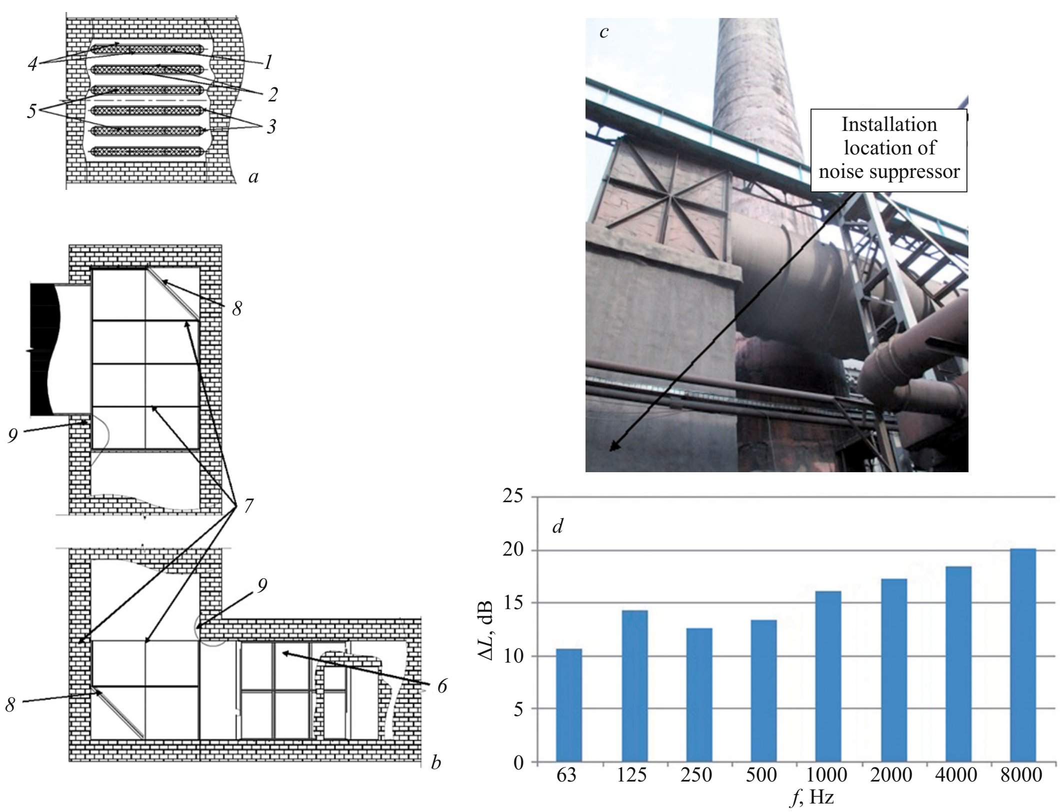

Fig. 5. An overall set of devices for noise abatement of an induced-draft fan: *a*, diagram of the plate silencer; *b*, diagram of the overall set of measures for noise abatement; *c*, installation site of noise absorption devices; *d*, results of acoustic measurements of efficiency of the silencer; *1*, sound-absorptive material; *2*, perforated sheet metal; *3*, round fairings; *4*, silencer casing; *5*, silencer plates; *6*, single-stage plate silencer; *7*, sound-absorptive panels; *8*, ramp; *9*, special roundings.

The experience obtained in introducing highly efficient absorptive silencers of different types is an important step in solving the problem of noise abatement from forced-draft fans with moderate aerodynamic resistance.

CONCLUSIONS

1. Use of absorptive (dissipative) silencers of different types is effective method of noise abatement from forced-draft fans, which should be examined in an overall system for resolving the acoustic, aerodynamic, and other requirements.

2. The developed and introduced absorptive silencers of different types for noise abatement of forced-draft blowers and induced-draft fans demonstrated reliability and high performance characteristics.

3. The acoustic tests that were conducted after installation of silencers show their high acoustic efficiency, making it possible to abate noise from power-generating equipment to a specified value with moderate aerodynamic resistance.

4. It is expedient to use sound-absorptive structures to improve the aerodynamics of the air-gas path. In this case, after introducing measures for noise absorption the total aerodynamic resistance of a path can decrease in certain cases by hundreds of pascals.

5. The experience obtained in the system-wide introduction of absorptive silencers of various types will facilitate a solution for the acoustic safety of the population.

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