Noise Sources of Combined Heat and Power Plants and Methods for Noise Estimation in Adjacent Urban Areas

V Gusev¹, V Ledenev², A Antonov³, I Matveeva⁴

¹Head of Laboratory, Research Institute of Building Physics, Lokomotivny driveway 21, Moscow, 127238, Russia
²Professor, Tambov State Technical University, str. Sovetskaya 106, Tambov, 392000, Russia
³Head of Chair, Tambov State Technical University, str. Sovetskaya 106, Tambov, 392000, Russia
⁴Associate Professor, Tambov State Technical University, str. Sovetskaya 106, Tambov, 392000, Russia

E-mail: gusev-43@mail.ru

Abstract. Combined heat and power plants (CHP) are permanently operating enterprises for the production of electrical and thermal energy. They are located, as a rule, in cities and in large settlements, create significant noise pollution for the buildings adjacent to them. Protection from the noise of the territories adjacent to the heat and power plants, especially residential buildings, is a topical scientific and practical problem. Based on the results of field measurements, the article identifies and shows the main external sources of noise that determine the noise impact of the heat and power plants on the environment of the metropolis. Such sources include large-sized ground and above-ground equipment: air intake of blower fans and chimneys, transformers, gas distribution unites, gas pipelines, cooling towers. Reliable basic data on their acoustic power and the required amount of noise reduction have a special role for the development of optimal protection from the point of view of acoustics and economics from the noise of such sources. They can only be determined by calculation for a number of equipment sources of combined heat and power plants. The article presents new, computational methods that allow you to determine the desired data and, accordingly, to qualitatively design the necessary acoustic building noise reduction tools based on the methods of shielding, sound insulation and sound absorption.

1. Introduction

Combined heat and power plants represent the industrial enterprises for the production of electrical and thermal energy with a continuous cycle of work with a large number of radiating noise from the main and auxiliary equipment located inside and outside buildings. For these reasons, they, on the one hand, ensure the vital activity of the population of cities; on the other hand, they create noise that exceeds the norms of urban areas. Noise pollution depends on the number of power units of combined heat and power plants, which include turbine generators, steam boilers with blower machines, transformers, as well as the power of this equipment. The acoustic surveys of the thermal power plants of Moscow, built at different times, have established that each of them has 15–20 large-sized noise sources that produce a 24-hour negative environmental impact. They can be divided into two groups
[1,2]. Some of them are ground-based sources: the frame of the thrust and blow machines (smoke exhausters and blower fans), transformers, air intakes of tower cooling towers, gas control unites and gas pipelines. Their noise on most objects is partially shielded by buildings and structures. Ground-based sources are located at a height of 10 ÷ 180 m from the ground. They include blower fans of blast systems, chimney mouths, glazing of main buildings and rooms for turbine generators with a glazing area of more than 500 m². An exemplary scheme of noise-emitting elements of gas-air systems of thrust and blow in steam boilers is shown in Figure 1.

![Figure 1. Schemes of gas-air systems of thrust and blow of steam boilers.](image)

Increased noise from above-ground sources, depending on their power, extends beyond the limits of enterprises at a distance of 800-1600 m [3,4]. With a total impact, they create considerable noise levels on the territories adjacent to energy enterprises, including residential buildings. These excesses are especially high in residential areas of Moscow at night. As can be seen from the experimental data shown in Figure 2, this excess reaches 15-18 dB in octave frequency bands at distances from the boundaries of some medium and large CHP plants, shown in Figure 2 in brackets. The sound levels are 52-55 dBA and exceed the standard values by 12-15 dBA. The accuracy of the noise values shown in Figure 2 should be noted. They were obtained in previous years, when the urban background noise in general was significantly lower than at present, and the measurements were performed during the quietest periods of the night. At other times of night and day, the noise of enterprises is essentially camouflaged with background urban noise.

The energy enterprises also have a group of much more powerful sources of noise. These sources are associated with the release of steam into the atmosphere. There is a temporary increase in sound level by 30-40 dBA within a radius of several kilometers [1] with emissions. Since steam emissions occur, as a rule, at starting and stopping operations on boilers, these sources are sources of episodic action. Therefore, these operations should be performed only in the daytime.
As the long-term experience of the work of Research Institute of Building Physics in this area has shown, tools known from building practice are suitable for reducing the noise of heat and power plants equipment. These include the installation of acoustic screens [5, 6] for transformers and for air intakes of cooling towers, the use of a sound insulation coating [7–10] for gas distribution substations, gas pipelines and air ducts, the installation of plate silencers with one and two steps [11, 12] for blower fans and smoke exhausters, the use of sound insulation glass [6] for the glazing of the main buildings of energy companies, etc.

As the experience of introducing the tools in the heat and power plants of Moscow shows, they have the effect of reducing noise mainly within the enterprises themselves in the areas where noisy equipment is located. The effect is insignificant outside of enterprises, and especially near residential buildings. Protection against noise often with a margin of acoustic efficiency is carried out, as a rule, on one or two of the entire group of similar sources. The limited implementation of measures to reduce noise is due to the lack of substantiation of the significant material costs of the noise reduction of a large number of large-sized noise sources of enterprises. Choosing protective measures in insufficient volume, their acoustic and economic estimation is performed. This is largely due to the lack of reliable information about the acoustic characteristics of noise sources.

The article discusses the possibility of determining the acoustic characteristics of noise sources and data on the required noise reduction, this information is necessary for the design of acoustically efficient and cost-effective means of protection against noise.

2. Estimation of acoustic characteristics of noise sources of combined heat and power plants
It is advisable to apply the accurate instrumental studies to obtain the initial data in enterprises with a changeable mode of operation. Such studies cannot be performed at energy facilities with a continuous cycle of work. This is due to the fact that at any point of observation, located on the territory of urban development that is remote from the enterprise, besides the noise of the enterprise, there is a high noise background. Background significantly affects the accuracy of measurement results. In cases
where it is possible to determine the total noise of an object at a measuring point, it is impossible to distinguish from it separately the characteristics of noise belonging to any one source.

Thus, practically the only way to determine the required noise reduction, information about which is necessary for the design of noise protection equipment, is to perform acoustic calculations with known data on the acoustic power of sources. They can be passport noise characteristics of the equipment or noise characteristics obtained in the operating conditions of the equipment.

From the sources indicated earlier, the noise characteristics have only the thrust and blow machines and transformers. They must be determined in natural conditions on the basis of measurements or by calculations for other sources. This applies primarily to the duct of blower fans, and the mouths of chimneys.

The sound power levels of the mouth of a chimney or air intake of a blower fan can be determined based on a simple expression [3,11]:

\[ L_{W_{\text{canv}}} = L_{W_i} - \Delta L_{W_{\text{canv}}} - \Delta L_{W_{\text{sil}}}, \]  

(1)

where \( L_{W_i} \) - passport sound power levels of smoke exhausters, blow fans, dB; \( \Delta L_{W_{\text{canv}}} \) - efficiency of the silencer, if installed, dB; \( \Delta L_{W_{\text{sil}}} \) - reduction of sound power levels in the gas-air channel, dB, determined by the formula

\[ \Delta L_{W_{\text{canv}}} = \sum_{i=1}^{n} \Delta L_{W_{\text{canv}}} + \sum_{i=1}^{n} \Delta L_{W_{\text{esd}}} + \Delta L_{W_{\text{wes}}} + \Delta L_{W_{\text{wcp}}} + \Delta L_{W_{\text{esp}}}; \]  

(2)

where \( \Delta L_{W_{\text{canv}}} \) - reduction of levels on the straight sections; \( \Delta L_{W_{\text{esd}}} \) - reduction of levels on cornering; \( \Delta L_{W_{\text{wes}}} \) - decrease of levels in branches; \( \Delta L_{W_{\text{wcp}}} \) - decrease of levels in the pipe base; \( \Delta L_{W_{\text{esp}}} \) - decrease of levels in chimney; \( \Delta L_{W_{\text{es}}} \) - decrease of levels as a result of reflection from the end of the channel.

Values \( \Delta L_{W_{\text{canv}}} \) and \( \Delta L_{W_{\text{es}}} \) can be determined by calculating the noise distribution inside the channels and pipes.

Traditional techniques based on the principles of wave acoustics were used to estimate the distribution of sound energy in any channels for several decades, in the country and abroad. In this case, the channels are considered as waveguides of a certain size. These techniques provide satisfactory calculated data for the cases of ordinary small and medium channels with small transverse dimensions. With large channel sizes, their use is limited at best to the low frequency range. Wave methods do not provide reliable data on the distribution of sound energy in large channels in the medium and high frequencies.

In this connection, calculation methods based on the statistical energy theory of the formation and propagation of reflected sound energy in closed air volumes were proposed for the noise estimation in large-sized ducts of gas-air systems of heat and power plants and determining noise characteristics in chimneys and air intakes [13-15]. A rather effective among them is the source estimation function method [14]. The sound pressure levels in the gas-air channel, on the basis of which the sound power levels of these sources are then determined, in this case they are calculated using the formula

\[ L = L_{W_i} + \log \left[ \exp \left( \frac{-m_i r_i}{\Omega r_i^2} \right) + \frac{2(1-\overline{\alpha})}{\Omega_l} G_i \right], \]  

(3)

where \( r_i \) - distance from the noise source to \( i \) calculated point; \( \overline{\alpha} \) - average sound absorption coefficient in the channel; \( \Omega \) - spatial angle of radiation of sound energy by the source of noise to the
channel; $G_i$ - function of the influence of space-planning and acoustic parameters of the channel on the amount of reflected energy in its $i$ point

$$G_{i} = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} \frac{\exp(-\gamma_{mn} r_{mn})}{r_{mn}};$$  

$$\gamma_{mn} = \sqrt{\frac{l_{x} (\ln \beta_{1} + \ln \beta_{2}) + l_{y} (\ln \beta_{3} + \ln \beta_{4}) + 2 m \cdot l_{x}}{(l_{x} + l_{y})^2}};$$

$\beta_{i} = (1 - \alpha_{i}) \div \beta_{i} = (1 - \alpha_{i})$ – coefficients of sound reflection by channel fencing with coordinates $x_{1} = 0, x_{2} = l_{x}$, $y_{3} = 0, y_{4} = l_{y}$; $r_{mn}$ – distance from the calculated point to the source image; $m, n$ – combinations of integers except $m=n=0$.

By comparing the experimental and calculated data, it was found that in order to ensure the required accuracy in practical calculations, it is sufficient to limit to $8–10$ orders of the accounted members of $G$ function over the entire range of possible changes in sound absorption coefficients of unlined channels [14].

The noise characteristics, obtained in this way, provide the possibility of calculation for noise levels from air ducts and chimney mouths in the residential area or directly in a residential house at a distance specified from the enterprise. The calculation is performed by a well-known formula that determines the distribution of noise in the buildings under the action of a point source.

It is possible to use the calculation method presented in [16] to assess the environmental impact of glazed planes of enterprises, which are the main buildings with flat sources of finite rectangular sizes. The calculation formulas proposed in it allow the calculation of the levels of sound distribution from such sources. They take into account the directivity factor of the sound emission and the position of the calculated points relative to the source. According to [16], if the calculated points are located at distances two and more times larger than the maximum source size, the direct sound from the glazing can be calculated with sufficient accuracy as from a point source.

We use computer simulation that implements the developed computational methods [17] to assess the noise impact of thermal power plants on the environment and to predict its levels in a given place in an urban area after the implementation of protective measures. The principles of such modeling of the distribution of noise in urban buildings from industrial facilities with powerful noise sources are considered in [18]. It is shown that modeling can be effectively used in the development of measures to protect against noise objects in the adjacent residential buildings.

3. Conclusion

Thus, at present, Research Institute of Building Physics has developed the methods for noise calculation distributing inside large-sized ducts of gas-air systems and chimneys. Computer implementation of the methods makes it possible to assess the noise emitted from the mouths of pipes and air ducts and, accordingly, its distribution in the territories adjacent to the energy enterprises. The methods are applied in solving practical problems of sound attenuation at the energy enterprises of Moscow and Moscow region.

4. References

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