Increasing safety of thermal and nuclear power stations
energy equipment by reducing noise

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Abstract. Noise is the most important factor of physical effects at normal operation thermal and nuclear power equipment. Increasing the safety of the power equipment of thermal power (TPS) and nuclear power stations (NPS) is important task. This task is also associated with a decreasing the noise from power equipment. The problem of noise reduction by thermal and nuclear power equipment in the surrounding areas is discussed. Here are the original theoretical developments of the education of the most intense noise sources. There is also given and original examples of devices to reduce noise from them: from steam emissions, draft machines, cooling towers, etc. Creating mathematical models of thermal or nuclear power plants allows us to consider the effect of the limiting factors in the development of the noise safety from TPP and NPS. Mathematical models allow us to study the effects of sound power sources and its amount, location of sources at the site, the mode of operation of the equipment, index of their direction, the orientation of the power equipment and other factors on the noise levels in the surrounding area. The results of the original tests various silencers and acoustic barriers are given. The importance of complex noise reduction on the totality of sources of noise to ensure noise sanitary standards in the surrounding area are shown.

1. Introduction
Noise is the most important factor of physical effects at normal operation thermal and nuclear power equipment. Increasing the safety of the power equipment of thermal power (TPS) and nuclear power stations (NPS) is important task. Noise reduction from power equipment is essential to ensure the safety of thermal and nuclear power plants personnel, as well as residents of the surrounding area.

Noise negatively influences health of the person. Noise impact increases probability of mistakes during the work of the staff. It is extremely dangerous – reduces equipment operation safety. It is absolutely inadmissible for power stations and especially for nuclear power stations.

Government policy is based on the implementation of a number of sanitary standards. The Federal laws "On Protection of Atmospheric Air" and "Concerning the Protection of the Natural Environment" oblige running actions for decrease noise from sources to sanitary standards which are established by SN 2.2.4/2.1.8.562-96 for jobs and the surrounding area (the residential area) [1].

In our country width of the sanitary protection zone is determined depending on a class of the enterprise or production. Here only five classes of objects, distances of sanitary protection zones (SPZ) for which the following: 1st class - 2000 m; 2nd class - 1000 m; 3d class - 500 m; 4th class - 300 m; 5e class - 100 m.

For example, the thermal power stations (TPS) with an equivalent electric power of 600 MW and above, the coal and fuel oil using as fuel, treat the enterprises of the first class and must to have SPZ not less than 1000 m, using gas and oil-gas fuel must to have the SPZ belong to the enterprises of the second class and must to have the SPZ not less than 500 m. The Heating and Power Plant (HPP) and regional
boiler houses with a thermal power of 200 Gcal and above, using coal and black oil fuel, belong to the second class with the SPZ not less than 500 m, using gas and black oil fuel (the last — as reserve) belong to the enterprises of the third class with the SPZ not less than 300 m [2].

The sanitary rules install minimum sizes of sanitary area. Real sizes can be more and are defined by means of the acoustic calculation.

2. Mathematical modeling

The TPS and the NPS mathematical modeling allows to solve in a complex problem of increase in TPS and NPS power equipment safety from noise. On the one hand, modern software allow to define sound level isolines and/or sound pressure level, on the other hand to find the equipment noise characteristics which provide sanitary norms on the sanitary protection zone border (fig.1). Noise characteristics can be the limiting factor at new capacities installation or old site reconstruction. Such situation is especially urgent for sites near residential areas.

The solution of a task is definition of the equipment noise characteristics at which admissible sanitary norms will be carried out, as in workplaces so in the surrounding residential area on sanitary protection zone border.

At the same time noise characteristics of the equipment is:

\[ L_{\text{win}} = L_{\text{win0}} - \Delta L_{\text{win}} \]  

where \( L_{\text{win0}} \) — equipment initial noise characteristic, dB; \( \Delta L_{\text{win}} \) — possible noise reduction from a source.

Sound pressure level at distance from a source, when noise source and reference points are located in the open air, is determined by a formula [3]

\[ L_p(DW) = L_{\text{win}} + D_c - A \]  

where \( L_{\text{win}} \) — sound power level in octave bands of \( n \) noise source, dB; \( D_c \) — index of directivity, dB; \( A \) — attenuation in octave bands in case of sound distribution from noise source to the receiver, dB;

\[ A = A_{\text{div}} + A_{\text{atm}} + A_{\text{gr}} + A_{\text{bar}} + A_{\text{misc}} \]  

where \( A_{\text{div}} \) — attenuation because of geometrical divergence; \( A_{\text{atm}} \) — attenuation because of a sound absorption the atmosphere; \( A_{\text{gr}} \) — attenuation because of ground influence; \( A_{\text{bar}} \) — attenuation because of barries; \( A_{\text{misc}} \) — attenuation because of other effects.

The set of \( n \) of sources create in each of reference points with coordinates \( x, y, z \) the noise level determined by the known law:

\[ L_c(x,y,z) = 10 \log \left( \sum_{i=1}^{n} 10^{0.1L_i(x,y,z)} \right) \]  

At the same time the total sound pressure level has to be less or is equal to admissible sanitary norms.

\[ L_c(x,y,z) \leq L_{\text{st}} \]  

For the opportunity will be defined for this purpose by a row of conditions.

At first, noise reduction actions from a source have restrictions \( \Delta L_{\text{win}} \). There exist a limit for noise reduction value for each of octave band for each of \( n \) sources.

For example, limit noise reduction value by the plate silencer set:

- in a metal channel box makes about 50 dB,
- in the channel with brick or concrete walls to 76 dB.

Attenuation on the barrier \( Dz \) in any octav band it is less than 20 dB in case of diffraction on one edge (thin barriers) and 25 dB in case of diffraction on two edges (thick barriers).

Besides there are some more restrictions.

The equipment (noise sources) settle down in the territory of the enterprise according to certain requirements (fire safety, reliability of operation, etc.).
At the same time for sources from 1 to \(i\) coordinates \(x_i, y_i, z_i \ldots \), and for sources from \(i+1\) to \(n\) coordinates aren't rigidly interconnected.

3. **Classification of noise sources and main noise reduction methods**

On TPS and the NPS are a large number of intensive noise sources. The quantity of sources for large objects can reach hundreds of units. Noise from sources located in facilities (turbines, boilers, pumps, etc.) will determine in many respects by the soundproofing properties of building walls. The emitted noise frequency range strongly differs from sources. It could be from low frequency (compressors, the coal equipment) to high-frequency (steam emissions). Noise sources layout can be at height of \(h_1\) to \(h_2\) over earth level. Noise level is influenced by equipment operation modes, also, as well as a directivity index, site orientation in relation to the residential area [4]. As shown in [5], the task in a general view is three-dimensional.

Thus, equipment noise parameters can be important along with other technical characteristics. Noise parameters can be the limiting factor in case of new capacities installation or old site reconstruction. Such situation is especially urgent for sites in case of their placement near residential areas.

To reduce noise from the most intensive noise sources apply silencers, acoustic barriers. It is possible to achieve noise reduction in estimated points. The task can be solved by alternative calculation by computer in case of allowing for the sources relocation restriction from each other. Calculation is carried out for octave bands from 63 to 8000 Hz.

Classification of the TPS main sources and methods of noise reduction from them is given in tab. 1.

The silencers providing quiet environment throttling (steam silencers) (fig.2) [6] belong to the main methods of TPS noise reduction; noise reduction silencers in channels from smoke exhausters, the fans (fig.3) [8-9], compressors [7]; acoustic barriers for noise reduction of coolers and transformers (fig.4) [10]; sound insulation of the casing exhauster fans, coal equipment, walls of facility; acoustical absorption of site building walls. Data specified in table 1 are correct for the NPS. Complex application of actions for noise reduction allows to improve safety of TPS and the NPS [6].

| Main sources | Main noise reduction methods |
|--------------|-----------------------------|
| 1. Steam emission | Complex of actions: |
| 2. Fans | 1. Silencers, providing a quiet throttling of the |
| 3. Exhauster fans | environment (steam silencers, silencers for gas |
| 4. Fuel preparatory equipment (gas | distribution substation) |
| 5. Transformers | 2. Silencers for noise reduction in channels from the |
| 6. Cooling towers | fans, smoke exhausters, compressors |
| 7. Compressor unit | 3. Acoustic barriers for noise reduction of coolers and |
| 8. Noise from boiler-turbine workshop | transformers |
|               | 4. Sound insulation of cases exhausters fans, coal |
|               | equipment, walls of workshop |
|               | 5. Sound absorption on the building walls |

4. **Conclusion**

1. Safety of TPPs and nuclear power plants is associated with ensuring the ultimate noise characteristics of equipment. The ultimate noise characteristics of the equipment depend on the initial noise characteristics and their possible reduction by various measures for noise attenuation.

2. It is shown that sound pressure levels at distance from TPS and the NPS depend on type and operating modes of the equipment, index of directivity, site orientation in relation to the residential area and marginal efficiency of possible actions of noise reduction.

3. It is expedient to use three-dimensional mathematical model for finding the limit equipment noise characteristics for TPS and the NPS.
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Figure 1. Results of calculation for power station model.
Figure 2. MPEI steam silencers

Figure 3. Exhauster silencers
Figure 4. Acoustical barriers: a — with a visor; b — Γ shape