

PROTECTION OF ENVIRONMENT AGAINST NOISE OF COOLING TOWER

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Abstract. Alternative variants of decrease in noise level from working mechanical-draft towers and tower salterns are analyzed. Various variants of constructive performance of blocks of a packing and placing of these blocks taking into account features of aerodynamic conditions in cooling towers are offered. One of variants offers displacement upwards blocks of a packing of film type on certain distance from the top part air entrance windows section mechanical-draft towers. Other variant provides a step arrangement of blocks of shortlayerwise a packing on height of tower saltern. Characteristics and results of comparative tests of shortlayerwise a packing are resulted.

Keywords: cooling tower, aerodynamic conditions, noise, blocks of a packing, ecology, environment.

1. Introduction

Ecological requirements on protection of environment against influence of various industrial targets last years constantly increase.

Such widespread element of industrial and power objects as the saltern from the point of view of preservation of the environment represents a source of noise and a source of emissions of aerosols. Salterns section, single and tower the big individual capacity, under the existing sanitary code of the Russian Federation and the countries of the European Community, should meet the requirements of protection of environment against noise completely. It is especially important at placing of salterns on roofs, or near to inhabited, medical and industrial buildings. As a source of noise the saltern represents a construction in which noise is created mechanical-draft towers by installation (if it mechanical-draft tower) and noise of falling water.

Noise from mechanical-draft tower installations is characterized by low and average frequencies from 63 to 500 Hz (Hertz). Noise from movement of falling water, "rain" noise, in a saltern is characterized by frequencies from 500 to 8000 Hz (Пономаренко and Арефьев 1998; Пособие по... 1989).

In mechanical-draft towers salterns, the area of cross-section section less than 16 m², the greatest contribution to noise level is brought mechanical-draft tower by installation. In a case big the sizes of section of a saltern the considerable share in the general noise created by a saltern, is brought by the noise created by movement gravitationally of falling water – "rain" noise. The last is especially appreciable on high frequencies.

2. Noise characteristics of a saltern

Noise created by a saltern estimate under its noise characteristic. On compound frequencies of octava strips in a range 63 – 8000 Hz on distance of 1 m from sound active surfaces are considered to be level of sound pressure of a saltern the noise characteristic of a saltern. Here under sound active a surface that part of a saltern where noise radiation is maximum is understood. In section mechanical-draft towers, single and tower salterns sound active a surface are:

- air entrance windows;
- an air outlet from diffuser or saltern towers;
- the case of the fan of a saltern.

Level of sound pressure of a saltern – L , [dB] (decibel), it is possible to define under the composition (Пономаренко and Арефьев 1998):

$$L = 20 \cdot \lg(P/P_0) \quad (1)$$

where P – operating value of sound pressure, [Pa]; P_0 – threshold size of root-mean-square sound pressure. According to (Пономаренко and Арефьев 1998): $P_0 = 2 \cdot 10^5$, [Pa] (Pascal).

3. Ecological aspects of a problem

It is possible to carry the following to the major factors influencing noise level in salterns.

At noise from the fan of a saltern great value have:

- diameter of a wheel of the fan;
- district speed of a wheel of the fan;
- a profile of shovels of a wheel of the fan;

- number of shovels of a wheel of the fan;
- type of a drive of the fan;
- a design of bearings.

At noise from water of "rain" falling in a saltern great value have:

- "Rain" noise;
- Noise of drops (streams) of water at their contact with a water mirror in saltern pool;
- Noise of drops (streams) of water at their interaction with the top part of the block of a packing;
- Distance from the bottom part of blocks of a packing to a mirror of water of pool of a saltern;
- Distance from water distributing system to the top part of blocks of a packing;
- A water pressure in water distributing packings;
- Type of water distributing packings of a saltern;
- Orientation of water distributing packings in a saltern (top, lateral or bottom);
- Type of blocks of a packing (film, drop or drop-film).

For quality standard of ecological aspects of a problem of noise level in a saltern it is comparable it with noise from transport, and also noise level at the industrial enterprises (see the table 1).

As it is visible from the data presented in the table, level of a sound from an operating saltern is comparable to similar parameter of machine-building factories, trams and lorries.

Table 1. Comparative data on various sources of noise (Денисов *et al.* 2011; Пушнов *et al.* 2007)

Nr.	Source of noise	Sound level, dB
1	Lorry	85 – 96
2	Car	82 – 88
3	Bus	80 – 95
4	Tram	75 – 96
5	Railway transportation	80 – 100
6	Underground	89 – 93
7	Compressor station	90 – 100
8	Machine-building factories	80
9	Tower saltern	80 – 87 ¹

¹Here standard value of level of sound pressure in dB (A) with the amendment on a scale A (Пушнов *et al.* 2007) is resulted. Modified on a scale A level of sound pressure in dB (A) in *i* octave strip of frequencies is calculated under the composition: $L_{pA_i} = L_{pi} + dLA_i$.

The ecological aspect of a considered problem is connected by that under noise influence of a various origin, including operating salterns, there are considerable groups of the population, especially in cities. So, according to work (Тупов 1999) under constant noise influence lives from 20 % to 40 % of the population of megacities. Because of the raised noise level in cities work capacity of the population decreases on 10 %, and level of diseases increases by 30 %. On Fig 1 the zone, characteristic for

noise of an industrial tower saltern of type BG-2600 is shown. It is necessary to notice that almost any industrial production is anyhow connected with use of systems of turnaround water supply, so also salterns. Therefore the urgency of decrease in noise level in salterns is obvious.

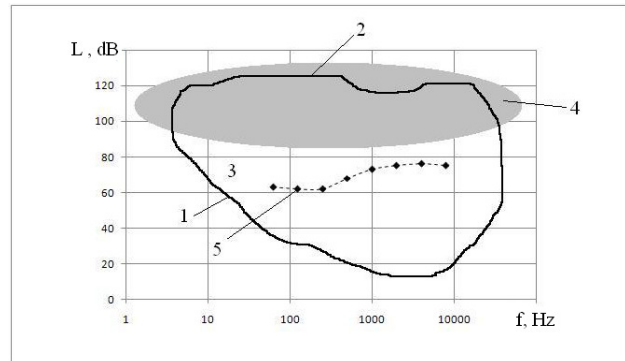


Fig 1. A zone of audibility of the person: 1 – an audibility threshold; 2 – a painful threshold of sensitivity; 3 – an audibility zone; 4 – a zone, characteristic for noise from the power equipment; 5 – sound pressure upon distance of 1 m from entrance windows of saltern BG-2600

4. The analysis of noise characteristics

In work (Прспект фирмы ООО “СПИГ – Восток”) the diagram of distribution of noise level 4 section mechanical-draft tower from which it is possible to conclude is shown that noise of falling water at ground level prevails. Radiated sound capacity is proportional to the expense of water, speed of water drops at the moment of falling, and also depth of water in pool. The estimation of level of the sound capacity radiated by a saltern can be carried out under the formula (Тупов 1999):

$$L_p = L_m + 10 \lg q_w \quad (2)$$

where q_w – the expense of water counting on 1 m² the areas of cross-section section of a saltern, m³/(m²·h); L_r – level of the sound capacity radiated by a saltern, depending on compound frequency, dB.

The specified dependence looks like, shown on Fig 2. At the big density of building of city district adjoining to salterns, the noise radiated by a saltern, can become important composed in the general noise background.

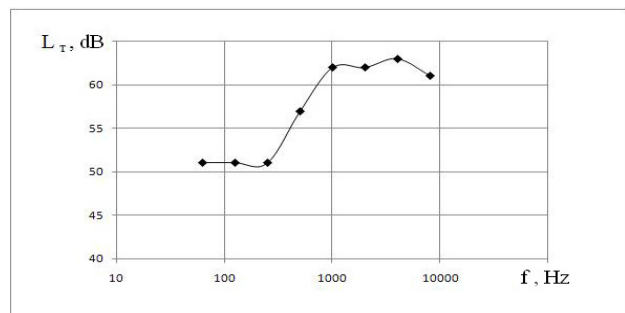


Fig 2. Level of the sound capacity radiated by a saltern, depending on compound frequency $L_r=f(f)$

The spectral structure of the noise radiated by working saltern in surrounding space is difficult that speaks structure of radiating elements of a saltern (the fan, a reducer, noise of falling "rain", etc.). Therefore the total level of sound pressure with such difficult spectral structure L is defined on levels of sound pressure of separate components in all octave strips of frequencies under the formula of logarithmic addition:

$$L_{pa} = 10 \cdot \log \sum_{i=1}^{i=n} 10^{0.1 \cdot L_{pi}} \quad (3)$$

Thus noise attenuation on distance is equal:

$$L_2 = L_1 - 20 \cdot \lg(r_2/r_1) \quad (4)$$

where r_1 – distance on which sound pressure makes size L_1 , m; r_2 – distance on which counted sound pressure settles down L_2 , m.

5. Model of noise of falling water in a saltern

As, as shown of (Пономаренко and Арефьев 1998; Пособие по... 1989; Тупов 1999) greatest noise level in tower and mechanical-draft towers salterns is in works at upper edge level air entrance windows and is defined basically by noise of "rain" of falling water in a saltern. We will consider settlement model of such noise. It is possible to present capacity of the sound radiated by a saltern in surrounding space in the form of a following equation:

$$W = M \cdot h \cdot [A (H/h)^m + B (E/h)^n] \quad (5)$$

where W – capacity of a sound, [W] (Watt); M – productivity, kg/s; h – a mark of an arrangement of water distributing system, m; H – height of the block of a packing, m; E – distance from the bottom part of a packing to saltern pool, m; A , B , m , n – empirical factors; $A = 0,95 \cdot 10^{-5}$; $B = 1,8 \cdot 10^{-5}$; $m = 2$; $n = 2$.

The noise level within a packing element can be estimated under the composition (Тупов 1999):

$$L_p = L_p^1 - 10 \cdot \lg(S/2) \quad (6)$$

where L_p^1 – level of the sound capacity radiated by the individual channel, dB;

S – the area of section of the individual channel, m^2 .

Apparently from the composition (6) essential influence on level of sound capacity renders geometrical parameter of a channel element, namely – the area of cross-section section S .

At distances from a radiation source $r < 2l$ where l – length of the channel in diameter d , level of sound pressure can be calculated under the composition:

$$L = L_p - R + 10 \cdot \lg(d/8r) \quad (7)$$

where d – diameter of the channel, m; r – distance to a settlement point, m; R – noise extinguishing effect of elements of the block of a packing (depends on a packing design, it is defined by practical consideration by a technique (Grubliauskas and Butkus 2009).

As channels in packing blocks have the difficult geometrical form and, as a rule, are formed by vertical corrugated sheets with slanting гофрами, it is represented expedient instead of parameter d to use parameter d_e – the hydraulic radius of the channel, m (Аэров *et al.* 1979):

$$d_e = 4S/P \quad (8)$$

where P – channel perimeter, m.

Thus, the composition (7) definitively looks like:

$$L = L_p - R + 10 \cdot \lg(d_e/8r) \quad (9)$$

On Fig 3 dependence of level of sound pressure – L from compound frequency of a tower saltern of type BG – 2600 is shown. Measurements of level of sound pressure were made on distance of 1 m from entrance windows of the specified saltern. From data presented on Fig 3 it is visible that the noise spectrum of a saltern has almost equal characteristics for octava strips with compound frequencies 1000 – 8000 Hz a little lowered characteristics (on 15 %) for frequencies less than 1000 Hz. Sound level on distance of 1 m from windows of salterns is in a range 80 – 87 dB.

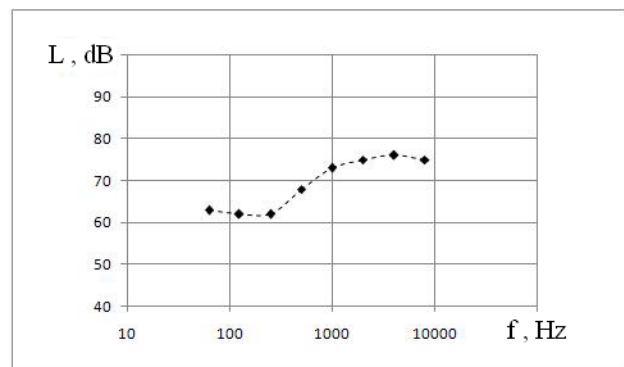


Fig 3. Dependence of level of sound pressure – L from compound frequency of a tower saltern of type BG – 2600

6. The offered technical decision of a saltern with the lowered noise level

From the equation (5) follows that geometrical characteristics and the location of blocks of a packing influence level of the sound pressure radiated by a saltern in surrounding space. On the other hand removal of a source of a sound from sound active surfaces which concern air entrance windows, also promotes decrease in level of sound pressure. On it specifies the schedule in Fig 4.

It is possible to offer that removal of blocks of a packing from air entrance windows on 3 ÷ 4 m upwards at the expense of constructive reduction of height of these blocks, will allow to lower noise level on 4 ÷ 6 dB. For comparison we will specify that, for example, installation

in entrance windows of a saltern of a jalousie allow to reduce sound level only on $2 \div 3$ dB (Тупов 1999). Thus, change of a design and the location of blocks of a packing in a saltern allows to reach in $2 \div 3$ times big effect on noise level decrease in a saltern.

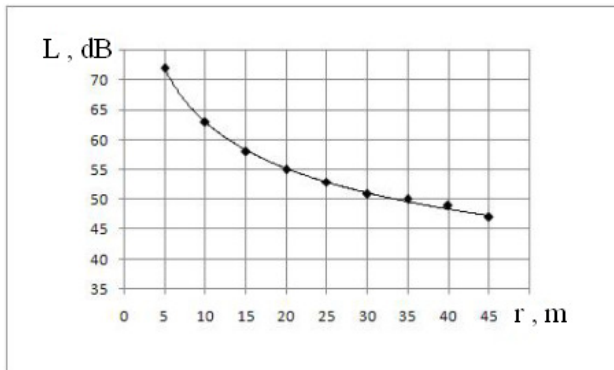


Fig 4. Noise level decrease - L with increase in distance from a noise source - r

The general view of a standard tower saltern is shown on Fig 5. The offered scheme of a new arrangement of blocks of a packing in the saltern case is shown on Fig 6.

Use of blocks of a packing of type KSN (shortlayer-wise a packing) as have shown spent by us at stand VNNIG of a name of B.E.Vedeneeva aerothermal tests, allows to receive the same efficiency (depth of cooling of turnaround water in a saltern) under other identical conditions, as at the standard block having in 2 times the big height. Comparative aerothermal characteristics of block KSN and the standard block are shown on Fig 7 in the form of graphic dependences of numbers of Merkelja – Me from the relative expense of air – λ , $Me = f(\lambda)$.



Fig 5. The General view of a tower saltern

As height of blocks of the modernized packing of type KSN it is essential less, than at standard, there is a possibility to place them on higher mark, having removed their thereby from entrance windows and to lower thereby level of sound pressure in a saltern on $4 \div 6$ dB.

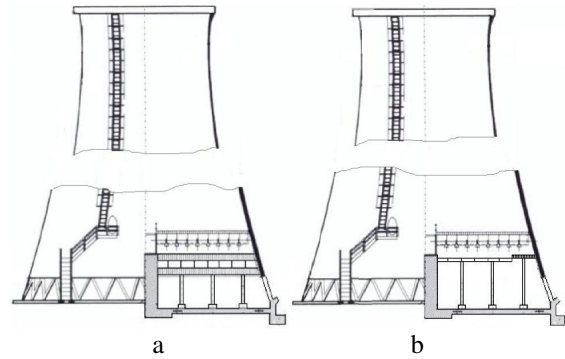


Fig 6. The scheme of arrangements of blocks of a packing in a tower saltern: and – standard; b – offered

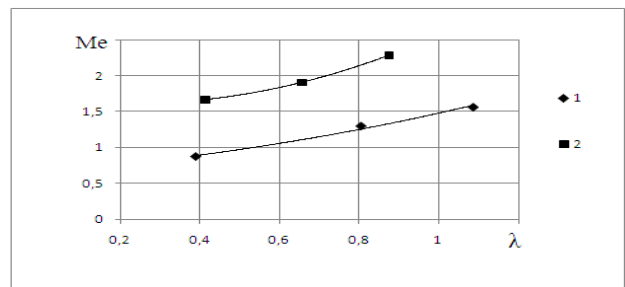


Fig 7. Comparative aerothermal characteristics of block KSN – 2 and the standard block – 1

Hus offered design of a saltern with a new arrangement of the modernized blocks of a packing of type KSN is developed in MSUEE taking into account features of aerodynamic conditions in the case of a tower saltern. The field of speeds in the tower saltern which general view is shown on Fig 5, has essential features in cross-section section of a saltern on its height (Fig 8 see). Lifting packing blocks on the big height rather air entrance windows, we place them in more favorable area of a saltern, as well from the point of view of uniformity of a field of speeds of an air stream. And it, in turn, according to (Пономаренко and Арефьев 1998; Рябушенко 2009) leads to increase in depth of cooling of turnaround water in a saltern, i.e. efficiency of process испарительного coolings.

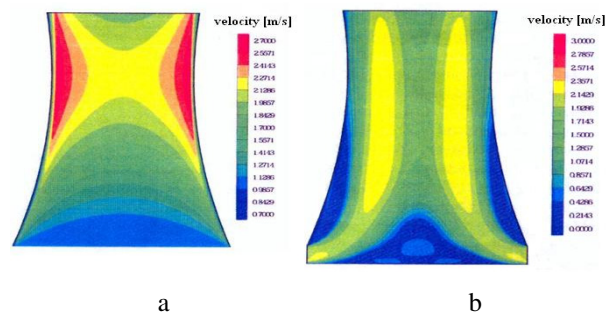


Fig 8. Results of calculations of speed of an air stream: and - vertical (on height of a saltern from a packing upwards); b - horizontal (on all height of a saltern) (Zúñiga – González 2005)

Aerodynamic conditions in a saltern are in detail analyzed in works (Пушнов *et al.* 2007; Zúñiga – González 2005; Pushnov *et al.* 2008; Pushnov *et al.* 2007; Арефьев and Гладков 1977; Сухов and Румянцева 1989; Витковская 2005; Пушнов *et al.* 2006). For tower salterns of the big diameter where as a whole level of speeds more low, than in mechanical-draft towers, especially important is an arrangement of blocks of a packing in a zone of the greatest speeds of air. Taking into account a real field of speeds in a tower saltern, on – visible, the arrangement of blocks of a packing a ledge – on higher mark in a peripheral part of a saltern (close air entrance windows) and on rather lower mark in the central part of a saltern is optimum. Such arrangement of blocks of a packing in a tower saltern allows to provide simultaneously favorable conditions for access of cold atmospheric air from an entrance window in the central part of a saltern (Fig 6b see), and also simultaneously provides noise level decrease in an entrance window by results of calculations of the equation (9) on $4 \div 6$ dB. Thus in the central part of a saltern it is expedient to place blocks of a packing of drop type from trellised elements which suppose moving of an air stream both in axial, and in radial directions. And in a peripheral part near to windows to place a packing of film type KSN. Thereby optimum conditions for evolution of a stream and its pass through a volume layer of a trellised packing will be created without breaking the general structure of streams in a saltern.

Thus, the offered technical decision allows to solve three problems:

- to increase depth of cooling of turnaround water in a saltern;
- to lower noise level;
- to lower probability in a saltern (Пушнов and Лозовая 2010).

For the first time the new scheme of placing of blocks of a packing on some removal upwards from air entrance windows has been developed in MSUEE also on the basis of the analysis of aerodynamic conditions in a saltern and offered in work (Пушнов and Лозовая 2010) for decrease льдообразования in a saltern (Fig 9 see). According to the stated concept the new scheme of placing of blocks of a packing in a tower saltern allows to lower also thus noise level on $4 \div 6$ dB.

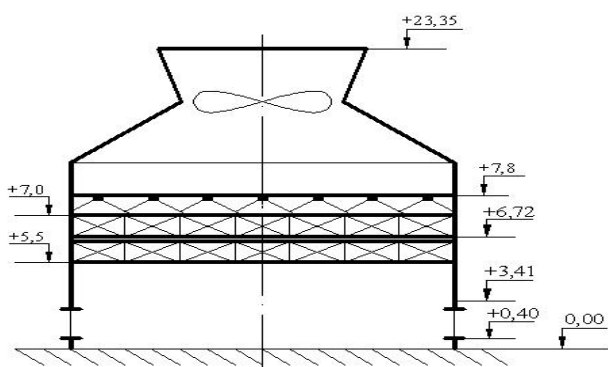


Fig 9. The scheme of placing of new blocks of a packing of type KSN in a saltern of type SK-400 on a mark of +6,72 m

7. Conclusions

1. On the basis of the analysis of various sources of noise in operating salterns the model for forecasting of level of sound pressure of falling water in a saltern depending on loading on water, heights of a packing, distance of blocks of a packing from an entrance window of a saltern is offered, etc.
2. New constructive decisions tower and mechanical-draft towers are offered, allowing at the expense of a new arrangement of blocks of a packing to lower noise level on $4 \div 6$ dB at simultaneous increase in depth of cooling of turnaround water in a saltern.

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