Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 20 Issue 1 Version 1.0 Year 2020
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

# Calculations of Heat Transfer in Furnaces of Steam Boilers under Laws of Radiation of Gas Volumes and Development of Innovative Designs of Furnaces

By Anatoliy Nikolaevich Makarov

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*GJRE-F Classification: FOR Code: 290901*

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## I. Introduction

In Russia on thermal power plants (fig. 1), about 2000 power units with a capacity of 30 to 1200 MW are installed. The power units include a steam boiler, a steam turbine, and a turbine generator. Dimensions of buildings of power plants in which power units are installed depending on dimensions of steam boilers. The height of steam boilers can reach up to 100 m. In the furnaces of steam boilers, 80–85% of the fuel and energy resources extracted and used in the world, including Russia, are burned.

*Fig. 1:* Thermal power plant

Total rated capacity of power units of the thermal power plants (TPPs) and combined heat and power plants (CHPPs) of Russia is 160,000 MW. Every hour, in the furnaces of steam boilers(SB) of thermal power plant (TPPs)and combined heat and power plants (CHPPs), 35,730 tons of fuel are burned in the form of heat equivalent in fuel oil or 600 railway tanks with a capacity of 60 tons of fuel oil, which is ten trains with 60 tanks each. A day in the furnaces of TPPs and CHPPs steam boilers of Russia burn above 240 trains of heavy fuel oil equivalent. It is significant to increase the efficiency of the furnaces of steam boilers and steam turbines, to organize the rational combustion of fuel in the furnaces since only 1% of the fuel saved per day will be 8580 tons in fuel oil equivalent or 2.4 trains. Saving of 1% of fuel per year will be 876 trains in fuel oil equivalent of 60 tanks in each or 3 million 132 thousand tons of fuel oil.

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## II. The Problem of Heat Transfer Calculation in the Furnaces of Steam Boilers

In the 20th-21st centuries, widespread flaring in furnaces, combustion chambers of gaseous, liquid, pulverized fuel was widely adopted. Flaring of fuel is characterized by volumetric radiation, a three-dimensional model of radiation. Radiation heat transfer accounts for 90–98% of the total heat transfer in the furnaces of steam boilers [1, 2], torch heating [3], and electric arc steel-smelting furnaces [4, 5]. In a torch, an electric arc emits quadrillion atoms, the radiation of each atom to the calculation site must be taken into account, which is an extremely complex task. To calculate the thermal radiation of the torch to the calculation site, it is necessary to solve the triple integral equations of heat transfer by radiation [6]. There were no solutions to the triple integral equations for determining the fluxes of thermal radiation, the angular emission coefficients of the torch to the calculation site, and the average path length of the rays from the emitting atoms to the calculation site were not found.

It is believed that the problem of calculating heat transfer in torch furnaces and power plants was eliminated with the advent of computers and the beginning of the use of the numerical computational technique for integral equations of heat exchange and calculation methods Pl-approximation, Monte Carlo, Schwarzschild-Schuster, Eddington, Chandrasekhar, spherical harmonics.

Numerical and other methods are based on the law of thermal radiation of solids, the Stefan-Boltzmann law. However, long-term theoretical and experimental studies of heat transfer have shown that the thermal radiation of the gas volumes of flares does not obey the Stefan – Boltzmann law, and the calculation error is 90–180% or more [5–9].For example, the furnace of a steam boiler of a power unit with a capacity of 300 MW of a power plant is a rectangular parallelepiped with a width, depth, height of 14, 7, 35 m, respectively. When working on fuel oil in the furnace, every hour burns 67 tons of fuel. A high-temperature radiating gas volume of the torch is formed in the furnace, filling the entire space of the furnace. The torch emits all the atoms, which amount is approximately equal to the quantity of grains of sand in the Sahara Desert. The radiation of each atom to the calculation site must be taken into account, which was not done in the 20th century. Throughout the 20th century the torch in furnaces and combustors was "a black box," an unexplored object of radiation. To save fuel when burning in steam boiler furnaces, to increase the efficiency of a steam boiler, it is necessary to organize correctly combustion of liquid, powdered, gaseous fuel in the burners, to rationally place the burners on screen surfaces of fire chambers. It is possible to correctly place the burners on the screen surfaces if there is an exact methodology for calculating heat transfer in the furnaces of steam boilers, which allows obtaining a calculation result corresponding to the true heat transfer in the steam boiler furnaces.

Having performed dozens of calculations using the exact methodology with different locations of the burners in the furnace, you can find a rational arrangement of the burners at which the heat flow of the flame is aligned along the perimeter and height of the furnaces, the efficiency of steam boilers is increased, in-pipe deposits, operating costs and fuel consumption are reduced. Exact methods for calculating heat transfer in flare furnaces and combustion chambers were absent throughout the 20th century. Calculation methods that existed in Russia and other industrialized countries (zonal, numerical, Pl approximations, Monte Carlo, Schwarzschild – Schuster, Eddington, Chandrasekar, spherical harmonics) did not allow to obtain a complete picture of heat transfer in flare furnaces and combustion chambers [1– 5].

All of the above methods are based on the law of thermal radiation of blackbody, Stefan - Boltzmann solid body and the emission of gas volumes of torches does not obey the law of blackbody, the law of radiation of a solid body and the calculation error is 90-180% or more. This error led to the fact that throughout the 20th century in the textbooks, monographs, articles in Russian and foreign scientists, there was no information on the distribution of heat flows and radiation in the furnaces on the axis of symmetry of the display surfaces and their periphery (Fig. 2), on the causes of damage to the burner devices, uneven vaporization, and in-pipe deposits on the height and perimeter of the screen surfaces.

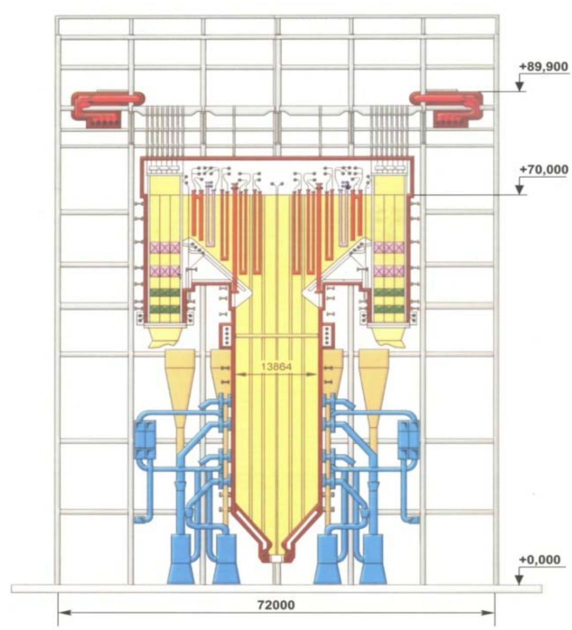


*Fig. 2:* Furnace of 500 MW power unit steam boiler

Local knowledge of heat transfer was obtained in the course of numerous laborious experimental studies of heat transfer in the furnaces of the steam boiler. Expensive time-consuming and resource-consuming experimental methods of heat transfer research did not allow to obtain a complete picture of heat transfer due to its complexity, low efficiency, lack of serial devices for measuring the heat flux of radiation on the heating surfaces in flare furnaces and combustion chambers.

The lack of reliable methods for calculating heat transfer in flare furnaces and combustion chambers led to the containment of their development, improvement, creation of innovative, more advanced flare furnaces, furnaces with a different arrangement of burners and flares in them (Fig. 3). The rational location aligned to the heat flows on the heating surfaces, evaporation, and in-line sediments in torch furnaces, the heating period becomes shorter, and the fuel consumption in flaring furnaces [10, 11], reduced fuel consumption and operating costs for removing intra pipe deposits.

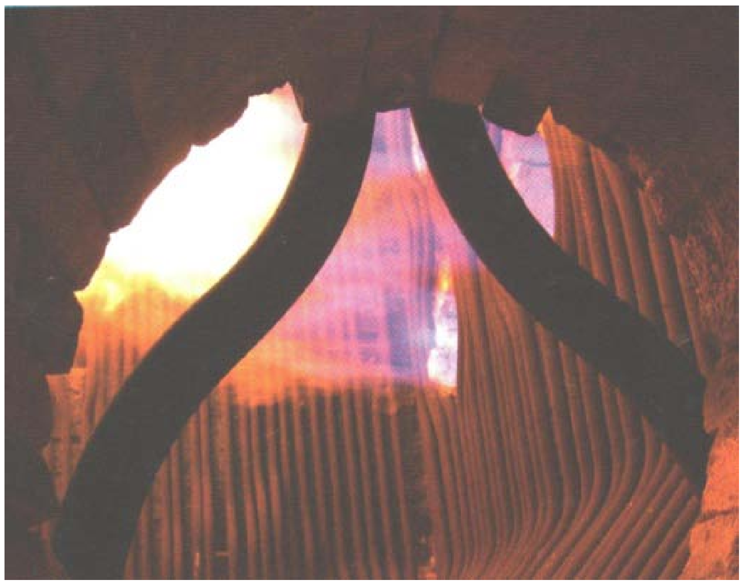

*Fig. 3:* Interior view of the furnace of the steam boiler, burner, torch

The lack of a reliable method for calculating heat transfer did not allow the calculation of heat transfer and to predict the creation of more advanced efficient flare furnaces [11] and combustion chambers. The design of most of the direct-flow furnaces of steam boilers and flare heating furnaces has not made any fundamental changes for several decades, contributing to the equalization of the distribution of the fluxes of radiation of the flares on the heating surfaces.

## III. The Laws of Thermal Radiation of Gas Volumes of Torch Furnaces

In 1996-2001 an author discovered the laws of thermal radiation of gas volumes of flares, the laws of radiation of isothermal isochoric coaxial cylindrical and concentric spherical gas volumes [5–10]. To comply with centuries-old scientific traditions and copyright laws of thermal radiation of gas volumes of torches in a diploma for scientific discovery, articles, textbook [5-10] are similar to the laws of radiation of a black body, the laws of Stefan – Boltzmann, Planck, Wien, Bohr's postulates [9] named after the author who discovered them - the laws of Makarov. Based on the scientific discovery, a new concept for calculating heat transfer in flare furnaces of steam boilers and combustion chambers of gas turbine plants was developed [5, 10].

With the discovery by the author of the article of the laws of thermal radiation of gas volumes (Table 1) of torches, it became possible to calculate heat transfer (distribution of heat fluxes overheating surfaces) with high accuracy, to predict a change in the distribution of heat fluxes overheating surfaces with a change in the design of torch furnaces [11], furnaces, combustion chambers and the location of burners and torches in them. With the discovery of the laws of thermal radiation of gas volumes, it became possible to make changes in the design of furnaces, combustion chambers and calculate the rational arrangement of burners and torches in them, create innovative flare furnaces and combustion chambers in which heat fluxes are aligned overheating surfaces, time is reduced heating, fuel consumption, operating costs for flushing boilers from intra pipe deposits, the cost of pilot studies of the combustion chambers of gas turbine plants, the number of destruction of the combustion chambers is reduced, hence the resource of their work increases.

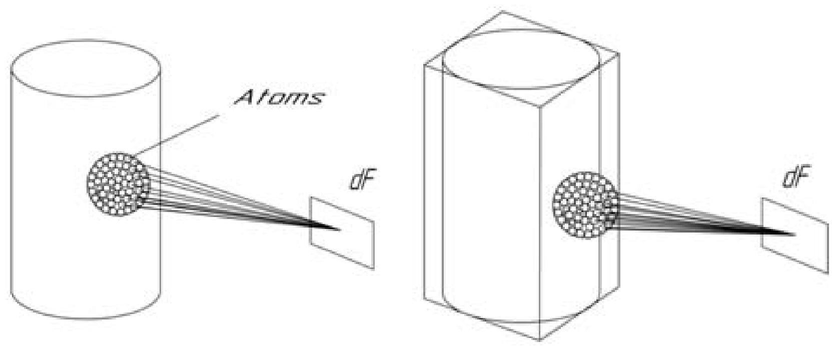


*Fig. 4:* Radiation to the calculation site of the df atoms of a cylindrical gas volume (a) and a gas volume in the form of a rectangular parallelepiped (c)

Fig. 4. Shows the radiation from cylindrical gas volumes to the calculated area. Mathematical notation of the laws of heat radiation from cylindrical gas volumes of the torches is given in Table 1 [6].

*Table 1:* Mathematical notation and formulation of the laws of heat radiation from cylindrical gas volumes

| Law number | Mathematical notation of the law | Law formulation |
|---|---|---|
| I | $q_{FdF} = \frac{\varphi_{F_0dF} \cdot P_F \cdot e^{-kl}}{F_0} = \frac{\varphi_{F_0dF} \cdot P_F}{F_0 \cdot e^{kl}}$ | Heat radiation flux density incident on the calculated area from the cylindrical gas volume is directly proportional to its power, the angular radiation coefficient and is inversely proportional to the absorption coefficient, the average beam path length from the atoms of the volume to the site and the site area. |
| II | $l_1 = l_2 = l_3 = \ldots = l_i = \left(\sum_{i=1}^{n} \frac{l_i}{n}\right) = l$ | The average beam path length from radiating atoms to the calculated area is equal to the arithmetic mean distance from the symmetry axis to the calculated area. |
| III | $\varphi_{F_1dF} = \varphi_{F_2dF} = \varphi_{F_3dF} = \ldots = \varphi_{F_idF}$ | Angular coefficients of radiation from coaxial cylindrical gas volumes to the calculated area are equal. |
| IV | $q_{F_1dF} = q_{F_2dF} = q_{F_3dF} = \ldots = q_{F_idF}$ | Flux densities of radiation from coaxial cylindrical gas volumes to the calculated area are equal. |
| V | $q_{F_1dF} = \sum_{i=1}^{n} q_{F_idF}$ | Flux densities of heat radiation from cylindrical gas volume of large diameter and its cylindrical axis of symmetry to the calculated area are equal when the heat capacities released in them are equal. |

In Table 1 the following symbols are used : q is the density of the heat flux incident on the calculated area (CA) from the cylindrical gas volume (CGV), kW/m$^2$; φ is the angular radiation coefficient (a portion of the radiation) from the CGV to the CA; P is the radiation power of the CGV, kW; k is the absorption coefficient of the CGV; l is the average beam path length from all atoms of CGV to the CA, m; F is the surface area of the CA, m$^2$; indices denote the numbers of gas volumes from 1 to n.

In 2011 the author of this article Makarov A. N. received a diploma for the scientific discovery [13]. According to the first law of heat radiation from cylindrical volumes, the heat radiation flux density of cylindrical gas volume to the calculated area $q_{FodF}$ is directly proportional to the radiation power of the volume $P_F$, the proportion of the radiation on the calculated area $\varphi_{FodF}$ of the total radiation from the volume and inversely proportional to the site area $F_0$, the absorption coefficient of the gaseous medium k, the average beam path length l from the atoms of the volume to the area.

The open laws of thermal radiation of ionized gas (electric arcs) and non-ionized (flares) gas volumes, as well as all fundamental laws of physics, are universal, multidisciplinary, applicable to several sectors of economic activity.

These laws are used to create innovative devices and methods in many industries: metallurgy, energy and various industries [4-11].

The open laws of thermal radiation of gas volumes make it possible to calculate with high accuracy for any calculation site the radiation of each atom and the total radiation of all atoms that make up the torch. It should be borne in mind that with the discovery of the laws of thermal radiation of gas volumes, the extremely complex problem of calculating, using one radiation formula of quadrillion torch atoms to any calculation site in flare furnaces and combustion chambers, was solved. Based on open laws, the author developed a method for calculating heat transfer in flare furnaces and combustion chambers, the basic calculation formulas of which are given in the table. 2 [11].

In the table. 2 the following conventions are used: $q_{in}$ – is the density of the heat flux incident on the i-th elementary area on the heating surface, $q_{in\phi}$ – is the density of the flux of thermal radiation incident on the i-th area from the torch, taking into account the absorption of the torch radiation; $q_{ino.ф}$ – is the flux density of thermal radiation incident on the i-th area b caused by the reflection of the radiation from the torch from the walls, hearth, arch, products; $q_{inп}$ – is the flux density of thermal radiation incident on the ith site from the radiating walls, the hearth, the lid, taking into account the reflection and absorption of radiation; $q_{ino.п}$ – the flux density of thermal radiation incident on the i-th platform, caused by the reflection of surface radiation from walls, hearths, lids, ingots; $q_{iкон}$ – convective flux density of the torch and combustion products of the i-th site; $q_{inn}$– is the radiation flux density of the combustion products to the i-th site, $\varphi_{фji}$ – is the local angular emissivity of the j-th cylindrical source to the i-th site, $P_{фj}$ – is the power of the j-th cylindrical source, Fi is the area of the i-th elementary area, $\psi_{фjk}$ – is generalized angular emissivity of the jth volume zone (jth cylindrical source) to the kth surface, $\varphi_{фjk}$ – is the average angular emissivity of the jth cylindrical source to the kth surface, $\varphi_{ji}$ – is the local angular emissivity of the jth surface on i-th platform,$Q_{jc}$ – stream own radiation of the j-th surface, $t_i$ = 20$^0$C - temperature of the products; tg.sr = = 1400$^0$C - average temperature of combustion products, gas; αcon - heat transfer coefficient by convection, with free convection $\alpha_{кон}$ = 11.6 W / (m$^2$ · $^0$C); at the beginning of heating, $q_{iкон}$ = 16.2 kW / m$^2$,$\varphi_{ncji}$ – is the local angular emission coefficient of the jth volume of combustion products to the ith site, $P_{ncj}$ – is the power of the jth volume of combustion products,$\varepsilon_j$ – is the emission coefficient of the jth surface; cs is the emissivity of a completely black body; Tj – is the surface temperature; $F_j$ – is the area of the jth surface.

*Table 2:* Equations, formulas for calculating heat transfer in flare furnaces and combustion chambers [11]

| S. No. p/p | Name of the formula, equation | Equation, formula | Measurement units |
|---|---|---|---|
| 1 | The density of the total heat flux incident on the calculation site | $q_{in} = q_{in\phi} + q_{ino.ф} + q_{inп} + q_{ino.п} + q_{iкон} + q_{inn}$ , | kw/m$^2$ |
| 2 | The share of power allocated to the settlement site | $P_1 : P_2 : \ldots : P_n = T_1^3 V_1 : T_2^3 V_2 : \ldots : T_n^3 V_n$ | - |
| 3 | The density of the heat flux of radiation incident on the calculation site from the torch (the first law of thermal radiation of cylindrical gas volumes) | $q_{inф} = \sum_1^n \frac{\varphi_{фji} P_{фj}}{F_i} e^{-kl}$ | kw/m$^2$ |
| 4 | Density of the heat flux of radiation caused by the reflection of the torch radiation from the surfaces to the calculation site | $q_{ino.ф} = \sum_1^n \frac{P_{фj}(\psi_{фjk} - \varphi_{фjk} e^{-kl})}{F_k}$ | kw/m$^2$ |
| 5 | Density of a heat flux of the radiation falling on the calculation site from the radiating surfaces | $q_{inп} = \sum_1^n \frac{\varphi_{ji} Q_{jc}}{F_i} e^{-kl}$ | kw/m$^2$ |
| 6 | Density of the heat flux of radiation caused by the reflection of radiation surfaces and incident on the calculation site | $q_{ino.п} = \sum_1^n \frac{Q_{jc}(\psi_{jk} - \varphi_{jk} e^{-kl})}{F_k}$ | kw/m$^2$ |
| 7 | Density of convective flow from the torch and combustion products to the calculation site | $q_{iкон} = \alpha_{кон}(t_{г.ср} - t_{и})$ | kw/m$^2$ |

| | | | |
|---|---|---|---|
| 8 | The density of the radiation fluxes of the combustion products to the calculation site | $q_{inc}=\sum_{1}^{n}\frac{\varphi_{ncji}P_{ncj}}{F_i}e^{-kl}$ | kw/m2 |
| 9 | Corresponding flux of surface radiation | $Q_{jc}=\varepsilon_j c_s (T_j/100)^4 F_j$ | kw/m2 |

## IV. Calculation of Heat Transfer in the Furnace of a Steam Boiler

According to the laws of thermal radiation of gas volumes [10, 11] (see table. 1) and the methodology for calculating heat transfer in flare furnaces and combustion chambers (see table 2) developed on their basis, the heat transfer in the furnace of a steam boiler of a power unit was calculated to be 800 MW. The calculation results of heat transfer in the furnace of a steam boiler TGMP-204 are presented in Fig. 5, 6.

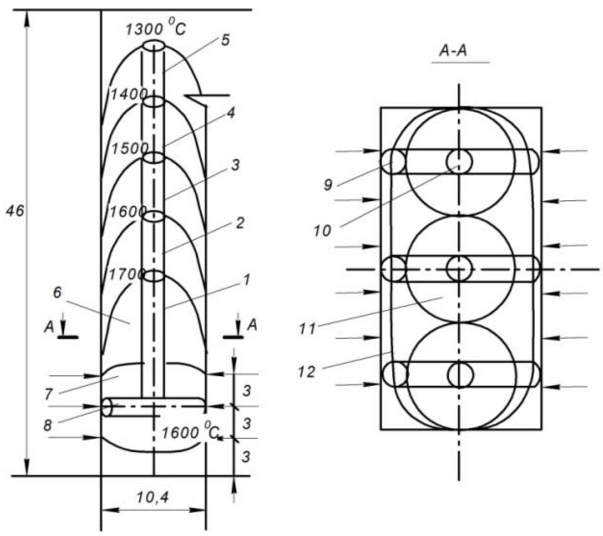


*Fig. 5:* Distribution of isotherms in the furnace of the steam boiler TGMP-204: 1-6, 10–12 - vertical radiating cylindrical gas volumes; 7–9 - horizontal radiating cylindrical gas volumes

The results of the calculation and measurement of the torch thermal radiation flux along the vertical axis of symmetry of the front wall are presented in Fig. 6 graphs 1 and 2. As can be seen from Fig. 6, the results of the calculation of measurements of torch radiation fluxes coincide or differ by no more than 5–8%, which confirms the high accuracy of the calculation results and the correspondence of the open laws of thermal radiation of gas volumes of the torch and the calculation methods developed on their basis for real processes of thermal radiation of the torch and heat transfer in furnaces of steam boilers. The results of heat transfer calculations in the furnaces of steam boilers showed that the components of the total heat flux incident on the calculation site (see Table 2, the first equation) are in the following ratio: the heat flux from the torch is 95%, the sum of the remaining components does not exceed 5 % of the total heat flux. The heat flux of the torch is extremely unevenly distributed along the perimeter of the furnace and varies on the front wall from 780 kW / m$^2$ on the axis of symmetry to 180 kW / m$^2$ on the periphery of the wall. Hence the variation in heat flux of the torch along the perimeter of the front wall is 4.3 times.

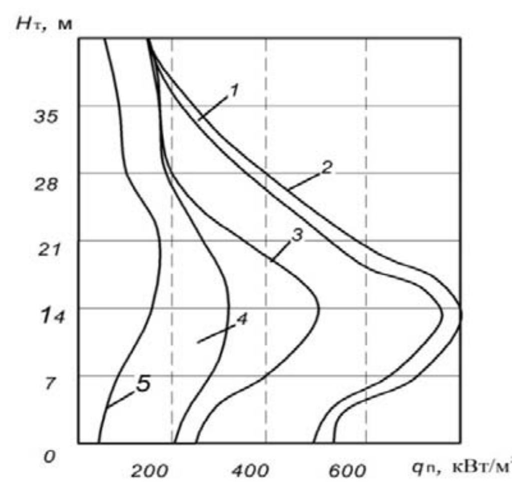


*Fig. 6:* The density distribution of the total radiation flux along the walls of the furnace: 1 - along the vertical axis of symmetry of the front wall; 2 - the same measurement result; 3 - along the vertical axis of symmetry of the sidewall; 4 - along the vertical axis at the periphery of the side wall; 5 - along the vertical axis on the periphery of the front wall.

Thermal fluxes of the flame of the torch are extremely unevenly distributed along the height of the furnace, the difference in the values of heat fluxes along the height of the front wall on its axis is 490% (from 780 kW / m$^2$ at furnace height of 14 m to 160 kW / m$^2$ at height of 42 m) (see Fig. 6).The values of heat flux on the front, and side walls vary greatly. A significant difference in the distribution of thermal radiation fluxes of the torch along with the height and perimeter of the walls negatively affects the intensity of vaporization and the amount of deposits in the pipes. From Fig. 6 it follows that the maximum vaporization is characterized by the Central section of the frontal wall, located at the height of 14 m (here we have the maximum deposits in the pipes). At the height of 14 m on the periphery of the frontal wall, the heat fluxes of the torch are 4.3 times less compared to the Central site, the intensity of vaporization and the amount of deposits is also 4-5 times less compared to the Central site. Along with the height of the walls, we have a similar unevenness in the heat flux of the torch and deposits in the pipes. All this leads to a significant unevenness of vaporization and deposits in the furnace tubes. Pipe sections located at a height of 14 m intensively precipitate sediments, their inner diameter decreases and the steam boiler needs to be stopped to flush in-pipe deposits, while deposits are insignificant in the peripheral sections of the front wall and sidewalls. If the boiler continues to run without flushing, deposits on the central section of the front wall become so significant that it will be necessary to stop the boiler and replace pipes with deposits of the central sections of the front wall with new pipes.

## V. Development of Innovative Furnaces of Steam Boilers

For many years, there was no accurate design information about the processes of heat transfer in the furnaces of steam boilers, so the design of direct-flow steam boilers has not changed for decades. The scientific discovery of the laws of thermal radiation of gas volumes made it possible to calculate the heat transfer in the furnaces of steam boilers and obtain complete information about the heat transfer in the furnaces, including data on the extremely uneven distribution of torch radiation fluxes along the perimeter and height of the furnace screen surfaces, to develop constructive solutions and new furnace devices, in which heat fluxes on screen surfaces and deposits in pipes are aligned, the operational costs of flushing boilers are reduced [12-15]. In fig. Figure 7 shows the innovative furnace of a steam boiler [12], in which at a distance of 0.33 the height of the furnace from the hearth, the front, rear and side walls are made at an angle of 4–6 ° with an inclination inward of the furnace with the formation of a tetrahedral truncated pyramid. When the upper part of the walls is made in the form of a tetrahedral truncated pyramid, the screens of the upper part approach the torch, the heat flows in the upper part of the walls increase, the height and perimeter are aligned (Fig. 8); vaporization is carried out evenly along the height and perimeter of the screens. The reduction of heat flow to the screens at the bottom reduces the number of deposits in the pipes, helps to slow down corrosion, increases the service life and the period between acid flushes of the boiler.

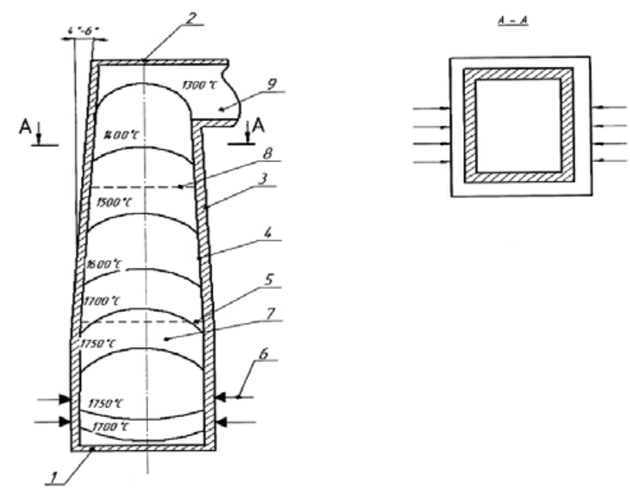


*Fig. 7:* The furnace of a steam boiler for combustion of gas-oil fuel with an inclination of part of walls inside: 1-under; 2-the arch; 3-walls; 4-screens; 5, 8-the lower and upper parts of the furnace, respectively; 6-burner; 7-torch; 9-flue

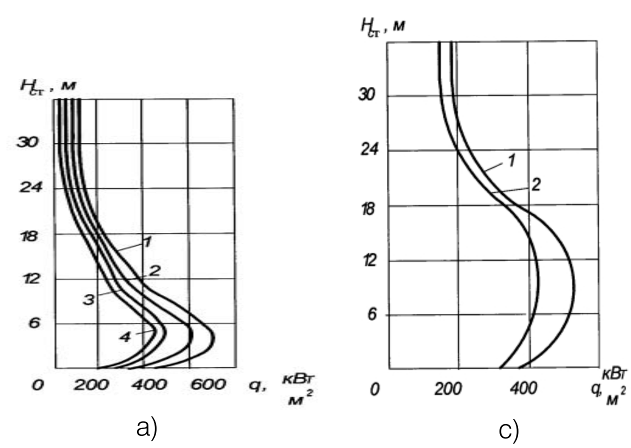


*Fig. 8:* The calculated distribution of the heat flux of the torch before (a) and after reconstruction (c): 1–4 is the distribution of heat fluxes along the symmetry axis of the front and side walls (a) 1, 2 is the distribution of heat fluxes on the axis of symmetry and on the periphery of the front and side walls, respectively (c)

In order to equalize the torch heat fluxes along the height and perimeter of the screen surfaces, a furnace made in the form of two truncated cones facing each other with large bases [15] (Fig. 9), as well as a furnace made in the form of two large bases facing each other truncated pyramids [13, 14] (Fig. 10). Patents for inventions [12-15] were obtained for the proposed furnaces.

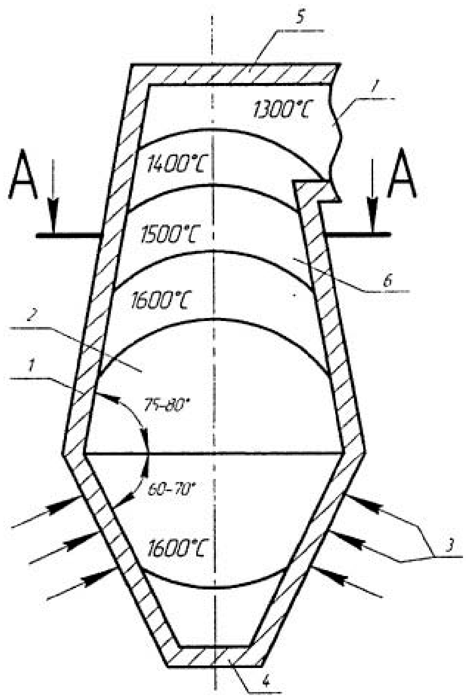


*Fig. 9:* Steam boiler furnace in the form of two truncated cones: 1-walls; 2 screens; 3-burners; 4- hearth; 5-arch; 6 – torch

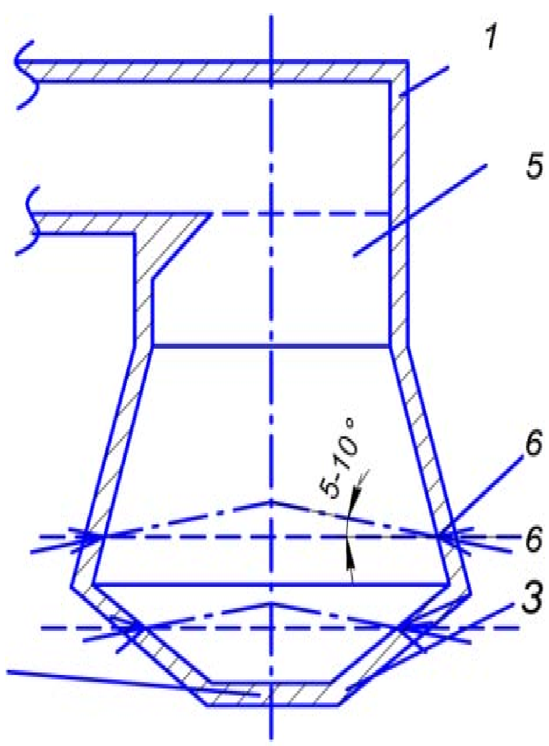


*Fig. 10:* Steam boiler furnace in the shape of two truncated pyramids: 1 - walls; 2 - arch; 3 - hearth; 4, 5 - screens; 6 – burners

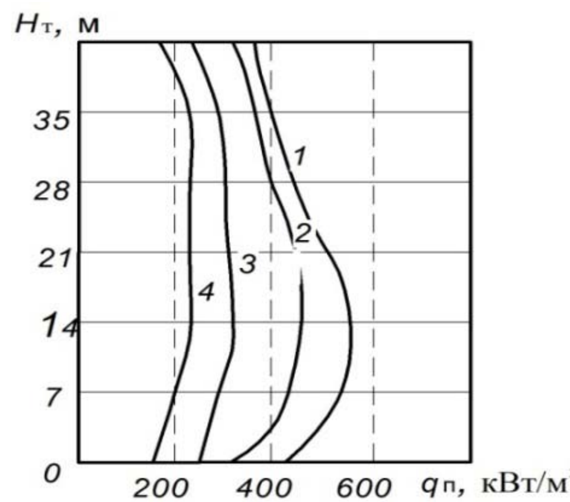


*Fig. 11:* Distribution heat fluxes along the height and perimeter of the walls of the furnace, shown in Fig. 10: 1–4 - the density of thermal radiation fluxes, respectively, along the axis of symmetry of the front, side walls and on the periphery of the side and front walls

The calculation according to the laws of thermal radiation of gas volumes made it possible to obtain complete information about the torch thermal radiation flows incident on the frontal, rear, side walls along the perimeter and height, on the reasons for the unevenness of deposits along the perimeter and height of the furnaces, the unevenness of vaporization in the pipes, and the reasons for burner burnout [9] and other physical phenomena occurring in the furnaces of steam boilers. Using the laws of thermal radiation of gas volumes in the design of furnaces will allow us to analyze the effect of changes in the location of the burners in the width and height of the furnaces, calculate their optimal location, achieve equalization of vaporization and deposits in pipes, increase the efficiency of steam boilers by 1-3%, reduce fuel consumption and operating costs for flushing pipes.

Fundamental laws of physics are the basis for the development of theories, calculation methods, with the help of which all existing types of engineering and technologies were created in the 20th-21st centuries, electrification, mechanization, automation, computerization of industry, agriculture and everyday life were carried out [10]. Open Makarov A.N. the laws of thermal radiation of gas volumes, like all fundamental laws of physics, have multi disciplinarity, use in various sectors of economic and economic activity: in energy, metallurgy, in various industries, in education [11].

## VI. Conclusion

The open laws of thermal radiation of gas volumes and their practical use in calculating heat transfer in flare furnaces made it possible to determine with high accuracy the distribution of torch radiation fluxes along the perimeter and height of the furnaces, to identify the causes of burn-out nodes of burner assemblies in the furnaces and the unevenness of deposits inside the pipes around the perimeter and height of the pipes and to develop innovative furnaces of steam boilers, which eliminate the above disadvantages [12-15]. The practical use of the laws of thermal radiation of gas volumes in heat transfer calculations in flare heating furnaces made it possible to calculate the distribution of torch radiation fluxes along heating surfaces, to find out the reasons for the uneven distribution of heat fluxes on the surfaces of heated products, and to develop innovative torch furnaces with a rational arrangement of burners and torches in the furnaces at which it is aligned distribution of heat flows over heated products, reduced heating time of products, consumption fuel, increases the productivity of furnaces [11].The use of open laws and the methodology for calculating heat transfer in the combustion chambers of gas turbine plants developed on their basis makes it possible to determine the distribution of the thermal radiation flux of the torch over the surface of the flame pipe at the stage of designing the combustion chambers, to organize effective cooling of the surface of the flame pipe, onto which the maximum heat flux of the flame falls, to exclude burnout of a flame tube, increase its service life, reduce the cost of experimental studies of combustion chambers and at the design stage to create conditions for long-term reliable operation of combustion chambers [16].

With the scientific discovery of the laws of thermal radiation of gas volumes of torches and electric arcs, it became possible for the first time to calculate the heat transfer in electric arc and flare furnaces and combustion chambers with high accuracy, to improve the heat transfer and design of electric arc and flare furnaces of industrial enterprises, furnaces and combustion chambers of gas turbine plants of electric stations save million kWh of electricity and million tons of liquid, gaseous, pulverized fuel, reduce pollutant emissions, reduce technogenic load on the environment and in many cities around the world. For a similar scientific discovery by the author of the laws of thermal radiation of gas volumes, for the discovery of the laws of thermal radiation by Wine and Planck of solids, blackbody, Wine in 1911, Planck in 1918 was awarded the Nobel prize in physics [10]. In 1921, Einstein was awarded the Nobel prize in physics for the discovery of the photoelectric effect of radiation, which was of similar importance, and for the development of the theory of the atom and radiation from it.The laws of thermal radiation of gas volumes, as well as the laws of thermal radiation of solids, blackbody, belong to the fundamental laws of physics, its section "Quantum Physics of Thermal Radiation." Bohr was the last scientist to receive the Nobel Prize in Physics for discovering the fundamental laws of physics. The discovery of the fundamental laws of physics is an outstanding event in the life of humanity, which occurs once every 50-80 years. Confirmation of this fact is physics textbooks for schools and universities, which set out a little more than 30 laws discovered by humanity over 3 thousand years, starting from the III century BC. From the law of Archimedes and ending with the last fundamental laws, postulates discovered by Bohr in 1913.

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