RADIANT HEAT TRANSFER IN THE FURNACE SPACE WITH VARIABLE VOLUME

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Annotation: The article presents the basic calculation formulas for solid fuel boilers with a movable grate. Calculations have shown that a change in the volume of the furnace leads to a change in radiant heat transfer.

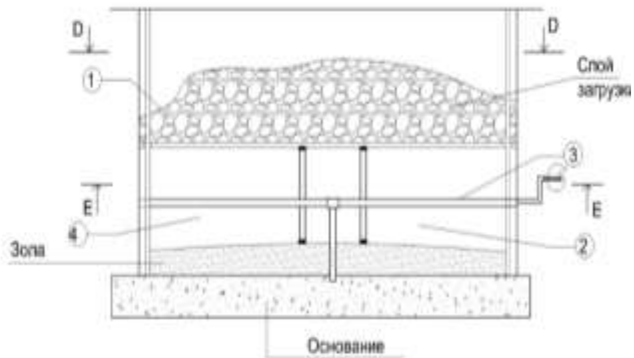
Key words: hot water boiler, solid fuel, furnace, grate, combustion products.

Аннотация:В статье приведены основные расчетные формулы для водогрейных котлов на твердом топливе с подвижной колосниковой решетки. Расчеты показали, что изменение об’ема топки приводит к изменению лучистого теплообмена.

Ключевые слова: водогрейный котел, твердое топливо, топка, колосчниковая решетка, продукты горения.

Hot water boilers for solid fuels include a firebox with a grate, heat-receiving gas ducts and a number of auxiliary elements [1, 2]. In some cases, for the combustion of various fuels and the need to control the temperature of the combustion products, hot water boilers with movable grates are used.

In furnaces with a movable grate, the thermal regime changes depending on the position of the grate (Fig. 1). The geometric characteristics of the furnace are given in table. 1.



Rice. 1. Sema firebox with a movable grate.

Table 1 - Geometric characteristics of the firebox

Wall surface		Furnace volume	
Name	Value	Name	Result
Furnace bottom surface, $м^2$	0,2826	Furnace volume	$1{,}1304 \cdot 10^{-1}$
Side surface of the firebox, $м^2$	0,7536		
Firebox ceiling, $м^2$	0,27033	The volume of the central flue pipe	$9{,}8125 \cdot 10^{-3}$
The inner surface of the central exhaust pipe,$м^2$	0,314		
The surface of the ceiling of the exhaust pipe,$м^2$	$1{,}2265 \cdot 10^{-2}$		
Sum	$H_{ст} = 1{,}632795$ $м^2$	Sum	$V_т = 1{,}228525 \cdot 10^{-1} м^3$

In the furnace space and gas ducts of a hot water boiler, radiant heat exchange occurs between the gas (combustion products) and the gas-limiting surfaces of the combustion space and gas ducts. In this case, part of the energy emitted by the gas is absorbed by the surfaces, and part of it is reflected into the gas. The resulting heat flow between the gas and the surface is determined by the difference between the amount of energy emitted by the gas at the surface and the amount of energy absorbed by the gas from the radiation of the surfaces. Design equation for determining the heat flux density transferred from the surface gas to the confining gas

$$q_{\text{г.c}} = C_0 \frac{\varepsilon_c+1}{2}\left[\varepsilon_\text{г}\left(\frac{T_\text{г}}{100}\right)^4 - A_\text{г}\left(\frac{T_c}{100}\right)^4\right] \quad (1)$$

Where $T_\text{г}$ – gas temperature; T_c – surface temperature; ε_c – the degree of blackness of the surface; $\varepsilon_\text{г}$ – gas emissivity; $A_\text{г}$ – absorption capacity of the gas at surface temperature.

The degree of emissivity for flue gases is determined by the formula

$$\varepsilon_\text{г} = \varepsilon_{CO_2} + \varepsilon_{H_2O} \quad (2)$$

Where ε_{CO_2} и ε_{H_2O} – emissivity of carbon dioxide and water vapor.

To determine the law of change in the degree of blackness of gases in the furnace space with a changing volume of the furnace, we set the distribution of the degree of blackness of gases by a polynomial of the second degree

$$\bar{\varepsilon_\text{г}} = a + b\bar{t} + c\bar{t}^2 \quad (3)$$

Where $\bar{t}$ – relative temperature in the combustion chamber, $\bar{t} = t/t_\text{т}$; $\bar{\varepsilon_\text{г}}$ – relative blackness of gas, $\bar{\varepsilon_\text{г}} = \varepsilon_{\text{г},t}/\varepsilon_{\text{г},t_0}$; $\varepsilon_{\text{г},t}$ – degree of blackness of gas at temperature t; $\varepsilon_{\text{г},t_0}$ – the degree of blackness of gases at the temperature of the gases at the outlet of the boiler flue;

a, b и c – polynomial coefficients determining from known boundary conditions

$$\text{at} \quad \left.\begin{array}{lll} \text{при } \bar{t} = 0; & \frac{d\varepsilon_\text{г}}{d\bar{t}} = 0; & b = 0 \\ \text{при } \bar{t} = 0; & \bar{\varepsilon_\text{г}} = 1 & a = 1 \\ \text{при } \bar{t} = 1 & \bar{\varepsilon_\text{г}} = 0{,}45 & c = 0{,}55 \end{array}\right\} \quad (4)$$

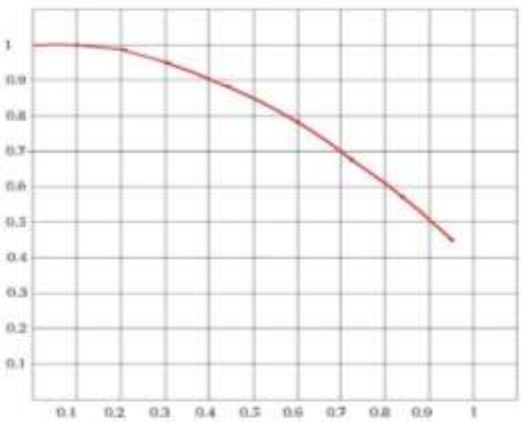
Taking into account the found coefficients (3), the polynomials distribution of the degree of emissivity of gases in the combustion chamber will have the form

$$\bar{\varepsilon_\text{г}} = 1 - 0{,}55\bar{t}^2 \quad (5)$$

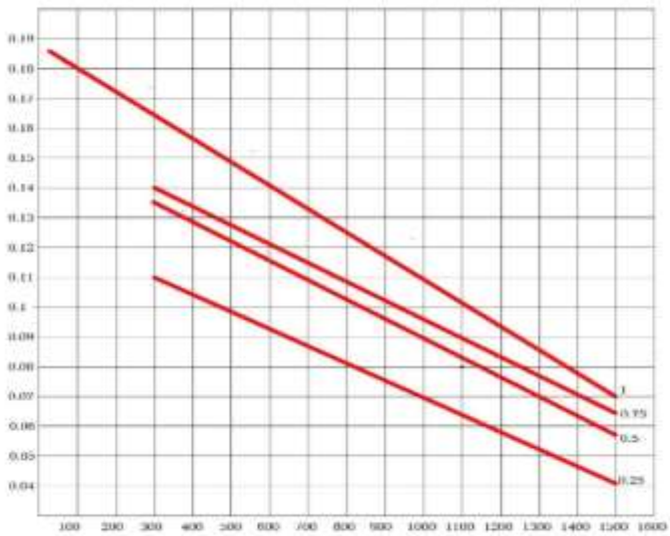
A graph of the change in the degree of emissivity of gases, constructed according to the obtained dependence, is shown in Fig. 2Comparison of fig. 2. with the calculated data given in the technical literature shows a good match. On the chart in Fig. 3 values are given

$\bar{\varepsilon_\text{г}}$ for different values of the position of the grate.

$\bar{\varepsilon_\text{г}}$



Rice. 2. Degrees of blackness of fuel combustion products.



Rice. 3. Change in the emissivity of combustion products in the furnace depending on

on the temperature and the relative location of the grate.

The absorption capacity of gases at the wall temperature is determined by

$$A_г = \varepsilon_{CO_2}\left(\frac{T_г}{T_с}\right)^{0,65} + \beta\varepsilon_{H_2O} \tag{6}$$

The degree of blackness of gases at an average temperature of gases is determined

$$\varepsilon_Г = \varepsilon_{co_2} + \beta\varepsilon_{H_2o} \tag{7}$$

Thermal load of the pipe surface due to radiation

$$q_л = \frac{1}{2}(\varepsilon_с + 1)C_o\left[\varepsilon_г\left(\frac{T_г}{100}\right)^4 + A_г\left(\frac{T_c}{100}\right)^4\right] \tag{8}$$

Radiant heat transfer coefficient

$$q_л = \frac{q_л}{t_г - t_с} \tag{9}$$

Calculation results of carbon dioxide emissivity ε_{CO_2} and water vapor and gases at various temperatures are given in table. 2, 3 and 4.

Table 2 - Emissivity of carbon dioxide ε_{CO_2} and water vapor ε_{H_2O} at different gas temperatures and different furnace volumes $\bar{h}_т$

Temperature $T_г$	$\bar{h}_т$=1	$\bar{h}_т = 0,75$	$\bar{h}_т$=0,5	$\bar{h}_т$=0,25
	$pl = 0,003908$	pl =0,0032879	$pl = 0,002751$	$pl = 0,0018461$
1773	0,05	0,047	0,041	0,031
1573	0,06	0,055	0,05	0,042
1373	0,07	0,065	0,06	0,05
1173	0,08	0,078	0,07	0,06
973	0,083	0,08	0,072	0,068
773	0,085	0,07	0,066	0,062
573	0,076	0,072	0,067	0,06

Table 3 - Emissivity of water vapor ε_{H_2O}

Temperature $T_г$	$\bar{h}_т$=1	$\bar{h}_т = 0,75$	$\bar{h}_т$=0,5	$\bar{h}_т$=0,25
	$pl = 0,003908$	pl =0,0032879	$pl = 0,002751$	$pl = 0,0018461$
1773	0,02	0,018	0,017	0,01
1573	0,025	0,022	0,02	0,013
1373	0,035	0,03	0,028	0,017
1173	0,042	0,036	0,034	0,021
973	0,05	0,048	0,036	0,028
773	0,066	0,056	0,053	0,038
573	0,078	0,068	0,064	0,05

Table 4 - Emissivity of gases $\varepsilon_Г$

Temperature gases	$\bar{h}_т$=1	$\bar{h}_т = 0,75$	$\bar{h}_т$=0,5	$\bar{h}_т$=0,25
	$pl = 0,003908$	pl =0,0032879	$pl = 0,002751$	$pl = 0,0018461$
1773	0,0704	0,06572	0,05868	0,0414
1573	0,086	0,07788	0,0708	0,0552
1373	0,1064	0,0962	0,08912	0,06768
1173	0,1236	0,11544	0,10536	0,0794
973	0,135	0,12992	0,10944	0,08712
773	0,1536	0,12824	0,12112	0,0942
573	0,1571	0,14272	0,13356	0,11

Tables 2, 3 and 4 are obtained by calculation:

$$\varepsilon_{H_2O} = \varepsilon_{H_2O,1773} \cdot \left(\frac{1773}{T_г}\right)^{1,6} \bar{h}_т^{0,5} = 0,02 \left(\frac{1773}{T_г}\right)^{1,6} \quad (10)$$

Then the dependence for determining the absorption capacity of gases after some transformations will have the form

$$A_г = \bar{h}_т^{0,5} \cdot \left(\frac{1773}{T_г}\right) \left[0,05 \left(\frac{T_г}{T_c}\right)^{0,65} + 0,0208 \left(\frac{1773}{T_г}\right)^{0,6}\right] \quad (11)$$

Radiant heat transfer between combustion products and a heat-receiving wall

$$q_л = \frac{1}{2}(\varepsilon_c + 1)C_o \left[\varepsilon_г \left(\frac{T_г}{100}\right)^4 + A_г \left(\frac{T_c}{100}\right)^4\right] \quad \text{at } \bar{h}_т = 1 \quad (12)$$

Radiant heat transfer in the general case:

$$q_л = \frac{1}{2}(\varepsilon_c + 1)C_o \left[\varepsilon_г \left(\frac{T_г}{100}\right)^4 - A_г \left(\frac{T_c}{100}\right)^4\right] = \frac{1}{2}(\varepsilon_c + 1)C_o \bar{h}_т^{\,0,5} \left[\varepsilon_г \left(\frac{T_г}{100}\right)^4 - 0,19 \left(\frac{T_c}{100}\right)^4\right] \quad (13)$$

Here $A_г$ for engineering calculations with an accuracy of 5% can be represented by the dependence:

$$A_г = \left[\varepsilon_{CO_2} \left(\frac{T_г}{T_c}\right)^{0,65} + 0,0208 \left(\frac{1773}{T_г}\right)^{0,6}\right] - = 0,19 \cdot \left(\frac{1773}{T_г}\right) \quad (14)$$

Thus, a change in the volume of the furnace leads to a change (decrease or increase) in radiant heat transfer.

Literature

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