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CALCULATION OF STANDARDS FOR PERMISSIBLE ENVIRONMENTAL IMPACT FOR BOILERS WITH KNOWN TECHNICAL CHARACTERISTICS

Emission of thermal power stations and boilers is regulated in accordance with the unified national regulatory requirements, taking into account the specifics of energy production, its life-sustaining function and is aimed at ensuring that air pollution is prevented as much as possible. The purpose of the regulation of emissions of thermal power plants is to limit its adverse impact on the air basin by developing, for the entire thermal power plant and each source of emissions on it, the maximum allowable emissions – control (in grams per second) and per annum (in tons per year), ensuring sanitary hygienic standards. Sanitary standards include the maximum permissible concentration, which reflects the level of components in the air that is safe for humans. In practice, several substances are simultaneously present in the air, the presence of which causes multicomponent air pollution. The atmospheric pollution index, which is calculated for a group of substances, is often used as a complex indicator of the degree of air pollution. Currently, mostly applied methods of component-wise assessment of atmospheric air quality are used in practice. When calculating atmospheric pollution by boiler houses, the total volumes of fuel combustion products are determined experimentally or by calculation. This article provides empirical formulas for calculating the above standards – the volume of flue gases, the maximum one-time emissions of ash, sulfur oxides, carbon and nitrogen for various boilers with known technical characteristics. Also, using the above formulas, a comparative analysis of the level of air pollution depending on the quality of various types of fuel burned in various types of boilers.

Key words: thermal power plants, maximum one-time emissions of ash, sulfur oxides, carbon, nitrogen.

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Белгілі техникалық сипаттамалары бар қазандықтар үшін қоршаған ортаға рұқсат етілген әсер ету нормативтерін есептеу

Жылу электр станциялары мен қазандықтардың шығарындыларын нормалау энергетикалық өндірістің ерекшелігін, оның тыныс-тіршілігін қамтамасыз ететін функцияларын ескере отырып, бірыңғай жалпы мемлекеттік нормативтік талаптарға сәйкес жүргізіледі және атмосфералық ауаның ластануын барынша ықтимал болдырмауды қамтамасыз етуге бағытталған. Жылу электр станцияларының шығарындыларын нормалаудың мақсаты санитарлық-гигиеналық нормативтердің сақталуын қамтамасыз ететін барлық ЖЭС және ондағы шығарындылардың әрбір көзі үшін, шекті жол берілетін шығарындылар-бақылау (секундына граммен) және жылдық (жылына тоннамен) әзірлеу жолымен әуе бассейніне оның қолайсыз әсерін шектеу болып табылады. Санитарлық-гигиеналық нормативтерге атмосфералық ауадағы компоненттер құрамының адам үшін қауіпсіз деңгейін көрсететін шекті жол берілетін концентрация жатады. Практикада ауада бір мезгілде бірнеше заттар бар, олардың болуы атмосфераның көп компонентті ластануын тудырады. Атмосфералық ауаның ластану дәрежесінің кешенді көрсеткіші ретінде заттар тобы үшін есептелетін атмосфераның ластану индексін жиі пайдаланады. Қазіргі уақытта практикада атмосфералық ауаның сапасын көбінесе компоненттік

бағалау әдістері қолданылады. Атмосфераның қазандықтармен ластануын есептеу кезінде отынның жану өнімдерінің жалпы көлемін тәжірибелік немесе есептік жолмен белгілейді. Бұл мақалада жоғарыда аталған нормативтерді есептеуге арналған эмпирикалық формулалар келтірілген – түтін газдарының көлемі, белгілі техникалық сипаттамалары бар әртүрлі қазандықтарға арналған күлдің, күкірт оксидтерінің, көміртегінің, азоттың ең көп бір реттік шығарындылары. Сонымен қатар, келтірілген формулаларды пайдалана отырып, әр түрлі қазандықтарда жағылатын отынның әр түрлі түрлерінің сапасына байланысты атмосфералық ауаның ластану деңгейін салыстырмалы талдау жүзеге асырылды.

Түйін сөздер: жылу электр станциялары, күлдің максималды бір реттік шығарындылары, күкірт оксиді, көміртек, азот.

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Расчеты нормативов допустимого воздействия на окружающую среду для котлов с известными техническими характеристиками

Нормирование выбросов тепловых электрических станций и котельных производится в соответствии с едиными общегосударственными нормативными требованиями с учетом специфики энергетического производства, его жизнеобеспечивающей функции и направлено на обеспечение максимально возможного предотвращения загрязнения атмосферного воздуха. Целью нормирования выбросов тепловых электрических станций является ограничение ее неблагоприятного воздействия на воздушный бассейн путем разработки, для всей ТЭС и каждого источника выбросов на ней, предельно допустимых выбросов – контрольных и годовых, обеспечивающих соблюдение санитарно-гигиенических нормативов. К санитарно-гигиеническим нормативам относится предельно-допустимая концентрация, которая отражает безопасный для человека уровень содержания компонентов в атмосферном воздухе. На практике в воздухе одновременно присутствует несколько веществ, наличие которых вызывает многокомпонентное загрязнение атмосферы. В качестве комплексного показателя степени загрязнения атмосферного воздуха часто используют индекс загрязнения атмосферы, который рассчитывается для группы веществ. В настоящее время на практике применяются преимущественно методы покомпонентной оценки качества атмосферного воздуха. При расчетах загрязнения атмосферы котельными устанавливают общие объемы продуктов сгорания топлива опытным или расчетным путем. В данной статье приведены эмпирические формулы для расчета вышеназванных нормативов – объемов дымовых газов, максимально разовых выбросов золы, оксидов серы, углерода, азота для различных котлов с известными техническими характеристиками. Также, с использованием приведенных формул, осуществлен сравнительный анализ уровня загрязнения атмосферного воздуха в зависимости от качества различных видов топлива, сжигаемого в различных типах котлов.

Ключевые слова: тепловые электрические станции, максимально разовые выбросы золы, оксида серы, углерода, азота.

Introduction

Thermal power plants are one of the largest sources of heat and electricity, however they are sources of air pollution. The release of thermal energy of fuels (the energy of chemical bonds in molecules) occurs in a purely chemical way due to the rearrangement of the outer electron shells, i.e. at the atomic-molecular level, without affecting deeper structures (ions, electrons of internal shells and their excited states). With the help of thermal energy of organic fuels in boilers of thermal power

plants, steam is produced from water, which enters the turbine, rotates of the electric generator [1-3].

However, at the same time, a large amount of harmful combustion products is emitted with the flue gases of the boilers. Possessing high toxicity, they cause significant harm to the environment and human health. Large volumes of exhaust gas streams of products of combustion – complicate the effective use of cleaning devices. The construction of high chimneys allows dispersing harmful substances over a large area, reducing locally the surface concentration of pollutants, but does not

reduce the general pollution of the atmosphere as a whole [4-9].

Environmental protection in close proximity to thermal power plants is a very urgent task that requires solving a whole complex of scientific and practical problems. One of these problems is the problem of quantifying possible negative effects from the systematic effects of thermal power plants on the atmosphere for a particular region [10-12].

In accordance with the law on the protection of atmospheric air in Kazakhstan, the following regulatory indicators are established: maximum permissible concentrations (MPC) of pollutants in the air, maximum permissible emissions (MPE) and temporarily agreed emissions (TAE) of harmful substances into the atmosphere. The procedure and methodology for the development of standards for emissions of pollutants into the atmosphere for existing, reconstructed, constructed and designed TPPs and boilers of any capacity is established by the "Industry instruction on the rationing of emissions of pollutants into the atmosphere for thermal power plants and boilers".

The purpose of rationing emissions of thermal power plants is to limit the adverse effects of thermal power plants on the air by developing maximum permissible emissions – control in g/s and annual in t/year, ensuring compliance with sanitary and hygienic standards; the establishment of schedules to achieve the level of MPE, temporarily agreed emissions (if necessary), as well as technological (specific) emission standards for each boiler plant [13-16]. When calculating the pollution of the atmosphere by boiler-houses, the total volumes of the combustion products of fuel are established by trial or calculation. The calculation and practical methods for assessing the quality of atmospheric air include methods that allow the construction of mathematical models of atmospheric pollution [17].

Calculation method

The enlarged calculation of emissions of pollutants into the atmosphere is based on the following basic data: the amount of fuel burned in the region (in tons of standard fuel) by type (gas, fuel oil, various types of solid fuel, including coal); the characteristics of the types of fuel burnt at the power plants of this region, including their calorific value, sulfur content, ash content, etc.; indicators of fuel combustion regimes affecting the release of pollutants; the effectiveness of environmental

protection equipment (ash collectors, flue gas desulfurization devices and flue gas cleaning from nitrogen oxides).

The calculation in this case is carried out according to the dependencies given below.

Amount of ash, solid particles, thousand t/year:

$$M_{out}^{ash} = \sum_{i=1}^n M_{out i}^{ash} \quad (1)$$

where i is the type of fuel; n is the number of types of fuel burning at the power stations of the region in the year in question; M – the amount of waste ash generated in the boilers of power plants in the region that burn this type of fuel in the year under review, thousand t/year, is calculated using the following formula:

$$M_{out}^{ash} = 0.01 * B \left(\alpha_{out i} A_i^W + \frac{q_{4i} Q_{Hi}^W}{32680} \right) \quad (2)$$

where q is heat loss with ash from mechanical incomplete combustion of fuel, %; α is the proportion of ash carried away from the furnace to the boiler flue gas ducts when burning the i -th type of fuel (can be taken as 0.9); A_i^W and Q_{Hi}^W ash content (%) and heat of combustion (kJ/kg) of the i -th type of fuel, respectively, 32680 – heat of combustion of carbon, kJ/kg.

The amount of sulfur oxides, tons/year, is determined by the formula

$$M_{out}^{SO_2} = \sum_{i=1}^n M_{out i}^{SO_2} \quad (3)$$

where $M_{out}^{SO_2}$ is the amount of waste sulfur dioxide produced in boilers of power plants of the region burning this type of fuel in the year under review, thousand t/year, is calculated using the following formula

$$M_{out i}^{SO_2} = 0.02BS^W(1 - \eta'_{SO_2})(1 - \eta''_{SO_2}) \quad (4)$$

where S^W is the sulfur content in the fuel per working mass, %, η'_{SO_2} is the fraction of sulfur oxides bound by fly ash in the boiler; η''_{SO_2} – the proportion of sulfur oxides trapped in the ash collector along with the capture of solid particles; 0.02 is the conversion factor for the molecular weight of sulfur to the molecular weight of sulfur dioxide.

Nitrogen oxides, thousand t/year (in terms of NO_2):

Outgoing

$$M_{out}^{NO_2} = \sum_{i=1}^n M_{out i}^{NO_2} \quad (5)$$

where $M_{out}^{NO_2}$ is the amount of nitrogen oxides generated in boilers of power plants in the region that burn this type of fuel in the year in question, thousand t/year:

$$M_{out i}^{NO_2} = 0.034 * 10^{-7} KBQ_H^W \left(1 - \frac{q_4}{100}\right) \beta_1 (1 - \varepsilon_1 r) * \beta_2 \beta_3 \varepsilon_2 \quad (6)$$

where K is a coefficient characterizing the yield of nitrogen oxides, kg/g of reference fuel; B – fuel consumption of this type burned at power plants of the region in the considered year, thousand t/year; Q_H^W – calorific value (kJ/kg) of the i -th type of fuel; β_1 is the coefficient taking into account the effect on the yield of nitrogen oxides on the quality of the burned fuel; β_2 – coefficient taking into account the design of the burners; β_3 – coefficient taking into account the type of slag removal: with liquid slag removal

and $\beta_3 = 1.4$, in all other cases $\beta_3 = 1$, ε_1 is the coefficient characterizing the efficiency of the effect of recirculating gases depending on the conditions of their supply to the furnace; ε_2 is the coefficient characterizing the reduction of nitrogen oxide emissions when part of the air is supplied in addition to the main burners, is determined from Figure 1; r is the degree of recirculation of flue gases. The values of the coefficient ε_1 at nominal load and $r \leq 30\%$ are taken in accordance with the data below.

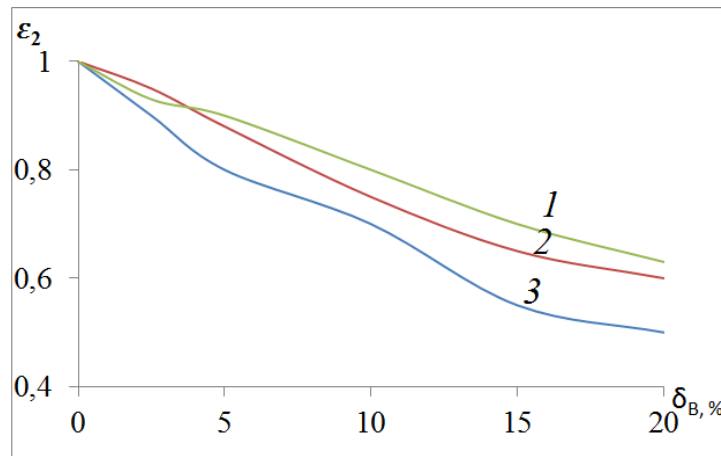


Figure 1 – Graph of determining the values of the coefficient ε_2 :
1 – gas, fuel oil; 2 – coal; 3 – gas; δ_B – the proportion of air supplied in addition to the main burners

The results of determining the volume of the maximum single emissions during coal
Technical characteristics of the boiler:

| | |
|---|--------------------|
| Estimated fuel consumption in the boiler, B | 1000g/s |
| Exhaust gas temperature at the mouth of the pipe, T_g | 145 ⁰ C |
| Coefficient of excess air in front of the chimney, ξ_g | 1.75 |
| Heat loss with ablation from mechanical incomplete combustion of fuel | 1.00% |
| Mechanical, q_{mech} | 4.00% |
| Chemical, q_{chem} | 1.00% |
| Proportion of solids retained by ash collector | 0.85 |
| The proportion of sulfur oxides associated fly ash in the boiler | 0.10 |

Characteristics of the investigated coal are given in the Table 1.

Table 1 – Fuel characteristics

| Fuel | Coal composition, % | | | | | | | |
|---------------|---------------------|------|------|-------|------|------|------|-------|
| | W | S | A | C | H | N | O | Q |
| Karaganda | 10.6 | 1.04 | 35 | 43.21 | 3.6 | 1.21 | 5.24 | 18.56 |
| Ekibastuz | 8.43 | 0.7 | 43 | 0.79 | 2.64 | 0.79 | 6.07 | 16.83 |
| From the task | 32.8 | 4.1 | 28.8 | 24.7 | 3.6 | 24.7 | 5.0 | 11.48 |

Odds characterizing:

| | |
|---|-----|
| Proportion of heat loss due to CO content in combustion products R | 1.0 |
| The effect of heat on the output NO_2 , β_1 | 0.9 |
| Burner design, β_2 | 1.0 |
| Type of slag removal, β_3 | 1.0 |
| The effectiveness of the recirculating gases, depending on the condition of their submission to the furnace, ϵ_1 | 1.0 |
| Emission reduction NO_x with two stage afterburner ϵ_2 | 1.0 |
| Flue gas recirculation rate, r | 0 |
| Output of nitrogen oxides, kg/t, conditional fuel, ψ | 5.9 |

The results of the calculation of maximum one-time emissions (according to the “Era” program) are given in Table 2.

Table 2 – Calculated theoretical volume and maximum one-time emissions

| Fuel | Theoretical volume, m^3/kg | | | Maximum one-time emissions, g/s | | | |
|---------------|--|----------------|------------------|---------------------------------|-------------------------------|----------------------------------|--------------------|
| | V_0 | V_{Σ}^* | V_{atm} | Ashes, M_s | Sulfur dioxide, SO_2 | Carbon monoxide, M_{CO} | Nitrogen oxide, NO |
| Karaganda | 8.49 | 3.81 | 9.54 | 48.03 | 18.72 | 17.58 | 3.21 |
| Ekibastuz | 8.25 | 9.19 | 24.11 | 54.08 | 12.6 | 15.94 | 2.91 |
| From the task | 3.12 | 8.22 | 22.32 | 38.83 | 73.8 | 11 | 2 |

Preliminary electron-beam processing of coal leads to a reduction in emissions into the atmosphere, reduces the amount of ash and slag, and reduces maximum-one-time emissions (Table 2-3) from at least 0.6% to 9% for different greenhouse gases.

Conclusion

The establishment of standards for the allowable impact of the activities of heat and power engineering facilities on the environment should ensure compliance with the quality standards of its components the purity of the atmospheric air. Emissions of pollutants

contained in the flue gases are subject to normalization, if they create minimum calculated surface concentrations.

For the quantitative determination of emission standards of nitrogen oxides, sulfur oxides, carbon oxides and other toxicants used empirical formula. The calculations carried out according to these formulas showed good consistency with the data found experimentally for boilers with known technical characteristics in which coals of different quality were burned. Also, using the above formulas, a comparative analysis of the level of atmospheric air pollution was carried out, depending on the quality of various types of fuel burned in various types of boilers.

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