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AUTOMATIC CONTROL SYSTEM OF BOILER INSTALLATION, EQUIPPED WITH CONTROL FACILITY OF FLUE GASES CONTENT, BASED ON OPTIC – ABSORPTION INFRARED METHOD

Functional scheme of control subsystem of flue gas content by means of optic – absorption infrared method, compensating the impact of atmospheric dust and excess humidity is developed on the basis of boiler unit control system. Automatic control system provides high energy resources efficiency of boiler unit operation.

Key words: *boiler installation, optic-absorption infrared method, control system, flue gas, frequency regular, measuring conterter, controller, algorithm.*

Introduction

Industry is main consumer of fuel, greater part of it being burt in boiler installation (BI). The problem of rational usage of energy resources in Ukraine is linked with reliable and efficient operation of these installations. Efficiency factor of boiler, as well as, does not attain maximum possible values. Main reasons are: low quality of technical maintenance and repair, slow introduction of organizational-technical measures, enabling to provide the reduction of fuel consumption for generation of thermal energy.

Efficiency of boiler installations functioning directly depends on the availability of reliable information concerning technological. The lack of control-measuring instruments, such as gas analyzer, can cause inefficient operation of installation, in particular, poor fuel combustion/ Determination of burning products content provides the possibility to evaluate: degree of fuel burning process completeness (losses due to chemical incompleteness of burning), conditions of fuel burning (coefficient of air excess), character of fuel burning in separate zones of the boiler (availability of low temperature zones), dynamics of burning process, observance of limiting norms of harmful substances emission into the atmosphere [1].

Aim of research is the improvement of control reliability of boiler installations fuel gases content of reach optimum burning mode in the furnace of boiler unit.

Main part

In existing systems of automatic control of boiler installation regulation of “fuel - air” ratio is performed by the following parameters: pressure (consumption) of fuel and pressure of air on the burners without correction by the content of flue gases. The amount of air is defined by the value dilution of boiler furnace. Regulation of such parameters is carried out by means of obtarators, i.e., by increasing air resistance of gas-air path while functioning of fan motors and smoke exhauster of fuel capacity. This leads to excess expenditures of electric energy.

Application of frequency regulators (FR) allows to solve the problem of coordination of mode parameters and energy consumption of boiler installations (BI) with varying character of boiler load. Actuality of the problem of energy saving is that FR plays an important role in energy balance and dynamics of the FR ration and electric energy tariffs widen economic boundary of their application. Usage of FR for boiler installation (BI) allows to maintain required ratio “fuel-air” with high accuracy and automate furnace burning, reducing the time from minimum necessary in this case gas consumption and carbon dioxide emissions are reduced.

To maintain optimum ratio ” fuel-air”, on one hand, it is necessary, depending on the amount of supplied fuel, apply necessary amount of air in the furnace of the boiler, and on the other hand-eliminate from the boiler burning products with preset intensity [4]. The given regulation with high accuracy is performed by means of BI automatic control system (with the control of oxygen content in exhaust gases). Functional diagram variable speed drives regulation system is shown in Fig. 1.

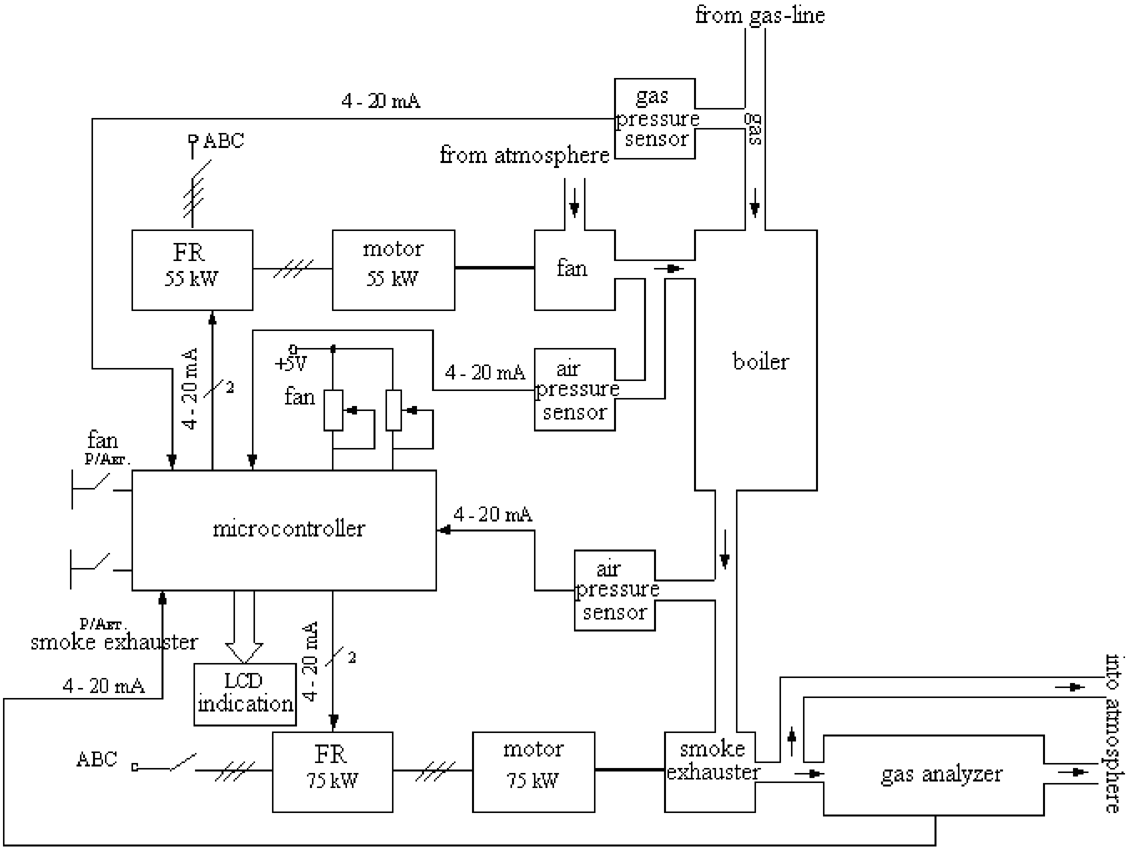

Fig. 1. Functional diagram of BI control system aimed at monitoring of flue gases content

Control of burning products of boiler installations we suggest to perform by means of gas analytical system, based on optic-absorption infrared (OAIR) method. Physical principle of such system operation is the following: absorption of optic radiation of the gas is measured, the gas is investigated in the section of spectrum, where it has intensive absorption band, that does not coincide with absorption bands of other gases, which might be in analyzed gas mixtures.

Physical representation of absorption is the following: when optic radiation passes through gas tray, molecules of gas, absorbing quanta of radiation, corresponding to different frequencies, are excited, i.e., they increase the amount of their energy. If ultraviolet and visible radiation or radiation of shortwave part of infrared spectrum are absorbed, then the amount of electrons energy increases that is, energy, corresponding to oscillations of atoms nuclei and rotation energy of the molecule around the centre of gravity. If quanta, which corresponds to longer wave region of optic radiation spectrum (from several micrometers to hundreds of micrometers) then oscillatory-rotational and correspondingly, purely rotational degrees of freedom are excited. As a result of this process absorption spectra of molecules consist of a number of bands of complex structure. Depending of the nature of flue gas infrared absorption spectra of gas mixture molecules are of individual character, which further allows to identify the gas. Fig. 2 shows infrared (IR) spectrum of flue gases absorption of boiler installation (bands of oscillatory – rotational absorption spectrum of flue gas are well seen) [2].

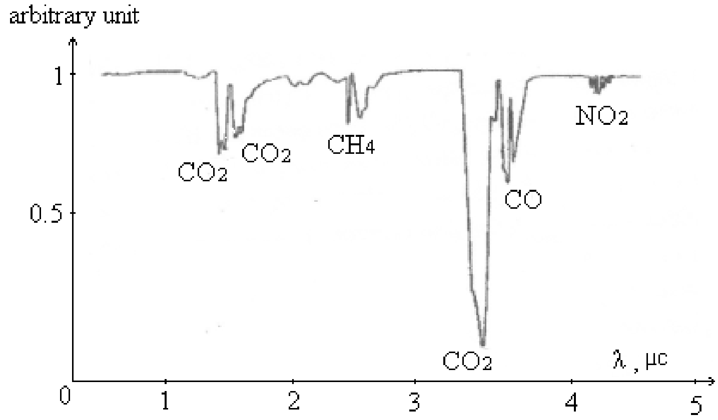

Fig. 2. Oscillatory – rotary absorption bands of flue gas by IR radiation

As Fig. 2 shows, in IR band of the spectrum there are specific characteristics of gas absorption registration, the gas being analyzed due to availability of oscillatory-rotating absorption bands. The value of radiation flux, passed across measuring tray, containing gas, being analyzed, can be defined, applying Lambert – Bar law:

$$I_{out} = a \cdot [1 - \exp(-b \cdot \varphi)], \tag{1}$$

where I_{out} – is output electric signal (current), a,b – are constants, μ – is mass concentration of the component.

The form of dependence, representing the function (1) for constant length of optic (l = *const*), is shown in Fig. 3.

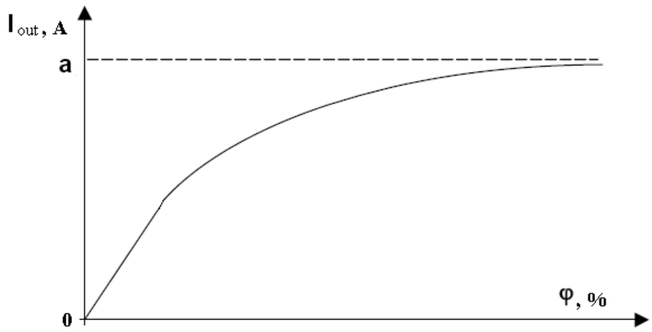

Fig. 3. Graphic representation of the function (1)

Infrared radiation is absorbed by all gases O_2, N_2, H_20, Cl_2 and monatomic gases. Absorption spectrum of monatomic gases or metal vapor differs from infrared spectrum of molecule absorption by its simplicity and it consists not of band, but of separate lines, in many cases, located only in ultraviolet region of spectrum. Prior to application of OAIR method we suggest stabilize gas by such parameters: temperature, humidity, pressure, dust (purification of gas sample from atmospheric dust).

If OAIR method is applied without stabilization of these parameters, then identification and determination of concentration of gas mixture components will not be accurate. The composition of flue gas comprises such basic components: oxygen, carbon dioxide, carbon oxide, nitrogen dioxide, water (vapour) and atmospheric dust (after stabilization of gas sample, content of water and atmospheric dust can be neglected). Total content of these gases and components is 99,9%. Other components of flue gases are on the level of microconcentrations and practically do not influence on determination of heat losses. That is , we can use expression (prior to stabilization of gas sample):

$$\mu(O_2) + \mu(NO_2) + \mu(CO_2) + \mu(CO) + \mu(H_2O) + soot = 100\% \tag{2}$$

where μ_x – is mass concentration of gas mixture, expressed in per cent.

Optimization of combustion process is suggested to perform by the component – O_2. It enables to correct the ratio fuel-air at the input of the object [5]. But physically oxygen does not absorb IR radiation (it is seem for Fig. 2, where the line of oxygen absorption is missing), that is why, it is suggested to determine CO, CO_2, NO_2 practically, and O_2 – analytically (after sample stabilization):

$$\mu(O_2) = 100\% - [\mu(NO_2) + \mu(CO_2) + \mu(CO)]. \tag{3}$$

The structure of flue gas content of boiler units [3] is shown in Fig. 4. in the form of dependence of air excess coefficient (AEC) on the concentration of flue gases of boiler units.

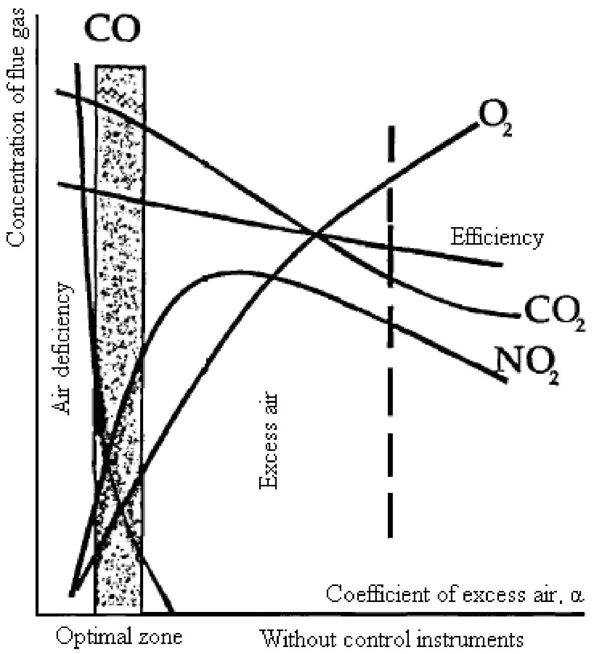

Fig. 4.Structure of boiler installations flue gases content

Optimum zone is such a concentration of the components, at which combustion of fuel with low AEC is provided. In [9], optimum AEC, that equals 1.25 (±0.01) was determined for the boiler ДЕ-25-14 ГМ. Increase of optimum AEC results in increase of nitrogen oxides concentration value. On condition of the decrease of optimum carbon oxides concentration increases, and, consequently, losses caused by incomplete chemical combustion increase. Main parameter, determining correcting impack on the value air excess is the content of residual oxygen in flue gases. Non sufficient amount of air causes incomplete combustion of products in the furnace of the boiler and, as a result, leads to excessive combustion of fuel. Excess of air also leads to excessive combustion of the fuel for heating of excessive air in the structure of waste gases [4].

Development of functional diagram of the system Gas-analytic (GA) system we will build on the principle of direct action – this is, a system, where all transformations have one direction: from the input to output. The system will be built in accordance with the structural diagram, having such functional units: unit for stabilization of input parameters, measuring converter, information processing unit, information representation unit.

Unit for stabilization of input parameters (USIP). Sample, taken for analysis of gas mixture directly from chimney, has a variety of parameters, namely temperature, humidity, pressure dust. If fuel gas with non stabilized parameters is supplied directly on measuring converter, this will lead to obtaining at the output the information about the content of fuel gas with great error. That is why, we propose to include USIP in the structure of GS. Unit for stabilization of input parameters (USIP) must meet the following requirements: fast operation rate, efficient and reliable cleaning from mechanical admixtures, reduction to the requirements value of mixture humidity, stabilization of temperature and pressure.

At the next stage gas sample passes across primary and secondary measuring converters (PMC and SMC). Operation principle of PMC and SMC is the following. IR radiation from the source arrives in two, located closely and parallely to each other, trays – operation and comperative. Gas is pumped across operational tray, it is analyzed, and comparative tray contains air, free of this gas.

Thus comparisson channel is formed. Further, beams of optic are subjected t modulation in antiphase to each other by means of obturator, which is rotating disk with slots. Then optic radiation passes across interference light filter, that has bandwidth where the line of gas absorption being analyzed, drops. Further both modulated beams with the help of concentrator are directed to pyroelectric photo detector. The conversion of radiation flux into alternative electric signal, proportional to it by the magnitude occurs and its amplification takes place. After that the signal is amplified to unified magnitude in main amplifier and is sent to information processing unit.

As a result of development of industrial controllers, it is quite logical to process measuring information by means of these devices, providing interface of initial signal with controller input. For system realization we use programmable logic controller, manufactured by VIPA company series Sytem 200V. By means of system 200V new high productive control systems, meeting modern requirements can be created.

Measurements are carried out in constant mode. Functional diagram of the system, intended for control of flue gas content of boiler installations is shown in Fig. 5 (the diagram is shown in the form of single-channel structure, but practically the system is multichanel one for multicomponent analysis of gas mixture).

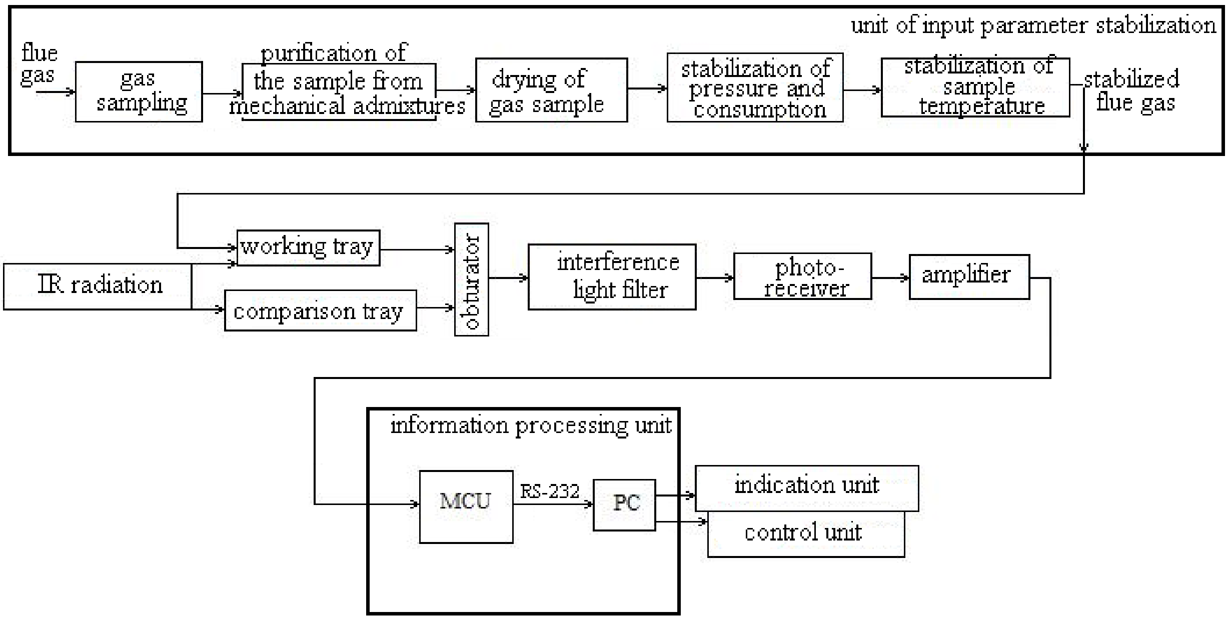

Fig. 5. Functional diagram of control system of boiler installations flue gases content

Program realization. For realization of the task, put forward, we use program package WINPLC7 for configuration, programming, debugging of the program and diagnostics of VIPA controllers of all series [7]. The program will be written in programming language Ladder Diagram (LAD) – language of relay-contact circuits [8]. Operation algorithm of the program is shown in Fig. 6.

Algorithm of the program is the following: alternative electric information signal concerning the content of flue gas arrives from gas analyzer. This signal is received by functional unit scaling analog value and is converted in a variable that corresponds to the value of unified electric signal (current) within the range of 4 – 20 mA.

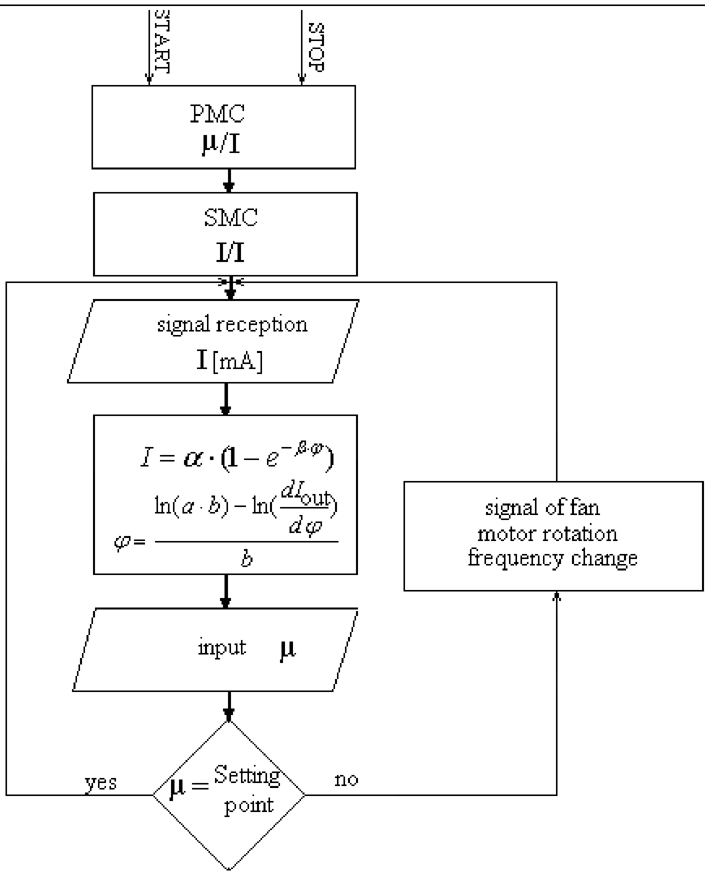

Fig. 6. Algorithm of program operation

Further the transformation of electric signal corresponding concentration of certain flue gas is performed. Transformation is carried out in accordance with functional dependence, shown in the formula (1). After obtaining the data regarding the amount of a certain gas it is compared with settings. If concentration is within the admissible limits, then air is supplied to the furnace with the same intensity. If concentration out of settings, then less or greater amount of the air (depending on the signal) is supplied to the furnace. The process of air supply in the furnace is realized by means of frequency regulator. Process of control and monitoring is constantly performed in real time mode.

Fig. 7 and 8 show change of oxygen concentration in the flue of boiler installations (Fig 7 - without correction of oxygen content in waste gases, Fig. 8 – with correction).

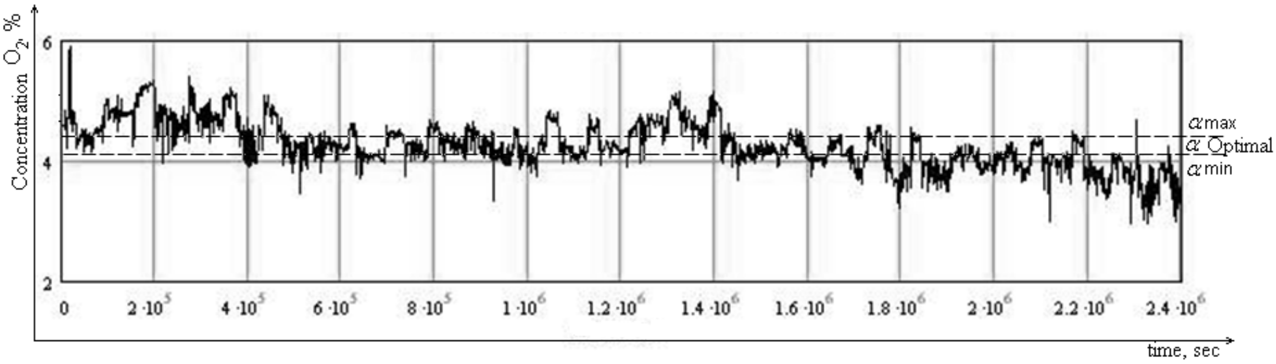

Fig. 7. Change of oxygen concentration in flue gases without correction

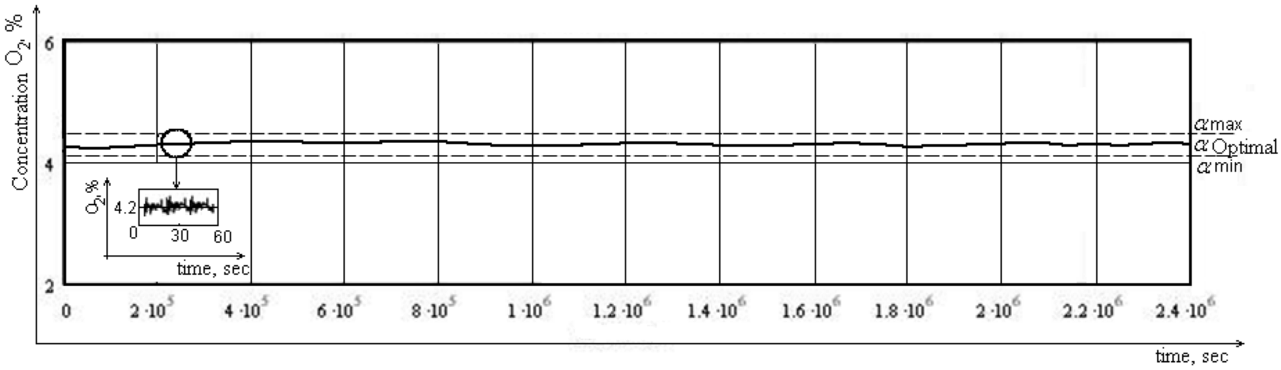

Fig 8. Change of oxygen concentration in flue gases with correction

Using oxygen formula $\alpha = \dfrac{21}{21 - O_2[\%]}$ for optimum value of CAE α=1,25, ±0,01 (on the example of ДЕ-25-14 ГМ boiler), we will calculate optimum concentration of oxygen in flue gases . Thus, $\mu(O_2)\min = 4{,}06\%$ and correspondingly $\mu(O_2)\max = 4{,}33\%$. Hence, the conclusions can be made, that boiler installation (BI), functioning with the control of flue gases content, ahs high energy saving efficiency. During the whole period of operation, concentration of oxygen is within optimum limits (Fig. 8).

Conclusions

The given research considers the system of automatic control of boiler installation, equipped with subsystem of flue gases content control, based on optic – absorption infrared method with compensation of atmospheric dust and excess humidity influence. Algorithm of flue gases control program of boiler installations to support optimum ratio “fuel-air” in the furnace boiler is presented, Boiler instullation functions efficiency during the whole period of operation, correcting the quantity of air in the furnace, according to the content of waste gases.

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