UPGRADING OF BOILERS AND FURNACES EQUIPMENTS BY USING ENERGY AND ENVIRONMENTAL DIAGNOSIS

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Abstract: *Energy and environmental diagnosis consists in analysis of the operation, in current conditions and after upgrading of boiler and furnace equipments, based on energy balance and emission of pollutants in real and optimized conditions, where parameters after upgrading are determined by simulating operation using appropriate software. The paper describes the algorithm of energy and environmental diagnosis software and its application in upgrading of heating furnace.*

Keywords: *energy balance, energy and environmental audit, mathematical model, heat furnace, fuel consumption, preheaters*

1. INTRODUCTION

Upgrading of boilers and furnaces is imposed by EU directives to achieve until 2020 an increase of energy efficiency by 20% and reduce emissions of greenhouse gases with 20% [1].

Upgrading of boilers and furnaces is a result of feasibility studies, which are based on energy audit component, namely an analysis based on energy balance. Real energy balance of the equipment are developed starting from structural and functional data already known from the primary records and possibly thermotechnical measurements. By analyzing real energy balance, including comparison with worldwide performance systems and technologies, resulting optimized solutions corresponding energy balances [2,3].

This analysis has been extended in recent years in the environmental field by introducing the notion of energy and environmental audit. Thus, to real energy balance pollutant emission values of equipment are added, resulting from primary records and eventually from measurements and the optimized versions are taken into account and pollutants emission values of companies supplying the new systems [4,5].

Upgrading of boilers and furnaces based on energy audit or energy and environmental audit has the disadvantage of not taking into account the quality elements brought by the new installation. Balance does not take into account the change process parameters obtained by upgrading equipment. Thus, have been developed simulation models for the operation of boilers and furnace equipment, on which can be designed and upgraded new equipments and can quantify exactly new functional parameters, including fuel consumption. In that manner it introduces the notion of energy and environmental diagnosis that includes simulation of boilers and furnaces equipment which add energy and environmental audit.

2. DESCRIPTION OF ENERGY AND ENVIRONMENTAL DIAGNOSIS ALGORITHM

Energy and environmental diagnosis algorithm developed for upgrading of boilers and furnaces equipments, shown in figure 1, involves performing several steps.

In the first stage, analysis of the heating system (boiler or furnace) working in real conditions, based on functional and structural data from primary records was conducted. Shall be established operating conditions for which thermotechnical measurements are made. All these are inputs to the energy and environmental audit software of heating system after which are obtained the following results:

- structure of real energy balance;
- actual energy characteristics [specific energy consumption (fuel), yield, primary recovery rate and secondary recovery rate of secondary energy resources (SER) depending on productivity (fuel flow)];
- real environmental characteristics (emission of various pollutants: CO, CxHy, CO_2, NOx, particulates depending on fuel flow).

The results will be analyzed in comparison with those of equipments with similar performance, in order to establish solutions for modernization.

In a first step, the effects of different upgrading solutions application are quantified by energy and environmental audit software, according to new data expected to be obtained by optimization:

- preheating temperature for air combustion, residual fuel (waste), water supply or load;
- values regarding coefficient of excess air and the exhaust gas composition, given the characteristics of the new combustion systems and automation;
- characteristics of insulating materials etc.

Thus, the structure of optimized energy balance together with energy and environmental features are obtained.

When using new burners and additives (combustion catalysts or reducing pollutant emissions and platform to establish the most important functional parameters:

- fuel flow depending on its pressure;
- combustion air flow depending on its pressure;
- minimum excess air coefficient (over which no longer obtain emissions) and flue gas composition corresponding to different modes of operation etc.

These parameters are determined depending on method of additive injecting, type and amount of additive used. For exact quantification of the effects regarding application of new solutions, an analysis are performed by simulating the operation of the proposed heating system with new features in optimized version, with specific software. Thus are obtained even new values

deposition), tests will be made on the experimental

of functional parameters necessary for dimensioning of proposed equipments (heat exchangers, combustion installations etc.).

Dimensioning of proposed equipment for boiler or furnace upgrading consists of heat exchangers, combustion installations is achieved by specific software. Thus, it can establish values of investments in new combustion equipments, heat exchangers, automation systems etc. which, together with additional costs related to additives and other economic data are inserted economic and technical analysis software for upgrading heating system. Values of the main technical and economic indicators: productivity P, criteria Z, RIA, IRR, amortization of investment, which allow appropriate decision, are obtained.

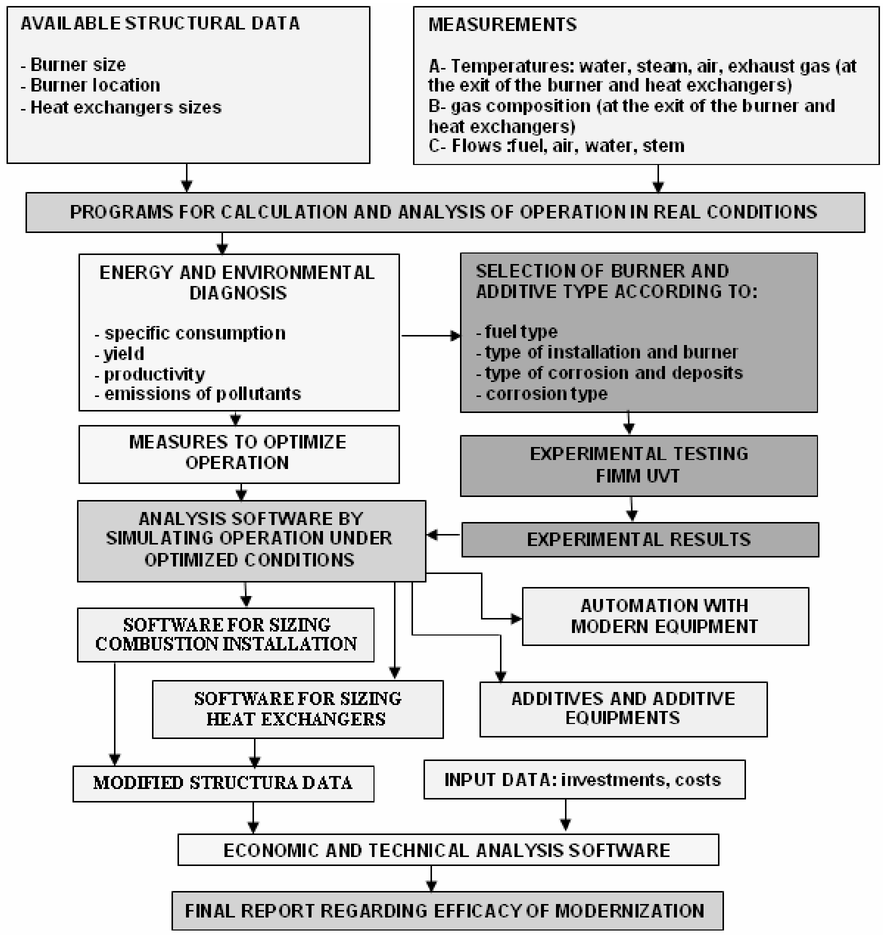

Figure 1. Algorithm of energy and environmental diagnosis developed for upgrading of boilers and furnaces equipments

3. APPLICATION OF ENERGY AND ENVIRONMENTAL DIAGNOSIS FOR UPGRADING OF HEATING FURNACE

3.1. Analysis of heating furnace operation in real and optimized conditions

Heat furnaces of steel mills, in most cases, works with mixture of combustible residual gases (blast furnace gas, coke oven gas, converter gas) and natural gas. To reduce the specific fuel consumption of these heating furnaces involves reducing natural gas consumption, which requires, for keeping constant combustion temperature and fuel preheating combustion air.

Application of energy and environmental audit in the case of a heating furnace supplied with lower calorific value fuel mixture (PCI) of 8400 kJ/m^{3}N consisting of blast furnace gas and natural gas equipped with a preheater radiation, where the preheating combustion air temperature is up to 310 ^{0}C, led to upgrading of furnace by adding a new preheater for fuel preheating temperature (TC) up to 400 ^{0}C and combustion air temperature (TA) up to 600 ^{0}C. For these preheat maximum temperatures of fuel mixture can work with minimum calorific value of 4040 kJ/m^{3}N, in conditions of achieving a minimum adiabatic temperature of 1750 ^{0}C.

By using mathematical model of energy and environmental audit and data processing from multiple experimental batches, running in initial conditions, have been obtained the following average values:

- combustion air preheating temperature 250 ^{0}C;
- exhaust gas temperature from furnace 1100 ^{0}C;
- coefficient of exhaust gases excess air 1.2;
- useful energy transferred and energy lost through the walls and the accumulation 648,760 kJ/t;
- specific fuel consumption 54.83 kgcc /t (1kgcc=29295kJ).

The following values are considered constant:

- useful energy transferred;
- lost energy through walls and accumulation;
- temperature of the exhaust gas from the furnace;
- coefficient of exhaust gases excess air;

By using energy and environmental audit mathematical model specific fuel consumption of furnace (c) has been calculated, depending on variable values preheating temperatures (TC, TA) and the lower calorific value of fuel mixture (PCI).
Thus, figure 2 shows the nomogram for determining the specific fuel consumption (c) and the lower calorific value of the fuel (PCI), depending on the preheating combustion air (TA) and fuel temperature (TC).

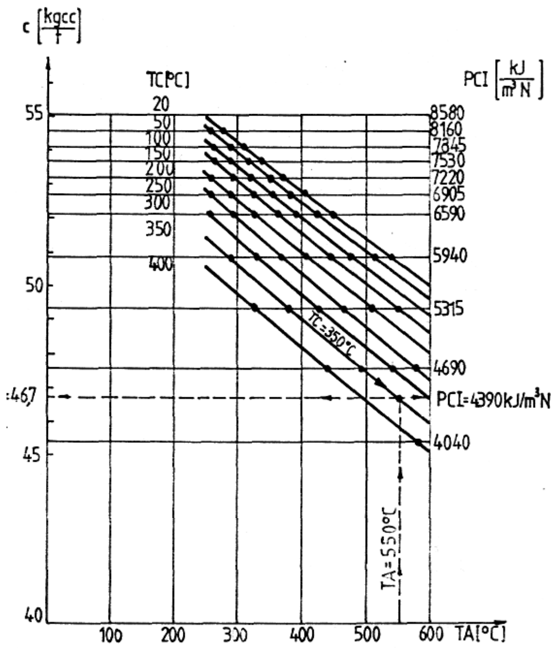

Figure 2. Nomogram for determining the specific fuel consumption (c) and the lower calorific value of the fuel (PCI), depending on the preheating combustion air (TA) and fuel temperature (TC)

From this nomogram is found that by simultaneously air combustion and fuel preheating can substantially reduce specific fuel consumption and save natural gas. Thus, with air preheating to 550 ^{0}C, repectively, to 350 ^{0}C for fuel, specific fuel consumption will decrease from 54.83 kgcc/t to 46.7 kgcc/t, while reducing the proportion of natural gas in fuel mixture, from a lower calorific value of 8400 kJ/m^{3}N to 4390 kJ/m^{3}N.

3.2 Functional parameters settings for furnace in optimized conditions

Qualitative analysis regarding heating furnace operation, under optimized conditions, is led by a heat transfer mathematical model software to highlight fuel consumption at different ratios of natural gas into fuel and to establish required parameters for combined preheater design.
This mathematical model was applied to heating furnace that uses fuel mixture (natural gas and blast furnace gas) with lower calorific value of 8400 kJ/m^{3}N.
The furnace is equipped with preheater initial radiation and the new combined preheater where the combustion air and the fuel is preheated up to 600 ^{0}C, respectively 400 ^{0}C.
In the case of furnace upgraded with the new combined preheater, this can operate with natural gas and gas furnace fuel mixture up to lower calorific value of

4040 kJ/m^{3}N. Fuel flow variation during a charge, for example, for the three operational solutions of furnace, is shown in figure 3:
- with radiation preheater and fuel mixture with lower heating value of 8400 kJ/m^{3}N;
- with combined preheater and fuel mixture with lower heating value of 8400 kJ/m^{3}N;
- with combined preheater and fuel mixture with lower heating value of 4040 kJ/m^{3}N.

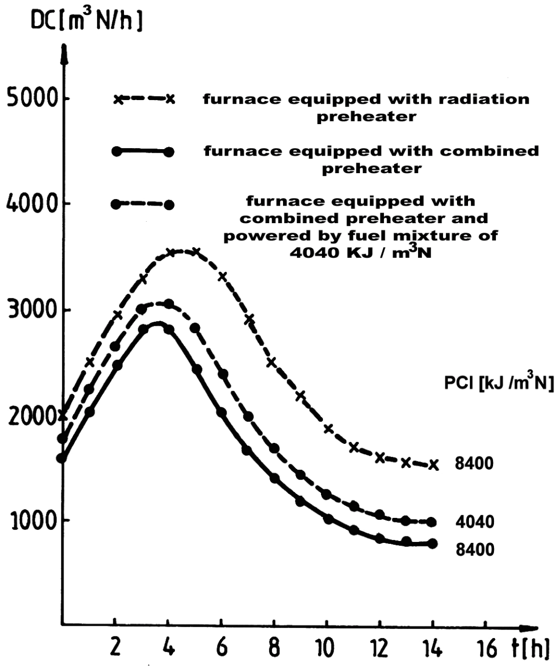

Figure 3. Fuel flow variation (DC) depending on the time, for a computer simulated charge, by using a furnace equipped with radiation preheater and low calorific fuel mixture PCI 8400 kJ/m^{3}N, with combined preheater and fuel mixture with PCI 8400 kJ/m^{3}N and respectively mixt preheater and fuel mixture with PCI 4040 kJ/m^{3}N

3.3 Designing and testing of combined preheater

Combined preheater comprises three operating areas: one for radiation, one for convection of combustion air and another for gas furnace and natural gas fuel mixture convection. Sizing of combined preheater was performed with own software, which allowed the choice of optimal version for both operation with initial fuel mixture having PCI 8400 kJ/m^{3}N and fuel mixture with PCI 4040 kJ/m^{3}N.

The most important functional feature of combined preheater is the variation of heat transfer global coefficients with fuel flow. This feature is present, for example, in figure 4, where the flue gas temperature at combined preheater entering is and 1100^{0}C and usually excess air coefficient $\alpha = 1.2$, in case of operating with low calorific fuel mixture having PCI 8400 kJ/m^{3}N. On this feature is presented, besides theoretical values determined by using own computer programs and experimental results obtained on the first combined preheater from the heating furnace.

Figure 4 confirm the validity of theoretical calculations, experimentally determined values are consistent with those calculated by using own software for sizing heat exchangers.

Industrial experimental results reveal the following points:
- average temperature of air at the exit from combined preheater is for more than two times higher by comparison to that obtained by using the original radiation preheater;
- maximum temperature at the exit from combined preheater, reaches the optimal values, 600°C and 400°C for combustion air, respectively fuel;

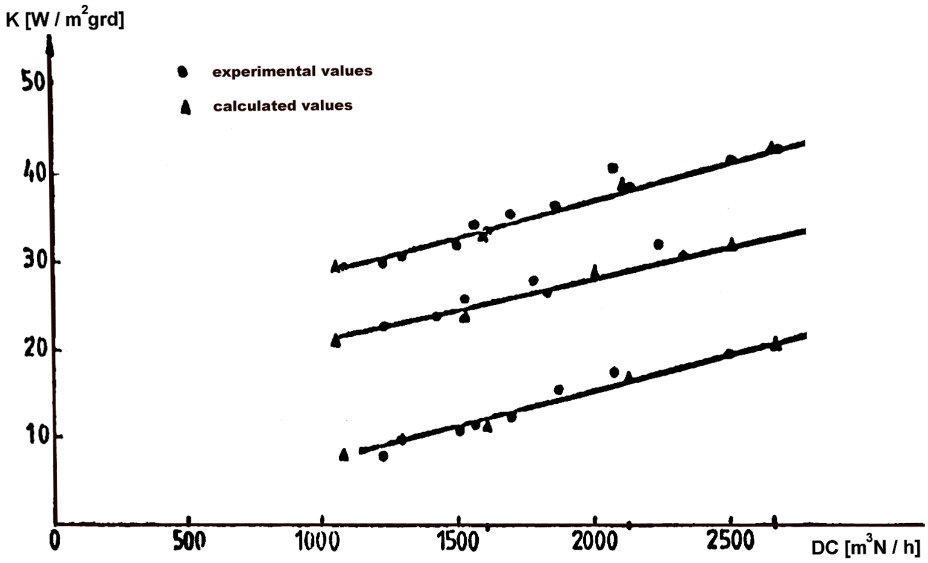

Figure 4. Heat transfer global coefficients variation with fuel flows (DC) when the gas temperature is 1100 ^{0}C and excess air coefficient is 1.2, in case of operating with low calorific fuel mixture having PCI, 8400 kJ/m^{3}N

- energy introduced into the furnace by air and fuel preheated reported to the energy developed by the fuel combustion, reaches maximum values of 0.35 MJ;
- decrease of specific fuel consumption with approx. 24%, by using fuel with lower heating value of 8400 kJ/m^3N

From theoretical calculations performed by simulating operation of combined preheater has results a reduction of specific fuel consumption by 23.8%, which confirms the good correlation between the theoretical results and those obtained from industrial experiments.

4. CONCLUSIONS

Energy and environmental diagnosis consists in analysis of the operation in current conditions and after upgrading the boiler and furnace equipment by using computer programs, in several stages, based on energy balance and emission of pollutants in real and optimized constructive solutions based on heat transfer, by simulating the operation of the boiler or furnace equipments for establishing functional parameters including those required for designing new systems.

Also, by using computer programs, in case of energy and environmental diagnosis, sizing of new exhaust gas heat recovery systems and technical and economic calculation regarding different improved solutions are performed.

Upgrading of heating furnace that works with lower heating value fuel mixture of 4040 kJ/m^3N, in order to preheat the fuel to max. 400^0C and combustion air until 600^0C, by adding a new combined preheater was done.

From experimental data and mathematical model of energy and environmental audit, specific fuel consumption of heating furnace, depending on the values of variables described in the content of the paper, has been calculated. Data revealed a reduction in fuel consumption by 8.13 kgcc/t, while reducing the proportion of natural gas in gas blast furnace mixture, from a lower calorific value of 8400 kJ/m^3N to 4390 kJ/m^3N.

Results regarding implementation of energy and ecological diagnosis in case of heating furnace revealed the utility of computer programs and also the effects concerning decrease of the fuel consumption. Research highlights a reduction in specific fuel consumption by 23.8%.

5. REFERENCES

[1] EEA. 2010. Energy related particulate matter emissions (EN-07), Jan.2010. [www.eea.europa.eu/EN].
[2] Gaba, A., Auditul energetic in metalurgie, Ed. Bibliotheca, Targoviste, 2003.
[3] Raducanu, C., Patrascu, R., Paraschiv, D., Gaba, A., Auditul energetic, Ed. AGIR, Bucuresti,2000.
[4] Nicolae, A. s.a., Management de mediu in industria materialelor metalice, Ed. Fair Partners, Bucuresti 2001.
[5] ***XIIth International Scientific and Technical Conference "Power Engineers Forum GRE2010", May 31 - June 2, 2010, Szczyrk, Poland.
[6] Gaba, A., Arderea ecologica a combustibililor, Ed. Bibliotheca, Targoviste, 2005.
[7] Gaba, A., Transferul de caldura in instalatii industriale, Ed. Bibliotheca, Targoviste, 2004.