UDC: 697.326:004
DOI: 10.5937/SE2101021I
Research article
www.safety.ni.ac.rs

NIKOLA IGIĆ[1]
GORAN STEVANOVIĆ[2]

[1,2] Kvalitet a.d.
Joint-stock company for
quality testing

[1]nikola.igic@kvalitet.co.rs
[2]goran.stevanovic@kvalitet.co.rs

ANALYSIS OF ENERGY EFFICIENCY AND SAFE HANDLING OF HEATING BOILERS ACCORDING TO SRPS EN 303-5

Abstract: *Optimization of heat transfer process during combustion of solid fuels in heating boilers as well as constant monitoring of energy flows, contribute to energy efficiency improvement. Standard SRPS EN 303-5: 2016 defines requirements, methods and test procedures for evaluating safety, combustion quality and particulate emissions into the environment, performance characteristics and criteria for energy efficiency, as well as labeling and safe handling. Accordingly, the paper examines the efficiency of heating boilers based on the reduction of heat losses that occur due to radiation, convection and conduction, and analyzes the integrated aspects of safety through permissible emission limit values, as well as safe handling and fire protection.*

Key words: *heating boilers, energy efficiency, safe handling, SRPS EN 303-5:2016.*

INTRODUCTION

Accelerated development and implementation of technologies for the production of heat and electricity from renewables have not significantly reduced the use of renewable energy sources. It is estimated that by 2030, fossil fuels will account for 85% of the global energy mix [1].

The concept of energy efficiency has always been popular when it comes to energy issues. Recently, this concept has become not only a question of the economic viability of certain systems but also a very significant factor in a struggle to protect the environment [2,3]. In this sense, energy efficiency measures in coal-fired heating plants and thermal power plants are particularly important, as they reduce fuel consumption for the same amount of useful energy, resulting in lower emissions of carbon monoxide, nitrogen oxides, bound hydrocarbons and other particulate matter [4].

Construction Product Regulation (Official Gazette of RS, no. 83/2018) stipulates that space heating devices must comply with technical requirements that rely on conformity standards that specify not only the required characteristics but also methods for testing the mentioned characteristics. Measurement of these characteristics is carried out with the aim to determine the performance of the device - efficiency, gas emissions, particulate emissions and reliability under changing operating conditions.

Therefore, the paper analyzes the efficiency of manually filled solid fuel heating boilers with a nominal heat output of up to 500 kW, according to the SRPS EN 303-5: 2016 Heating boilers - Part 5: Heating boilers for solid fuels, manually and automatically stoked, nominal heat output of up to 500 kW - Terminology, requirements, testing and marking.

CALCULATION OF BOILER EFFICIENCY

The degree of utilization of heating boilers is calculated on the basis of: heat losses during combustion, losses due to incomplete combustion, losses that occur due to radiation, convection and conduction, and unburned carbon loss in ash:

$$\mu_k = (1 - Q_a - Q_u - Q_s - Q_b)\ 100\% \qquad (1)$$

where:

μ_k - degree of utilization of heating boilers;

Q_a - heat losses during product combustion;

Q_u - losses due to incomplete combustion;

Q_s - losses that occur due to radiation, convection and conduction;

Q_b - unburned carbon loss in ash.

It is estimated that the boiler efficiency can be improved by reducing losses that occur due to radiation, convection and conduction.

When examining surface temperature, mean surface temperature must be measured at rated heat output. In order to do that, a measurement must be performed on each surface of the boiler at five sport at least. Under the same conditions, critical temperatures must be measured (for example, boiler doors, control levers, etc.). Losses are calculated taking into account total energy input. In that sense, we have examined two cases in which insulation losses and the degree of efficiency differ.

Case I, the measurement method involves temperature measurement at heated surfaces where the insulation losses are 3.4% and the total efficiency is 88.3%, Table 1.

Table 1. *Surface temperatures – case I*

	front door	back	right	left	up	down
a [m]	1,34	1,34	1,34	1,34	0,91	0,91
b [m]	0,61	0,61	0,91	0,91	0,61	0,61
T1 [°C]	90	24	32	29	44	25
T2 [°C]	82	28	30	33	36	25
T3 [°C]	114	29	29	52	40	24
T4 [°C]	61	30	24	30	34	26
T5 [°C]	95	33	26	30	28	26
T6 [°C]	98	37	25	45	41	24
T7 [°C]	97	38	24	28	57	24
T8 [°C]	118	24	22	29	30	23
T9 [°C]	82	25	23	42	31	25
T10 [°C]	45	24	24	34	37	24
T11 [°C]	49	25	25	50	41	24
T12 [°C]	37	23	26	40	60	23

In Case II, insulation made of 5 cm thick glass wool with thermal conductivity λD = 0.04 W/mK was placed on the front side, i.e. on a metal support. In this case, the insulation losses are 1.2%, the overall efficiency is 91.0%, Table 2

Tabela 2. *Surface temperatures – case II*

	front door	back	right	left	up	down
a [m]	1,34	1,34	1,34	1,34	0,91	0,91
b [m]	0,61	0,61	0,91	0,91	0,61	0,61
T1 [°C]	32	27	36	28	47	24
T2 [°C]	29	26	29	27	38	25
T3 [°C]	30	33	29	28	36	24
T4 [°C]	30	27	26	25	39	25
T5 [°C]	30	25	25	24	28	26
T6 [°C]	32	23	30	26	44	23
T7 [°C]	33	21	28	26	48	24
T8 [°C]	32	22	25	23	30	22
T9 [°C]	34	21	25	22	29	25
T10 [°C]	25	22	22	22	41	24
T11 [°C]	24	22	23	22	60	24
T12 [°C]	26	22	27	26	33	22

Comparative analysis of the tables leads to the conclusion that energy efficiency is better in the second case, but the impact of other elements should also be taken into account. When calculating the overall efficiency, the improvement may be perceived in terms of insulation improvement.

Heat loss

In the indirect method, it is necessary to be familiar with this loss type of loss. It can be obtained by the following procedure. The outer boiler casing is divided into areas of similar temperature (insulated surfaces, doors, flue gas connections, connecting pipes, the boiler base) and their temperatures are measured through the surface thermostat. The heat emission from the surface section is calculated as follows:

$$Q_x = F_x \alpha (t_m - t_L) \quad (2)$$

Where:

Q_x - heat emission from a surface section in W;
F_x - the surface area of the section in m^2;
α - heat transfer coefficient in $W/(m^2K)$;
t_m - mean surface temperature of the section in °C;
t_L - room temperature (measured at 7 points, 1,5 m from the front of the boiler at a height equal to half the boiler height) in °C.

Approximate heat transfer coefficients relative to the temperature of the surfaces can be obtained from Figure 1.

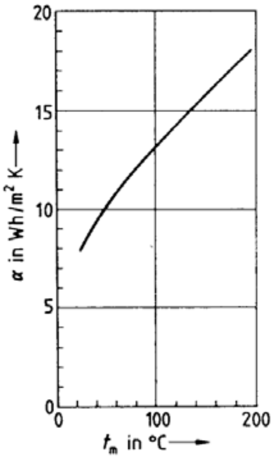


Figure 1. *Total heat transformation figure by radiation and free convection to the horizontal and vertical surfaces at an ambient temperature t_L=20 °C as a function of the mean surface temperature t_m*

SAFETY REQUIREMENTS OF THE STANDARD SRPS EN 303-5:2016

According to the general requirements of SRPS EN 303-5:2016 standard, the minimum performance requirements, as well as the safety requirements for heating boilers have been defined. Performance requirements are related to the power supplied to water and energy efficiency relative to the calorific value of solid fuels. However, both aspects largely depend on boiler construction and technical and technological solutions applied during construction. Decision criteria for determining boiler class are clearly defined by the standard SRPS EN 303-5. These requirements are usually met during boiler testing, and the measured values for the reference operating conditions are within the limits specified in Table 3, which has an impact on the class of boilers.

Table 3. *Emission limit values according to SRPS EN 303-5*

Heating	Fuel	Nominal heat output	Emission limit values								
			CO			OGC			Dust		
			mg/m³ at 10 % O_2								
		kW	class 3	class 4	class 5	class 3	class 4	class 5	class 3	class 4	class 5
Manual	Biogenic	≤ 50	5 000	1 200	700	150	50	30	150	75	60
		> 50 ≤ 150	2 500			100			150		
		>150 ≤ 500	1 200			100			150		
	Fossil	≤ 50	5 000			150			125		
		> 50 ≤ 150	2 500			100			125		
		>150 ≤ 500	1 200			100			125		
Automatic	Biogenic	≤ 50	3 000	1 000	500	100	30	20	150	60	40
		> 50 ≤ 150	2 500			80			150		
		>150 ≤ 500	1 200			80			150		
	Fossil	≤ 50	3 000			100			125		
		> 50 ≤ 150	2 500			80			125		
		>150 ≤ 500	1 200			80			125		

Note: *The dust values in this table are based on the gravimetric filtration method. The test report should indicate the method used. The emission of particulate matter, measured in accordance with the European Standard, does not include condensing organic compounds which may form additional particulate matter when the flue gas is combined with ambient air. Therefore, the values cannot be directly compared with the values measured using the dilution tunnel method. Nor can they be converted into particle concentrations in the surrounding air.*

Measuring emissions of gases and particles is performed for periods required for the combustion of the amount of fuel that corresponds to the quantity of one filling inside the boiler furnace [5].

Boiler construction should meet general safety requirements in order to:

- prevent dangerous accumulations of flammable gases (> 5% CO) in the combustion chamber and in the flue gas ducts;
- withstand stresses that occur during normal operation;
- enable heat transfer media (water) not to be heated to the dangerous limit (≤ 110 ° C);
- avoid flame rollout and falling embers, in case when the boiler is properly handled;
- avoid hazardous gas leakage from a heating boiler, heating device or built-in bunker into the boiler installation place.

Components - built-in electrical components used during regulation and safety must meet the general requirements for electrical appliances safety - SRPS EN 60335-1 [6].

The manufacturer must do a risk assessment after the use of an appliance and give instructions for safe operation in the Operating Instructions, making sure that installation and commissioning have been completed by fully qualified personnel. Particular attention should be paid to the following hazards that can occur during heating boiler operation:

- elevated temperatures at the outer casing of the heating boiler and other boiler components used for operation;
- possible electric shocks;
- injuries from mechanical force during handling.

Components of the outer casing of the heating boiler, thermostat, safety appliances, and electrical components must be installed in such a way that the temperatures of their surfaces, while in operating mode, do not exceed the temperatures specified by the manufacturer or the temperatures specified in the component standard.

The materials for the components exposed to pressure must comply with generally accepted technical requirements. They must be suitable for that purpose and intended use. The supplier must deliver the proof of mechanical and physical properties of the materials used, as well as their chemical composition.

Safety during handling should be essential when designing the heating boiler. Also, the heating boiler must be designed and packaged so that it can be stored safely and without damage.

Heating boilers shall be equipped in such a way that they could be easily moved by means of internal transport in cases when they cannot be moved manually due to the weight, size, or shape of the boiler or its components.

Parts of the structure that are accessible during use and maintenance shall not have sharp edges and corners that could cause damage or injury to the person during handling or maintenance.

Engines and fans must be installed in a way to comply with the requirements for noise and vibration during use [7].

CONCLUSION

The significance of energy efficiency of heating boilers is reflected not only in its cost-effectiveness but also in environmental protection. By reducing energy losses in the process of heat production, regardless of the condition of the existing equipment, it is possible to significantly increase the efficiency of the boiler plant. In addition to the operating mode, losses have a serious impact on the costs of thermal energy generation. Of course, the loss of energy cannot be reduced to zero, but it tends to be reduced to a minimum. In case of heating boilers, it is assumed that highly efficient heating boilers are those scoring over 90% for energy efficiency. In harmony with this, the reduction of heat losses must be done by radiation, convection and conversion, which was done in case II by making insulation from glass wool. The safety of device handling must comply with a harmonized standard.

REFERENCES

[1] Y. Shi, J. Wang, Z. Liu: “On-line monitoring of ash fouling and soot blowing optimization for convective heat exchanger in coal-fired power plant boiler, Applied Thermal Engineering, 78, 2015.

[2] V. Marić: “Techno economic analysis and performance evaluation of heat pump systems and hot water boiler”, Zbornik radova Fakulteta tehničkih nauka, broj 06, 2021.

[3] V.Vučić, M.Radović Vučić: Environmental concerns of energy chain as a reflection of sustainability, Safety Engineering, Vol.8 (2), pp. 109-113, 2018

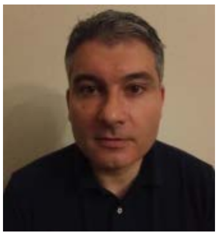
[4] G. Jankes, N. Tanasić, M. Stamenić, T. Simonović, N. Petković, A. Nikolić, M. Radosavljević, M. Saleta: Analiza mogućnosti unapređenja energetske efikasnosti kod toplana i industrijskih kotlarnica na ugalj, Naučno-stručni simpozijum Energetska efikasnost - ENEF 2017, Banja Luka, 3-4. novembar 2017.

[5] D. Antić, I.Krstić, A, Đorđević: Indikatori energetskih performansi tehnoloških Sistema, Safety Engineering, Vol. 3(3), pp. 151-160, 2013.

[6] SRPS EN 60335-1:2012/A1:2020, Aparati za domaćinstvo i slični električni aparati - Bezbednost-Deo 1: Opšti zahtevi - Izmena 1

[7] SRPS EN 303-5, Котлови за грејање - Део 5: Котлови за грејање на чврста горива, ручно и аутоматски ложени, називне топлотне снаге до 500 kW - Терминологија, захтеви, испитивање и обележавање

BIOGRAPHY of the first author



Nikola Igić was born in Niš in 1970. He graduated from the Faculty of Mechanical Engineering in Nis and acquired the title of a graduate mechanical engineer. He was a Lead Engineer in the Laboratory for Gas Appliances Joint Stock Company for Quality Testing "QUALITY" Nis. He is currently the Head of the Sector for Assessment of Quality Management Systems.

ANALIZA ENERGETSKE EFIKASNOSTI I BEZBEDNOG RUKOVANJA KOTLOVIMA ZA GREJANJE PREMA SRPS EN 303-5

Nikola Igić, Goran Stevanović

Rezime: *Optimalnim iskorišćenjem prenosa toplote pri procesu sagorevanja čvrstih goriva u kotlovima za grejanje, kao i stalnim praćenjem energetskih tokova, postiže se veća energetska efikasnost. Standard SRPS EN 303-5:2016 definiše zahteve, metode i načine ispitivanja za bezbednost, kvalitet sagorevanja i emisije čestica u okolni prostor, radne karakteristike i kriterijume za energetsku efikasnost, obeležavanje i bezbedno rukovanje. U skladu sa tim u radu je izvršeno ispitivanje performansi kotlova za grejanje na osnovu smanjenja gubitaka toplote zračenjem, konvekcijom i prevođenjem i analizirani su integrisani aspekti zaštite kroz dozvoljene granične vrednosti emisija, kao i bezbednog rukovanja i zaštite od požara.*

Ključne reči: kotlovi za grejanje, energetska efikasnost, bezbedno rukovanje, SRPS EN 303-5.