Технічні науки

UDC 621.036.7

Fialko Nataliia

Doctor of Technical Sciences, Professor,

Corresponding Member of the NAS of Ukraine, Head of the Department

Institute of Engineering Thermophysics of the NAS of Ukraine

Stepanova Alla

Candidate of Technical Sciences (PhD),

Senior Scientific Researcher, Leading Researcher

Institute of Engineering Thermophysics of the NAS of Ukraine

Navrodska Raisa

Candidate of Technical Sciences (PhD),

Senior Scientific Researcher, Leading Researcher

Institute of Engineering Thermophysics of the NAS of Ukraine

Meranova Nataliia

Candidate of Technical Sciences (PhD),

Senior Scientific Researcher, Leading Researcher

Institute of Engineering Thermophysics of the NAS of Ukraine

Shevchuk Svitlana

Candidate of Technical Sciences (PhD), Leading Researcher

Institute of Engineering Thermophysics of the NAS of Ukraine

STUDY OF THE EXERGIC EFFICIENCY OF HEAT RECYCLING SYSTEMS FOR VARIOUS PURPOSE

Summary. *The paper presents the results of a comparative analysis of the exergy efficiency of heat recovery systems for various purposes for boiler plants. To study the exergy efficiency of heat recovery systems, a complex methodology was used based on exergy analysis methods and the application of efficiency assessment criteria. Heat recovery systems for various purposes are presented in the form of block diagrams with identification of exergy flows of coolants. Criteria for assessing exergy efficiency were selected, on the basis of which a comparative analysis of the exergy efficiency of heat recovery systems was carried out. Recommendations have been developed for the use of heat recovery systems for various purposes, taking into account the specifics of their application.*

Key words: *exergy efficiency, heat recovery systems, exergy losses, boiler plants.*

Introduction. Environmental problems and rising fuel costs determine increased interest in the research and implementation of effective heat recovery technologies. The decision on the advisability of implementing a particular recycling scheme should be based on comprehensive research, requiring the use of exergy analysis methods along with modern classical thermodynamic methods. Complex techniques based on the exergy approach make it possible to outline ways to reduce exergy losses in heat recovery systems and thus increase their exergy efficiency. In Ukraine, there is a fairly high potential for the introduction of highly efficient heat recovery technologies, which determines the importance and relevance of research conducted in this area.

Statement of the problem and research method. Methods based on the exergy approach, which are used to study the efficiency of power plants for various purposes, are currently quite common in the world [1-4]. Works [5-10] are devoted to the study of heat recovery systems of power plants using complex techniques that combine exergy analysis methods with other modern research methods: structural-variant methods, methods of thermal conductivity theory, multi-level optimization and others. Ensuring highly efficient operation of heat recovery systems for various purposes determines the relevance of relevant research and the need to expand it. In this work, heat recovery systems for various purposes of a gas-consuming boiler plant with a heating capacity of 2 MW were investigated. For the research, a complex methodology was used, combining structural-variant methods of exergy analysis and criterion-based methods for assessing the exergy efficiency of heat recovery systems.

The goal of the work is to increase the exergy efficiency of heat recovery systems for various purposes.

To achieve the goal, the following tasks must be completed:

- based on the structural-variant method of exergy analysis, develop structural diagrams of heat recovery systems for various purposes with identification of exergy flows between coolants;
- select criteria for assessing the exergy efficiency of heat recovery systems, calculate their values and conduct a comparative analysis of exergy efficiency for heat recovery systems for various purposes;
- develop recommendations for the use of heat recovery systems for various purposes, taking into account the specifics of their application.

Research results. Three variants of heat recovery systems were considered: a heat recovery system designed to heat heating network water, a combined heat recovery system designed to heat heating network water and heating and humidifying blow air, and a combined heat recovery system designed to heat water and blow air. In the first variant, the main element of the system is a condensation-type surface water-heating heat exchanger. In the second variant, a contact-surface water heater, a contact air heater and a water heater are used in the heat recovery scheme. The main elements of the third variant heat recovery system are water-heating and air-heating heat exchangers. Structural diagrams of heat recovery systems for various purposes have been developed with identification of exergy flows of coolants between individual discrete elements of a simple structure (Fig. 1-3). As part of the complex methodology used to study the exergy efficiency of heat recovery systems, criteria for assessing exergy efficiency were selected. This is a thermal exergy efficiency criterion that determines the exergy loss per unit of heat output $\varepsilon = E_{los}/Q$, as well as the exergy efficiency ηex. The results of calculating the energy characteristics are presented in Table 1.

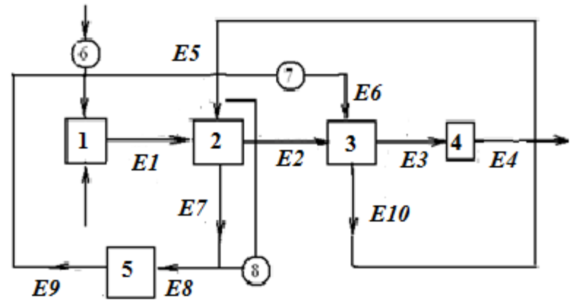

Fig.1. Block diagram of a boiler plant with a heat recovery system for heating heating water: 1 – burner device; 2 – boiler; 3 – water heater; 4 – smoke exhauster; 5 – heat consumer; 6 – fan; 6-8 – pumps; E1 – E4 – flue gases; E5 – E10 – water

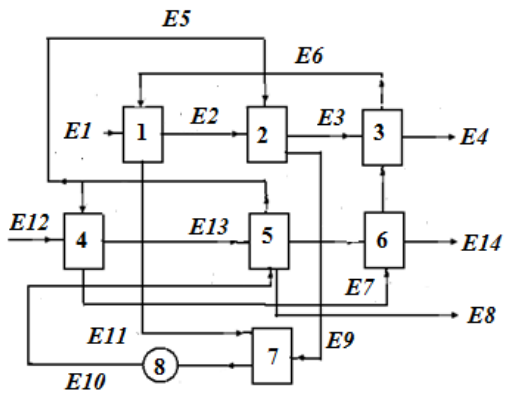

Fig. 2. Block diagram of a combined heat recovery system for heating and humidifying blown air:1 – air heater; 2 – contact heater and air humidifier; 3 – air preheater; 4 – water preheater; 5 – water heater; 6 – gas heater; 7 – water collector; 8 – pump; E1 – E4 – air; E5 – E11 – water; E12 – E14 – flue gases

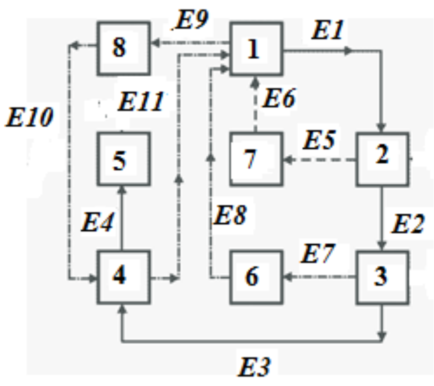

Fig. 3. Block diagram of a combined heat recovery system for heating water and blown air: 1 – boiler; 2.3 – water-heating and air-heating heat exchangers: 4– gas heater; 5 – smoke exhauster; 6 – fan; 7.8 – pumps; E1 – E4 – flue gases; E5, E6, E9 – E11 – water; E7, E8 – air

Table 1

Criteria for assessing the energy efficiency of heat recovery systems for various purposes

Purpose of the heat recovery system	ε	η_{ex} ,%
Heating of heating water	0,563	24,7
Heating of heating water and heating and humidification of blow air	0,221	32,5
Heating of water and blast air	0,154	37,8

For combined heat recovery systems, in which the number of consumers of recovered heat increases, namely, the recovered heat is used not only for heating water, but also for heating and humidifying the blown air, the value of the thermal exergetic efficiency criterion decreases, and the exergy efficiency criterion increases. The greatest exergy losses occur in the hot water heat exchanger, smoke exhauster and pumping system, the smallest - in the air-heating heat exchanger and gas heater. A rational way to reduce overall exergy losses in a heat recovery system is to reduce them in the pumping system and piping system. Such a solution can be provided by aggregating heat recovery systems. Thus, increasing the number of consumers of recovered heat in a heat recovery system and using rational ways to reduce overall exergy losses increases the efficiency of heat recovery systems for various purposes. Such conclusions correlate with the results of a study of the energy efficiency of all heat recovery systems: the thermal efficiency of a boiler installation when using combined heat recovery systems with deep heat recovery increases, on average, by 5%, the coefficient of fuel heat utilization - by 7%. In addition, such heat recovery systems are characterized by increased environmental safety. The choice of the optimal scheme for using recycled heat is determined along with the listed indicators of increasing efficiency, also the need for a certain type of coolant, the cost of fuel, the possibility of using effective heating surfaces, etc.

Conclusions.

1. Based on the structural-variant method of exergy analysis, structural diagrams of heat recovery systems for various purposes have been developed. Exergy flows between coolants have been identified.
2. Criteria for assessing exergy efficiency for heat recovery systems were selected, their values were calculated and a comparative analysis of the exergy efficiency of heat recovery systems for various purposes was carried out.
3. The analysis of heat recovery systems for various purposes was performed, taking into account the peculiarities of their application.

References

1. Zare V., Moalemian A. Parabolic trough solar collectors integrated with a Kalina cycle for high temperature applications. Energy, exergy and economic analyses. *Energy Conversion and Management.* 2017. 151. P. 681-692. doi: 10.1016/j.enconman.2017.09.028.
2. Picallo-Perez A., Sala J. M., Tsatsaronis G., Sayadi S. Advanced Exergy Analysis in the Dynamic Framework for Assessing Building Thermal Systems. *Entropy.* 2019. Vol. 22, No. 1. P. 32. doi: 10.3390/e22010032.
3. Sayadi S., Tsatsaronis G., Morosuk T. Splitting the dynamic exergy destruction within a building energy system in-to endogenous and exogenous parts using measured data from the building automation system.

Int. J. Energy Res. 2020. Vol. 44, No. 6. P. 4395–4410. doi: 10.1002/er.5213.

4. Seyitoglu SS., Dincer I., Kilicarslan A. Energy and exergy analyses of hydrogen production by coal gasification. *International Journal of Hydrogen Energy*. 2017. № 42. P. 2600.
5. Fialko N., Stepanova A., Navrodska R., Meranova N., Sherenkovskii J. Efficiency of the air heater in a heat recovery system at different thermophysical parameters and operational modes of the boiler. *Eastern-European Journal of Enterprise Technologies.* 2018. 6/8 (96). P. 43-48. doi: 10.15587/1729-4061.2018.147526.
6. Stepanova A. Analysis of the application combined heat recovery systems for water heating and blast air of the boiler unit. *Industrial Heat Engineering.* 2016. 38(4). P. 38-46. doi: https://doi.org/10.31472/ihe.4.2016.06.
7. Fialko N., Stepanova A., Navrodska R., Shevchuk S. Comparative analysis of exergetic efficiency of methods of protection of gas exhaust tracks of boiler installations. *Eastern-European Journal of Enterprise Technologies.* 2021. 3/8 (111). P. 42-49. doi: 1015587/1729.4061.2021/234026.
8. Fialko N., Stepanova A., Navrodska R., Gnedash G., Shevchuk S. Complex metods for analysis of efficiency and optimization of heat-recovery system. *Scientific and innovation*. 2021. 17(4). P. 11-18. doi: doi.org/10.15407/scine17.04.011.
9. Fialko N., Stepanova A., Navrodskaya R. Study of the efficiency of a combined heat utilization system using the graph theory methods. *International scientific journal "Internauka".* 2019. № 15(1). P. 61-63.
10. Fialko N., Stepanova A., Navrodskaya R., Presich G. Localization of exergy losses in the air heater of the heat-recovery system under different boiler operating modes. *International scientific journal "Internauka".* 2019. №12 (74). P. 30-33.