Assessment of the possibility of using heat-insulating and energy-saving equipment

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Abstract. The article deals with the problem of energy saving in the context of comparing contact heat exchangers. The advantages and disadvantages of various schemes are analyzed. It is proposed to use economizers of contact heat exchangers with active packing (HEAP) in boiler units of boiler houses. An analysis of the operation of one of the types of HEAP is given. The advantages of using HEAP with a two-circuit apparatus with a nozzle are considered. The main utilization plants and their parameters are described. Examples of the creation of designs for double-shell contact heat exchangers for the utilization of low-potential internal (side) energy resources (IER) are given. For branches of the chemical industry, a scheme of a scrubber-salt system using an intermediate heat carrier is proposed. The effective use of these devices for heating and humidifying air in ventilation and air conditioning systems is noted. The pros and cons of contact heat exchangers are considered in the framework of increasing the efficiency and environmental friendliness of the schemes. The ways of further increasing the efficiency of HEAP are consid

1 Introduction

Today, humanity is facing many challenges, among which one of the most acute is the global crisis. As the world faces the far-reaching effects of economic shocks, environmental degradation and the ever-looming specter of climate change, finding sustainable solutions has become paramount. Among the many ways to solve these problems, the most promising one stands out - the introduction of heat-insulating and energy-saving equipment in various industries. Researchers and developers of innovative technologies are working on the problems of heat recovery [1-4, 6], heat recovery [5, 7-8, 10], assessment of the potential use of thermal energy [9].

As energy demand rises and environmental concerns worsen, striking the delicate balance between economic growth and environmental conservation is more important than ever. Traditional energy-intensive practices are damaging the environment, exacerbating the global crisis and deepening its impact. However, rapid technological advances offer a glimmer of hope, paving the way for innovative solutions that can make a significant contribution to sustainable development.

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In this article, we will look at the potential of using heat-insulating and energy-saving equipment as a means of combating the global crisis. We will look at how such technologies can serve as critical tools to reduce emissions, reduce energy consumption, and improve social stability. Moreover, we will analyze the economic feasibility of using advanced systems.

Energy efficient technologies can have a positive impact on industries and industries around the world. From residential buildings to industrial complexes, from developing countries to advanced economies, these innovations have the potential to bring positive change on a global scale.

Ultimately, this assessment is aimed at taking active steps to address issues of resource efficiency and respect for the environment as the most important conditions for energy conservation.

2 Materials and methods

The previous article [11] discussed equipment that can effectively use high-potential waste heat. It was found that the simplest version of such equipment is a recuperative two-way heat exchanger consisting of bimetallic tubes. At the same time, the decrease in the temperature of gases below the dew point.

Even more efficient use of the latent heat of the phase transition is provided by contact economizers, which are used in hot water supply, air heating and the use of make-up water.

Along with the advantages of the two-circuit contact economizer circuit, its disadvantages were noted. One of them is the limited life of the heat exchanger due to the presence of CO_2 and O_2 in the water circuit. The solution to this problem requires the use of acid-resistant pumps and plastic pipes. Therefore, studies of contact heat exchangers are relevant to find the optimal solution.

Another type refers to contact heat exchangers with active packing (HEAP). They are installed in boiler houses built according to a standard design, usually behind the boilers. The generalized characteristics of HEAP are presented in Table 1.

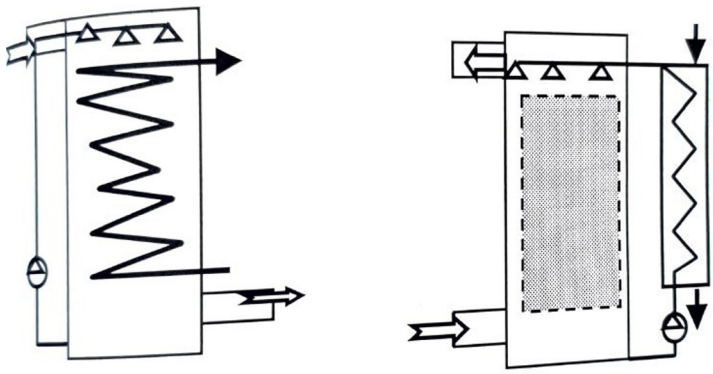
Table 1. Characteristics of HEAP.

Name	Power range, MW	Flue gas flow	Flue gas inlet temperature, °C	Weight, kg
HEAP	0.05-12.0	0.13-35.9	140-250	100 -12500

In HEAP (Figure1a), flue gases enter through the upper branch pipe and transfer heat to water, which irrigates the heating surfaces. After cooling, the gases are removed through the lower pipe. Cold water from the water supply comes from below and passes through the internal recuperative heat exchanger (tubular nozzle). The tubular nozzle is irrigated from the sprinkler with circulating water from the contact circuit. The heated water is removed through the external pipe.

HEAP can operate at a flue gas velocity of up to 8 - 10 m/s, due to which the dimensions are reduced and heat transfer is intensified. The disadvantage is the difficulty of revision and repair, stainless steel nozzle is more expensive than ceramic. The once-through circuit limits the temperature of the water heating.

If we compare the design of HEAP with a two-circuit apparatus with a passive nozzle (Figure 1b), then it should be noted that the latter has a counterflow scheme with water heating for heat supply in a remote heat exchanger of a recuperative type. As a result, the fuel heat utilization factor (FHU) in the economizer with a ceramic nozzle is noticeably higher (0.7) than in HEAP (0.5).



a b

Fig. 1. Contact utilizers. a - without a nozzle, b - with a nozzle.

In addition to the packed type, there are other chamber designs for a contact heat exchanger (cascade-disk, packed, nozzle, foam type, as well as airlift (bubble) type). The latter are recommended for low unit power and low temperature (up to 60ºC).

However, the use of contact economizers is limited due to the insufficient thermal power of consumers of water with a temperature of 50-55º C. In practice, greenhouses can be an unlimited consumer of low-grade heat, since a subsoil heating system needs water with a temperature of 40º C, and for irrigation − 20-22º C. If high corrosion protection of the gas duct is provided, then it is possible to refuse drying of the exhaust gases, and the condensate formed in the pipe is discharged into a waste tank and, after degassing (removal of CO_2 and O_2) and neutralization of the acid, is sent to feed the heating system of greenhouses, which allows for 10 - 15% reduction in chemical water treatment.

The use of contact economizers increases the efficiency of cast iron boilers by 15-18%. With real fuel costs, the payback period is 2 years.

Known designs of double-shell contact heat exchangers for the utilization of low-grade IER. For the chemical industry, a scrubber-salt system is proposed that uses an intermediate heat carrier - an aqueous solution of calcium chloride with a boiling point of 140°C (Figure 2).

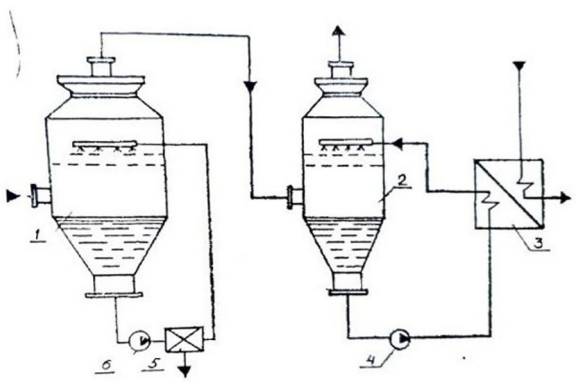


Fig. 2. Schematic diagram of the heat removal of low-temperature gases with an intermediate heat carrier: 1 - scrubber-washer, 2 - scrubber-cooler, 3 - heat exchanger, 4, 6 - pumps, 5 - filter.

First, the gas is washed with a coolant without heat removal in the first scrubber, then it is cooled in the second scrubber with the same coolant. The heated heat carrier transfers

heat to the feed water entering the thermal demineralization plant. Such devices are used for heating and humidifying air in ventilation and air conditioning systems.

Technical indicators of contact heat exchangers for steam and hot water boilers are given in Table 2.

Table 2. Generalized characteristics of double-circuit heat exchangers for different types of boilers.

Indicators	Boiler type	
	Steam	**Hot water**
Thermal performance of the heat exchanger, MW	2.63	6.50
Heat exchange surface, m^2	101.5	124.1
Heated water consumption, m^3/h	51	185
Temperature of heated water, ºC		
Initial	10	10
ultimate	50	40
Flue gas temperature, ºC		
At the entrance	120	210
At the exit	40	50
Aerodynamic drag, Pa	780	1150

3 Results and Discussion

The joint efforts of design organizations made it possible to develop contact economizers for power boilers, which make it possible to increase the efficiency of thermal power plants by 8–12%. In these schemes, in addition to hot water for own needs, heat is recovered through heating the combustion air by 7-10°C.

Aqueous solutions of lithium chloride, lithium bromide, and calcium chloride were tested as primary coolants. They can be heated to 100°C or more. However, a little more than 10% of the entire IER resource can be used for air heating. For the rest of the waste energy, we have to look for other consumers.

The advantage of contact heat exchangers is that the water of the primary circuit cleans the flue gases from impurities. This reduces harmful emissions into the atmosphere. Primary water additives such as soda or lime can suppress emissions of up to 80% sulfur dioxide and 30% nitrogen oxides.

The spread of contact heat exchangers in the large energy sector is constrained by the fact that the deep (up to 40 °C) cooling of flue gases worsens their dispersion in the atmosphere, which aggravates the environmental situation around the plant. In addition, the flue gas cooling process cannot be brought to complete condensation of moisture. If the combustion products behind the contact heat exchanger have a humidity of 100%, then it will condense in the flue. To avoid condensation, the flue gas has to be dried by passing part of the hot gas (up to 15%) through the bypass flue, bypassing the contact economizer, and in the real case, the increase in efficiency due to heat utilization will be not 15, but 10% of the boiler's thermal capacity. Helps to increase the efficiency of the boiler room | drying of combustion products with relatively dry air from the upper zone of the boiler room. Another important direction of using HEAP may be schemes with cooling of return water in the heat supply network using lithium bromide refrigerating machines or heat pumps at the heat consumer up to 10 -15 °C.

4 Conclusion

Thus, along with the scheme of a two-circuit contact economizer widely used in industry, steel be used in boiler rooms with contact heat exchangers with a passive nozzle. The

efficiency of the latter by the coefficient the use of heat is 40% higher compared to the conventional design of the heat exchanger. The design of the contact chambers heat exchangers can differ markedly in the nozzles used. Since the use of these economizers with limited by the insufficient thermal power of consumers of water with a temperature of 50-55 °C, in this case, greenhouses are an unlimited consumer of low-grade heat. In subsequent work, it is planned to consider equipment for the utilization of low-grade waste heat. It should be noted that these solutions will help to preserve sustainable development and the natural environment in the era of the global crisis.

Acknowledgement

This study is conducted in order to conduct a qualitative analysis of energy saving and adaptation of the developed methods and devices for a specific city, district and region and to attract additional funds.

References

1. J. Antonio Gutiérrez Trashorras, Eduardo Álvarez Álvarez, José Luis Río González, José Manuel Suarez Cuesta, Jorge Xiberta Bernat Design and Valuation n of a heat recuperator for steel slags. Applied Thermal Engineering, **56**, **1–2**, 11-17 (2013)
2. Hui Zhang, Hong Wang, Xun Zhu, Yong-Jun Qiu, Kai Li, Rong Chen, Qiang Liao A review of waste heat recovery technologies towards molten slag in steel industry, Applied Energy, **112**, 956-966 (2013)
3. J.-A. Mumith, C. Makatsoris, T. Karayiannis, Design of a thermoacoustic heat engine for low temperature waste heat recovery in food manufacturing: a thermoacoustic device for heat recovery, Appl. Thermal Eng., **65**, **1–2**, 588–596 (2014)
4. D.M. van de Bor, C.A. Infante Ferreira, Anton A. Kiss Low grade waste heat recovery using heat pumps and power cycles, Energy, **89**, 864-873 (2015)
5. Sarah Brückner, Selina Liu, Laia Miró, Michael Radspieler, Luisa F. Cabeza, Eberhard Lävemann Industrial waste heat recovery technologies: An economic analysis of heat transformation technologies *Applied Energy*, Volume **151**, 157-167 (2015)
6. B. Delpech, B. Axcell, H. Jouhara, *A review on waste heat recovery from exhaust in the ceramics industry*, Int. Conf. on Advances in Energy, Systems and Environmental Engineering (ASEE17), **22** (2017)
7. S. Mukherjee, A. Asthana, M. Howarth, R. Mcniell, Waste heat recovery from industrial baking ovens, Energy Procedia, **123**, 321–328 (2017)
8. Yiyu Men, Xiaohua Liu, Tao Zhang, A review of boiler waste heat recovery technologies in the medium-low temperature range, Energy, **237**, 121560 (2021)
9. L. Theisinger, T. Kohne, M. Weigold, Modeling approach and simulation study to assess the utilization potential of industrial waste heat in district heating systems, Procedia CIRP, **105**, 339-344 (2022)
10. M. Manente, Y. Ding, A. Sciacovelli, A structured procedure for the selection of thermal energy storage options for utilization and conversion of industrial waste heat, J. of Energy Storage, **51**, 104411 (2022)
11. I.A. Guschin, *Improving the efficiency of energy saving through the use of thermal energy*, IOP Conf. Ser.: Earth Environ. Sci., **1212**, 012003 (2023)