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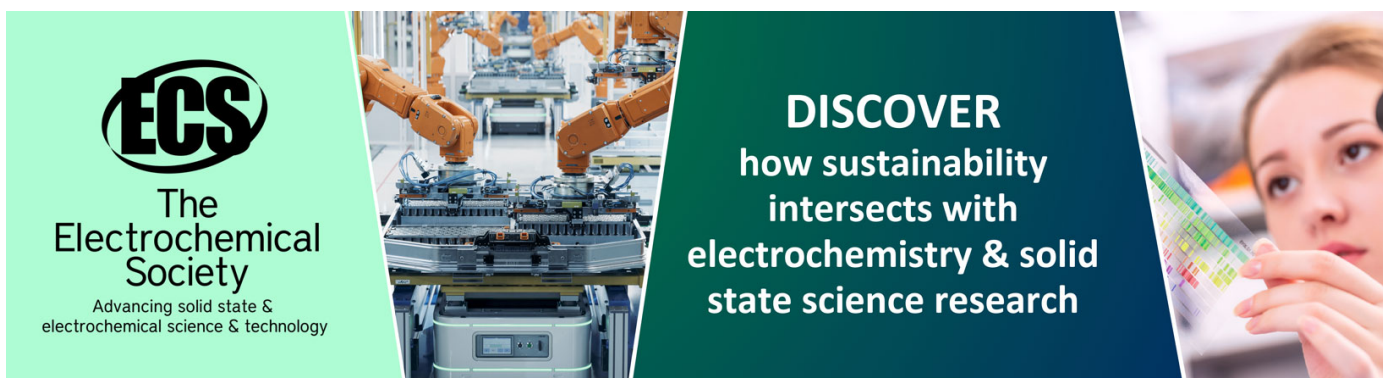
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To cite this article: V S Ezhov *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **789** 012020

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Development of experimental designs of the integrated heater for the disposal of low-potential waste heat of ventilation emissions

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Abstract. The aim of the study is to develop an experimental design of a complex air heater, conduct and analysis of the experiments, as well as to determine the main characteristics of the thermo-electric generator during the utilization of low-potential heat-La exhaust gases. The experimental setup consists of two units – thermoelectric generator operating on the principle of cross-heat exchanger heat exchange for heat recovery with parallel warmed of the supply air, which is supplied in the form of a mixture in the burner boiler unit and adsorber unit, filled blast furnace slag for the purification of waste gases from nitrogen oxides, c and carbon.

1. Introduction

The actual problem of development of fuel and energy and housing and communal complexes of the Russian Federation is the problem of energy saving and environmental safety. The solution of these problems will ensure a steady increase in the efficiency of heat generation and distribution from the source to the final consumer. Closely related to this is the economic growth of the country, the improvement of the environmental situation and the safety of the population [1].

One of the main directions of increasing the efficiency of heat-generating plants is the use of devices and sets of equipment to reduce the heat content and temperature of smoke gases, reduce emissions of flue gases and, as a consequence, increase environmental safety adjacent to the boiler area. To achieve these goals, the paper proposes to use the effect of thermoelectricity, which provides Autonomous power supply of anticorrosive equipment and intensification of the process of adsorption of harmful components by granular blast-furnace slag in a complex air heater [2].

Application in boiler equipment [3] of deep heat recovery or installations of use of latent heat of vaporization of the leaving flue gases (for example, contact heat exchangers, air heaters) increases the General efficiency of a boiler room by 1-3%.

Air heaters [4] make it possible to utilize heat emissions from boilers by contact of flue gases and blast air supplied from the upper zone of the boiler (air heaters of various types increase fuel economy by 1-4%) [5].

For the implementation of increasing the degree of heat recovery the resection of the gases used, the effect of thermoelectricity is a phenomenon of direct conversion of heat into electricity in conductors by direct heating and cooling of junctions of two conductors passing current. In the first approxi-



mation, the appearance of thermo-pods depends only on the material of conductors and the temperatures of hot and cold junctions [6].

For this purpose, the Department of Heat, gas and water Supply of the SWSU developed several innovation structures of air heaters [7-10], the main scientific novelty of which is the utilization of low-potential heat of exhaust gases with temperature up to 150°C and direct generation of electricity due to the effect of thermoelectricity.

2. Research methods

Air taken by the heater from the laboratory room was used as a working medium. Tests on heat exchange at counterflow in the thermal-electric section were carried out for a number of fixed speeds and air consumption at the experimental unit [10].

A fragment of a thermoelectric generator of an autonomous air heater with an indication of the main structural dimensions on figure 1 [10]. The red arrows indicate the flow of hot air from the air heater located on the left side. Blue circles indicate the flow of cold air from the axial fan located at the bottom. In this case, the flow direction is from bottom to top. (to the observer).

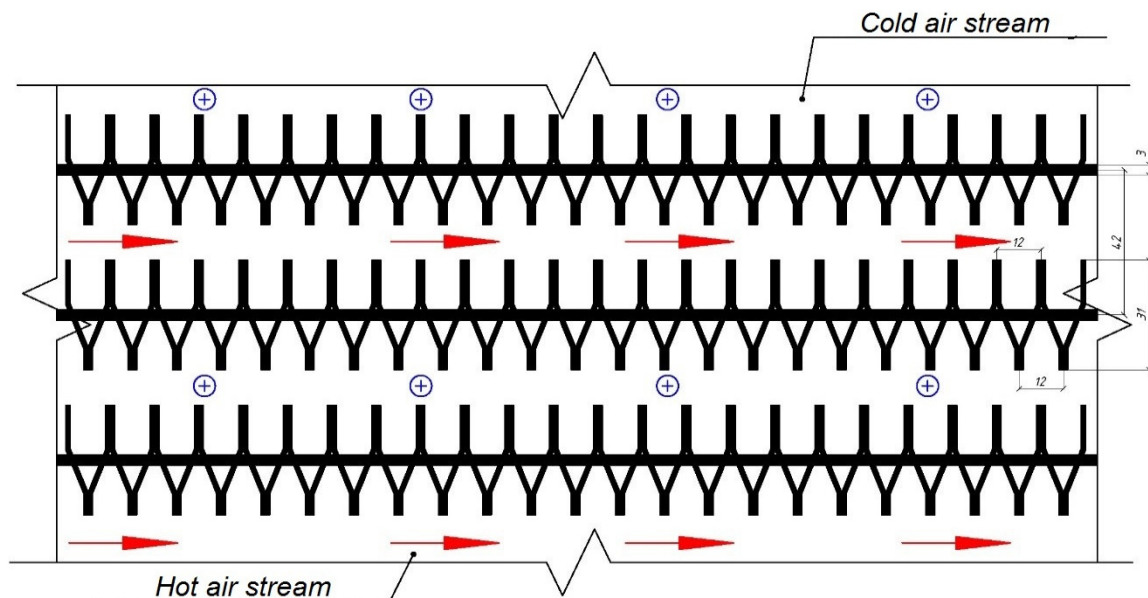


Figure 1. – Fragment of a thermoelectric generator.

The main characteristics of thermionic elements made of chrome (M1) and copper (M2) are: coefficient of thermo-EMF $\alpha = 12.97 \cdot 10^{-3}$ V/K; q -factor $= 2.8 \cdot 10^{-3}$ K⁻¹ and conductivity $\sigma = 8 \cdot 10^4$ Ohm⁻¹·m⁻¹ [8].

The flow temperature was determined as the arithmetic mean value of mercury thermometer readings at the points of entry and exit from the channels of thermoelectric sections [9].

The average air velocity in the channels of thermoelectric sections was determined by the expression:

$$\bar{\omega} = c_h \cdot \omega_{\text{анем}} \quad (1)$$

c_h is the coefficient of flow unevenness

The total heat perception of the air flow was determined from the heat balance equation, [12]:

$$Q' = \bar{\gamma}_g \cdot \bar{G}_{\text{кан}} \cdot (t'_{\text{вх}} - t'_{\text{вх}}) \cdot 10^3 \quad (2)$$

where $\bar{\gamma}_{in} = c_{in} \cdot \rho_{in}$; c_{in} , ρ_{in} – heat capacity and density of the air flow at its average temperature, kJ/(kg° C), kg/m³; \bar{G}_{chn} – air flow rate in the channel, $\bar{G}_{chn} = \bar{\omega} \cdot F_{chn}$, m³/h; t'_{in}, t'_{ext} – air temperature at the inlet and outlet of the channel of the heat exchange element, for the passage of the heated air, °C; F_{chn} – the cross-sectional area of the channel, determined from the geometric dimensions of the channel, m.

A general view of the experimental setup on figure 2.



Figure 2. Scheme of the experimental setup. 1 – housing; 2 – pipe for the inlet of the heating medium; 3 – construction Hairdryer; 4 – axial fan; 5 – stand for the fan; 6 – LEDs.

To determine the heat transfer coefficient, the method of stationary heat flow was used, in which Newton-Richman law is used [12]:

$$dQ' = \alpha_{F_{cm}} (t'_{s.cm} - t') dF_{cm}, ^\circ\text{C}; \quad (3)$$

where $t'_{in.sd}$, t' – the temperature of the heat-emitting surface and the air, respectively, °C; F_{sd} – the area of the heat-emitting surface, m².

In that case, if all the values included in equation (3) are related to small elements of the body surface, the average coefficient of heat transfer from the heat-emitting surface was determined for each individual experiment, respectively, from the expression [11]:

$$\bar{\alpha}' = \frac{\frac{1}{L} \int_0^L q(x) dx}{\frac{1}{L} \int_0^L (t'_{s.cm} - t') dx} = \frac{Q'}{F_{cm} (\bar{t}'_{s.cm} - \bar{t}')} , \text{BT}/(\text{m}^2 \cdot ^\circ\text{C}); \quad (4)$$

F_{sd} – the calculated heat transfer surface of the heat exchange surface, m²; \bar{t}' – the average temperature of the heated air flow in the channel, determined from the ratio, °C:

$$\bar{t}' = \frac{t'_{ex} + t'_{in}}{2}, ^\circ\text{C} \quad (5)$$

where $\bar{t}_{in.sd}$ - the average temperature of the heat exchange surface from the heated air flow, determined by the formula (6), °C:

$$\bar{t}'_{e.cm} = \bar{t}_{cm} - \frac{Q'}{\frac{\lambda_{cm}}{\delta_{cm}}}, ^\circ\text{C} \quad (6)$$

where δ_{sd} - the thickness of the heat transfer surface 2 mm; λ_{sd} - the coefficient of thermal conductivity of the material of the heat transfer surface of heating, W/(m·°C); \bar{t}_{sd} - the average wall temperature determined by the formula (7), °C:

$$\bar{t}_{cm} = \frac{\bar{t}' + \bar{t}''}{2}, ^\circ\text{C} \quad (7)$$

where \bar{t}'' - the average temperature of the heating air in the channel, determined by (8) similarly (5), °C.

$$\bar{t}'' = \frac{t''_{ex} + t''_{oblx}}{2}, ^\circ\text{C}; \quad (8)$$

where t''_{in}, t''_{ext} - the air temperature at the inlet and outlet of the channel of the heat exchange element, for the passage of the heating air, °C.

The average value of the coefficient [11] of heat transfer for each experiment was determined from the following ratio:

$$\bar{k} = \frac{Q'}{F_{cm} \cdot \Delta \bar{t}}, \text{Bt}/(\text{m}^2 \cdot ^\circ\text{C}); \quad (9)$$

where $\Delta \bar{t}$ - the average temperature head (°C), determined at $\frac{\Delta t_{\delta}}{\Delta t_{\mathcal{M}}} \leq 1,7$, with sufficient accuracy, as the arithmetic mean temperature difference according to the formula:

$$\Delta \bar{t} = \frac{\Delta t_{\delta} + \Delta t_{\mathcal{M}}}{2}, ^\circ\text{C}; \quad (10)$$

where $\Delta t_{\delta}, \Delta t_{\mathcal{M}}$ - the temperature difference between the media at the other end of the heating surface, respectively, °C

$$\Delta t_{\delta} = t''_{ex} - t'_{oblx}, ^\circ\text{C}; \quad (11)$$

$$\Delta t_{\mathcal{M}} = t''_{oblx} - t'_{ex}, ^\circ\text{C}. \quad (12)$$

The amount of heat received from the heating air was determined for each experiment as,

$$Q'' = \bar{\gamma}_{\delta} \cdot \bar{V}_{kan} \cdot (t''_{ex} - t''_{oblx}) \cdot 10^3, \text{Bt}. \quad (13)$$

The average heat transfer coefficient [11] from the heating air flow to the heat transfer surface was also determined for each individual experiment, respectively, from the expression:

$$\bar{\alpha}'' = \frac{Q''}{F_{cm} \cdot (\bar{t}'' - \bar{t}'_{e.cm})}, \text{Bt}/(\text{m}^2 \cdot ^\circ\text{C}); \quad (14)$$

F_{sd} - the calculated heat transfer surface of the heat exchange surface (wall); $F_{sd} = 0.049 \text{ m}^2$; \bar{t}'' - the average temperature of the heated air flow in the channel, °C; $\bar{t}_{in.sd}''$ - the average temperature of the heat exchange surface from the heated air flow, determined by the formula (15), °C:

$$\bar{t}_{e.cm}'' = \frac{Q''}{\frac{\lambda_{cm}}{\delta_{cm}}} + \bar{t}_{cm}, \text{ °C}; \quad (15)$$

where \bar{t}_{sd} - the average wall temperature, °C.

The average value of the heat transfer coefficient [12] for each experiment was determined from the following ratio

$$\bar{k} = \frac{1}{\frac{1}{\bar{\alpha}'} + \frac{\delta_{cm}}{\lambda_{cm}} + \frac{1}{\bar{\alpha}''}}, \text{ Bt/(m}^2 \cdot \text{°C)}. \quad (16)$$

Table 1 shows the results of experimental studies followed by the determination of the main characteristics of the thermoelectric generator.

Table 1. Results of experimental studies.

Name of the measured value	Designation	Dimension	The number of the series of experiments		
			1	2	3
The temperature of the heated air at the inlet to the channel	t'_{ex}	°C	25.4	25.4	25.4
Temperature of heated air at the outlet of the channel	t'_{ebx}	°C	27.7	28.1	29.2
Heating air temperature at the inlet of the channel	t''_{ex}	°C	81.7	150.4	178.7
Heating air temperature at the outlet of the channel	t''_{ebx}	°C	42.8	55.1	63.8
Air velocity in the channel for the passage of heated air	$\bar{\omega}_{ha2}$	m/s	5.1	5.1	5.1
Air velocity in the channel for the passage of heating air	$\bar{\omega}_{ep}$	m/s	1.1	1.1	1.1
Average temperature of heated air	\bar{t}'	°C	26.6	26.8	27.3
Thermal perception of heated air flow in one channel	Q'	W	552	660	990
The heat transfer coefficient from the wall of the channel to heated air	$\bar{\alpha}'$	W/(m ² ·K)	104.3	58.5	72.8
Voltage in an electrical circuit	V	V	1.14	2.02	2.26
Amperage	I	A	0.356	0.631	0.728
Power	N	W	0.406	1.275	1.645

Figure 3 graphically shows the dependence of the generated electric power on the heat flux perceived from hot air by thermoelectric sections in an autonomous air heater.

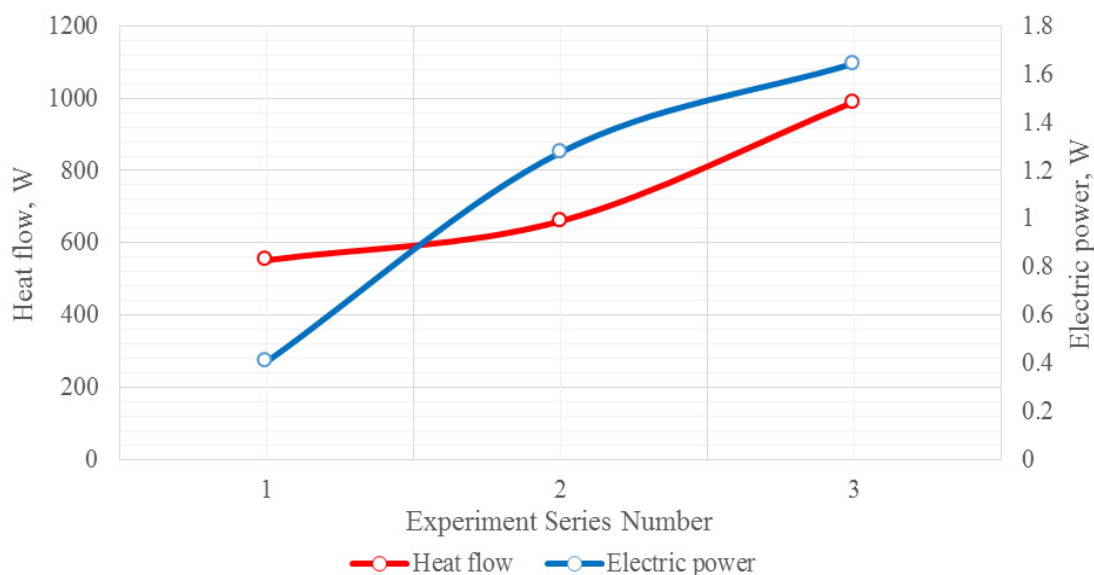


Figure 3. Schedule of dependence of generated electric power on heat flow in thermoelectric generator.

3. Conclusions

The main conclusions of this article are:

- an experimental design of the air heater is developed, which has a thermoelectric EMF source operating as a result of the passing conversion of heat into electricity, which allows to utilize the low-grade heat of the exhaust gases from 140°C to 60°C;
- experimental studies to determine the basic parameters of the thermoelectric generator at cross-heat exchange between the exhaust gases and cold air at the laboratory installation for heat recovery of the exhaust gas;
- as a result of cross-heat exchange, the discharge gas temperature at the outlet of the complex air heater is reduced by 40-60%, while an increase in the efficiency of the boiler unit by 1-1.5% is recorded as a result of an increase in the supply air temperature in the boiler burner device from 20°C to 55°C.

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