Evaluation of the use of thermoelectric generators in rooms with excessive heat release

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Abstract. The purpose of the work was to evaluate new methods and new technology for the manufacture of thermoelectric modules for use in rooms with excessive heat release. Investigation of heat release parameters for the possibility of converting them into electrical energy. A new design of the thermoelectric module with a new topological pattern is applied. The research of the parameters of new thermoelectric modules is carried out using the developed installation, with the help of which it was found that the efficiency of the new design is 16.5% higher than that of classical thermoelectric modules. At the same time, it was found that the cost of the new design is 8 times less than that of classical thermoelectric modules. The heat release of the equipment of the operating boiler house, located in the city of Irkutsk, was studied. In the course of research, it was revealed that the technological equipment intended for servicing four fuel oil boilers of the «DE 16-14 GM» type emits heat energy of about 100 kW, which can be converted into electrical energy with an efficiency of more than 30%. The studies have shown that there are innovative technologies, using which it is possible to convert heat losses in buildings with excessive heat release into electrical energy, thereby increasing the efficiency of the equipment used.

1. Introduction
Premises with excessive heat generation in various industries, in the field of consumer services, in the field of housing and communal services are not uncommon. The high temperature in the premises quickly tires the body, also leads to overheating of the body and can provoke heatstroke, occupational diseases.

At the moment, there are two main methods of dealing with excess thermal energy in rooms: ventilation and air conditioning.

For the efficiency of these systems, various recuperation systems are used, one of the promising recuperation units are units operating on the principle of a heat pump.

In recent years, actively began to take root heat pumps on the basis of thermoelectric modules [1-3]. With the help of thermoelectric modules, installations are created for converting thermal energy into electrical energy. This method worked well in the car structure. These generating devices produce a constant voltage that is consistent with the supply voltage of the vehicle without complex conversion devices [4-7].

With large temperature gradients, these devices have proven themselves well not only in the field of car construction. In the patent for the invention, scientists from the State Educational Institution of Higher Professional Education "Ufa State Aviation Technical University" A.F. Alloyarov and I.Kh. Badamshin offered an installation for converting low-grade heat into electrical energy using a heat pump
and thermoelectric generator. Using their installation, installed in a gas turbine station GTE 10-95 with an efficiency of 83%, having a useful electrical power of 10 MW and generating thermal energy of 15 MW, it becomes possible to increase the efficiency by 6%, while generating an additional 0.5 MW of electrical energy and 1.49 MW - thermal energy. [8].

The spread of technology of thermoelectric energy conversion is limited mainly by three factors [9-10]:
- **Design.** In this case, the efficiency of the thermoelectric modules decreases, because the sides of the module have a small distance between themselves.
- **Complex technological cycle.** The complexity of manufacturing thermoelectric modules increases their cost.
- **Limited space.** The electronics industry is the main buyer of thermoelectric module. For the electronics industry, the thermoelectric module should be as small as possible.

### 2. Methods

To expand the range of applications for devices with thermoelectric modules, we use a new method and new technology [11, 12] for the manufacture of thermoelectric modules. This method allows the manufacture of thermoelectric modules of various geometric configurations, directly adapting them to any life support system. In Fig.1 shows topological drawings and experimental samples of thermoelectric modules.

![Figure 1. Topological drawings and samples of thermoelectric modules](image)

**Figure 1.** Topological drawings and samples of thermoelectric modules
a - when the sources of heat and cold are large and at the same distance; b – when the overall dimensions of the heat and cold source have different dimensions; c – for use in systems where heat and / or cold sources are transported through pipelines.

To research the parameters of thermoelectric modules, the stand shown in Fig.2.
Figure 2. Stand for research of parameters of thermoelectric modules.

Description of the stand: The investigated thermoelectric module (1) is placed on the table (2) with heating, a radiator from a personal computer with water cooling is installed on the thermoelectric module (3). The temperature on the sides of the thermoelectric module is controlled by the TRM-2 thermostat using a solid-state relay (5) and an electromagnetic valve (6). The magnitude of the thermo-electromotive force under load, which is set by the resistance bridge (7), is fixed by the device of the "OVEN" company, brand IMS-F1(8), while monitoring the voltage value, current consumption and power. Temperature control of thermoelectric elements, hot and cold sides of the thermoelectric module, as well as sources of "heat" and "cold" is carried out by thermocouples (9), the data is recorded by the TPM138 meter-regulator. Data from all devices through the interface (11) are sent to a personal computer (12).

Studies at this stand have shown that the new method increases the efficiency of thermoelectric systems by an average of 16.5%, while reducing its cost by 8 times [13-14].

3. Results and its discussion

As an experiment, we carried out a survey of a boiler house in the Zeleny district of Irkutsk. Table 1 shows the technical readings of the boiler room.

| № | The name of indicators | Units | Value |
|---|------------------------|-------|-------|
| (a) | Specified power | MW | 91,3 |
| | | Gcal / h | 78,7 |
| | | MW | |
| (b) | Maximum calculated connected load | Gcal / h | 34,8 |
| | | MW | 30,0 |
| | | thousand MW. | |
| (c) | Annual heat production: | thousand Gcal / year | 62,450 |
| | | thousand MW. | 53,836 |
| (d) | Annual heat supply: | thousand Gcal / year | 60,068 |
| | | thousand MW. | 51,783 |
| (e) | Average annual specific fuel consumption for the production of 1 Gigacalories of released heat | kg.e.f. (equivalent fuel) | 205,1 |
This boiler house has 4 fuel oil boilers of the DE 16-14 HM type, and 7 units of heat exchange equipment such as Steam Heater 1-53-7-4 and 14 units of Water-Water Heater-14-273-4, this equipment is intended for for heating network water in the heating system and hot water supply.

Calculation of excess heat release from process equipment in a boiler room:

Heat transfer to premises due to solar radiation through glazed surfaces:

\[ Q_{r,oct} = F_{oct} \cdot q_{oct} \cdot A_{oct} \cdot K_s, \text{ Вт} \]

where \( A_{oct} \) – coefficient for double glazing with twin sashes is 1.15;
\( F_{oct}, F_p \) - glazing and coating surface area in \( \text{м}^2 \);
\( q_{oct}, q_p \) – heat flux entering through 1 m of the glazing surface (depending on the cardinal direction of the glazed surface and the latitude of the settlement) and coating, \( \text{W} / \text{м}^2 \);
\( K_s \) – glazing shading coefficient (\( K_s = 0.8 \)).

The heat input from the electric motors of mechanical equipment and the machines driven by them, installed in the common room, is determined by the formula:

\[ Q_{общ} = N_y \cdot k_{cn} \cdot (1 - k_n \cdot \eta + k_r \cdot k_n \cdot \eta) \cdot 10^3, \text{ Вт} \]

\( Q_{total} \approx 830 \text{ W}. \)

where \( k_{cp} \) – the coefficient of demand for electricity, taken from the table (\( k_{cp} = 0.4 \));
\( k_{cof} \) – factor taking into account the completeness of the load (\( k_p = 1 \));
\( k_t \) – indoor heat transfer coefficient (\( k_t = 1 \));
\( \eta \) – efficiency of the electric motor at full load;
\( N_i \)– installed (nominal) power of electric motors or rectifiers, kW.

Heat dissipation from all operating pumps is on average \( Q_{total} \approx 13.8 \text{ кВт}. \)

The heat input from steam heaters PP1-53-7-4 and water heaters WWH-14-273x4000 installed in the common room is found using the formula:

\[ Q = 1.3 \cdot n \cdot F_s \cdot (t_{sur}-t_a) \cdot 4/3 \]

\[ Q = 1.3 \cdot 1.625 \cdot 9.5 \cdot (55-21)^{4/3} = 2297.62 \text{ Br} \]

where \( n \) - coefficient, which depends on the surface temperature, at 55°C \( n = 1.625 \).
\( F_s \) - surface area, \( \text{м}^2 \);
\( T_a \) - indoor air temperature;
\( T_{sur} \) – surface temperature

Heat dissipation from all operating steam heaters PP1-53-7-4 and water heaters WWH-14-273x4000 average \( Q_{pp} \approx 20.68 \text{ kW}. \)

Heat dissipation from deaerators №1,2,3 DA 100/25:

\[ Q_d = 1.3 \cdot 1.773 \cdot 62.8 \cdot (60-21)^{4/3} = 59.4 \text{ kW} \]
In addition to heat losses that are present in the boiler house due to the technological process and which are discharged into the environment with waste gases, we have heat losses from the technological equipment itself. The value of heat losses from the technological equipment that ensures the operation of the boilers is \( Q \approx 100 \) kW. These heat losses are carried out in the low temperature range. Currently, there are no cheap technologies that could effectively convert heat loss into useful work [15]. Using a new method and new technology, we are able to convert these heat losses into electrical energy with an efficiency of over 30%.

4. Conclusions

Research of the magnitude of heat losses in the building of a boiler house and analysis of available methods for converting heat losses using thermoelectric modules have shown that the use of new technologies and new methods can reduce heat losses. The introduction of new innovative solutions will help to increase the efficiency of using technological equipment in rooms with excessive heat generation. Analyzing the data of the research carried out, it is clear that using the latest developments in the field of thermoelectric energy, we have the opportunity to obtain additional energy resources in the form of electrical energy.

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