Results of development of an experimental heat exchanger

V A Ershov, T I Zimina, A S Govorkov, N A Ivanov and N N Ivanov
Irkutsk National Research Technical University, 83 Lermontov street, Irkutsk, 664074, Russia
E-mail: ziminati@istu.edu

Abstract. For stable technology of electrolysis with an increase of current, it requires efficient heat removal from elements of construction, including from the waste process gases. Reasonability of cooling the electrolytic gases before cleaning is due to the desire to reduce physical volume of cleaned gases, that, in turn, reduces the operation expenditures of gas cleaning units. The article describes feasibility of waste gases cooling in the production of aluminium with the help of the electrolytic method.

1. Introduction
It is known that in the production of aluminum with anodic gases, removed into the system of gas cleaning units (GCU), up to 3% of heat is carried away from electrolysers with a self-baking anode, and from electrolysers with calcined anodes - 12.5% [1, 2]. At the same time, volume of the dust-gas-air mixture withdrawn from the electrolyser with the self-baking anode is on the average 600 ÷ 1000 m3/h, and with the calcined anodes - 7000 ÷ 14000 m3/h [3].

One of the most effective solutions for utilizing heat from gases is the use of heat exchangers [4, 5, 6]. This method has its draw-backs, because it requires maintenance due to the tendency of the tubular to clog, and it requires additional equipment (water pipe, heat exchange circuit, measuring equipment, etc.).

2. Development of the thermoelectric converter
The advantage of this technology is the recovery of heat energy, which allows to achieve greater energy efficiency of production thanks to: heating water for production needs; for heating, power generation, preheating of alumina or calcined anodes [7]. Ultimately, efficiency of the use of heat exchangers should be assessed from the standpoint of capital and operating expenditures[8, 9].

According to the design, heat exchangers are of different types, and shell-and-tube design is much more compact and efficient in terms of heat transfer and less expensive to be constructed (there is no need for a rigid body due to water pressure). Using the method of mathematical modeling and with the help of laboratory studies [1, 10], it was determined that the most optimal, in terms of mass, overall dimensions, strength and performance characteristics is the design shown in figure 1.
Figure 1. General view of the experimental heat exchanger.

The body of the experimental heat exchanger (EHE) is made in the form of a "pipe" of rectangular cross-section. 13 (thirteen) cooling blocks, consisting of heat-exchange elements, are inserted inside the body. The blocks are fixed to the frame by means of a bolted connection on the gaskets at the top and bottom of the body by the process windows made in the outer walls. The windows are closed with lids on the gaskets (Figure 2).

Figure 2. Experimental heat exchanger in section.

Cold water is supplied through the bottom cover via the piping system, pressure and rate of water supply to each heat exchange unit is regulated by means of a ball valve mounted on the water supply pipes.
On the bottom cover there are branch pipes through which one coolant passes through the space between supporting structure. To increase the heat transfer, fining of the heat exchange tubes is used, which represents a tape soldered along the entire length of the tube.

Diagram of gas and water flow in the heat exchanger, which is being developed, is shown in Figure 3.

Conical junctions, that connect the heat exchanger with the gas ducts, are mounted on the ends by the bolted connection to the body and to the shell.

The heat exchange part, through which the coolant passes, consists of 169 pipes. Pipe still of heat exchangers and fins were made of copper sheet, there are holes in the fins to increase heat transfer and gas flow.

Heat exchange elements are made in the form of copper tubes and mounted in a block (Figure 4), dimensions and weight of which were selected taking into account the convenience of installation and maintenance during operation.

---

**Figure 3.** Diagram of heat exchanger (longitudinal section).

**Figure 4.** Heat exchanger unit.
Body of the heat exchanger is a shell welded from 2 flanges of a closed section joined together by longitudinal beams of the angle section. There are steel sheets reinforced with vertical stiffeners on the inner side. Thickness of the wall of the shell is determined by the pressure of the production environment and the size of the shell, considering the data on the calculation of the plastic deformations of metal.

Supporting structure of the heat exchanger shell is supported by a rigid frame made of a C-beam. The structure of the rigid frame was selected by modeling with the calculation of plastic deformations as a result of load stresses considering the safety factor. On the support platforms there are adjusting bolts for adjusting the position of the rigid frame during structural fabrication.

3. Conclusion
On the basis of the results of virtual modeling and optimization of the design, an experimental heat exchanger was created, which is currently being tested in industrial conditions. In the future, recovered heat will be used to increase the energy efficiency of production by using thermal energy to preheat the anodes and alumina.

The use of accumulated thermal energy will allow to increase the technical and economic performance of aluminum smelters, reduce capital expenditures in operation and design of gas cleaning systems and rationally solve the problem of utilization of process gases.

Acknowledgement
This paper has been prepared with financial support from the Ministry for Education and Science of Russian Federation (Order No.218 adopted on the 9th of April 2010 by the Government of the Russian Federation.) within the framework of the project 02.G25.31.0181 “Development of heavy duty energy efficient technology for aluminum RA-550” in the framework of realization of complex projects in high-tech production, approved by the RF Government decree No. 218 from April 9, 2010.

References
[1] Kondrat’ev V V, Rzhechitskii E P, Karlina A I, Sysoev I A and Shakhrai S G 2016 Metallurgist vol 60 5-6 571–5
[2] Kuz’min M P, Kondrat’ev V V, Larionov L M, Kuz’mina M Y and Ivanchik N N 2017 Metallurgist vol 61 1-2 86–91
[3] Kondrat’ev V V, Ershov V A, Shakhrai S G, Ivanov N A and Karlina A I 2016 Metallurgist vol 60 7-8 877–82
[4] Ershov V A, Sysoev I A and Kondrat’ev V V 2013 Metallurgist vol 57 3-4 346-351
[5] Shakhrai S G, Nemchinova N V, Kondrat’ev V V, Mazurenko V V and Shecheglov E L 2017 Metallurgist vol 60 9-10 973–7
[6] Sysoev I A, Ershov V A and Kondrat’ev V V 2015 Metallurgist vol 59 5-6 518–525
[7] Shakhrai S G, Budnik E V and Kondratiev V V 2013 Metallurgist vol 56 9-10 700–4
[8] Shakhrai S G, Gron V A, Kondrat’ev V V, Nikolaev V N and Belyanin A V 2015 Metallurgist vol 59 1-2 126–130
[9] Shakhrai S G, Korostovenko V V, Gron’ V A, Kondrat’ev V V and Belyanin A V 2014 Metallurgist vol 58 1-2 138–140
[10] Kondrat’ev V V, Nikolaev V N, Rzhechitskii E P, Kornyakov M V and Afanas’ev A D 2014 Metallurgist vol 57 9-10 779–782