

Electrical Preheating of Cathode Blocks for Collector Bar Casting in Aluminum Electrolysis Cells

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Abstract

Optimally designed modern aluminum electrolysis cells are made of high-quality materials and are designed for service life of more than five years. Their productivity and technological efficiency are largely determined by the quality of the electrical contact created between the cathode blocks and steel collector bars. Before collector bar casting, preheating of the cathode blocks is required, for which several technologies are used. One of them is gas preheat, which does not provide the necessary uniformity of heating. In 2014-2018, "ISO" Ltd, together with "RPC MHD", Ltd, we designed, manufactured and implemented installations for preheating of cathode blocks before casting of the cast iron for the following cell technologies: S-8B, S8Ba, S8BM, OA-300M2, SHpVV, SHpBM, SHpVV-120kA, SHpVV-105kA. We have put in operation the installations of the type UENB-R-01, UENB-R-02 and UENB-R-03 in Krasnoyarsk, Bratsk and Shelekhovo branches of "ISO" Ltd, in which electric heating is used with the help of tubular electric heaters developed by "RPC MHD" Ltd. Cooperation to improve the designs of installations allowed replacing gas heating which achieved the required characteristics, in particular, uniform temperature distribution on the surface of the cathode blocks and steel collector bars in the ranges of 350 - 410 °C and 430 – 550 °C, the difference between the average temperature of the blooms and the average temperature of the cathode blocks not least than 100°C, the period of preheating is 120 minutes. The efficiency of electric preheating is confirmed by reliable and long-life operation of the cathodes in electrolysis cells of type S-8B, S8Ba, S8BM, OA-300M2.

Keywords: Cathodes of aluminum electrolysis cells, electrical preheating of cathode blocks, steel collector bars, temperature distribution.

1. Arrangement of Installation and Process Cycle

The technological peculiarity of cathode sections heating by flame of gas burners with subsequent casting of iron is a considerable uneven temperature distribution on the surface of cathode block with appearance of a critical temperature difference over the block volume, what may lead to cracking of cathode block during its exploitation. In addition, the use of gas burners for heating requires increased safety measures and complex, expensive gas stations.

The use of tubular electric heaters has several significant advantages, namely:

- allows to achieve greater uniformity of heating over the surface and significantly reduce the temperature differential across the volume of the cathode block;
- there is no impact of combustion products on the surface of the cathode blocks;
- simplicity and ease of maintenance during operation;

- relatively low capital expenditures for equipping the production site with secondary technological equipment.

These advantages were a decisive factor in the choice of the technological concept and in 2014 LLC "RUS-Engineering" and LLC "RPC MHD" began to jointly develop and manufacture an experimental-industrial sample of the installation UENB-R-01 type with tubular electric heaters for Shelekhovo branches of LLC "RUS-Engineering" [3]. The main structural elements and general view of this installation are presented on Figure 1 [4]. The installation for heating of the cathode sections of aluminum electrolysis cells consists on: thermal chamber open type 1, transports cart 2 used to transport the cathode sections 3, which consist from: carbon block, steel collector bars and welded to its aluminum busbars. Transports carts 4 are interconnected in such a way that when one cart is in the thermal chamber 1, the other cart associated with it is in the loading and unloading area of the cathode sections 10 or 11.

The inner volume of the thermal chamber 1 is divided into separate sections by partitions 12 fixed on a flat arch 13. The heating system 18 is represented by tubular electric heaters type ET-380-67-152-4505. Electric heater elements are placed in protective tubes 19, which are fixed by means of U-shaped retainers 20. Control of temperature is carried out by thermocouples 21, which are connected to the input of a programmable logic controller, where the measured temperature value is compared with a predetermined temperature value. When the temperature exceeds a predetermined value, the regulator, in accordance with the control signal, changes the power.

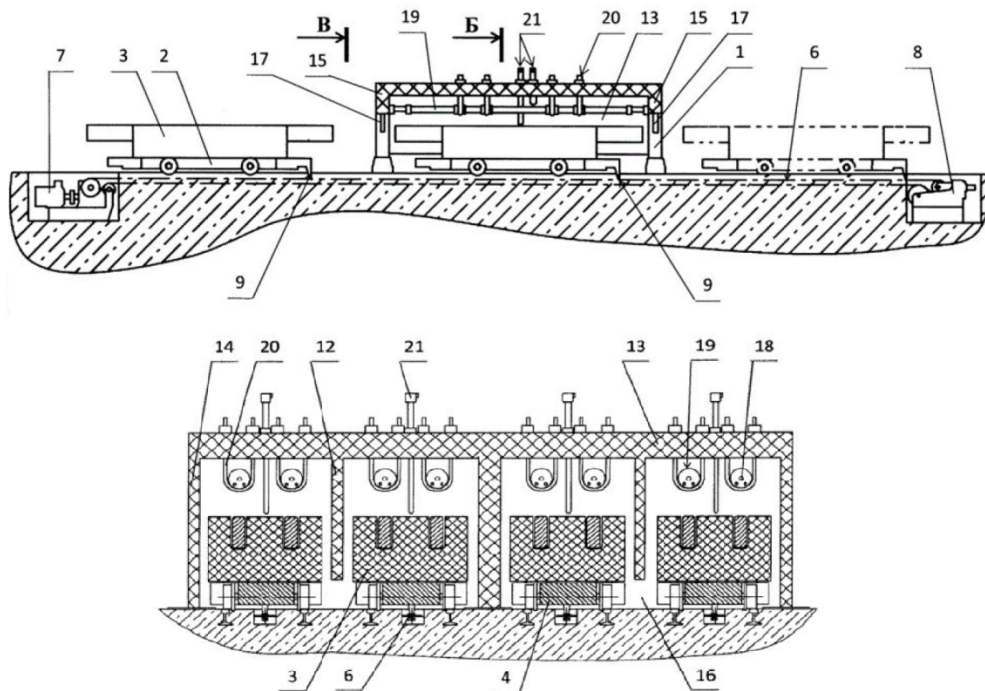


Figure 1. The scheme of installation: 1 - thermal chamber; 2 - transports cart; 3 - cathode sections; 4 - frame of transports cart; 5 - rails; 6, 7, 8 and 9 - the drive of carts; 10 and 11 - zones of loading and unloading of cathode sections; 12 - partition; 13 - the arch; 14 and 15 - walls; 16 - the lower part; 17 - prechamber protection; 18, 19 and 20 - tubular electric heaters with retainers; 21 - thermocouples.

The installation operates as follows. The cathode sections 3 are alternately mount on transports cart 4, which are in the loading position, in one of the zones 10 or 11. Then the cathode sections are assembled. On transports carts, the cathode sections are move to the heating zone of the

thermal chamber 1. The heating of the cathode sections in each line continue for a specified time, independent from of the heating of the other lines. At the end of the specified heating time, the sound signal is switch on. The prechamber protection are takeout and transport cart with heated cathode sections, ready for casting, are rolled out of the thermal chamber, and another transport cart with the cathode section of the same line rolls into. The pre-heating cycle is repeated.

2. Industrial Operation and Installation Modifications

Installation UEHB-R-01 type (Fig. 2 and 3) is designed to pre-heat the cathode sections of electrolyzers S8B, S8BM, OA-300M2 type and was put into commercial operation in April 2015 in one of the workshops of Shelekhovo branch of LLC "RUS-Engineering".

With an electric power is 85% from nominal one, the installation has the following technological characteristics:

- full power: 540 kW;
- the pre-heating of cathode sections S8B, S8BM type is 100 minutes in a preheated installation (for OA-300M2 it is 140 minutes);
- average surface temperature of the cathode block $t_{\text{block}} = +470..500^{\circ}\text{C}$;
- average surface temperature of steel collector bar $t_{\text{bar}} = +460..480^{\circ}\text{C}$;
- temperature of welded joint t_{wj} does not exceed 100°C ;
- productivity, pieces/day: 16 (for S8B/S8BM cathode sections types) or 12 (for OA-300M2 cathode sections type).

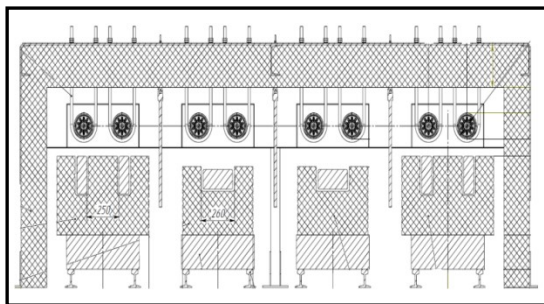


Figure 2. Cross section of UEHB-R-01



Figure 3. View on UEHB-R-01

During the first year of operation of the pilot installation UEHB-R-01, operating experience was obtained, and a number of design flaws were identified, it's were taken into account by LLC "RUS-Engineering" and LLC "RPC MHD" during design in 2016 of installation UENB-R-02 type for Bratsk branch (Fig. 4)

For eliminate these drawbacks, in construction of UEHB-P-02 following changes were made:

- modified the design of the prechamber protection in accordance with the proposals of service of operation;
- applied of automated control systems on the element base (such as "Siemens"), which provides visualization and recording of parameters. Using the PID-controller with Phase-Freqence modulation;
- automated the process of temperature measurement using stationary infrared sensors. It is possible to control the surface temperature of the surface of cathode section using a contact thermocouple during the heating process;
- for ensure uniform pre-heating of the pair "block-steel collector bars" of cathode sections S-8B, S-8Ba, ShpVV, ShpBM, ShpVV-120kA, ShpVV-105kA types the configuration of tubular electric heaters and the arch was adapted.

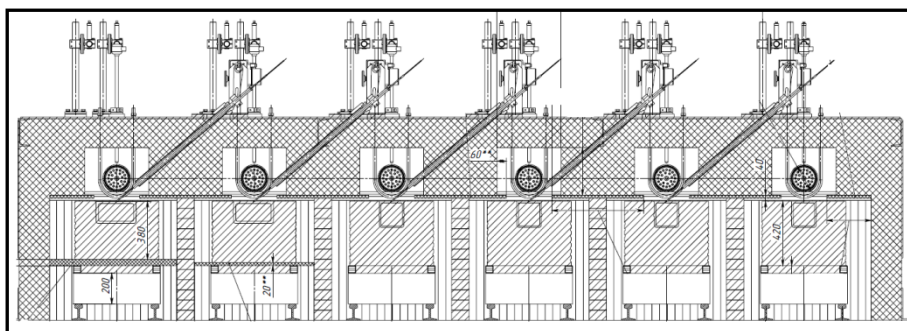


Figure 4. Cross section of UEHB-R-02

The actual technological characteristics of UEHB-R-02 at nominal power R_{nom} have the values:

- full power: 480 kW;
- time of heating of the cathode sections within 170-190 minutes in a preheated installation;
- average surface temperature of the cathode block $t_{block} = +350..360^{\circ}\text{C}$;
- average surface temperature of steel collector bar $t_{bar} = +360..440^{\circ}\text{C}$;
- temperature of welded joint t_{wj} does not exceed 60°C ;
- productivity, pieces/day: 24 cathode sections S8B type or 48 cathode sections another types.

During the operation of UEHB-R-02 on Bratsk branch of LLC "RUS-Engineering" from December 2017 to the present, features of operation of the installation of this design have been identified, which generally do not impair the energy efficiency of the installation, but lead to a decrease of its productivity and operation. In view of this, it was decided to make a number of changes in the design during its commercial operation: to upgrade the prechamber protection, to increase the heat insulation of tubular electric heaters, to change the driver of contact thermocouples, to upgrade the arch and to replace the control systems with more interference-resistant ones.

Accumulated experience in the design and operation of installations for pre-heating cathode sections two types allowed LLC "RUS-Engineering" and LLC "RPC MHD" to design and make the two-section pre-heating installation for cathode sections UEHB-R-03 type for Taishet branch (Fig. 5 and 6).

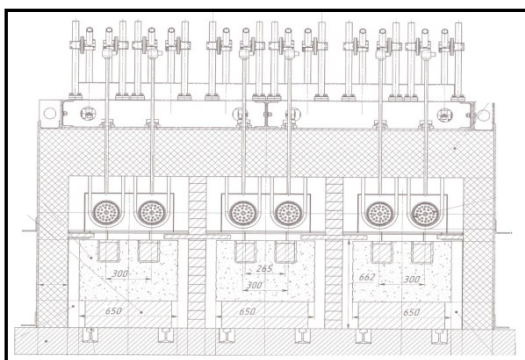


Figure 5. Cross section of UEHB-R-03



Figure 6. View on UEHB-R-03

The design feature of this installation, which is executed in the form of two separate identical sections, makes it possible to operate these sections separately, in two different branches: in Krasnoyarsk and in Bratsk branches.

3. Conclusions

1. Installations for pre-heating cathode sections of aluminum electrolyzers with tubular electric heaters UENB-R types, jointly developed by LLC "RUS-Engineering" and LLC "RPC MHD", in the amount of 3 units were put into operation in 2015-2019 in Krasnoyarsk, Bratsk and Shelekhovo branches and provide the needs of 90% of the volume of the enterprise consumed by cathode sections for electrolyzers.

2. The indicators achieved on the installations confirm the compliance of the actual technical characteristics required in the assignments.

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