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Technology of Aerodynamic Separation of Industrial Room

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***Abstract*—To obtain an appropriate picture of emissions through the aeration lantern of the block based on the location of the experimental area, a flexible shut-off screen was applied together with electrolyzers RA-400. Sampling was carried out along the horizon of the upper edge of the electrolyzer with the fully covered tub and during the exposing by means of the quick-detachable/installed attachments. The study of aerodynamics and the sampling of extended sources – the aeration lantern, input ventilation and the area above the depressurized electrolyzer – was carried out under moderate weather conditions (no strong winds) and close to mean standard atmospheric pressure and humidity. According to the results of instrumental studies through the use of formulas for the calculation of aerodynamic parameters, the following characteristics of dust-gas-air flows organized by the gas suction and gas-cleaning systems were calculated: the density of gas medium in operating conditions; the dust-gas-air flow motion speed at the site of measurement; the volume of gas under operating conditions; the volume of gas under normal conditions. With the electrolyzer covered, at the point closest to the gas removal system, the concentration of hydrogen peroxide in the sample was the lowest. Further, with the increasing distance from the gas removal system, the concentration increased slightly, but at both points was below the MAC (maximum allowable concentration). The concentration of hydrogen peroxide (expressed as fluorine) in the gas removal system was defined. In the mode of replacement of anodes, the volume of gas removal increased. The concentration of hydrofluoride was also below the maximum permissible concentration in the operation area. The concentration increases before the anodes replacement point was negligible, and at the third point after the covers removal was quite noticeable. The concentration of hydrogen peroxide (expressed as fluorine) in the gas removal system is defined.**

***Keywords*— heat exchanger, electrolyzer, ANSYS, testing, production of aluminum**

I. INTRODUCTION

Currently, the requirements for energy and resource saving [1-5] are being tightened due to the problem of an increasing shortage of electricity [6-11]. This is due to the fact that the pace of development of large cities exceeds the previously laid down: the social sphere, housing construction and industrial production are developing. At the same time, aluminum smelters are one of the largest energy consumers with a slightly variable load schedule and a high degree of dependence on the source of electricity and its cost. The technology of aluminum electrolysis is constantly being improved towards increasing the unit power of electrolyzers. Leading aluminum companies in the world are striving to operate powerful electrolyzers operating at high amperage (300-500 kA), since their use can increase the economic efficiency of new plants by reducing specific capital and operating costs.

A fairly large number of studies have been carried out in the areas of energy efficiency and energy saving of aluminum production [12-19]. One of the promising directions is the development and implementation of efficient heat exchangers [20].

II. FORMULATION OF THE PROBLEM

With the aim of identify an adequate picture of emissions through the aeration lantern of the housing, taking into account the location of the experimental plot together with the RA-400 electrolyzers, a flexible cut-off screen was used. The flexible cut-off screen is an airtight PET-cloth covering the airflow from the mark of the housing 0 to the mark of +18,600 (Figure 1). Signal smokes showed that in the presence of curtain, horizontal airflows were practically suppressed.

Figure 2 shows a sketch of installing a flexible screen of cut-off system on blocks using a halyard's system.

Figure 3 shows a photograph of a stretched screen in an electrolysis housing.

Figure 4 shows the location scheme of the points of measurement of aerodynamics and sampling of lantern emissions.

During the measurements during the stationary electrolysis mode, the shelter was stretched with the help of halyards, while there were no horizontal aerodynamic flows in the lantern, which allowed the correct sampling and measurement of aerodynamics. Before mounting the cut-off screen and after installing it, signal smokes created by smoke bombs was used to control the absence of movement of aerodynamic flows.

To assess the shelter efficiency and increase emissions during technological operations (change of the anode), aerodynamic flows are cut off from the electrolyzer with cut-off screen height along the upper cut of the electrolyzer, as shown in Figure 5. The cut-off screen is mounted on a quick collect -my / disassembled frame, while its area should not impede the normal operation of personnel and technological crane. In this case, sampling was carried out along the horizon of the upper cut-off of the electrolyzer with a completely covered bath and during opening periods using quick-detachable / installed equipment (Figures 5-7).

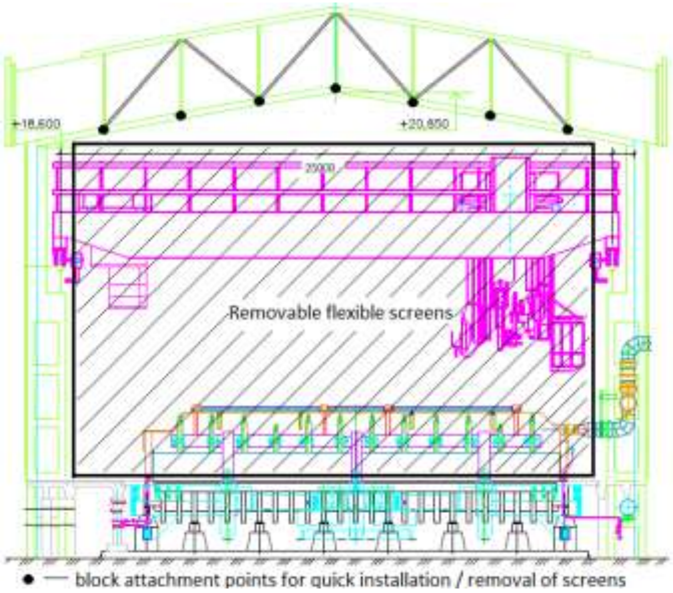

Fig. 1. A thumbnail image of the installation of a flexible screen of the cut-off system on the blocks using a halyard's system (side view)

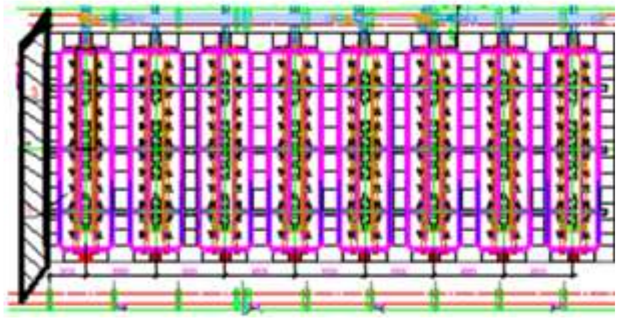

Fig. 2. A thumbnail image of the installation of a flexible screen of cut-off system on the blocks using a halyard's system (top view)

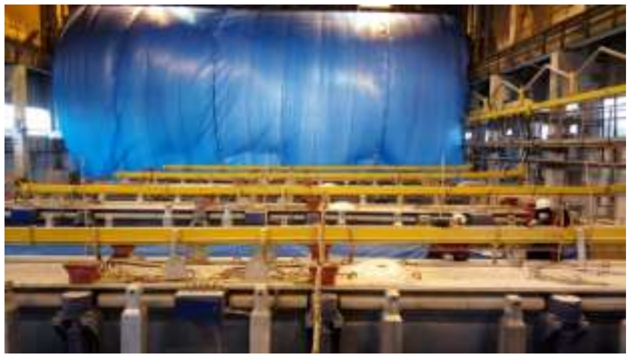

Fig. 3. General view of the stretched flexible cut-off screen

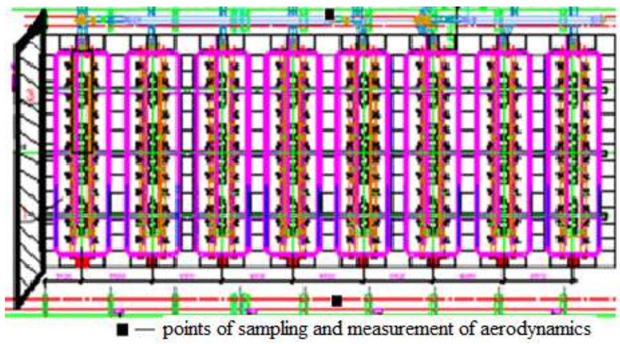

Fig. 4. Layout of the points of measurement of aerodynamics and sampling of lantern emissions

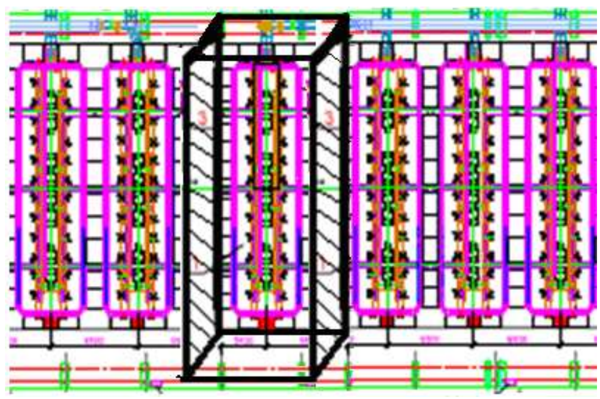

Fig. 5. Location of cut-off screens of the electrolyzer

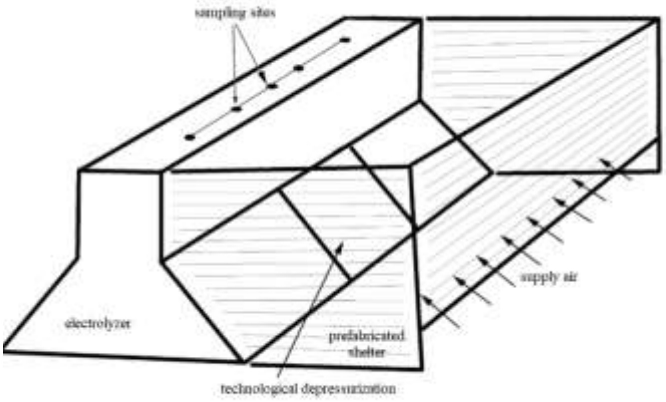

Fig. 6. Schematic representation of the installation of the cut-off screen for sampling during technological operations

Fig. 7. General view of the installation of the cut-off screen for sampling during technological operations

A diagram of the sampling and aerodynamic research sites for stationary operation is shown in Figure 8, and for technological depressurization, see Fig. 9. At the same time, sampling and aerodynamic research were carried out at the point of the combined gas duct before gas cleaning and at the point of the combined gas duct after gas cleaning.

Aerodynamics studies and sampling in extended sources - aeration lantern, forced ventilation and the area above the unsealed electrolyzer were carried out under calm weather conditions (no strong wind) and close to average standard atmospheric pressure and air humidity.

III. Calculation of Aerodynamic Parameters of Dust-Gas-Air Flows

Based on the results of instrumental studies using formulas for calculating the aerodynamic parameters given below, the following characteristics of dust-gas-air flows of an organized gas suction and gas purification systems were calculated:

- density of the gaseous medium under working conditions;
- the speed of the dust-gas-air flow in the section under measure;
- gas volume under working conditions;
- gas volume under normal conditions.

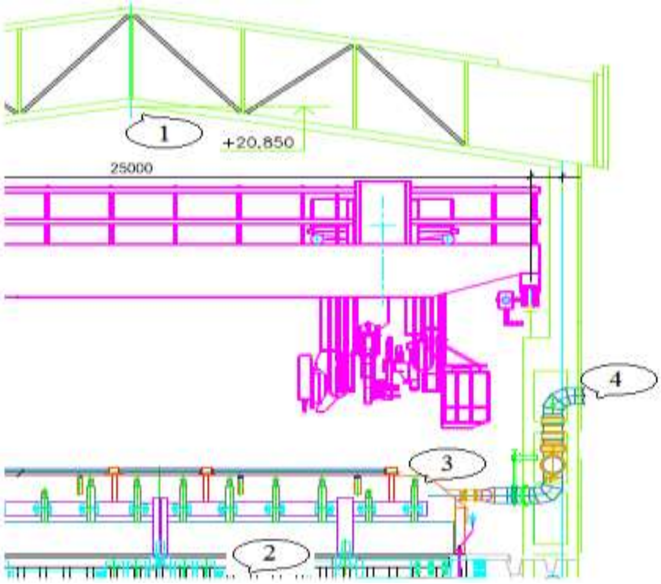

Fig. 8. Diagram of places for sampling and research of aerodynamics in a stationary mode of electrolysis (extended sources - at least 10-12 points in aerodynamics and at least 3 samples at 6 points, gas ducts - aerodynamics and at least 3-5 samples at each point): 1 - aeration lantern of the housing above the experimental plot, 2 - fresh air ventilation, 3 – collector girder (aerodynamics), 4 - internal ducts (aerodynamics)

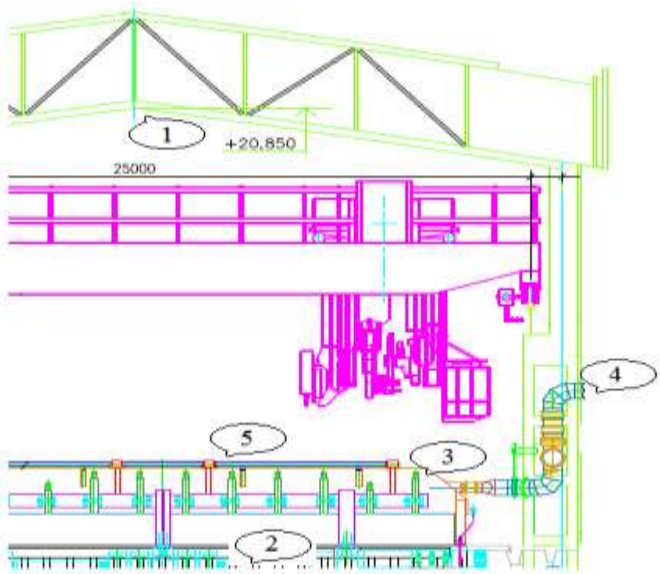

Fig. 9. Scheme of places for sampling and research of aerodynamics during technological depressurization of the electrolyzer (extended sources - at least 10-12 points in aerodynamics and at least 3 samples at 6 points, gas ducts - aerodynamics and at least 3-5 samples at each point): 1 - aeration lantern of the housing above the depressurized electrolyzer (control and comparative measurement of 2-3 points), 2 - supply ventilation in the area of the depressurized electrolyzer, 3 - collector girder (aerodynamics), 4 - internal ducts (aerodynamics) and gas outlet from a depressurized electrolyzer, 5 - the area above the shelter of the electrolyzer

The density of the gaseous medium under working conditions:

$$\gamma_p = \gamma_0 \cdot \frac{273}{760} \cdot \frac{\left(B_{атм} \pm P_{ст}\right)}{\left(273 + T_г\right)} \quad (1)$$

where: γ_0 = 1.29 kg / m^3 - air density under normal conditions;

B_{ATM} - barometric pressure at the time of measurement, bar;

P_{CT} - static pressure (vacuum) in the duct, bar;

T_T - the temperature of the gas medium ° C.

Gas velocity at the metering site:

$$w = \sqrt{\frac{2 \cdot g \cdot P_D}{\gamma_p}} \quad (2)$$

where: g = 9.8 m / s^2 - acceleration of free fall;

R_D - dynamic gas pressure in the measurement area, mm water column;

Gas consumption at the measurement site under working conditions:

$$Q_p = w \cdot S \cdot 3600 \quad (3)$$

where: *S* is the cross-sectional area of the gas duct at the measurement site.

Calculation formulas for the determination of environmental indicators [21-23]:

- pollutant emissions during the interoperational mode:

$$\text{Aeration lantern emission} = (S_{\text{AF}} - S_{\text{PV}}) \cdot V_{\text{AB}} \cdot 10^{-6} \quad (4)$$

where:

- S_{AF} - weighted average concentration of pollutants in emissions from an aeration lantern, mg / m^3;
- S_{PV} - weighted average concentration of pollutants in the supply ventilation, mg / m^3;
- V_{AB} - the volume of aerational air removed through the lantern, m^3 / h;
- 10^{-6} - conversion factor mg to kg.

Gaseous pollution capture coefficient in the system of gas treatment (Efficiency$_{GT}$)

$$\text{Efficiency}_{\text{GT}} = 100 \cdot C_{out} / C_{in} \quad (5)$$

where:

- C_{out} - the concentration of the pollutant at the outlet of the gas treatment, mg / m^3;
- C_{in} - concentration of pollutant at the inlet from the gas treatment, mg / m^3.

Coefficient of capture of pollutants by the shelter of the electrolyzer (Efficiency$_{SH}$)

$$\text{Efficiency}_{\text{SH}} = 100 \cdot M_{\text{P GTP}} / \left(M_{\text{P GTP}} + M_{\text{P AL}}\right) \quad (6)$$

where:

- $M_{P\ GTP}$ - mass of pollutant at the inlet to the gas treatment, kg / h;
- $M_{P\ AL}$ - mass of pollutant emitted through the aeration lantern, kg / h.

The coefficient of capture of suspended particles in the system of gas treatment (Efficiency$_{GT\ S}$)

$$\text{Efficiency}_{\text{GT S}} = 100 \cdot M_{\text{S out}} / \left(M_{\text{S in}} + M_{\text{AL}}\right) \quad (7)$$

where:

- $M_{S\ out}$ - mass of suspended particles emitted after gas treatment, kg / h;
- $M_{S\ in}$ - mass of suspended particles entering the gas treatment, kg / h;
- M_{AL} - the mass of alumina supplied for purification in gas treatment, kg / h.

Specific emission of pollutants:

$$\text{Specific emission of pollutants} = (M_{\text{P AL}} + M_{\text{P out}}) / M_{\text{AL}} \quad (8)$$

where:

- $M_{P\ AL}$ - mass of pollutant removed through the aeration lantern, kg/h;
- $M_{P\ out}$ - mass of pollutant emitted after gas cleaning, kg/h;
- M_{AL} - aluminum performance, t/h.

IV. Methodology of Instrumental Measurements

Instrumental measurements of the aerodynamic characteristics of gas-air flows were made in accordance with GOST 17.2.4.06-90 “Methods for determining the velocity and flow rate of dust and gas flows emanating from stationary sources of pollution” using calibrated instruments: a pneumometric tube of the NIOGAZ design, an alcohol micromanometer MMN-2400 (5) -1.0, the MONOLIT gas analyzer, the differential DMC-01 digital pressure gauge, mercury and digital thermometers.

The amount of air leaving the lantern was determined according to MVI 2420 / 006-97 / 006 “Methodology for measuring the amount of air removed by the general exchange ventilation of the electrolysis buildings of aluminum plants (lantern's gases)” by the air speed measured by a digital anemometer and the area of open apertures available during the period of instrumental measurements.

Suspended substances (total dust, including solid fluorides, alumina, tarry substances and benz (a) pyrene) in the exhaust gases from the electrolysis cells were determined according to MVI No. PrV 2000/4 “Methodology for measuring mass concentration of dust in industrial emissions of organized suction” (gravimetric method).

In the lantern's supply air, in the working area, suspended solids (total dust) were determined according to MU No. 1719 “Methodological instructions for determining dust in the air of the working area and in ventilation systems”.

Gaseous fluorides (HF) were determined according to MVI No. PrV 2000/7 “Methodology for measuring the mass concentration of hydrogen fluoride in industrial emissions of organized suction” (photometric method) and MVI 2420 / 798-96 / 792 2 “Methodology for measuring the mass concentration of gaseous fluorides in the air removed by general-exchange ventilation from the electrolysis bodies of aluminum smelters” (photometric method). For the working area, the analysis was carried out according to the method of MU 2246-80.

The determination of fluorine in the solid phase from gases leaving the electrolysers was carried out according to the MVI No. PrV2000 / 3 “Methodology for Measuring the Mass Concentration of Solid Fluorides in Industrial Emissions” (potentiometric method).

The determination of salts of hydrofluoric acid was carried out according to MU No. 5930-91 for measuring the potential of a fluoride-selective electrode.

The determination of aluminum oxide in the solid phase was carried out according to the “Methodology for measuring the mass concentration of aluminum in industrial emissions into the atmosphere by the photometric method with aluminone” M-12 “Research and Production and Design Company “Ecosystem”.

The determination of sulfur dioxide in the working area, lantern’s air and supply air was carried out according to MU No. 1642-77, VMU “Chemical analysis of atmospheric air with sampling for solid film adsorbents”.

In the gases entering the gas purification and in the emissions after purification, the dioxide content was determined using the MONOLIT gas analyzer.

Benz (a) pyrene was determined from solutions of resinous substances in n-octane according to MVI No. 2420 / 793-96 / 0787.

V. Conclusion

Based on the results of instrumental studies using formulas for calculating aerodynamic parameters, the following characteristics of dust-gas-air flows of an organized gas suction and gas purification systems are calculated:

- the density of the gaseous medium under working conditions;
- the speed of the dust and gas flow in the measurement area;
- gas volume under working conditions;
- gas volume under normal conditions.

Thus, with a sheltered electrolyzer at the point closest to the gas removal system, the concentration of hydrofluoride in the sample is the lowest. Further, as the distance from the gas removal system, the concentration increases slightly, but at both points below the MAC. The concentration of hydrofluoride (in terms of fluorine) in the gas removal system was determined. In anode replacement mode, the volume of gas removal was increased. The concentration of hydrofluoride was also lower than the MPC in the working area. The increase in concentration to the place of replacement of the anodes was insignificant, and at the third point after the shelters removed, it was quite noticeable.

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