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VACUUM INCREASE IN THE ELECTROLYTIC CELL WITH THE AIM OF REDUCING EMISSIONS INTO THE WORK ENVIRONMENT

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Abstract

In the production of the primary aluminum, waste gases occur as a byproduct in electrolytic cell. Such gases are drained to the Gas Treatment Centre by degassing system where, before discharging into the atmosphere, are purified by adsorbing to the active surface of alumina (Al_2O_3). Gases enriched alumina is, by pneumatic transportation, returned to electrolytic cell. When performing operations on the cell, such as anode replacing and aluminum tapping from the cells, these gases are emitted into the electrolysis hall, which directly affects the environment and the health of employees. Thus, the purpose of this work is to increase the vacuum in the cells exhaust system in order to reduce emissions into the electrolysis hall during performance of the aforementioned operations, with minimal investment and utilization of existing resources.

Keywords: electrolytic cell; the Gas Treatment Centre; waste gases; anode replacing; aluminum tapping; exhaust system

1. Introduction

In the process of aluminum reduction, there are number of factors that could adversely affect both the health of direct employees and their work environment. One of these factors includes emissions from the electrolytic cells that occur as a byproduct of the production of primary aluminum. Hydrogen fluoride (HF), as a byproduct of the electrolysis of alumina, is one of the most harmful gases when it comes to impact on human health and therefore place great emphasis on the reduction in the working environment [1]. The emergence of the HF in the electrolytic cell is attributed to two reactions:

The electrochemical oxidation of hydrogen at calcined carbon anode;
The reaction of moisture with present AlF_3 [2].

Mentioned reaction of forming HF is shown by the equation (1):

$$AlF_3 + H_2O \rightarrow Al_2O_3 + 6HF \quad (1)\ [3]$$

High concentrations of hydrogen fluoride generated, leave the cell during the operation of anode replacing and aluminum tapping and thus directly endanger the health of employees.
In the last few decades, the aluminum industry has invested a great deal of knowledge and resources to the adverse impacts of aluminum production to the lowest possible level. For this purpose, the specific system for exhaust gases from an electrolytic cell and filtering before releasing to atmosphere has being developed.
Since the conditions, in the global aluminum market, are constantly changing, involved in the production process are daily faced with the need for increasing or decreasing the production of primary aluminum. Of course, with increased production of aluminum, there's an increase in the production of waste gases, which requires large investments in the field:

- Cell exhaust gas system
- Gas treatment centers capacity increase

It is important to emphasize that in addition to the above mentioned hydrogen fluoride, electrolytic aluminum production process, unfortunately, includes a range of waste gases generated by the oxidation of impurities present in the raw materials.
This paper will emphasize increase in exhaust gases from the electrolytic cell towards gas treatment center in during the following operations:

- Aluminum tapping
- Anode replacing

Considering that these activities include the longest stage of exposure to harmful impacts. These phases include the following operations:

- Removing anode butts
- Insertion of material removed under anode into molds
- Keeping the cell open during new anode replacing

The low price of aluminum on the world market and high electricity prices currently create a very unfavorable financial climate for the production of primary aluminum. This reduces investment of aluminum companies in the development of both existing and the construction of new systems to reduce emissions. Therefore, it is our goal to, with minimal investment and utilization of existing resources, increase the negative pressure in the cell when performing the above mentioned operations and thereby reduce emissions of gases in the electrolysis hall and the environment. The increase in negative pressure at the outlet suction tube of superstructure will be based on the installation of a system based on the principle of the ejector. Measurements will be made by a device for measuring the negative pressure, and the analysis of data will be used to evaluate the performance of the developed system.

2. Working principle of the ejector

Ejectors are devices that are used for fluid or mixture of fluids transfer. The working principle of the ejector is simple because does not require the driving engine but uses the energy of the input drive fluids for suction, compression and suppression of the vacuumed fluid. Operating fluid operates at a higher pressure, as opposed to the vacuumed fluid that streams under the influence of lower pressure. Ejectors can be used for high pressures and negative pressure for small and large flows, high and low temperatures [4].
The main parts of the ejector are:

- Nozzle with a connector for operating fluid
- Vacuum chamber
- Diffuser

The operating fluid, while passing through the nozzle, forms a stream jet that rapidly enters the vacuum chamber and creates a negative pressure for suction of the secondary fluid. At the entrance to the vacuum chamber particles of the operating fluid encounter particles of vacuumed fluid. Fluid particles collide and mix and form a homogenous mixture, which flows to the diffuser. On the way to the chamber, particles of the operating fluid lose some of their kinetic energy and at the same time slow down, and the particles of vacuumed fluid receive part of the kinetic energy and thereby accelerate. After the entrance of the diffuser, due to expansion of the streaming space, a stream flow of the mixture is slowing down, the speed decreases and the pressure increases until the exit of the ejector. The output pressure depends on the relationship between pressure and flow of the vacuumed and operating fluid and is always higher than the vacuumed and lower than the operating pressure [5].

It is worth mentioning that there are also ejectors without diffuser. In comparisons of ejectors with diffuser and without diffuser it has been observed that ejectors with a diffuser provide a higher injection coefficient for the same ejector diameter values and the same parameters of working fluid. For the same values of nozzle diameter, the injection coefficient is higher for lower values of mixing room diameter [12].
In our case the principle of ejector without the diffuser was used because if the diffuser was installed, the gas flow at normal vacuum from the electrolytic cells would be reduced.

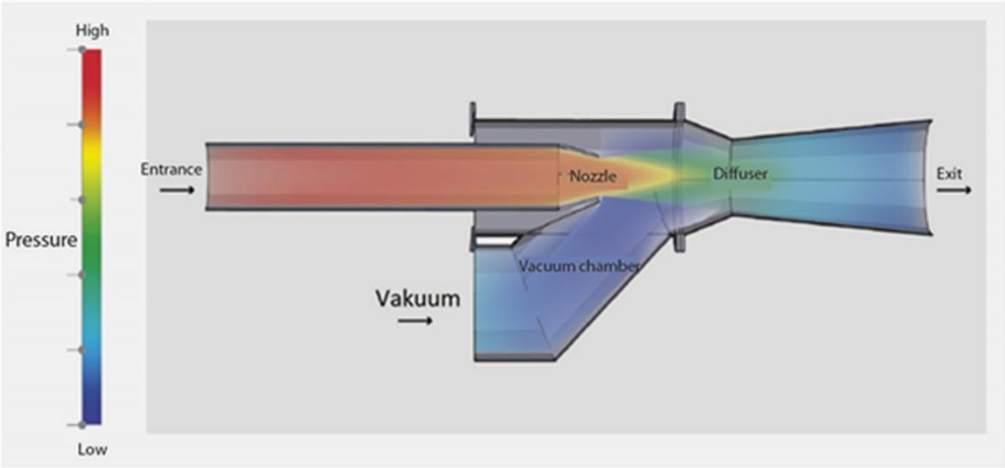

Figure 1: Working principle of the ejector [6]

3. Dry gas processing (Gas Treatment Centre)

Principle of the dry scrubbing system is simple [9]. Scrubbers operate by direct extraction of flue gases from electrolytic cells into reactors where gases react with active alumina. At first, poisonous fluoride and HF are adsorbed from the gas mixture onto active alumina surface. Gases are vacuumed into the Venturi tube shape like reactor located in front of the bag filters. In the opening of the reactor is injected fresh alumina and alumina from recirculation (enriched with fluorine). The alumina, enriched with gases and dust particles, stops on the filter bags and is being collected in the filter baskets. Effectiveness of the cleaning process depends on details of the system and the process. In terms of reaction mechanism, hydrogen fluoride, at purification temperatures up to 150 °C binds onto alumina by:

- Direct chemisorption of HF at reactive sites on the alumina surface with formation of Na-F and/or Al-F species and with additional monolayer being physically adsorbed on top of chemisorbed layer [10].
- Physical adsorption of HF on the alumina surface (hydroxyl groups bonded to surface and/or physisorbed by water to form alternating layers of HF and H2O) [11].

It is preferred to use such a structural form of alumina that has a larger specific surface area (**B.E.T. - m^2/g**) and therefore the maximum capacity of chemisorption. By the implementation of the emitted gases through a layer of alumina it is possible to restore all the fluorine in cells. Under the normal operating conditions, all alumina required for the production of aluminum is used for catching fluorine i.e. goes through the gas treatment plant before dosing into cells.

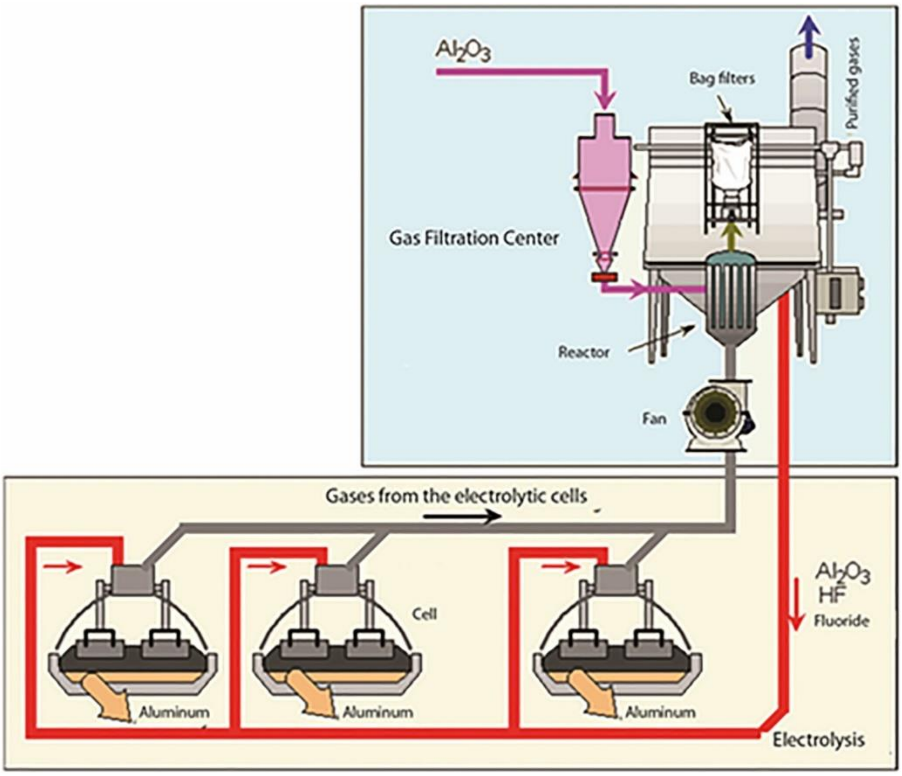

Figure 2: Schematic illustration of the filtration center operation

4. Negative pressure increase in electrolytic cell

For the operation of aluminum tapping and anode replacing in electrolytic cell, two systems for increasing the negative pressure were developed.

- The increase in negative pressure with a fan with an electric motor. This operation involves the operation of one fan at a group of cells, embedded in bypass tube. The system is quite expensive to install and maintain. This system called Process Gas Suction System, was developed by the company Norsk Hydro Aluminum (International Patent Application No. WO 01/36716) [7,13].
- The increase in negative pressure on the ejector principle. In these cases, the brand new line of a dividing pipeline is installed. A blower with a large amount of small pressure air is used as a source of air. This system was developed by the company AP Technology called JIBS (Jet Induced Boosted Suction) (U.S. Pat. No. 4,668,352) [8,13]

As already mentioned, the aim of this work is to develop a similar system with minimal investment and the use of its own resources. The system that we have developed is similar to the system developed by AP Technology. As the operational fluid, in this case, is used compressed air obtained from the compressor station through an existing line of the dividing pipeline that is used to start bath perforation cylinders and alumina dispenser cylinders and aluminum fluoride (AlF_3). Also, the type of the nozzle is different than one used in JISB system.

Compressor station has five compressors in which each compressor has a capacity of 37,7 m^3. Maximum operating pressure is 10 bars and the current pressure is 8.5 to 9 bars. Compressed air is supplied directly to superstructure of the cells. Connection to installation of the compressed air is made at the entrance of the pipeline in the superstructure of the cell.

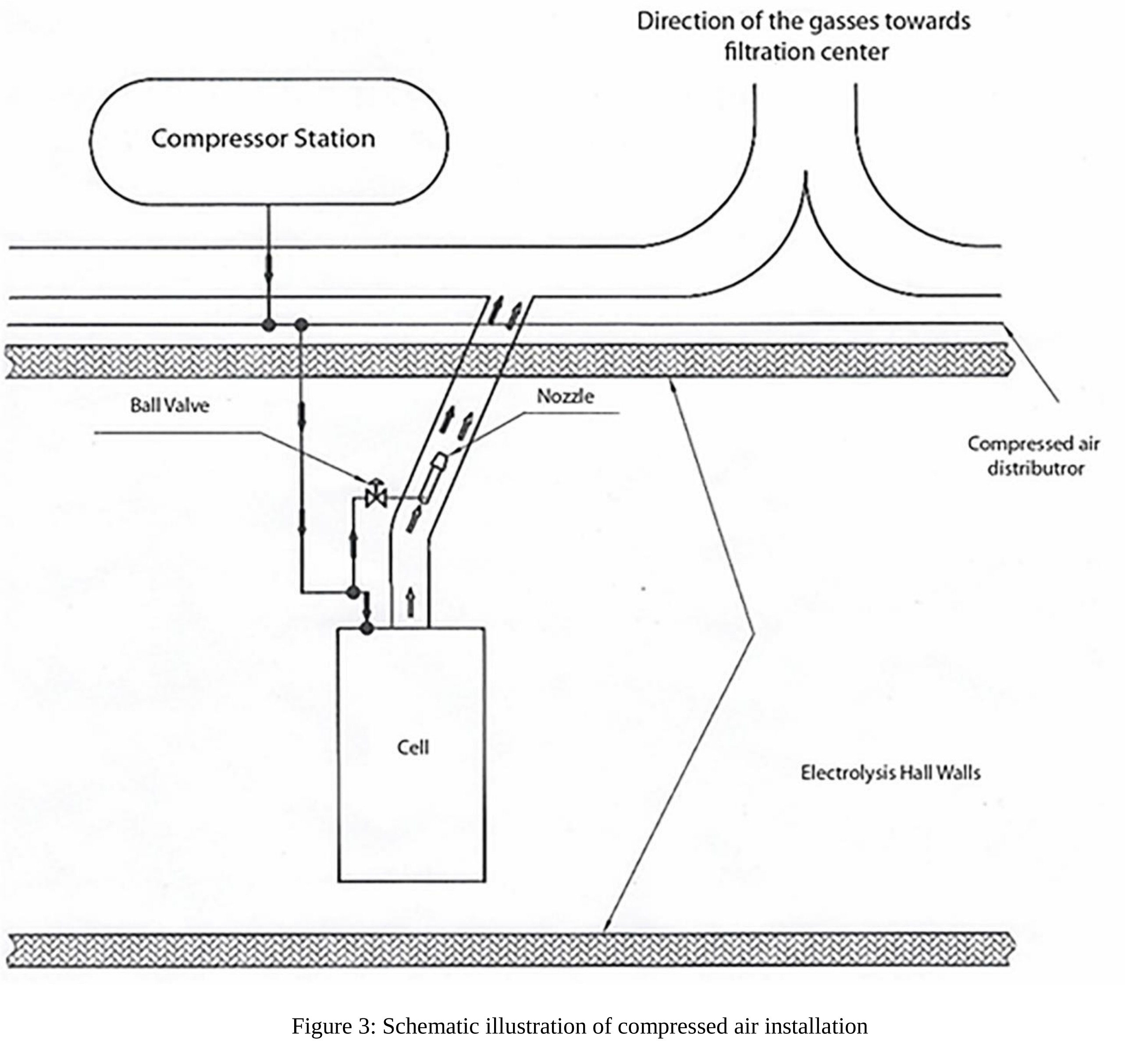

Figure 3: Schematic illustration of compressed air installation

The nozzle for the operating fluid is incorporated in gas discharge tube from electrolytic cells to the filtration center. During the installation of the system, the cell currently stays out of compressed air and, therefore, a very important factor is a system speed installation in order to avoid disturbances in the cell. Before the start of the operation of replacing the anodes and extraction of metals, the operational fluid, i.e. compressed air is passed by a ball valve.

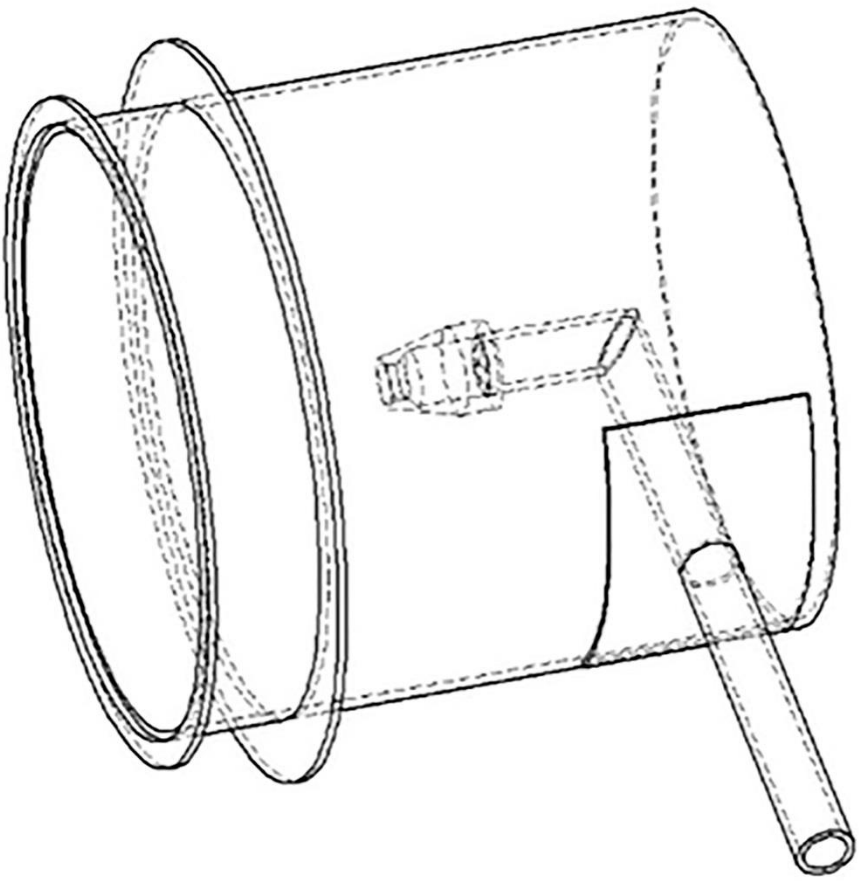

Figure 4: Nozzle in the pipe

The system is installed to a group of 32 cells. Measurements shown in the *Table 1*, were done by differential pressure gauge with the range from -137 to + 137 bars.
The results of negative pressure on certain cells were below the average of other cells and, upon turning on the built-in system, errors of the bath perforator occurred at the same cells. The reason for this is, most likely, the system pressure drop. Subsequently, cartridge filters of compressed air are changed after which the results were similar to results from other cells.
As shown in the *Table 1*, a significant increase in negative pressure is obvious at all cells with installed system. In average, negative pressure is increased for 130% (from -2,7 mbar to -6,2 mbar)

Cell Number	System Off	System On
1	-1,8	-4,7
2	-2,1	-6,6
3	-1,9	-6,8
4	-2,0	-6,2
5	-2,2	-5,5
6	-2,3	-6,8
7	-2,3	-6,3
8	-2,7	-6,9
9	-1,9	-4,4
10	-2,7	-6,3

11	-2,1	-5,7
12	-2,3	-5,9
13	-2,5	-5,0
14	-2,1	-5,7
15	-3,6	-5,6
16	-3,9	-8,1
17	-2,8	-5,0
18	-3,0	-5,9
19	-3,5	-6,4
20	-3,3	-5,9
21	-2,0	-5,3
22	-3,1	-6,7
23	-3,7	-7,9
24	-3,7	-7,9
25	-3,2	-6,9
26	-3,3	-6,2
27	Off	
28	-3,5	-8,0
29	-3,2	-6,7
30	-2,0	-5,9
31	Off	
32	-2,0	-4,7
Average	-2,7	-6,2

Table 1: Measurement results

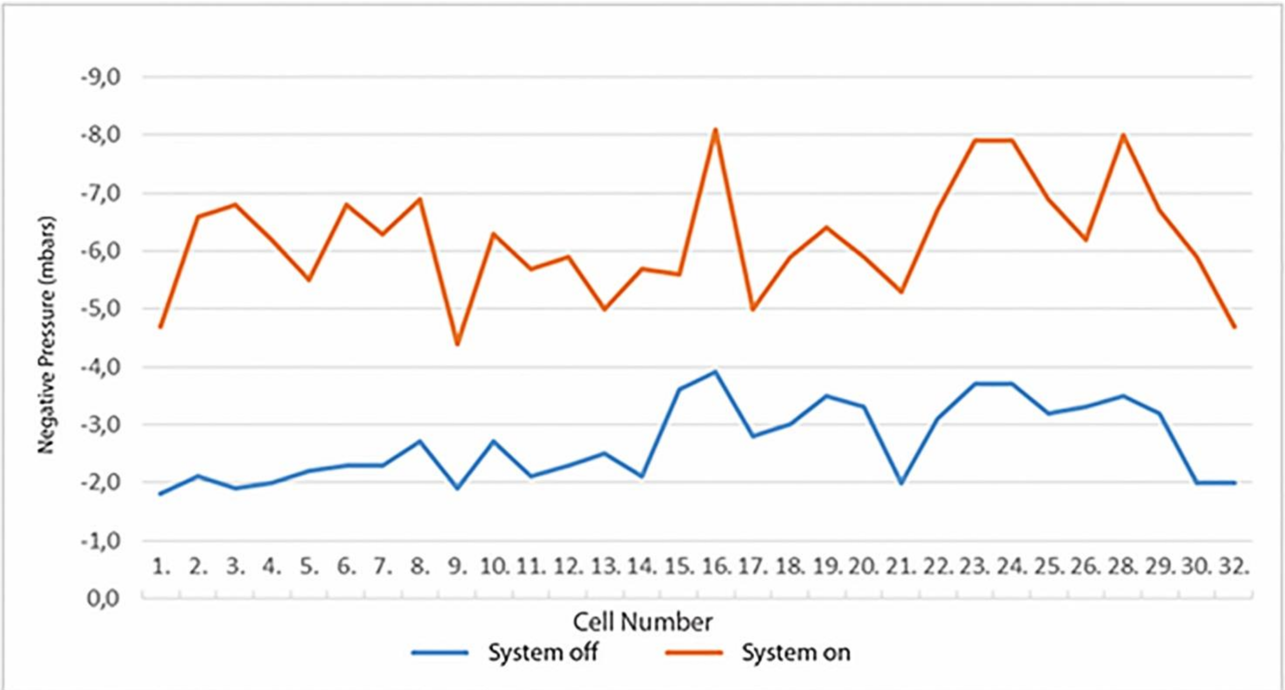

Figure 5: A diagram illustration of the measurement results

5. Conclusion

As mentioned in the introduction, the aim of this study was, with own resources and minimum investment, to develop a system which will help to increase the negative pressure in the electrolytic cell and thus reduce emissions of waste gases in the electrolysis hall and the environment.

The system that was installed at 32 electrolytic cells is completely developed with own resources. Measuring the negative pressure at these 32 cells, the increase for approx. 130% was registered. Installation and commissioning of the complete system takes about 10 minutes, and without obstruction of the technological process of production of primary aluminum. If further measurements of working conditions in cell environment prove that the installation of the system reduced emissions of HF in the hall of Electrolysis, considering investing in automating of the developed system will be intense. This means automatic start of the system for increase of the negative pressure on the cell control panel during aluminum tapping and anode replacing.

In addition please note that:

- Norsk Hydro Aluminium in its literature [7] with its system predicts increase of suction, i.e. gas flow from elecrolytic from 5000 Nm3/h to 15 000 Nm3/h
- AP Technology in its literature [8] with its system predicts icrease of suction, i.e., gas flow from the electrolytic cell as 2x the nominal base flow

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