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ALUMINA and BAUXITE

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DECREASE OF HEAT CONSUMPTION AT NEPHELINE PROCESSING TO ALUMINA AND BY-PRODUCTS

Vladimir G. Kazakov[1], Vadim A. Lipin[2]

[1]St. Petersburg State Technologic University of Plant Polymers
4, Ivana Shernykh st., St. Petersburg, 198095, Russia
[2]St. Petersburg State Polytechnical University
29, Polytechnicheskaya st., St. Petersburg, 195251, Russia

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Abstract

The technological and heat engineering substantiation for a new process arrangement for nepheline production using the sintering process is presented. In this process desilication of aluminate liquor and evaporation of a soda liquor is combined in one stage. As a result the thermodynamic performance (exergic efficiency) increased from 70 to 90% and the steam requirement decreases 1.6 together with improvements in operational reliability of equipment.

Introduction

The processing of non bauxite raw materials, including nepheline, is still carried out in regions with limited quality or economic availability of bauxite.

Nepheline is valuable chemical raw material. Nepheline can be sintered to produce alumina, cement, potash, soda and gallium, etc. [1-4].

The advantage of the sintering method in comparison with the Bayer method is that a reduced amount of waste can be achieved, provided, all the products can be sold.

The disadvantages include the use of more power, fuel and steam. This results in a very high energy consumption, the reduction of which is the subject of this paper.

Steam vapour is mainly used in two processes, namely autoclave desilication of aluminate liquor and concentration of carbonate liquor, which combined consume process energy of 10-12 GJ/t of alumina.

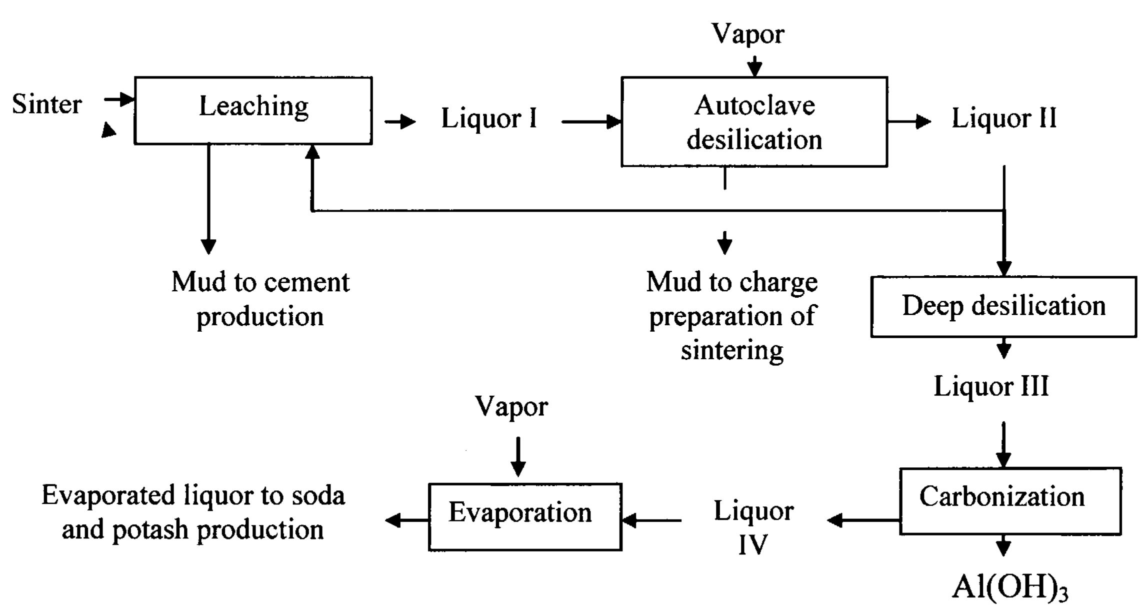

Figure1. Existing diagram of aluminate liquors received from nepheline by sintering method processing

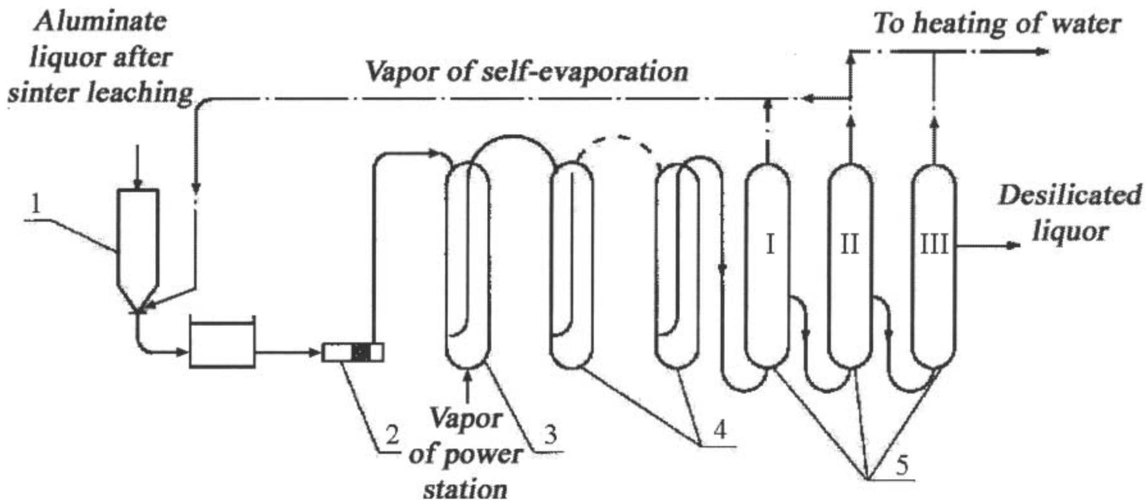

Figure 2 Schematic hardware-technological flowsheet of autoclave desilication

The autoclave flow sheet and use of exergic analysis

The purpose of autoclave desilication is the reduction of silica in liquor as a means of reducing alumina in the alumina product. This process consumes energy in the form of heat of nearly 6 GJ/t of alumina.

In autoclave desilication process as shown in Fig 2, the aluminate liquor after sinter leaching is heated to 70C (liquor 1) using the steam vapour from the desilication vessels. It is then pumped to an autoclave heated to 80-85C, using steam vapour from a thermal power station. Liquor overflows from one autoclave to the next.
Next, the aluminate liquor is concentrated in three steps of self evaporation as the pressure of each stage is reduced by self throttling.
Vapour from the first and second stages is used to heat the incoming liquor, vapour from the third stage is used to heat water for technological needs.

An estimation of the thermodynamic performance of each element of the desilication process has been carried out by an analysis of the exergy increment (5) and results are shown in Table 1.[5]. This shows that the exergic efficiency of this process is low at 64.41%. Consideration of thermal processes proceeding in consistently connected elements of existing method of autoclave desilication shows that throttling of aluminate liquor are characterized high exergic efficiency (92,46, 90,55 and 88,5 %). The total supply of exergy to throttling makes up 27,11 % from the general exergy brought in autoclave desilication.

Supply of heat in heating autoclaves for heating of aluminate liquor up to reactionary temperature is characterized low exergic efficiency (65,91 %) with portion of exergy supply in this process of 44,28 %. Low exergic efficiency in this stage results in a low exergic efficiency of heat scheme of autoclave desilication as a whole.

Thus from the power point of view autoclave desilication could be improved.

In the autoclave desilication process there is an intensive scaling up of surfaces of heat-exchange and reactionary equipment by sodium hydroaluminum silicate. This is also an area for hardware-technology improvement.

Exergic efficiency of the process can be essentially increased by increase in the internal regeneration of heat of cooperating heat streams. Such a technique is possible by the reorganization of heat exchange between desilicated liquor and the liquor acting on desilication. The practical realization is possible after overcoming the scaling of heat-exchange equipments by sodium hydroaluminum silicate scum.

The technological scheme of evaporation at the stage of carbonate liquor concentration and it exergic test

Concentration by evapouration during production of soda and potash is the main consumer of vapour from the thermal power station.

Neutralized carbonate liquor contains from 3000 up to 5000 mole of waters on 100 mole of dry salts and is very far from saturation by salts which is reached at content 1100-1200 mole of waters on 100 mole of salts. Therefore water as a solvent is removed prior to the precipitation of soda from carbonate liquor.

Evaporation is putting into practice in four-case evaporator (Fig 3). Vacuum in last case of evaporating battery is created by the barometric condenser. The condenser is cooled by water from system of a water-turn. Not condensed gases delete by water-ring vacuum pumps.

Table 1 Exergic characteristics of autoclave desilication

	Name of process	Input exergy		Exit exergy		Exergic efficiency of process, %
		GJ/t Al_2O_3	Portion in total admission exergy, %	GJ/t Al_2O_3	Portion in total admission exergy, %	
1	Heating of aluminate liquor	0,42	10,45	0,27	6,72	63,31
2.	Heating of liquor in autoclave	1,78	44,28	1,17	29,10	65,91
3	Throttling of liquor at first stage of self-evaporation	0,34	8,46	0,31	7,71	92,46
4	Throttling of liquor at second stage of self-evaporation	0,45	11,19	0,41	10,20	90,55
5	Throttling of liquor at third stage of self-evaporation	0,30	7,46	0,26	6,47	88,5
6	Heating of washing water	0,54	13,43	0,33	8,21	61,49
7	Throttling of vapor from power station to consumer	0,19	4,73	-	-	-
	Total	4,02	100	2,75	68,41	68,41

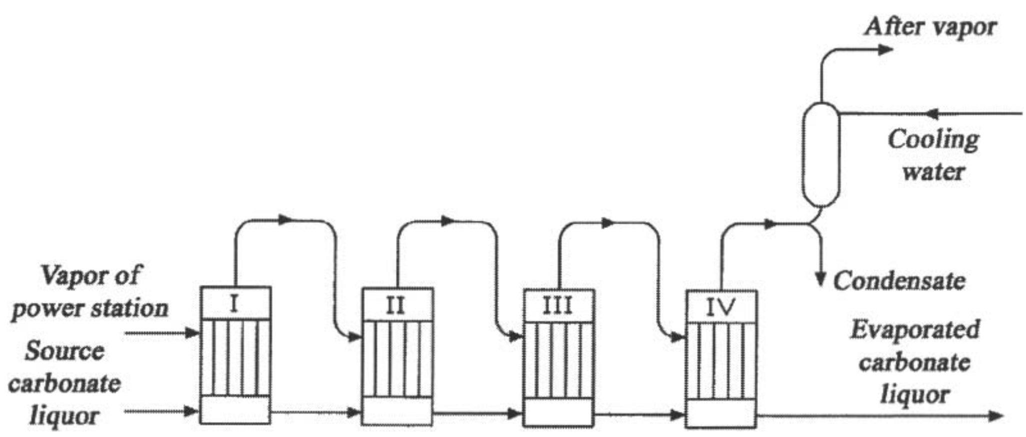

Figure 3. Schematic hardware-technological flowsheet of carbonate liquor concentrating evaporation

As it is known in the direct-flow circuit design of evaporation the solution arrives in case overheated in relation to the temperature of boiling of solution in the subsequent evaporator. When the solution arrives in the evaporating device, it boils. It accepts temperature of boiling of a solution in this device.

Working of the evaporating battery is characterized by the high specific charge of vapor (0,4 - 0,5 t/t of H_2O).

For the purpose of estimation of thermodynamic perfection degree of the heat processes proceeding in components of concentrating evaporating battery it is executed exergic the analysis based on the method of exergy increment[5].

Exergy analysis of the characteristics of the process of evaporation of the solution can be concluded that the exergy efficiency of this process is low and is 66%. This efficiency is defined as the heat processes of evaporation in 1-st and 4-th cases with efficiency of 73 % and 63 % accordingly at 53 % of the input exergy in these processes, the total exergy of the input elements in the evaporation process. Evaporation is characterized by the great value allocated exergy in the environment with material streams on an output from 4-th case of the evaporating battery. This value is about 12% of the total exergy of the input elements in the evaporation residue concentrating.

The low exergic efficiency of evaporation in 1-st case is a consequence of the irreversibility of heat process of liquor heating up to boiling temperature.

The low exergic efficiency of 4-th case is a consequence of the high degreee of thermal process irreversibility in this case.

Total exergic characteristics of autoclave desilication of aluminate liquor and evaporation of soda liquor and the recommendation under the new scheme

Total exergic characteristics of autoclave desilication of aluminate liquor and soda liquor evaporation are shown in Table 3.

Exergic efficiency of similar processes is insignificant (69 % autoclave desilication and 66 % evaporation at total exergic efficiency 67 %.

The advanced scheme of aluminate liquors processing and it exergic the analysis

Autoclave batteries of aluminate liquor desilication and evaporation of carbonate liquor exergic have revealed the general elements and sequence of technological operations and to offer the advanced scheme of aluminate liquors processing (Fig 3).

Evaporation of high silica aluminate liquor with step heating of initial liquor to reactionary temperature in the heat exchanger of mixtures and the specified time limit of ageing before receipt of aluminate liquor in the first case of evaporating battery with the greatest completeness answer the provision of requirements of thermodynamic efficiency increase.

In the suggested scheme of technology of heat the technological function of autoclave desilication is kept but without consumption of vapor from an external source. Autoclave desilication of aluminate liquor in the suggested technology to minimize holding of the liquor at the reactinary temperature.

Self-evaporation of aluminate liquor aand the passage of the first case in the last case is characterized high exergic efficiency. Self-evaporation of aluminate liquor promotes increase in intensity of heat exchange in boilers of evaporating devices by exception of single-phase preboiling range and reductions of zone of superficial boiling.

Technological advantages of the advanced scheme are high efficiency of use of heat energy of vapor, absence of encrusted adjournment on walls of equipment, and also a barometric condenser and allied with it capital and operational expenses.

A design for the direct-flow diagram of evaporation of high silica aluminate liquor is shown in Fig 5. The results of heat calculation of evaporation indicates that such scheme is characterized by the low specific charge of vapor (0,29 t/t of evaporated water). Thus a consumption of vapor to autoclave desilication is minimized.

The analysis of exergic characteristics (Table 4) allows one to draw a conclusion about a high thermodynamic performance (exergic efficiency is characterized by value of 92,42 %) proposed for the process of evaporation of high silica aluminate liquor. Exergic fluxes brought to evaporating devices have close values. Combined they make a value of 79 % from general brought exergy in system and define general exergic efficiency of the evaporating battery.

Exergic efficiency of heaters has also high value. In heaters 0 - 4 they are at a level of 98 %.

Table II. Exergic characteristics of soda liquor concentration

	Name of process	Input exergy		Exit exergy		Exergic efficiency of process, %
		GJ/t Al_2O_3	Portion in total admission exergy, %	GJ/t Al_2O_3	Portion in total admission exergy, %	
1	Evaporation of liquor at first case	1,48	31,03	1,11	22,64	72,96
2	Evaporation of liquor at second case	0,73	15,44	0,59	13,13	85,04
3	Evaporation of liquor at third case	0,85	17,75	0,72	14,82	83,49
4	Evaporation of liquor at fourth case	1,12	23,41	0,71	15,02	64,16
5	Removal of heat stream with vapor of fourth case	0,59	12,37	-	-	-
	Total	4,77	100	3,13	65,61	65,61

Table III. Total exergic characteristics of aluminate liquor autoclave desilication and carbonate liquor evaporation

	Name of process	Input exergy		Exit exergy		Exergic efficiency of process, %
		GJ/t Al_2O_3	Portion in total admission exergy, %	GJ/t Al_2O_3	Portion in total admission exergy, %	
1	Autoclave desilication of aluminate liquor	4,02	45,76	2,76	31,40	68,62
2.	Evaporation of sodium liquor	4,77	54,24	3,15	35,84	66,08
	Total	8,79	100	3,13	67,24	67,24

Table IV. Exergic characteristics of evaporation of high silica aluminate liquor

	Name of process	Input exergy		Exit exergy		Exergic efficiency of process, %
		GJ/t Al_2O_3	Portion in total admission exergy, %	GJ/t Al_2O_3	Portion in total admission exergy, %	
1	Heat process at first case of evaporator	1,01	19,16	0,95	18,03	94,10
2.	Heat process at second case of	0,94	17,84	0,87	16,51	92,54

	evaporator					
3	Heat process at third case of evaporator	0,84	15,94	0,78	14,80	92,85
4	Heat process at fourth case of evaporator	0,74	14,05	0,67	12,71	90,46
5	Heat process at fifth case of evaporator	0,62	11,76	0,56	10,63	90,39
6	Heat process at heater of liquor number 0	0,06	1,14	0,06	1,14	100
7	Heat process at heater of liquor number 1	0,15	2,85	0,15	2,85	98
8	Heat process at heater of liquor number 2	0,13	2,47	0,13	2,47	98
9	Heat process at heater of liquor number 3	0,12	2,27	0,12	2,27	98
10	Heat process at heater of liquor number 4	0,11	2,09	0,11	2,09	98
11	Heat process at heater of liquor number 5	0,28	5,31	0,24	4,55	85,71
12	Heat process at heater of liquor number 6	0,27	5,12	0,23	4,36	85,16
	Total	5,27	100,00	4,87	92,42	

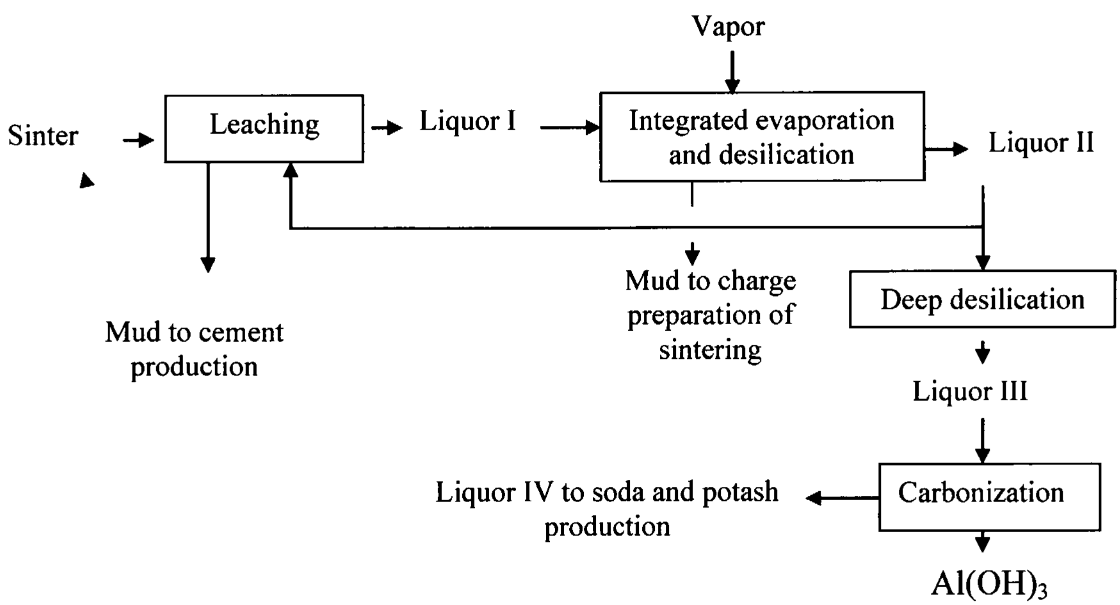

Fig. 4 Advanced flowsheet processing of aluminate liquors received from nepheline by sintering method

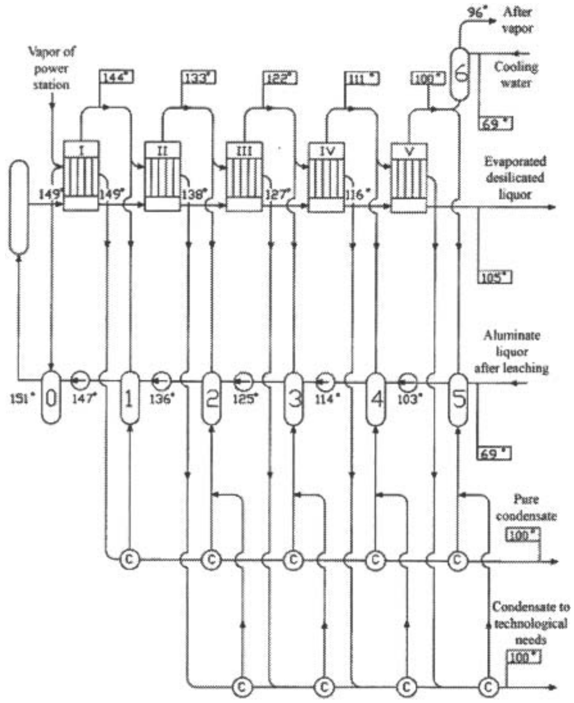

Fig.5. The advanced hardware-technological flowsheet of high silica aluminate liquor evaporation:
I, II.. V – case of evaporating devices;
0,1 ... 6 - heaters of mixture;
C-self-evaporators.

Conclusion

An energy increments method was carried out to calculate the technological processes of autoclave desilication of aluminate liquor and evaporation of carbonate liquor.

It was found that the process of the autoclave desilication is characterized by low (65,91 %) exergic efficiency. The main processes influencing the exergic efficiency are heating of barometric water and aluminate liquor.

The analysis of exergic streams distribution in concentrating evaporation shows that process of evaporation is characterized by low exergic efficiency (~66 %). The efficiency of the thermal processes of evaporation in 1-st and 4-th case have with an efficiency of 72,7 % and 63,4 % accordingly at 53 % brought exergy in these processes from general brought exergy. Besides evaporation is characterized by a large value of allocated exergy in an environment with material streams on an output from 4-th case of the evaporating battery. This value makes up 12,4 % from general brought exergy in members of concentrating evaporation.

The aluminate liquor autoclave desilication and carbonate liquor such as the thermodynamic system is characterized low exergic efficiency namely 67,12 % that causes high specific charge of steam from thermal power station namely 12,86 GJ/t of alumina.

On the basis of exergic and technological analyses of processes of aluminate liquor autoclave desilication and carbonate liquor evaporation the advanced five-interrupted scheme of aluminate liquor evaporation with heaters and preliminary keeping of liquor before its coming in the first case of evaporator has been devised.

The high efficiency of the advanced scheme is set. Exergic efficiency makes up 92,42 %, the specific charge of vapor makes up 5.03 GJ/t of alumina.

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