AA02 - Technology Options for Mixed Bauxites

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Abstract

The choice of digestion technology for a new alumina refinery depends on the type of bauxite proposed to be used. For a predominantly gibbsitic bauxite with low levels of boehmite, it is generally accepted that a temperature of 140-150 °C attained finally in an autoclave is the technology choice (other than a very few refineries that operate at 100-105 °C). For mixed bauxites, however, there are different options; single or two stage digestion, tube or autoclave digesters, range of temperatures etc. Each of these options has its own pros and cons. This paper presents the details of these options and compares the broad differences with respect to equipment configurations especially Flash stages, heaters, and evaporation. The effect of boehmite content on these, as well as on efficiency and consumption parameters are evaluated using heat & mass balance calculations.

Keywords: Mixed bauxite, boehmitic bauxite, tube digestion, double digestion, digestion technology.

1. Introduction

Alumina is present in bauxite mainly as its hydroxide form apart from some associated with silica and goethite. There are three forms of alumina hydroxides (or "hydrates"). These are; i) gibbsite or tri-hydrate alumina ($Al(OH)_3$ or $Al_2O_3.3H_2O$), ii) boehmite or mono-hydrate alumina ($AlOOH$ or $Al_2O_3.H_2O$), and iii) diaspore, another form of mono-hydrate. Bauxite is the primary raw material for the over-whelming majority of alumina production is of three distinct types; i) tri-hydrate or gibbsitic bauxite (with very low mono-hydrate content), ii) mixed bauxite, typically consisting of significant proportions of both gibbsite and boehmite, and iii) mono-hydrate bauxite consisting mainly of boehmite or diaspore.

Total global bauxite reserves are estimated to be about 30 billion tonnes whereas the total production in 2019 was about 370 million tonnes [1]. The total alumina production in 2019 was about 132 million tonnes including 8.4 million tonnes of chemical grade alumina [2]. The list of top 10 countries with largest bauxite reserves as of 2019 is presented in Figure 1 [1].

It should be noted that Cameroon is emerging as a country with a large bauxite reserve and so, the above list will undergo changes in the coming years.

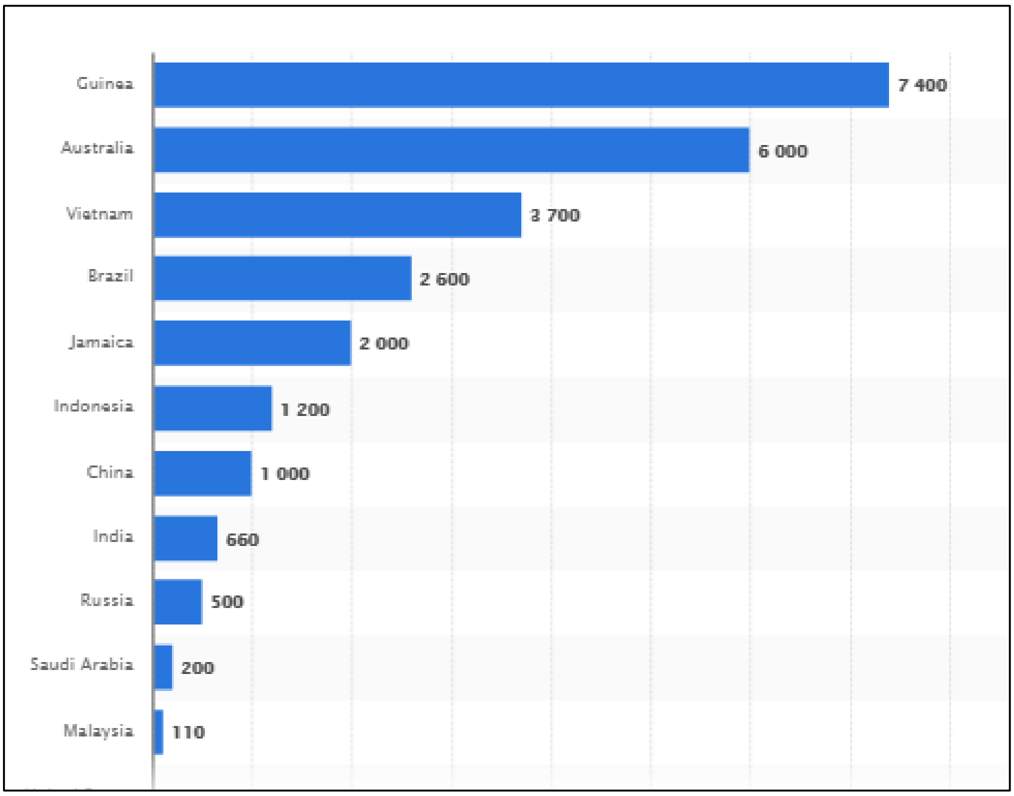

Figure 1. Top 10 countries with largest bauxite reserves- 2019 (million tonnes).

The deposits of Guinea, East Coast of India, Suriname and Brazil are generally gibbsitic bauxites. Deposits in Europe, Middle East and China are generally mono-hydrate bauxites. The rest of the deposits are mixed bauxites as defined above.

When a new alumina refinery is being designed, the choice of digestion technology becomes a particularly important design criterion. This mainly depends on the type of bauxite that is expected to be processed in that refinery over its design life. Gibbsitic bauxites are typically digested at a temperature of 140-150 °C. Mixed bauxites need about 240-250 °C for economic recovery of alumina content. Monohydrate or diasporic bauxites, however, need very high temperatures of 270-280 °C. There are of course instances of a refinery processing gibbsitic bauxite with only about 2-3 % boehmite opting for a temperature of about 240 °C, so that even the low content of boehmite is not lost, which does depend on the overall economics. Similarly, there have been instances of remarkably high temperature (270-280 °C) digestion technology being chosen for the mixed bauxites having 3-5 % boehmite only, based on the assessment by the Technology provider.

This paper deals with the various options available as digestion technology for Mixed bauxites and evaluates the possible effects of boehmite content on various design aspects.

2. Digestion Technologies

The two main process efficiency requirements while processing any bauxite are: 1) Maximum possible alumina extraction and 2) Maximum possible and satisfactory desilication of sodium aluminate liquor at the digestion stage. Maximum alumina extraction ensures all the alumina values that can be, are recovered, so as to minimise bauxite consumption and that the bauxite residue has a minimum alumina content. Maximal desilication ensures that scaling issues in the heat exchangers and pipelines are minimized, as is also silica impurity content in product.

2.1 Tri-hydrate or Gibbsitic Bauxites

As mentioned previously, gibbsitic bauxites are generally processed at a digestion temperature of 140-150 °C using pressure autoclaves. At these temperatures and corresponding pressures, the gibbsite content in bauxite reacts with caustic soda rapidly (within about 10 minutes) to form sodium aluminate. The total digestion time, however, depends on the desilication requirement, which is aided by the presence of a pre-desilication step, performed in large tanks under atmospheric conditions, typically at 90-100 °C.

Some refineries employ digestion at about 105 °C under atmospheric pressure conditions at very high caustic soda concentration, followed by a post-desilication step to bring silica under control. However, only a handful of refineries practice this technology currently, and this paper will not address this technology and approach in detail.

A generalized block flow diagram for a low temperature digestion process used for gibbsitic bauxite is presented in Figure 2.

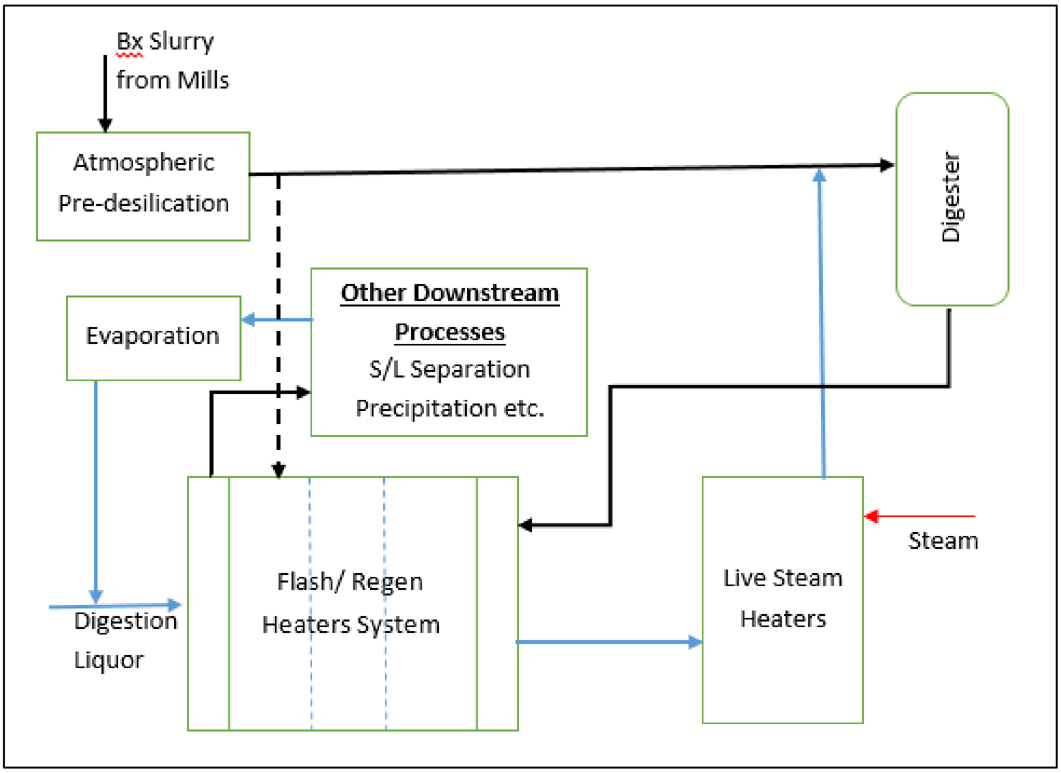

Figure 2. Simplified block diagram for tri-hydrate or gibbsitic bauxite.

There are two variations that are practiced. The first is “Dual Streaming”, where the spent liquor - after evaporation and fresh caustic addition - (called ‘digestion liquor’ in this paper) is heated to above 170 °C separately in regenerative and live steam heaters and mixed with pre-desilicated bauxite slurry at about 95 °C before they are sent to the autoclave pressure digesters. The second is “Single Streaming”, where the pre-desilicated bauxite slurry is mixed with digestion liquor prior to being heated together in regenerative and live s team heaters. Injection of steam is often required inside the autoclave pressure digesters to achieve and maintain the required digestion temperature. The number of flash stages and the corresponding regenerative heaters is generally 3 or 4.

2.2 Mixed Bauxite

2.2.1 Direct High Temperature Digestion, DHTD

One option for mixed bauxite, "Direct High Temperature Digestion" (DHTD), which has been used over the years in many refineries, is essentially the same as the single streaming process, other than the temperature involved, which will be about 250 °C inside the digesters. The temperature of slurry leaving the heaters is limited to 210-220 °C due to caustic embrittlement and silica scaling issues, and to minimise titanium scales. Hence, injection of high-pressure steam inside the digesters is essential to attain and maintain digestion temperature of about 250 °C, as depicted in Figure 3. The number of flash stages would be 7-10 depending on the final digestion temperature.

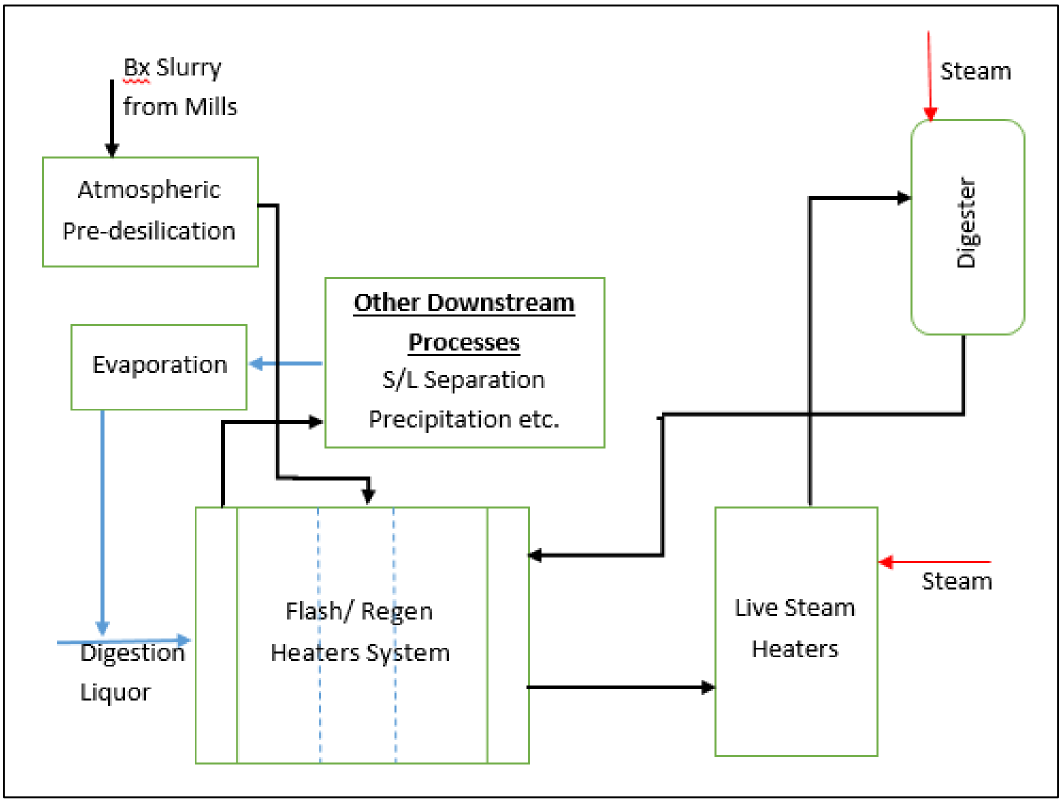

Figure 3. Simplified block diagram for mixed bauxite – DHTD.

2.2.2 Double Digestion, DD

In the last two decades or so, a new concept called "Double Digestion" has been reported and some refineries processing mixed bauxites have already been converted to this technology. The gibbsite content in bauxite is extracted in a low temperature digestion (LTD) section at 140-150 °C. The resultant pregnant liquor and residue is quickly separated using pressure decanters, before the residue containing un-extracted gibbsite (if any), boehmite in bauxite, and any reverted boehmite, is digested in a high temperature digestion (HTD) section at 220-250 °C.

Two alternatives are possible in applying the double digestion concept. The first is "Co-current Double Digestion" (DDCo), wherein digestion liquor is passed through both the LTD and the HTD sections and is mixed after residue separation. The second is "Counter-current Double Digestion" (DDCt), wherein digested liquor from the HTD section is recirculated to the LTD section after residue separation, along with the required quantity of original digestion liquor.

The general block diagrams of DDCo and DDCt are presented in Figures 4 and 5.

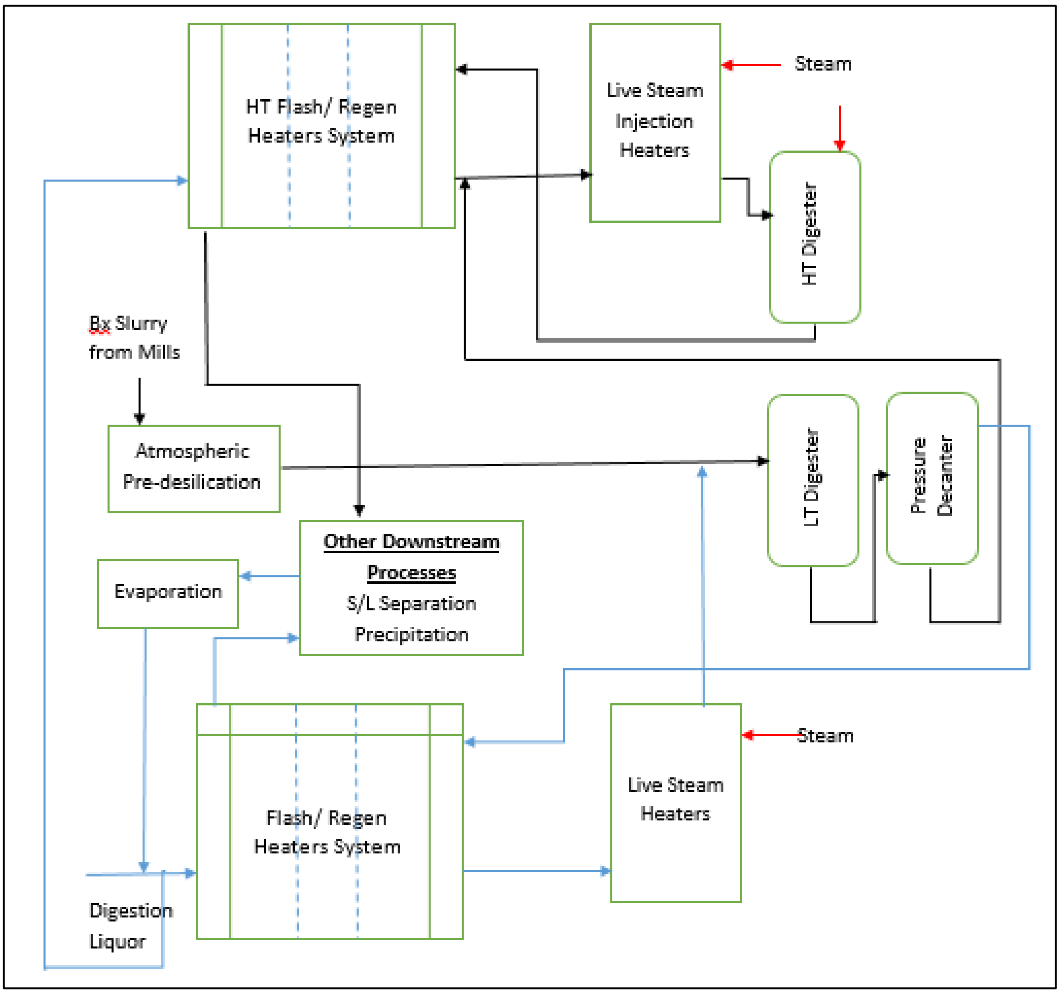

Figure 4. Simplified block diagram for mixed bauxite – DDCo.

The proportion of the digestion liquor in the LTD and HTD sections depend very much on the gibbsite and boehmite contents in the bauxite, the total extractable alumina content in the residue after LTD and also the final A/C of the pregnant liquor targeted. There may be a requirement to pass flash vapour and hot liquor between HTD and LTD sections in order to maintain heat balance.

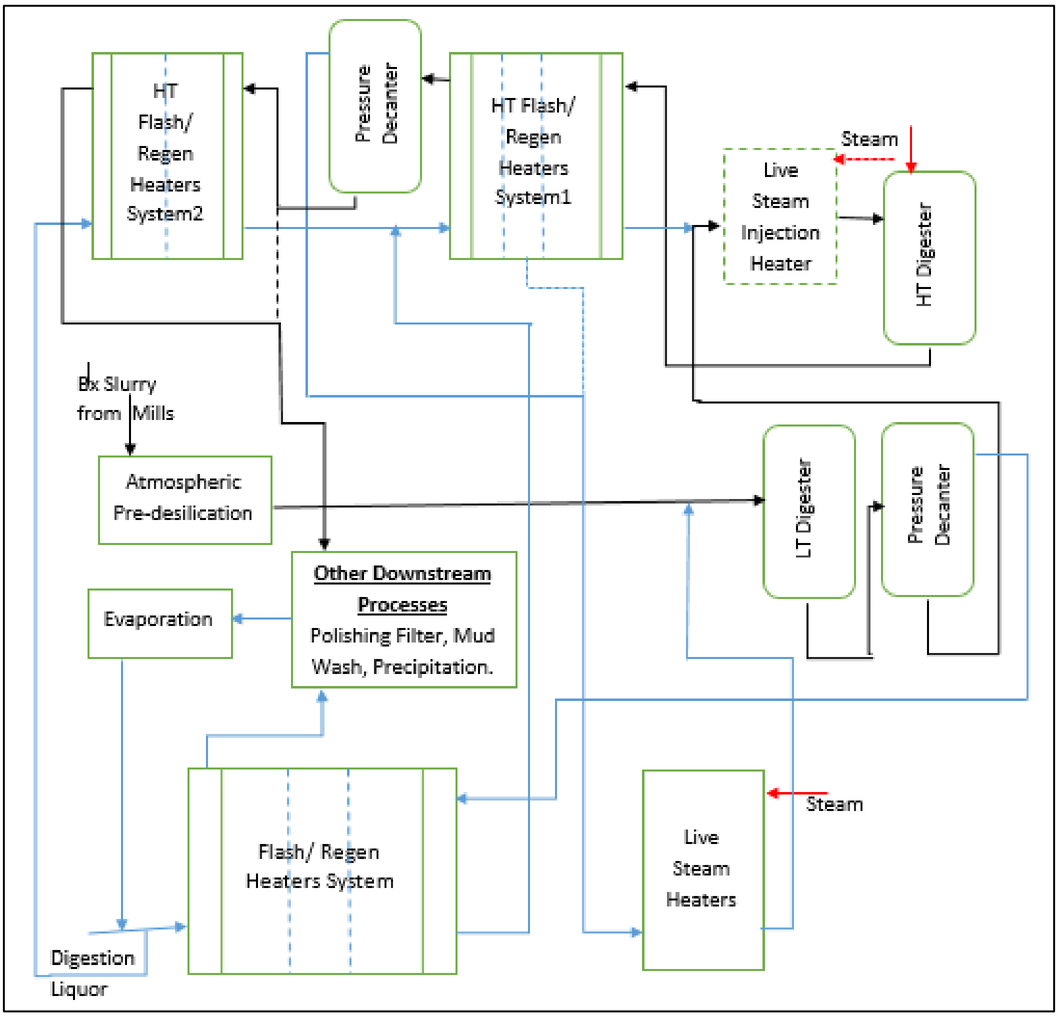

Figure 5. Simplified block diagram for mixed bauxite – DDCt.

2.2.3 Tube Digestion, TD

Tube digestion technology (TD), was mainly developed for mono-hydrate bauxites, as detailed in the next section, but is increasingly being used for mixed bauxites in recent years. A simplified block diagram is presented in Figure 5 in Section 2.3. For mixed bauxites, some variations from the general arrangement presented are possible. These may be the avoidance of evaporation altogether, the use of pressure autoclaves, etc.

2.3 Mono-hydrate Bauxite

Mono-hydrate bauxites containing predominantly boehmite or diaspore need very high processing temperatures of the order of 270-280 °C (and sometimes higher). Since the traditional methods of heating the liquor and bauxite slurry and digesting in pressure autoclaves at these high levels are not economically viable or practicable, tubular heaters and tube digesters had been developed and are being used in many refineries currently.

A general block diagram of the tube digestion process is presented in Figure 6.

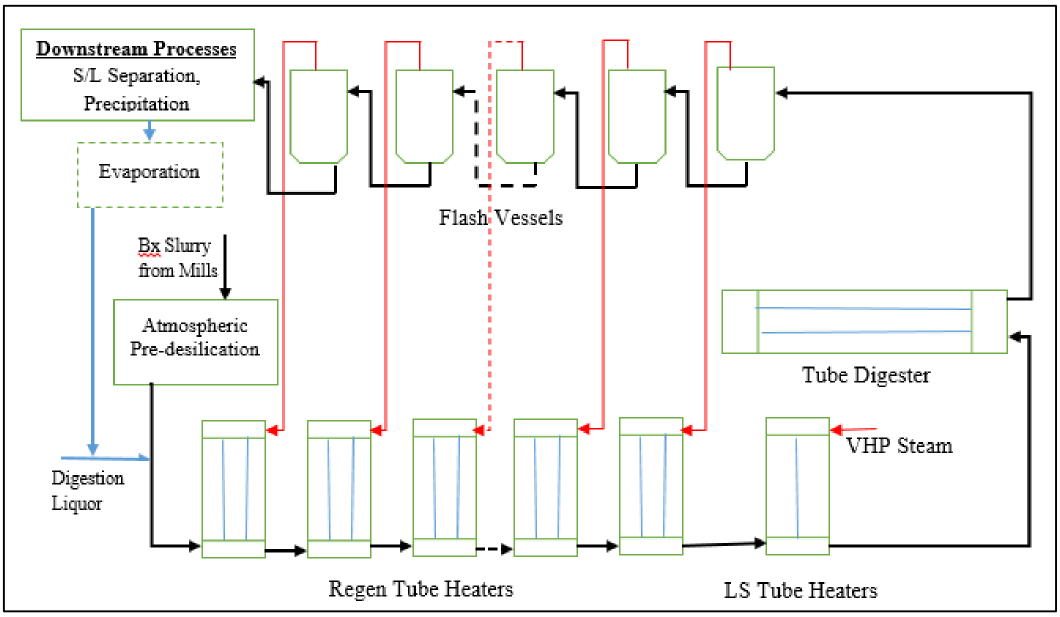

Figure 6. Simplified block diagram for mono-hydrate bauxite – tube digestion.

2.4 Design and Operation Aspects for Mixed Bauxites – Effect of Boehmite Content

Preliminary calculations were made for the design of the digestion and related sections of an alumina refinery which propose to process mixed bauxite. Iterative heat and mass balance calculation were done across the system. For this exercise, two bauxite qualities are considered. These are designated as Bx-1 and Bx-2. The extractable alumina values for these bauxites are given below:

	Tri-hydrate alumina, THA (or) gibbsitic alumina	Mono-hydrate alumina, MHA (or) boehmitic alumina
Bx-1	35 %	6 %
Bx-2	30 %	11 %

Three options; DDCo, DDCt and TD, are considered for comparative evaluation. Appropriate assumptions have been made with respect to boehmite reversion in the LTD section and boehmite extraction in HTD section. Digestion temperatures have been chosen based on experience. A nominal annual capacity of 0.8 million tonnes is considered. For plant capacities of 1.6 million tonnes and above, some of the downstream sections can be combined into one train although the digestion and related sections will be of 2 trains.

Of course, it should be mentioned that before any design is evaluated for an actual case, the corresponding bauxite needs to be tested thoroughly. This is to ensure that the optimum process conditions of pre-desilication temperature and time, digestion temperature, time, caustic concentration, target A/C etc., are chosen for the design.

A summary of the results of the evaluation is presented in Tables 1-3.

Table 1. Summary of results – design aspects - effect of boehmite.

Design Aspects		**Bx-1 (35/06)**			**Bx-2 (30/11)**		
		TD	**DDCo**	**DDCt**	**TD**	**DDCo**	**DDCt**
LTD Section							
No. of LP Flash Tanks & Regen. Liquor Heaters/ UA	MCal/h C		3/ 600	3/ 800		3/ 600	3/ 800
No. of LP Live Steam Liquor Heaters/ UA			1/ 600	1/ 2000		1/ 600	1/ 1500
HTD Section							
No of LP Flash Tanks & Regen. Liquor Heaters/ UA	MCal/h C		4/ 1200			4/ 1200	
No of LP Flash Tanks & Regen. Slurry Heaters/ UA		4/ 1100			4/ 1100		
No of HP Flash Tanks & Regen. Liquor Heaters/ UA			2/ 500	4/ 1300		2/ 500	4/ 1300
No of HP Flash Tanks & Regen. Slurry Heaters/ UA		6/ 1100			6/ 1100		
No of VHP Live Steam Slurry Heaters/ UA		1/ 1100			1/ 1100		
General							
Evaporation	t/h	175	290	270	175	290	270

Table 2. Summary of results – operation aspects - effect of boehmite.

Operation Aspects		**Bx-1 (35/06)**			**Bx-2 (30/11)**		
		TD	**DDCo**	**DDCt**	**TD**	**DDCo**	**DDCt**
LTD Section							
Slurry Flow	t/h		1325	1650		1190	1700
No of Pressure Decanter/ Slurry Flow	t/h		1/ 1400	1/ 1650		1/ 1200	1/ 1700
HTD Section							
Slurry Flow	t/h	1620	700	830	1630	985	1200
No of Pressure Decanter/ Slurry Flow	t/h			1/ 800			1/ 1150
General							
No of Atmospheric Decanter/ Slurry Flow	t/h	1/ 1800	1/ 1000		1/ 1850	1/ 1300	
Maximum Steam Pressure	kPa	9200	4400	4400	9200	4400	4400

Table 3. Summary of results – consumption and efficiency aspects - effect of boehmite.

Operation Aspects		**Bx-1 (35/06)**			**Bx-2 (30/11)**		
		TD	**DDCo**	**DDCt**	**TD**	**DDCo**	**DDCt**
Bauxite	t/t	2.663	2.638	2.630	2.740	2.727	2.714
Total Steam	t/t	1.95	1.95	1.97	1.97	2.15	2.06
Overall Recovery	%	91.2	92.4	92.8	88.5	89.5	89.9
Precipitator Liquor Productivity	g/L	83.4	79.5	78.0	83.2	77.2	77.9

Among the three options evaluated for the mixed bauxite, the major differences between the double digestion and tube digestion technologies with respect to design, are the requirement of very high steam pressure, larger numbers of HP flash tank/ heaters and VHP heater for the tube digestion option. This is somewhat compensated by the lower evaporation requirement by about 35-40 %. The whole tube heater system in tube digestion technology option needs to be designed for a slurry flow rate of about 1800 t/h whereas in the double digestion technology options, liquor heaters are only employed for indirect heating.

It is seen from the results that as long as the total of THA and MHA is maintained, the change in boehmite content from 6 to 11 % does not have any effect on the design aspects of digestion and related systems. What changes is of course the operation aspects – slurry flow into digesters and pressure and atmospheric decanters by about 30-45 %. This would call for the design and installation of larger HT digesters and pressure and atmospheric decanters. There is a 5-10 % increase in total steam consumption with the increase in boehmite content.

3. Summary

For the design of a new alumina refinery that proposes to use mixed bauxite containing gibbsite and substantial amounts of boehmite, there are many options for the digestion technology to be considered. These are DHTD, DDCo, DDCt and TD. This paper has evaluated these options and has worked out design considerations for the digestion and related sections of the refinery.

Changes in boehmite content with corresponding reverse changes in gibbsite content in bauxite seem to have little effect on the TD process, whereas the same results in a large change in slurry flow values. This would adversely affect the process or may call for an overdesign initially. Hence, it is essential that bauxite quality with respect to overall extractable alumina, gibbsite and boehmite is controlled within a narrow band when the refinery is in operation.

An evaluation of the three options for a 35 % gibbsitic alumina/ 11 % boehmitic alumina bauxite (details of which are not presented in this paper) also indicate and emphasize the above conclusions.

It is essential that laboratory tests are conducted with representative bauxite (including those that may be considered anomalous) under the conditions of the various options to establish optimum process conditions and also to arrive at overall gibbsite/ boehmite extraction values and boehmite reversion values which are critical inputs to the H&M balance evaluation.

There are pros and cons of each of the technology options examined. These have been discussed elsewhere [3]. A detailed evaluation of capital cost, refinery footprint requirement and equipment, operation and maintenance associated with these options, and of course, the effect on operating cost due to raw material and utility consumption will throw up the most suitable option.

For an existing alumina refinery processing Mixed bauxite employing DHTD technology, the choice for upgrading, either to achieve energy and cost efficiencies or to increase plant capacity, would perhaps be limited to variations of DD technology.

4. References

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