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NEW DEVELOPMENT MODEL FOR BAUXITE DEPOSITS
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DEDICATED COMPACT REFINERY

Peter-Hans ter Weer[1]
[1]TWS Services and Advice, Imkerweg 5, 1272 EB Huizen, The Netherlands; twsservices@tiscali.nl

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1. Abstract

An alternative development approach for bauxite deposits proposed in a TMS 2011 paper[1] results in a more efficient use of resources and lowers the threshold to develop bauxite & alumina projects.

The new approach represents a paradigm shift from "Bigger is Better" to "Smart & Small", and is based on an alumina refinery with the following characteristics:

- **D**edicated plant design and layout, "designing a greenfield plant as a brownfield expansion", resulting in lower capital cost per tonne of alumina (tA) capacity;
- **C**ompact plant production capacity, resulting in a simple and limited scope, further improving capital cost per tA capacity; and
- **S**ustainability embedded in the design.

The current paper explores some aspects of this "**DCS**-model" such as design basis, plant areas, equipment sparing and layout, applied to a 400,000 t/y alumina refinery. Sustainability will be the subject of a separate paper.

2. Starting Point

The TMS 2011 paper showed that the increase in the design / initial capacity of greenfield (bauxite mine and) alumina refinery projects over the past decades had as a major consequence that worldwide only a small number of companies develop mostly very large greenfield bauxite and alumina projects, often taking a decade and more. The paper proposed an alternative approach.

The key aspect of the alternative approach is a dedicated refinery design and layout for a specified production capacity. Loosely put: "*design a greenfield plant as a conventional brownfield expansion*". This means tailoring the design to the equipment and infrastructure requirements (e.g. earth works, power, water supply, piperacks, roads, cable trays) of the selected production capacity. This approach enables optimizing plant layout for the design capacity, it impacts positively on commodity volumes, and puts the focus on a "lean" design. Consequentially the design excludes provisions for future expansions, which should have their own economic justification.

A second important aspect is to apply the dedicated design & layout approach to a compact refinery capacity of ~0.3-0.6 Mt/y (high end limited by the objective to end up with a total project capital cost below 1 billion US$ – the mega project threshold; low end by logistical limitations, i.e. dependent on plant location).

These two aspects result in significantly lower capital cost per tA capacity compared with current plant design[2]. To ensure acceptable economics for the overall project, infrastructure capital should be limited. At the same time such a project has few infrastructural requirements, especially if located close to an existing port.

The third aspect, sustainability, is partly inherent to the new approach (optimized plant layout, lean design, efficient use of resources, low capital cost per tA capacity). Sustainability will be the subject of a separate paper.

The main advantages of the new approach are:

- The smaller project capital cost (lower risk) enables the development of bauxite & alumina projects by smaller companies without a need to form (complex) joint ventures, thus increasing the number of companies potentially interested in developing bauxite deposits. Competition increases, resulting in a more efficient use of (capital and bauxite) resources.
- Small and simple projects carrying less risk require less time to develop, construct & start-up, positively impacting economics.
- Long term alumina refining projects based on this approach require a small bauxite deposit (a deposit of ~40 Mt could support a 0.4 Mt/y project for 30 years), meaning that worldwide the number of bauxite deposits lending themselves to development increases, again improving the use of resources.
- The new development model may be applied also to the development of part(s) of a large deposit.
- In some cases the new approach enables value creation through alumina refining rather than being limited to bauxite export sales (attractive to the host country and to companies developing bauxite & alumina projects).
- An adapted version of the new development model may in some cases enable bauxite deposit development even in locations with little existing infrastructure, albeit at a larger than compact scale.

Note that the proposed alternative approach is independent of the selected refinery technologies. In summary: the key is to purposely do things differently rather than doing different things.

The above approach, dubbed "DCS-model", is illustrated in the current paper for a 400 kt/year alumina refinery.

3. Basis of Design

3.1 Bauxite Quality

Although the **DCS** approach is applicable to all bauxite qualities, the bauxite quality assumed in this paper is shown in Table 1.

Table 1 – Bauxite Quality Used

Item	
Chemical (% w/w, dry basis – except moisture)	
Total Alumina (Al_2O_3)	44.5

[1] Reference [1].
[2] Reference [1], Tables 5 and 6.

Available Alumina[(1)]	38.5
Boehmitic Alumina	1.5
Total Silica (SiO_2)	2.6
Reactive Silica[(1)]	1.6
Iron Oxide (Fe_2O_3)	27.5
Titanium Dioxide (TiO_2)	2.0
Total Organic Carbon (as C)	0.10
Moisture	9.5
Physical	
Bulk Density, t/m^3	1.5
True Density, t/m^3	2.7
Specific Heat, MJ/t/deg C	1.0
Bond Ball Work Index, kWh/t	11.0

(1) At digestion conditions

3.2 Alumina Refining Process

3.2.1 General

The characteristics of the above bauxite quality (mainly Gibbsite, minor Boehmite) enable low temperature digestion in a benchmark version of the Bayer process. Although the **DCS** approach is applicable to all digestion technologies, slurry heating (sometimes called single streaming) has been assumed in this paper as digestion technology. The steam temperature and pressure required for low temperature digestion enables first using high pressure boiler steam for the co-generation of power. This results in an energy and capital efficient refining process.

3.2.2 Main Unit Operations

The main unit operations of the selected refining process are:

- **Grinding and Pre-Desilication** (Figure 1). Bauxite reclaimed from a bauxite stockpile and spent liquor is added to a grinding mill (ball mill assumed). Mill slurry discharge is classified and oversize material is returned. The alumina bearing minerals in the undersize material are sufficiently liberated for extraction in digestion. The dense bauxite slurry discharging from the mill is forwarded to desilication tanks.
- **Digestion** (Figure 1). Bauxite slurry from the last desilication tank is mixed with additional spent liquor in the digester feed tank. Diluted feed slurry is charged to a series of heat exchangers. Process steam released by flash tanks is directed to their related heat exchanger for stage-wise regenerative heating. The last two heating stages operate (partly) on live steam from the steam plant. The discharge from the last heating stage is directed to the digester vessels. Slurry from the last digester vessel is cooled to atmospheric boiling point by stage-wise flashing as described.

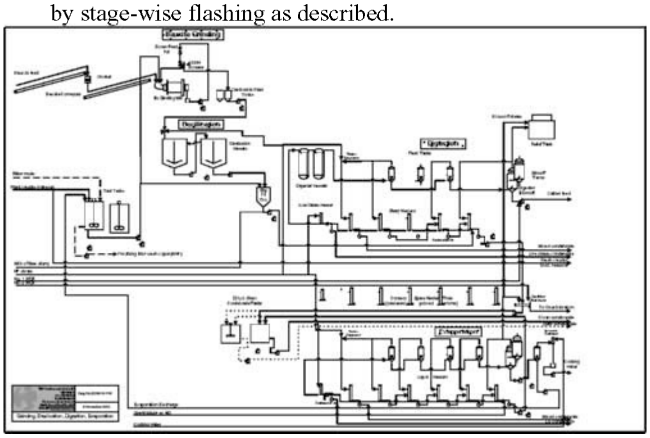

Figure 1 – Grinding, Desilication, Digestion, Evaporation

- **Residue Settling and Washing** (Figure 2). Digestion discharge slurry, at a temperature just below atmospheric boiling point, is directed to a high rate settler / decanter where the bauxite residue ("red mud") is settled and separated from the pregnant / green liquor. The settler underflow slurry with the bauxite residue is sent to a counter current decantation (CCD) wash system for the recovery of dissolved alumina and caustic soda values in the solution adhering to the solids, and the wash liquor stream is combined with the digestion discharge slurry. The CCD system consists of a wash train comprising a number of high rate thickeners. The underflow discharge slurry of the last wash stage containing the washed residue is pumped to the residue disposal area. Overflow from one of the wash stages is heated to ~100°C and added to a causticizer reactor tank (Figure 2) while a milk of lime slurry is added, to recover caustic soda from sodium carbonate (Na_2CO_3). The discharge of the reactor is returned to the CCD circuit as wash water. Clear settler overflow flows on to a security (polishing) filtration facility to remove remaining fine solids which could potentially contaminate the product alumina.

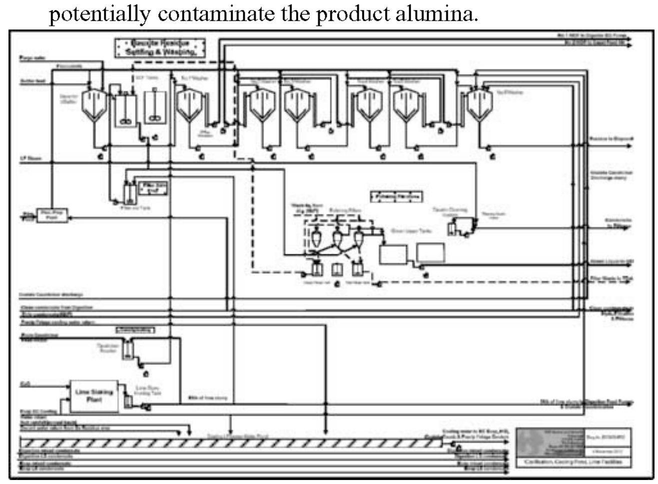

Figure 2 – Clarification, Cooling/Process Water Pond, Lime

- **Heat Interchange & Precipitation** (Figure 3). Green liquor filtrate from security filtration passes through plate heat exchangers, counter current to spent liquor returning from precipitation for heat interchange (stage 1), and cooling water (stage 2). Cooled green liquor is directed to the precipitation area, which includes split liquor and split seed systems, agglomeration and growth sections, product and seed classification and inter-stage cooling. The discharge from the last precipitator containing spent liquor and alumina hydrate crystals is directed to a number of cyclone classification steps, which separate coarse crystals (product alumina hydrate) from the fine material (used as seed hydrate). The final classification stage takes place in a seed thickener.
- **Product Filtration** (Figure 3) **and Calcination.** The coarse hydrate slurry flow from precipitation is directed to product filtration. Alumina hydrate production (the Bayer Loop) operates independently from the calcination operation; alumina hydrate is therefore stored whenever the calcination capacity is constrained. Stored hydrate is reclaimed as soon as operating conditions allow. Alumina hydrate crystals from precipitation are washed and calcined to smelter grade ("sandy") alumina. Stationary calciners are applied, incorporating heat recovery from combustion gases. The

alumina discharging from the calciners may be directed to a rail or ship loading silo or to a belt conveyor system to ship loading facilities depending on the refinery location.

- **Liquor Evaporation** (Figure 1) and Impurity Removal (Figure 3). Spent liquor returning from precipitation passes through an evaporation area for the removal of water added in other areas of the process, returning liquor caustic concentration to the digestion starting level. Evaporation operates on flash steam and low pressure live steam from back pressure steam turbines of the steam and power plant. Live steam condensate from Digestion and Evaporation is returned to the boilers as feed water. Flash steam condensate is used for washing of bauxite residue and hydrate. Oxalate is formed from organic carbon in the bauxite, flocculants, etc. To control oxalate concentration in plant liquor at an acceptable level, part of the seed thickener overflow is directed to seeded oxalate crystallisation. Crystallizer discharge is filtered and collected, with oxalate crystals being directed to oxalate removal. Product oxalate is dissolved in condensate and added to a reactor tank together with milk of lime slurry to form virtually insoluble Calcium-oxalate ("oxalate causticisation"). The discharge of the reactor tank is pumped to the last bauxite residue washer, where Ca-oxalate mixes with bauxite residue and is eventually trapped in the residue to disposal. The removal of other organic compounds is achieved by the earlier mentioned CCD washer overflow causticisation, by the oxalate removal processes, and by removal with the (adhering liquor of the) bauxite residue.

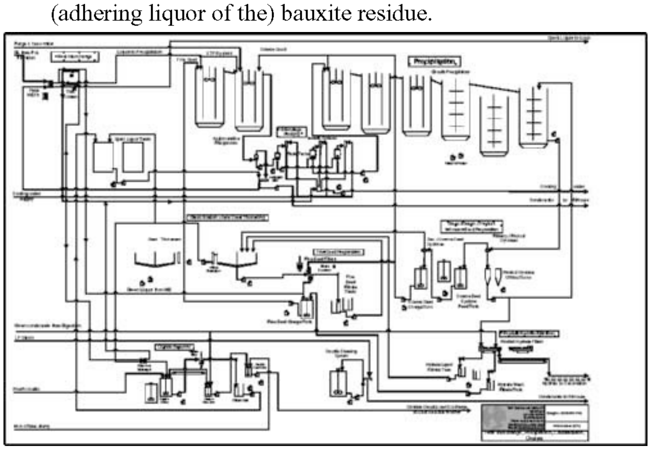

Figure 3 – Heat I'change, Precipitation, Classification, Oxalate

3.3 Equipment Sparing

The **DCS** equipment sparing philosophy aims at finding an optimum between the costs related to plant downtime (loss of production, ongoing fixed operating costs) and the costs of lowering downtime (capital and operating costs). Key items are:

- The role of equipment cleaning / descaling: strictly following the cleaning schedules and methods for the various pieces of equipment is essential to achieve the overall plant operating factor, and is an integral part of operating and maintaining the plant at design conditions.
- The use of common spare equipment where possible (e.g. Desilication forwarding / discharge pump; train of heaters for Digestion / Evaporation; CCD washers overflow pumps; Cloudy filtrate / Filter waste tank & pump).
- If an outage would result in an immediate alumina production loss, a spare is installed (e.g. Digester feed pump; Primary Cyclone Underflow Tank), or equipment bypassing facilities are installed (e.g. for Digester feed tank) or extra capacity in upstream / downstream equipment is included (e.g. Green liquor tank). This also applies to frequently maintained equipment (e.g. many pumps; DSM screens; Desilication feed tank; Green liquor heat exchangers).
- No sparing is included for the grinding mill (ref. section 3.4); nor for the CCD washers and flash vessels which can be by-passed, accepting transient process efficiency reductions.
- A spare precipitator is installed and the third tank can be used both as agglomerating as well as growth precipitator.
- The refinery operates continuously with planned outages, accounted for in the overall plant operating factor, being used to service equipment. The sparing philosophy assumes no scheduled extended total plant shutdowns.

Note that the sparing philosophy may require adjusting to a specific plant location.

3.4 Plant Design Elements

The principle of the **DCS** plant is a dedicated design for a specified production capacity ("designing a greenfield plant as a brownfield expansion"). For a 400 kt/y plant the design includes:

- One grinding mill: required minor and major maintenance activities (some occurring only once every 5-10 years) are accounted for in the overall plant operating factor.
- The Digestion and liquor Evaporation areas positioned next to each other, enabling sharing a common spare train of heat exchangers. Rationale: using the same hot-end temperatures in Digestion and Evaporation, and an Evaporation cold-end similar to its feed temperature, the Evaporation flow rate is similar to that of Digestion. The design results in the entire spent liquor flow passing through Evaporation. Advantages: equipment standardization, simplified operations & maintenance, less (types of) spare parts.
- The bauxite residue discharging from the CCD wash train contains less than ~8 g/l caustic soda (expressed as Na_2CO_3) in the adhering liquor, enhancing disposal options.
- The last two on-line precipitators operate with agitators allowing to vary slurry levels, thus accommodating volume take-up when descaling a tank.
- Precipitators are mechanically cleaned / descaled. Main advantages: no major plant volume / plant liquor caustic concentration fluctuations, i.e. better control of both, allowing a narrower "safety range" for the control of liquor super-saturation (SS), enabling to run it at a higher level. Put differently: tank cleaning and plant volume / liquor concentration control have been separated. Other advantages: no further spare precipitators / tanks of similar size) are required and (caustic cleaning) steam savings.
- The filters for hydrate to calcination, for fine seed for precipitation and for oxalate removal are located in one building. The same comment as above applies with respect to equipment standardization, operating procedures, etc.
- A hydrate storage facility between precipitation and calcination, enabling the Bayer circuit to operate

independently and as undisturbed as possible from calcination. Two calciners are installed, both normally in operation. At nominal hydrate production rate the feed rate will be less than calciner nameplate capacity. When a calciner is off-line for maintenance, the capacity of the remaining unit is maximized, however it will not meet the plant design production rate and hydrate is stored. Stored hydrate is recovered as soon as the second calciner is brought back on line and calcination capacity is maximized for both units. Stored hydrate should be kept at a minimum. By uncoupling the Bayer circuit from calcination, product quality control can be optimized.

3.5 Operating Factor & Main Operating Parameters

The plant operating factor and main operating parameters for the 400 kt/year **DCS** plant can be found in Table 2. They are based on the considerations of sections 3.4 and 3.3 and were generated with an Excel model simulation of the alumina refining process.

Table 2 – Main Operating Parameters 400 kt/y Refinery

Item		
Plant Overall Operating Factor, %		93
Main Operating Parameters		
Test Tank	Liquor Flow, m^3/h	508
	Liquor C(1), g/l	336
	Liquor A/C, ratio	0.433
Pre-Desilication	Temperature, deg Celsius	98
	Retention Time, h	24
Digestion	Slurry Feed Flow, m^3/h	583
	Temperature, deg Celsius	150
	Retention Time, min.	60(2)
	Discharge C, g/l	310
	Discharge A/C, ratio	0.753
CCD	Wash Liquor Flow, m^3/h	113
	Last Washer Underflow C, g/l	7
Precipitation	LTP Flow, m^3/h	544
	Green liq. to Seed Reslurry(3), m^3/h	58
	Retention Time, h	35
	LTP C, g/l	276
	LTP A/C, ratio	0.738
	LTP C/S, ratio	0.897
	Net precipitation yield, kg/m^3	82
Evaporation	Evaporator Feed Flow, m^3/h	570
	Hot End Temp, deg C	150
	Discharge Temp, deg C	93
Calciner Utilization	%	93(4)
Bauxite Factor, tBx(bone dry)/tA		2.74
Residue Factor, tRes to Disposal (bone dry)/tA		1.30

(1) Caustic concentration, expressed as Na_2CO_3
(2) It is possible that a retention time of about 30 min would be adequate
(3) Combines with the LTP flow in the agglomeration section
(4) Assuming a calciner overhaul once every 18 months

4. Main Refinery Equipment

The main equipment list (excluding pumps) for the 400 kt/y **DCS** plant resulting from the modeling exercise and based on the above outlined sections is shown in Table 3. It excludes equipment related to alumina and raw materials storage & distribution (e.g. caustic soda, coal, heavy fuel oil, etc), with the exception of sulphuric acid (incorporated in the digestion area). The steam and power plant, warehouse, workshops, change house, main office, clinic, firefighting and storage yards are also excluded (site dependent and thus affected by operations and maintenance philosophies).

Table 3 – Main Equipment List 400 kt/y Refinery (excl. pumps)

Item & Capacity	No. Oper./Spare
Bauxite Grinding & Pre-Desilication	
Grinding Mill (1.9 MW ball mill), 170 t/h (wet bauxite)	1/-
Bauxite Conveyor, 170 t/h (wet), varying lengths	2/-
Roll Crusher, 170 t/h (wet)	1/-
Sieve Bend (DSM Screen), 100 m^3/h slurry feed	4/1
Desilication Feed Tank, 30 m^3	1/1
Pre-Desilication Tank, 1,740 m^3	2/-
Slurry Contact Heater	1/1
Digestion	
Test Tank, 1,200 m^3	1/1
Digester Feed Tank, 300 m^3	1/-
Train of vertical 5 flash & 1 live steam S&T HEX(16)	1/1(1)
Digester Vessel, 300 m^3	2/-
Thermo Compressor, using live steam and flash steam	1/1(1)
Flash Tank (pressure), cone bottom, 50 m^3	3/-
Blow-off Tank, cone bottom, 200 m^3	1/1
Safety Relief Tank, 1,000 m^3	1/-
Clean Condensate Tank, 340 m^3	1/-
Dirty Condensate Tank, 340 m^3	1/-
Sulphuric Acid Cleaning Facilities	1/-
Evaporation	
Train of vertical 6 flash & 1 live steam S&T HEX(16)	1/1(1)
Thermo Compressor using live steam and flash steam	1/1(1)
Flash Tank (pressure), cone bottom, 50 m^3	4/-
Blow-off Tank, cone bottom, 200 m^3	1/1
Flash Tank (vacuum), 80 m^3; Bar. Condenser; Hot Well	1/-
Bauxite Residue Settling & Washing, & Lime Related	
High Rate Settler(2) / Washer + o'flow standpipe(3)	7/-
Settler Overflow Tank, 1,200 m^3	1/1
Lime Slurry Holding Tank, 70 m^3	1/-
Causticizer Reactor, 200 m^3	1/-
Caust. Feed Htr(4) using flash steam & cond., 360 m^2	1/-
Lime Ageing / Filter Aid Tank, 200 m^3	1/-
Oxalate Causticisation Tank, 30 m^3	1/-
Polishing / Security Filtration	
Vertical Leaf Filter, 265 m^2	2/1
Green Liquor Tank, 1,300 m^3	1/1
Cloudy Filtrate Tank, 80 m^3	1/1(5)
Filter Waste Tank, 80 m^3	1/1(5)
Caustic Cleaning Tank, 80 m^3	1/-
Caustic Cleaning Heater (live steam; hor.), 40 m^2	1/-
Heat I'Change, Precipitation & Interstage Cooling	
Main Green Liquor-Spent Liq. Plate HEX., 1,310 m^2	1/1(6)
LTP-Cooling Water Trim Cooler Plate HEX, 70 m^2	1/1(6)
Gr Liq to Fine Seed Prep-Cool. Water Plate HEX, 20 m^2	1/1(6)
Precipitation Tank, average 4,500 m^3 (7)	7/1(8)
First Stage Flash Tank (vacuum), 10 m^3	1/-
Second Stage Flash Tank (vacuum), 20 m^3	1/-
Third Stage Flash Tank (vacuum), 70 m^3	2(par.)/-
Horizontal S&T HEX (against spent liquor), 110 m^2	1/-
Barometric Condenser	3/-
Hot Well (Vacuum Seal Pot)	1/-
Hydrate Classification & Fine Seed Filtration	
Primary / Product Cyclones Cluster	1/-(9)
Secondary / Coarse Seed Cyclones Cluster	1/-(9)
Primary Cyclones Underflow Tank, 80 m^3	1/1
Secondary Cyclones Feed Tank, 730 m^3	1/1(10)
Coarse Seed Charge Tank, 730 m^3	1/1(10)

Seed Thickener, 1,800 m^3 & Overflow Standpipe	1/1
Spent Liquor Tank, 1,200 m^3	1/1
Multiple Leaf Vertical Disk Filter, 46 m^2	1/1(11)
Fine Seed Charge Tank, 220 m^3	1/1(12)
Fine Seed Filtrate Tank, 100 m^3	1/1(13)
Oxalate Removal	
Oxalate Removal Feed Flow Plate HEX (Cooler), 30 m^2	1/-
Oxalate Crystallizer, 220 m^3	1/1(12)
Multiple Leaf Vertical Disk Filter, 46 m^2	1/1(11)
Oxalate Seed Recycle Conveyor, 21 t/h solids (wet), 15m	1/-
Oxalate Filtrate Tank, 100 m^3	1/1(13)
Oxalate Dissolution Tank (Dissolver), 30 m^3	1/-
Product Hydrate Filtration, Washing & Storage	
Horizontal Hydrate Pan Filter, 36 m^2 de-liquoring area	1/1
Hydrate Liquor Filtrate Tank, 50 m^3	1/1(14)
Hydrate Wash Filtrate Tank, 50 m^3	1/1(14)
Hydr./Seed/Ox Removal Caustic Cleaning Tank, 750 m^3	1/-
Caustic Cleaning Heater (live steam; hor.), 110 m^2	1/-
Filters Discharge Conveyor, 90 t/h, 25 m	1/-
Hydrate to Calciners Conveyor, 90t/h, 30 m	1/-
Hydrate to Calciners Conveyor, 90t/h, 65 m	1/-
Covered Hydrate Storage Pad, 13,400t (wet), 65x30x13m	1/-
Hydrate to Storage Conveyor, 90 t/h, 95m	1/-
Recovered Hydrate to Calciners Conveyors, 30 t/h(15)	(15)
Calcination	
Stationary Calciner, 790 tA/d	2/-

(1) Common spare heater train and thermo compressor
(2) Also referred to as decanter or thickener
(3) The tank normally operating as 1st washer can also be lined up as settler
(4) Horizontal heater located in Digestion / Evaporation area
(5), (10), (11), (12), (13) and (14) Common spare for indicated equipment
(6) Operated and maintained / cleaned as "set"
(7) Last three on-line precipitators have agitators that allow running at variable tank levels
(8) The third precipitation tank may be lined up as agglomeration as well as growth tank
(9) Individual cyclones can be maintained or replaced
(15) Final configuration to be decided at later stage
(16) Flash steam HEX at 800m^2 and live steam HEX at 600m^2 each

5. Dedicated Layout – Plant Proper

5.1 Basis

A key advantage of the **DCS** design is that the plant layout is optimized. This may be realized in various ways, depending on bauxite quality (boehmite, TOC, oxalate, etc), selected process technologies (digestion, impurity removal, equipment types – filters, heat exchangers, etc), plant location specifics (rainfall – water balance, legal requirements, soil conditions, gravity flow between precipitators, etc), operating and maintenance philosophies, etc.

Note that the current paper covers the layout relating to the process plant proper (refer comment in section 4).

5.2 Layout Considerations

The following layout considerations are based on the selected refining process described in section 3.2, and the **DCS** design, sparing, operating parameters and equipment described in sections 3.4, 3.3, 3.5 and 4. However most of these would (fully or partly) apply also if other technology choices are made.

- Position the Digestion and liquor Evaporation areas next to each other because of close similarity of type of equipment (heat exchangers, flash tanks, etc), thus enabling the sharing of a common spare train of heat exchangers, improving operating and maintenance efficiency, etc (Figure 4). The causticizer feed heat exchanger is located in the Digestion / Evaporation area because Evaporation export steam and Digestion flash condensate is used to heat the CCD-washer overflow to causticisation. Attention should be given to maintain the free caustic concentration in the spent liquor through Evaporation at the hot end within acceptable levels.

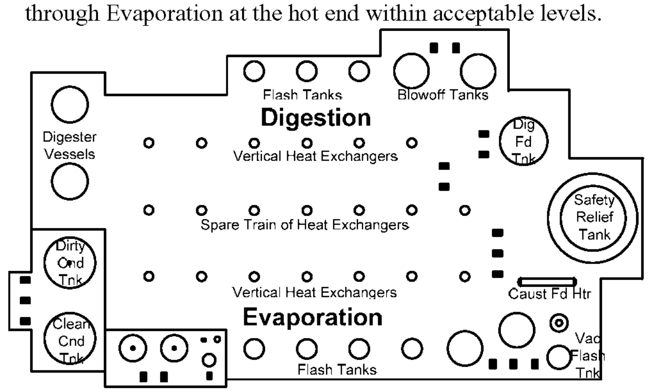

Figure 4 – Layout of Digestion /Evaporation Areas

- Place the bauxite residue settler and washers in a horseshoe shape for easy access to washer overflow standpipes and pumps, etc (Figure 5). Lime related areas are positioned next to each other (similar operating and maintenance requirements) and close to the washer train (three of the four lime additions are related to the settler / washer train).

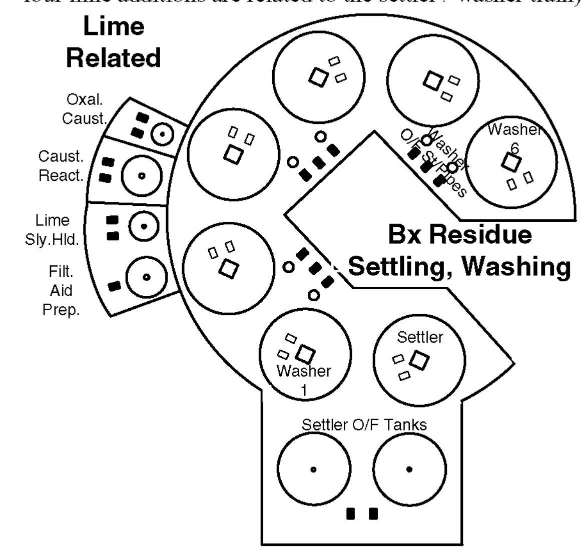

Figure 5 – Layout of Residue Settling, Washing & Lime Areas

- Place the filters for hydrate to calcination, fine seed for precipitation and oxalate removal, as well as the cyclone classification areas in one building (similar equipment, operating and maintenance procedures, spare parts, sharing of common spare tanks and pumps, etc) (Figure 6).
- Position Security Filtration related equipment close to each other for operating and maintenance efficiency reasons.
- Position Heat Interchange, Precipitation and Interstage Cooling close to each other as these have many interactions (minimizing liquor/slurry pipeline distances).

- Construct in the center of the plant a facility accommodating the plant control room (including control of the Steam and Power plant), operations office and plant laboratory.
- Position the main steam consumers (Digestion and Evaporation) and the Steam and Power plant close to each other to minimize energy losses.
- Place if feasible the bauxite crushing, grinding and pre-desilication areas close to each other and to the Digestion area to minimize slurry pipeline distances.
- Create good crane access to all major equipment from 15m wide plant roads.
- If economically justifiable consider pipe trenches instead of piperacks for road crossings (ease of access).

Figure 6 – Layout of Hydrate Classification/Filtration & Oxalate Removal Areas

5.3 <u>Overall Plant Layout</u>

The resulting overall process plant layout for the 400 kt/y DCS plant is presented in Figure 7, showing that the approach leads to a compact, simple and efficient layout with a small Bayer loop. It also illustrates that the goal to "design a greenfield plant as a brownfield expansion" (tailoring the design to the equipment and infrastructure requirements of the specified production capacity) is achievable: most of the infrastructure is integrated in the process areas and only limited infrastructure is required outside those.

Major advantages of this layout:

- **Lower Capital Cost**:
  - Lower commodity volumes (concrete, structural steel, piping, etc): volumes for a greenfield plant designed along this approach are similar to that of a brownfield expansion of an existing refinery[3], resulting in lower capital cost per tA production capacity[4].
  - Equipment standardization (e.g. same heat exchangers for Digestion and Evaporation areas, same filters for fine seed and oxalate) results in simpler engineering and design, and less (types of) spare parts.
  - Use of common spare equipment resulting in less spares.
- **Lower Operating Cost**:
  - Lower pumping energy.
  - Increased operating (e.g. filter re-clothing) and maintenance efficiency (e.g. heater cleaning) due to clustering similar types of operations / maintenance.
- **Ease of Operations, Maintenance and Control**:
  - Control center: central control room / office / laboratory.
  - Short distances between process areas.
  - Access to equipment.
  - Limited number of equipment sizes and types due to equipment standardization.

1. P.J.C. ter Weer, "New Development Model for Bauxite Deposits" (paper presented at Light Metals 2011, San Diego), pp 5-11.

For further information, please contact P.J.C. ter Weer at twsservices@tiscali.nl or visit www.twsservices.eu.

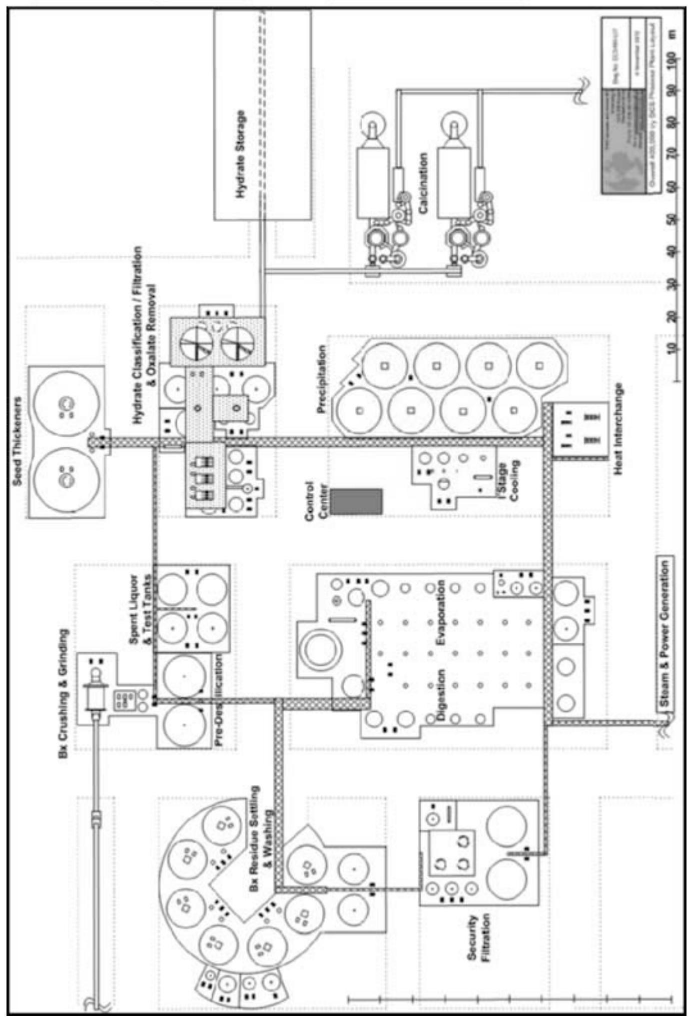

Figure 7 – Overall 400 kt/y **DCS** Process Plant Layout

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3 Reference [1], Figure 5.
4 Reference [1], Table 5.