IBAAS 2023
TECHNICAL LECTURE SERIES

IMPROVING YIELD WHILE MAINTAINING PRODUCT QUALITY IN BAYER PRECIPITATION CIRCUITS

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Objectives

Purpose of lecture:

- Challenge the mode of operation of alumina refinery precipitation circuits;
- Demonstrate the extent to which liquor productivity can be increased
- Higher liquor productivity and product quality operating conditions are opposed
- Discuss how to realize increased liquor productivity without compromising product quality.
- Potential cost / benefit if the product quality bottleneck challenge is resolved

Liquor productivity versus product quality case

Why high liquor productivity ?

- Higher production rates
- Lower unit cost of production
- Better environmental outcomes
- Better bottom line (profit)

Reasons for controlling alumina quality

- Smelter operators requirement
- Environmental requirements
- Better refinery operability

BUT

Product quality and high liquor productivity conditions oppose each other.

Consequently, product quality at the expense of production.

Liquor Productivity (Yield)

Factors affecting liquor productivity (alumina yield) are:

- Precipitation circuit design, (well mixed tanks or classifiers)
- liquor composition (presence and levels of impurities such as sulphate chloride, carbonate, oxalate, etc. “JUNKATES”),
- Slurry properties (e.g. oxalate rafters leading to slurry disgorgement)
- Operating conditions (factors which influence the kinetics of alumina precipitation reaction)

  Temperature,
  Seed charge
  Supersaturation (liquor A/C).

Refinery liquor compositions and yields

Refinery	A	B	C	D
A	186.2	202.1	153.3	175.6
C	255.0	275.0	210.0	238.9
S	300.0	302.9	256.1	279.4
A/C	0.730	0.735	0.730	0.735
C/S	0.850	0.908	0.820	0.855
Na2CO3	45.0	27.9	46.1	40.5
NaCl	10.0	10.0	20.0	9.0
Na2SO4	0.8	0.5	22.0	34.0
Na2C2O4	2.8	3.5	3.1	3.1
TOC	12.0	15.0	20.0	16.0
TS (calc'd)	333.7	342.3	330.7	345.0
Est. Yield (g/L)	**75.0**	**85.0**	**62.0**	**70.0**

Refinery yields are dictated by the precipitation design as well as their liquor composition.

While total soda tends to be similar from refinery to refinery, impurities levels (JUNKATES) vary significantly due to bauxite processed.

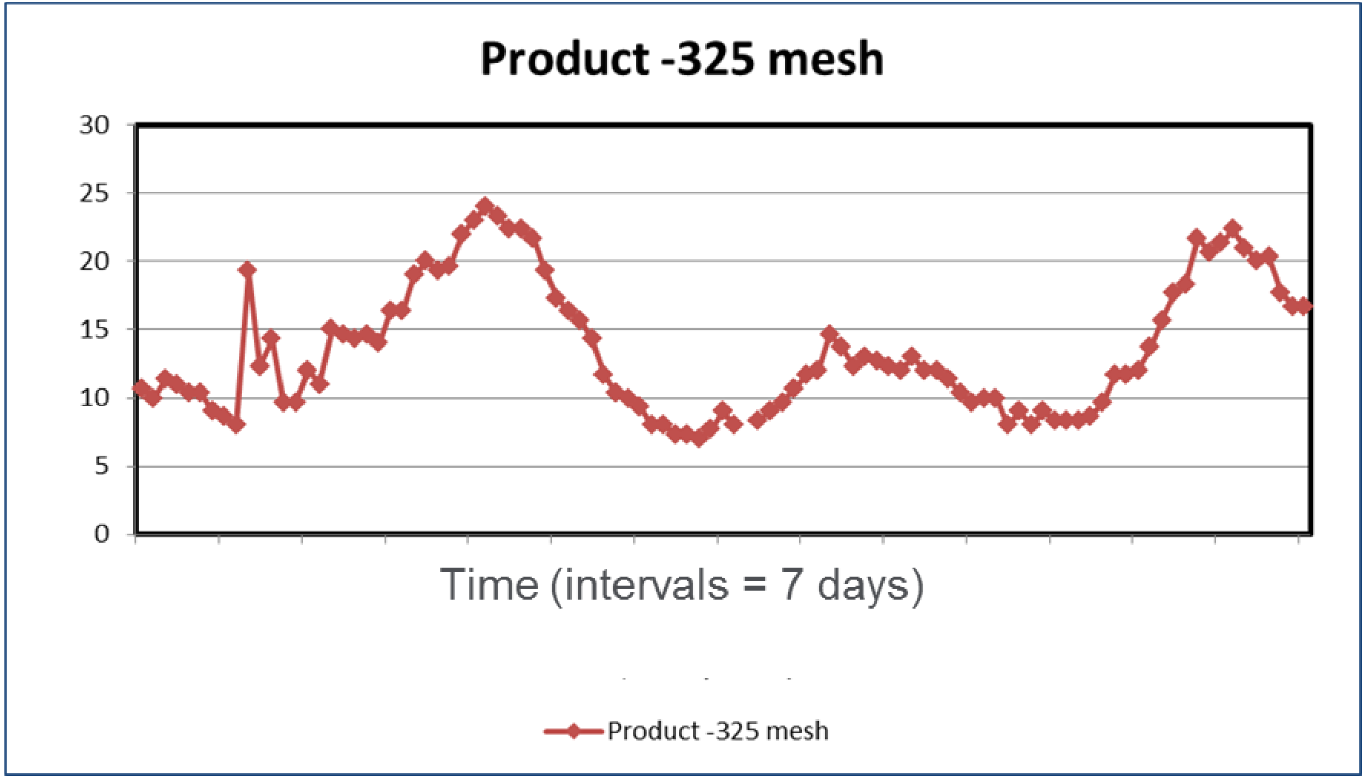
Thus the ACTIVE caustic varies from refinery to refinery due to the presence of “JUNKATES”.

Product quality requirements

Some critical product quality requirements affected by high liquor productivity are:

- Alumina soda content, (soda incorporation in hydrate leading high product soda)
- Particle size, (too much fines in product due to excessive nucleation)
- Particle strength (attrition index)

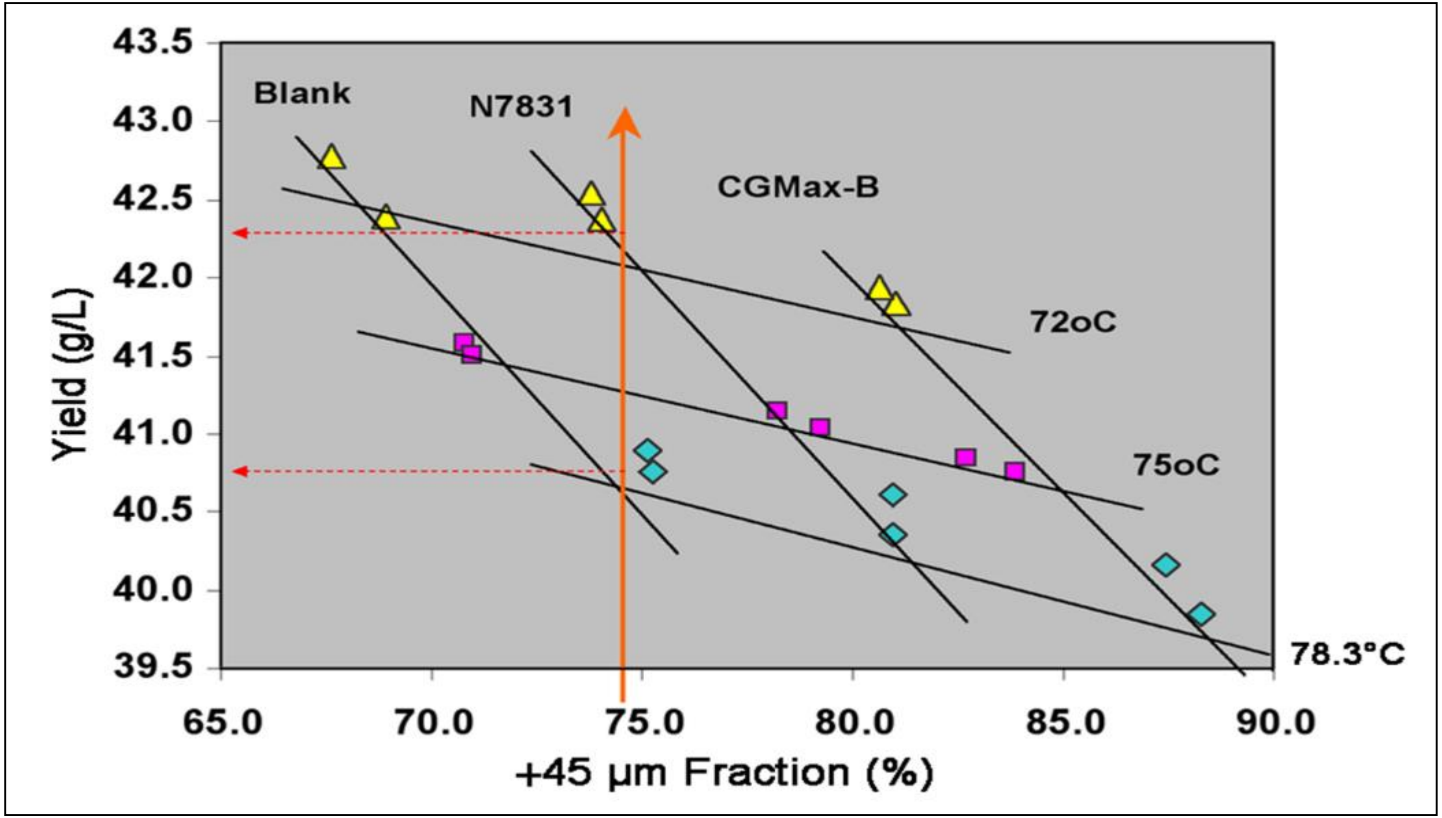
Cycles in refinery product quality (Particle size)



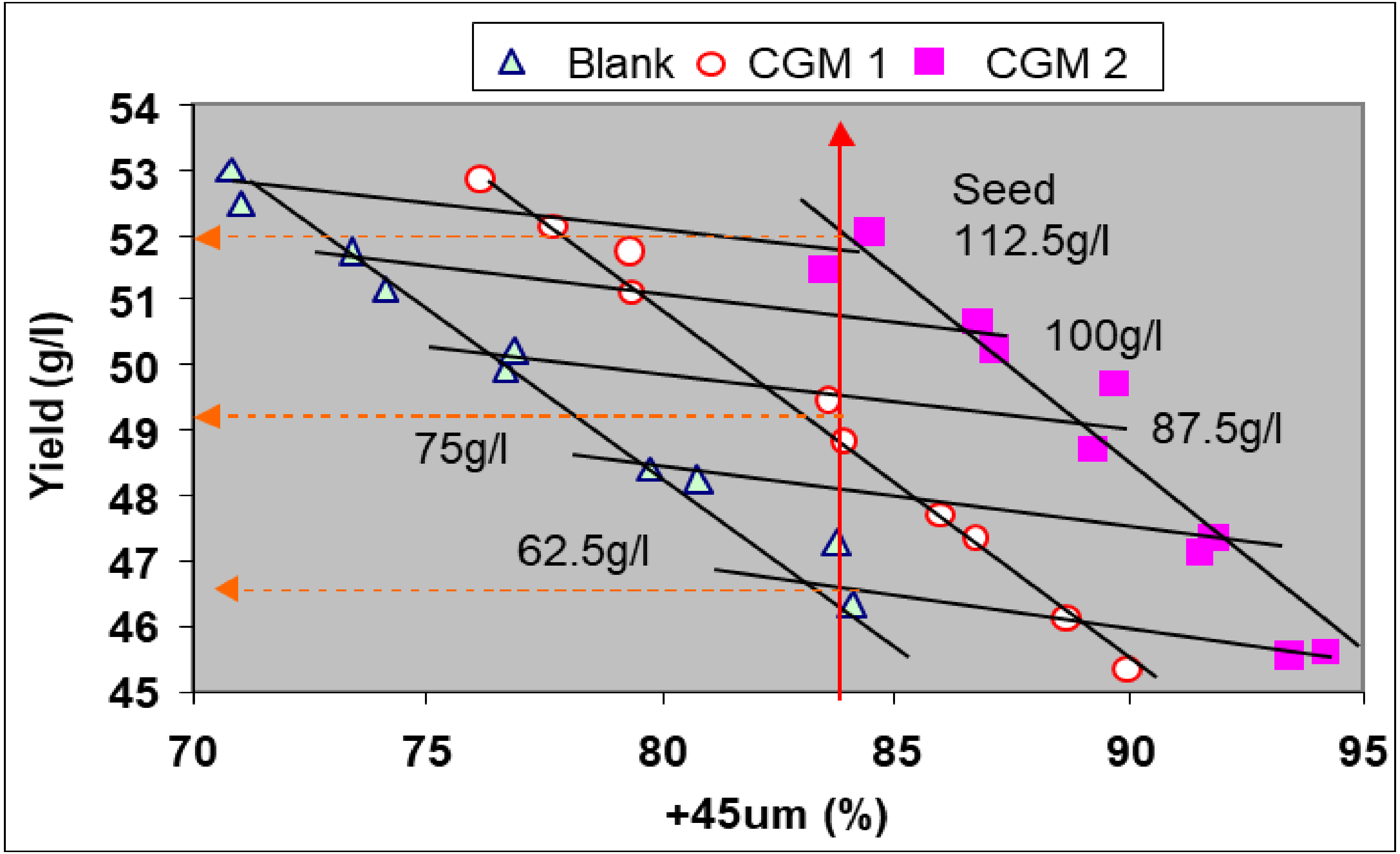
Liquor productivity vrs Product Quality (Particle Size)

Control Parameter		*Yield(g/L)*	*Particle Size*
Temperature	↓	↑	↓
Initial A/C	↑	↑	↓
Surface Area (seed charge)	↑	↑	↓
Caustic concentration (constant A/C)	↑	↑	↓
Holding time	↑	↑	↑

Fill temperature versus Yield



Seed charge versus yield

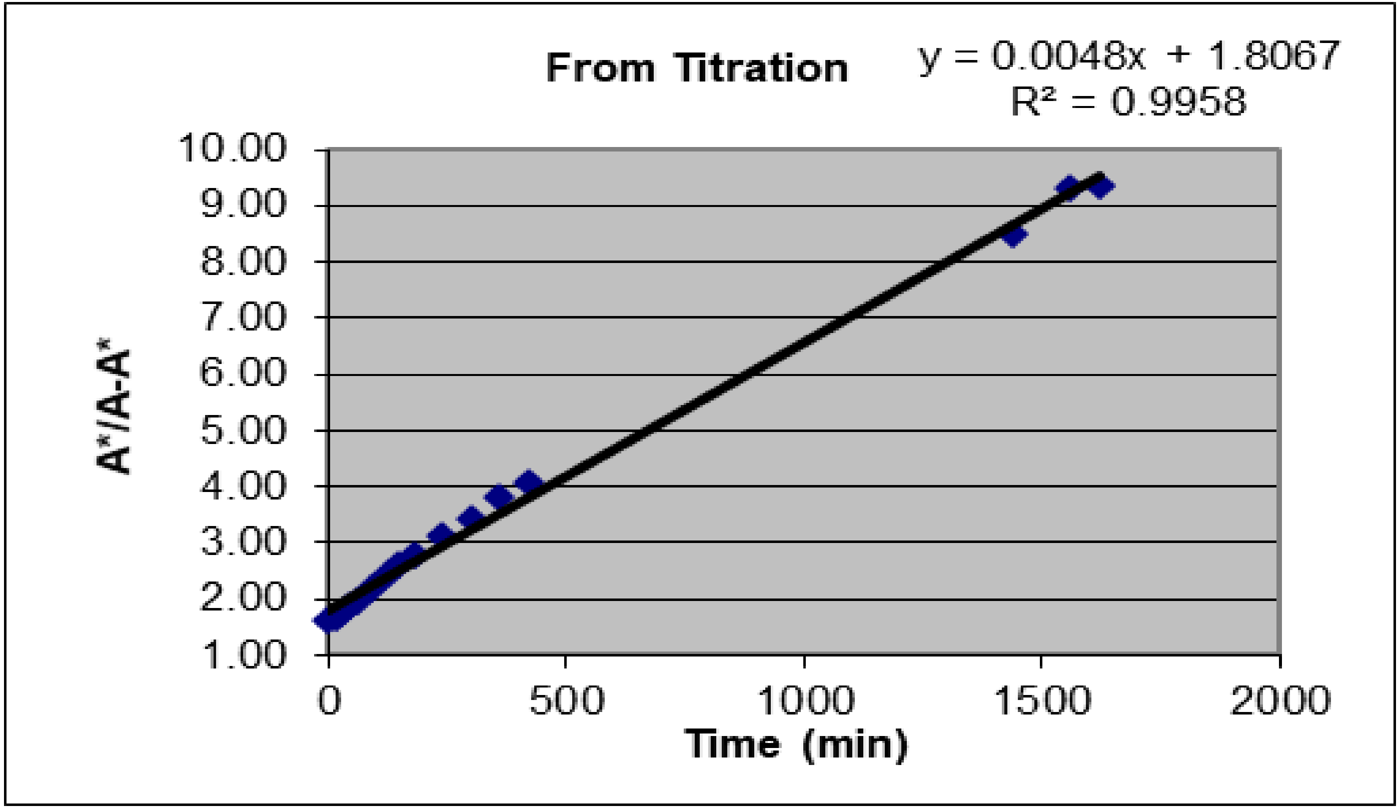


Modelling of precipitation circuit

Modelling assumptions:

- yield only model;
- the precipitation tanks are continuous stirred tank reactors (CSTRs);
- second order precipitation kinetics with respect to relative supersaturation (based on laboratory kinetic test)
- the surface area used is laboratory measured surface area from particle size analyzer and corrected with a seed surface activity factor;

Alumina precipitation kinetics



Precipitator performance equation

Performance equation for each CSTR precipitator :

$$k.S.A.\tau = \frac{X_{Ai} - X_{Ai+1}}{X_{Ai+1}^2}$$

Where k is Arrhenius rate constant,

k = ko* exp(Ea/RT) ($min^{-1}g/m^2$)

ko is pre-exponential factor
Ea is Activation energy for gibbsite precipitation, J/mol
R is gas constant, J/(mol.K)
T is Temperature, deg K

Precipitator performance equation

Performance equation for each CSTR precipitator :

$$k.S.A.\tau = \frac{X_{Ai} - X_{Ai+1}}{X_{Ai+1}^2}$$

Where S is Specific surface area of hydrate particles (m^2/g)
A is surface activity factor for hydrate particles
τ is slurry residence time (min)

Precipitator performance equation

Performance equation for each CSTR precipitator :

$$k.S.A.\tau = \frac{X_{Ai} - X_{Ai+1}}{X_{Ai+1}^{2}}$$

Where X_{Ai} is initial relative supersaturation entering tank i

$X_{ai} = (C_{Ai} - C_A^*)/C_A^*$

C_{Ai} is initial alumina concentration entering tank i, g Al_2O_3/L
C_A^* is equilibrium alumina solubility at feed liquor conditions, g Al_2O_3/L,
Rosenberg - Healy solubility equation.

X_{ai+1} is relative supersaturation exiting tank i+1

$X_{ai+1} = (C_{A1} - C_A^*)/C_A^*$

C_{ai+1} is alumina concentration exiting tank i+1, g Al_2O_3/L

Model set up and calibration for refinery A

	Agglons	Interm	Final	
Supersaturation	0.692	0.561	0.437	-
Rate constant	0.01323	0.00294	0.00154	g/(m2.min)
Residence time	396.8	826.6	1069.0	min
Trains	1	1	4	#
Tanks per train	5.5	8	10.5	#
Total No. of tanks	5.5	8	44.0	#
SSA	0.022	0.022	0.022	m2/g
Seed activity	**0.62**	**0.62**	**0.62**	#
A In	**150.5**	**103.8**	**83.2**	g/L
A Out	**103.8**	**83.2**	**79.4**	g/L

Tank no.		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Agglons	Row 1	0.476	0.355	0.280	0.230	0.194	0.167					
Intermediates	Row 1	0.489	0.432	0.386	0.349	0.318	0.292	0.270	0.251			
Finals	Row 1	0.430	0.424	0.417	0.411	0.405	0.399	0.393	0.387	0.382	0.376	0.371
	Row 2	0.430	0.424	0.417	0.411	0.405	0.399	0.393	0.387	0.382	0.376	0.371
	Row 3	0.430	0.424	0.417	0.411	0.405	0.399	0.393	0.387	0.382	0.376	0.371
	Row 4	0.430	0.424	0.417	0.411	0.405	0.399	0.393	0.387	0.382	0.376	0.371

Calibration data for refinery A (steady state)

INPUTS	Calibration data (Refinery A)		
	A	150.5	g/L
	C	226.2	g/L
	S	254.9	g/L
	A/C	0.665	
	C/S	0.887	
	NaCl	1.17	g/L
	Na_2SO_4	0.64	g/L
	TOC	8.77	g/L
	Aggloms	Interm	Final
Temp, deg C	80.6	65.9	59.9
Flow, m3/hr	1163.9		
Alumina Solubility, A* gpl	89.0	66.5	57.9
Relative Supersaturation	0.692	0.561	0.437

Model Calibration

	Refinery A data	Model data
Final overflow A, g Al_2O_3/l	84.09	84.07
Final overflow A/C	0.350	0.350
Plant yield, g Al_2O_3/l	71.24	71.26

Potential Production Improvements

As an example, for a hypothetical 1 MTPA plant with a yield of 70 gpl, LTP flow of 1650 m3/hr, the following yield benefits can be achieved by adjusting fill temp and seed charge in precipitation and applying crystal growth modifier.

Fill temp decrease	**Temp decrease**	**Yield increase**	**Annual production increase**
	1.0	0.8	11000
	2.0	1.6	22000
	4.0	3.1	42000
	6.0	4.5	60000
Seed charge increase	**Seed increase**	**Yield Increase**	**Annual production increase**
	5%	0.3	4700
	10%	0.7	9000
	15%	1.0	13000
	20%	1.3	17000
	25%	1.6	21000

Note: Actual yield will vary from refinery to refinery as it is a function of both liquor chemistry and precipitation design. So actual yield increase needs to be estimated for each refinery.

Approach to production improvement

Assess capacity for the precipitation conditions to be manipulated using existing capacity without any capital investment (low hanging fruit).

Manipulate precipitation conditions such as temperature, seed charge, alumina to caustic ratio, caustic concentration, etc., to determine the optimum yield and hence production gains that can be achieved.

Compare product quality specifications to actuals being achieved in the refinery to assess if there are opportunities to capitalize on.

Test tools for controlling product quality to ensure any product quality excursions can be controlled.

Utilize low hanging fruits first.

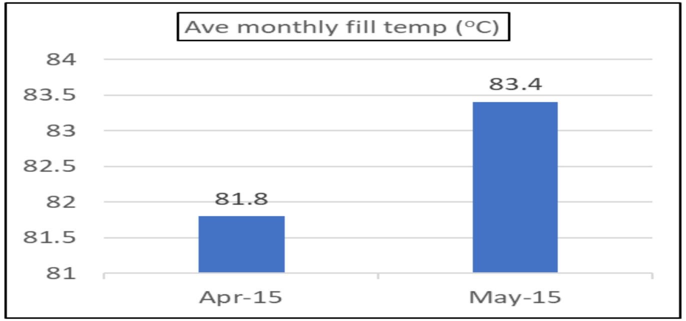
Assess if capital investment in equipment is required to capture the remaining production opportunities and if they are economically viable.

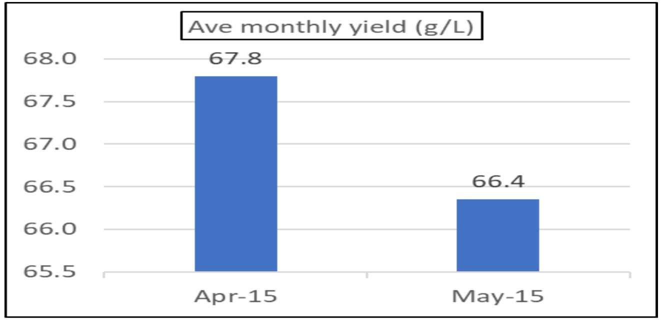
Plant trial outcome at refinery A (Temp impact)

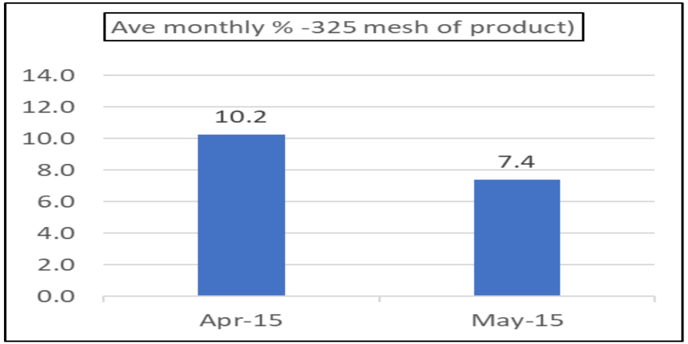
At constant ave monthly seed charge of approx. 112 g/L,

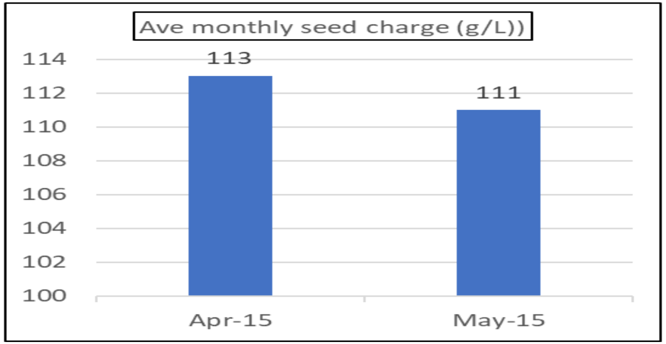
- 1.6 deg C decrease in temp resulted in 1.4 g/L increase in yield.

- Product -325 mesh remained within Target (8 to 13%)





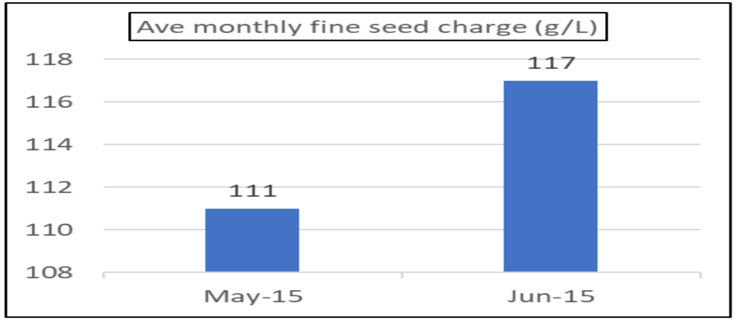


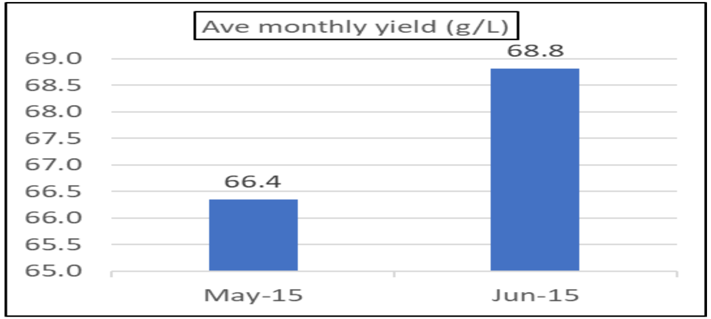


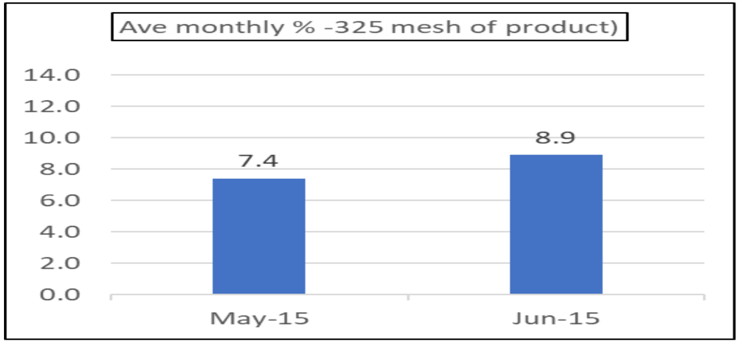
Plant trial at refinery A (seed charge impact)

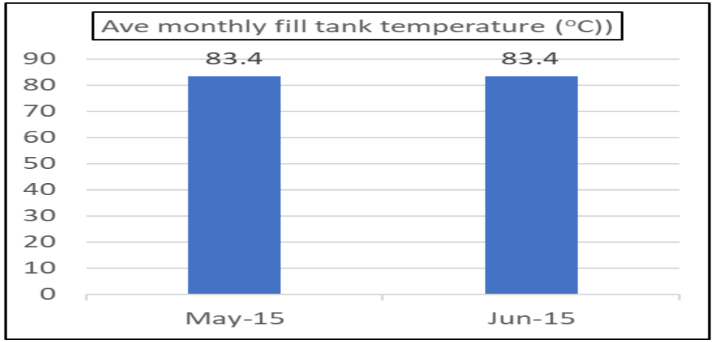
At constant ave monthly fill temp of 83.4 deg C,

- 5.4% Increase in seed charge resulted in 1.4 g/L increase in yield.
- Product -325 mesh remained within Target (8 to 13%)









Conclusions

Refinery operators desire high liquor productivity for profitability and environmental reasons.

However, operating factors that promote high liquor yield are opposed to required product quality.

Consequently refineries tend to operate below the optimum liquor yield levels in order to maintain product quality.

Consolidated Bauxite, Alumina and Aluminium Consultancy (CBAAC) has developed models and tools that allow refineries to operate at conditions allowing high yields to be achieved without compromising on product quality.

A plant trial of these tools at an alumina refinery has demonstrated promising results.

The plant trial also demonstrated that significant yield improvements can be achieved without modification of the precipitation circuit.

End of presentation

Thank You for your attention

Discussions