Light Metals 2011 *Edited by: Stephen J. Lindsay*
TMS (The Minerals, Metals & Materials Society), 2011

OPTIMIZATION OF HEAT RECOVERY FROM THE PRECIPITATION CIRCUIT

Michael Simpson[1], Sushant Hial[1] and Rashmi Sangram Singh[1]
[1]Vedanta Aluminium Ltd., Lanjigarh, Kalahandi Dist., Orissa – 766027, India

Keywords: Interstage Coolers, Heat Transfer, Steam Savings

Abstract

In the Bayer process, temperature profile across the precipitation circuit plays a major role in maximization of the precipitation yield while maintaining product quality. For this reason, plate heat exchangers are used both at the inlet to Precipitation and between precipitation stages at Vedanta Aluminum's Lanjigarh alumina refinery. The cooling medium for the Heat Interchange Department (HID) is spent liquor, while for the Interstage Coolers (ISCs) of Precipitation, both spent liquor and cooling water are used.

A simple model was built using existing heat exchanger performance data, along with heat and mass balances across the Heat Interchange Department (HID) and Precipitation. This was then used to determine feasible modifications for improving heat recovery in the Precipitation circuit. The results obtained have indicated a process steam reduction of 2 % can be achieved with minor modifications.

Introduction

In the Bayer process, the temperature profile across the precipitation circuit plays a major role in maximizing the liquor productivity. The supersaturation of the liquor increases as the temperature decreases. Thus the enhancement of precipitation rate is assisted with the help of inter stage coolers across the precipitation unit. The cooling media used in the ISCs are spent liquor and alkaline cooling water.

Presently, heat gained by the cooling water is not utilized as the water loses its heat in the alkaline cooling tower. This loss can be prevented by replacing cooling water with spent liquor as an alternative cooling media in ISC – 2. Further heat can be recovered from the precipitation circuit by drawing the inlet slurry to ISC – 1 from further upstream tanks such as the last agglomerator. The recent installation of new ISCs as part of a debottlenecking project will enable the spent liquor temperature to be kept below 55^0C consistently. This liquor therefore becomes a good heat sink for hot precipitation slurry, compared to original design when it was at 60^0C.

Process Description

The objective of the Precipitation unit is to produce Alumina "Hydrate" (Alumina tri-hydrate or gibbsite) suitable for downstream calcination to produce sandy metallurgical grade alumina. This is achieved by prolonged contact between pregnant liquor and suspended hydrate seed, under conditions conducive to crystal growth and precipitation of alumina from solution.

The chemistry of precipitation, which is the reverse of digestion, is quite simple. In digestion, $Al(OH)_3$ dissolves in NaOH to form a complex anion and this complex ion comes out of solution as solid $Al(OH)_3$ in the precipitation reaction as per the following equation:-

$$Al(OH)_3 + NaOH \underset{\text{Precipitation (Cool)}}{\overset{\text{Digestion (Heat)}}{\rightleftharpoons}} Al(OH)_4^- + Na^+$$

The primary factors which affect the precipitation yield are well documented by authors such as Hond, Hiralal and Rijkeboer [1], They are:

- Initial Liquor Alumina(A) and Caustic(C) Concentration
- Holding Time
- Temperature
- Seed Surface Area
- Liquor Impurities such as carbonates

To maximise precipitation yield, temperature drop is an important parameter that can be controlled within the Precipitation Department. For this reason, interstage coolers have been provided between the precipitation tanks to reduce the temperature of the slurry. Approximately 60% of current precipitation train flow passes through the ISCs, in order to maintain velocity in the correct range through the coolers. The cooling medium for the 1st ISC is spent liquor from hydrate seed thickener overflow, while the cooling medium for other ISCs is cooling water from the alkaline cooling tower. The flow of these cooling media are monitored and controlled to achieve the desired temperature profile across the precipitation circuit.

Heat Balance Determination

By utilising the well known heat balance equations below [2, 3, 4], and a series of iterations, the final spent liquor temperature can be determined for given pregnant liquor to HID and spent liquor to ISC temperatures

$$Q = U x A x dT_{LM} \quad (1)$$
$$Q = M_h x Cp_h x (T_{hi} - T_{ho}) \quad (2)$$
$$Q = M_c x Cp_c x (T_{co} - T_{ci}) \quad (3)$$

Where for any heat exchanger:
Q=Heat transferred between the streams (kW)
U= Effective overall heat transfer coefficient ($kW/m^2/^0C$)
A= Heat transfer area(m^2)
dT_{LM}= Log-mean temperature difference (^0C)
M_h = mass flow rate of hot stream (kg/s)
Cp_h= Specific heat capacity of hot stream ($kJ/kg/^0C$)
T_{hi} = Inlet temperature of hot stream (^0C)
T_{ho} = Outlet temperature of hot stream (^0C)
M_c = mass flow rate of cold stream (kg/s)
Cp_c= Specific heat capacity of cold stream ($kJ/kg/^0C$)

T_{ci} = Inlet temperature of cold stream (^{0}C)
T_{co} = Outlet temperature of cold stream (^{0}C)

Existing Heat Balance

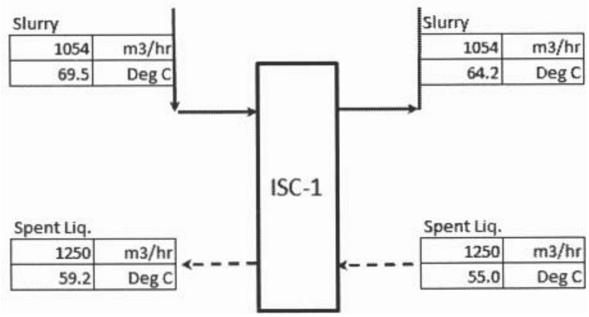


Fig 1: Spent liquor temperature increased by 4.2^{0}C after passing through ISC - 1

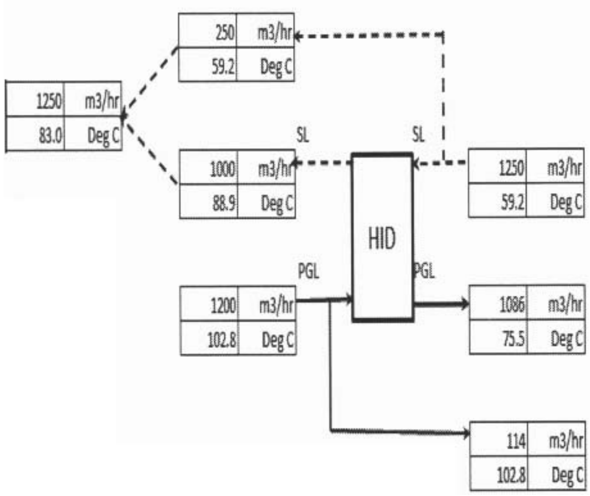


Fig 2: Spent liquor temperature increased to 83^{0}C after passing through HID

In the existing system, slurry feed for ISC-1 is from the fourth tank which is normally the second growth tank. The spent liquor temperature is raised by 4.2^{0}C across the ISC as shown in Fig. 1. As shown in Fig 2., the spent liquor temperature also increases by 23.8^{0}C in passing through the HID. In the existing scenario, there is also a temperature raise of 10 ^{0}C in the alkaline cooling water which is used as the cooling medium in ISC – 2.

Proposed Modifications with Schematic Diagram

To recover the heat through spent liquor it is proposed to:
(1) Use spent liquor as cooling media in ISC-2
(2) Feed slurry from an upstream precipitation tank having higher temperature
Detailed analysis was done across HID and Precipitation by using the historical performance data of the heat exchangers and hence their appropriate heat transfer coefficients (U value). The different scenarios considered are as follows:

i) ISC – 1 slurry input from last agglomerator Tank:-
High precipitation temperatures are only required to aid the agglomeration process. Instead of taking slurry input to ISC-1 from the second growth stage, we can utilize slurry from the last agglomerator without impacting on the precipitation sizing control. In this case there will be 6.7^{0}C rise in spent liquor temperature across ISC – 1 as shown in Fig 3. The inlet slurry temperature will be 77.9^{0}C and the outlet spent liquor temp will be 61.7^{0}C. The net spent liquor temp after HID will be 83.7^{0}C as shown in Fig 4. A further advantage of this move will be a reduction in the solids concentration through the ISC which is expected to improve its life. The liquor will be of a higher scaling potential however and caustic wash frequency might need to be adjusted. New piping will be required from second precipitator tank (normally last agglomerator) along with third precipitator (alternate last agglomerator) to the ISC-1.

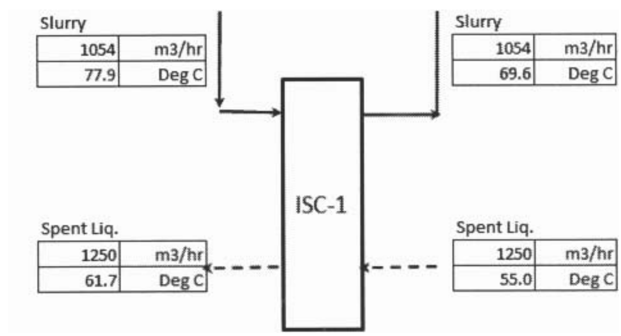


Fig 3: Spent liquor temperature increased by 6.7^{0}C after passing through ISC – 1

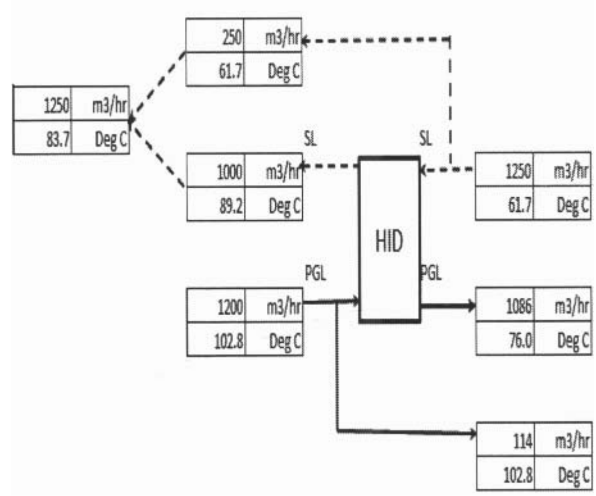


Fig 4: Spent liquor temperature increased to 83.7^{0}C after passing through HID

ii) Spent Liquor as cooling media in both ISC – 1 & 2:-

For this scenario, there will be 6.7^{0}C rise in spent liquor temperature across ISC – 1 and 2 as shown in Fig 5&6.The net spent liquor temp after HID will be 83.7^{0}C, shown in Fig 7.

Here the spent liquor flow will be in series i.e. the outlet from ISC – 2 will be the inlet to ISC – 1. Spent liquor piping already passes by the ISC-2 to feed ISC-1 and hence this modification will be simple. Analysis of the additional pressure drop from passing through two ISCs shows that the net positive suction head required for the HID pumps will still be met easily.

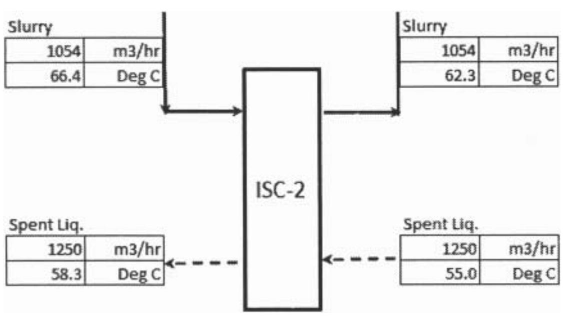


Fig 5: Spent liquor temperature increased by 3.3^{0}C after passing through ISC – 2

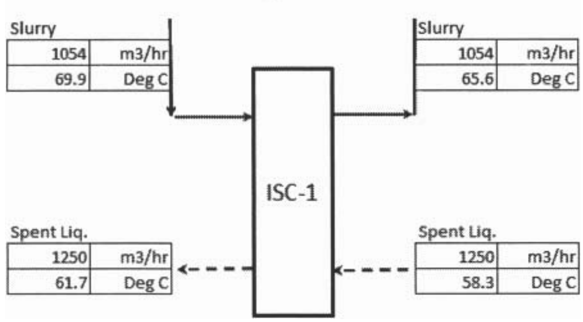


Fig 6: Spent liquor temperature increased by 3.4^{0}C after passing through ISC – 1

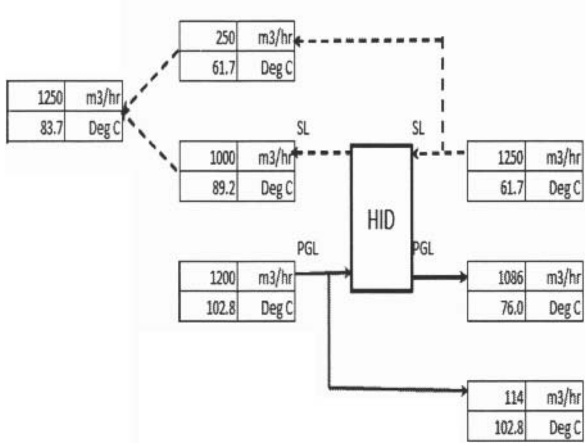


Fig 7: Spent liquor temperature increased to 83.7 ^{0}C after passing through HID

iii) Spent Liquor as cooling media in both ISC – 1 & 2 and ISC – 1 slurry input from last agglomerator:-

This is a combination of the actions from cases(i) and (ii). There will be 9.2^{0}C rise in spent liquor temperature across ISC – 1 and 2 as shown in Fig 8&9.The net spent liquor temp after HID will be 84.8^{0}C , shown in Fig 10.The spent liquor flow will again be in series (i.e. the outlet from ISC – 2 will be the inlet to ISC – 1) and the ISC – 1 slurry input will be from last agglomerator.

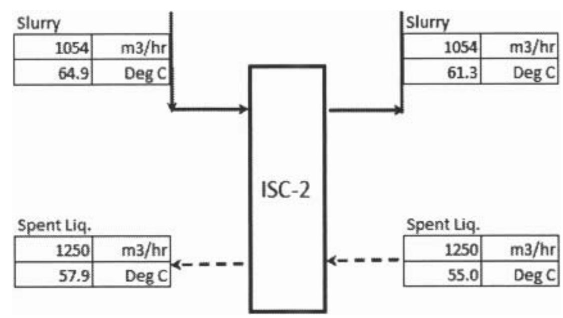


Fig 8: Spent liquor temperature increased by 2.9^{0}C after passing through ISC – 2

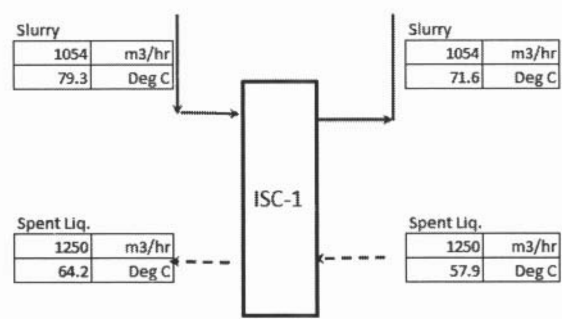


Fig 9: Spent liquor temperature increased by 6.3^{0}C after passing through ISC - 1

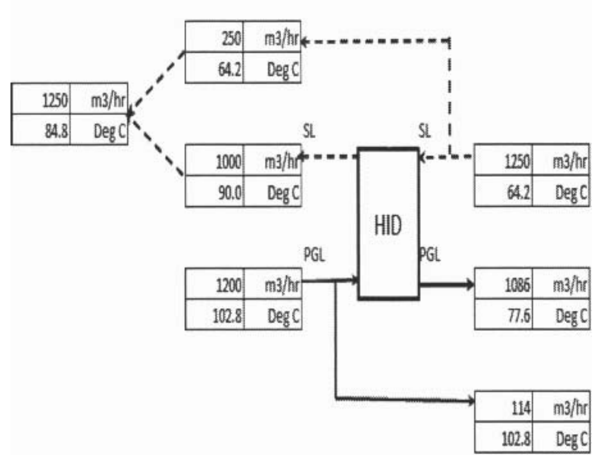
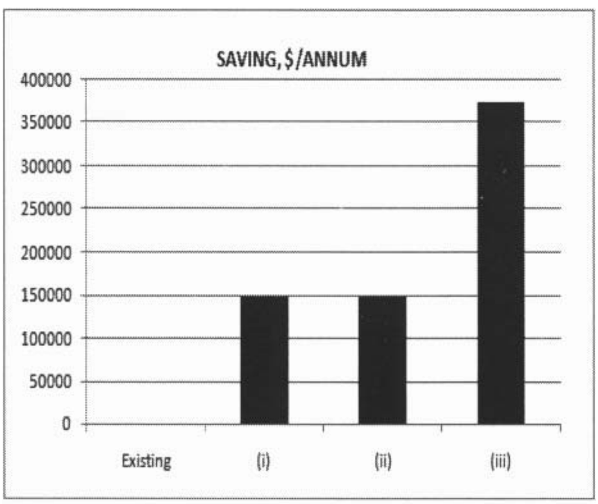


Fig 10: Spent liquor temperature increased to 84.8 ^{0}C after passing through HID

Expected Benefits

Table 1: Cost saving analysis with different modification options

Condition	Existing ISC - 1 with SL	(i) ISC - 1 inlet from Last agglo	(ii) ISC - 1 & 2 with SL series flow	(iii) ISC -1 & 2 with SL series flow as cooling media with ISC 1 slurry inlet from last agglo
SL Flow, M3/hr	1250	1250	1250	1250
SL Temp. after HID, Deg C	83.0	83.7	83.7	84.8
Heat,Q,KJ/Sec	129294	130447	130445	132225
Heat Gain w.r.t existing, KJ/Sec		1153	1150	2931
Net Mass of Steam Saving, T/hr		1.52	1.52	3.86
Saving, $/day	0	404	403	1027
Saving, $/Annum	0	147467	147126	374867



Graph 1: Savings / annum for different scenarios.

Conclusions

Up to 3.86 t/hr of steam can be saved by modifying ISC-2 to utilise spent liquor at 55^{0}C as the cooling medium and taking slurry input to ISC–1 from the last agglomerator. Further detailed analysis of the mechanical and operational feasibility along with the cost of the modifications for each scenario will be carried out.

At a price of $11.1/t steam, the cost savings vary from $147,000-$375,000 per annum and should be adequate to give a good return on investment as only minor modifications are anticipated to be required.

References

1. Roelof Den Hond, Iwan Hiralal and Ab Rijkeboer *" Alumina yield in the Bayer Process – past, present and prospects"* , Light metals 2007 , 37 – 42
2. Don W. Green, James O. Maloney , *"Perry's Chemical Engineers"* Handbook – seventh Edition – Sections 5-12,11-14
3. Nicholas P. Cheremisinoff, *"Handbook of Chemical Processing Equipment"* , 1 - 62
4. Max S. Peters, Klaus D. Timmerhaus and Ronald E. West , *"Plant Design and Economics for Chemical Engineers"* – Fifth Edition, 643 - 748