# Alumina Hydrate Suspension in the Draft Tube Precipitator Design – Batch versus Continuous Operation

**Kumaresan T.[1], Kiran Bhor[2], Vilas Tathavadkar[3], Ashish Mishra[4], Prasanta Bose[5] and Rohit Chourasia[6]**
1. Senior Scientist (Metals and Mining)
2. Senior Scientist (Metals and Mining)
3. Senior Vice President & Function Head (Metals and Mining)
Aditya Birla Science and Technology Company (P) Ltd., Navi Mumbai, India
4. Assistant Manager (Production)
5. General Manager (Technical)
6. Head (Production)
Hindalco Industries Limited, Muri, India
Corresponding author: kumaresan.t@adityabirla.com

## Abstract



Industry scale draft tube precipitator designs for the Bayer process have the task to uniformly suspend alumina hydrate particles with minimum power consumption. During operation, the hydrate concentration in the overflow will be uniform if particles are uniformly suspended in the entire precipitator volume, otherwise gradients in hydrate concentration may prevail. The strength of the draft tube pumping capability and the nature of the annular region flow pattern determines the quality of hydrate suspension in the entire precipitator volume. Batch operation exhibits an axial up flow pattern in the annular region. However, when draft tube precipitators are connected in series through launders, the annular region flow pattern converts to swirling flow that affects hydrate suspension. Consequently it is vital to maintain the characteristic flow pattern required for hydrate suspension during continuous operation.

**Keywords:** Alumina precipitator, mixing, draft tube, swirl flow, hydrate suspension.

## 1. Introduction

In the Bayer precipitation area, the overall economics of the process depends on the recovery of alumina by seeded precipitation from the caustic aluminate liquor, and the production of alumina trihydrate with a desirable size distribution. This result depends on favourable conditions of temperature, supersaturation, particle concentration, shape and size. Precipitation processes are of great industrial importance in the chemical, pharmaceutical and metallurgical process industries.

Loh et al. (2000) concluded that the precipitation process is the rate determining step in the production of aluminium hydrate by the Bayer process [1]. This unit process not only determines the productivity but also the product qualities of size and strength. When the local environment is supersaturated, the particles tend to grow, while on the other hand when the local environment is saturated or unsaturated, the particles tend not to grow or to dissolve.

The mixing in large scale vessels can determine whether favourable or non-favourable conditions for precipitation exist. Green (2002) indicated that to a large extent, convective mixing determines the macro-environment both temporally and spatially and the in-homogeneity in the macro flow pattern ultimately affects the local environment of temperature, supersaturation and particle concentration [2].

Bourne and Sharma (1974) studied the effect of draft tubes on the critical propeller speed of a particle suspension using the flat-bottomed stirred vessel [3]. They observed a 26% reduction in the propeller critical speed for a particle suspension in the presence of a draft tube. Fort (1986) studied the effect of a draft tube on the flow pattern produced by pitched blade turbines using a conical shaped draft tube, where the diameter gradually varied from top to bottom [4]. It was observed that the average volumetric flow rate increased by ~100% in the presence of a conical-shaped draft tube.

Later, Tatterson (1982) observed that the use of draft tubes in stirred vessels enhanced the circulation time and avoided the short circulation of the flow produced by a pitched blade turbine [5]. Further, he studied the effect of draft tube diameter on the circulation time, observing that the draft tube with smaller diameter gave a lesser circulation time (19.2 %) than the draft tube with larger diameter. The draft tube length was maintained constant throughout the experiments.

The comprehensive study published by Kumaresan et al. (2005) investigated the flow pattern for the narrow draft tube and illustrated the effect of two alternative lengths of a draft tube on the flow pattern and, hence, on the mixing performance [6]. The taller draft tube configuration results in an increase in secondary flow number, and consequent decrease in mixing time by 22%.

Lane (2006) studied the effect of two aspect ratios of draft tube agitation configurations on the flow pattern and particle density distribution [7]. The impeller was modeled as a constant source model in their CFD studies for both the aspect ratio designs. They concluded that the unstable re-circulating vortex bursts transport the particles to the tank surface for the smaller aspect ratio design.

Wu et al. (2012) studied the off-bottom particle settling height for swirl flow rotor configuration, draft tube agitator and multi staged agitator [8]. They justified that the draft tube agitation system is more efficient for particle suspension. Brown et al. (2014) investigated the effect of mesh density with various combinations of turbulence models in the taller aspect ratio tanks using CFD [9]. A simulation with a medium level of mesh density using a momentum source model was compared with the impeller rotation model. The predicted CFD simulation results were validated using laser Doppler anemometer experiments for normalized mean axial velocities.

Previous publications have extensively studied the effect of draft tubes on the flow pattern, circulation time and mixing time in batch stirred tanks. Very few references are available concerning draft tube agitation with a focus on alumina precipitators with taller aspect ratio ($H/T \geq 2$). The present work illustrates the importance of the change in the characteristic flow pattern of draft tube precipitator from batch to continuous operation and its impact on the hydrate suspension.

## 2. Draft Tube Precipitator Design

The brief overview of literature reported above reveals that published investigations put more emphasis on the shorter draft tubes when focused on batch operation. The draft tube precipitator design considered in this study has a tank diameter of 14m, draft tube diameter of 4.6m, liquid height of 36m and draft tube height of 27m. The higher aspect ratio design ($H/T > 2$) in refineries always helps to minimize the energy consumption compared to air lift agitation or multistage mechanical agitators.

## 6. References


1. Loh, J. S. C., Fogg, A. M., Watling, H. R., Parkinson, G. M., Hare, D.O., 2000. A kinetic investigation of gibbsite precipitation using in situ time resolved energy dispersive X-ray diffraction. *Phys. Chem. Chem. Phys*. 2, 3597 – 3604.
2. Green
3. Bourne, J. R., Sharma, R. N., 1974. Suspension Characteristics of Solid Particles in Propeller-Agitated Tanks. 1st European conference on mixing. B3, 25-38.
4. Fort, I., 1986. Flow and Turbulence in Vessels with Axial Impellers. In Mixing: Theory and Practice; Uhl, V. W., Gray, J. B., Eds. 3, 133-195.
5. Tatterson, G. B., 1982. The Effect of Draft Tubes on Circulation and Mixing Times. Chem. Eng. Commun. 19, 141-147.
6. Kumaresan, T., Nere, N. K., Joshi, J. B., 2005. Effect of Internals on the Flow Pattern and Mixing in Stirred Tanks. *Ind. Eng. Chem.* Res. 44, 9951-9961.
7. Lane, G., 2006. Flow instability in an alumina precipitator fitted with a draft tube circulator. 5th Int. Conf. on CFD in the Process Industries, CSIRO, Melbourne, Australia. 1 – 6.
8. Wu, J., Lane, G., Livik, I., Nguyen, B., Graham, L., Stegink, D., Davis, T., 2012. Swirl flow agitation for scale suppression. *Int. J. Min. Proc.* 44, 19-29.
9. Brown, G.J., Whyte, D.S., Fletcher, D. F. 2013. Dynamic flow modelling in precipitator vessels – A study of turbulence modeling approaches. *Applied mathematical modeling.* In press.
10. Landberg, G. G., 1970. Draft tube arrangement for starting-up and settled solids. U.S. patent (3532327).
11. Kumar, A., Kumaresan, T., Pandit, A. B., Joshi, J. B., 2006. Characterization of flow phenomena induced by ultrasonic horn. *Chem. Eng. Sci.* 61, 7410-7420.
12. Kumaresan, T., Kumar, A., Pandit, A. B., Joshi, J. B., 2007. Modeling Flow Pattern Induced by Ultrasound: The Influence of Modeling Approach and Turbulence Models. *Ind. Eng. Chem. Res.* 46, 2936-2950
13. Harvey, A.D., Rogers, S. E., 1996. Steady and Unsteady Computation of Impeller-Stirred Reactors. *AIChE Journal*. 42, 2701- 2712.
14. Weetman, R.J., 1997. Automated Sliding Mesh CFD Computations for Fluid foil Impellers. Proc. 9th Eur. Conf. Mix. 11, 195.
15. Aeschbach, S., Bourne, J. R., 1972. The attainment of homogeneous suspension in a continuous stirred tank. *Chem. Eng. J.* 4, 234 - 242.
16. Hoekstra, A. J., Derksen, J. J., Van Den Akker, H. E. A., 1999. An experimental and numerical study of turbulent swirling flow in gas cyclones. *Chem. Eng. Sci.* 54, 2055 – 2065.
17. Howk, R., Giralico, M., 2008. Stat-up method for draft tube mixing. U.S. patent (7331704 B2).
18. Ayranci, I., Machado, M. B., Madej, A. M., Derksen, J. J., Nobes, D. S., Kresta, S. M. 2012. Effect of geometry on the mechanisms for off-bottom solids suspension in a stirred tank. Chem. Eng. Sci. 79, 163–176.