

# AKW Equipment + Process Design Expertise in Alumina Refineries

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## Abstract

As the Bauxite and Alumina industry currently face important market challenges, a key objective is to improve and optimize the overall process chain, from bauxite mining and processing through to the refinery and smelter process. Since 1978, AKW Equipment + Process Design delivered more than 50 projects in alumina refineries. There, AKW A+V hydrocyclones AKA-VORTEX and distributors AKA-SPIDER have been operating successfully for several decades. For the special conditions of hot caustic soda, AKW Equipment + Process Design proprietary polyurethane hydrocyclones are also used with great success, contributing to significant cost savings without compromising process performance. Beside this traditional approach, AKW Equipment + Process Design recently introduced its unique twin hydrocyclone concept for alumina classification. Also made of our proprietary polyurethane, this newly introduced system is capable of delivering further cost savings, especially through smaller footprint and easier maintenance. An explanation of the installation and operation of such alumina clusters in a refinery will be shown as an example.

**Keywords:** Alumina refinery; alumina classification; twin hydrocyclones; annular distributor.

## 1. Introduction

Alumina is usually produced from bauxite in the well-established Bayer process. This process utilizes the thermodynamic properties of the caustic soda-aluminum hydroxide system. In the Bayer process, a caustic soda liquor flows in a circuit which is fed with ground bauxite and then heated to digestion temperature. The bauxite's alumina minerals dissolve at the elevated temperatures and pressures in the digesters. Afterwards, the undissolved material from the bauxite, i.e. the bauxite residue or red mud, is removed from the process by means of thickeners and/or filters. The supersaturated liquor is then cooled to induce crystallization. To accelerate the precipitation process to commercially feasible rates, previously precipitated alumina tri-hydrate (fine seed, coarse seed) is added to the pregnant liquor to improve the crystallization rate and product quality. At the end of the precipitation process, alumina tri-hydrate can be separated by hydrocyclones into product, fine and coarse seed and de-liquored by filters. In a last process step, the aluminum hydroxide is converted to alumina by calcination. [1, 2]  
The "all time modern process philosophy" can be summarized in the following manner:

- decreasing of energy consumption by improvement of liquor productivity;
- decreasing of Al-hydrate losses;
- increasing the particle strength of alumina;
- improving alumina handling,
- minimizing the environmental impact;

It has to be taken into account that the Bayer process is constantly evolving and the specific techniques employed in this highly sophisticated industry for the various steps of the process do vary from refinery to refinery. Always however, alumina tri-hydrate crystal formation (the nucleation and growth of alumina tri-hydrate crystals), and the precipitation and collection

thereof, are critical steps in the economic recovery of aluminum values in all plants. Bayer process operators strive to optimize their crystal formation and precipitation methods to produce the greatest possible product yield from the Bayer process, while producing crystals of a given particle size distribution. A relatively high coarse, and low fines content in alumina product is beneficial to the subsequent processing steps required to convert alumina to aluminum metal. The state of the art technique to separate the coarse particles as product and the fine particles as seed (coarse and fine seed) is presently hydrocyclones. [3]

## **2. Application of hydrocyclones in the Bayer process**

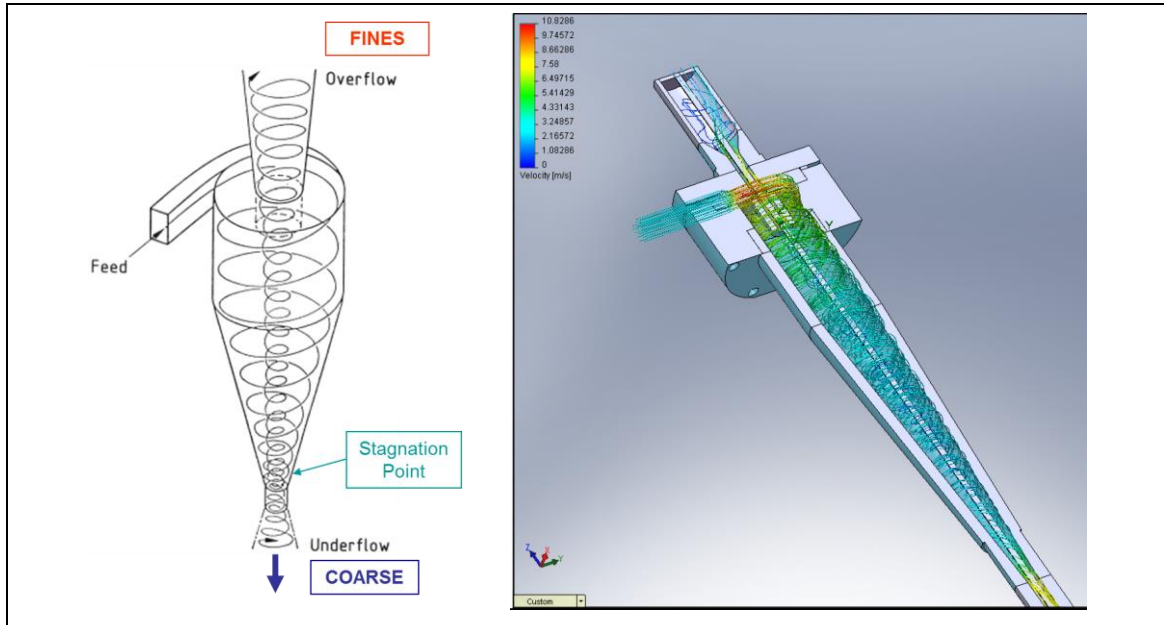
The use of hydrocyclones in the alumina industry using the Bayer process goes back to a development in the late sixties between VAW, a German alumina producer (Schwandorf, Lünen, Stade) and AKW A+V. Shortly after this successful introduction of cyclones in the Bayer process, NABALCO, Gove was the first Australian refinery to install AKW A+V hydrocyclones in 1978. In Australia Kwinana, Pinjarra and Wagerup followed in the 1990s.

### **2.1. About the operational principal of hydrocyclones**

The hydrocyclone can be classified as a mechanical separation device in which sedimentation takes place in a centrifugal field. It is rather like a tube centrifuge with a nonrotating body. If the rotation of the basket in a centrifuge is regarded purely as a feature of design, and not as an essential functional factor, then the hydrocyclone can be regarded as a solid-wall overflow centrifuge with automatic slurry discharge.

The simple construction of the hydrocyclone, and in particular the lack of rotating parts, means it can be made of a variety of materials and in different shapes, which is an advantage in combating wear and corrosion.

Rotational motion in a hydrocyclone is produced by the suspension entering tangentially under pressure. Flow is at first down the inner wall of the cylindrical section and the cone, as far as the stagnation point near the cone apex. There, because the opening is small, the downward primary vortex is forced to turn upwards again, forming the secondary vortex. This revolves tightly around the air core near the axis and finally leaves the cyclone body through the upper axial nozzle, or vortex finder. In a cross section of the body, both spirals rotate in the same direction; in longitudinal section, however, they move in opposite directions.



**Figure 1. Flow pattern of the hydrocyclone.**

The phase separation of the suspension takes place during this double vortex flow. The suspended particles, at least the coarse fractions, move outwards to the wall of the cyclone, where they flow downwards as a screw-shaped slurry stream. This leaves as the underflow stream through the apex opening, or underflow nozzle. The nozzle is closed hydraulically by the underflow slurry stream, thus preventing the main stream of suspension, now thinned or clarified, from entering. The main volumetric stream is then forced to move through the inner vortex and leave the cyclone via the vortex finder, which acts as an overflow outlet (and therefore is also known as the overflow nozzle).

Cyclones should not be designed only according to the size of the flow to be handled. For achieving small cut sizes the use of a small cyclone diameter  $d$ , with the length  $l$  as long as reasonable is of advantage. Large capacities can be obtained by using many small cyclones in parallel. For coarse separations, cyclones with a larger diameter are used.

An increasing solid content of the feed causes decreasing efficiency of separation due to the hindered settling of particles. This means on the other hand, a low solid content of the feed results in a high efficiency of separation, because the influence of hindered settling is low. The cut size of a hydrocyclone, defined as  $d_{150}$ , is mainly influenced by the diameter of the hydrocyclone itself, but other geometrical ratios of the hydrocyclone influence the cut size, for example:

- the geometry of the feed part,
- the total length of the hydrocyclone,
- the diameter of apex and overflow nozzle,
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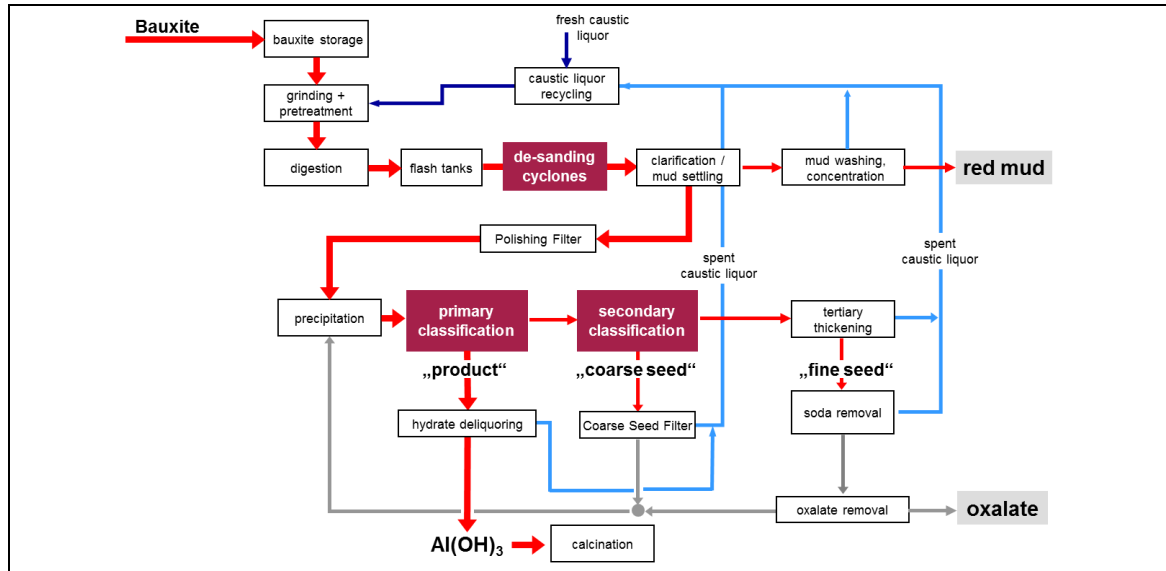
A coarser cut size for example is caused by;

- a smaller diameter of the apex;
- a bigger diameter of the overflow nozzle;
- a reduction of the total length of the hydrocyclone by removal of cylinder parts;
- a bigger angle of the conical part (up to a flat bottom).

## 2.2. Typical sub-process where hydrocyclones are used

In principal there are 4 applications for hydrocyclones inside an alumina refinery:

- close circuit bauxite milling;
- de-sanding of digested slurry;
- hydrate classification;
- stripping cyclones.



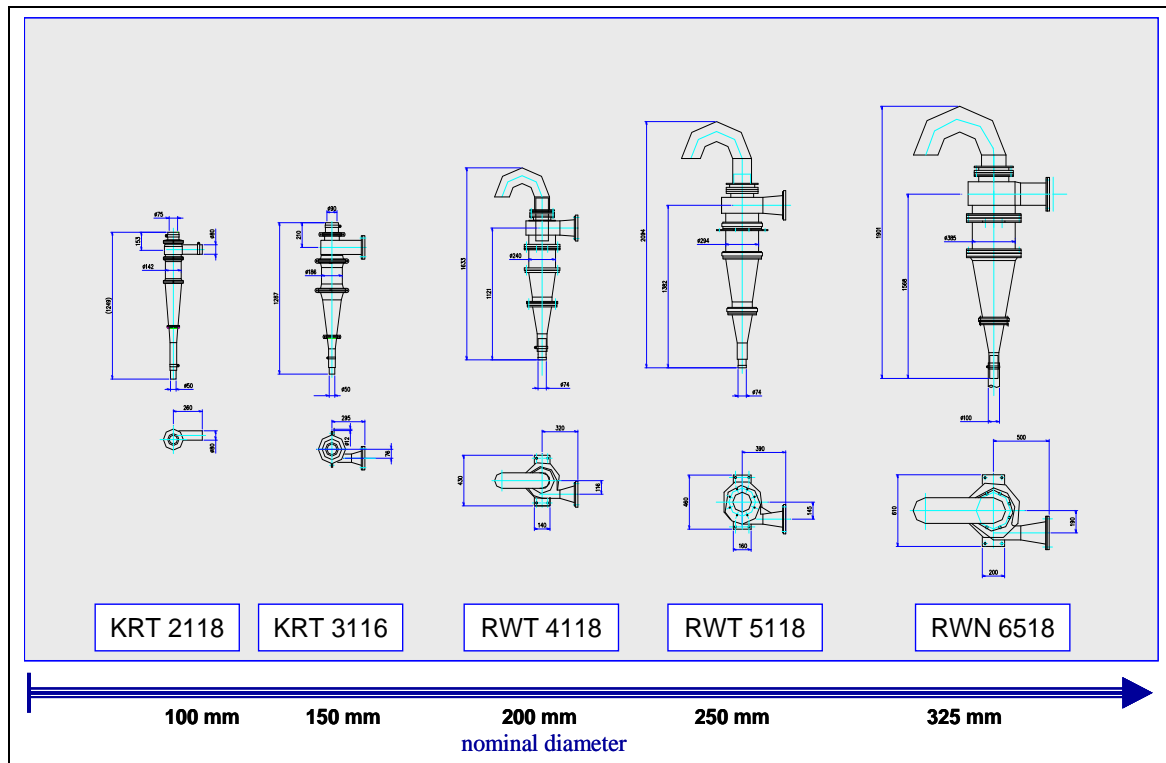
**Figure 2. Schematic flow sheet of the Bayer circuit and application for hydrocyclones.**

This paper focusses on the **hydrate classification** (primary and secondary classification).

Hydrocyclones had been used in the past either in parallel or series with settlers. The process target was the optimization, debottlenecking and expanding of existing plants. Modern greenfield plants incorporate hydrocyclone clusters in hydrate classification to eliminate the use of settlers as classifiers. For Hydrate classification two different applications have to be distinguished:

- product classification;
- seed classification.

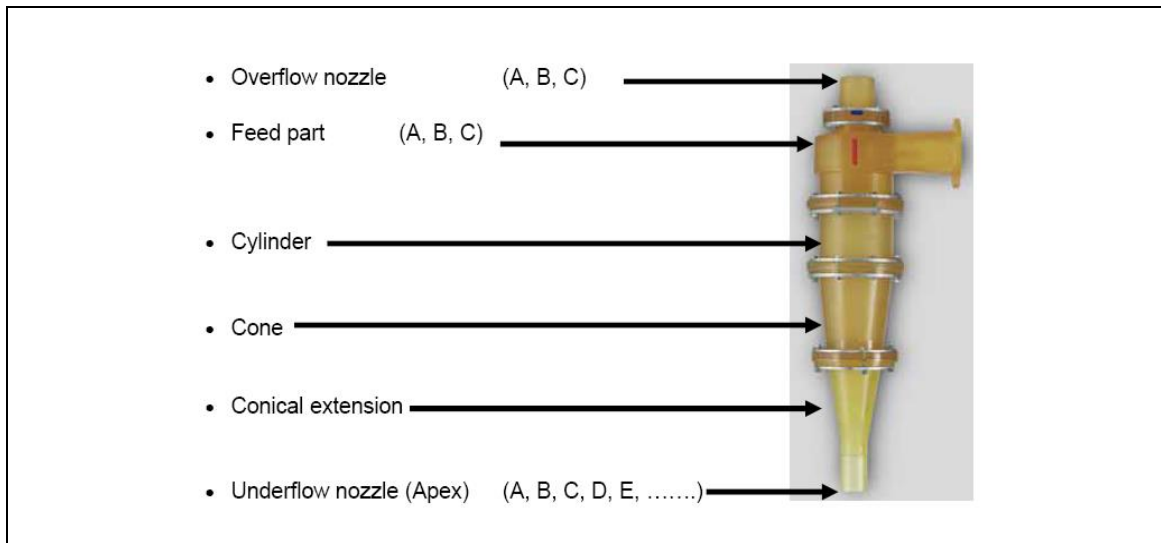
Standard type cyclones for hydrate classification have a range from 100 mm up to 325 mm. The smaller cyclones with 100 mm – 150 mm nominal diameter are used for seed separation and the bigger cyclones with 200 mm – 325 mm are used for the product classification.



**Figure 3. Standard type hydrocyclones of AKW A+V for hydrate classification.**

The AKW A+V hydrocyclones are manufactured from a highly wear-resistant special polyurethane and consists of several replaceable sections connected by means of clamps or flanges. Inlet sections, overflow and underflow nozzles are available with different nozzle cross-sections and are exchangeable in the modular system. Special adaptation to the specific application is therefore possible, even after years of operation.

The cyclones of AKW A+V are of a modular design so that they can be adapted to each particular application in an optimum way. The different feed parts and overflow nozzles do have different geometrical sizes. Thus influences the capacity of a cyclone as well as the separation characteristics. The combination of feed part and overflow nozzle is called “modification”. Generally, the cyclones consist of the following components which are connected to each other by brackets, loose flanges or bolted threads:



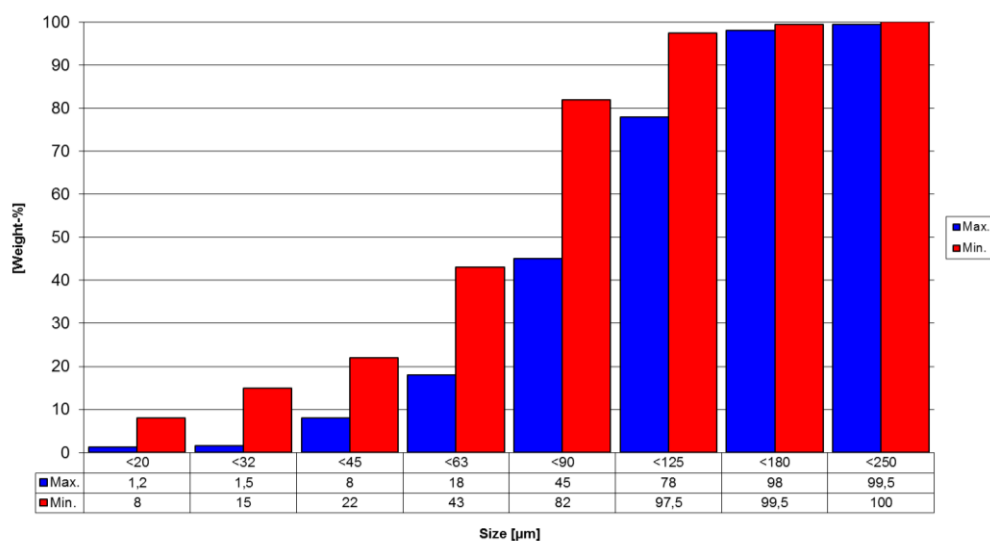
**Figure 4. Components of a hydrocyclone.**

### 2.3. Process targets and practical results

For alumina tri-hydrate classification, one up to three stages of cyclone clusters are used to produce a defined product (maximization of +45 $\mu$ m particles) and a coarse and fine seed which are recycled into different stages of precipitation. Due to the increased quality demand of the aluminum smelters (electrolysis), the requirements for the coarse product (sandy alumina) have also risen. The result of the cycloning, with respect to the amount of particles +45 $\mu$ m in the product (underflow) is influenced (besides the geometry of the hydrocyclone itself) by:

- solids content of the feed;
- amount of particles +45 $\mu$ m in the feed;
- number of stages;
- pressure drop;
- achievable solids content of the underflow.

In Figure 5 below, the minimum and maximum values for the particle size distribution (PSD) of the hydrocyclone feed (first stage) of a refinery in South America are shown.



**Figure 5. Particle size distribution (PSD) of product cyclone feed.**

A quite normal quality demand is a value of 97 – 98 % of coarser particles (+45 $\mu$ m) for the product. This target should be achieved with “high” feed solids content and also with fluctuations in the amount of particles +45  $\mu$ m in the feed.

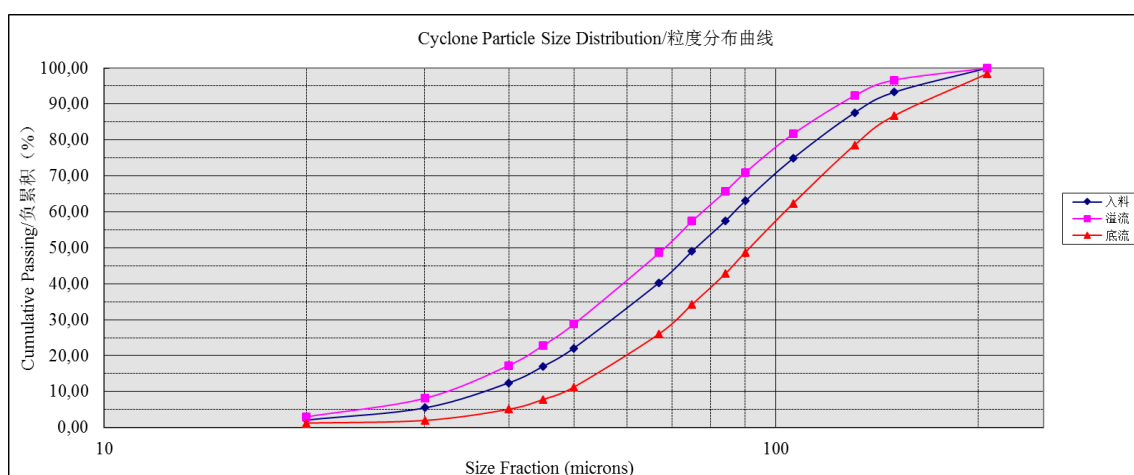
Normal feed parameters for the first classification step comprise a solids content of the feed in the range of 400 – 500 g/l and a +45 $\mu$ m fraction in the range of 78 – 92 %.

In Table 1 below, the average values of a single step classification with a 200 mm  $\varnothing$  hydrocyclone, type RWT 4118 are shown. It can be seen that the classification efficiency depends on the solid content of the feed, but that good results have been achieved up to 540 g/l.

**Table 1. Practical results of classifying with RWT 4118.**

Average values out of 1600						Mass Recovery [w.-%]
PSD (+ 45 Micron)			Solids Concentration (g/l)			
Feed	Overflow	Underflow	Feed	Overflow	Underflow	
87,1	83,3	96,5	229	189	977	21,7
89,2	84,0	97,3	278	191	991	38,9
91,6	87,5	97,6	322	208	994	44,7
90,4	86,4	97,3	375	220	991	53,2
90,9	89,3	97,4	418	273	961	48,5
88,2	84,5	96,0	468	260	972	60,6
91,8	88,2	97,3	539	276	967	68,3

In a Chinese refinery a series of tests were performed with a 250 mm  $\varnothing$  hydrocyclone, type RWT 5118 II. Figure 6 below shows the PSD of feed, overflow (OF) and underflow (UF). These data have been achieved with a pressure drop of 160 kPa and a feed solids content of 610 g/l. The feed has a -45  $\mu$ m particle fraction of 17 %, while the -45  $\mu$ m particle fraction is reduced to 8 %.



**Figure 6. Test results of a 250  $\varnothing$  mm hydrocyclone with a feed of 610 g/l.**

In parallel, a 150 mm  $\varnothing$  hydrocyclone, Type TRT 3128 (TWIN type) was tested. The results of a test with a pressure drop of 185 kPa and a feed solids content of 530 g/l are shown in Figure 7. The -45  $\mu$ m fraction in the feed was 21 % and in the UF just 7 %.

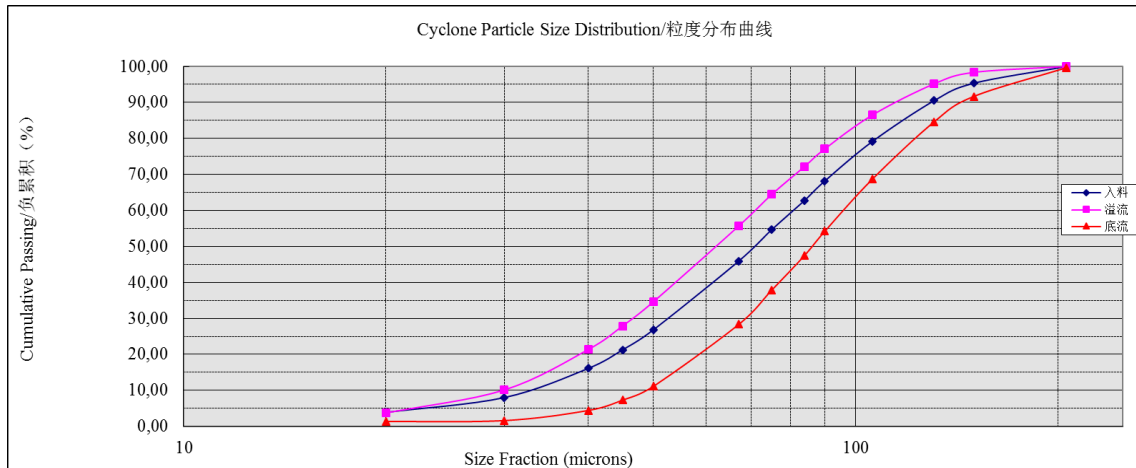


Figure 7. Test results of a 150 Ø mm hydrocyclone with a feed of 530 g/l.

#### 2.4. The TWIN type hydrocyclone

With the unique TWIN feed part, which is available for our 100 mm, 150 mm and 200 mm Ø hydrocyclones, it is possible to reduce the foot print of the necessary distributors, resulting in less steelwork for the same capacity, and a reduction in the number of necessary valves. Both of these effects reduce the investment costs for the refineries.

The TWIN hydrocyclone works in the same way as a normal SINGLE hydrocyclone, but has a doubled capacity for one inlet. The principal is shown in Figure 8.



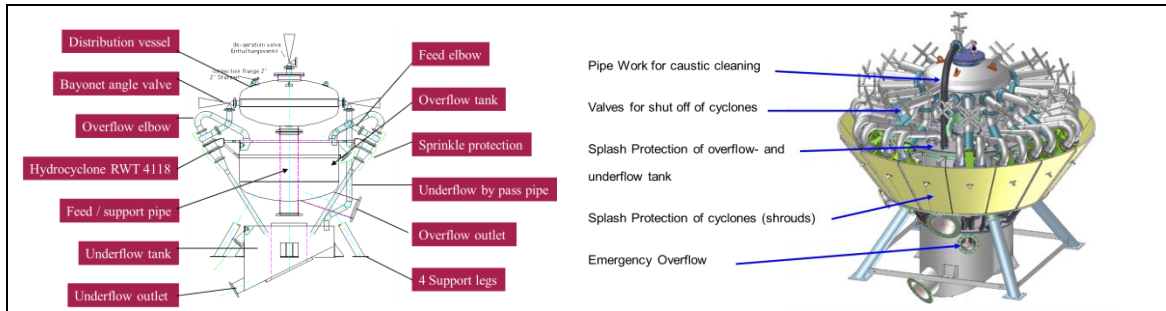
Figure 8. Twin feed part of AKW A+V and an example of a TWIN type hydrocyclone.

This type of hydrocyclone has been tested and operated with very good success for more than ten years and is presently installed in different refineries in Asia and South America.

The dimensions of the three available TWIN types are shown in Figure 9.



The AKW A+V distribution system for cyclones and the specially designed associated equipment, the unique way of mounting the cyclones in a slightly inclined position and the material the hydrocyclones are made of, are based on decades of sometimes painful experience. These long term experiences and the constant feedback from our clients have made it equipment which today contributes substantially to improving the quality of the end product of the alumina industry. The final layout depends on the client's special requirements concerning health and safety, and available space.



**Figure 11. Examples of the basic design of distributors for alumina refineries.**

The following pictures (Figure 11) show examples of installations in alumina refineries.



**Figure 11. Examples of the basic design of distributors for alumina refineries**

#### 4. Conclusion

The use of hydrocyclones in the alumina industry using the Bayer process goes back to a development in the late sixties between VAW, a German alumina producer (Schwandorf, Lünen, Stade) and AKW A+V.

For Al-hydrate classification, one to three stages of cyclone clusters are used to produce a product where  $-45\mu\text{m}$  particles is minimized, and a coarse and fine seed which are recycled into different stages of precipitation.

The special demands of alumina refineries concerning the feed conditions (temperature, caustic soda, solid content, ...) have to be addressed with a well-considered approach to the whole classification system, consisting of;

- the hydrocyclone itself (MOC, shape, dimensions ,...)
- the installed accessories (valves, splash protection, hoses ,.....)

The individual layout, of course, depends on the special requirements of the clients concerning health and safety, and available space.

In state of the art refineries, hydrocyclone installations as product cyclones and seed cyclones are an integral part of the process chain. To underline the benefit of such an installation a paper of the TMS Light Metals Congress 2005 is cited.

*“Alpart’s old classification units consists of gravity settlers for Primary, Secondary and Tertiary material. The Primary material was then washed counter-currently across settled hydrate tanks. Sump material that consisted of fines was also recycled to the primary vessels via a Sump Relay Tank (SRT). This consisted of material varying from 10-20% on  $-44\ \mu\text{m}$ , and  $\approx 6\%$  on  $-20\ \mu\text{m}$ , the highest in terms of percentage for  $-20\ \mu\text{m}$  in any stream in the circuit, except for the tertiary seed. This stream recycled  $\approx 3000\text{tpd}$  at  $3000\ \text{gpm}$ , and averaged  $>200\text{gpl}$  solids. It consisted mainly of Hy-tank (Hydrate Tank) overflow and sump material. The resultant overload of classification caused excess fine seed, the use of higher temperatures, and 3-4 agglomeration trains along with fine seed re-digestion to maintain seed balance. This meant at times  $\sim 80\%$  of product material came from agglomeration trains, giving a weak product.*

*To improve the product cut and capture, a series of cyclones were installed above the settled hydrate tanks. Upon completion, hydrate capture increased from 50% to 80%, and cut improved to 55% on  $-44\ \mu\text{m}$  through the cyclones.*

*However, there was still considerable hydrate re-cycle, as the settled hydrate tanks were still allowed to overflow. Since September 2003, a ‘Classification Control Philosophy’ was implemented to change the operating mode.*

*The focal points of the philosophy were:*

- Cycloning of all product material.
- Pumping Primaries at specified rates to maintain a ‘soft hydrate bed’ and reduce pressure variations to cyclones.
- Removing SRT traffic from the product primaries.
- Operating the Hy-tanks as agitated vessels and do not overflow.

*The result was a 50% reduction in the recycle load on the classification and sump system. Furthermore, this mode of operation has helped to reduce secondary overflow solids and maintain good seed balance. This has ensured that there is only need for 2-3  $\approx 2.5$  agglomeration trains, under normal operating conditions, with no need for re-digestion of fine seed.” [5]*

## 5. References

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