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HYDROSEPARATORS, HYDROCYCLONES AND CLASSIFIERS AS APPLIED IN THE BAYER PROCESS FOR DEGRITTING (DESANDING) OF DIGESTED BAUXITE, AND FOR SAND WASHING TO RECOVER SODA

F. Krause, N.C. Beaton, K.D. Grüner

DORR-OLIVER GmbH
Friedr.-Bergius-Str. 5, D 6200 Wiesbaden, FRG

ABSTRACT

The presence of coarse sand particles in digested bauxite slurry has led to many problems in the downstream units of alumina plants. Desanding of the digested slurry is therefore essential, as well as sand washing for maximum recovery of soda.

The application of Hydroseparators, hydrocyclones and rake classifiers to desanding and soda recovery is discussed.

Using illustrative examples, process parameters and operating conditions for desanding and sand washing are described in this paper.

INTRODUCTION

In the BAYER-PROCESS, ground bauxite mixed with a solution of caustic soda, is fed to autoclaves where DIGESTION is carried out at high temperature and pressure.

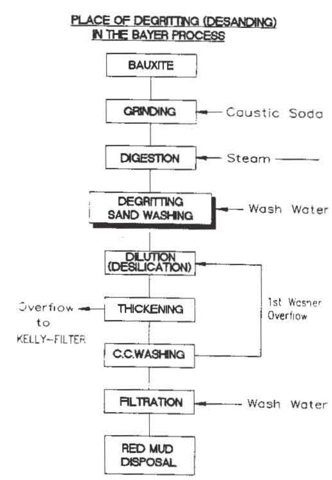
Most of the alumina dissolves by forming sodium aluminate. The insoluble residue, the so-called "RED MUD" must be separated from the solution and washed for maximum recovery of soluble soda.
This is done by countercurrent decantation in rake thickeners and washers, followed frequently by final dewatering on roller discharge drum filters.

The coarse fraction of the red mud solids, the so-called "SANDS", may cause serious mechanical problems in the thickeners as well as in the filters.
Therefore, this coarse fraction must be removed before the red mud enters the thickeners.
This is done in a DEGRITTING (DESANDING) station (Fig. 1.), where the separated sands are further washed for soda recovery.

Proper protection of the thickeners is important. They should not be burdened with surges of sands, especially where outward raking is practised. Blockages and breakages of rake mechanisms have occured due to temporarily poor degritting.

Also, agitators in roller discharge filters have been blocked or even broken because of sand accumulation in the filter vat.

Emphasis must therefore be placed on a well designed degritting plant.



Degritting Requirements

The importance of degritting varies, with the kind of bauxite and with the grinding and digestion conditions. It is not easy to generalize in this field, where the quantity and size distribution of the sands differs from one plant to another.

Very often, the users themselves specify the separation they require.

Degritting takes place after the digested bauxite has been diluted in flash tanks.

The following general guidelines apply:

- If the BAUXITE is ground sufficiently fine in closed circuit with an integrated classifying device, then degritting may not be necessary.
- "Sand"-concentration in the digested bauxite slurry is erratic. Therefore, SAND SURGES have to be considered during equipment sizing.
- For OUTWARD-RAKING-settlers and washers with flat bottoms, as well as for smooth operation of red mud drum filters, it is necessary to degrit at 100 micrometers (150 mesh), leaving a maximum of 1 - 2 % of the feed solids above this particle size.
- For INWARD-RAKING settlers and washers with sloping bottoms the thickeners can accommodate particle sizes up to 250 micrometers (60 mesh) in the feed.

EQUIPMENT

Degritting (Desanding) can be carried out in combinations of the following classification equipment (Fig. 2):

- HYDROSEPARATORS
- HYDROCYCLONES
- RAKE-/SCREW-CLASSIFIERS

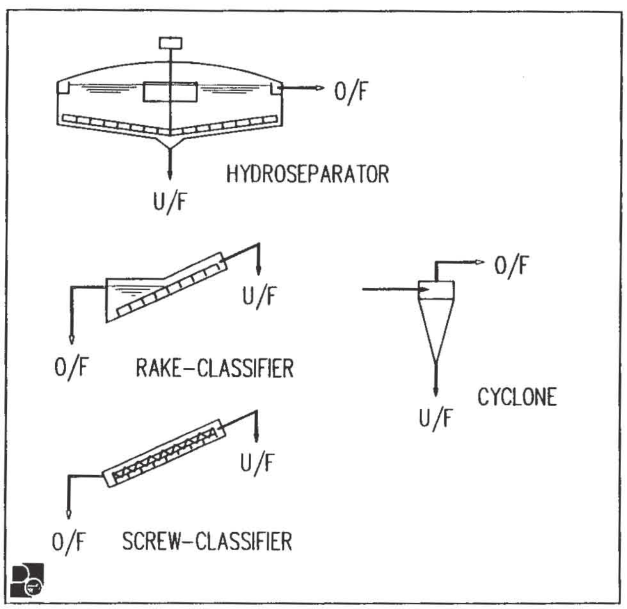


FIG. 2: CLASSIFICATION EQUIPMENT FOR RED MUD DEGRITTING/SAND WASHING

While the overflow of the degritting units is pumped to the settlers (e.g. DORR-OLIVER CABLETORO®-THICKENERS), the underflow solids are washed in rake- or screw classifiers or in hydrocyclones.

Sometimes, a deliquoring classifier is used before the washing classifiers, after initial degritting using Hydroseparator or hydrocyclones.

HYDROSEPARATOR

Hydroseparators are cylindrical tanks with a sloping bottom of 20 - 25°, having radial rakes mounted on a vertical shaft (Fig. 3.). The rakes convey the settled material to the central discharge cone. Basically, their design is the same as for thickeners.

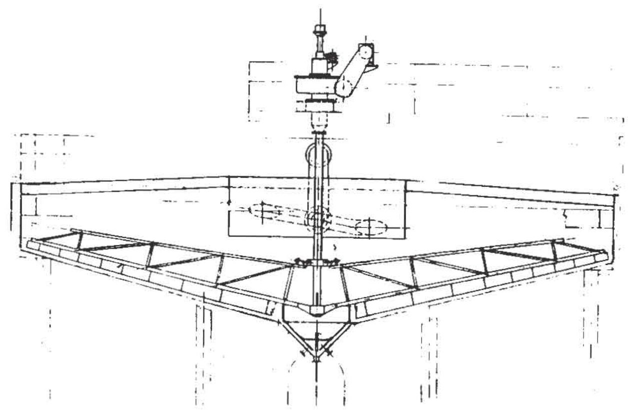


FIG. 3: GENERAL ARRANGEMENT OF HYDROSEPARATOR ("OVERLOADED THICKENER")

A Hydroseparator is essentially an overloaded thickener, where fine material is carried out in the overflow. Hydroseparators are used for separation in the 50 - 250 micrometer range.

Compared with rake-/screw-classifiers, the outstanding feature of Hydroseparators is the very large overflow capacity obtainable at low capital cost.
They are therefore used in preference to rake-/screw-classifiers for the first desanding stage because of the huge liquor quantities to be handled at this stage. Hydrocyclones however, are also equally applicable at this stage.

Comparison with Hydrocyclones

- An advantage is that the high overflow capacity is obtainable at low energy cost.
- Sand surges can, in principle, be handled more reliably, although the possibility exists to have stand-by cyclones available in the event of a serious underflow blockage.

- A main limitation of the Hydroseparator is its lack of flexibility in adjusting the size of separation. This is due to the fact, that unlike, for example, in a rake-/screw-classifier, the rake arms are deeply submerged. A change of rake speed cannot therefore be relied on for regulating the areal efficiency and consequently the size of separation. Such a regulation can be obtained only by changing the overflow rate or overflow density. By comparison, the size of separation in hydrocyclones can be adjusted - in certain limits - by changing the nozzles sizes.

- Other disadvantages of Hydroseparators are that:

  - The sharpness of separation is poorer (more fines in the underflow).

  - The underflow solids content is generally lower.

  This contributes to a greater proportion of undersize in the underflow, as well as increasing the quantity of soda going on to the sand washing station. As indicated below, an effective solution to this problem is the installation of a deliquoring classifier to treat the Hydroseparator underflow. This is also a frequent procedure, even with hydrocyclone desanding flowsheets.

Sand Surge Handling

With regard to "sand"-surges, experience has shown that the "sand"-concentration in the red mud discharge from the digesters is erratic. If the Hydroseparator discharge system is sized only for the average sand concentration in the red mud, then if a sand surge occurs, coarse particles will report to the overflow before the operator has had time to adjust the discharge valve. This can lead to mechanical troubles with the thickeners and filters.

The problem of sand surges is even more critical when hydrocyclones are used instead of a Hydroseparator. It is therefore recommended to select an underflow discharge system providing a maximum 20 % solids under normal conditions, allowing the solids to rise when sand surges take place.

Underflow discharge control is important. Preferably, a Hydroseparator installation should be sufficiently elevated that the underflow can flow to the classifiers by gravity.

As an alternate to gravity flow, a diaphragm pump can be considered. Effective continuous control of the underflow density is recommended.

Sizing Factors

When sizing a Hydroseparator one should keep in mind that besides attention to sand-surges, many other factors influence the settling rate. For example:

- Solids concentration (30-130 g/l)

- Solids specific gravity (2.7-3.3 g/cm³) (high iron content in the red mud increases the spec. gravity.)

- Liquid specific gravity (1.2-1.3 g/cm³) (depends on soda concentration.)

- Liquid viscosity and temperature

The settling rates, observed in practice are much lower than those predicted by Stoke's Law. This is illustrated in Fig. 4.

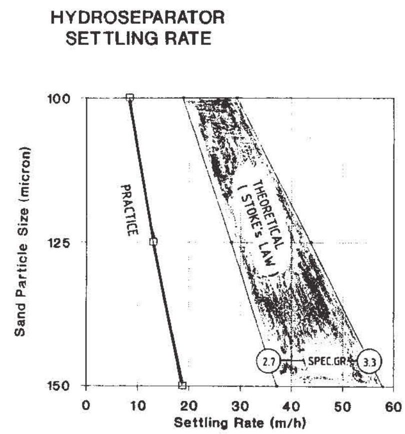


FIG. 4: HYDROSEPARATOR SETTLING RATE

HYDROCYCLONES

The hydrocyclone (Fig. 5.) is a cylindrico-conical chamber with a cone angle between 20°-30°.

FEED is introduced through a pressurised tangential inlet into the cylindrical section, with an inlet pressure ranging from 0.5 - 1.5 barg. The slurry takes up in a fast rotating motion and the solids are subjected to a high centrifugal force. The coarsest and heaviest particles discharge in a relatively thick UNDERFLOW through an adjustable apex-valve.

A vortex-finder or overflow pipe which is centred in the cylindrical feed chamber, and extends slightly below the feed inlet, delivers the fine and/or light fraction into the OVERFLOW.

In degritting/sand-washing applications, the flows involved are usually high, and the separation is relatively coarse - in the range of 65 - 150 micrometers.

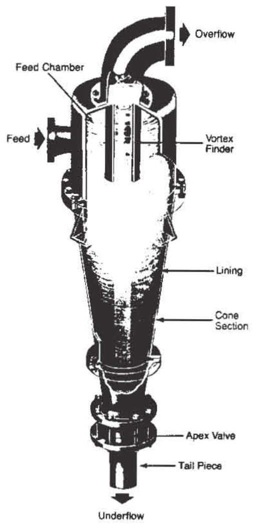


FIG. 5: HYDROCYCLONE ARRANGEMENT

Therefore, large diameter hydrocyclones are required, usually 36" (900 mm) and 48" (1200 mm) If the separation size required is in the lower end of the range, 18" (450 mm), 24"(600 mm) and 28" (700 mm) hydrocyclones can also be considered.

Due to the abrasive nature of the solids in the digested bauxite slurry, abrasion-resistant linings, or even better, hydrocyclones of solid NIHARD-steel are recommended. The composition and properties of Nihard are given in Table 1.

Composition of NIHARD

	C	3.0 - 3.6 %
	Si	0.4 - 0.8 %
	Mn	0.3 - 0.7 %
	S	0.15 % max
	P	0.30 % max
	Ni	3.3 - 4.8 %
	Cu	1.5 - 2.6 %
o	Tensile strength	26-35 kg/mm^2
o	Brinell hardness	590-700 kg/mm^2
o	Rockwell hardness	57-63 kg/mm^2

Under normal operating conditions, the solids content in the hydrocyclone underflow is relatively high (20 % - 40 %). However, as already mentioned, the solids concentration in the discharge of the digesters is usually erratic. Sand surges may take place and if the apex-nozzle is not sufficiently open, sand will go through the overflow into the thickeners.

As with Hydroseparators, hydrocyclones have to be sized keeping surging in mind. If a sand surge takes place, the solids concentration in the apex-discharge increases, but the flow remains the same, preventing sand being discharged in the overflow.

For 1st-stage-separation, either Hydroseparators or hydrocyclones are installed in practice. The general advantages/disadvantages of each classifier type have been given above. Choosing between one or the other is generally a matter of user's preference.

RAKE OR SCREW CLASSIFIER

Following the 1st-stage-separation, either in Hydroseparators or hydrocyclones, the underflow from these units has to be further deliquored and washed for maximum recovery of soluble soda. This is accomplished either in rake- or screw-classifiers or in hydrocyclones.

In essence, a rake-classifier (Fig. 7.) consists of a rectangular, sloped trough, open at the top end for sand discharge, with an overflow weir on the opposite side for discharge of the liquor/fine solids fraction. The drive for the rake mechanism is positioned near the top end of the trough.

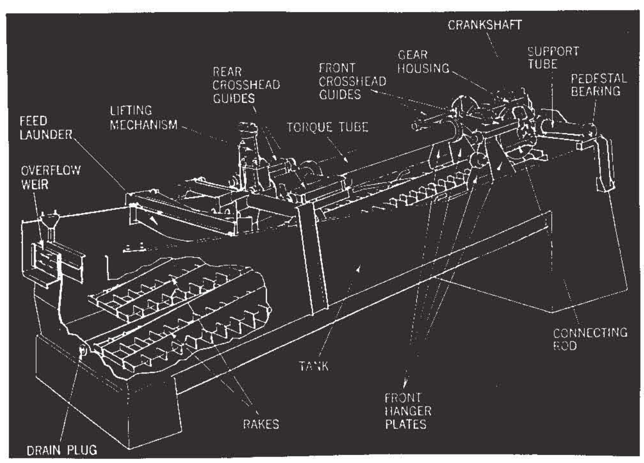


FIG. 7: SCHEMATIC DIAGRAM OF DORR-OLIVER RAKE CLASSIFIER

In operation, the rake classifier is always filled with slurry up to the overflow level, whereas the upper third of the sloping tank bottom remains above the liquid level. The feed launder is located in the lower pool area of the trough.

Feed flow to the unit is continuous. The finer particles in the feed together with the liquor, drain through the overflow weir. The coarser particles settle to the bottom of the trough and are transported by the reciprocating rakes - along the bottom, up the slopes - to the top end.

After being raked above the liquid level, the deliquored sand is entering the dry deck. With additional wash nozzles, the sand can be here washed for optimum recovery of soluble soda and will be further dewatered by the rake action and gravity.

The rake classifier is one of the earliest Dorr-Oliver products, originally invented by Dr. J.V.N. Dorr in 1900.

SCREW (SPIRAL) CLASSIFIER

The screw classifier has a similar inclined tank construction to the rake classifier. It contains a screw which is mounted parallel to the sloping tank bottom. The screw effects agitation of the liquor in the pool and conveys settled sand up the bottom of the trough to the discharge lip. Feed is introduced at pool level, while liquor discharges from an overflow weir.

Since the bottom part of the screw is submerged, a submerged bottom-bearing or shaft-seal is required. This is an added maintenance complication relative to the rake classifier where all bearings are above liquid level. In addition, exchange of rake blades is cheaper and simpler than replacement of the hard-faced surfaces of the screw.

Rake classifiers are generally considered to be the more efficient classifiers, having more effective agitation in the area where sand washing takes place. The reciprocating (intermittent pushing) action of the rake mechanism, combined with appropriate deck slope, provides ideal conditions for producing a well-washed and deliquored sand.

DELIQUORING CLASSIFIER

Noting the situation with regard to sand surges, it is advisable that a DELIQUORING-Classifier should be incorporated between a hydroseparator or first-stage-hydrocyclones and the washing classifiers. Its function is to deliquor and thoroughly drain the sands, so that the washing, which follows, will be most effective.
Rake classifiers in general are sized according to both their pool area and raking capacity.
To find the pool area, one divides the overflow volume by the actual settling rate (corrected for areal efficiency), which in turn is a function of rake speed.
Reducing the rake speed increases the effective settling rate, and areal efficiency increases.

The deliquoring classifier should have sufficient pool area for classification to accommodate the discharge flow from the first-stage-separation unit. The deliquoring-classifier is fed with more liquid than the washing classifiers and must therefore have more pool area. This is facilitated by keeping the rake speed low (5-6 strokes per minute (SPM)), and the deck slope at the minimum at 2"/foot (1:6). It must, however, be checked that the raking capacity (including allowances for sand surges) is adequate under these rake speed conditions.

In general, one can assume the rake product is at 65 - 70 % solids, which is higher than that obtainable from hydrocyclone underflows. Subsequent sand washing is therefore quite effective.

WASHING CLASSIFIER

The purpose of the washing classifier is to wash the sand (the rake product of the deliquoring classifier) by dilution and - on the dry deck - partly by displacement to a low soda content.

Comparison with Deliquoring Classifiers

- The settling velocities are higher because the soda- and slime-content of the sands are lower, and consequently, the viscosity of the liquid is less.
- The areal efficiencies are lower due to the higher raking speed used.
- The overflow rates are lower at the water to rake-solids ratios typically used (maximum 2:1).

The overall consequence of these differences is that sizing becomes based largely on solids raking capacity, as opposed to pool area. Allowances for sand surges are again made.

Washing-classifiers therefore run at higher rake speeds (strokes per minute), having a steeper slope for a longer dry deck. This results in a better dewatered rake product to minimize soda loss. The rake speed will be between 10-15 strokes per minute. The sand raking capacity is proportinal to the solids specific gravity, and to the rake speed.

Two countercurrent stages of classification washing, after deliquoring, are common in large desanding plants. Each additional stage decreases the soda loss for a given amount of wash water, or alternatively allows equal soda recovery for a smaller water flow. The benefits of staging depend on the savings associated with reduced evaporation costs (if applicable) and the value of the additional soda recovered.

WASHING HYDROCYCLONE

Washing hydrocyclones perform the same function as washing rake-/screw-classifiers. Sand slurry is diluted with wash liquor by mixing ahead of each washing hydrocyclone which then thickens the diluted slurry to its original level or higher. The selection of smaller diameter hydrocyclones then are used for first stage classification assures adequate capture of sand particulates in the underflow.

Comparison with washing rake-/screw-classifier

The principal advantages/disadvantages of hydrocyclones are as follows:

- Capital costs/space requirements are lower, especially when a low separation size is required.
- Operating costs are higher, due to pressurized feed.
- Wear on pumps and hydrocyclones leads to higher maintenance costs.
- Underflow solids are lower, requiring greater wash liquor ratios and/or additional countercurrent washing stages to achieve the same soda recovery at the same water-to-sands ratio. However, if the fines are sticky in character, the additional attrition available with cyclone systems may assist with fines separation and improve the washability of the sand.
- Capability to handle severe sand surges is lower.

DEGRITTING (DESANDING)-FLOW SHEETS OF ACTUAL INSTALLATIONS

Four alternative flow sheets from actual operating installations for degritting and soda recovery in digested bauxite slurries are given in Figs. 9-12. A summary of performance data from the four installations is shown in Table 2.

INSTALLATION A (Fig.9.)

- HYDROSEPARATOR
- DELIQUORING CLASSIFIER
- WASH-CLASSIFIER

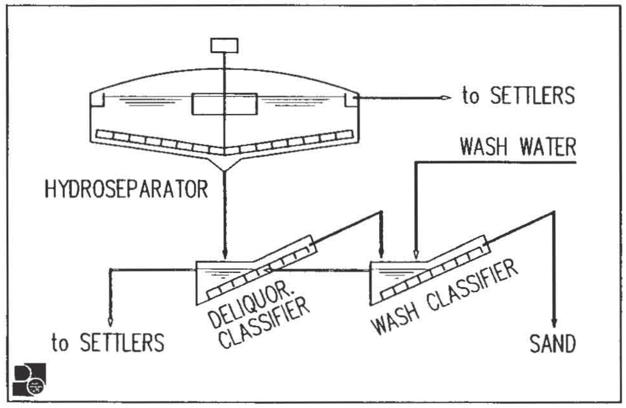


FIG. 9: HYDROSEPARATOR DESANDING-RAKE CLASSIFIER SAND WASHING

DEGRITTING (DESANDING) and SODA - RECOVERY - SYSTEMS				
• INSTALLATION	(A)	(B)	(C)	(D)
• EQUIPMENT (Separation) (Deliquoring) (Washing)	H'-SEPARATOR RAKE-CLASS. RAKE-CLASS. (SINGLE STAGE)	H'CYCLONES RAKE-CLASS. RAKE-CLASS. (TWO STAGE)	H'CYCLONES - SCREW-CLASS. (TWO STAGE)	H'CYCLONES - H'CYCLONES (THREE STAGE)
• SEPARATION SIZE (d_{95})	100 μ	100 μ	150 μ	65 μ
• WASH RATIO (m^3/ton solid)	1.5	1.0	2.0	2.5
• SODA in WASHED SAND (% Na_2O)	< 1	< 1	1	1
• FEED to SEP. UNIT (m^3/h)	1550	1800	1300	750
• FEED SOLIDS CONC. (g/l)	45	56	55-65	70
• FEED SODA (Na_2O) CONC. (g/l)	150	140	165	235
• PARTICLE SIZE > d_{95} (%)	10	33	6-10	30-45
• "SAND"-DISCHARGE (tons/h)	9	53	8	20

TABLE 2:

INSTALLATION B (Fig. 10.)

- HYDROCYCLONES
- DELIQUORING CLASSIFIER
- TWO-STAGE-WASH-CLASSIFIER

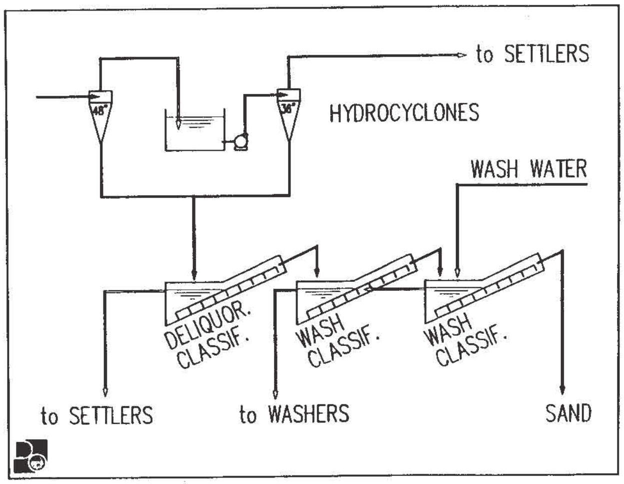


FIG. 10: HYDROCYCLONE DESANDING - RAKE CLASSIFIER SAND WASHING

INSTALLATION C (Fig. 11.)

- HYDROCYCLONES
- DELIQUORING CLASSIFIER
- WASH-CLASSIFIER

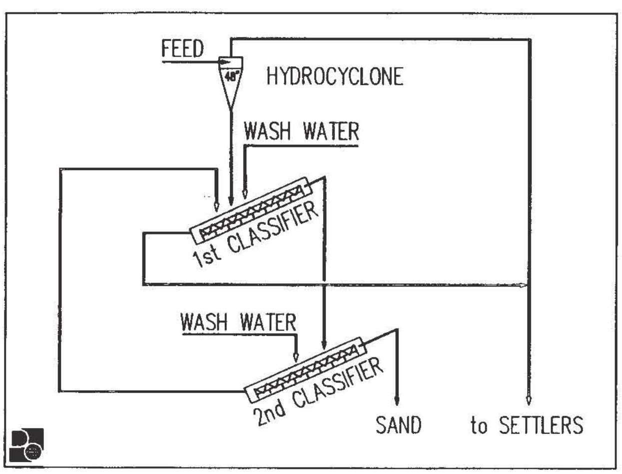


FIG. 11: HYDROCYCLONE DESANDING - SCREW CLASSIFIER SAND WASHING

INSTALLATION D (Fig. 12.)

- HYDROCYCLONES (SEPARATION)
- HYDROCYCLONES (THREE-STAGE-WASHING)

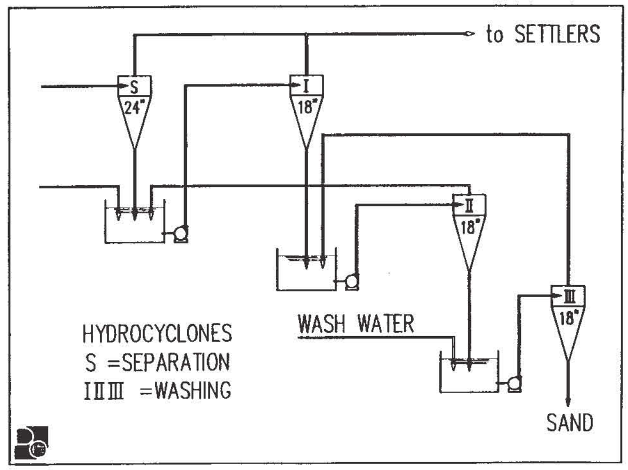


FIG. 12: HYDROCYCLONE DESANDING - SAND WASHING

These flowsheets utilise different combinations of degritting and sand washing equipment, and serve to illustrate the variety of flowsheets used in practice. The summary table indicates how feed characteristics and the degritting requirements differ from one plant to another.

CONCLUSIONS AND FUTURE OUTLOOK

Classification equipment comprising Hydro-separators or hydrocyclones and rake-/ screw-classifiers have been applied for desanding and sand washing in the alumina industry for over 80 years.

While the flowsheets and classification equipment selected continue to differ in detail, the commonest arrangement being selected today is probably a combination of hydrocyclones for desanding followed by two stages of sand washing using rake classifiers. Users continue to strongly influence the specific flowsheets to be employed.

The desanding process conditions are severe - high feed stream variability, high temperature operation, severe scaling and abrasion conditions. The equipment must therefore be of rugged construction with emphasis on reliability in continuous operation. There is every indication that the equipment in current use will continue to be applied in the future, there being no major new contenders for reliable cost - effective desanding service in this demanding application.