THE APPLICATION OF MICROCYCLONES IN THE MINERALS, CHEMICALS, FOOD, OIL & GAS INDUSTRIES

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ABSTRACT

New developments and the use of the latest manufacturing techniques have now made it possible to manufacture very small diameter hydrocyclones capable of separating particles as small as 2 microns in diameter. This creates the potential for hydrocyclones to replace more traditional physical separation processes in a number of applications.

The paper details how some of these miniature hydrocyclones have now successfully been used to treat a range of fluids containing solids predominantly finer than 50 microns within minerals, chemicals, food, oil & gas industries.

Applications include the production of high grade paper coating clay, the removal of ultra-fine neutralised chemical precipitates, starch washing to reduce protein levels, starch effluent treatment and the replacement of traditional cartridge and media filtration equipment within the petrochemical industry.

The paper also discusses the materials of construction, which need to be carefully selected for the different duties. Examples given include polyurethane for minerals applications where abrasion is a problem, polypropylene for the starch industry where approved food grade materials are required and ceramics for oil, gas and chemical industry applications.

INTRODUCTION

Hydrocyclones have been around for a long time and despite their apparent simplicity of design, they continue to generate intense research and development activity. A major focus of this development has been to produce hydrocyclones capable of even finer cut points and hence small-diameter microcyclones.

The necessity of producing such microcyclones has been the requirement to treat process streams from a wide range of industries that require solid-liquid separations at extremely fine cut points, sometimes as low as 1-2 microns. Traditional processes such as cartridge filters, centrifuges, settling pits, etc either cannot perform the separation or, at best, do so very inefficiently. Comparative microcyclone systems offer significantly reduced capital and operating costs and occupy a very small footprint. Such systems can either replace traditional equipment or work in conjunction with such equipment to increase their efficiency.

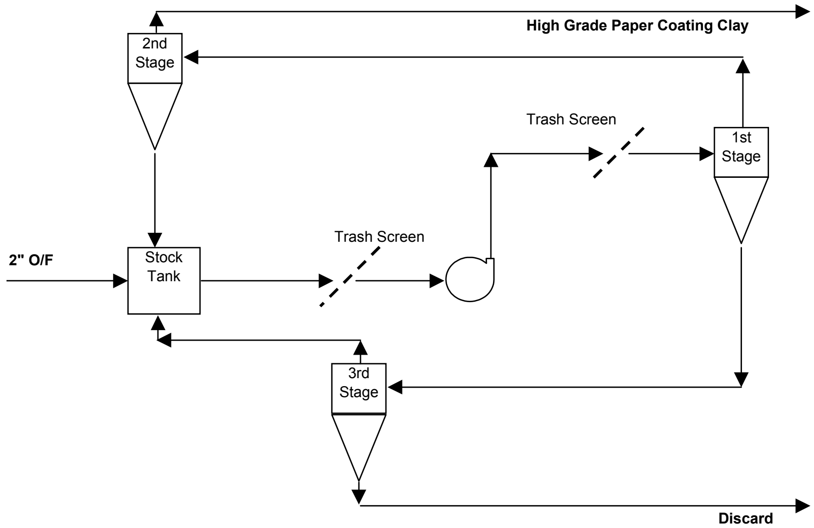
Material selection is very important and a wide range of materials are available depending on the application, including polyurethane, polypropylene and ceramic. By their nature, large numbers of microcyclones may be required and considerable design has gone into the assemblies required to accommodate them, ensuring ease of use, minimal maintenance and compact, easily-fitted units.

This paper describes, by way of case studies, Axsia Mozley's development of 10mm and 12mm diameter microcyclones (Microspin™ hydrocyclones) and how they have been successfully applied to applications within the minerals, chemicals, food, oil & gas industries for ultra-fine solid-liquid separations.

CASE STUDY 1: PRODUCTION OF HIGH GRADE PAPER COATING CLAY

A china clay company in the UK was in the business of mining kaolin and producing a range of graded clay products. One of these products was high-grade paper coating clay, requiring an ultra-fine size specification of approximately 80% minus 2 microns. Centrifuges had previously been used for this duty but were replaced with a 10mm microcyclone installation. The benefits of the hydrocyclone solution were easier and cheaper maintenance and operability, a more consistent and higher grade product, less susceptibility to feed pulp density fluctuations and the ability to operate at higher feed pulp densities, thereby offering higher capacity.

A schematic diagram of the circuit is shown in Figure 1.



Product	Stage 1 Feed	Stage 1 U/F	Stage 1 O/F	Stage 2 U/F	**Stage 2 O/F**	Stage 3 U/F	Stage 3 O/F
Flowrate, m3/h	20	5.5	14.5	4.5	**10**	2	3.5
% Solids w/w	10	17	7	10	**6**	30	7
% + 10 microns	18	35	3	7	**0.3**	45	7
% - 2 microns	45	19	68	55	**80**	13	51

Figure 1: Schematic Diagram of Circuit to Produce High Grade Paper Coating Clay

Operating Details

The feed to the 10mm microcyclone installation consisted of Mozley two inch hydrocyclone overflow, thickened in a stock tank. The feed size analysis was 18% plus 10 microns and 45% minus 2 microns. A constant displacement Mono pump was used to feed the installation at an inlet pressure of 170psi and a flowrate of 20m3/h, at a typical feed pulp density of 10% solids w/w. The first stage overflow was retreated in the second stage at a pressure of 85psi. The pressure drop across each of the three stages was 85psi. The second stage overflow was the finished product and proceeded to thickening, filtration and drying. The flowrate was 10m3/h at 6% solids w/w with a size analysis of 0.3% plus 10 microns and 80% minus 2 microns. The first stage underflow was retreated in a third stage with the third stage underflow reporting as waste. The third stage overflow and second stage underflow recirculated back to the stock tank. The size analyses of these two streams was similar to that of the feed.

Trash screening is essential when operating the microcyclones and a 300 micron strainer treated the discharge from the stock tank. There was an additional 1mm trash screen incorporated in the assembly prior to feeding the first stage.

Hydrocyclone Assembly

Five assemblies were used, each with the capacity to hold 60 microcyclones, and arranged in three stages. Two assemblies each containing 49 microcyclones formed the first stage, two assemblies each containing 35 microcyclones formed the second stage and one assembly fitted with 28 microcyclones formed the third stage. The five assemblies, complete with product collection chambers, feed chamber and trash screen, were mounted on an overhead track and clamped together with three high tensile rods. Maintenance was therefore exceptionally easy.

One pump ran the whole installation. The overflow and underflow from the first stage was directed to the second and third stages with no intermediate pumping. The number of microcyclones in each assembly was adjusted, using blanks, so that the pressure drop across each of the three stages was the same, i.e. the inlet pressure of 170 psi at the first stage was twice the inlet pressure of 85 psi at the second and third stages.

The microcyclones themselves were constructed from polyurethane to ensure maximum wear and abrasion resistance. This is typical for minerals-type applications. They were fitted with 2.6mm vortex finders and 2.0mm spigots. All the assemblies were constructed from stainless steel.

CASE STUDY 2: REMOVAL OF FINE SILT FROM RIVER WATER

A company in the UK has a requirement to remove ultra-fine silt coarser than 5 microns from river water prior to pumping to a Laboratory. A cartridge filter is used to remove any residual ultra-fine silt.

Operating Details

An installation similar to that used in Case Study 1 is employed but using only two assemblies, each containing 60 microcyclones. Operating at a pressure of 50 psi, the system treats 20m3/h of water with 17m3/h of water reporting to the overflow as final product. With a d_{50} cut point between 4 and 5 microns, 95% of particles coarser than 5 microns are removed to the underflow and returned to the river.

Hydrocyclone Assembly

The two assemblies, together with the product collection chambers, feed distributor and 300 micron trash screen, are clamped together with quick-release fasteners and suspended from an overhead track for ease of maintenance. The assemblies are manufactured from stainless steel and the microcyclones from wear and abrasion resistant polyurethane. The latter are fitted with 3.2mm vortex finders and 2.0mm spigots.

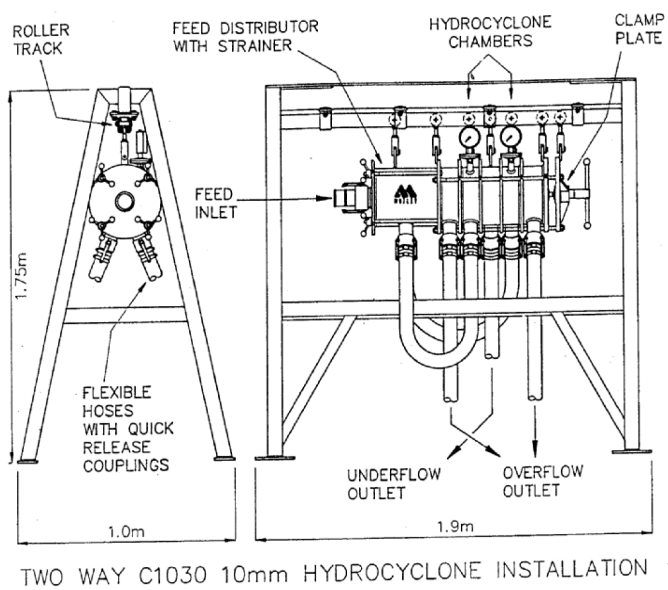


Fig 2: Schematic of River Water Treatment Plant

CASE STUDY 3: POTATO STARCH EFFLUENT TREATMENT

Several food manufacturers process potatoes for crisp production. A starch recovery system was required to collect and process the starch-laden waste water streams from the potato processing lines. This effluent was typically treated in settling ponds followed by centrifuges. However, due to the long settling times required, the starch produced would decompose, producing a grey, foul-smelling product sold only for animal feed. The introduction of a hydrocyclone-based solution considerably reduced treatment time, allowing the production of a crumbly, white starch product that could be sold with the main starch product.

Operating Details

At a typical facility, starch-laden waste is produced at two locations on each crisp production line, namely at the slice washing area and the inspection table. These collection stations are controlled by the local PLC, which delivers starchy water and solids to the Starch Recovery System. This is fully skid-mounted and PLC controlled. When the system is operational, the feeds from each crisp line are routed to a wedge wire screen that separates the coarse solids for partial drying in a screw compactor. The separated liquids pass into the buffer feed tank for further cleaning in a two-stage hydrocyclone system.

Typically, the starch is ultra-fine with approximately 30% minus 2 microns. Therefore, microcyclones are used for secondary stage processing, retreating the primary stage overflow. Both the primary and secondary stage underflows report to a rotary drum vacuum filter. The secondary stage overflow is returned to the recycled water system.

Approximately 80% of the starch is recovered as a filter cake and the recycled water contains typically 0.15% solids w/w compared to a feed solids concentration of 0.8% w/w.

A typical 24m3/h Starch Recovery System comprises two lines, each line processing 12m3/h and having the capability of operating either simultaneously or independently of the other.

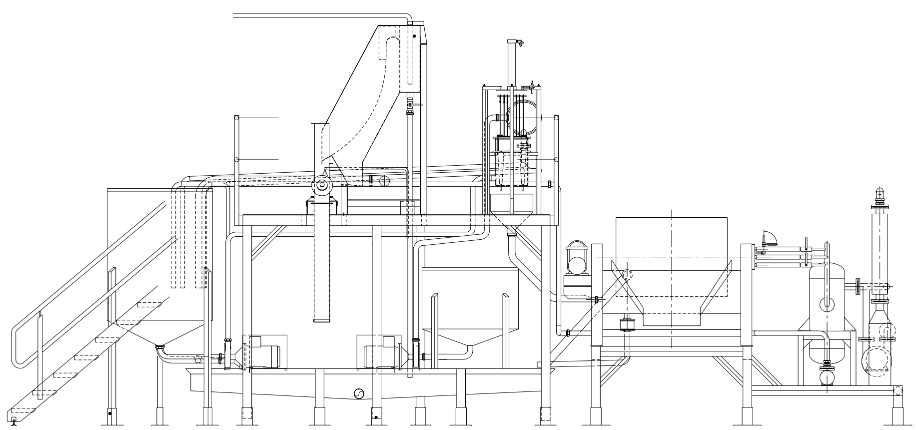


Fig 3: Typical Starch Recovery System

Hydrocyclone Assembly

The microcyclones used in each line are injection moulded in food-grade polypropylene. Polypropylene is suitable for use with non-abrasive materials such as starch at low concentrations. The microcyclones are housed in an enclosure that provides a common feed chamber and common overflow and underflow chambers. The enclosure consists of a 304 stainless steel feed chamber to which HDPE overflow and underflow covers are clamped by means of stainless steel quick release hoop clamps.

Each microcyclone is fitted with 2.5mm vortex finders and 1.5mm spigots. The assembly will hold 54 microcyclones and the number of operating microcyclones and blanks can be varied as required.

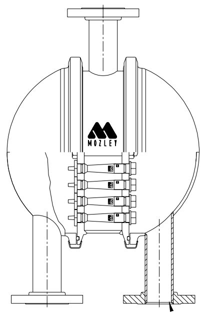


Fig 4: Schematic of Microcyclone Assembly for Starch Plant

CASE STUDY 4: CORN STARCH WASHING

In the corn wet milling process, the corn kernel is separated into its basic components, i.e. germ, gluten, starch, fibrous hull, water and solubles. Starch is obtained from corn for refining purposes by first separating the corn components within the kernel by steeping and then progressively removing the germ, fibrous hull and gluten to leave only the starch. The last stage in this process is washing of the starch slurry with fresh water to remove solubles and gluten. The washed starch is then stored ready for syrup manufacture.

Due to the very fine nature of the starch, microcyclones are used for the washing process and are incorporated into a multi-stage counter-current washing circuit.

Operating Details

In a typical circuit, up to 13 washing stages can be included. Each stage can contain up to 720 microcyclones fitted into a concentric 316 stainless steel housing. Blanks can be fitted to ensure the correct capacity for each stage giving hydraulic balance to the circuit. Maximum capacity for a housing with all 720 microcyclones fitted is 400m3/h. Typical microcyclones used in the washing stages are fitted with a 2.9mm vortex finder, 2.4mm spigot and 6° cone angle. The last stage is normally a thickening stage and microcyclones for this duty are fitted with a 2.9mm vortex finder, 2.6mm spigot and 8° cone angle.

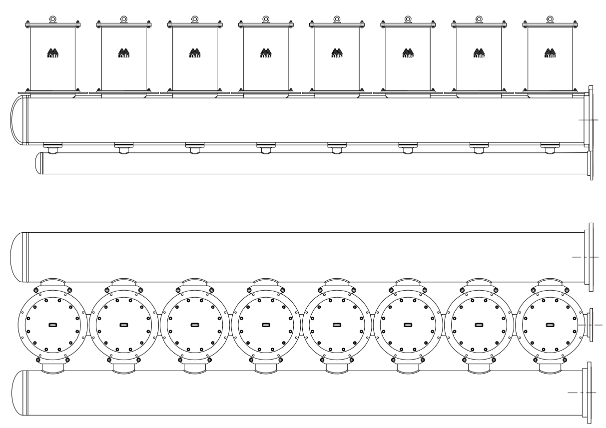


Fig 5: Schematic of Counter-Current Corn Starch Washing Stations

Hydrocyclone Assembly

The microcyclones used are injection moulded in food-grade polypropylene. Polypropylene construction also helps to eliminate problems associated with sulphur embrittlement, common with hydrocyclones manufactured from nylon. The concentric housings are manufactured from 316 stainless steel and offer a compact, straightforward and rugged construction, allowing the simple and speedy removal of the microcyclones.

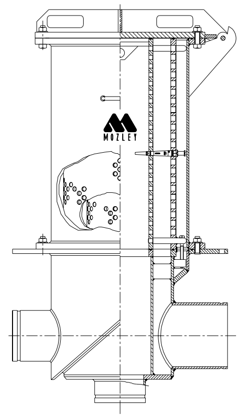


Fig 6: Schematic of Microcyclone Assembly for Corn Starch Washing

CASE STUDY 5: REMOVAL OF FINE NEUTRALISED SALTS

A chemical factory treated hydrochloric and sulphuric acid effluent streams with caustic soda. The precipitates formed were settled in lagoons and the clear solution discharged to the river. However, the lagoons were to become unusable in the near future and with changes in ownership of land and discharge consents, there was a requirement to design and install a dedicated effluent treatment plant.

It was proposed to treat both the acidic effluents with slaked lime. The hydrochloric acid stream is the main stream and also contains small quantities of hydrofluoric acid. Therefore, the salts formed are calcium chloride and calcium fluoride. Additional solids are small quantities of unreacted lime and magnesium oxide. The smaller second stream contains a small quantity of sulphuric acid and therefore calcium sulphate is formed on neutralisation with lime.

In addition, the size analysis of the neutralised salts was exceedingly fine with typically 41% minus 7 microns. The normal flowrate to be treated was 10m3/h but adequate over-capacity was required for feed surges.

A solid-liquid separation system, using Microspin hydrocyclones, was designed and built to treat the combined neutralised acid streams.

Operating Details

The system designed comprises three identical two-stage processing lines. Each line consists of direct-coupled first stage and second stage microcyclone assemblies with a capacity equal to the specified flowrate. The underflow from the first stage is re-treated in the second stage. Each line can be operated independently or in conjunction with either of the other two. Under normal operation, any one of the lines is operational with two lines non-operational. For operation at maximum flowrate, any two of the three lines are operational with one line non-operational.

In operation, the feed inlet valve and second stage overflow valve are fully open. The first stage overflow valve and second stage underflow valve are operated partially open. The former allows the correct pressure drop across the first stage to be set and the latter controls the final solids concentration. Once set, these valves are not adjusted further.

The first stage is designed to operate at a pressure of 75psi with a feed solids concentration of 0.5% w/w. The overflow solids concentration is 0.1% w/w and that of the underflow 2.6% w/w. Solids recovery to underflow is 84.5%. The second stage is designed to operate at a pressure of 75psi with a feed solids concentration of 2.6% w/w. The overflow solids concentration is 0.29% w/w and that of the underflow 20% w/w. Solids recovery to underflow is 84.9%. The overall solids recovery for both stages is 72.8%. The combined first and second stage overflow is approximately 50% minus 2 microns.

The secondary stage underflow is filtered on a rotary drum vacuum filter and both stage overflows report to a site effluent treatment plant where further solid-liquid separation occurs prior to river discharge.

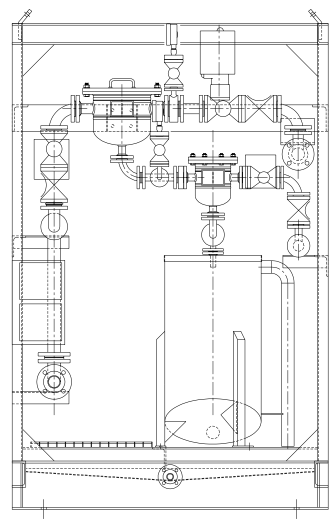


Fig 7: Schematic of Neutralised Salt Recovery Plant

Hydrocyclone Assembly

The microcyclones are manufactured in injection-moulded polypropylene, which is suitable for non-abrasive solids at low concentrations and at temperatures up to 100°C. The microcyclones consist of only two components that simply snap together: the body, containing the feed inlet, cone and spigot and the vortex finder inert. The body section is fitted with two 'O' rings that form a seal between the microcyclone and the assembly plates.

The microcyclones are housed in a stainless steel enclosure that provides common feed, underflow and overflow chambers. The primary and secondary stage assemblies can hold up to 60 and 20 microcyclones respectively and the number of operating microcyclones can be adjusted as required using blanks.

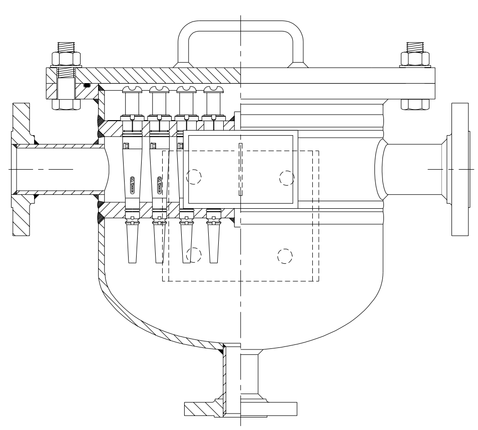


Fig 8: Schematic of Microcyclone Assembly for Neutralised Salt Recovery

CASE STUDY 6: OIL & GAS

The recent introduction of fine cut point microcyclones in a ceramic material is offering solutions to many separation problems within the oil and gas industry. As traditional users of cartridge and media filtration for small particle separation, the petrochemical industry is rapidly finding interesting applications for the non-clogging hydrocyclone approach.

There are currently no production size applications using the ceramic version of the Microspin. However, the interest shown by some oil majors has initiated a number of on-site trials, particularly in the field of heavy metal removal, such as mercury, from oil and condensate.

A lot of problems exist in the Far East oil fields with unwanted elements in crude oil. Any heavy metal in crude oil, even at low concentrations, has a very adverse affect on downstream processing, particularly refining. If these metals are first removed, the crude oils are far more saleable.

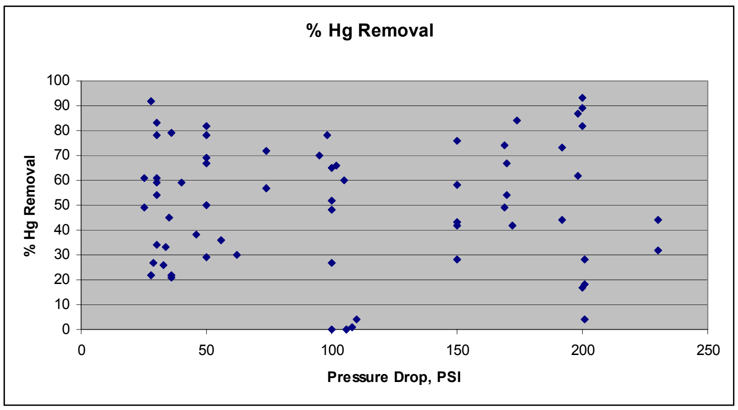


Fig. 9: Trial Results for Removal of Mercury in Condensate Using Microspin Hydrocyclones

Figure 9 summarises the results from trials conducted to remove mercury from condensate using Microspin technology. On average, approximately 60% of the mercury was removed, reducing the inlet concentration from approximately 8800 micrograms per litre to 3500 micrograms per litre. However, there was no clear correlation between the pressure drop across the hydrocyclones and the initial mercury concentration. The results did show that very high levels of mercury removal can be achieved but the question is why were the results not consistent? It has been suggested that this may be due to variations in the size of the mercury droplets and, in particular, the presence of droplets below about 3 microns in size. Further work is continuing to optimise and understand this process.

CONCLUSIONS

This paper demonstrates that small-scale microcyclones can offer a viable alternative or supplement to conventional centrifuge and filtration technology in a broad range of industries. Indeed, in many cases, microcyclones are the only option for the separation and recovery of ultra-fine particles from fluids.

Advantages of this technology are extremely small and compact assemblies with minimal maintenance requirements, ease of use and low capital and operating costs.

Materials of construction of both the microcyclones and their housings can be varied as required to suit a wide range of process conditions.