Introduction to Cyclones

What is a Cyclone?

A cyclone is a device that uses centrifugal forces to classify solid particles, in a liquid stream, by size and/or density.

What does a Cyclone do?

If a cyclone is fed with a sand and water mixture containing a range of particle sizes, most of the fine sand will report to the overflow (the top of the cyclone), together with most of the water. Most of the coarse sand will report to the underflow (the bottom of the cyclone), with a lesser part of the water.

This **Size Classification** is most often seen in milling, where the process requires a product of a certain particle size. A grinding mill needs a classifier to extract the particles that have been milled sufficiently finely, and to send oversize particles back to the mill for further grinding. A cyclone does this, with the cyclone overflow being the mill final product, and the underflow reporting back to the mill feed. This arrangement is known as closed circuit milling.

***Typical Sizing Applications**:* Milling.
Location: Gold, Platinum, Base metals, Chrome, Minerals processing plants.

Typical Sizing Applications: Splitting coarse and fine streams ahead of flotation plants.
Location: Platinum, Base metals, Minerals processing plants.

Typical *Sizing Applications*: Splitting reclaimed sands.
Location: Gold, Minerals processing plants.

A cyclone always operates with a size classification mechanism, but depending on the way a cyclone is used, it can be named differently:

Dewatering Cyclone: If the feed is fairly coarse, the cyclone will split almost all of the water, with very little solids to the overflow. Almost all of the solids will report to the underflow, at a higher pulp density than the feed. Here, the cyclone underflow is the required product, and underflow density is the critical factor.

***Typical Dewatering Applications**:* Ahead of a dewatering screen.
Ahead of tailings thickener, to reduce the load on the thickener.
Location: Gold, Platinum, Coal, Base metals, Chrome, Minerals processing plants.

***Typical Dewatering Applications**:* Dewatering dredger stream
Location: Water dam dredging, Sand mining by dredging.

Slimes Dam Building: This is a variant of the dewatering cyclone, where the underflow is used to build the tailings dam wall. Again, the cyclone underflow is the required product, and the client usually wants the maximum tonnage split to the underflow.

***Typical Applications**:* Building tailings dams, Reinforcing dam walls.
Location: Gold, Platinum, Base metals, Chrome, Minerals tailings.

Desliming Cyclone: The feed is fairly coarse, with some unwanted fines. The cyclone extracts the fines to the overflow. Again, the cyclone underflow is the required product, and the client usually wants the minimum amount of fines in the underflow.

Typical Applications: Ahead of spiral plants, Ahead of a jig.
Location: Base metals, Chrome, Minerals processing plants.

Degritting Cyclone: The feed is fine slimes (or almost clear water) with a low content of coarse grit. The cyclone extracts the grit to the underflow. The cyclone overflow is the required product.

Typical Applications: Ahead of a thickener to prevent sanding out.
Location: Gold, Base metals, Minerals processing plants.
Typical Applications: Degritting water.
Location: Water treatment plant, Water storage dams, Shaft settling dams, Foundry quench.

What are the Advantages of a Cyclone?

- No moving parts – so low maintenance,
- High capacity - a 600mm cyclone can handle up to 200t/h of solids,
- Low capital cost,
- Low operating cost,
- Rugged, simple to install and operate.

What Competes with a Cyclone?

Duty	Competing Unit	Cyclone Advantages	Cyclone Disadvantages
Coarse Size Classification	Screen	Capital Cost Operating Cost Capacity Compact.	Cut Efficiency Wetter Coarse Product.
Fine Size Classification	Rake Classifier Screw Classifier	Capital Cost Operating Cost Low Maintenance Capacity Compact.	None
Dewatering	Thickener Settling Pond	Capital Cost Operating Cost.	Fines in Overflow
Slimes Dam Building	Spigotting	Lower Piping Cost Operating Cost Higher Rate of Rise of Wall.	More Supervision Cannot Handle Very Fine Pulp.
Slimes Dam Building	Manual	Less Labour	More Piping Cannot Handle Very Fine Pulp.
Desliming	Hydrosizer “black box”	Capital Cost Capacity.	Cut Efficiency
Degritting	Settling Pond	Capital Cost Operating Cost.	None

How Does a Cyclone Work?

The pulp stream enters the cyclone at a pressure between 40kPa and 300kPa (for small cyclones), 150kPa for larger cyclones, pumped or gravity fed.

The **Feed Box** has a tangential or involute entry which causes the feed stream to swirl around the inside of the cyclone, setting up a "whirlpool" flow pattern, with an air core (or vortex) running up the centre.

Most of the water in the feed exits via the overflow outlet at the top, dragging finer particles with it. The **Vortex Finder** prevents the feed stream short-circuiting directly to the overflow.

The swirling action subjects the particles in the feed to centrifugal forces. Larger or heavier particles are flung outwards where they meet the sidewall of the cyclone, and are slowed down. This causes them to spiral down the **Cone Frustum(s)** of the cyclone and exit out the **Spigot**. The spigot is subject to high wear, which is why it is a small, easily replaceable item.

Some of the water in the feed also slows down due to contact with the sidewalls, and reports to the underflow. This water drags a portion of the feed with it, bypassing the classifying action of the "whirlpool" and causing some inefficiency in the cyclone's operation.

About the Cutpoint

The mechanism described above is not precise - as opposed to, say, a screen where the majority of particles smaller than the screen aperture pass through, and larger particles are retained. With a screen the cutpoint is very obvious - if the screen has an aperture of 1mm, then its coarse product will be mostly +1mm, and its fine product all -1mm.

Particles in a cyclone are subjected to differing centrifugal forces, and have a shorter or longer path outwards to the sidewall, depending on where they are in the feed, ie particles entering near the outside of the cyclone have a greater chance of eventually reporting to the underflow. Also, there is a "crowding" effect, where particles interfere with others, preventing them reporting to their intended destination.

Due to these factors, all particles in a cyclone have a possibility of reporting to either the overflow or underflow. Obviously, a very large particle has a very small possibility of reporting to the overflow, but it does have a possibility, even if it is very low. Since the feed stream contains millions of individual particles, if there is a possibility of a million to one, then one particle in a million (of that size) will "go the wrong way".

By varying certain parameters (described later) we can vary how much fines report to the overflow. So we need some measure to describe a cyclone's performance.

We cannot use the simple cutpoint as used to describe a screen because the range of probabilities means that to get a cyclone overflow with 100% minus say, 200 microns we must cut much finer than this.

It has been agreed that the best way to describe a cyclone's cut point is the d50. This is the size of particle which has a 50:50 probability of reporting to either the underflow or overflow.

Please note that the d50 cutpoint only describes the cyclone. It has nothing to do with the size grading of the cyclone's overflow or underflow streams (80% minus 75 microns etc.). Those gradings are dependent on the size distribution of the feed to the cyclone, and are commonly described as p80, p50, p20 etc.

The Effect of the Spigot on a Cyclone's Operation

It is a common misconception that the spigot affects a cyclone's cutpoint. This is not so.
The spigot size will not affect the d50 of the cyclone, or the size grading of the cyclone overflow.

What the spigot size does affect is the amount of water in the cyclone underflow. A smaller spigot restricts the underflow, and prevents too much water leaving. A larger spigot allows more water through.

Also as mentioned previously, a cyclone's flow pattern has an air core, or vortex running up the centre from the spigot up to the vortex finder.

The spigot must be small enough to allow the underflow solids to exit with minimal water, but big enough to allow the air core to operate. This sounds tricky, but is easy to check because of the "flare" angle of the underflow from the spigot.

When a cyclone is operating normally, with a stable air core, the underflow discharges from the spigot as a hollow cone. The inside angle of the cone - the flare angle - varies with the spigot size.

If smaller and smaller spigots are used the angle decreases, and the underflow gets denser (less water). This will continue until a point is reached where there is not enough room for the air core, and the cone collapses. The underflow then comes out in a solid stream - called "roping". This is not good, as the cyclone needs the air core for efficient operation. When roping occurs, the spigot is choking, ie discharging its maximum amount of solids, and any coarse solids that cannot get out of the spigot are therefore forced in the wrong direction, out the cyclone overflow.

Conversely, if the spigot is cut back larger and larger, the flare angle will increase, and the underflow density will decrease - more water. This also is undesirable, as the greater the water that is contained in the underflow, the more bypassing of fines is occurring in the cyclone (see page 4 above).

The optimum flare angle is 30 to 40 degrees.

Please note that the "correct" spigot size varies with the amount of tonnes fed to the cyclone, and the tonnage reporting to the underflow. Higher tonnages need a larger spigot.

Cyclone Parts Which Affect the d50 Cutpoint

The cutpoint of a cyclone can be altered by changing the diameter of the Vortex Finder, or the size of the feed opening, or by adding an Extended Feed Box.

A larger Vortex Finder gives an easier path to the overflow, and so coarsens the cutpoint. A smaller Vortex Finder gives a finer cutpoint. The vortex finder diameter is altered by changing the vortex finder.

A smaller inlet opening causes higher entry velocity, more centrifugal force, and so gives a finer cutpoint. The inlet size is made smaller by replacing the Inlet Wedge (where fitted) with a larger wedge, or by changing the cyclone feed box.

An Extended Feed Box gives a longer residence time in the cyclone, and so gives more time for the solids to be collected, hence a finer cutpoint.

Process Factors Which Affect the d50 Cutpoint

Higher feed pressure (speeding up the pump) causes higher centrifugal forces, and gives a finer cutpoint.

More dilution of the feed causes less crowding, and gives a finer cutpoint.
Higher feed density (% solids) gives more crowding and a coarser cutpoint

Heavier minerals are more effected by centrifugal force than lighter ones. So the same cyclone will have a finer cutpoint on chrome minerals (SG 4) than it will on silica sand (SG 2.6) or coal (SG 1.5).

Denser feed liquid (eg brine) will give a coarser cutpoint.

Pulp viscosity also affects the cyclone d50. A pulp with a high proportion of ultrafines or clays (eg kimberlite) will give a coarser cutpoint.

Installing a cyclone on its side will give a coarser cutpoint, as it becomes easier for fines to get out of the overflow.

Cyclone Feed Pressure Range

Most cyclones operate in the 50kPa to 100kPa feed pressure range.

Below a certain feed pressure, the flow patterns in a cyclone become unstable, and the air core will tend to collapse. We recommend a minimum feed pressure of 35 kPa for a cyclone mounted vertically, and 45 kPa for a cyclone mounted on its side.

Wear increases dramatically as feed pressure increases. We recommend a maximum feed pressure of 125kPa for fine feed, and a maximum of 100kPa for coarse feed, to prevent excessive wear. But for fine particles or dilute feeds, the maximum pressure can be as high as 300kPa for the smaller cyclones – 400mmØ and less.

Recommended maximum feed pressures are –

Cyclone Diameter	Maximum Feed Pressure (kPa)
Up to 400mm	300
400mm to 600mm	200
Larger than 600mm	150

Installation of a Cyclone

The cyclone overflow should discharge to atmosphere as soon as possible after the cyclone. If this is not possible due to plant layout restraints, then a breather pipe should be fitted immediately after the overflow bend, to prevent any possibility of siphoning.

The cyclone underflow should discharge freely (not submerged), and the spigot flare should be readily visible.

All cyclones should have a pressure gauge and protector fitted to the feed inlet, to allow basic diagnostics on the cyclone operation.

Causes of Problems in Cyclone Operation

A smooth inner surface of the cyclone is critical to ensure undisrupted flow patterns. The following can cause problems:

- Loose or torn linings can pulsate or flap.
- Parts that have been rubber lined by another party often have protruding joints.
- Home-made or pirated cone sections are often incorrect, giving a step-in at the cone joint

A cyclone can handle a range of feed flowrates, but does need a fairly steady feed. The following can cause feed fluctuations, and problems with the cyclone operation:

- Loose linings in the feed pipe to the cyclone.
- Loose lining, or air leaks in the suction pipe to the cyclone feed pump
- Badly worn pump packing can suck air
- Poor level control of the feed sump can cause the feed pump to suck air (snore) which can badly affect the cyclone (and damage the pump liners).
- A pipe discharging into the feed sump from a height will entrain air. If this is near to the suction, the pump will pull in the air, causing similar problems to a pump snoring.

Maintenance

Component Replacement
The only maintenance operation on a cyclone is the replacement of a component with another when the Linatex lining has worn through. All components of a cyclone can be purchased as spares from Linatex Australia.

All mild steel/Linatex lined components of a Linaex cyclone can be re-lined by local Linatex applicators, providing the component has been replaced before the steel shell has worn through. To prevent wear through requires regular internal inspection.

Routine Inspection Frequency
The frequency of internal inspection of a cyclone varies with the wear rate experienced in the duty. The wear rate in a duty depends on many factors of the feed, including –

- Mineral Characteristics – hard ore means higher wear,
- Particle Size – large particles give higher wear,
- Particle Shape and Sharpness – flat, sharp particles mean higher wear,
- Feed Pressure – higher pressure causes higher wear (square law),
- Feed slurry % solids – high % solids means higher wear.

Linatex recommend internal inspections every two months, until a good measure of the cyclone wear rate can be established.

Component Wear Life

As mentioned previously, the wear rate in a cyclone varies at different locations within the unit. Experience has shown that the ratio of wear life of the components is approximately:-

Component	Life Ratio
Overflow Box	18
Feed Box	12
Vortex Finder	12
Upper Cone	15
Lower Cone	9
Spigot	4
Discharge Regulator (Fishtail)	6

ie if the spigot lasts four months, the feed box is likely to last ±12 months. Whilst this is not exact, and cannot be guaranteed, it is a good general guideline.

For further information, please contact -

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Introduction to Separators

1.0 What is a Separator?

A Separator (also known as a fishtail cyclone) is a modified standard cyclone, designed for certain duties.

2.0 Where Would a Separator Offer Advantages?

- Dewatering and stockpiling duties where a high underflow density is required,
- As feed densifier ahead of a Screen, Attrition Cell or Classifier, where a constant underflow density is required.

3.0 How Does a Cyclone Work?

Please refer to the Linatex document "Introduction to Cyclones" for more detail on cyclone operation. The pulp stream enters the cyclone at a pressure between 40kPa and 100kPa (pumped or gravity fed).

The **Feed Box** has a tangential entry which causes the feed stream to swirl around the inside of the cyclone, setting up a "whirlpool" flow pattern, with an air core (or vortex) running up the centre.

Most of the water in the feed exits via the overflow at the top of the cyclone, dragging finer particles with it. The **Vortex Finder** prevents the feed stream short-circuiting directly to the overflow.

The swirling action subjects the particles in the feed to centrifugal forces. Larger and/or heavier particles are flung outwards where they meet the sidewall of the cyclone, and are slowed down. This causes them to spiral down the **Cone Frustum(s)** of the cyclone and exit out the **Spigot** at the bottom of the cyclone. The spigot is subject to high wear, which is why it is a small, easily replaceable item.

Some of the water in the feed also slows down due to contact with the sidewalls, and reports to the underflow. This water drags a portion of the feed with it, bypassing the classifying action of the "whirlpool" and causing some inefficiency in the cyclone's operation.

4.0 How Does a Separator Work?

A Separator has the same components as a standard cyclone, and the principles of operation are similar, with the same internal flow patterns.

But a Separator has -

- A rubber "fishtail" (underflow discharge regulator) fitted to the underflow,
- An oversize spigot, compared with a standard cyclone doing the same job,
- The overflow pipe deliberately extended to approximately two metres below the spigot, to induce a partial vacuum inside the cyclone.
- A small air bleed valve on top of the Separator or on the overflow siphon pipe.

Simply put, the vacuum sucks the fishtail closed. This holds the underflow back inside the cyclone until the weight of the solids is enough to open the fishtail and discharge. If there are no solids in the feed, nothing discharges from the underflow.

The air bleed valve on the Separator or on the overflow pipe allows fine-tuning of the underflow density. Less air = more vacuum = denser underflow, with less water and fines. More air = less vacuum = wetter underflow, with more water and fines in the underflow. Maximum vacuum should be approximately minus 35kPa.

5.0 What are the Advantages of a Separator Compared With a Cyclone?

Advantage	Standard Cyclone	Separator
Higher Underflow Density	Max of 50%-52% solids vol/vol. A thick mud that flows.	Max of 58% solids vol/vol. Wet sand that stacks up.
Less Fines in Underflow	Cyclone short-circuiting is proportional to U/F water content.	Separator U/F has lower water content, so less short-circuiting.
Constant Underflow Density	Underflow density varies if feed % solids changes.	Underflow density is independent of the feed density.
No Flooding	When solids feed is interrupted, underflow floods with water.	When solids feed is interrupted, the underflow solids stops.
Easy to Adjust Underflow Density	Must change the spigot to change the U/F density.	Simply adjust the vacuum bleed valve to adjust the U/F density.
Less Spigot Blockage	Small spigots can block with gravel, bolts etc.	Uses a larger spigot, so less prone to spigot blockages.
Less Spigot Wear	Spigot is a high wear item.	Spigot lasts up to 10x longer.

6.0 What are the Disadvantages of a Separator?

- **Cutpoint:** The d50 cutpoint of a Separator is coarser than a standard cyclone by approximately 10%.
- **Feed Pressure Range:** Standard cyclones will operate with a minimum feed pressure as low as 30kPa, and a maximum up to 300kPa. A Separator needs a minimum feed pressure of 40kPa, and above 120kPa the underflow density will decrease (water gets "blown" out of the fishtail).
- **Height Requirements:** The overflow siphon leg needs an extra two metres of headroom, compared with a standard cyclone.
- **Steady Feed:** A Separator is more sensitive to fluctuating feed volume/pressure than a standard cyclone.
- **Feed Density:** Separator feed density must be below 12% solids by volume (equal to 25% solids by weight for silica sand), to make sure there is enough water in the overflow to create the required vacuum.

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