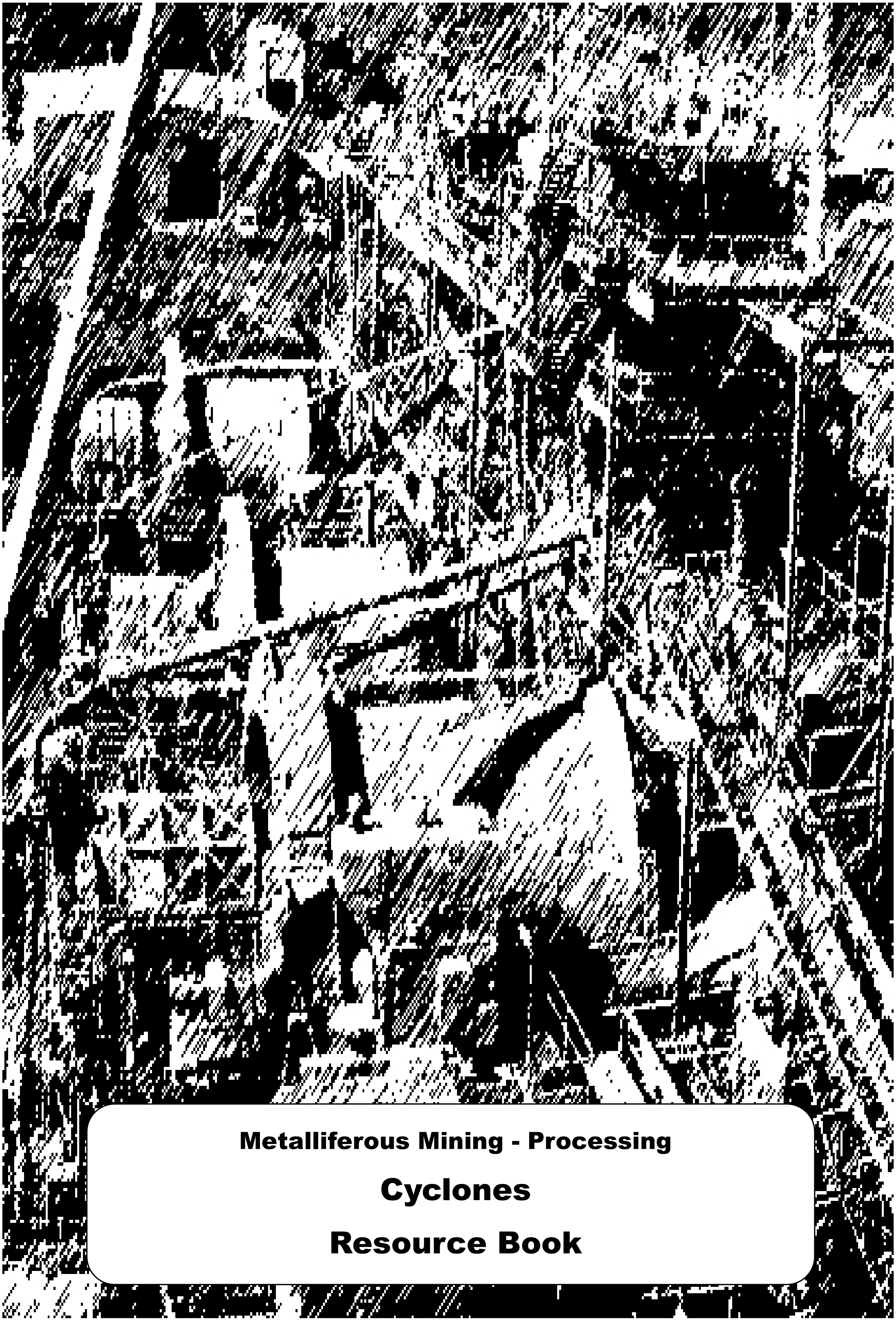


Metalliferous Mining - Processing

Cyclones

Resource Book

Table of Contents

Introduction to Cyclones

What is this module about?

This unit is about how we manage and use cyclones in the processing plant

What will you learn in this module?

- Explain the purpose of a cyclone
- Demonstrate an understanding of how a cyclone operates
- Identify the key components of a cyclone
- Demonstrate an understanding of the factors affecting cyclone performance

What do you have to do to complete this unit?

You will need to complete all the training tasks in your workbook, the review exercise and the assessment given to you by your supervisor.

Discuss the competency standards for this unit with the Training Coordinator or your supervisor.

What resources can you use to help?

If you need more information about topics in this unit, then you should approach:

- Your work mates and supervisor
- The training coordinator
- Metallurgists

Introduction

The purpose of the cyclones in the circuit is to size the mill discharge slurry. Two product streams are generated by the cyclones;

- A fine 'overflow' stream which reports to the leach/adsorption tanks.

- A coarse 'underflow' stream that is recirculated to the mills for further grinding.

The most important aspect of cyclone operation is that the particles in the overflow stream must be of a sufficiently fine size to facilitate acceptable gold recoveries in the CIL circuit.

The mechanism of separation occurring within the cyclone is known as classification. Classification is a method of size separation of a mixture of minerals on the basis of the velocity with which the grains fall through a fluid medium (usually water). Cyclones utilise centrifugal force to accelerate the settling rate of particles. Although the aim of cyclone operation is to separate particles by size, particle density, particle shape and other factors also affect the settling rate of particles and hence cyclone performance.

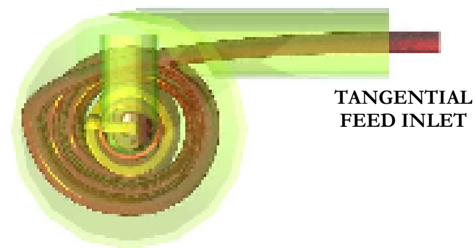
Cyclones are used in preference to screens as a means of size separation in the grinding circuit as they are more efficient at fine separation sizes.

Cyclone Cluster

HydroCyclones

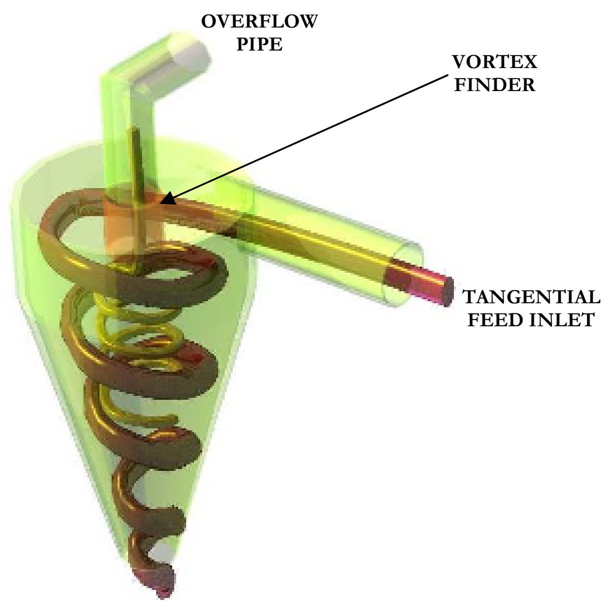
A typical hydrocyclone consists of a conically shaped vessel, open at its apex (spigot), or underflow, joined to a cylindrical section, which has a tangential feed inlet. The top of the cylindrical section is closed with a plate through which passes an axially mounted overflow pipe. The pipe is extended into the body of the cyclone by a short, removable section known as the vortex finder, which prevents short-circuiting of feed directly into the overflow.

The feed is introduced under pressure through the tangential entry, which imparts a swirling motion to the pulp. This generates a vortex in the cyclone, with a low-pressure zone air core along the vertical axis.



Particles within the cyclone flow pattern are subjected to two opposing forces;

- An outward centrifugal force and
- An inwardly acting drag force.



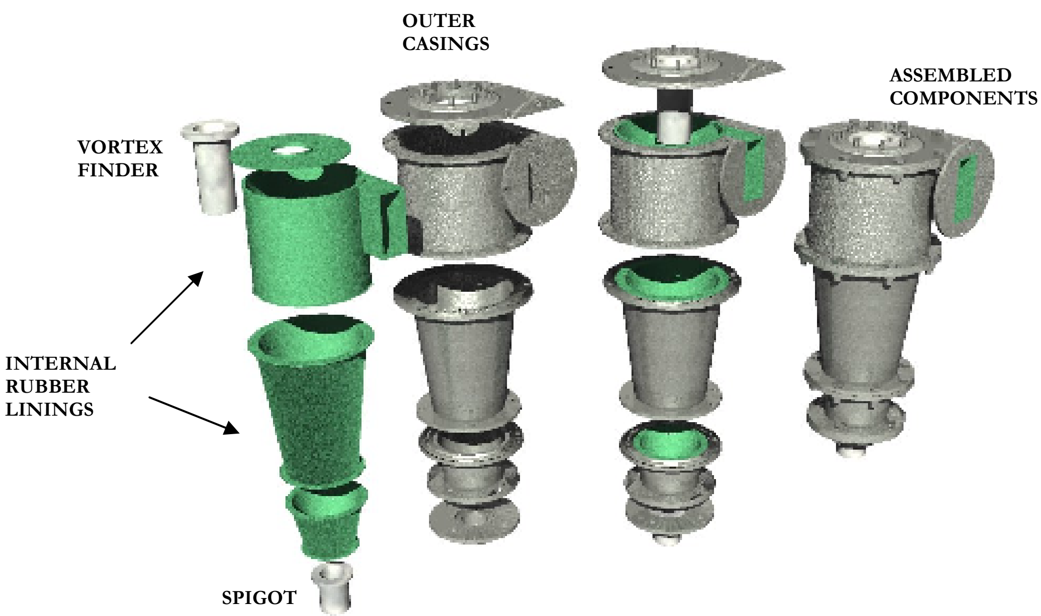
The centrifugal force developed accelerates the setting rate of the particles, thereby separating the particles according to size and specific gravity. Faster settling, coarser particles, move to the wall of the cyclone and migrate to the spigot opening. The drag force due to the viscous resistance of the pulp causes the slower settling particles to move towards the zone of low pressure along the axis and are carried upward through the vortex finder to the overflow.

Cyclone Components

Cyclones are constructed and assembled in a vertical modular system, bolted together. All components, except the spigots and vortex finders, have both an outer casing and an internal rubber lining which is replaced when sufficiently worn.

The spigots and vortex finders are generally constructed of hard wearing materials such as ceramic or polyurethane as both the overflow and underflow discharge are high wear points. The spigot and vortex finder diameters are monitored regularly to ensure they are of the correct dimensions, as determined by the plant metallurgists.

Pictured below are the components of a typical cyclone.



Factors Affecting Cyclone Performance

Cyclone Separation Performance Indicator

The separation or cut point produced by a cyclone is normally defined in terms of the P80.

The P80 separation is the particle size for which 80% of the cyclone overflow is finer than that size. For example, if a sample of cyclone overflow was passed through a bank of screens and 80% of the sample was found to pass through (finer than) the 75μm screen then the P80 point for the overflow is 75μm.

Cyclone Operating Pressure

The pressure at which the cyclones operate is an important parameter as it affects the cut point. The pressure is caused by the fact that the cyclone openings (spigot and vortex finder) provide a restriction on the flow of slurry through the system. This is analogous to partially closing a valve and therefore opening and closing cyclones will have an effect on cyclone pressure. Also, increasing the flow of slurry to a fixed number of cyclones (e.g. by adding more water to the discharge hopper or speeding up the cyclone feed pump) will also change the pressure.

Within limits, an increase in operating pressure will cause the cut point to drop (finer overflow). This is because the centrifugal force on the particles is increased, forcing more fine particles to the cyclone wall and hence reporting to the underflow. However, too great a pressure increase may exceed the operating capacity of the cyclones, causing coarse particles to report to the overflow.

It is important that the operating pressure is maintained by keeping an adequate cyclone feed hopper level. If the hopper level drops too far the cyclone feed pump will cavitate and the pressure will drop. During this transition coarse solids will report to the overflow. If the pressure falls too far, most of the slurry inside the cyclone will report to the underflow.

The operating pressure should be minimised while still maintaining the required separation. The lowest possible operating pressure will minimise energy consumed by the cyclone feed pump and also reduce pump and cyclone wear.

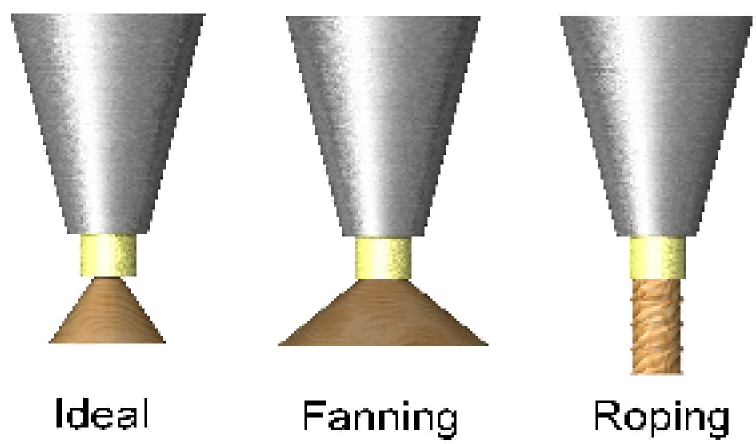
Vortex Finder and Spigot Diameters

The size of the cyclone openings (spigot and vortex finder) will affect the cut point considerably. The reasons are complicated but can be simplified by saying that increasing the size of either opening will allow more of the feed material out of that opening.

Therefore, at a given operating pressure, an increase in the diameter of the vortex finder will result in a coarser cut point as more feed material reports to the overflow. Hence it is important that the vortex finder diameters are monitored regularly and replaced if excessively worn.

Similarly, too large a spigot diameter will allow more fines and excess water to report to the underflow. Hence the overflow becomes finer and the underflow more dilute. Hence, like the vortex finder, the cyclone spigot should be periodically measured and replaced when worn.

Smaller spigot diameters will increase the pressure of the vortex and force more heavy coarse particles to the overflow. Too small a spigot diameter may lead to a condition known as 'roping', where an extremely thick pulp stream of the same diameter of the spigot is formed, and the air vortex may be lost and oversize material will discharge through the vortex finder.



Feed Size Distribution

The cyclone feed size distribution will affect the cyclone cut size and mass flows. A fine feed size distribution will result in a fine product size with the majority of the feed reporting to the overflow. A coarse feed size distribution will result in a coarse product size with the majority of the feed reporting to the underflow. It may be necessary to adjust the cyclone pressure/feed rate and feed density to achieve the required separation size to account for changes in feed size distribution.

Feed Pulp Density / % Solids

For a particle to "sink" to the wall of the cyclone and report to underflow it must 'fight' its way through all the other particles in the slurry. This gives rise to the concept of *'hindered settling'*, which stems from the fact that a particle will sink faster in a glass of clear water than it will in a glass of slurry at 50% solids because there is nothing to stop (or *hinder*) its fall in a glass of water.

In a cyclone, a higher feed density is analogous to a higher density (= more particles) in the glass of slurry. Particles will find it harder to sink so that only the large, heavy particles will make it to the wall. On the other hand, a lower feed density will allow the smaller, lighter particles to sink, reducing the cut point.

Therefore operating the cyclones at high feed % solids will reduce separation efficiency and result in a coarser overflow, as the drag force is increased on each particle causing the particles to remain nearer the centre. The cyclones should ideally be operated at the lowest feed density possible while still maintaining the required separation and overflow density.

Slurry Viscosity

Slurry viscosity (or "thickness") has one of the greatest effects on cut point of all the parameters, however, it's not something that is easily controlled as it is dependent on the mineralogy of the ore. For our purposes, slurry viscosity is dependent on slurry density and has the same effects (see above).

General Cyclone Response Guide

Change To Parameter	Direction of Change	Effect On			
		O/F Density	U/F Density	Recirculating Load	Cut Point
Cyclone Feed Density	Inc	Inc	Inc (small)	Dec	Inc
	Dec	Dec	Dec (small)	Inc	Dec
Number of Cyclones	Inc	Inc (small)	Dec	Inc	Inc
	Dec	Dec (small)	Inc	Dec	Dec
Pressure	Inc	Dec (small)	Inc	Inc	Dec
	Dec	Inc (small)	Dec	Dec	Inc
Feed Volume	Inc	Dec (small)	Inc	Inc	Dec
	Dec	Inc (small)	Dec	Dec	Inc
Spigot Diameter	Inc	Dec	Dec	Inc	Dec
	Dec	Inc	Inc	Dec	Inc
Vortex Finder Diameter	Inc	Inc	-	Dec	Inc
	Dec	Dec	-	Inc	Dec
Slurry Viscosity	Inc	Inc	Inc	Dec	Inc
	Dec	Dec	Dec	Inc	Dec

Cyclone Operation Troubleshooting Guide

The general cyclone operating philosophy at SDGM is to maintain a consistent cyclone feed density and cyclone operating pressure, whilst ensuring the vortex finder and spigot diameters are at the dimensions which generate the desired overflow P80 and density, as determined by the plant metallurgists.

Below is a troubleshooting guide for cyclone operation. It is important, however, to understand that changes made to remedy a particular problem in cyclone operation will also affect other processes in the circuit.

SITUATION	POSSIBLE CAUSES	SUGGESTED SOLUTION
Coarse Overflow	Cyclone liner blow-out	Stop feed to offending cyclone
	Feed size distribution too coarse	Add balls to mill, Change blend, Reduce feed rate
	Operating pressure too high	Reduce pressure
	Operating pressure too low	Increase pressure
	Feed density too high	Add water to circuit
	Feed pump cavitation	Maintain feed hopper level
	Spigots too small	Consult metallurgists
Excessively Fine Overflow	Feed density too low	Take water off circuit
	Spigot diameter too large	Replace worn spigot
	Operating pressure too high	Reduce pressure
	Vortex finder diameter too small	Consult metallurgists
High Overflow Density	Feed density too high	Add water to circuit
Low Overflow Density	Feed density too low	Take water off circuit