# Metallurgist Training Modules

Classifier Theory and Operating Practice

Classifier Surveying and Data Analysis

Practical - Plant Data Analysis

Thursday, 17 June 2004

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# Metallurgist Training Modules

## Classifier Theory and Operating Practice

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# Overview

## Classifier Theory and Operating Practice

- Classifier Objective
- Classification Properties
- Classifier Types
- Classifier Selection
- Screen Theory
- Screen Limitations
- Hydrocyclone Theory
- Hydrocyclone Operating Parameters
- Hydrocyclone Limitations
- Hydrocyclone Inspections

# Classifier Objective

**Classifiers perform one or more of the following:**

- Separation of coarse and fine fractions (mineral sands,scats removal, grizzly)
- Separation of high and low density particles (Heavy Medium Plant)
- Splitting a broad size distribution into fractions (Coal circuits, split flotation)
- To restrict the property distribution of particles entering downstream processes (Conventional flotation)
- To control closed circuit grinding (SAG mill cyclones)

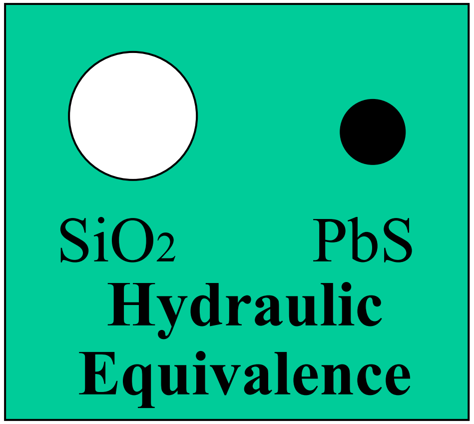
# Classification Properties

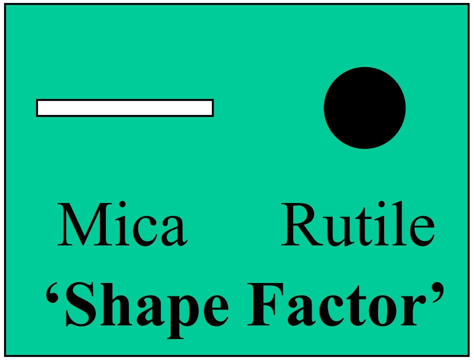
**Classifiers work on one (or more) of:**

- Particle Size
- Particle Density
- Hydraulic Equivalence
- Particle Shape

**And are limited by:**

- Medium Density
- Medium Viscosity
- Hydraulic Equivalence
- Particle Shape



# Classifier Types

# Classifier Selection

**Classifiers are selected based on:**

- Safety
- Environmental
- Throughput
- Product Size (Grizzly vs Gas Centrifuge)
- Product Solids Density (Scats vs Clarifier Overflow)
- Product Density (Gold vs Quartz)
- Feed Medium (Air vs Water)
- Feed Topsize (ROM Ore vs Regrind Feed)
- Maintenance

# Screen Theory

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- Screens may have bars, wire, circular, square or rectangular apertures.
- Screen undersize is a very sharp cut at the aperture size, although this increases as the screen wears.
- Screen oversize can be a very sharp cut as long as the screen is not overloaded.
- Screens often vibrate either straight, circularly or elliptically to allow stratification of the bed.

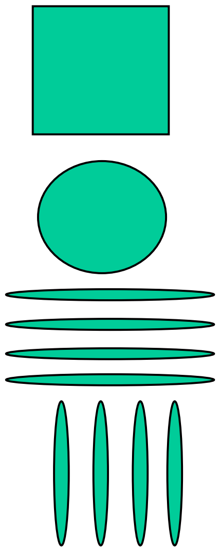
# Screen Theory

- Screen capacity is influenced by aperture size, feed characteristics and screen angle; low angles increase selectivity, steep angles improve throughput.
- Screens may have multiple ‘decks’ to split out particular size fractions.
- Screens may have multiple angles as material passes over the screen to compromise between throughput and separation efficiency.

# Screen Theory

- Aperture size is usually specified as slightly larger than required cutsize to prevent pegging of near-size material.

- Aperture type:
  - Simple
  - Superior Screen Life
  - Superior Capacity
  - Superior Separation



# Screen Limitations

- Very good for ‘coarse’ separations Screen capacity and efficiency drops off significantly for fine separations.
- Capital and maintenance cost of maintaining large screening plants may be uneconomic for fine separations.
- Efficiency can be heavily influenced by particle shape.
- Blinding can be a serious problem in some applications.

# Hydrocyclone (Cyclone) Theory

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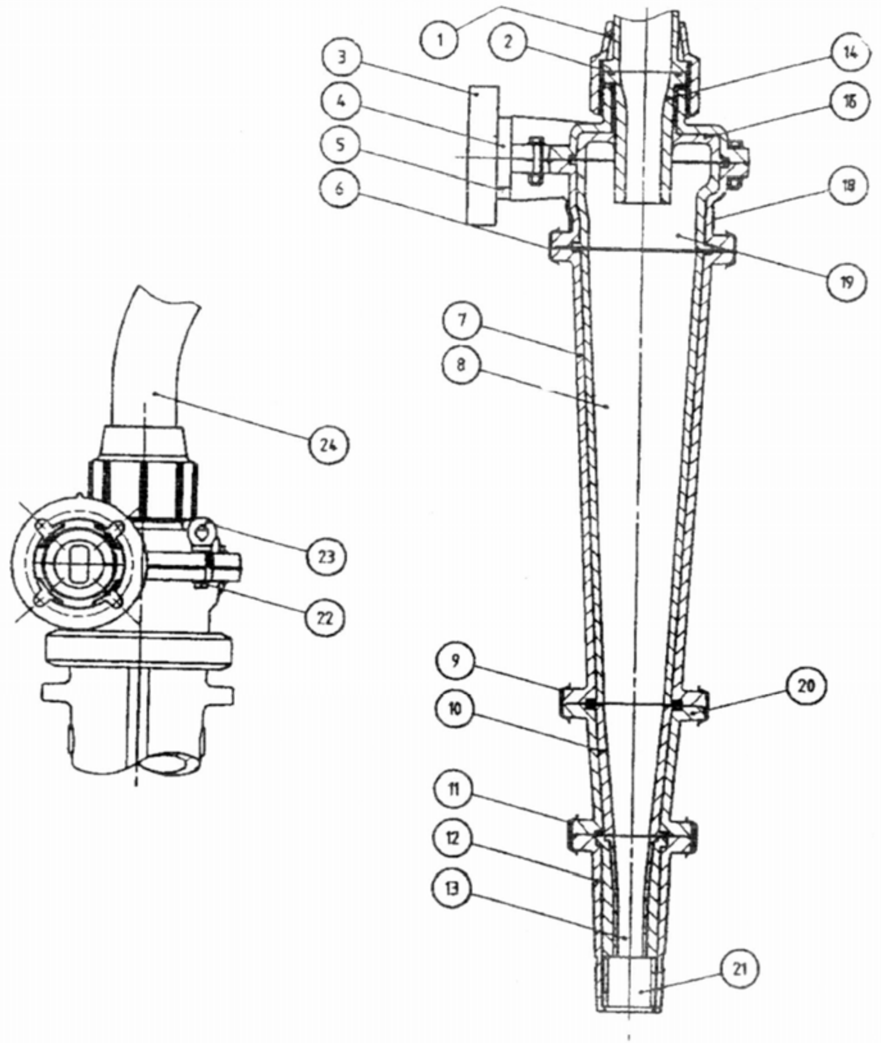
- Cyclones are continuous non-mechanical, hindered settling classifiers that improve separation rate through the application of centrifugal ‘force’.
- Cyclones have low maintenance requirements and high availability, can treat high throughputs, and are efficient at very fine particle separations.
- Cyclones suffer from hydraulic equivalence of particles, however this can be exploited in some applications (dense medium cyclones)

# Physical Cyclone Parameters

- Slurry fed tangentially under pressure
- Vortex finder to reduce bypass
- Vortex finder must be larger than spigot
- Cone angle dictates sharpness of cut
- Diameter dictates cutsize
- Number of cyclones determines throughput
- May be mounted at any angle
- Air core rotates counter to slurry



# Cyclone Mounting Angle

- Cyclones classify by opposing centrifugal and drag forces.
- Mounting a cyclone at an angle provides an extra 'G' for classification….
- ….but classification is not symmetrical across the cyclone.
- Although extensive trials can find an optimum between these two conditions, the large amount of engineering and testing involved often offsets the small potential gain.
- This parameter is *not* easy to manipulate in the plant.

# Cyclone 'Operating' Parameters

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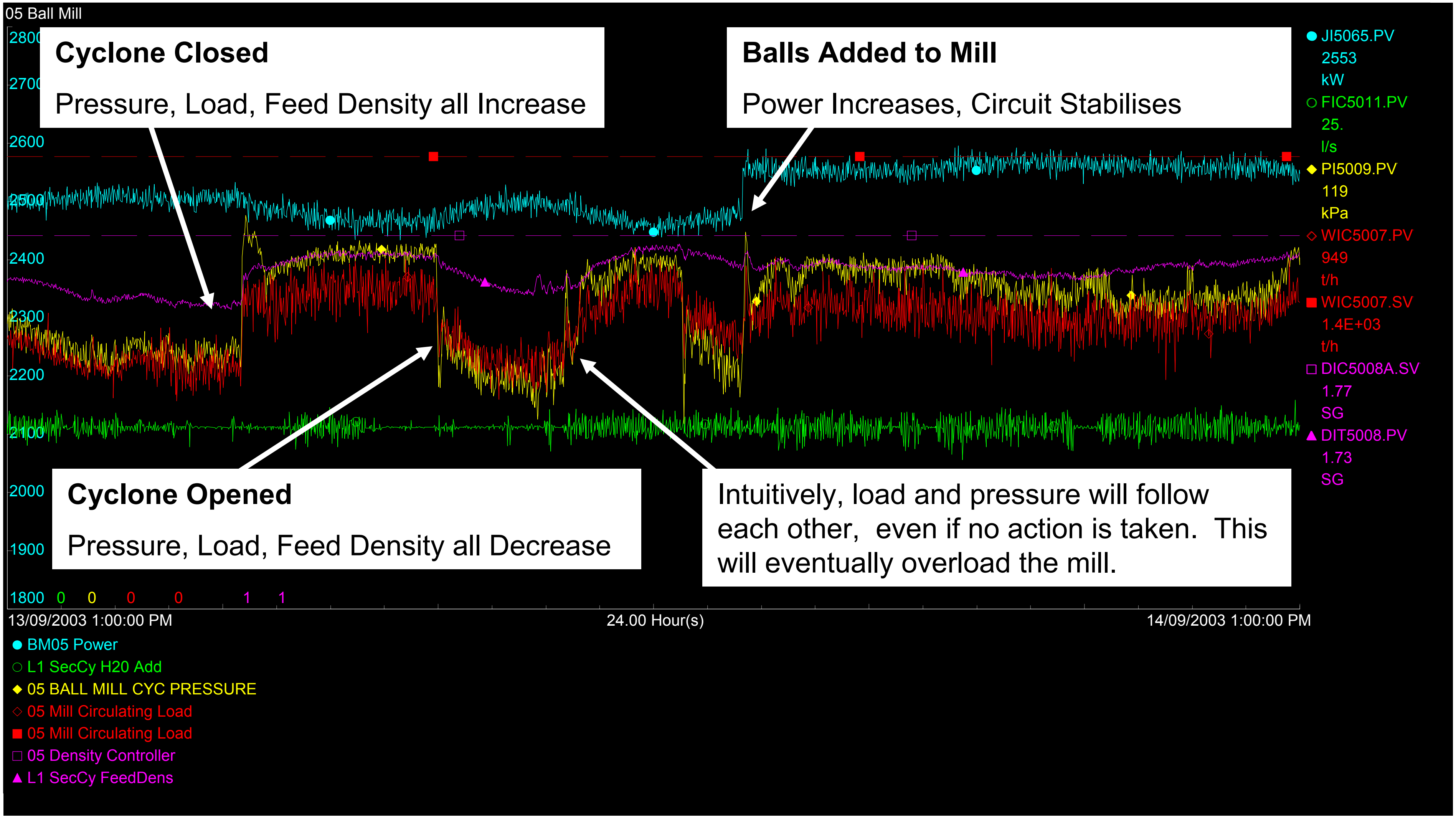
| Process Effect of Changing Operating Parameter | | | |
|---|---|---|---|
| | Cut Size | Recirculating Load | Cyclone Efficiency |
| ▲Pressure | ▼ | ▲ | ▲ |
| ▲Feed Density | ▲ | ▼ | ▼ |
| ▲Spigot Size | ▼ | ▲ | ▲ |
| ▲Vortex Finder Size | ▲ | ▼ | ▼ |
| ▲SAG Mill Transfer Size | ▲ | ▲ | ▼ |

# Cyclone Operating Parameters



# Cyclone Limitations

- The pressure change associated with cyclone addition/removal is often significant; cyclones are nearly always operating at a sub-optimal point.
- Density and recirculating loads limit throughput.
- Very low feed density results in the cyclone 'mass splitting' due to entrainment.
- Very high pressures result in poor cuts due to short circuiting and overloading of spigots.
- Overloading spigots ultimately results in 'Roping', a state where the air core has collapsed.
- For very fine cuts, hundreds (or thousands) of very small cyclones may be required.

# Cyclone Inspections

- Cyclones should be inspected internally at least quarterly.
- Vortex finder and spigot wear rate is monitored. Acceptable wear is +10% from installation.
- Loose rubber linings cause flow disturbances and the cyclone will soon ‘blow out’, usually at the flange.
- ‘Steps’ between lining sections interfere with the flow pattern in the cyclone.
- Cracked components must be removed.
- Cyclones must ALWAYS be inspected if daily sizings are excessive, or if there is any evidence to suggest balls have passed through them.

# Cyclone Inspections

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Ceramic lined middle cone after balls pass through cyclone.  A long time after…..

# Metallurgist Training Modules

## Classifier Surveying and Data Analysis

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# Overview

## Classifier Surveying and Data Analysis

- Screen Sampling
- Cyclone Sampling
- Cyclone Data Analysis
  - Size Distribution
  - Efficiency Curve
  - Corrected Efficiency Curve
  - Reduced Efficiency Curve

# Screen Sampling

- Screens include IsaSizers, Trommels, Grizzlys, Vibratory Screens, etc.
- Difficult to accurately (and safely!) sample off large screens due to requirement to cut full stream.
- Much easier to sample at product transfer points.
- Initial data analysis similar to cyclones.

# Cyclone Sampling

- Cyclone surveys require feed, overflow and underflow samples to be taken.
- Underflow and overflow samples are taken using 1/2 moon cutters, with an aperture at least 2.5 times the particle topsize.
- Underflow and overflow samples must cut the entire stream, as the cyclone classifies radially.

# Cyclone Sampling

- Feed samples are usually taken at the distributor, which is well mixed.
- Feed samples must be taken last due to the resulting drop in distributor pressure.
- Cyclones should operate steadily for 20 - 30 minutes prior to and between sampling campaigns.

# Cyclone Sampling

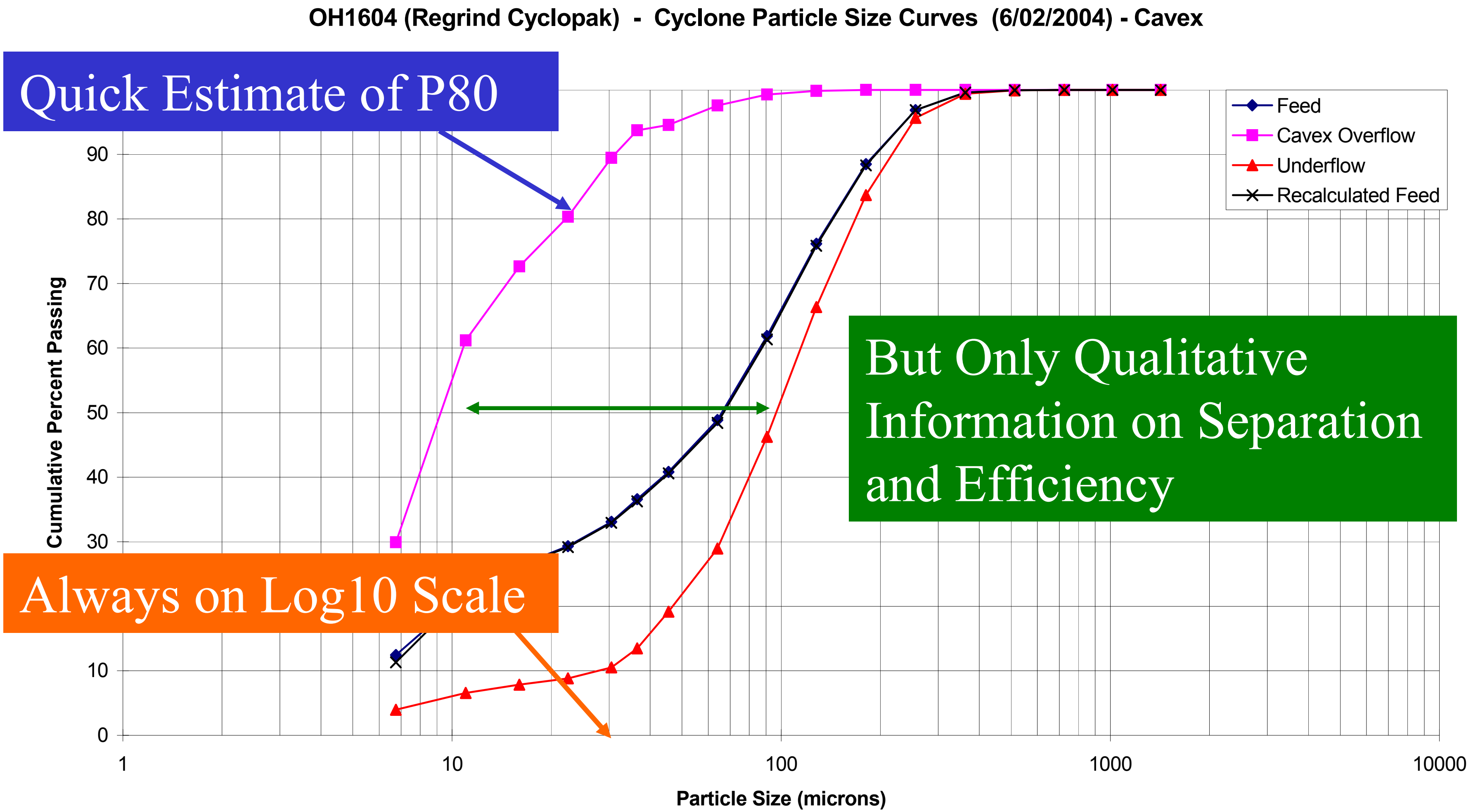
- Solids density and particle size must be considered when estimating required sample volume.
- Samples must contain enough solid to be representative of the size distribution (Gy's Formula).
- Samples must also contain at least 300g solid if screen sizing is required.
- Unless assaying of size fractions is required, laser sizing is usually adequate for very fine distributions.
- Samples of excessive size slow down lab processing.

# Cyclone Data Analysis

- Size distributions are the basis of all analysis.
- Distributions are plotted with respect to nominal particle size, not screen size.
- Cyclosizer/Laser Sizer fractions must be assigned a passing and nominal size based on material density.

| Isa Copper Ore SG 2.9 - 3.1 | | |
|---|---|---|
| Cyclosizer | Passing Size | Nominal Size |
| C1 | 29.5 | 33.5 |
| C2 | 18.8 | 23.5 |
| C3 | 13.2 | 15.8 |
| C4 | 9.3 | 11.1 |
| C5 | 5.8 | 7.3 |
| C6 | 3.9 | 4.8 |
| C7 | -3.9 | 2.0 |

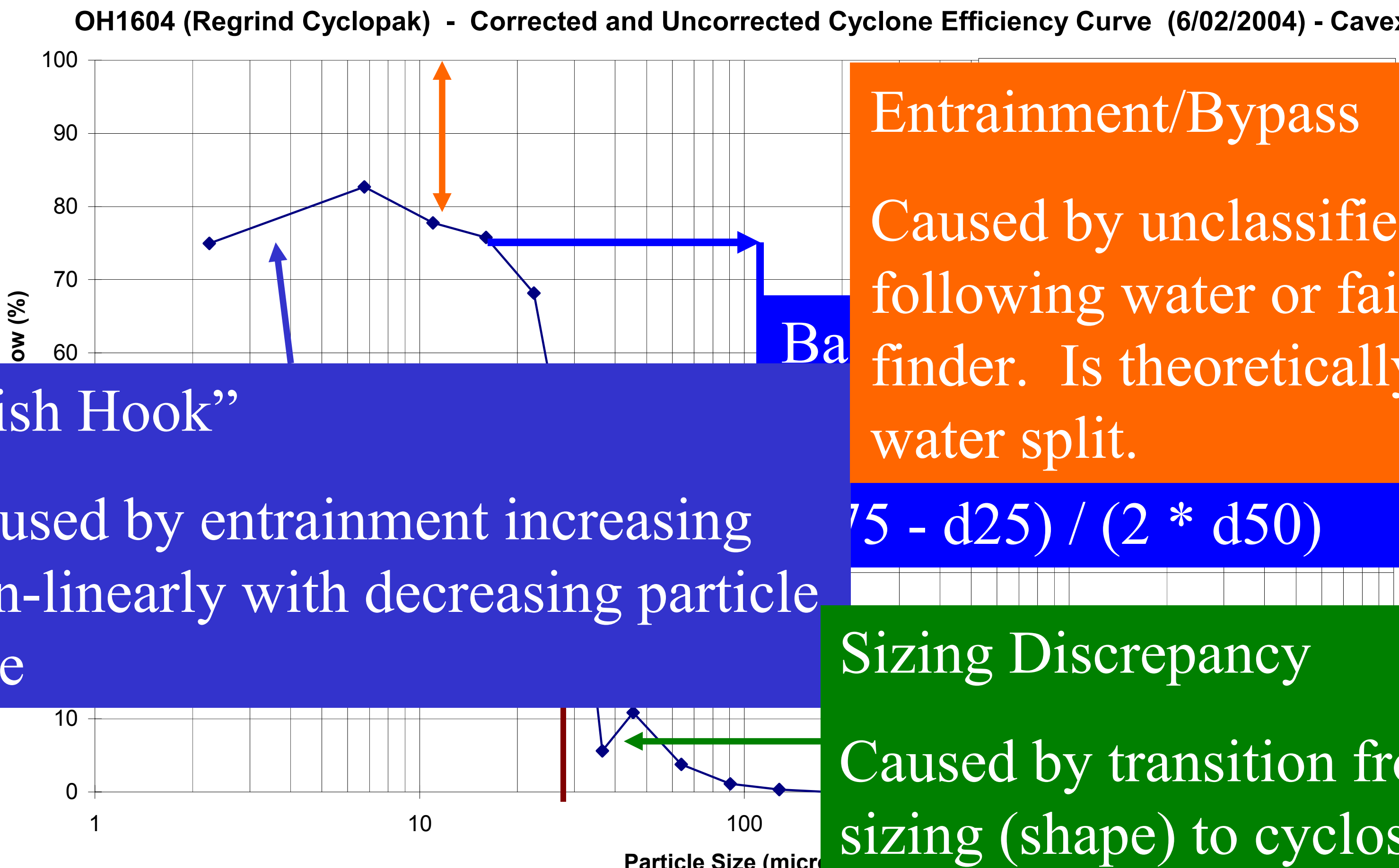
# Size Distribution



# Efficiency Curve

- Efficiency Curves allow quantitative evaluation of cyclone performance.
- Key features of efficiency curves allow interpretation of performance and provide explanations for deviations from targets.
- Cyclone efficiency curves in minerals processing applications should be plotted as recovery to overflow, which is the true product.
- Cutpoint (d50) is the size at which there is 50% chance of reporting to either U/F or O/F
- Work with recalculated feed to minimise discrepancy

# Efficiency Curve - Uncorrected




Ba

75 - d25) / (2 * d50)

Entrainment/Bypass

Caused by unclassified material following water or failed vortex finder. Is theoretically equal to water split.

"Fish Hook"

Caused by entrainment increasing non-linearly with decreasing particle size

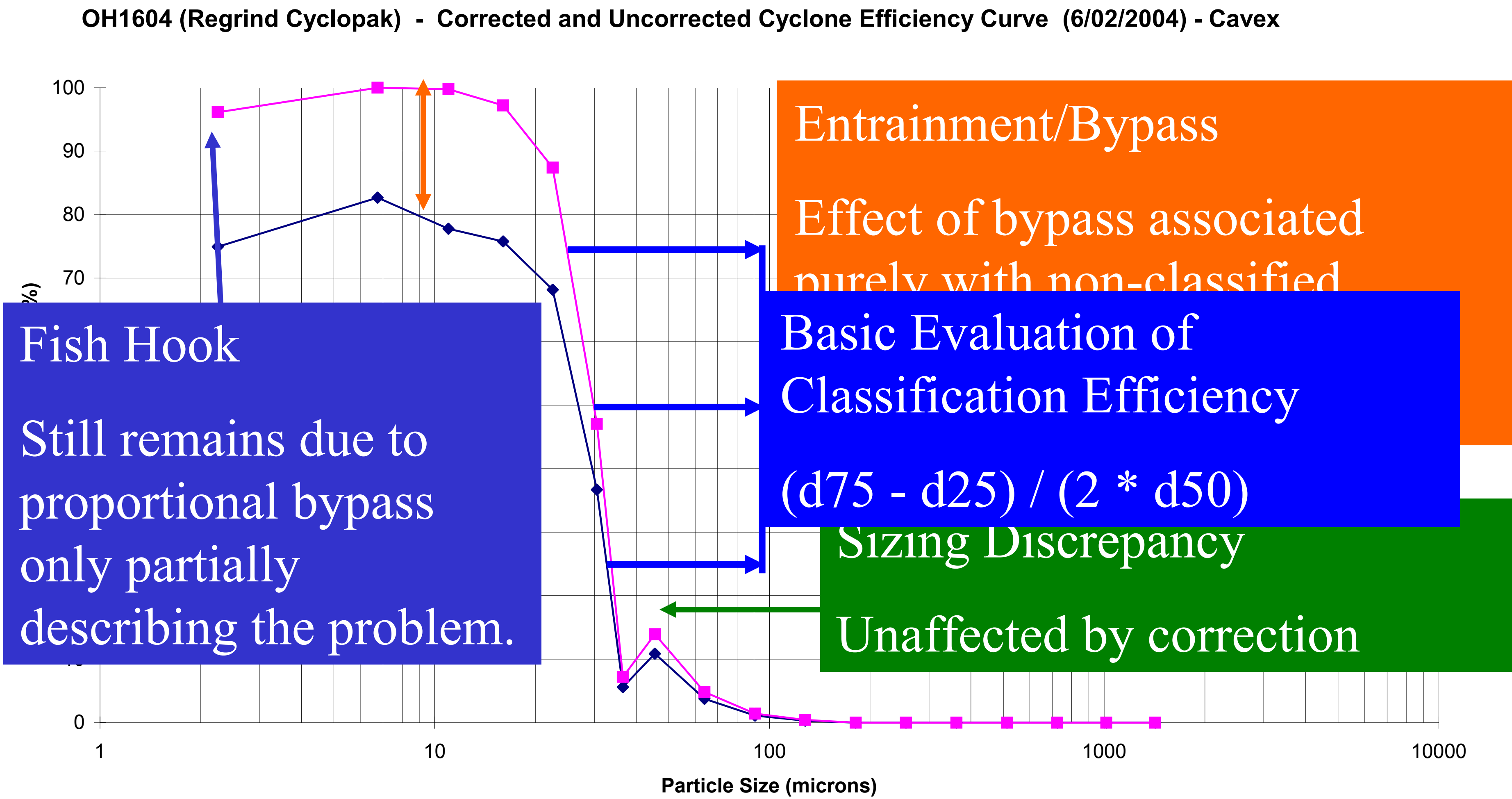
Sizing Discrepancy

Caused by transition from screen sizing (shape) to cyclosizing (hydraulic equivalence)

# Efficiency Curve - Corrected

- Uncorrected efficiency curves are useful for comparing conditions taken at short time intervals (hours), or several different cyclones/components taken during the same survey.
- They are not easy to compare if tests are done several days apart due to slightly different operating conditions, ore type, temperature, etc.
- Cyclone Efficiency numbers are often meaningless if bypass is significant.
- To compare curves for this purpose, it is necessary to correct the curve for bypass.

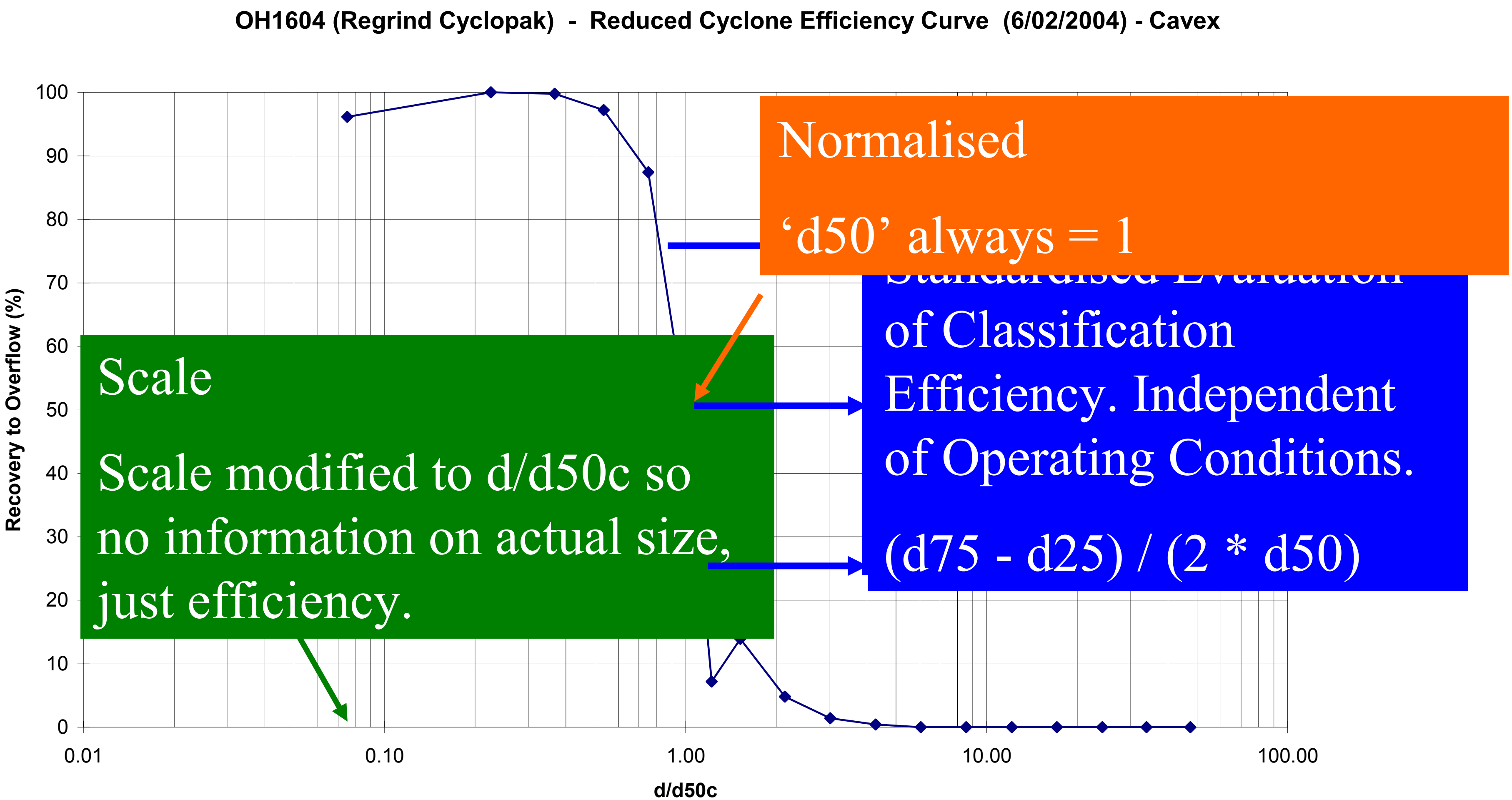
# Efficiency Curve - Corrected



# Reduced Efficiency Curve

- Corrected efficiency curves still suffer from variation based on random fluctuations in operating conditions.
- To eliminate the effect of such conditions (such as cyclone feed distribution), it is necessary to reduce the efficiency curve to fundamentals.
- Reduced efficiency curves therefore provide consistent information on cyclone classification efficiency, and are used to gather data for circuit modelling.
- JKSimMet and other modelling programs require parameters acquired from reduced efficiency analyses.
- Reduced curves only show classification efficiency. They *do not* give any data on cutpoint.

# Efficiency Curve - Reduced



# Metallurgist Training Modules

## Practical - Plant Data Analysis

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# Overview

- Using plant data:
  - Plot cyclone distribution data
  - Plot & Analyse Efficiency Curve
  - Plot & Analyse Corrected Efficiency Curve
  - Plot & Analyse Reduced Efficiency Curve
- Evaluate Cyclone Performance
- Presentation of Standard Template

# Solid Split

**Solid split = C/F = (f-t)/(c-t) = (f-u)/(o-u)**

**Mass Flowrates** → C/F

**'Assays' *in wt% solid*** → (f-t)/(c-t), (f-u)/(o-u)

But for classifier surveys, assay data is usually unavailable, and each size fraction will produce a (slightly) different solid split. % Solids is the most robust way to calculate solid split.

***But % solids is not in assay form and must be converted!***

# Dilution Ratio

$$Assay_x = \frac{\text{Mass Solid}_x}{\text{Mass Solid}_{Total}}$$

$$\%\ Solids = \frac{\text{Mass Solid}_{Total}}{\text{Mass Solid}_{Total} + \text{Mass Water}_{Total}}$$

**This term must be mathematically removed before % Solids can be used in Solid Split or Two Product Formula**

→ ***Dilution Ratio***

# Dilution Ratio

$$\text{Dilution Ratio} = \frac{100 - \%\text{Solids}}{\%\text{Solids}}$$

↓

$$\text{Solid Split} = \frac{C}{F} = \frac{f - t}{c - t}$$

# Solid Split - Size Distribution

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**To calculate overall solid split to overflow from size fractions, we must minimise the errors associated with the solid split for each size fraction.**

Sampled

$$\text{Solid Split} = \frac{\sum_i (o_i - u_i)(f_i - u_i)}{\sum_i (u_i - o_i)^2}$$

*Best estimate* based on all size fractions. Should be close to solid split based on dilution ratio if data integrity is good.

# Feed Recalculation

- Feed must be recalculated to maintain data consistency.
- Recalculated feed must be similar to sampled feed, otherwise data is invalid.
- Feed is recalculated from Solid Split.
- Choose a solid split value associated with a large separation.  May be size fractions, mass flows, dilution ratio, assays, etc.

$$f_{r_i} = \left(u_{a_i} * \left(1 - SS_o\right)\right) + \left(o_{a_i} * SS_o\right)$$

$$\mathrm{f}_{\mathrm{r}_\mathrm{i}} = \text{recalculated feed mass \% i}$$

$$\mathrm{u}_{\mathrm{a}_\mathrm{i}} = \text{actual underflow mass \% i}$$

$$\mathrm{SS}_\mathrm{o} = \text{Solid Split to Overflow}$$

# Develop Size Distribution Chart

- Develop % Passing and Cumulative % Passing Data.
- Plot overflow, underflow, feed and recalculated feed CPP against log10 nominal particle size.
- Nominal particle size is geometric mean of upper and lower screen (or cyclosizer etc.) sizes for the fraction.

# Develop Efficiency Curve

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- Plot recovery to overflow against nominal particle size
- Calculate recovery for each size fraction - use recalculated feed to minimise error.

$$\%\mathrm{Rec_i} = \frac{c_i * (f_i - t_i)}{f_i * (c_i - t_i)}$$

$$\mathrm{f, c, t = Mass\% \ of \ size \ i}$$

- Note key elements of the curve.
- Calculate *cyclone efficiency*

$$\alpha_e = \frac{d75 - d25}{2 * d50}$$

α used for convenience here. Do not try and directly use this α in modelling functions.

# Develop Corrected Efficiency Curve

- Calculate the Water Split to Overflow
  - calculate 'dilution ratio' with %water instead of %solid
  - calculate 'water split' = (f-t)/(c-t)
  - f,c,t=water dilution ratio=100-%H2O/%H2O
- Corrected recovery (efficiency) to overflow Eoc:

$$E_{oc_i} = \frac{E_{o_i}}{WS_o}$$

$$\mathrm{E}_{\mathrm{oc_i}} = \text{Corrected Rec of i to Overflow}$$

$$\mathrm{E}_{\mathrm{o_i}} = \text{Actual Rec of i to Overflow}$$

$$\mathrm{WS}_{\mathrm{o}} = \text{Water Split to Overflow}$$

# Develop Corrected Efficiency Curve

- Note components of corrected curve.
- Calculate *separation efficiency*

$$\alpha_c = \frac{d75 - d25}{2 * d50}$$

α used for convenience here. Do not try and directly use this α in modelling functions.

Perfect separation when $\alpha = 0$

# Develop Reduced Efficiency Curve

- Calculate d50c (≡ P50 of corrected curve)
- Plot Eoc vs d/d50c
- Note key components of curve.
- Calculate *reduced efficiency*
- Compare the three efficiency values

$$\alpha_r = \frac{d75 - d25}{2 * d50}$$

α used for convenience here. Do not try and directly use this α in modelling functions.

# Cyclone Performance Evaluation

- How is this cyclone performing?  Why?
- What could be done to improve performance?

# Standard Template

- A standard cyclone data analysis template has been developed.
- The standard template should be used for cyclone data analysis and presentation at Mount Isa Mines.
- The standard template:
  - Allows improved retention of corporate knowledge;
  - Allows other metallurgists to see and understand data and data location quickly;
  - Allows rapid and consistent analysis of classifier data;
  - Is correct!!

# End

References:


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2. Kojovic, T. et. al. (1996) *Mineral Comminution Circuits: Their Operation and Optimisation*, JKMRC, Brisbane

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