CLASSIFYING

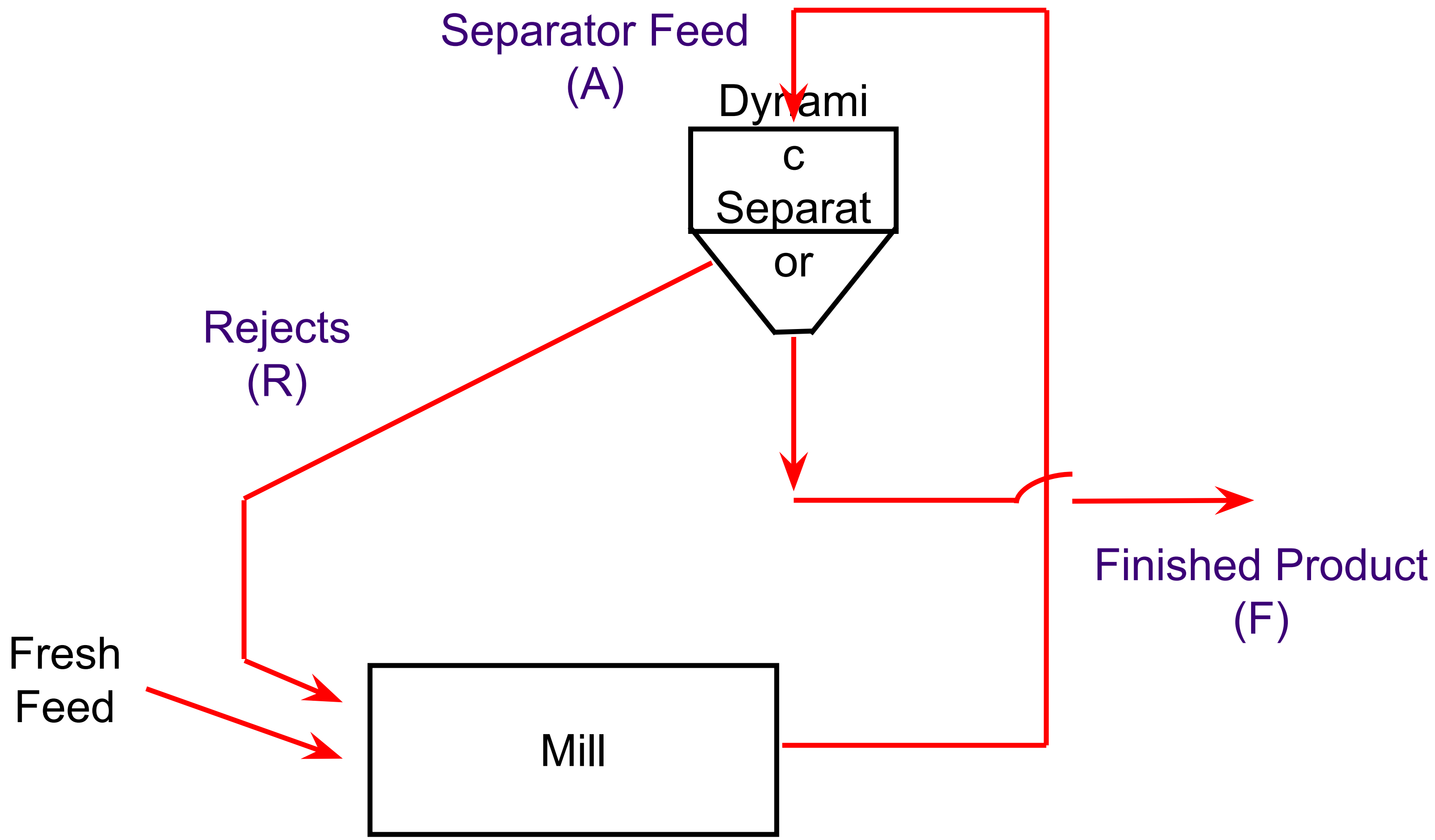
Key Separator Relations

Circulating Load
Tromp Curve

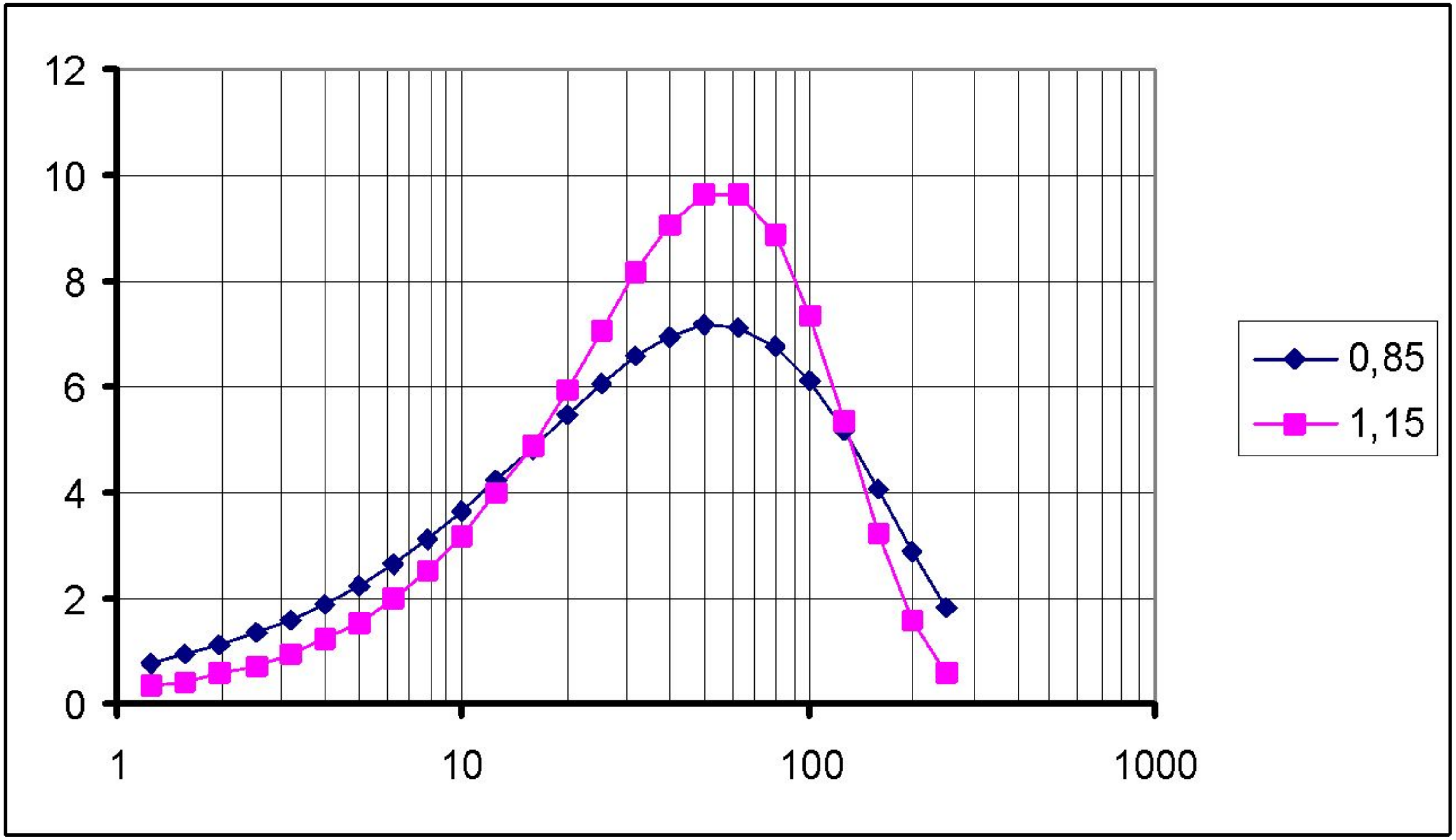
Why a separator?

- **Open circuit grinding is not very efficient:**
  - Overgrinding of fines
    - Useless for quality
    - Coating
  - No way to be sure of coarse rejects
  - Limitation of mill ventilation
- **Solution = separator**
  - Quick grinding is followed by extraction of the fines already produced, rejects going back to mill inlet
  - Retention time in the mill is reduced (20 to 5 min)
  - Direct actuator on finish product fineness

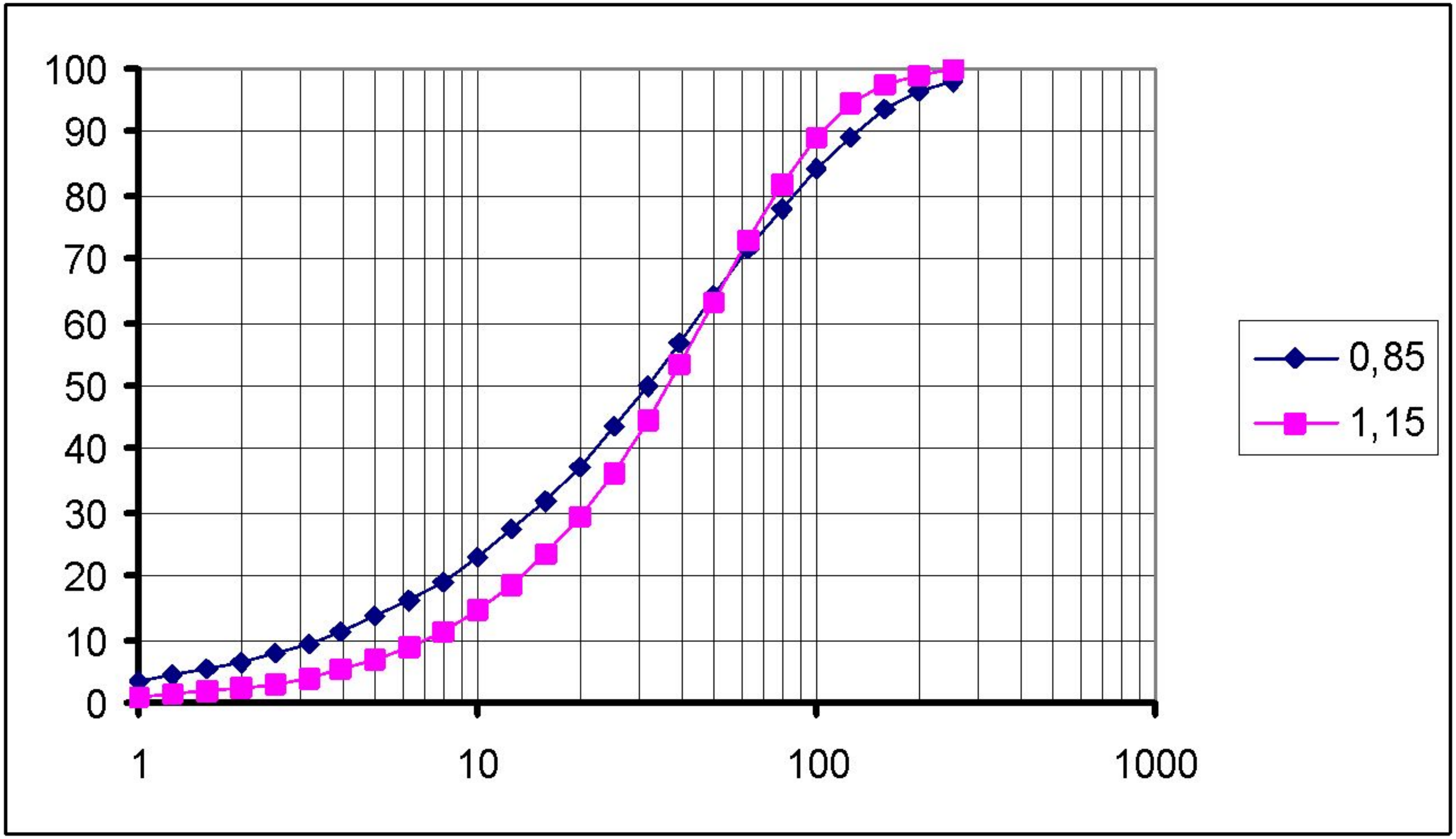
Closed circuit



Impact on product PSD



Impact on product PSD



Separation in general

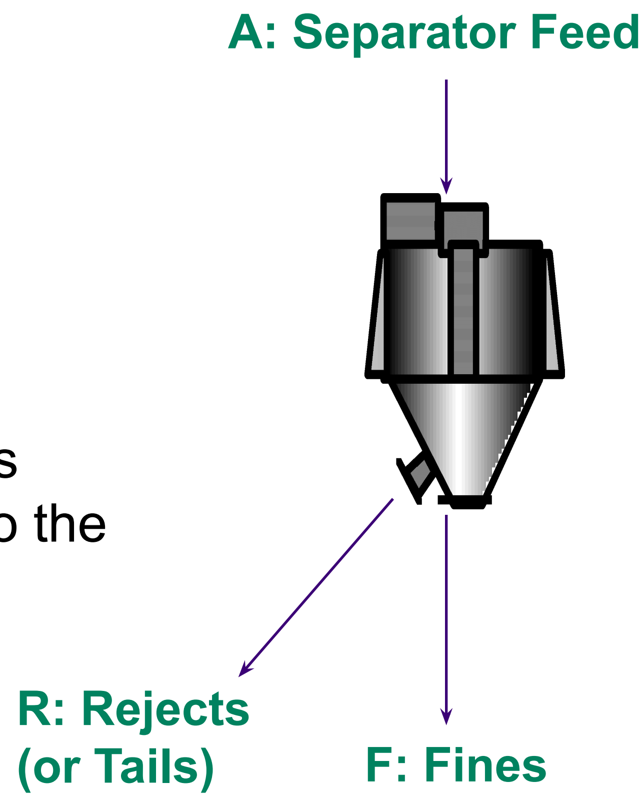
- **A SEPARATOR DOES NOT GRIND !!!**
  … but it helps optimize the efficiency of the mill

- **The "amount of closed circuit" is given by the circulating load**
  - The higher the CL
    - the more the material goes back to the mill
    - the shorter the retention time
  - Adjusting the CL will change the workshop efficiency and the product quality

Circulating Load (CL)

- **How can we determine it?**
  - C.L. = R/F (used by Lafarge)
  - Others define it as C.L. = A/F
  - Or A/F = 1+ R/F
- **Meaning?**
  - Number of material passages through the mill, in addition to the first one
- **What is the best CL?**

The best is unique to each circuit and can only be found by experimentation

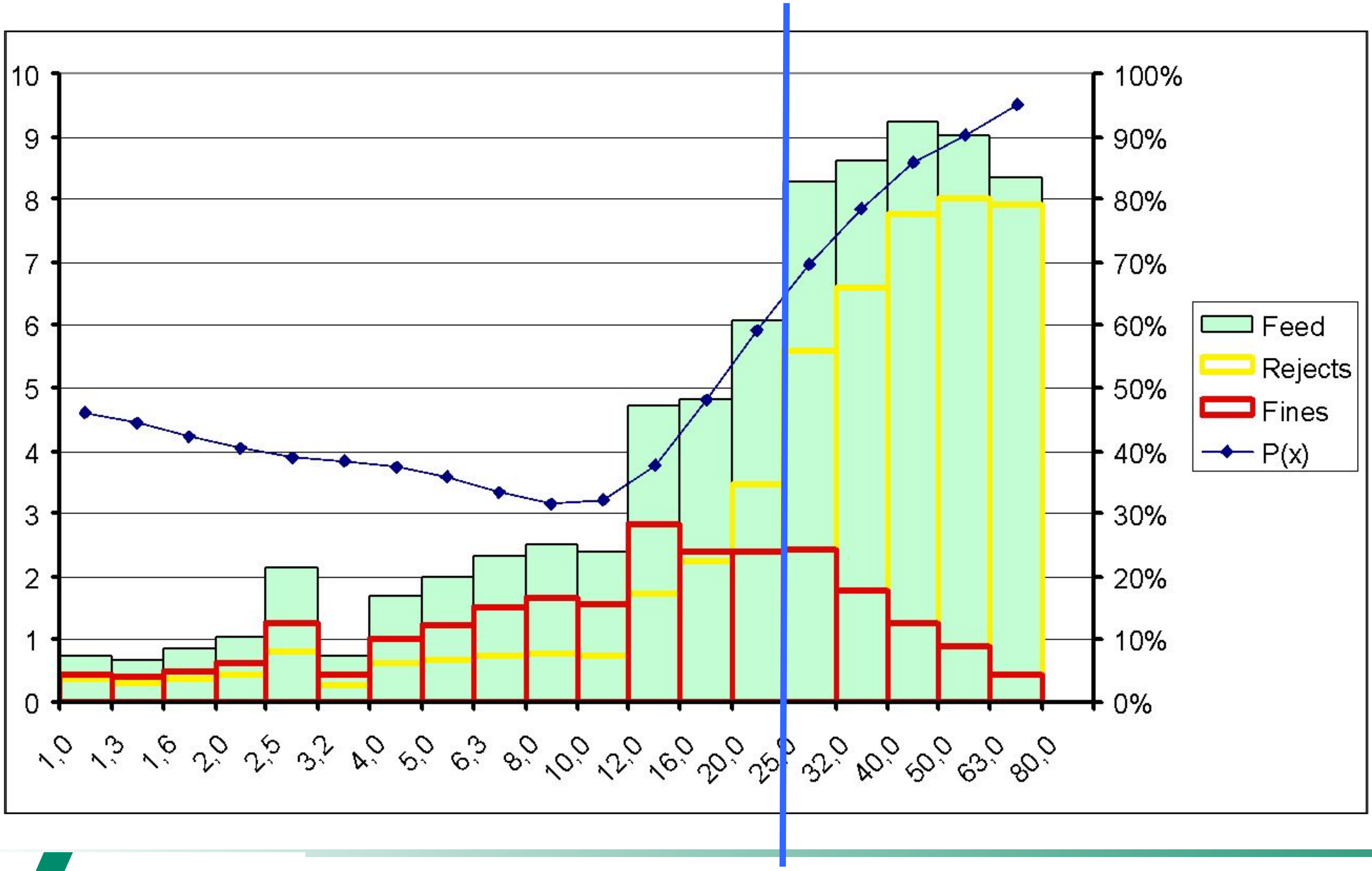


Separation efficiency

- How do we assess the efficiency of separation?
- The tool is the separation curve, or TROMP CURVE
- First, what do we expect of a separator?
  - …

Separation efficiency

- What do we expect of a separator?



Feed PSD

Ideal separation

Real separation

Tromp curve

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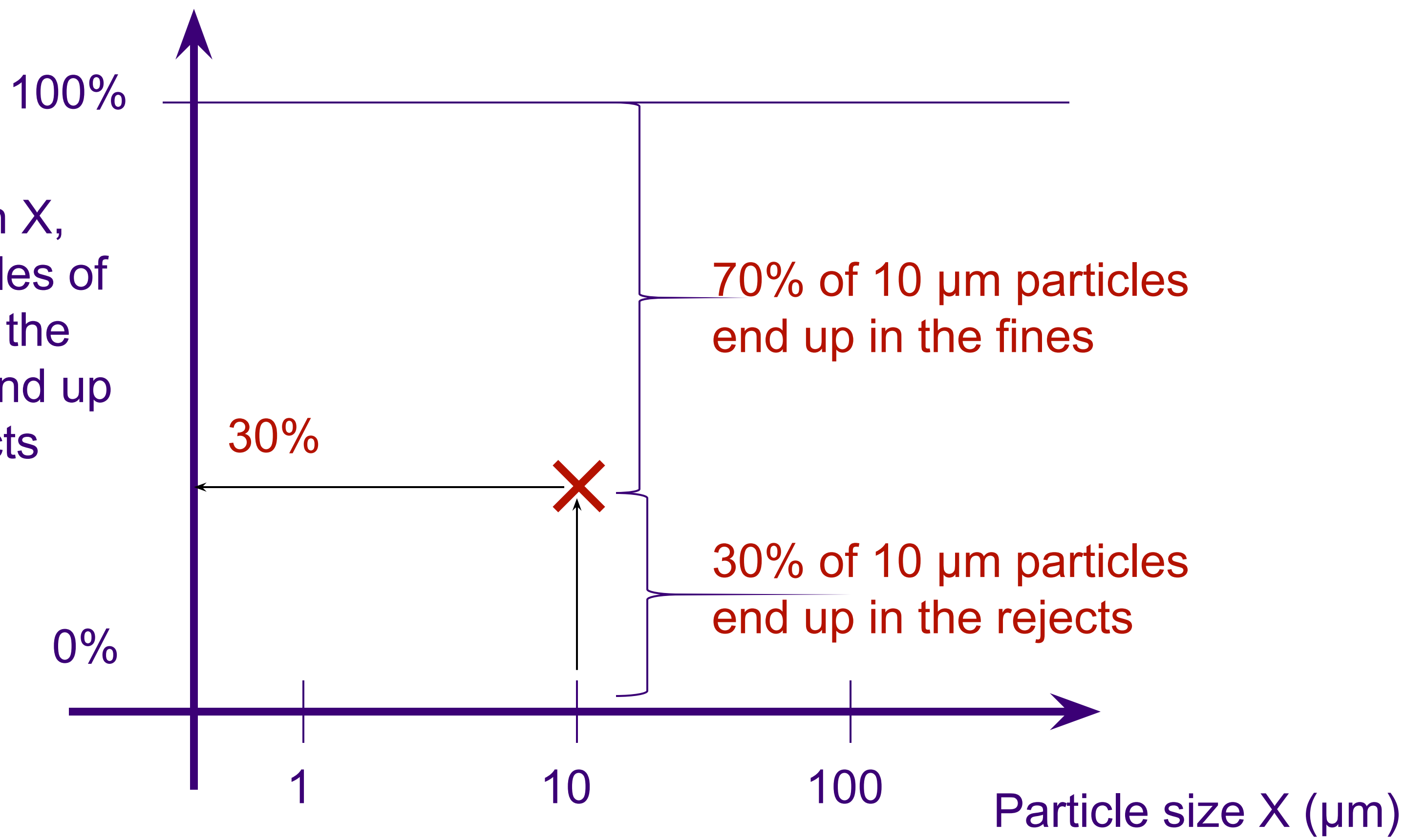
Tromp curve - Principle

For a given X,
% of particles of
this size in the
feed that end up
in the rejects



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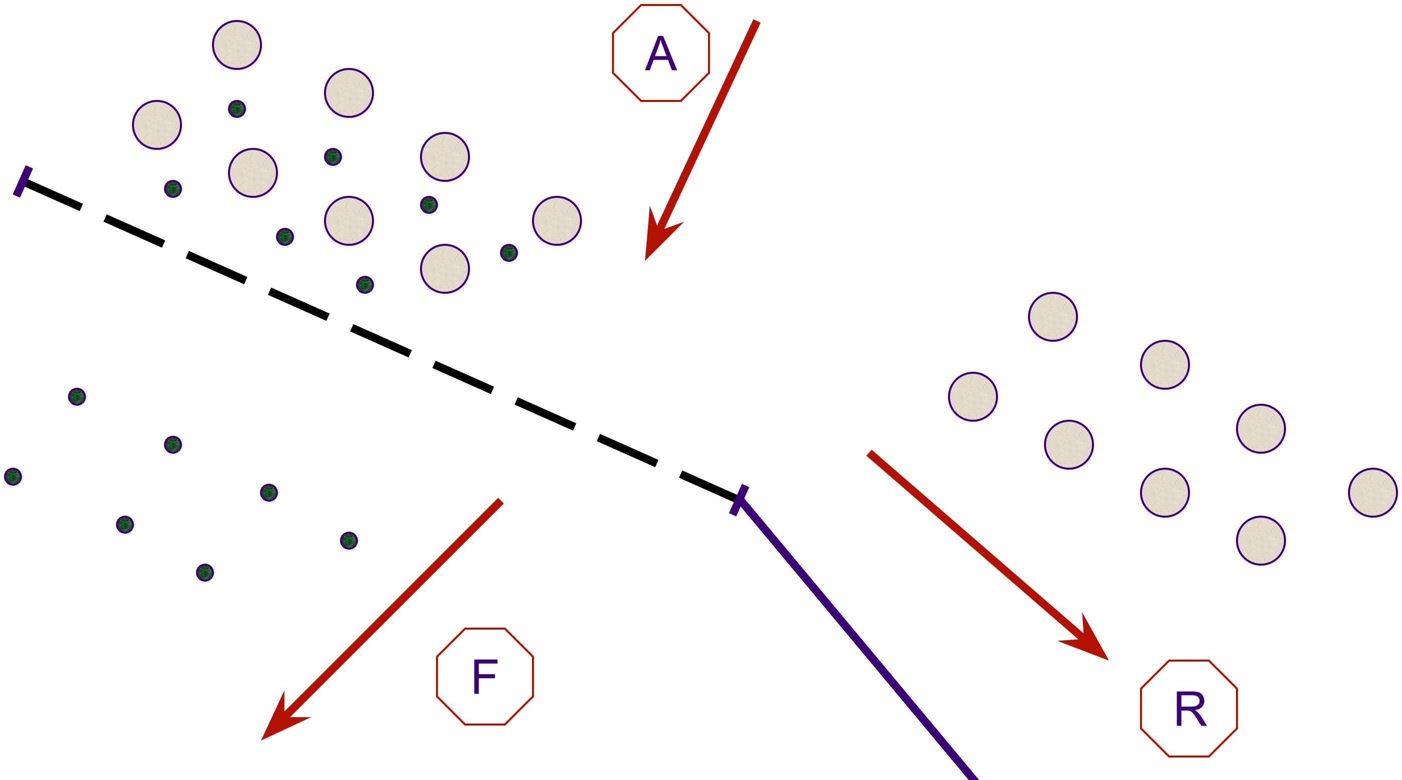
Tromp curve – example

- **Let's take the example of a sieve:**

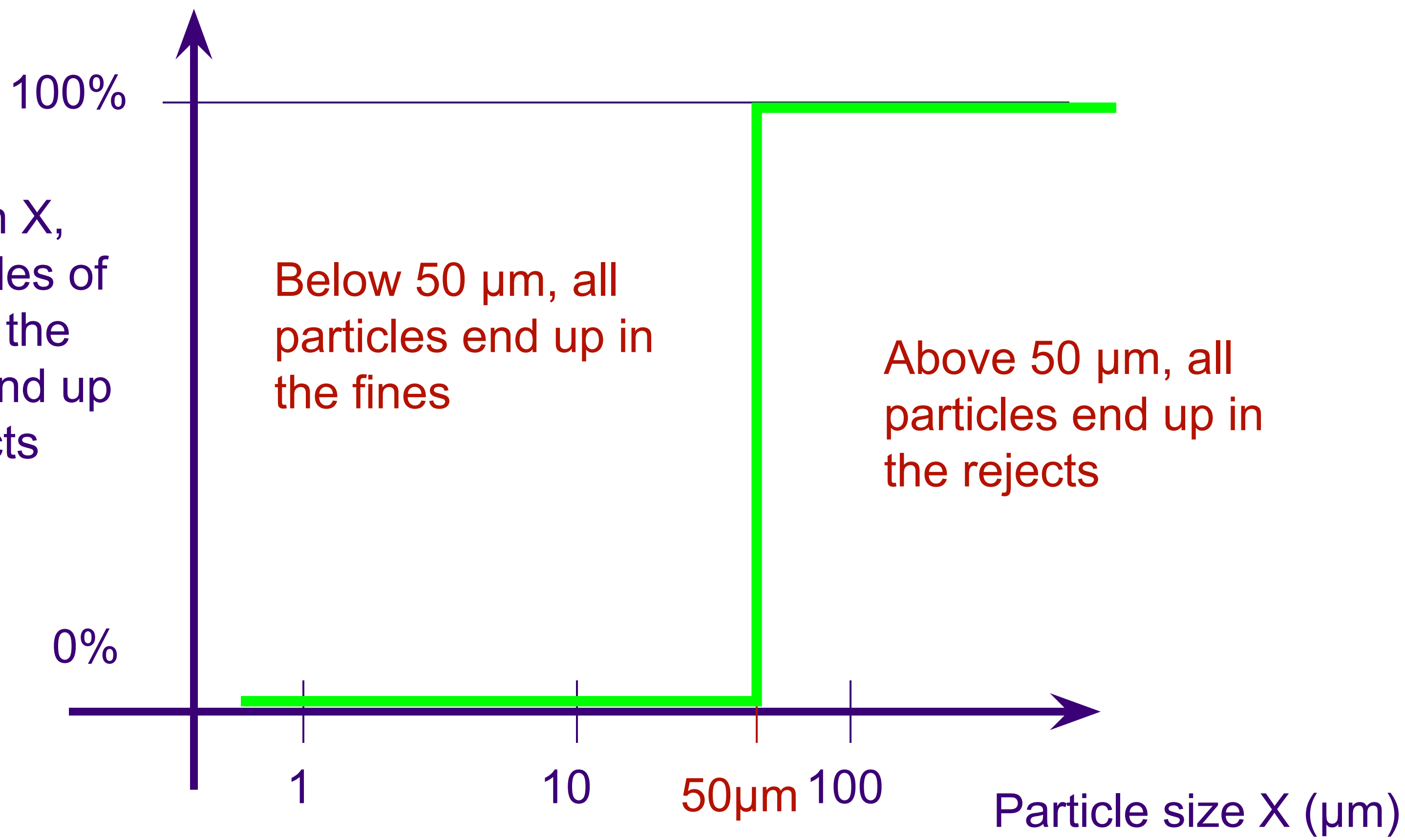
Tromp curve – example

- If screen and sieving are perfect:



Tromp curve – Perfect screen

For a given X,
% of particles of this size in the feed that end up in the rejects



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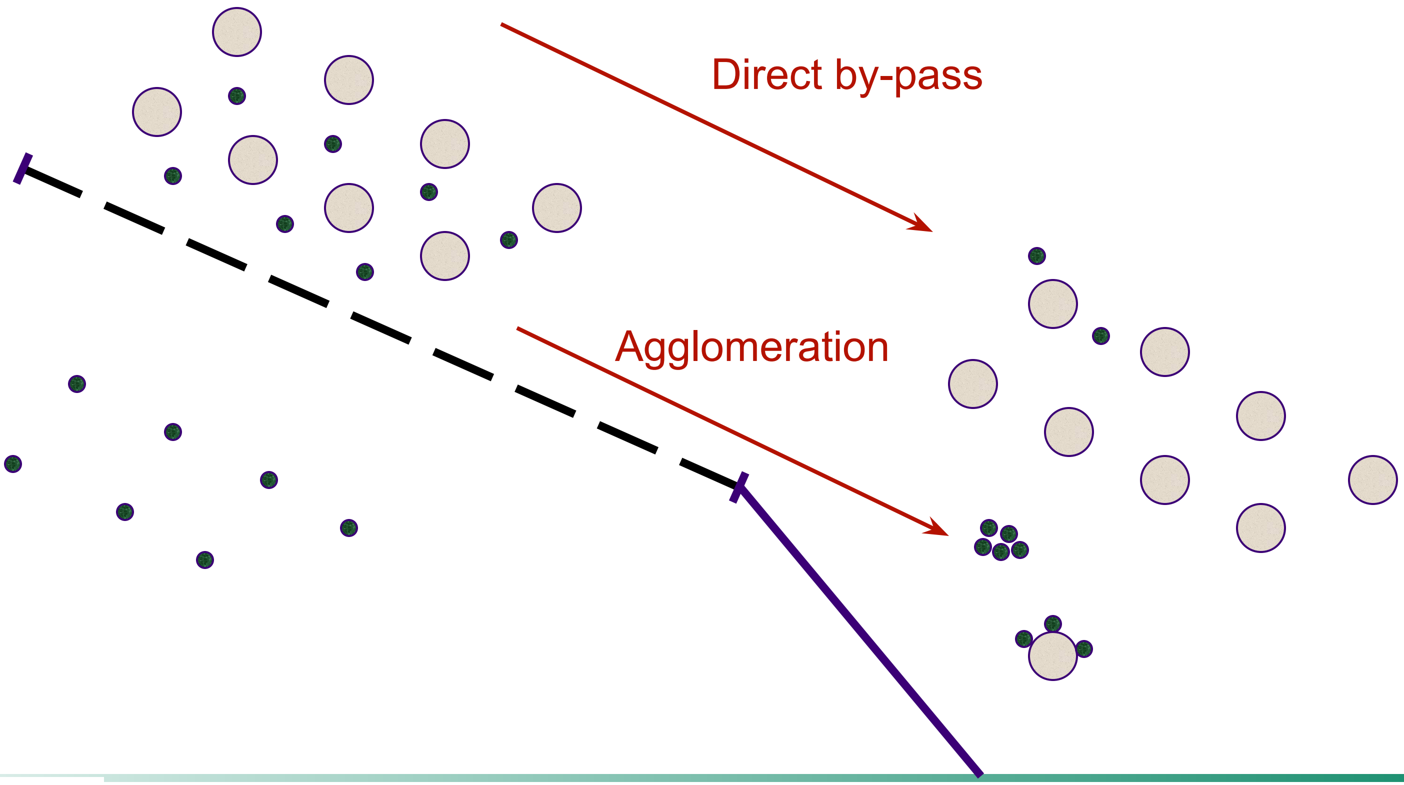
By-pass

- How can we find some fine particles in the rejects?:



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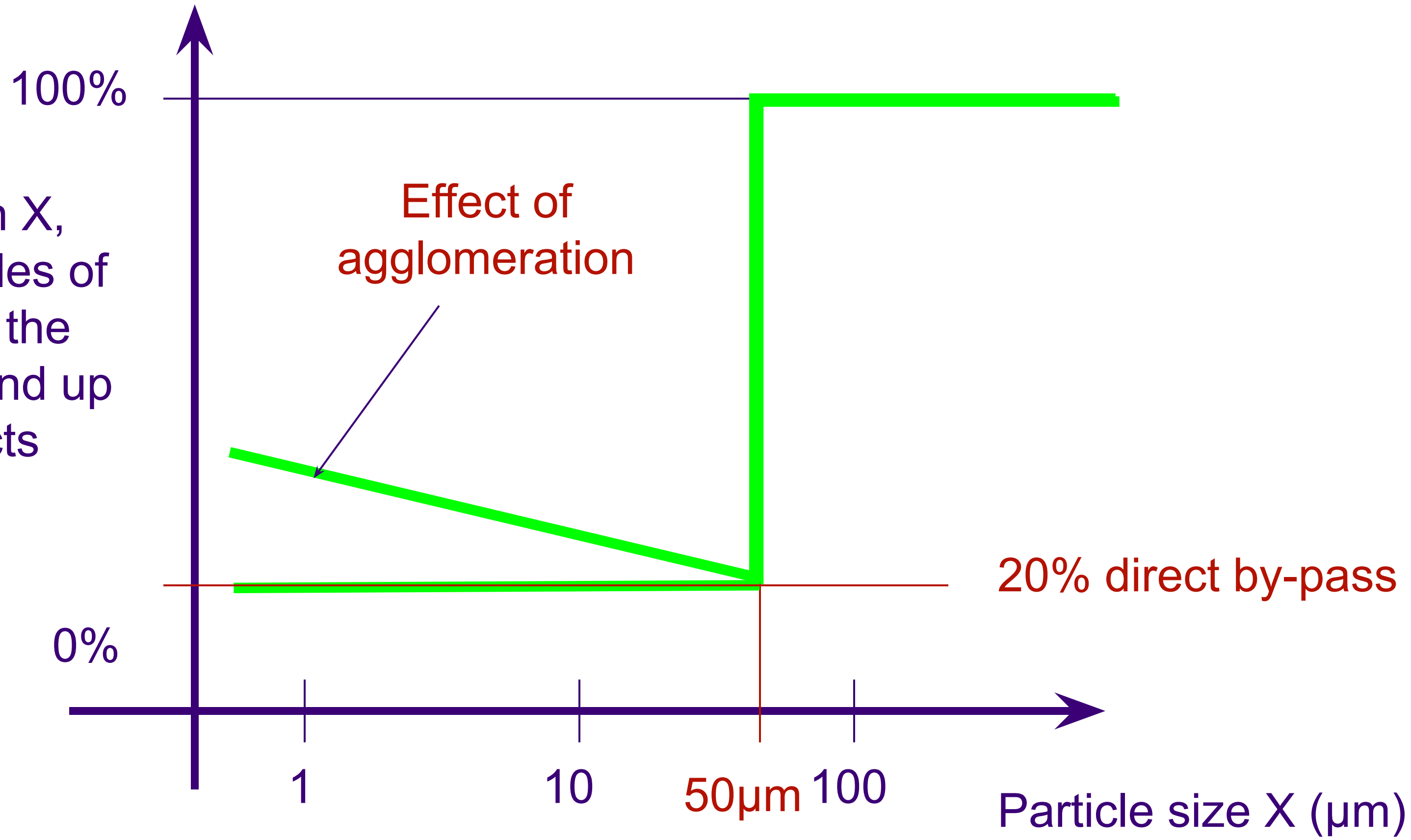
Tromp curve – With bypass

For a given X,
% of particles of this size in the feed that end up in the rejects



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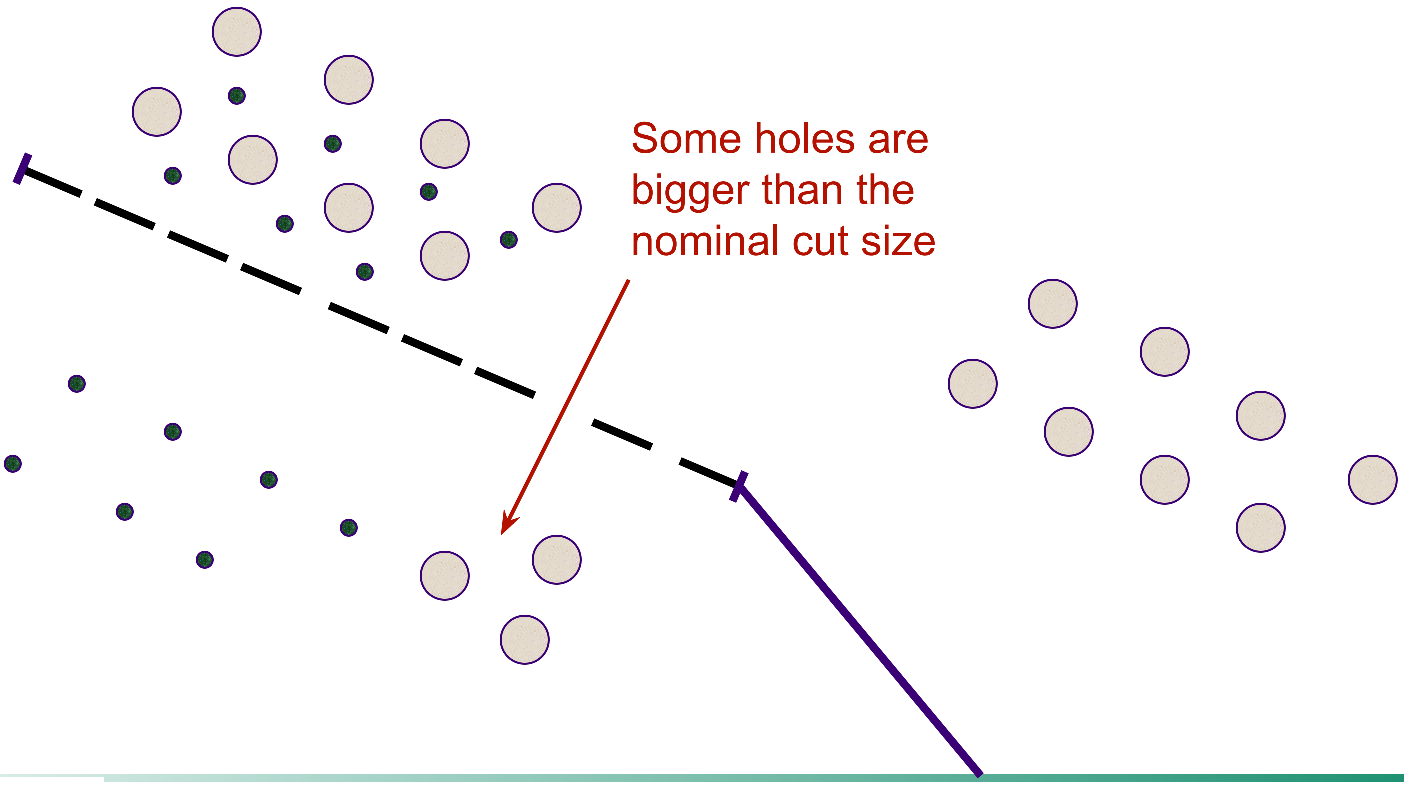
Imperfection

- **How can we find some coarse particles in the fines?:**



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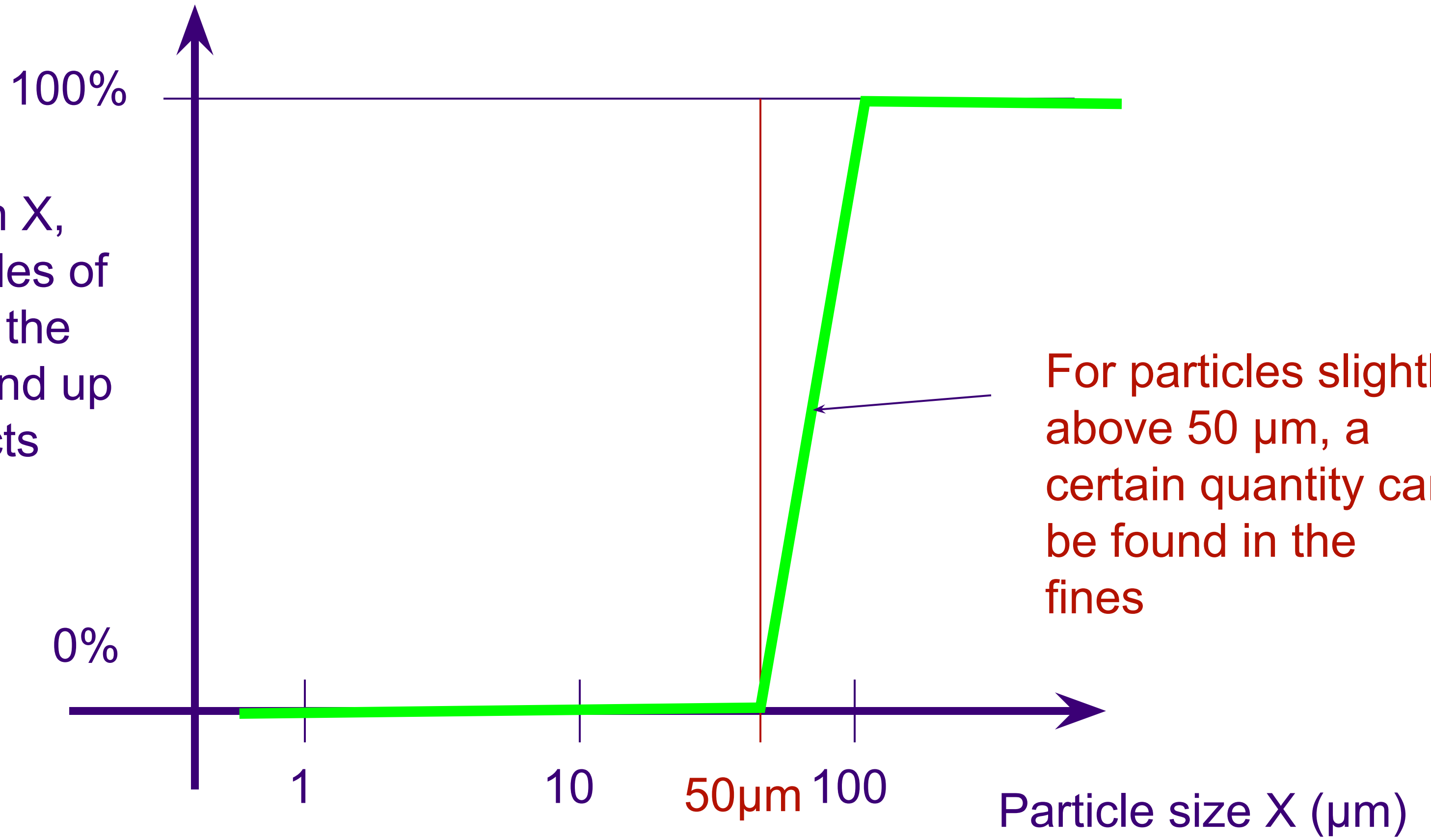
Tromp curve – With imperfection

For a given X,
% of particles of this size in the feed that end up in the rejects



For particles slightly above 50 µm, a certain quantity can be found in the fines

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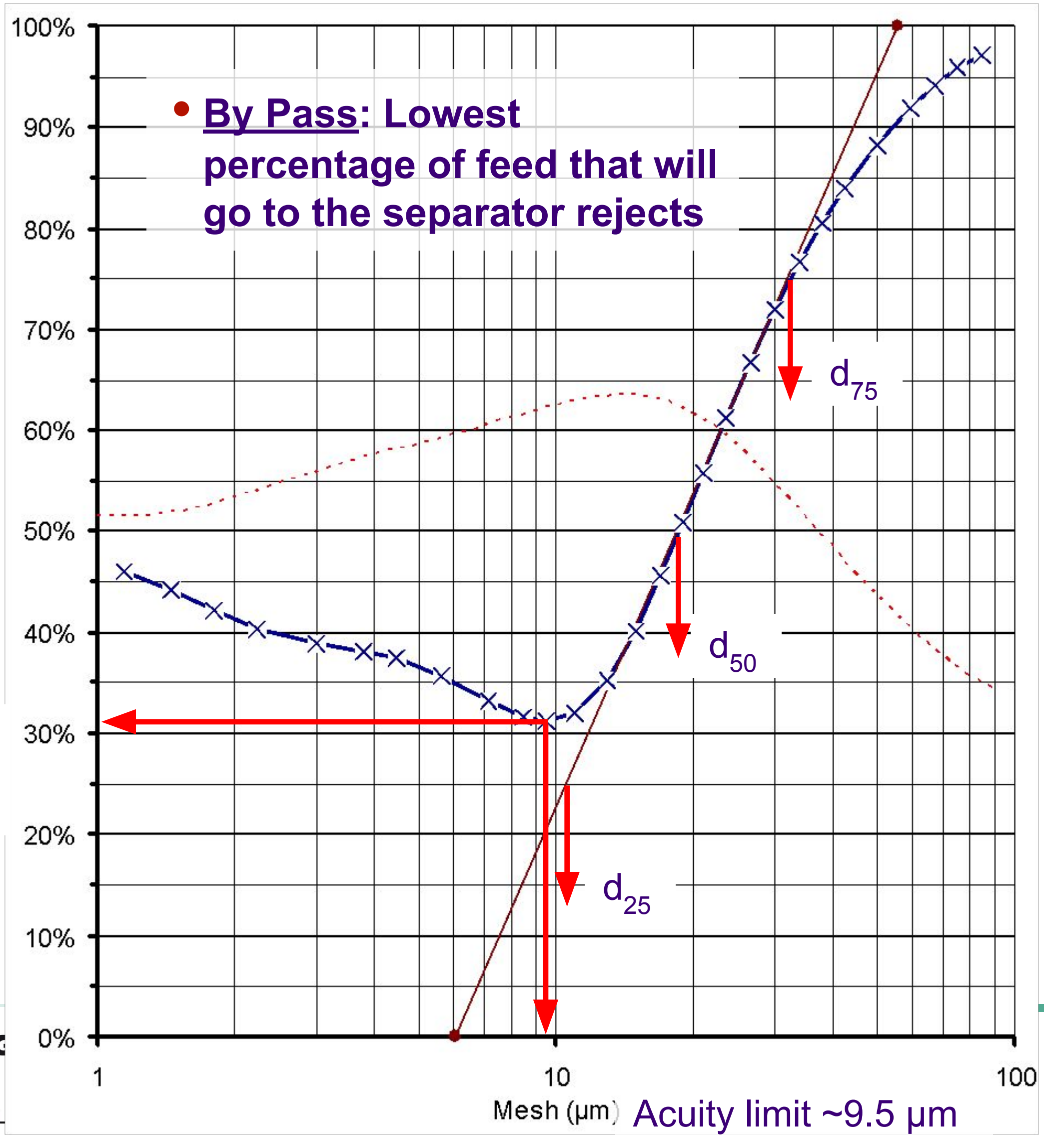
Tromp curve – General case



- **By Pass: Lowest percentage of feed that will go to the separator rejects**

By pass

31 %

Acuity limit ~9.5 µm

- **Acuity limit: Size at which selection is initiated. Below, the separator cannot distinguish between sizes**
- **Imperfection: Number characterizing the slope of the selection line =>**

  $I = (d_{75}-d_{25})/(2xd_{50})$

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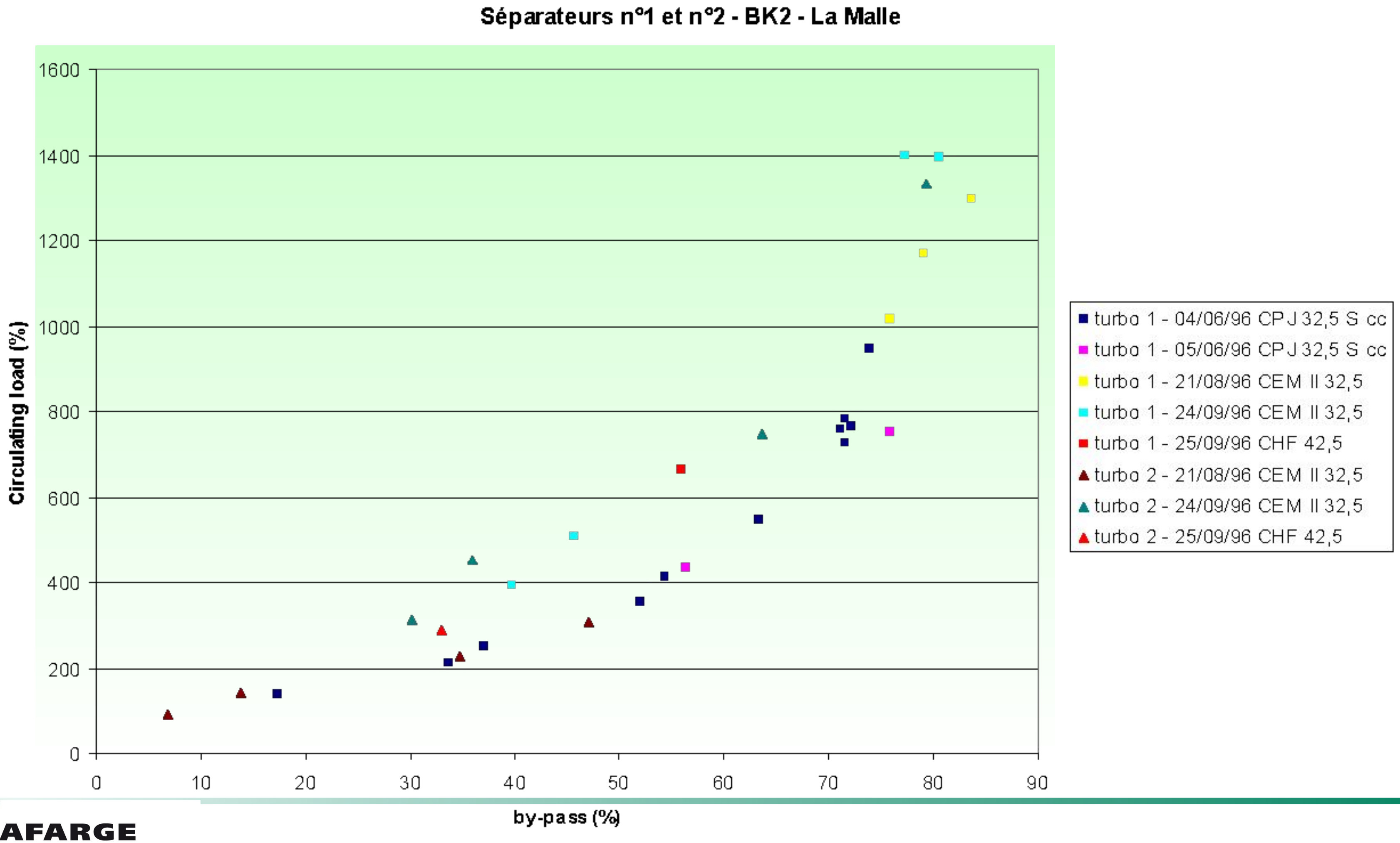
Tromp curve - Interpretation

- **By-pass**
  - Should be as low as possible
  - Directly linked to separator efficiency:
    - Fines sent back to the mill will be ground further
  - Impact of circulating load

- **Typical values:**
  - 1G 20 – 50%
  - 2G 10 – 35%
  - 3G 0 – 10%

Variation of the By Pass vs CL



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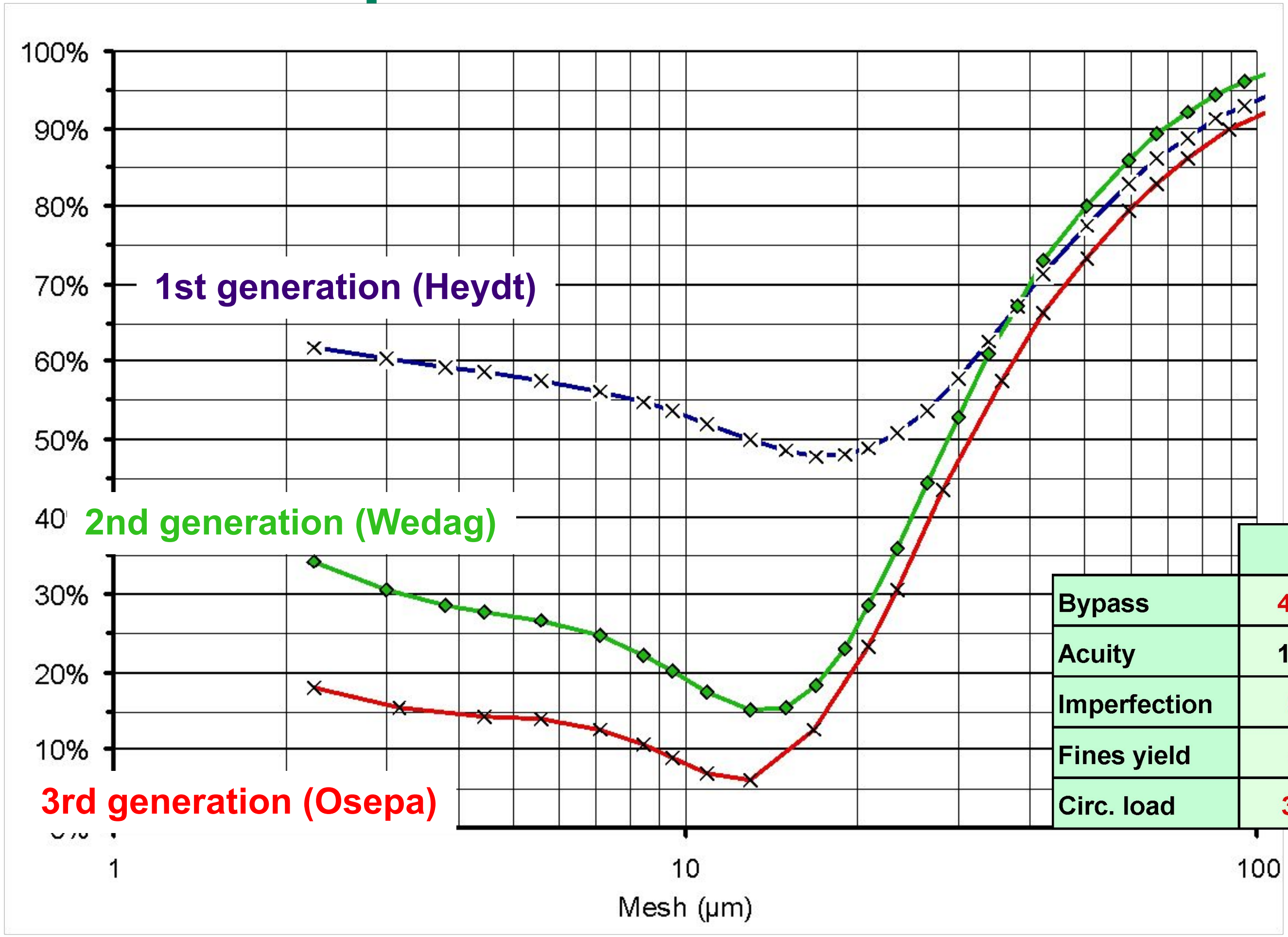
Tromp curve - Interpretation

- **Acuity limit**
  - Mainly depends on the fineness of final product
- **Imperfection**
  - Should be as low as possible
  - When high, presence of very coarse particles in the final product (for the same global fineness)

Tromp curve



	1G	2G	3G
Bypass	47,9%	15,1%	6,3%
Acuity	17 µm	13,0 µm	13,0 µm
Imperfection	0,71	0,40	0,45
Fines yield	44%	74%	86%
Circ. load	366%	238%	168%

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Typical values
Tromp curve

Parameter:	1st generation	2nd generation	3rd generation
Bypass	20 to 50 %	10 to 35 %	0 to 10 %
Acuity	17 to 36 µm	14 to 24 µm	15 µm
Imperfection	0.40 to 0.85	0.30 to 0.60	0.30
Circ. Load	200 to 350 %	100 to 250 %	100 to 250 %

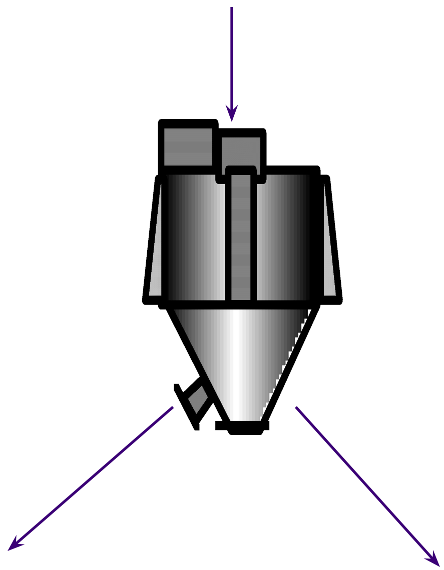
Building a Tromp curve

- **Mass balance**
  - Knowledge of a physical property of 3 flows gives access to R/A ratio
- **Let's apply to powders, using laser PSD**

Tromp curve: notations

Separator Feed

A = feed flow (t/h)
ax = % of feed in the « x » size class



x denotes any size class (between 2 consecutive sieve values x_i and x_{i+1})

Rejects

Fines

R = rejects flow (t/h)
rx = % of rejects in the « x » class

F = fines flow (t/h)
fx = % of fines in the « x » class

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Tromp curves – R/A calculation

- **Global mass balance:**

$$A = R + F \quad (1)$$

inlet flow to the separator equals the outlet flow

- **Partial mass balance for size “x”:**

$$A \times a_x = R \times r_x + F \times f_x \quad (2)$$

there is no grinding occurring in the separator

- **(1) & (2) =>**

$$\frac{R}{A}(x) = \frac{f_x - a_x}{f_x - r_x}$$

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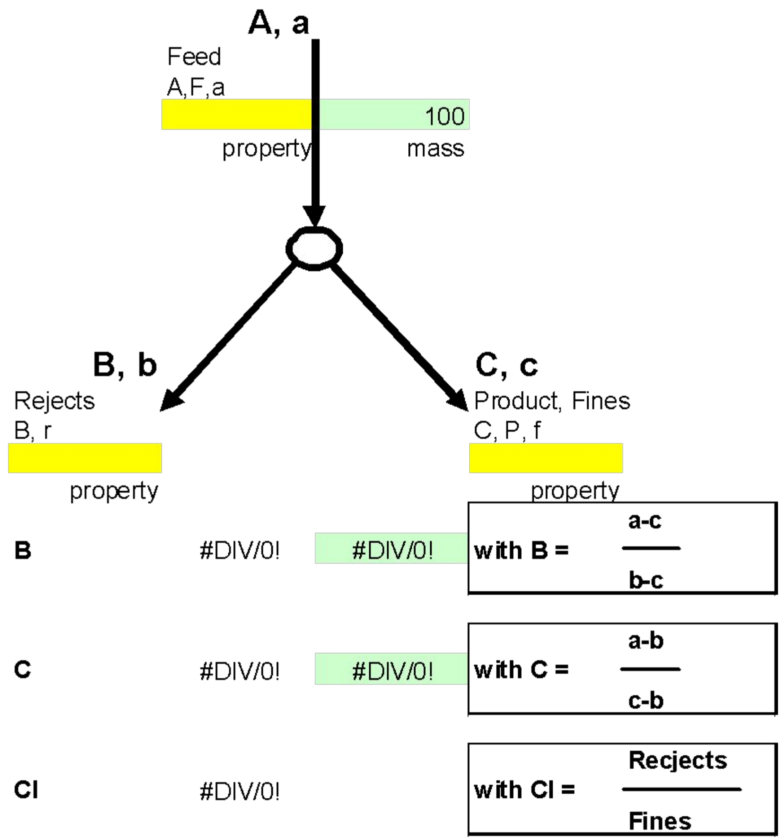
3 point junction (ABC formula)

Example:
- •Feed 3000 Blaine
- •Rejects 2000 Blaine
- •Product 3800 Blaine

•Question:
- •% rejects
- •% fines
- •CL



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3 point junction (ABC formula)

Example:

- Feed 3000 Blaine
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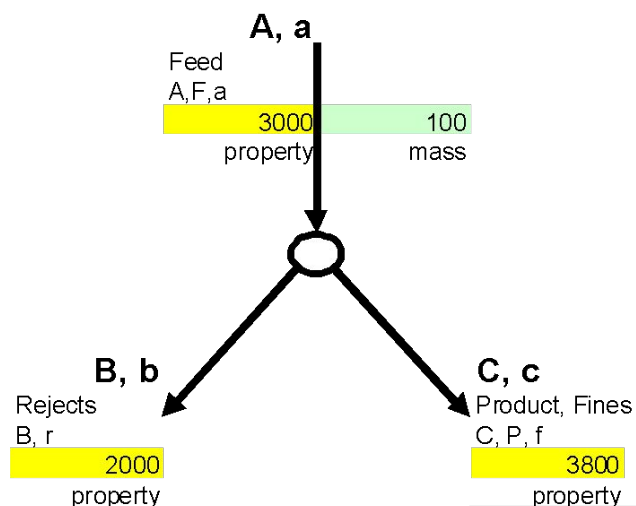
3 point junction (ABC formula)



B	0,44444444	44	**with B =** $\frac{a-c}{b-c}$
C	0,55555556	56	**with C =** $\frac{a-b}{c-b}$
CI	0,8		**with CI =** $\frac{\text{Recjects}}{\text{Fines}}$

Tromp curves – R/A calculation

$$\frac{R}{A}(x) = \frac{f_x - a_x}{f_x - r_x}$$

- **Interpretation:**
  - Using the laser PSD for separator feed, rejects and fines, we can calculate, for each size class « x », an estimate of the ratio R/A
  - NB: for different classes x, the predicted R/A may vary (due to the precision of sampling and PSD analysis)

- **The same formula can be used with other physical properties:**
  - Cumulative passing/residues at a certain sieve
  - Blaine fineness
  - …

Tromp curves – average R/A

- From all the values of R/A calculated before (one for each size class x), we use the best fit method to estimate the average R/A:

$$\left(\frac{R}{A}\right)_{average} = \frac{\sum (f_x - a_x) \times (f_x - r_x)}{\sum (f_x - r_x)^2}$$

- For the rest of the discussion, we consider that it is the « true » value, and will call it R/A

Tromp curves – final calculation

- From equations (1) and (2):

$$A = R + F \quad \text{and} \quad A \times a_x = R \times r_x + F \times f_x$$

we can calculate the value Px = proportion of material of size "x" ending up in the rejects:

- $Px = (R \times r_x) / (A \times a_x)$
- Finally:

$$Px = \frac{\frac{R}{A} \times r_x}{\frac{R}{A} \times r_x + \left(1 - \frac{R}{A}\right) \times f_x}$$

- For the plot, we use the geometric mean of the class size: $X = \sqrt{X_i \times X_j}$

Tromp curves - How to build?

- Evaluate and interprete the tromp curve for a given laser analysis