Crushing
Principles of Mechanical Crushing

QUARRY ACADEMY

Improving Processes. Instilling Expertise.

DYNO Dyno Nobel

SANDVIK

QUARRY ACADEMY

Objective

Explain the interaction between

rock material

and

crusher

Take home messages

The Take Home Messages will address:

- Trouble Shooting
- Improve Yield
- Improve Performance

QUARRY ACADEMY

Agenda

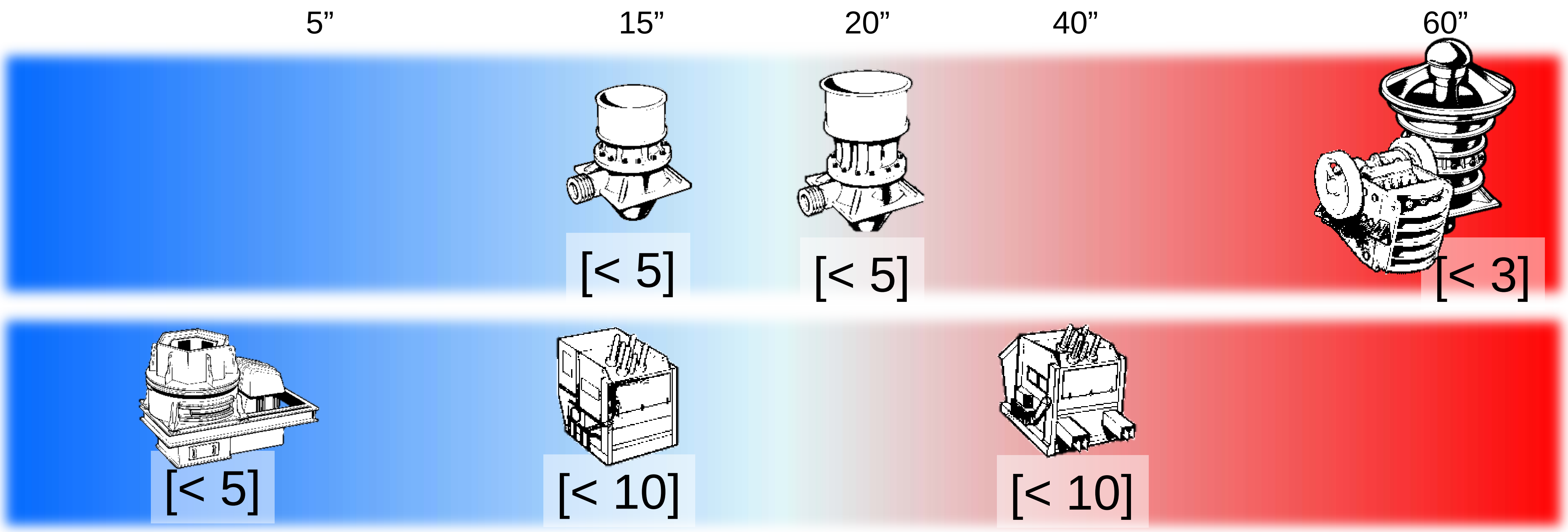
- Crusher Application
- Cone Crusher Operating Principle
- Crusher Capacity
- Crusher Operation
- Optimization and Crusher Performance Map
- Conclusions

NCC, Borås, Sweden

QUARRY ACADEMY

Crusher Selection

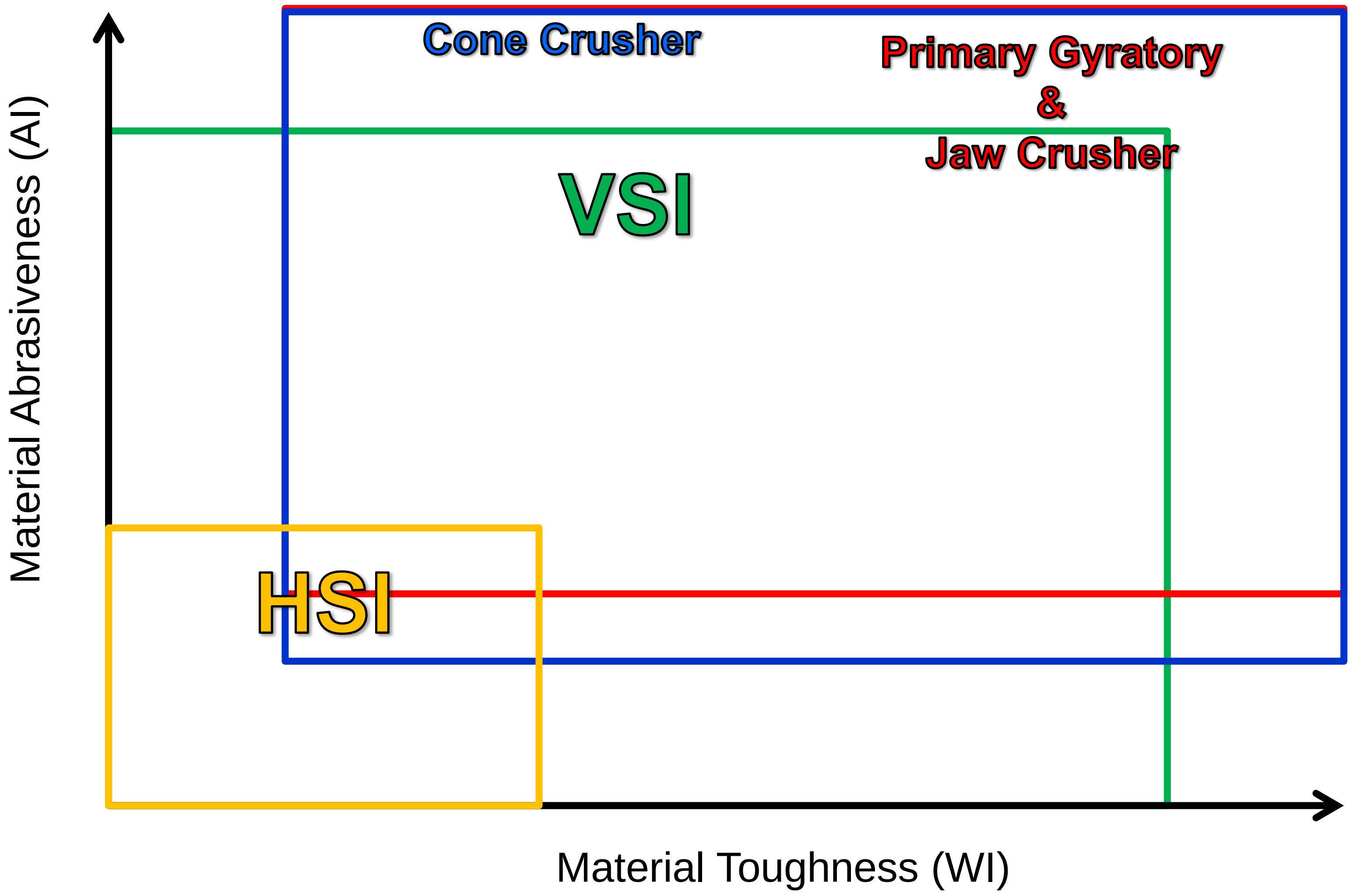
Feed size



[Reduction Ratio]

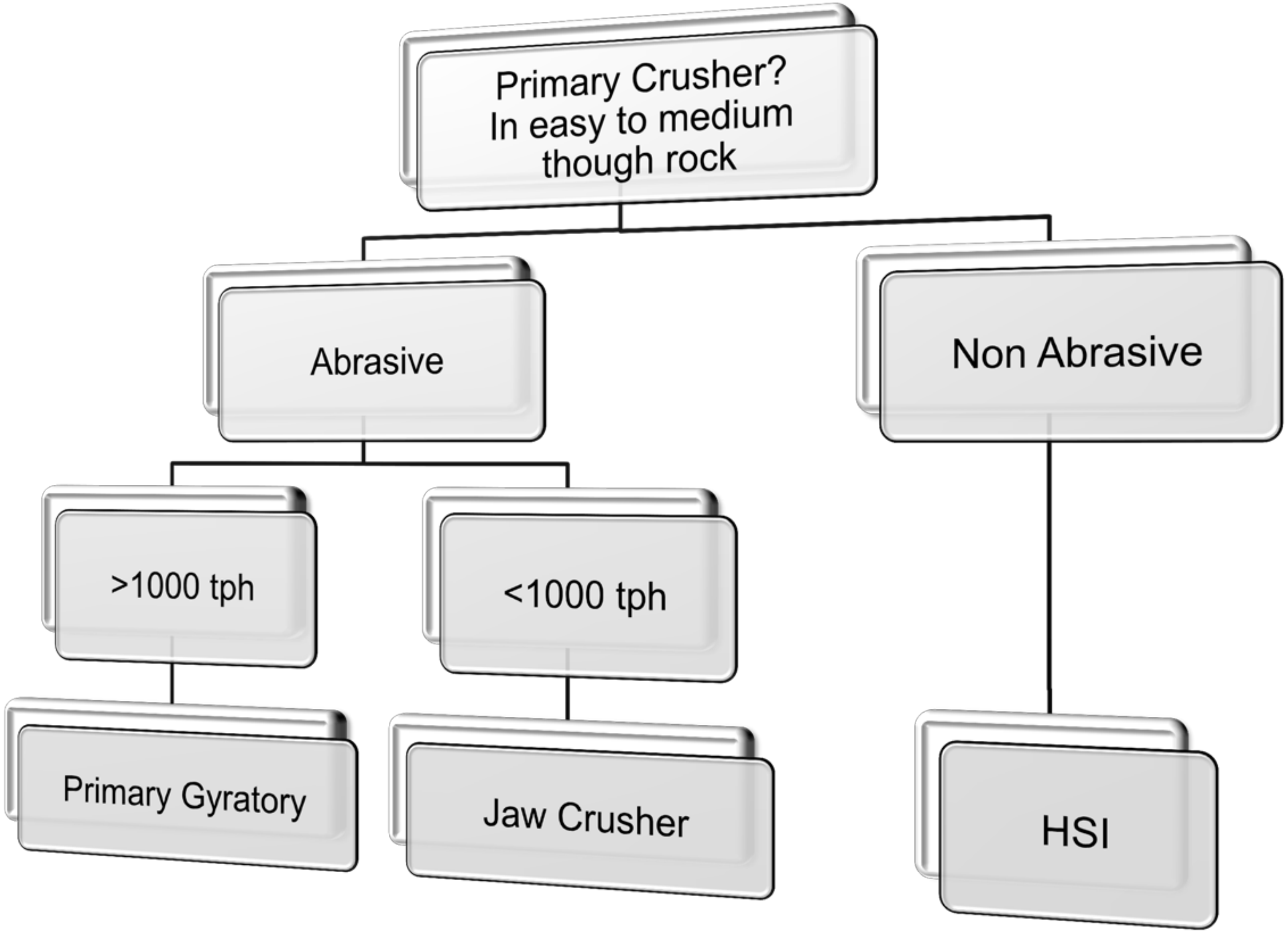
QUARRY ACADEMY

Crusher Selection



QUARRY ACADEMY

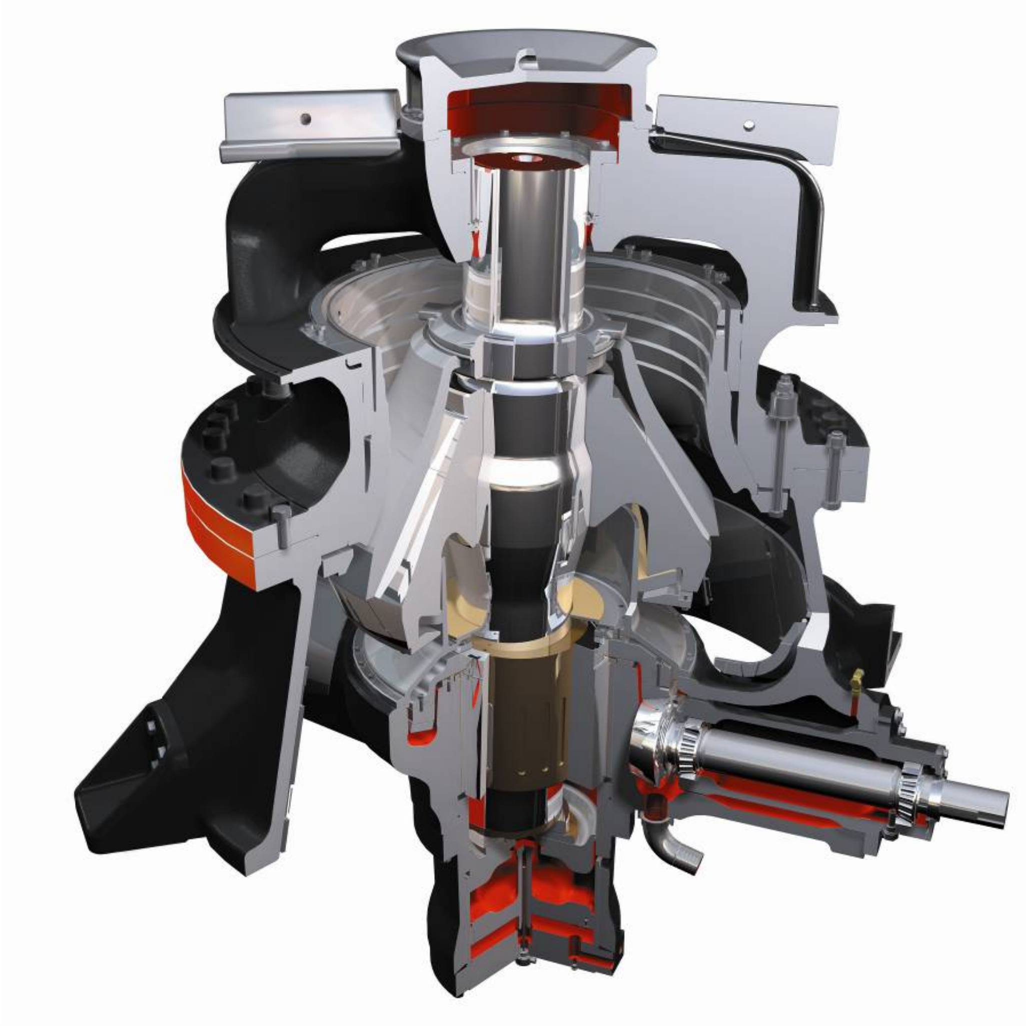
Crusher Selection



QUARRY
ACADEMY

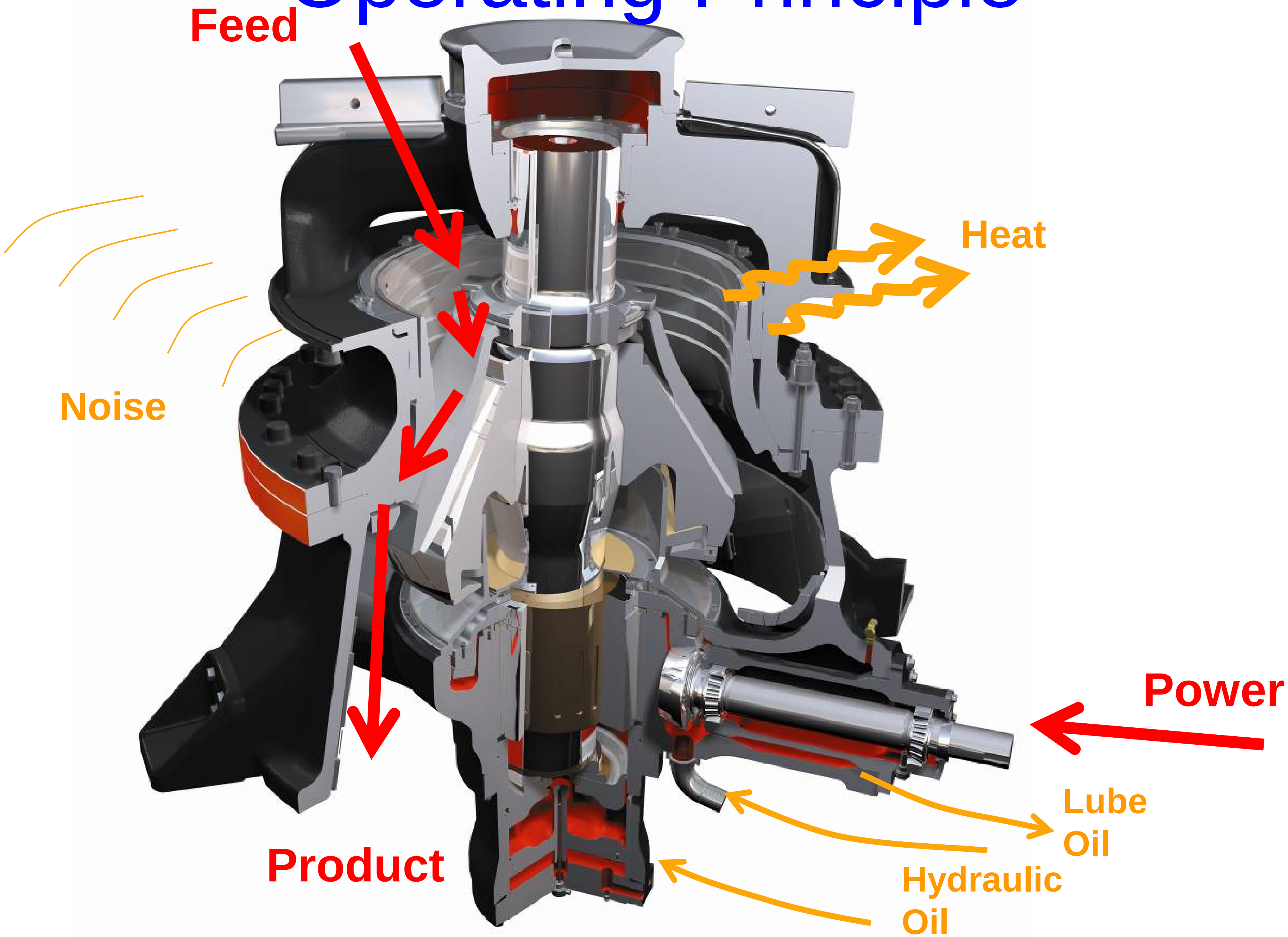
Cone Crusher

- Why Cone Crusher?
- The cone crusher design concept is an effective and smart way of realizing compressive crushing
- Aggregate Production
- Mechanical Liberation of Valuable Minerals



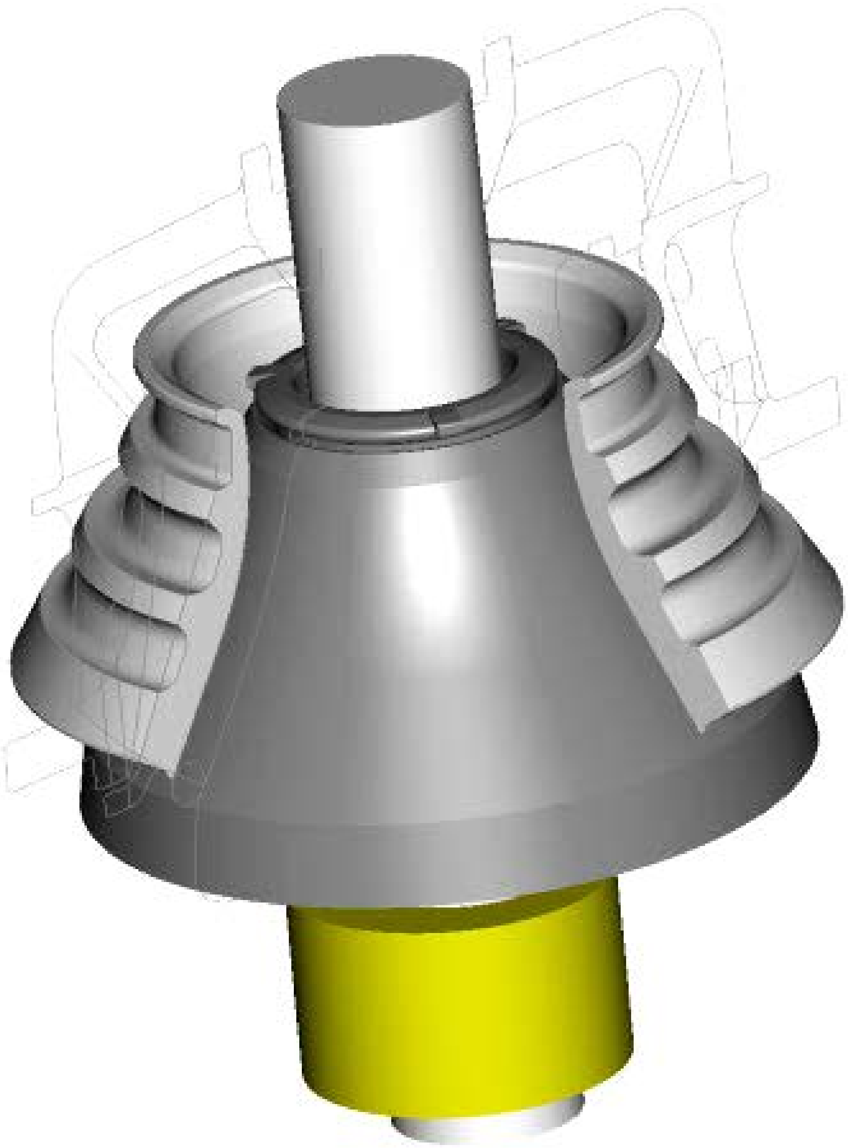
QUARRY ACADEMY

Operating Principle

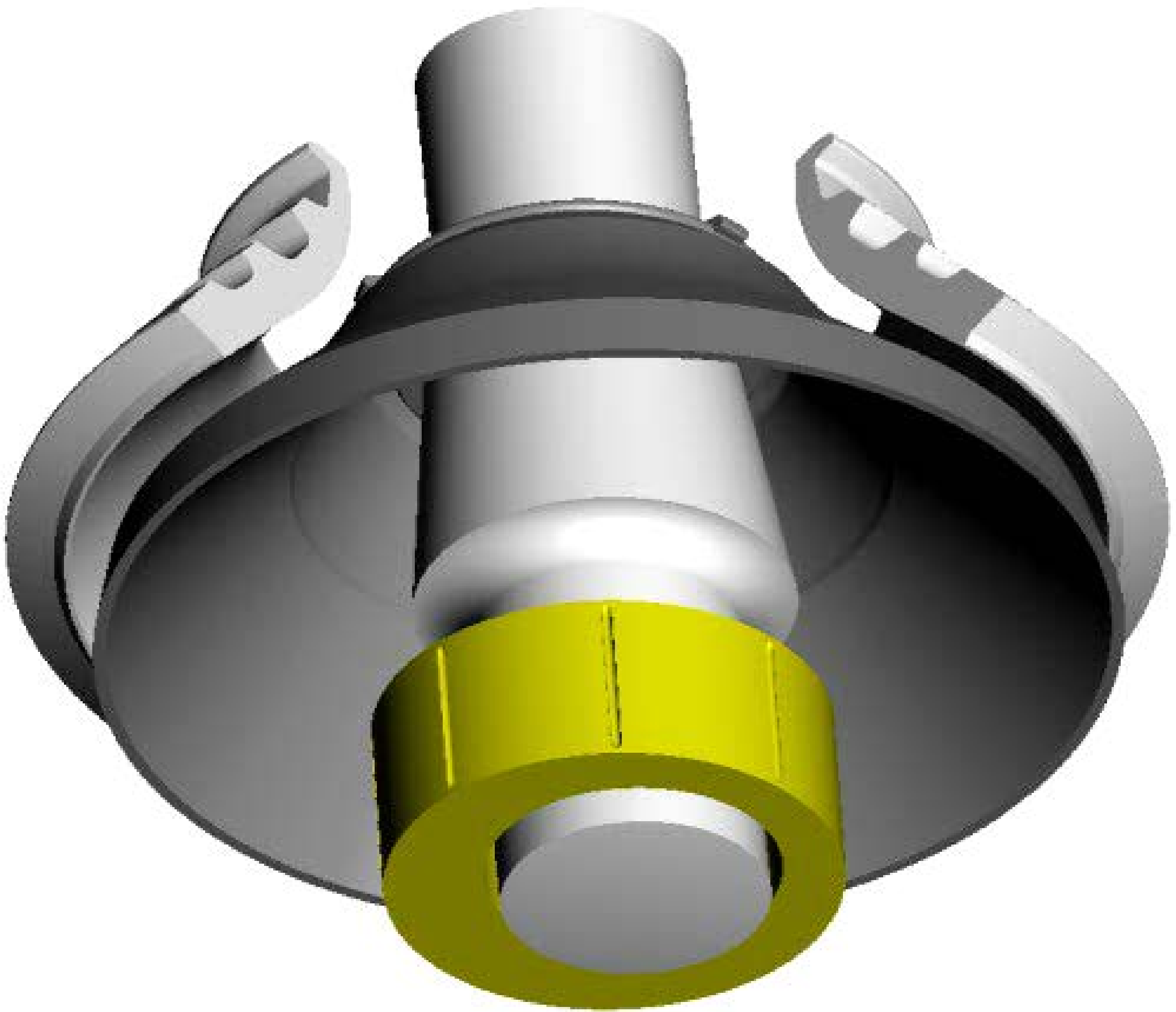


QUARRY
ACADEMY

Operating Principle

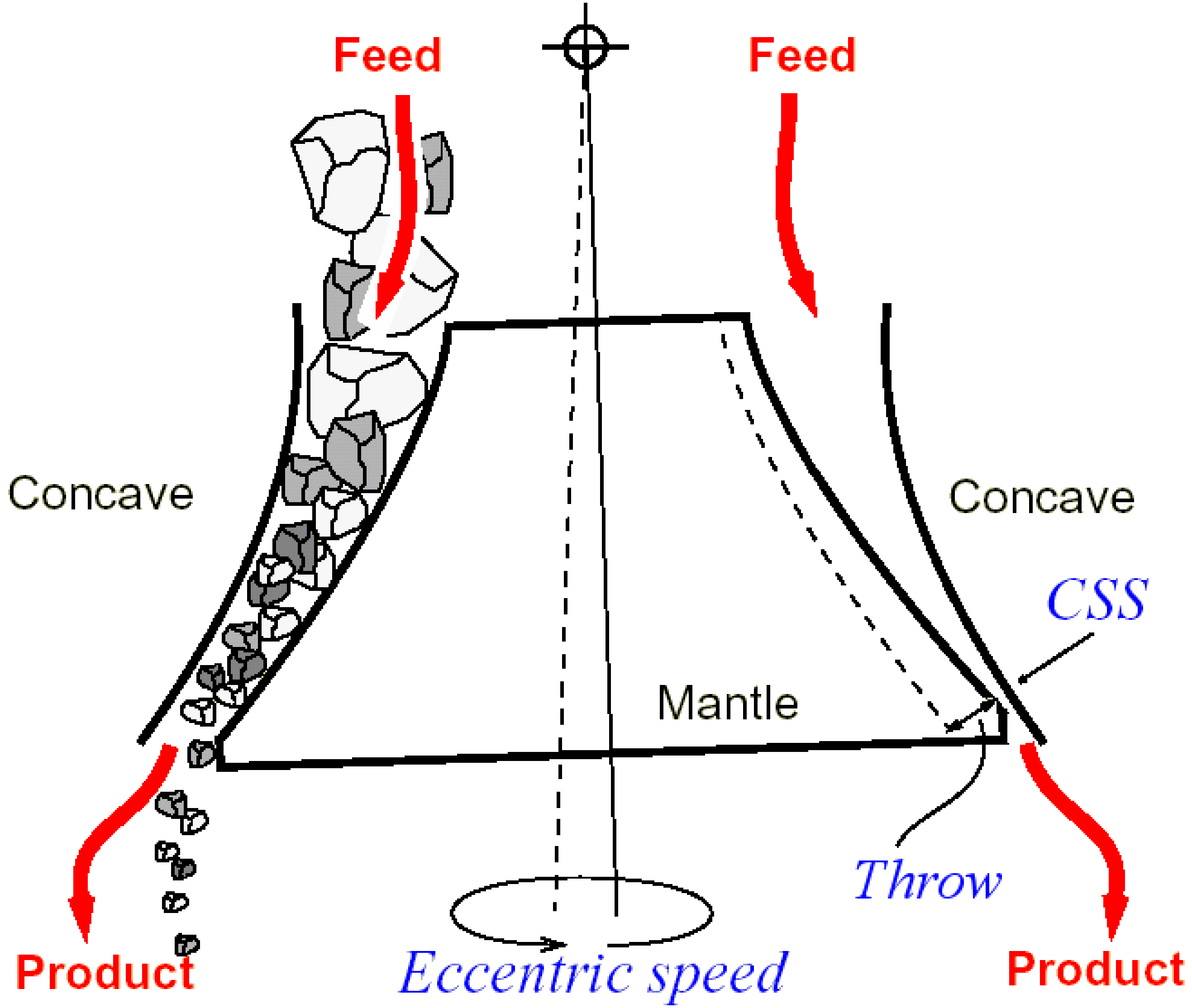


Operating Principle



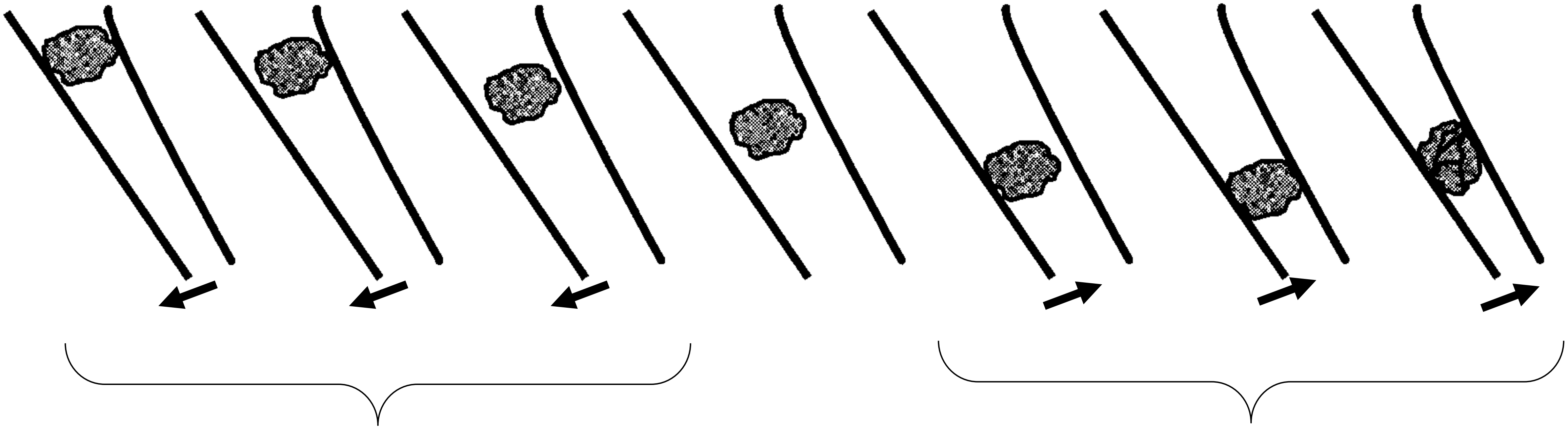
QUARRY ACADEMY

Operating Principle



OSS=CSS+Throw

Operating Principle

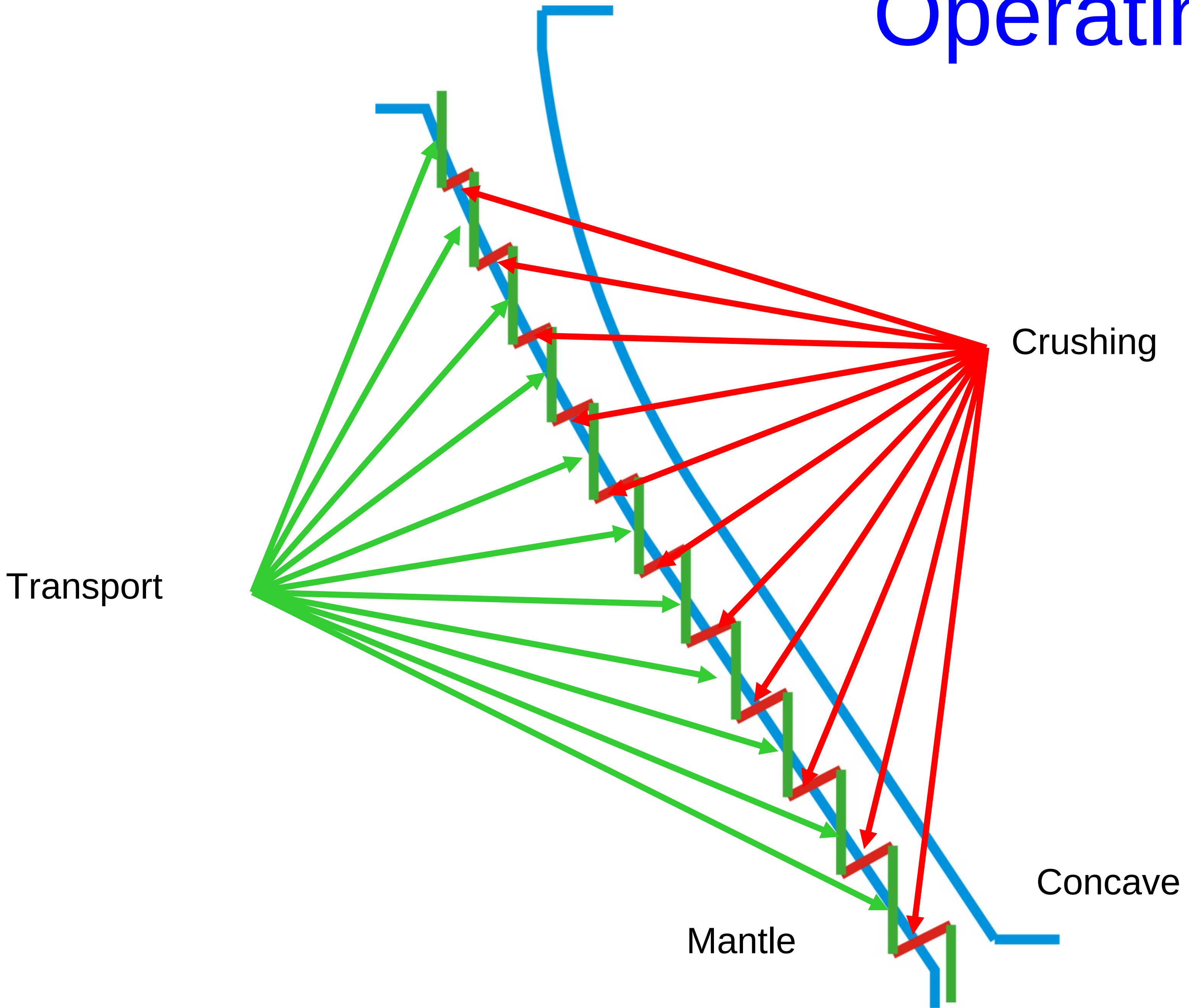


Opening Phase = Transport

Closing Phase = Crushing

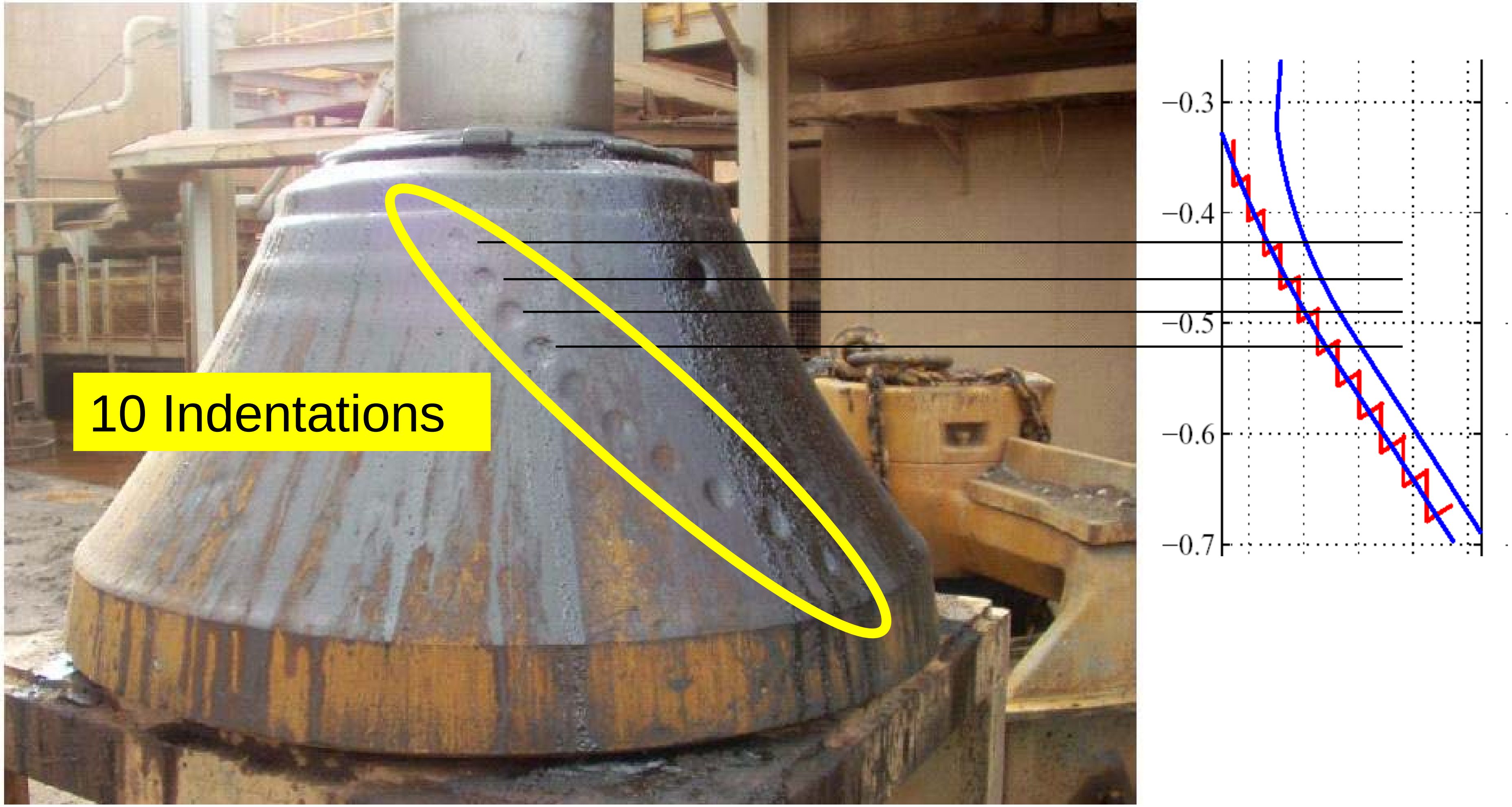
QUARRY ACADEMY

Operating Principle



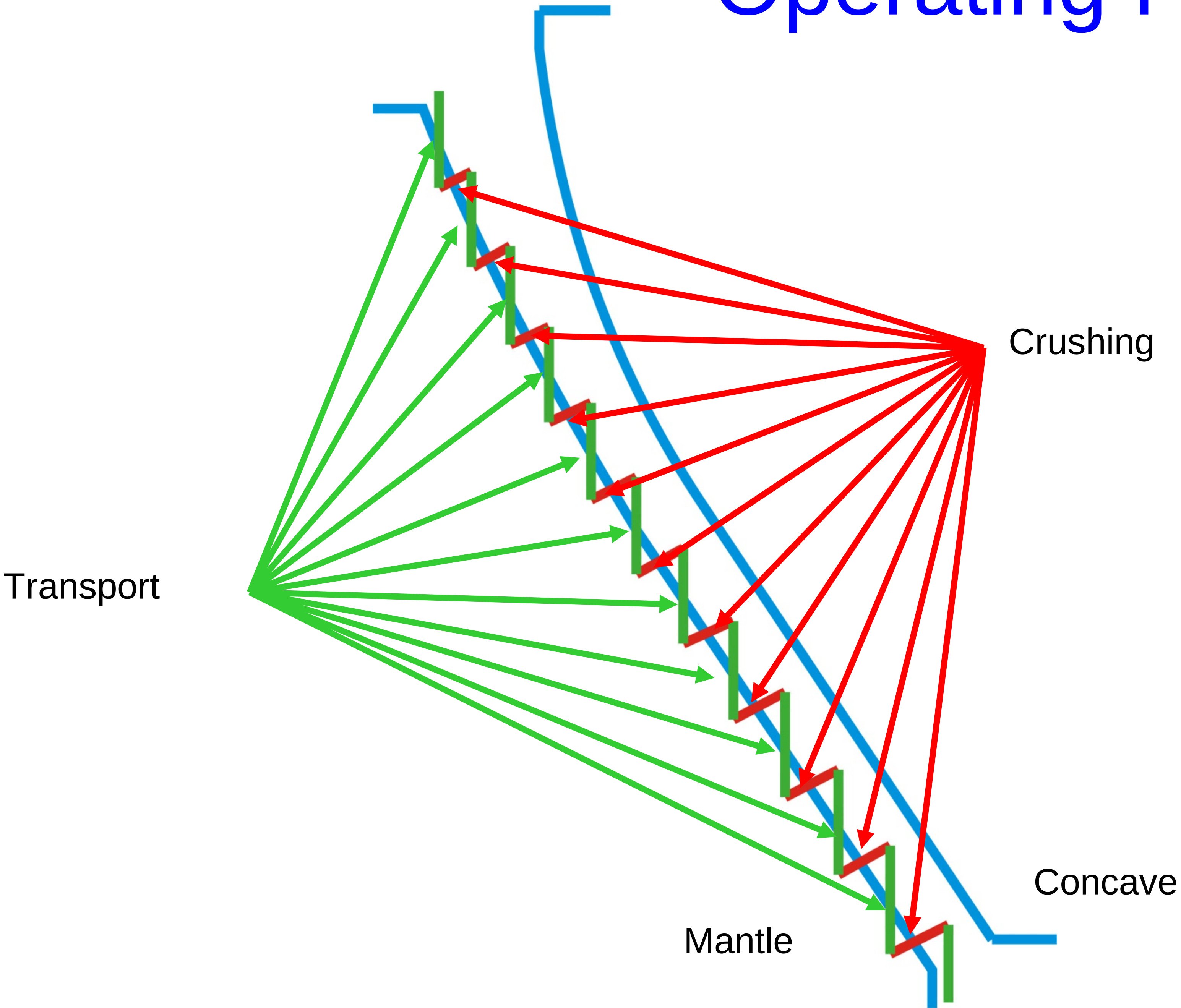
QUARRY ACADEMY

Operating Principle

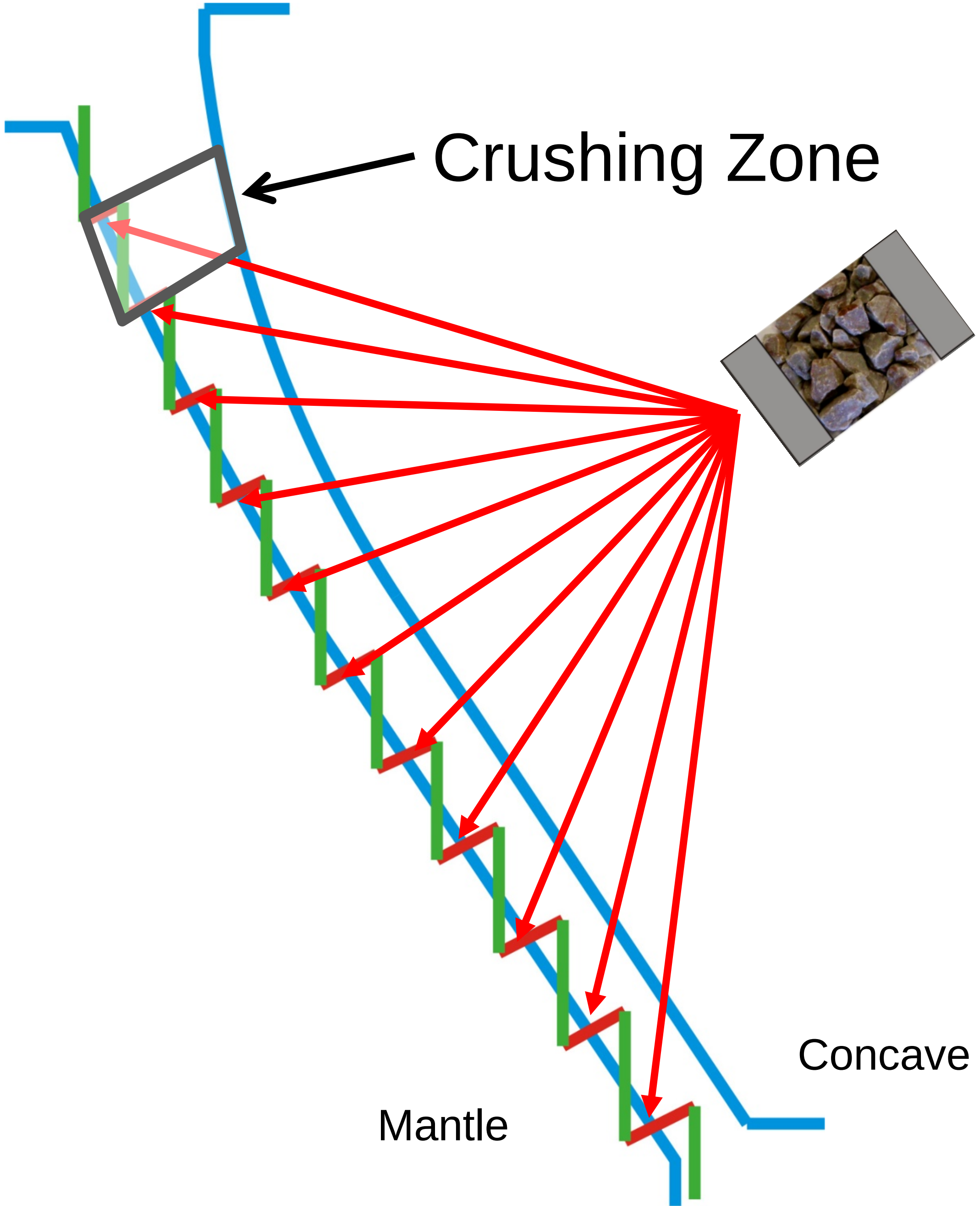


QUARRY ACADEMY

Operating Principle



Operating Principle



Single Particle Breakage SPB

Inter Particle Breakage IPB

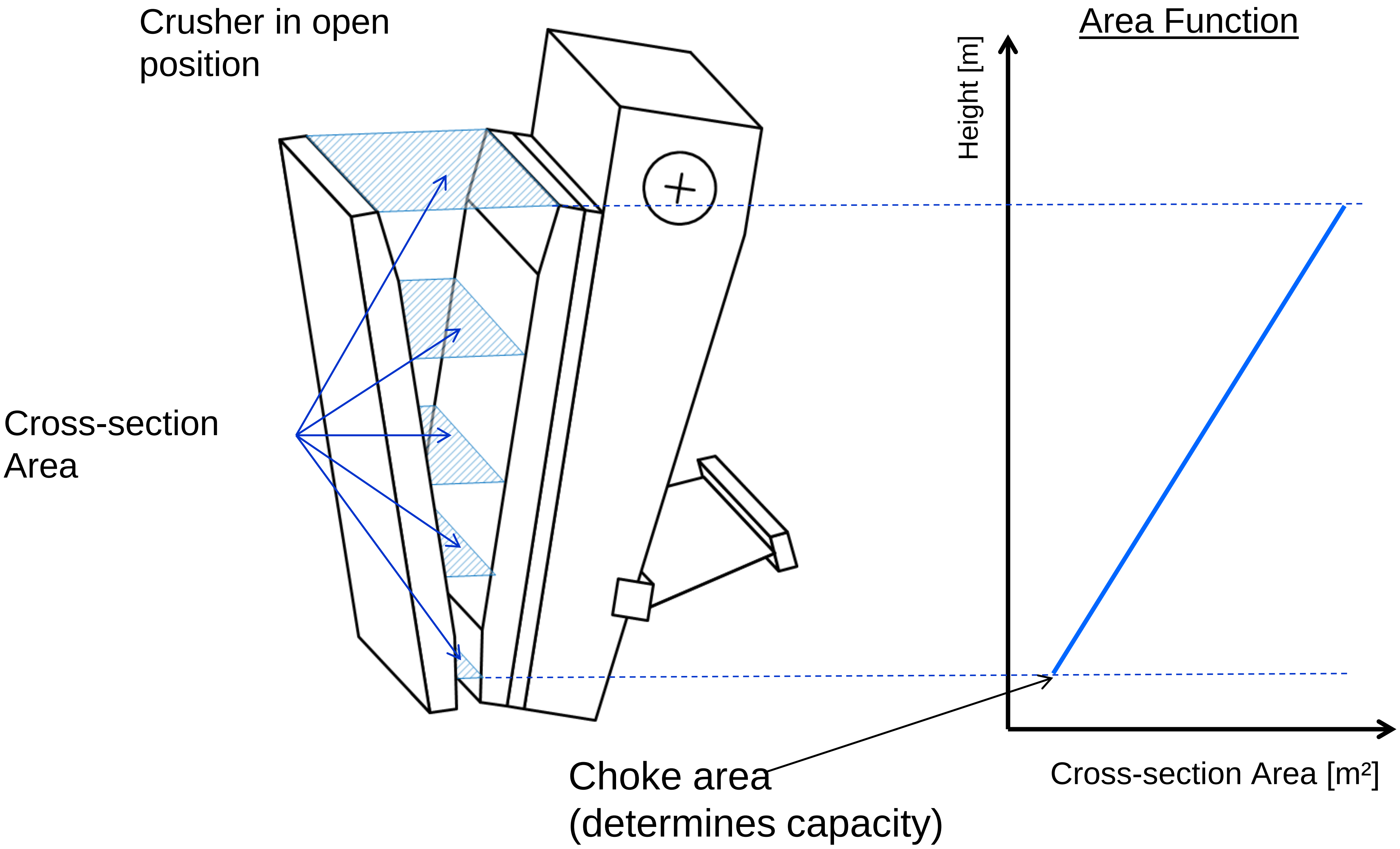
QUARRY ACADEMY

Operating Principal

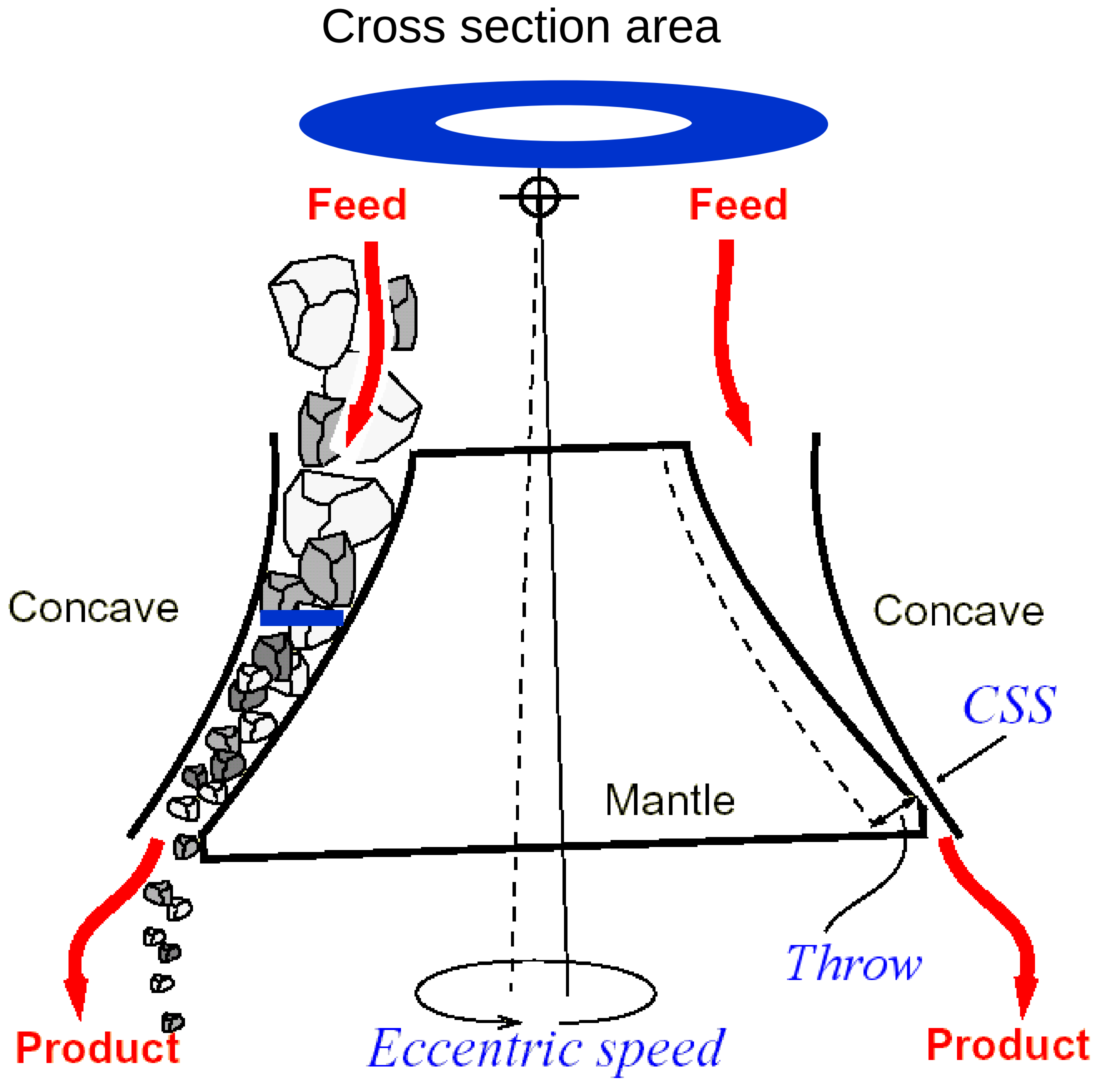
- In a cone crusher the stones are crushed with both SPB and IPB as the material moves down through the chamber.
- The relative amounts of IPB and SPB depends on factors like chamber design, crusher geometry, speed, css, eccentric throw, and others.

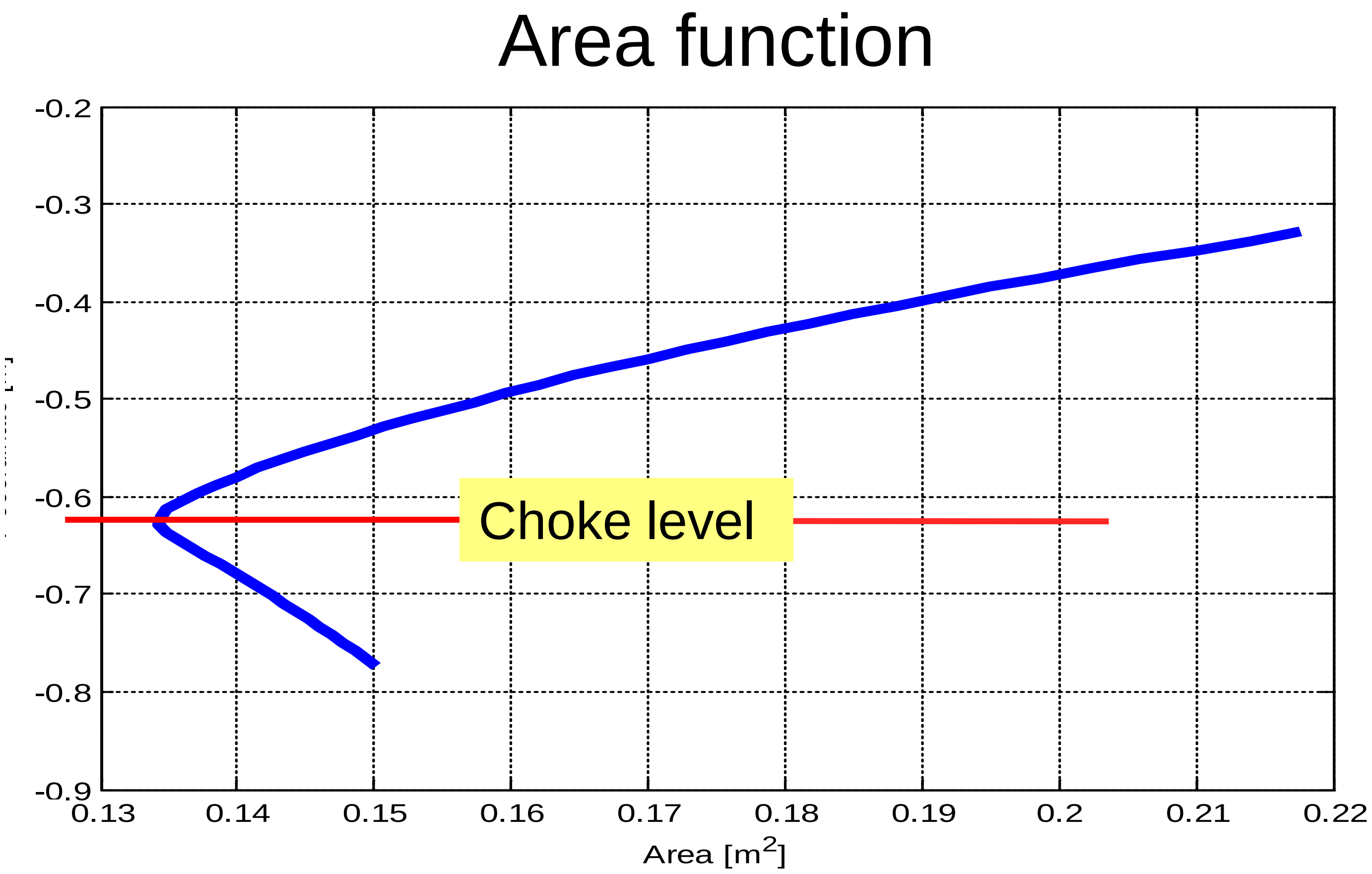
	SPB	IPB
Fines	Less	More
Shape	Flaky	Cubic
Force	Low	High

Crusher Capacity



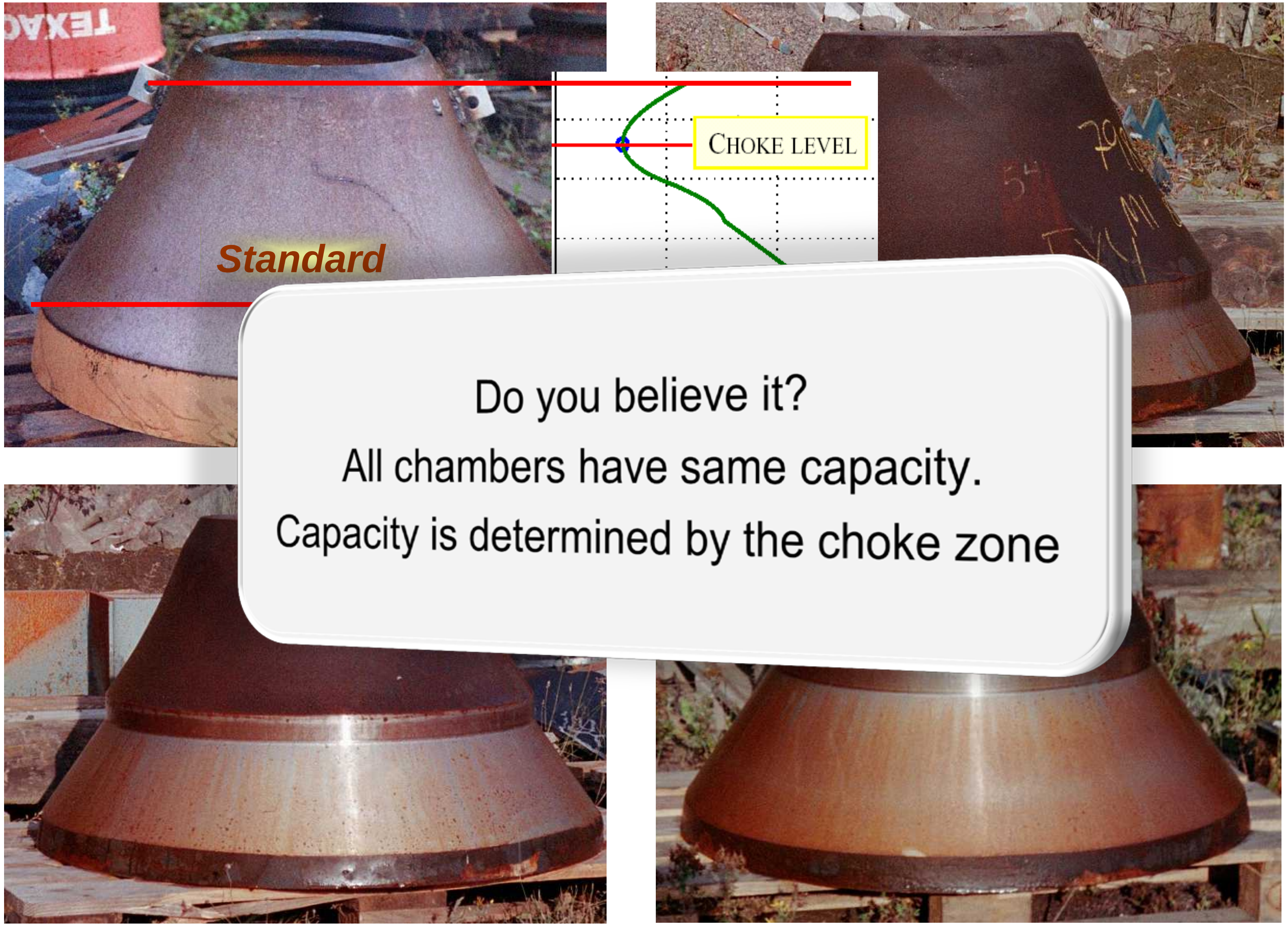
Crusher Capacity





QUARRY ACADEMY

Crusher Capacity



Do you believe it?

All chambers have same capacity.

Capacity is determined by the choke zone

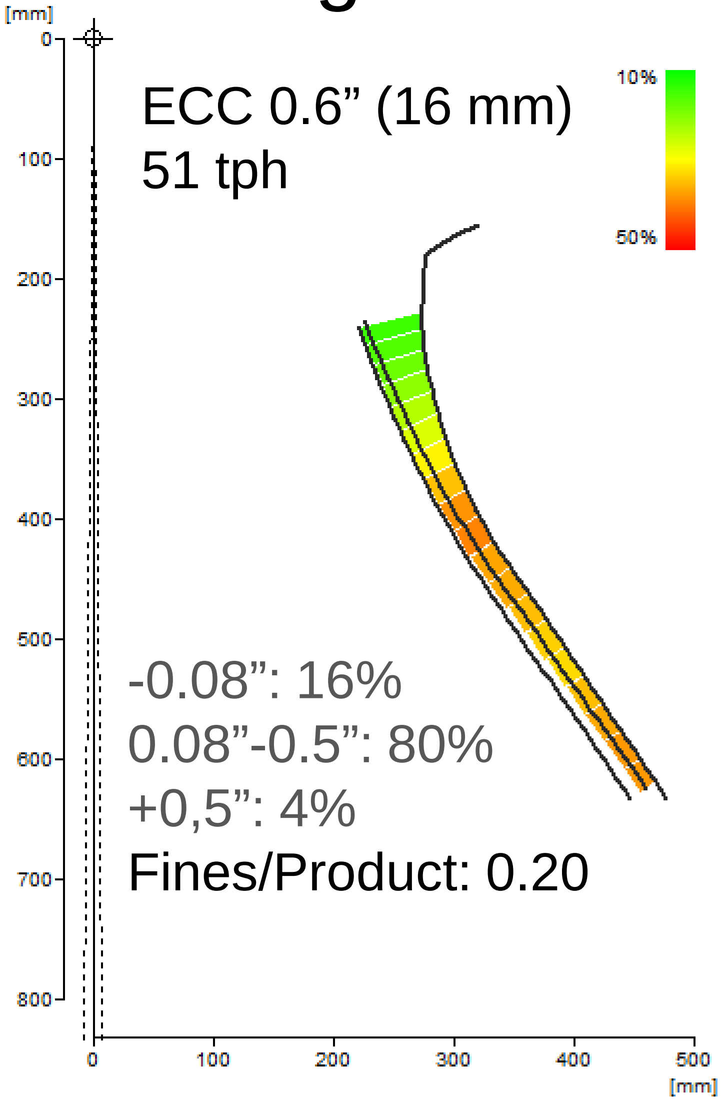
Crusher Operation

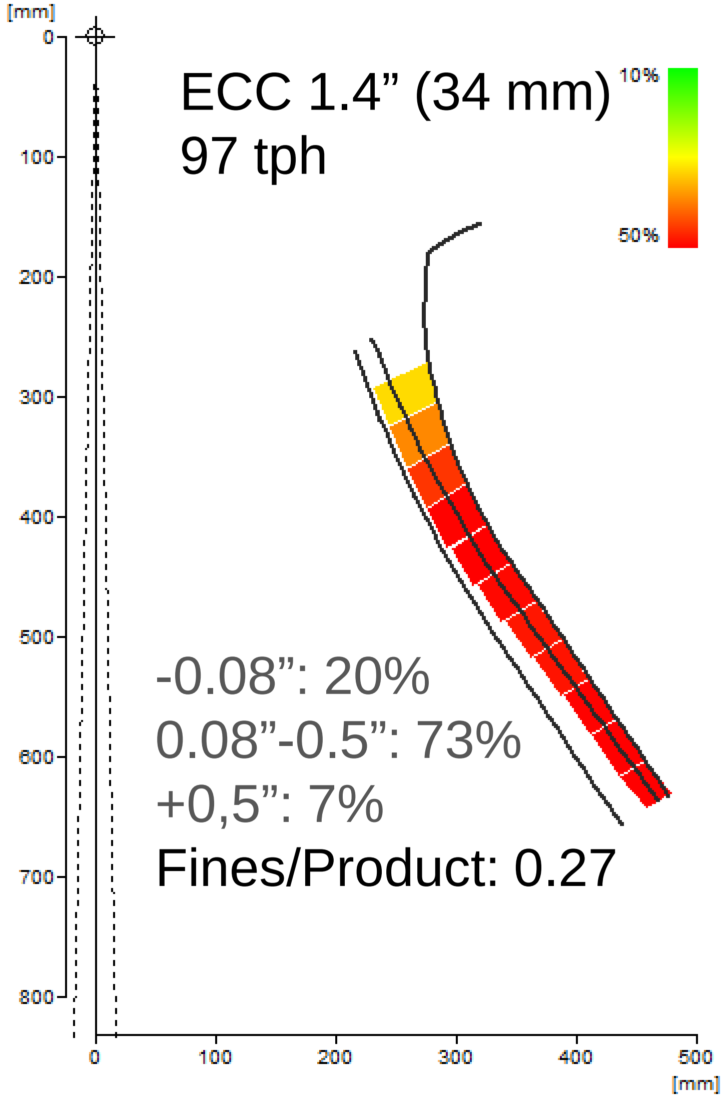
- As the market demand shifts can the crusher operation be modified?
- The crusher is likely to be installed for maximum production. Can it be changed to maximum efficiency?

- Understanding how breakage and capacity is effected by
  - Eccentric Throw
  - Speed
  - Closed Side Setting

Crusher Operation

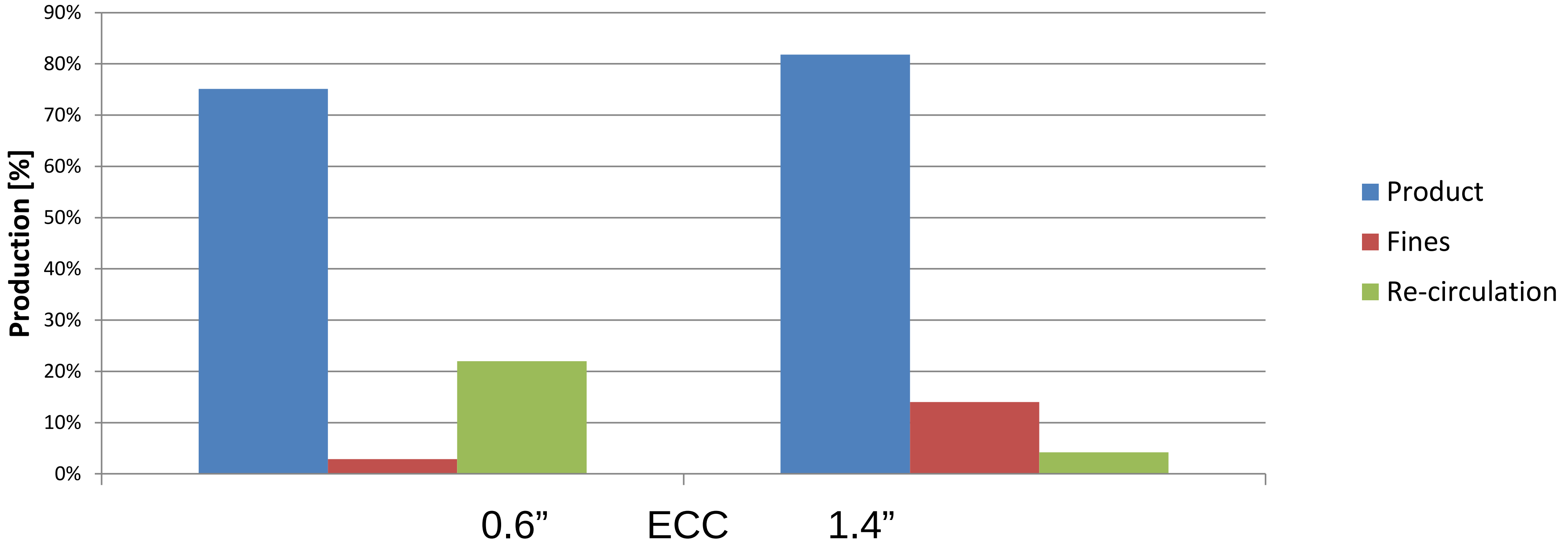
Running the crusher at different eccentric throws





Crusher Operation

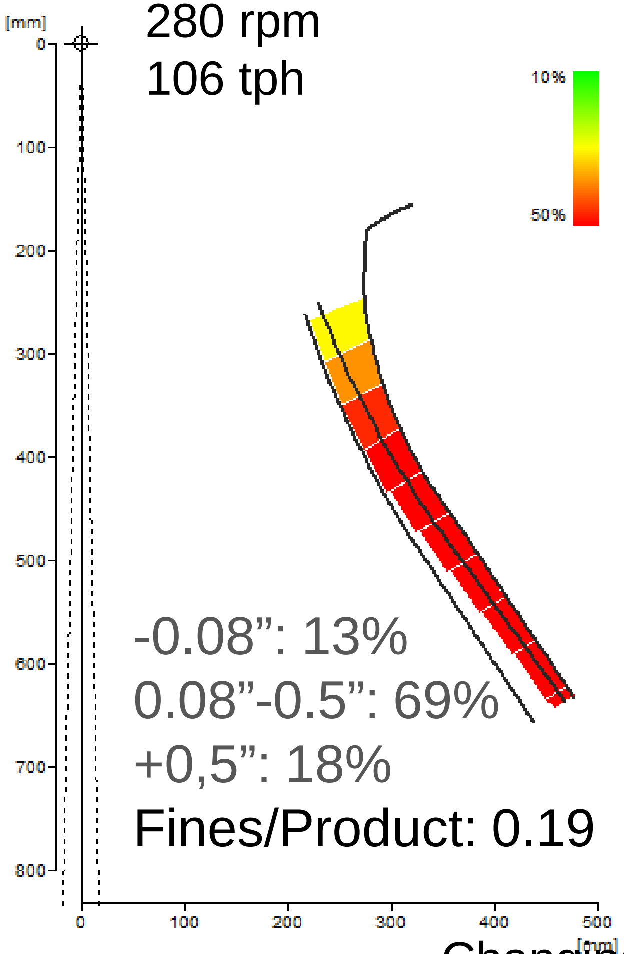
- Running the crusher at different eccentric throws, CSS optimized



Crusher Operation

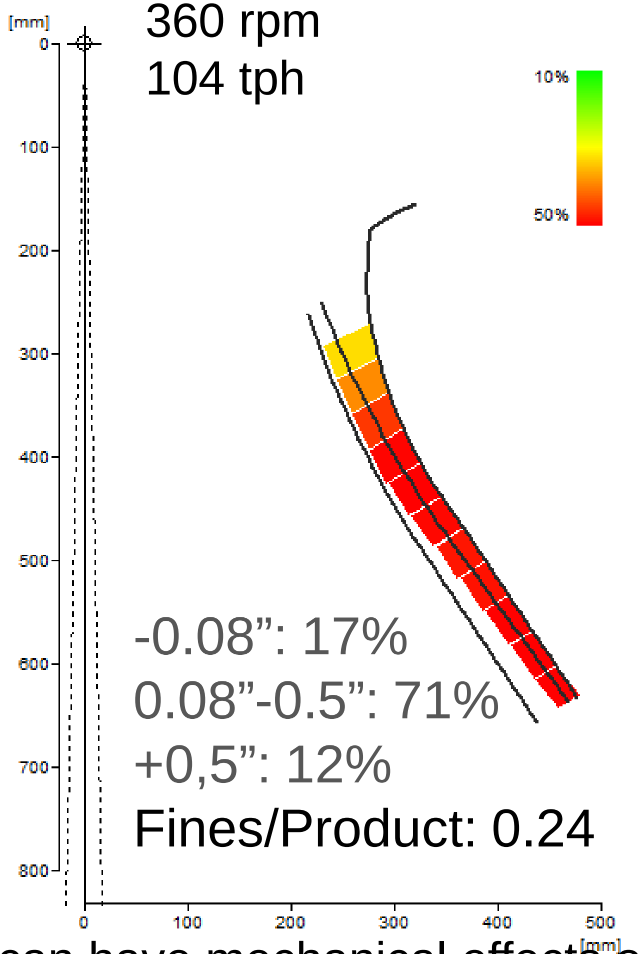
- Running the crusher at different speeds

280 rpm
106 tph



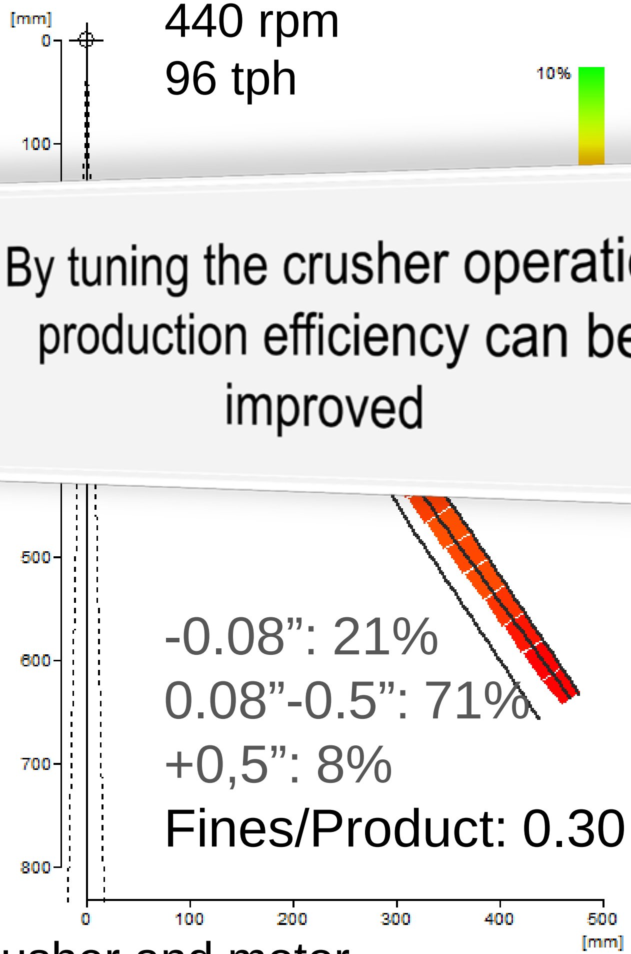
-0.08”: 13%
0.08”-0.5”: 69%
+0,5”: 18%
Fines/Product: 0.19

360 rpm
104 tph



-0.08”: 17%
0.08”-0.5”: 71%
+0,5”: 12%
Fines/Product: 0.24

440 rpm
96 tph



-0.08”: 21%
0.08”-0.5”: 71%
+0,5”: 8%
Fines/Product: 0.30

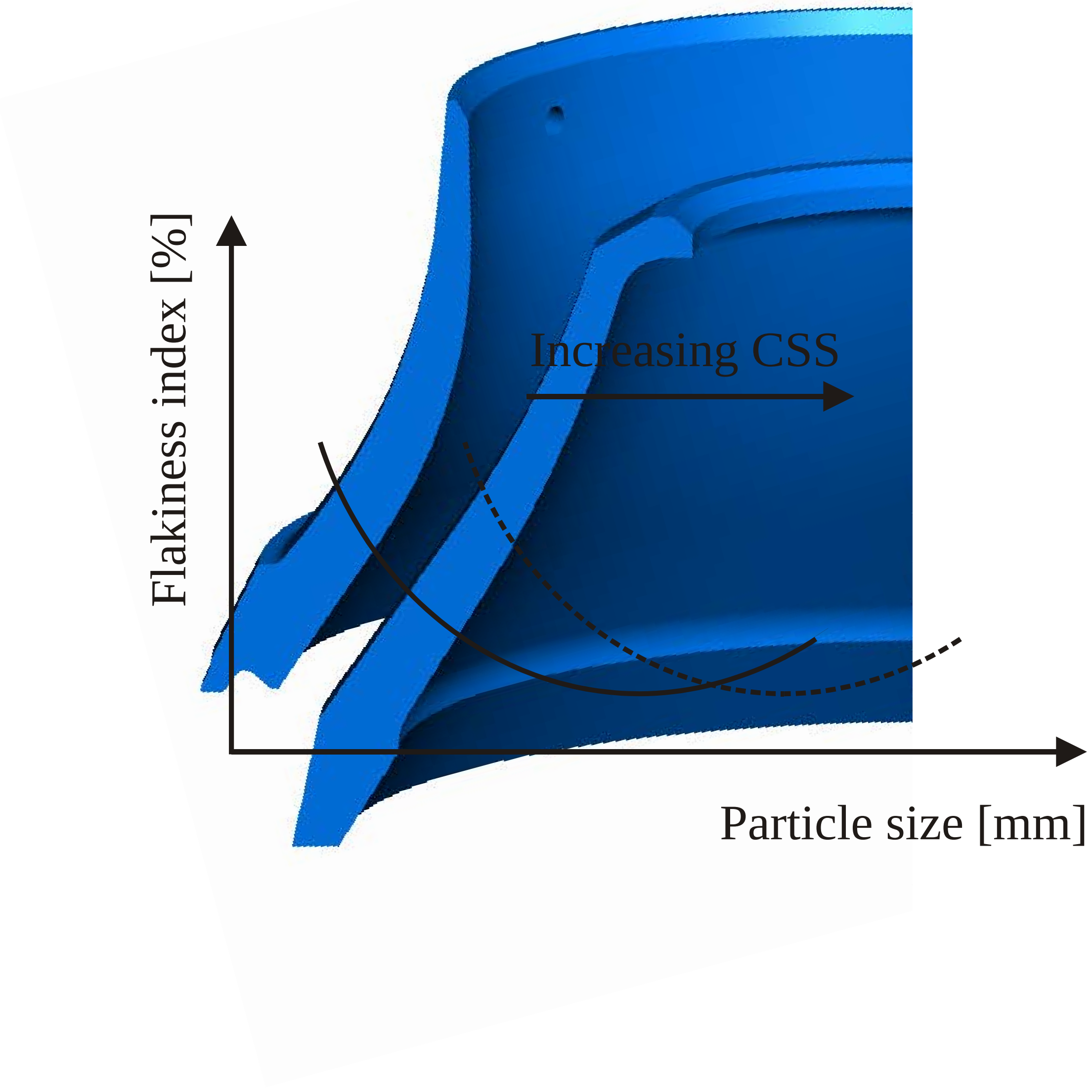
By tuning the crusher operation production efficiency can be improved

Changing speed can have mechanical effects on the crusher and motor

QUARRY ACADEMY

Crusher Operation

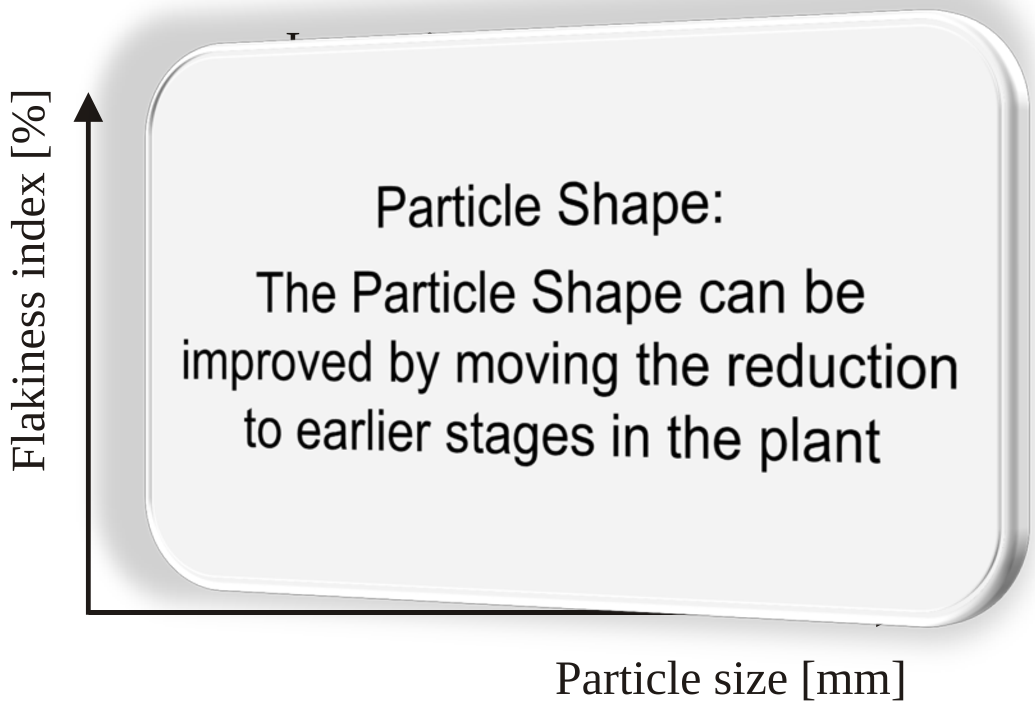
- Relation between CSS and Shape
  - The size where the best shape can be found is at CSS
  - It is very difficult for cubical stones larger then CSS to pass the chamber
  - Breakage of stones creates flaky particles. Smaller flaky stones will more easily find its way through the chamber



QUARRY ACADEMY

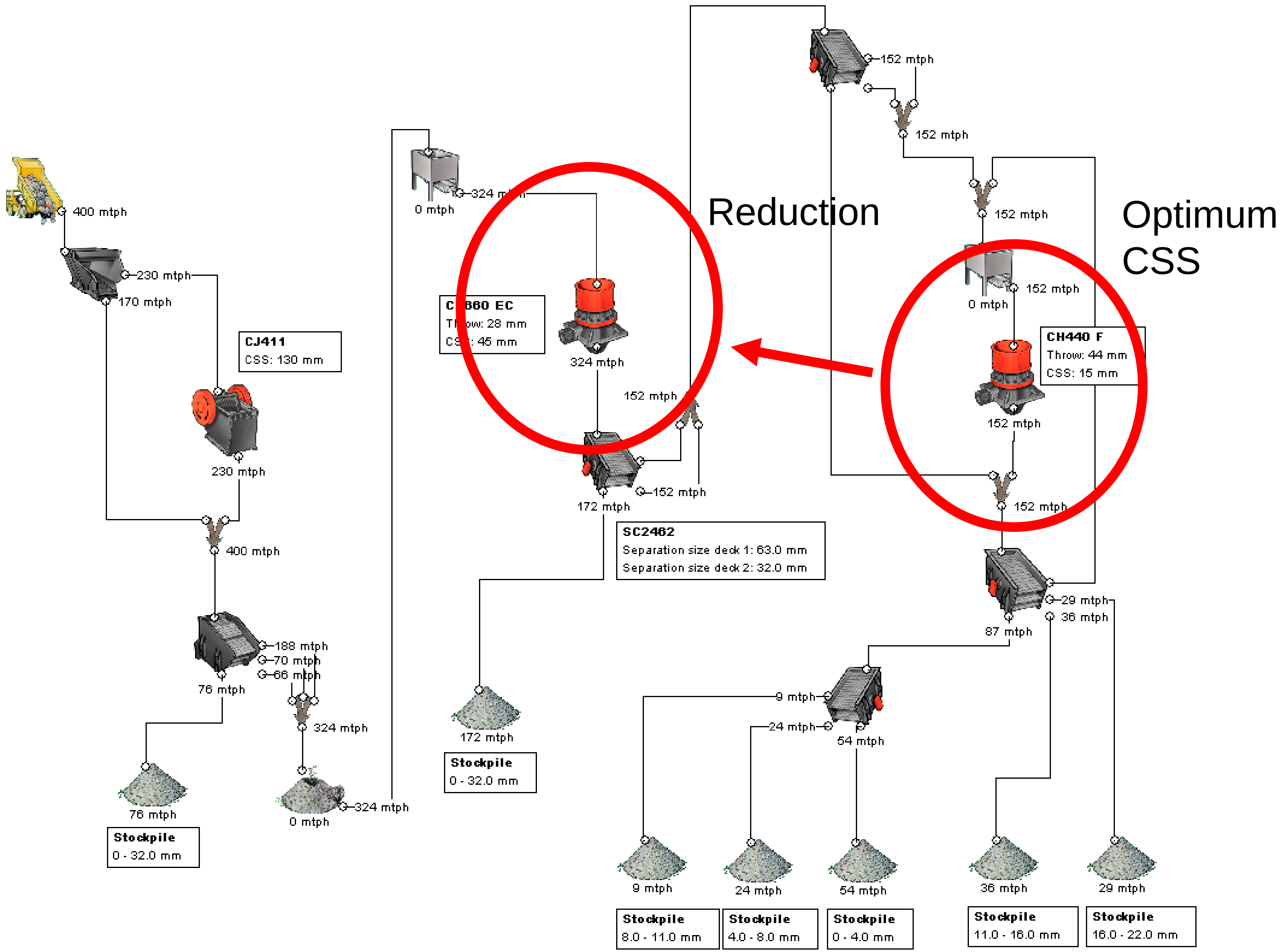
Crusher Operation

- Relation between Feed size and Shape
  - The greater reduction ratio the worse particle shape.
  - Inter particle breakage improves shape. When crushing a bed of material weaker particles will break first. Flaky or elongated particles are weaker then round.
  - Breaking round particles gives flaky material.



QUARRY ACADEMY

Crusher Operation



QUARRY ACADEMY

Optimization of a Final Crushing Stage

- Who is control of your process performance?
- What tools have been provided to make the production efficient?

- Maximize crusher yield
  - Production of valuable products
  - Efficient production of current product demands

- *Crusher Performance Map* will help guide the crusher operator

QUARRY ACADEMY

Optimization of a Final Crushing Stage

- This method applies to other crushers where a control variable is available
- The crushers are the last size reduction stage in the value chain.
- Over crushing is common.
- The connection between crusher setting and yield is often unknown
- The rock cannot be repaired.
- We need to control the crusher carefully.

QUARRY ACADEMY

Optimization of a Final Crushing Stage

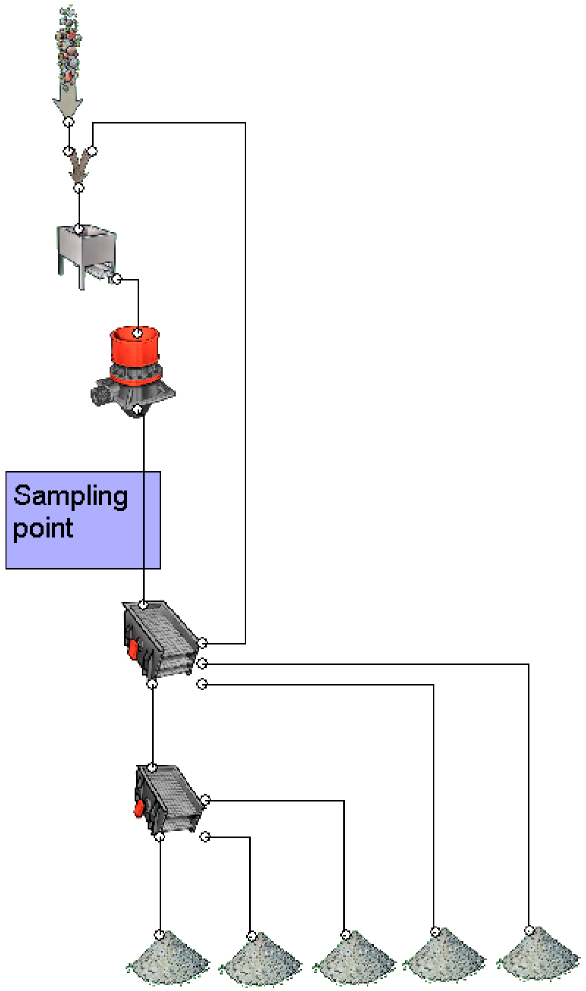
Planning → Sampling → Analysis → Optimization

- Optimization of one parameter (CSS) can be done by sampling and analysis
- The invested time and lost production will quickly be repaid by increased productivity
- Combine product yield and economic aspects
- This can be done by taking samples and making the analysis in MS Excel

Optimization of a Final Crushing Stage

Planning → Sampling → Analysis → Optimization

- Material from crusher is sampled
- Measure the capacity at each crusher settings. CSS will effect the final product capacity, especially in a closed circuit.
- Production of 4 valuable products
  - 0.08-0.16’’ (2-4 mm)
  - 0.16-0.32’’ (4-8 mm)
  - 0.32-0.64’’ (8-16 mm)
  - 0.64-0.87’’ (16-22 mm)
- By-product with no value
  - 0-0.08’’ (0-2 mm)



QUARRY ACADEMY

Optimization of a Final Crushing Stage

Planning | Sampling | Analysis | Optimization

- Run the crusher at different settings
- Take at least one sample at each setting. (Multiple samples are often useful)

- Special Attention to Safety when taking samples!!
- Position of point were samples are taking.
- Ensure that the conveyor will not start by accident.

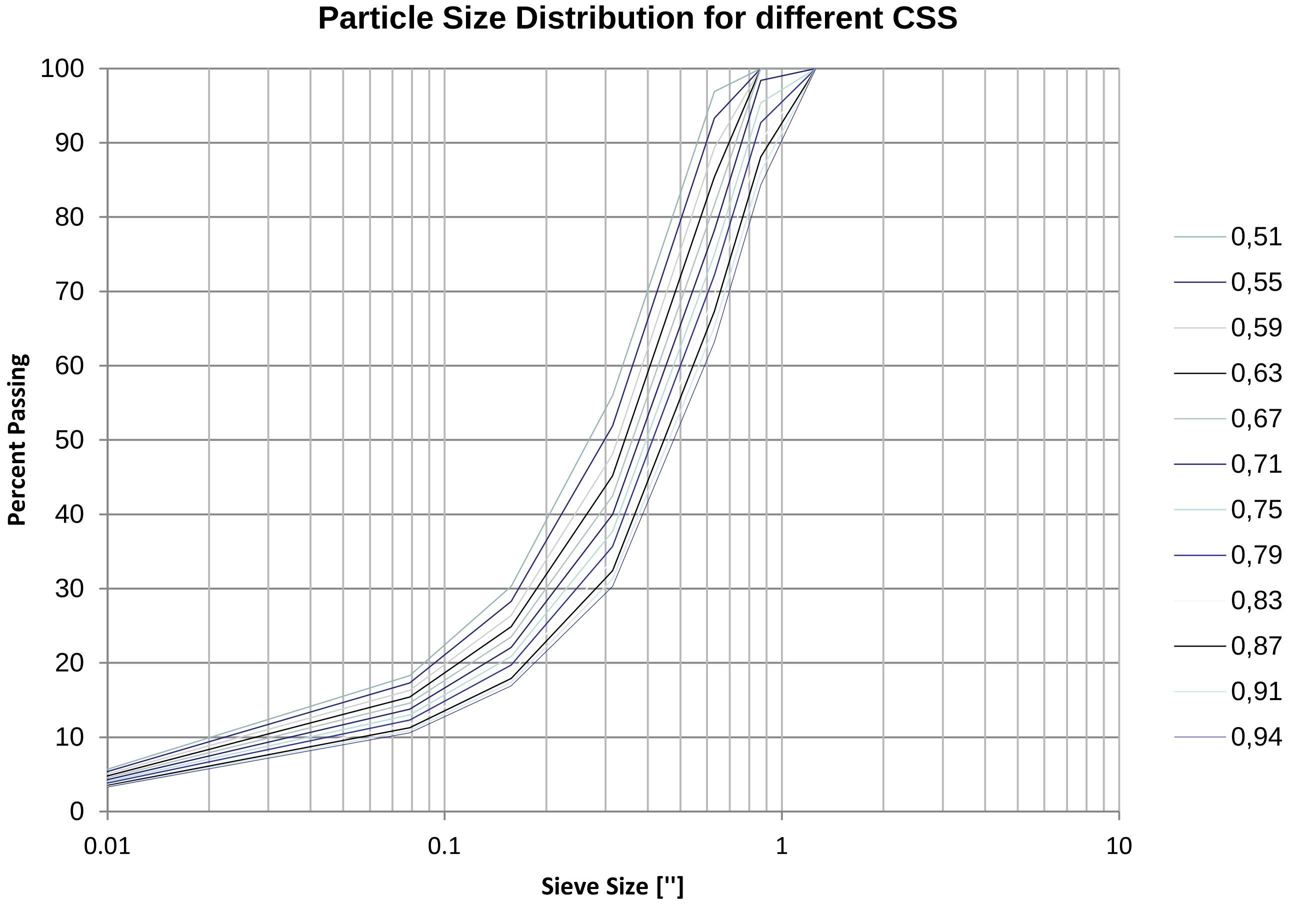
QUARRY ACADEMY

Optimization of a Final Crushing Stage

Planning | Sampling | Analysis | Optimization

- Particle Size Distribution Plots
- If taking single samples on each CSS the risk of getting inconsistent results might make the graph look strange.

- Impossible to determine optimum setting by only using particle size distribution graphs



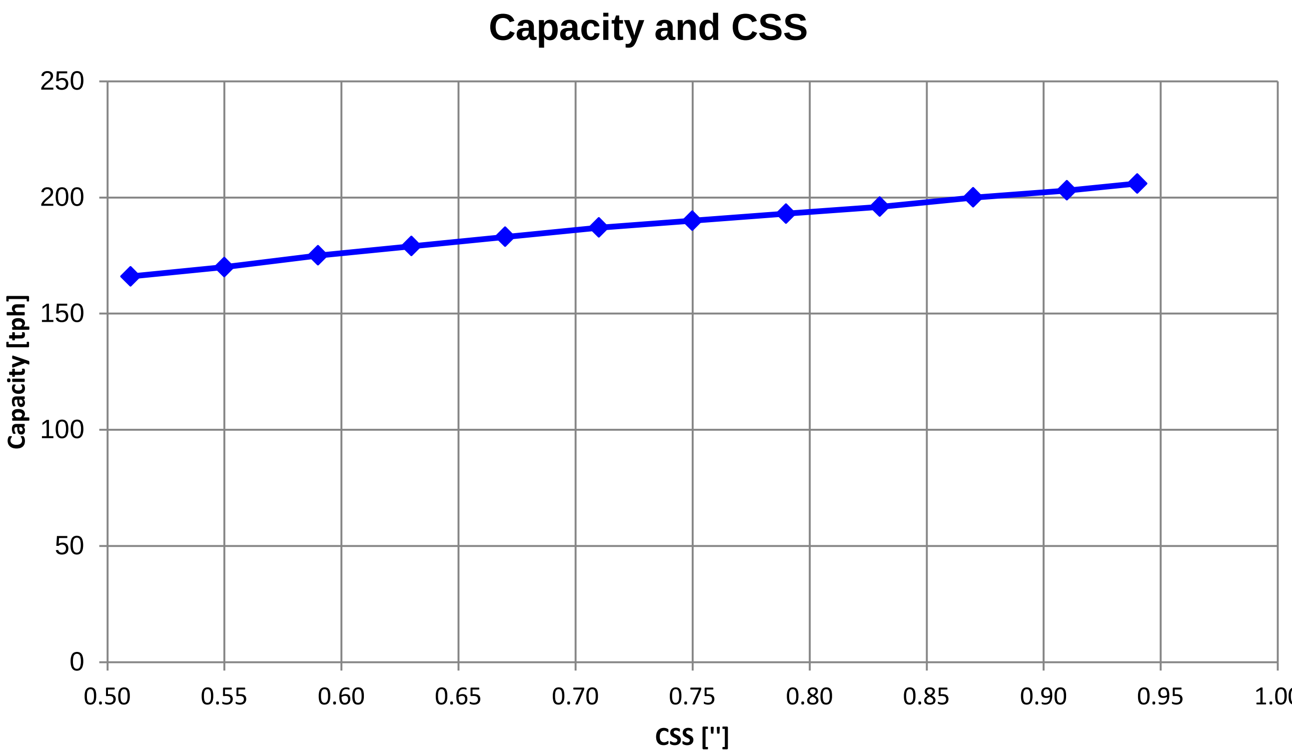
QUARRY ACADEMY

Optimization of a Final Crushing Stage

Planning | Sampling | Analysis | Optimization

- If taking single samples on each CSS the risk of getting inconsistent results might make the graph look strange.

- Impossible to determine optimum setting by only using particle size distribution graphs



QUARRY ACADEMY

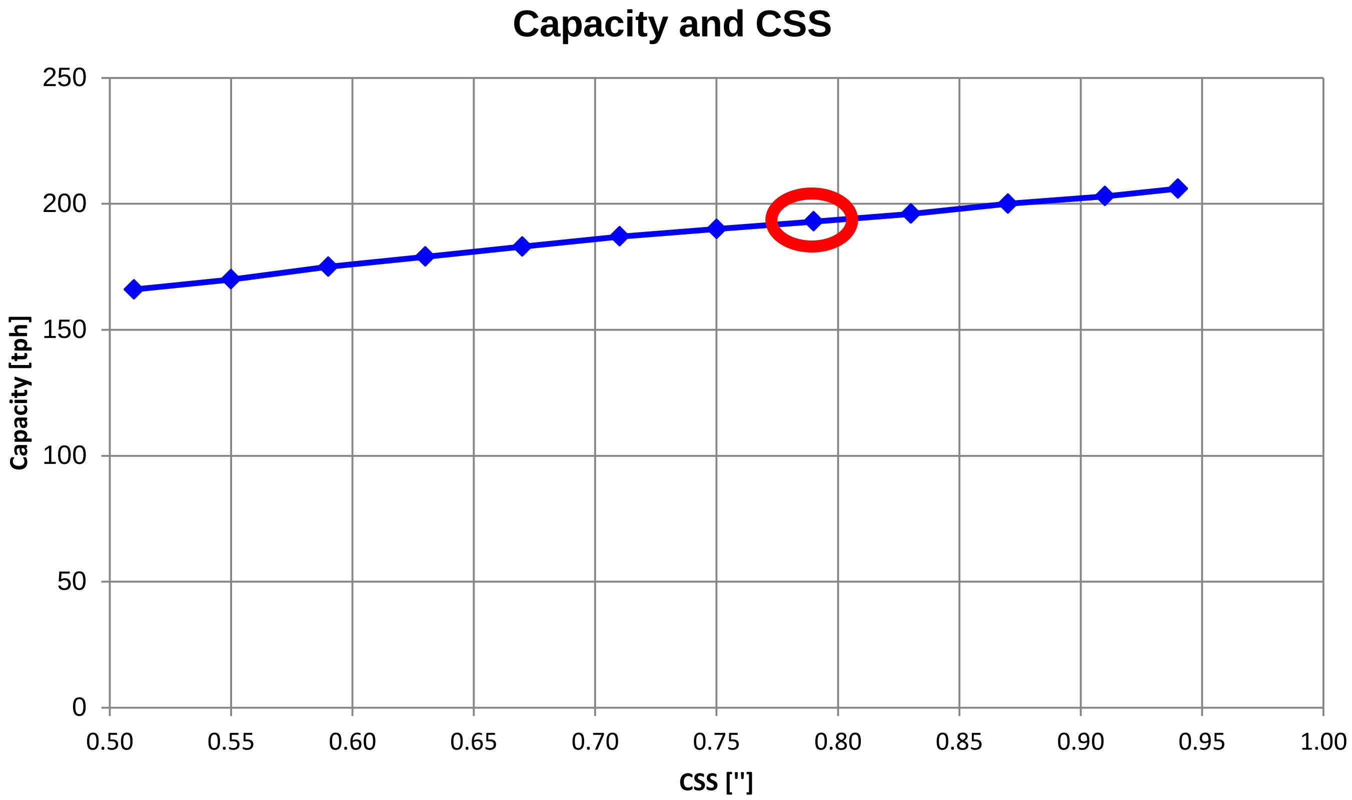
Optimization of a Final Crushing Stage

Planning → Sampling → Analysis → Optimization

- Combine the particle size distribution and capacity.
- Percentage of final product times the capacity gives the production capacity of each product.

- Example 0.08''-0.16'' mm at CSS 0.79'':
  - Percentage of crusher production
  - 20% - 11% = 9%
  - Crusher capacity
  - 193 tph

  - Total Production:
  - 193 tph x 9% = 17 tph



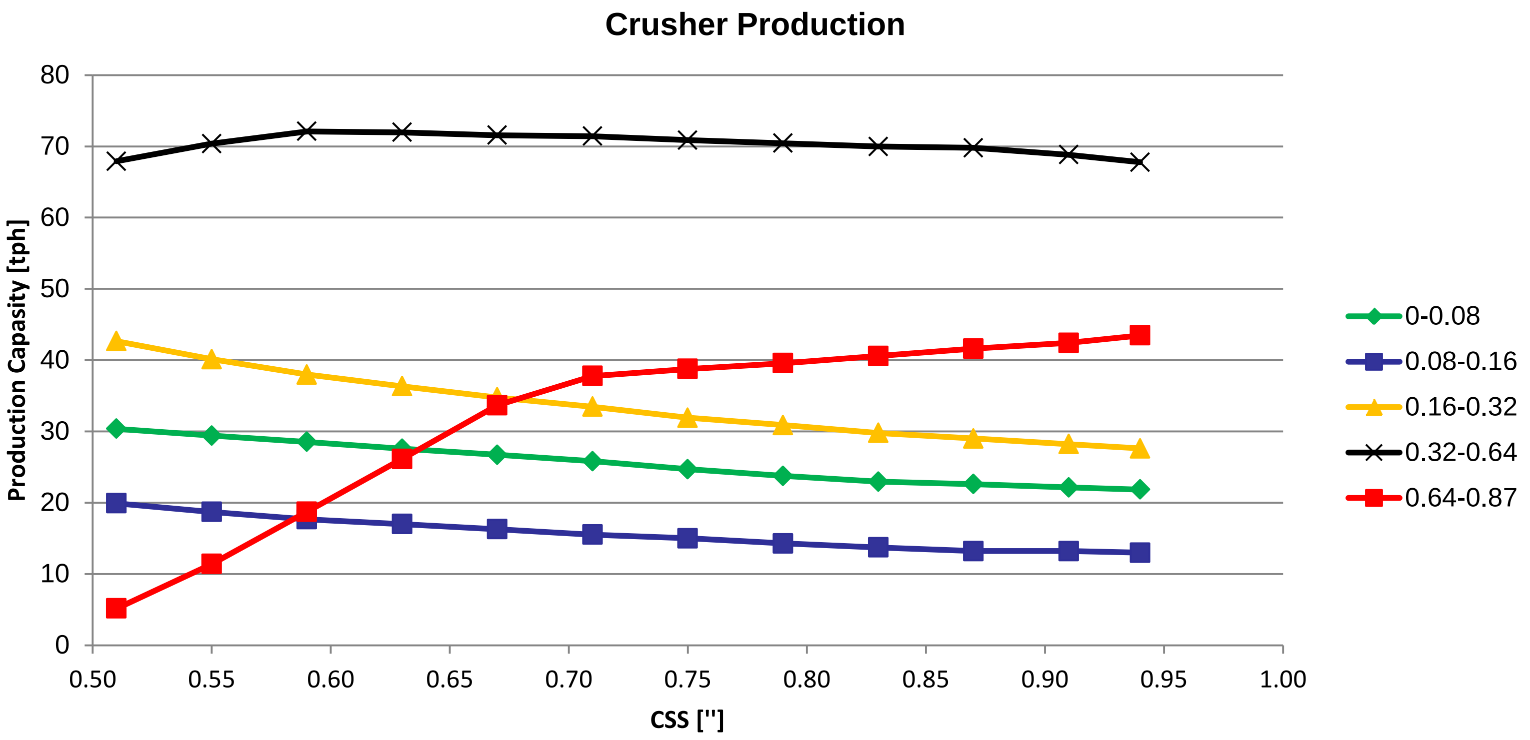
QUARRY ACADEMY

Optimization of a Final Crushing Stage

Planning → Sampling → **Analysis** → Optimization

- Entering all the values into MS Excel makes this easy to get production capacities.

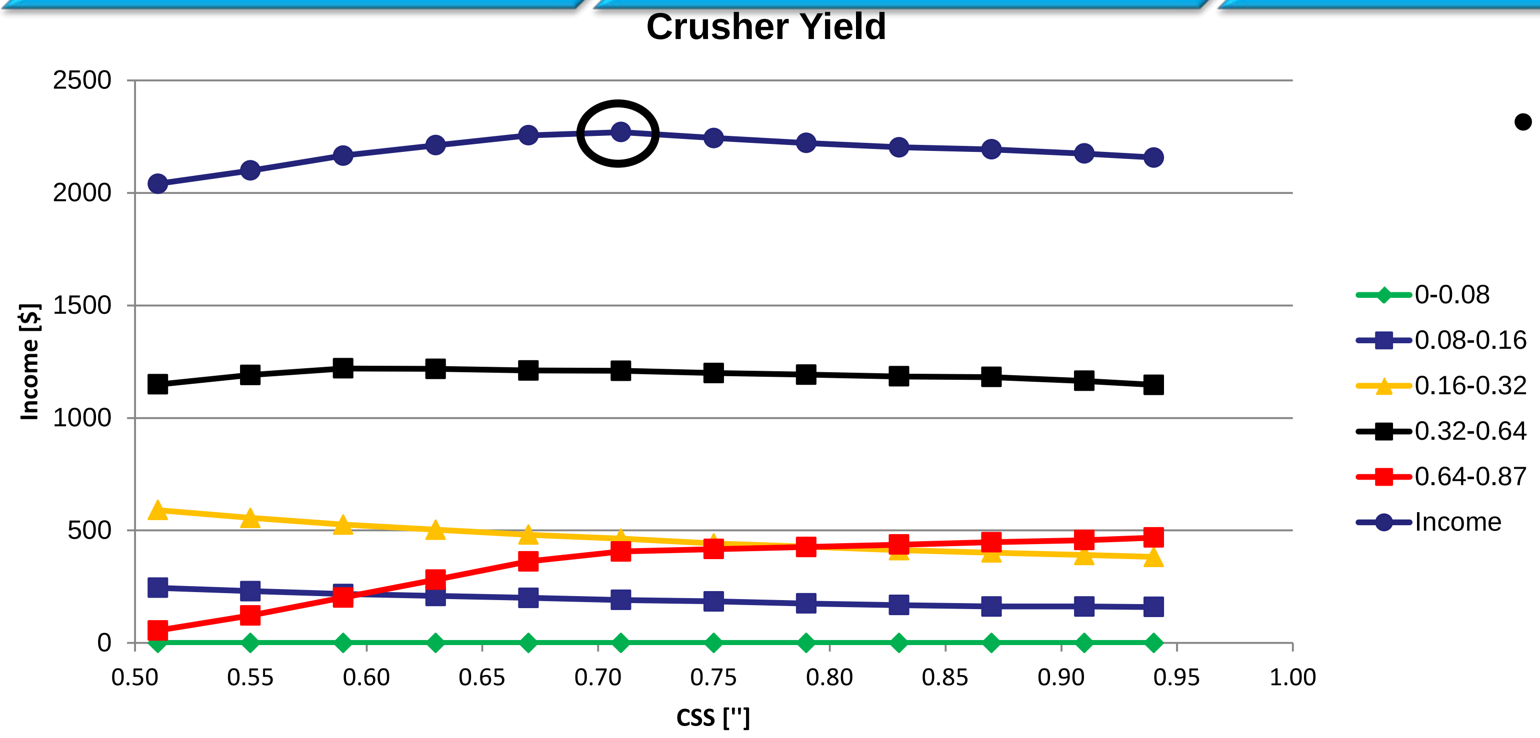
- Still difficult to determine the optimal setting



QUARRY ACADEMY

Optimization of a Final Crushing Stage

Planning → Sampling → Analysis → Optimization



- Use the price* per ton for all products:
  - 0-0.08’’: $ 0 (by-product)
  - 0.08-0.16’’: $ 12.30
  - 0.16-0.32’’: $ 13.85
  - 0.32-0.64’’: $ 16.90
  - 0.64-0.87’’: $ 10.80

- Make an income graph by combining prices with capacity

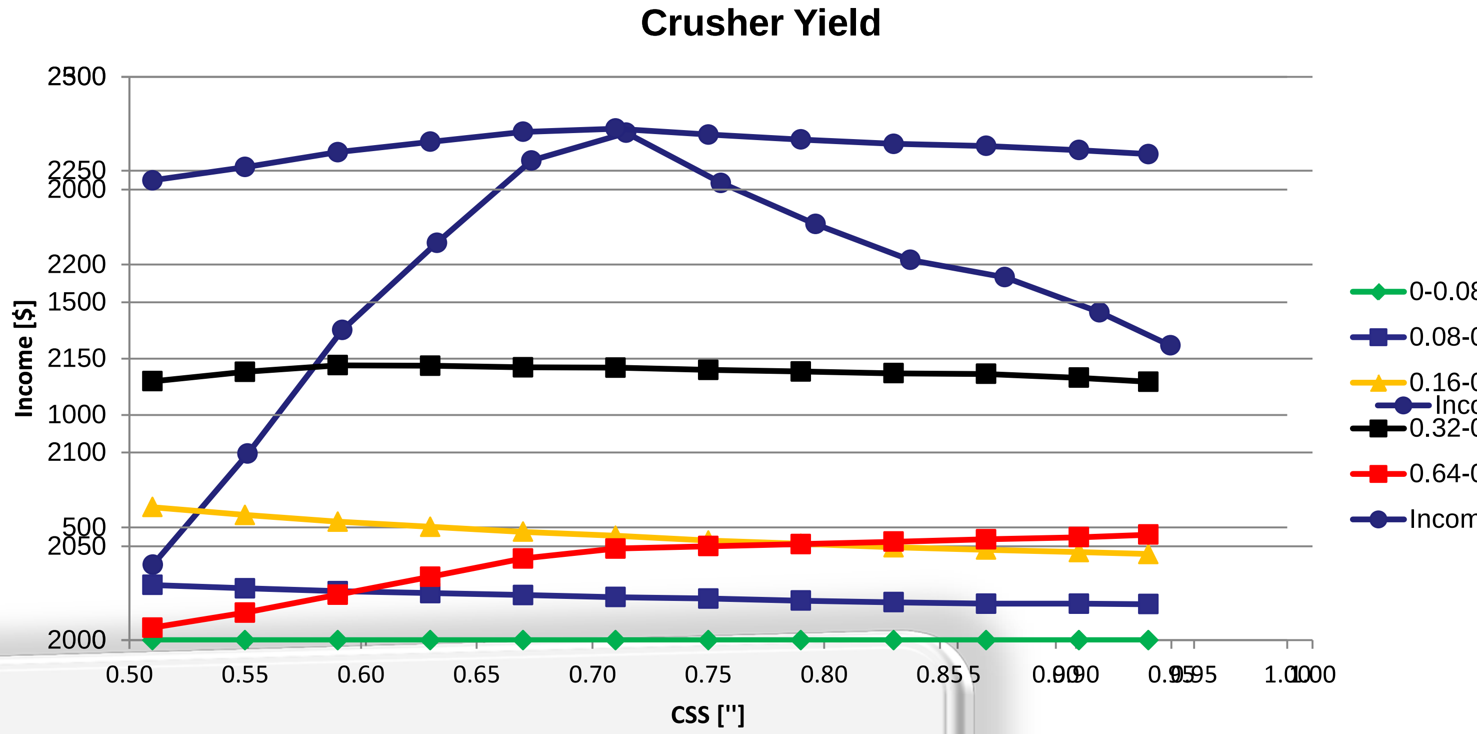
*All prices are estimates based on publicly available data

QUARRY ACADEMY

Optimization of a Final Crushing Stage

Planning | Sampling | Analysis | Optimization

- What difference does it make?
- Running the crusher 0.08'' off:
  - Decrease the profit by 58.5 $/h
  - Running the crusher at 1600 hours per year: 58.5*1600=$93600



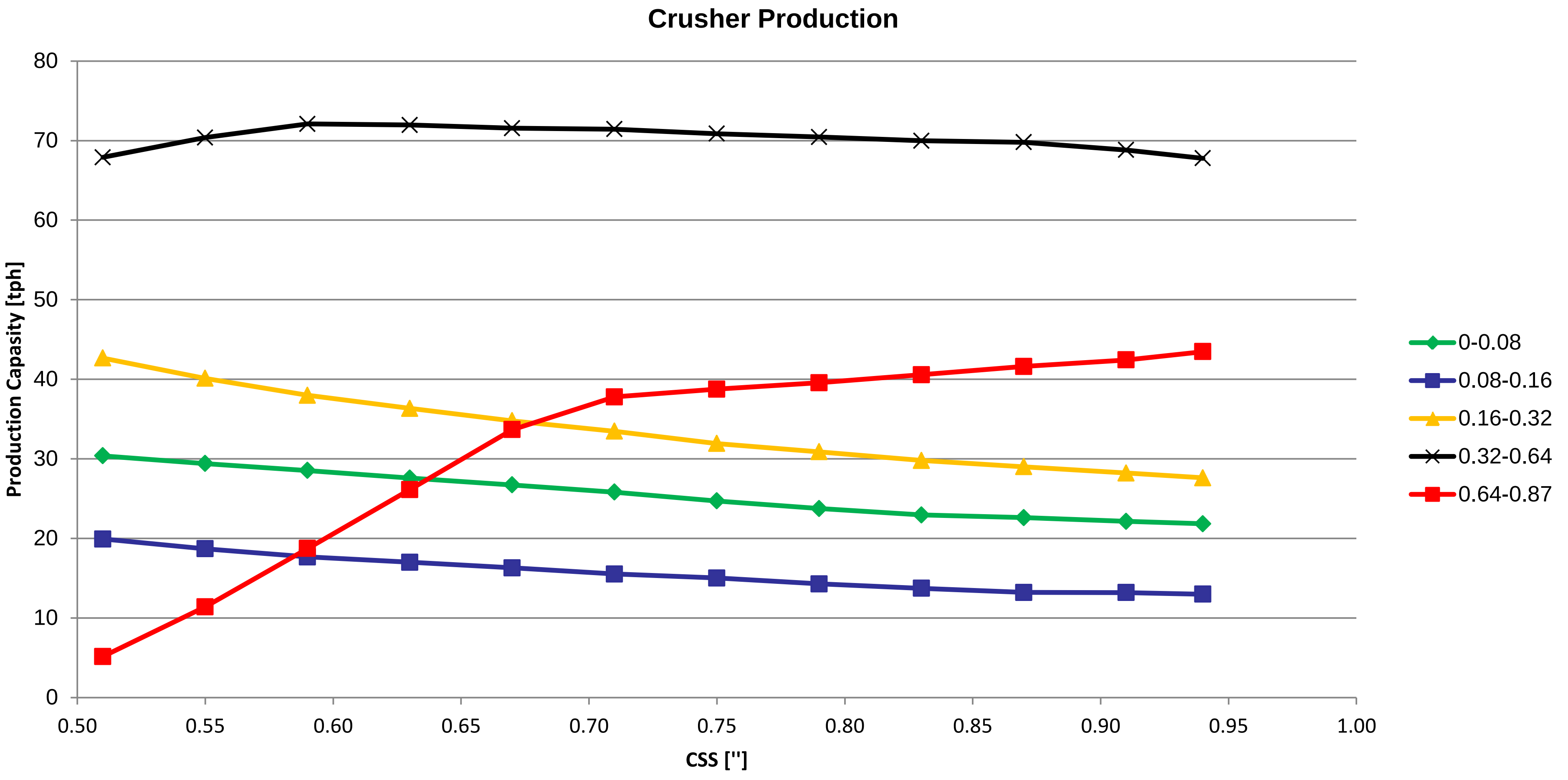
Optimization:

The effort put in to optimization will repay itself quickly

QUARRY ACADEMY

Crusher Performance Map

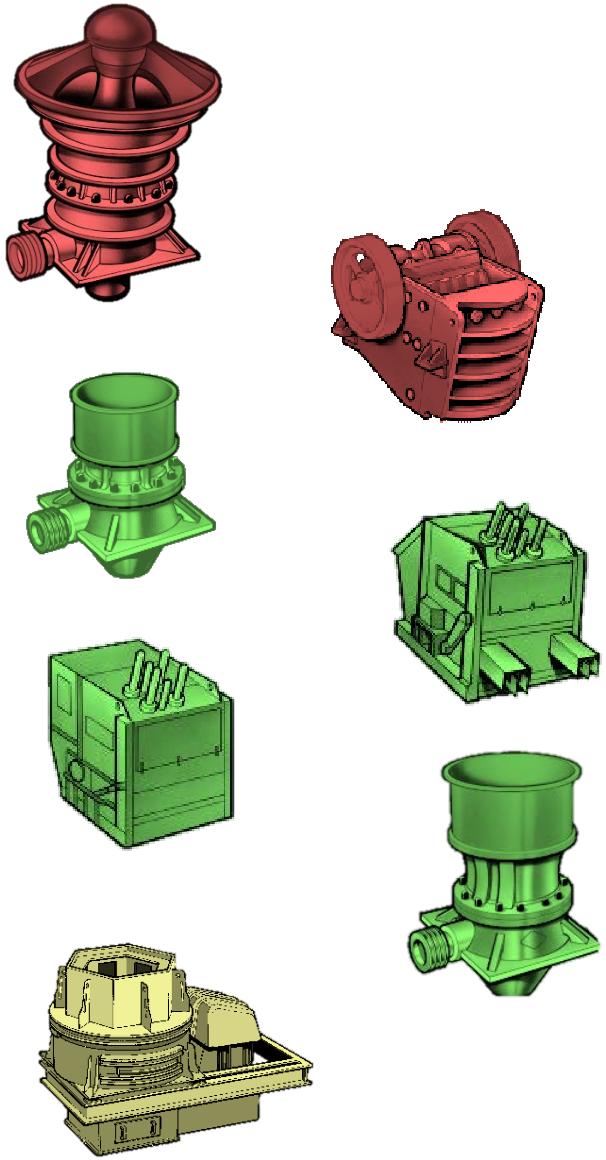
Planning → Sampling → Analysis → Optimization



QUARRY ACADEMY

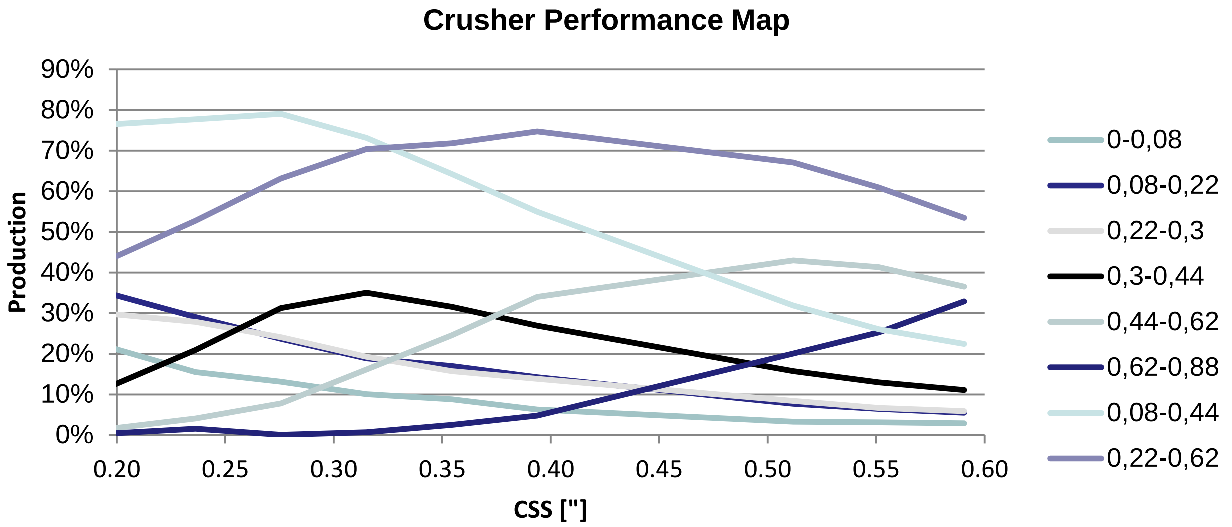
Crusher Performance Map

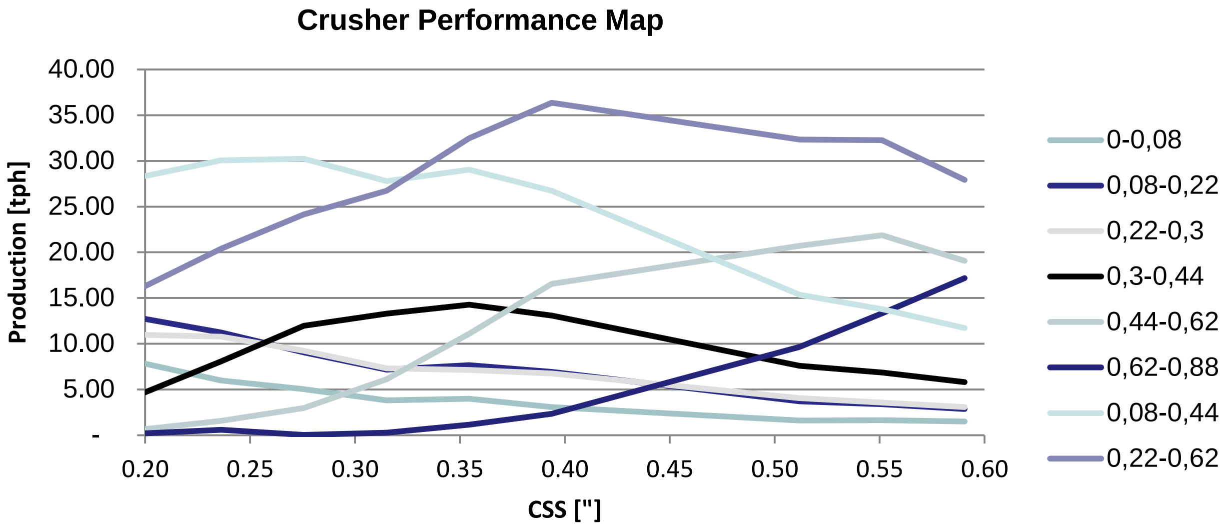
- The general idea:
  - Select a crusher where you think optimization will be beneficial
  - Make a plan for what you would like to test
    - CSS, Speed, Curtain Position…
  - Run a sampling campaign
    - Particle size distribution, shape, capacity
  - Do the analysis
    - Convert test results into values of performance
  - Find the sweet spot



QUARRY ACADEMY

Crusher Performance Map





QUARRY ACADEMY

Conclusions

Capacity is determined by the choke zone

By tuning the crusher operation production efficiency can be improved. Throw, Speed and Chamber Selection

The Particle Shape can be improved by moving the reduction to earlier stages in the plant and selecting correct CSS

Process Capacity and Crusher Capacity must correspond

The effort put in to optimization will repay itself quickly

The Crusher Performance Map can assist your operator with maintaining efficient production www.quarryacademy.com

QUARRY ACADEMY

Improving Processes. Instilling Expertise.

DYNO Dyno Nobel

SANDVIK