QUARRY ACADEMY

Improving Processes. Instilling Expertise.

DYNO
Dyno Nobel

SANDVIK

Getting Control
Alex Scott

QUARRY ACADEMY

Improving Processes. Instilling Expertise.

DYNO Dyno Nobel

SANDVIK

Lecture Overview

- A look at some of the issues which in the day to day operation influence crusher performance

- A look at some possible problems, trouble shooting tips and improvements.

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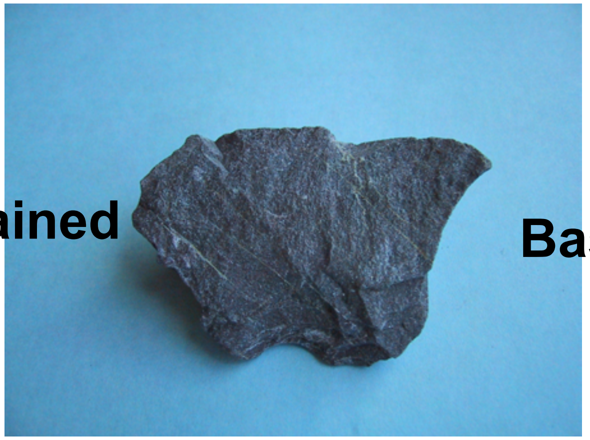
Our journey

- A look at material properties and their influence on equipment performance
- A look at the machine factors influencing equipment performance
- A look at some negative factors reducing equipment performance.
- A look at some take home messages which might improve performance.

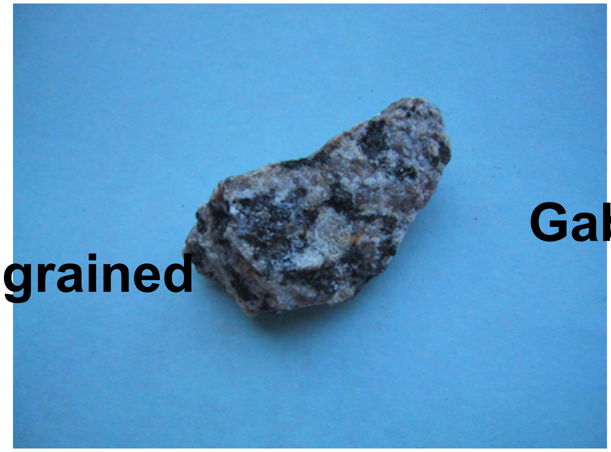
Raw Material
Species of rock

- IGNEOUS
  - ✓Surface - Fine grained
  - ✓Intrusive - Medium grained
  - ✓Deep - Coarse grained



Basalt

Diabase



Gabbro

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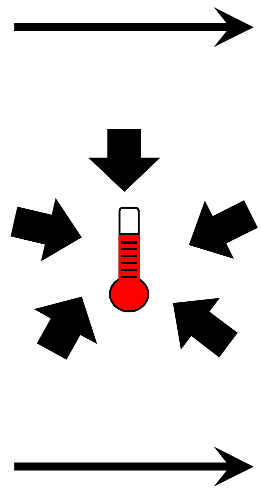
Raw Material
Species of rock

- METAMORPHIC

  ROCK TRANSFORMED IN THE EARTH´S CRUST DUE TO INCREASED PRESSURE AND TEMPRATURE

Limestone



Marble

Granite

Gneiss

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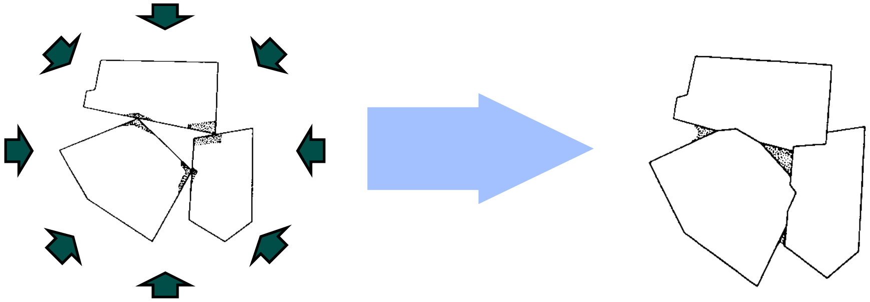
Raw Material
Species of rock

- SEDIMENTARY



Take Home Message

The grain structure of the raw material has an influence on the final shape of the finished product and the power and/or pressure pulled by the crusher

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Sandvik Test Methods
Impact Work index, W_i

Impact Work Index (WI)	Description of the Crushability
< 10	Very soft
10 – 14	Soft
14 – 18	Medium
18 – 22	TOUGH
22 – 26	Very TOUGH
> 26	ExtremelyTOUGH

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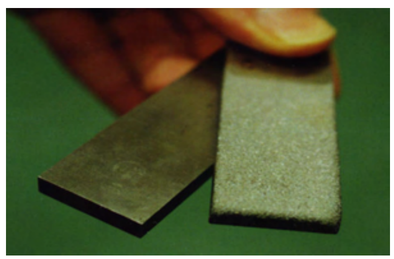
Sandvik Test Methods
Abrasion Index, AI



Abrasion Index (AI)	Description of the Wear
< 0.1	Very low wear
0.1 – 0.2	Low wear
0.2 – 0.4	Intermediate wear
0.4 – 0.6	Normal medium wear
0.6 – 0.8	High wear
> 0.8	Extremely high wear

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Sandvik Test Methods
Rawmaterial Properties

Material	WI	AI	Compressive strength (lbs/in^2)
Amphibolites	16	0.4	29000 - 43500
Andesite	16	0.5	24650 - 43500
Basalt	20	0.25	43500 - 58000
Diabase	18	0.28	36250 - 50750
Dolomite	12	< 0.02	7250 - 21750
Diorite	19	0.4	24650 - 43500
Gabbro	21	0.4	29000 - 50750
Greywacke	18	0.3	21750 - 43500

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Sandvik Test Methods
Rawmaterial Properties

Material	WI	AI	Compressive strength (lbs/in^2)
Gneiss	16	0.48	29000 - 43500
Granite	16	0.46	29000 - 45000
Limestone	11	< 0.01	11600 - 26100
Marble	12	< 0.02	14500 - 29000
Quartzite	16	0.75	21750 - 43500
Sandstone	10	0.75	4350 - 21750
Iron ore (Hematite)	11	0.5	14500 - 29000
Iron ore (Magnetite)	8	0.2	7250 - 21750

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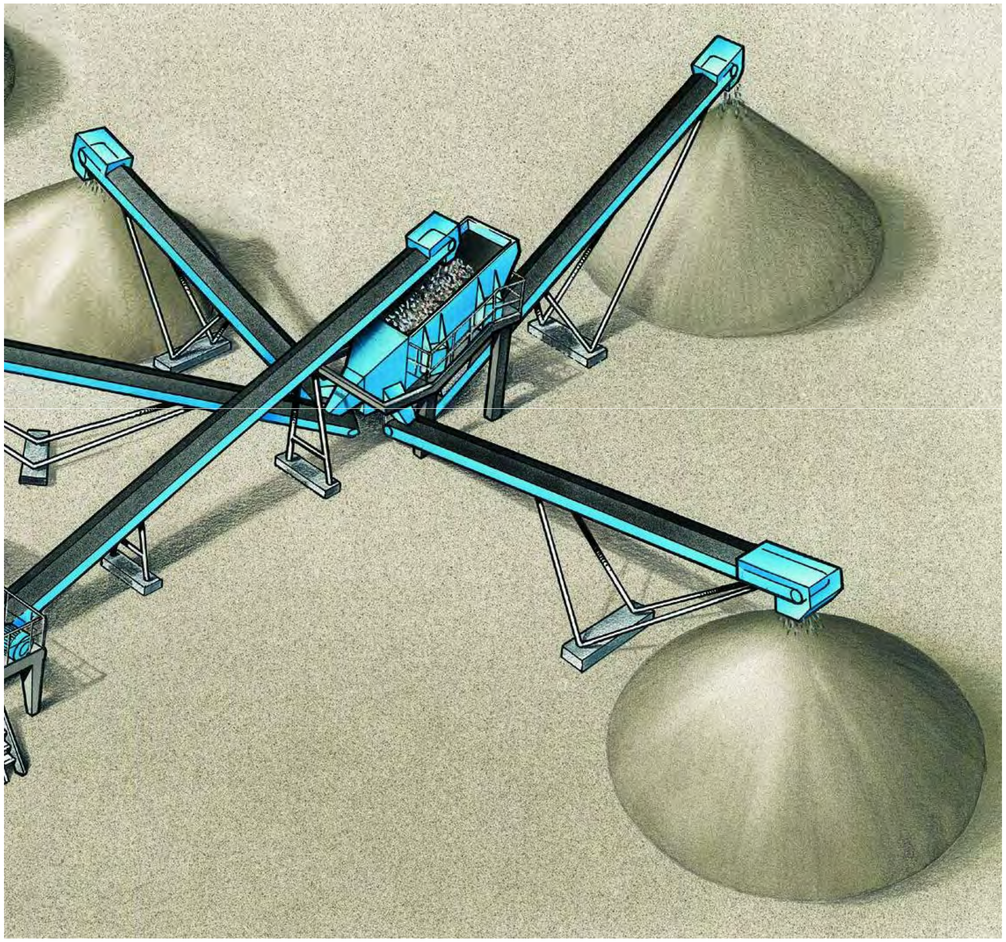
FINAL PRODUCTS



- Size
  - ✓ Fraction Limits
  - ✓ Misplaced Particles
  - ✓ Size Distribution
- Shape
  - ✓ Flakiness
  - ✓ Elongation
- Surface
  - ✓ Crushed Surface

QUARRY ACADEMY

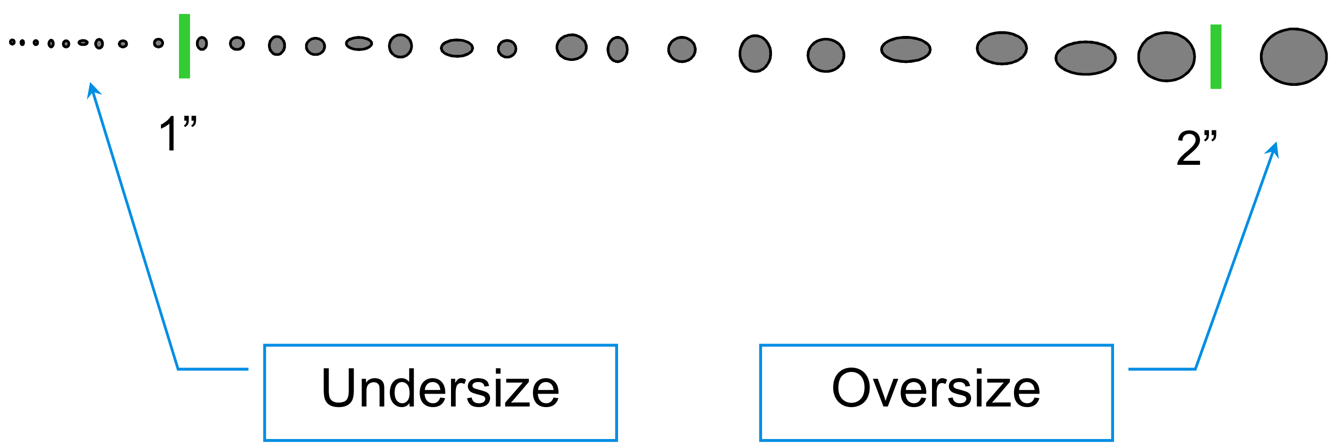
FINAL PRODUCTS
Misplaced particles

ASTM D 448-86,1988

Misplaced Particles 10/15

- ✓ **Oversize: 10 %**
- ✓ **Undersize: 15 %**

<u>Fraction 1” x 2”:</u>



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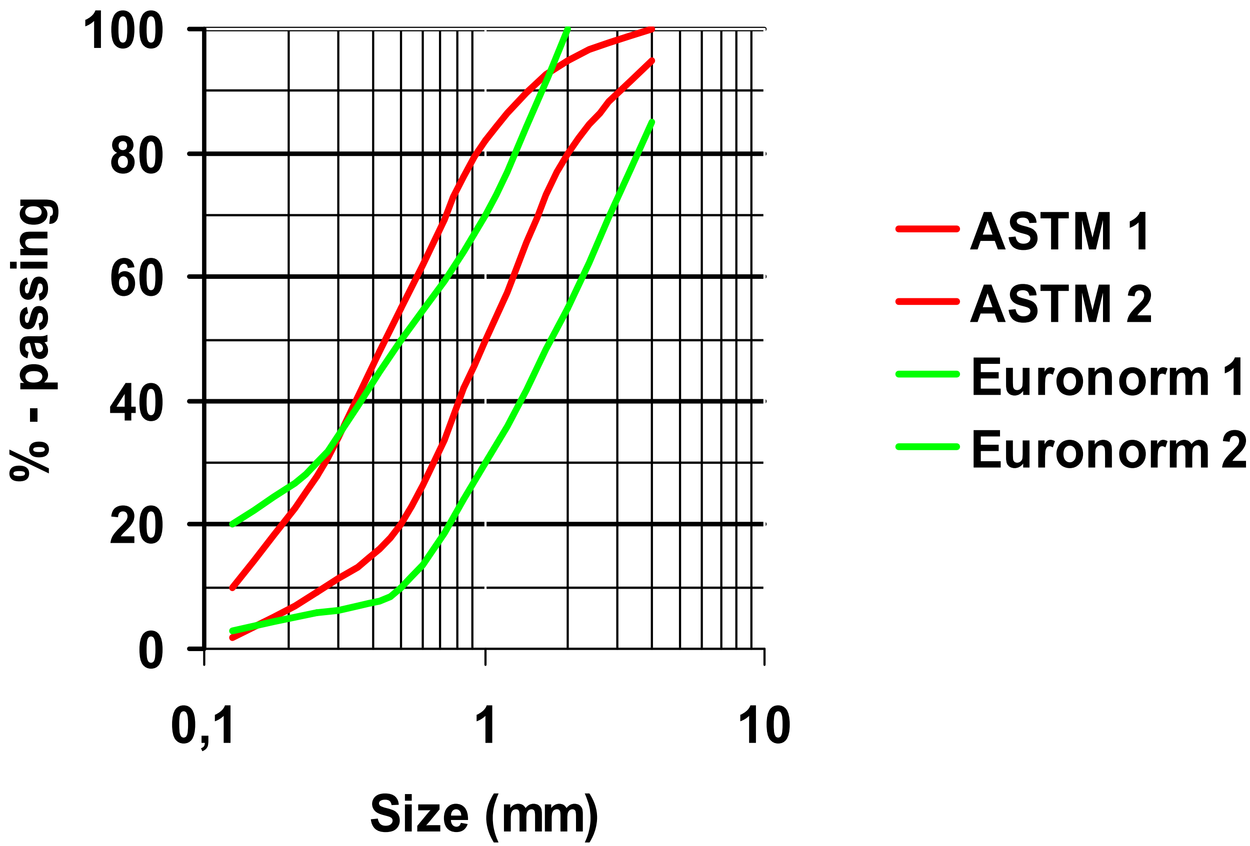
FINAL PRODUCTS
Curve limitations



Sand limits

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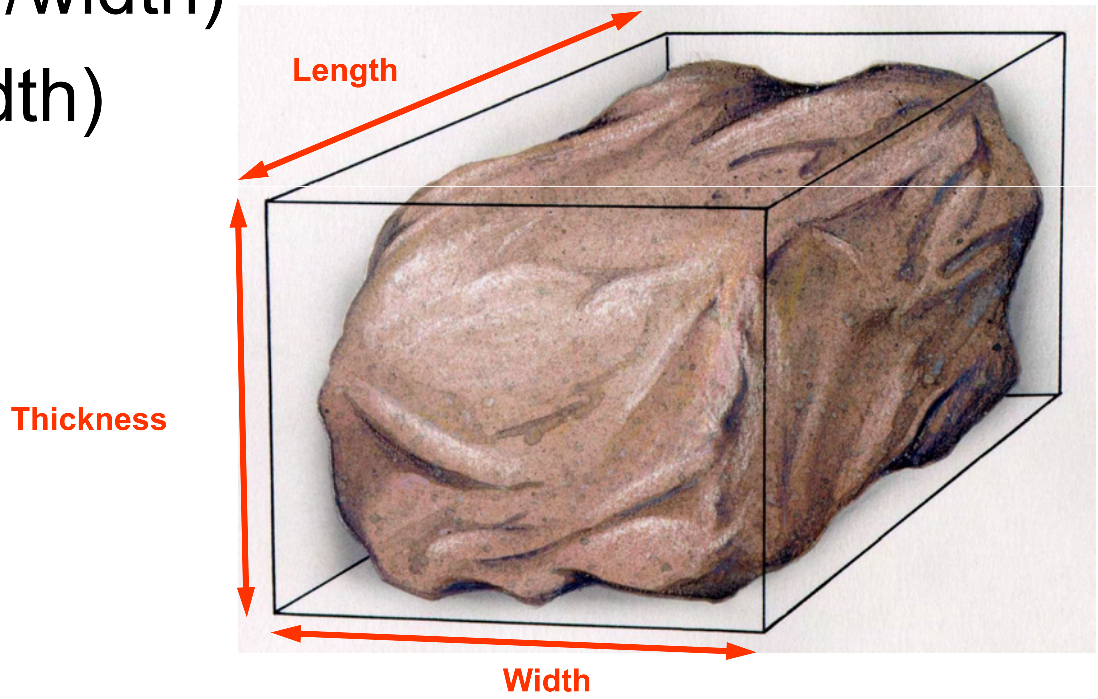
FINAL PRODUCTS
Particle shape

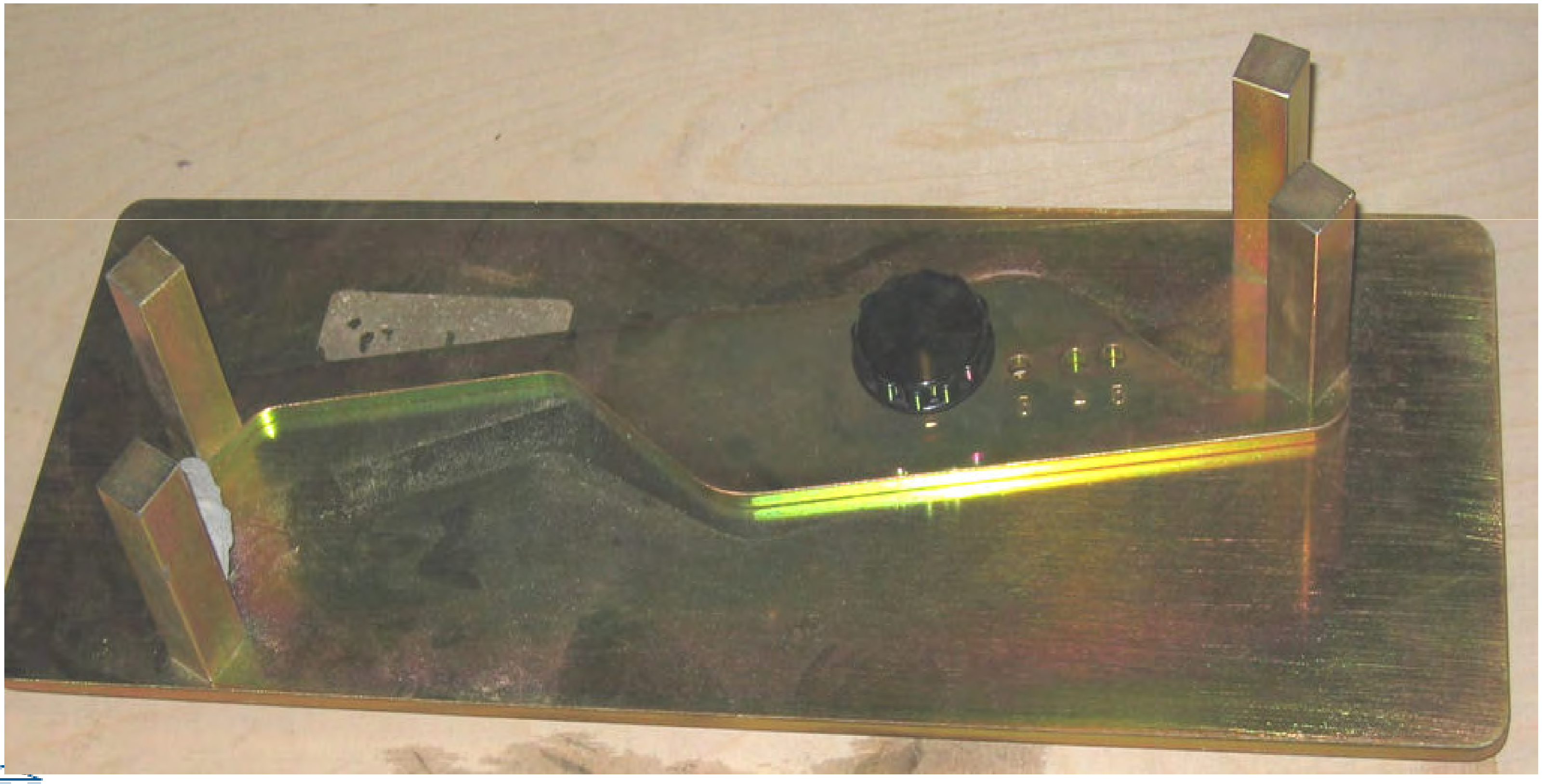
- Flakiness (length/thickness)
- Elongation (length/width)
- Flat (thickness/width)

ASTM D 4791



PARTICLE SHAPE

- ASTM
  - ✓ Flat (W/T ratio)
  - ✓ Elongated (W/L ratio)
- Ratio varies 1:2, 1:3, 1:4, 1:5



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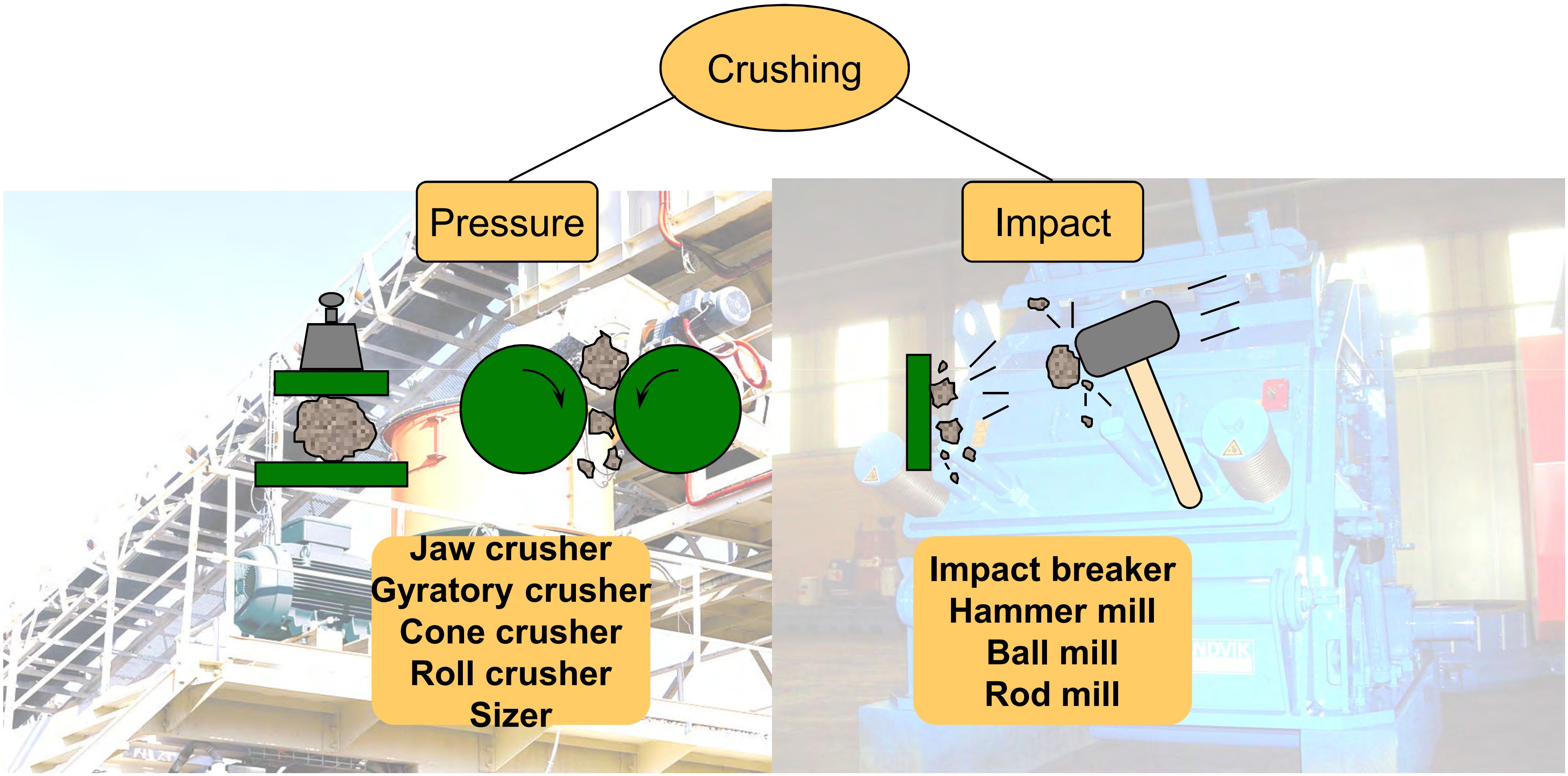
Crushers & crushing

A look at crushers and the mechanical and process material influences



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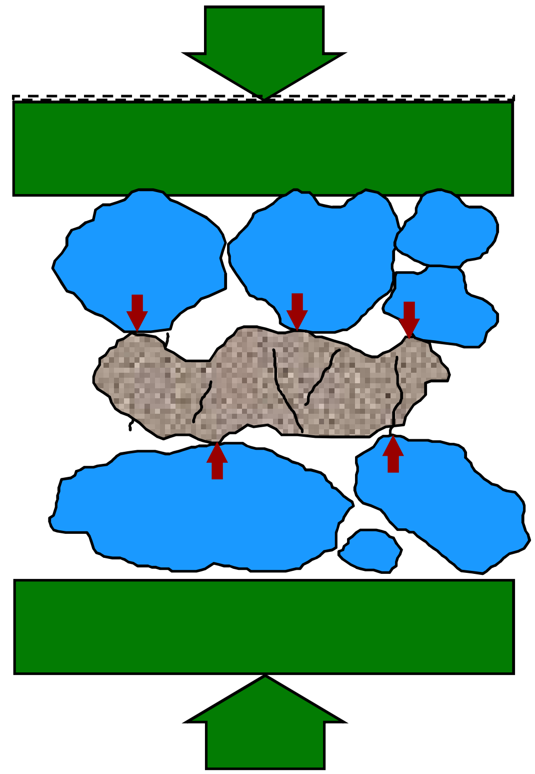
Compression Breakage

Stone on metal

Simple loading ⇨

More angular particles

Stone on stone



Complex loading ⇨

More cubical particles

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Cone crusher

Operation

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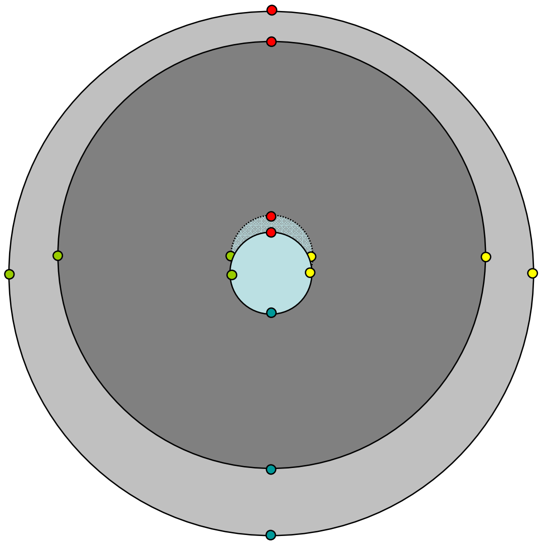
Eccentric Motion



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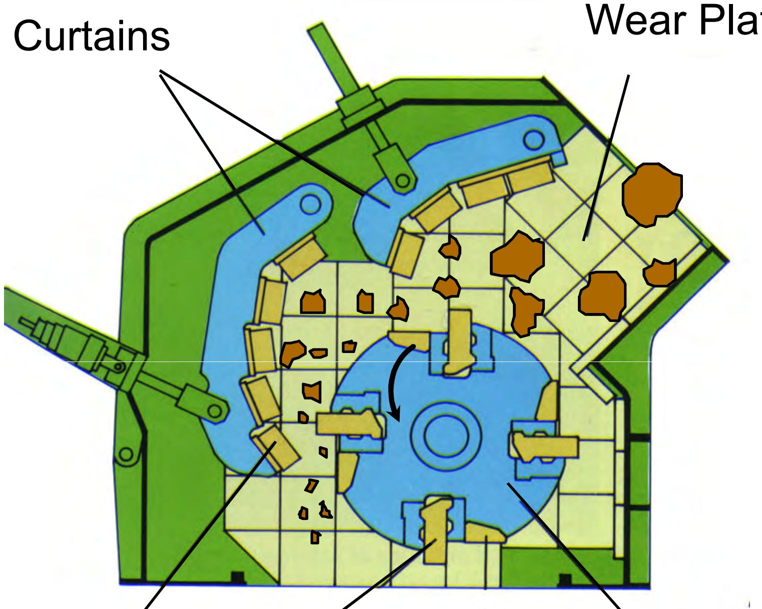
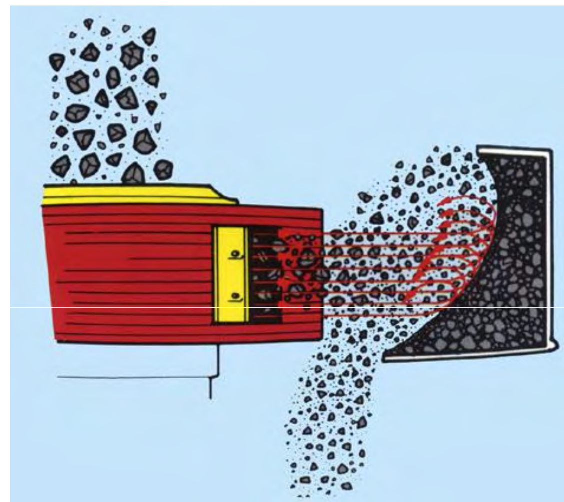
Impact
The stone is subjected to many random hits



Autogenous crushing



Details of a vertical impact crusher

The result is often a more cubical product with higher amount of fines.

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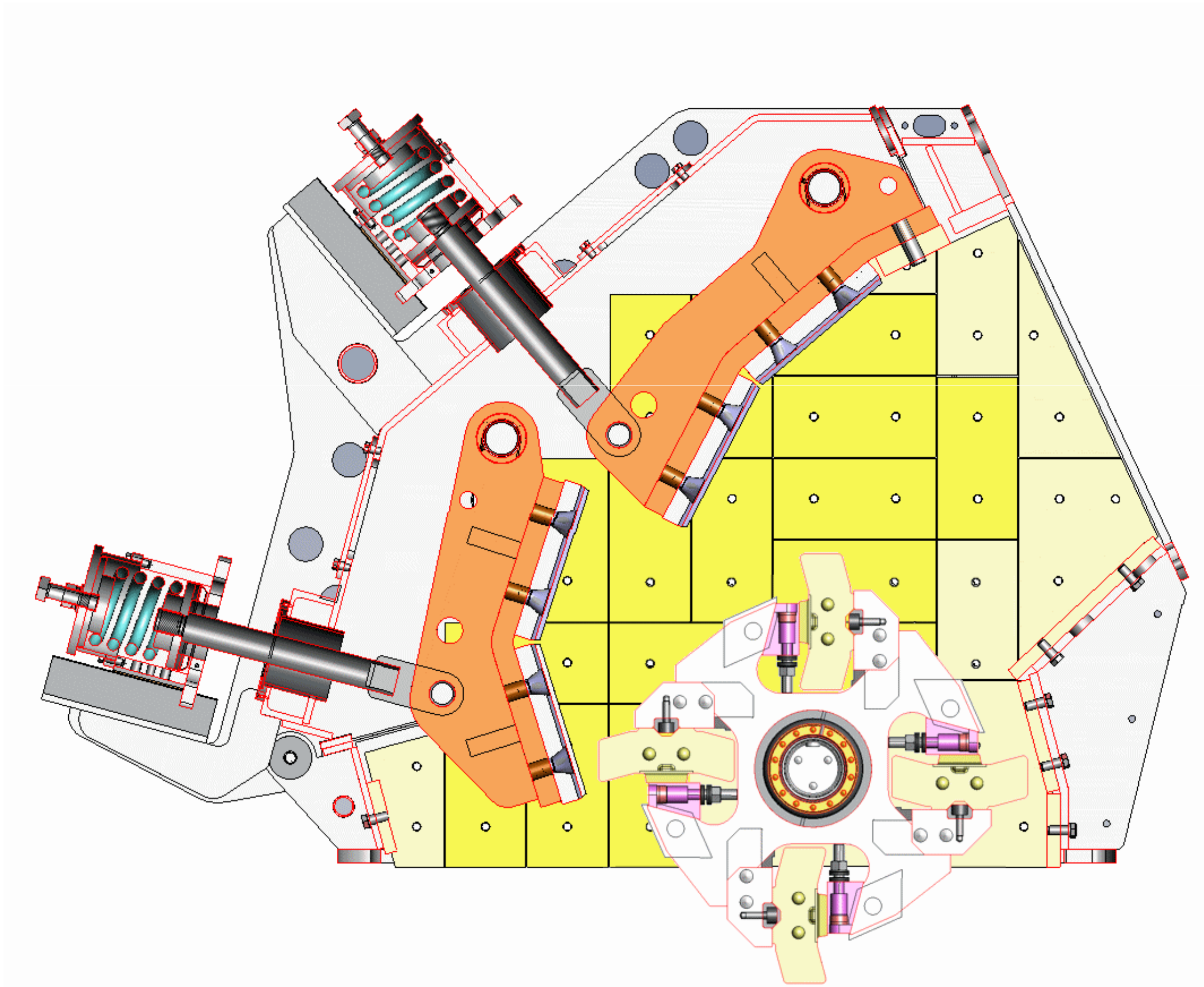
Impactor Operation



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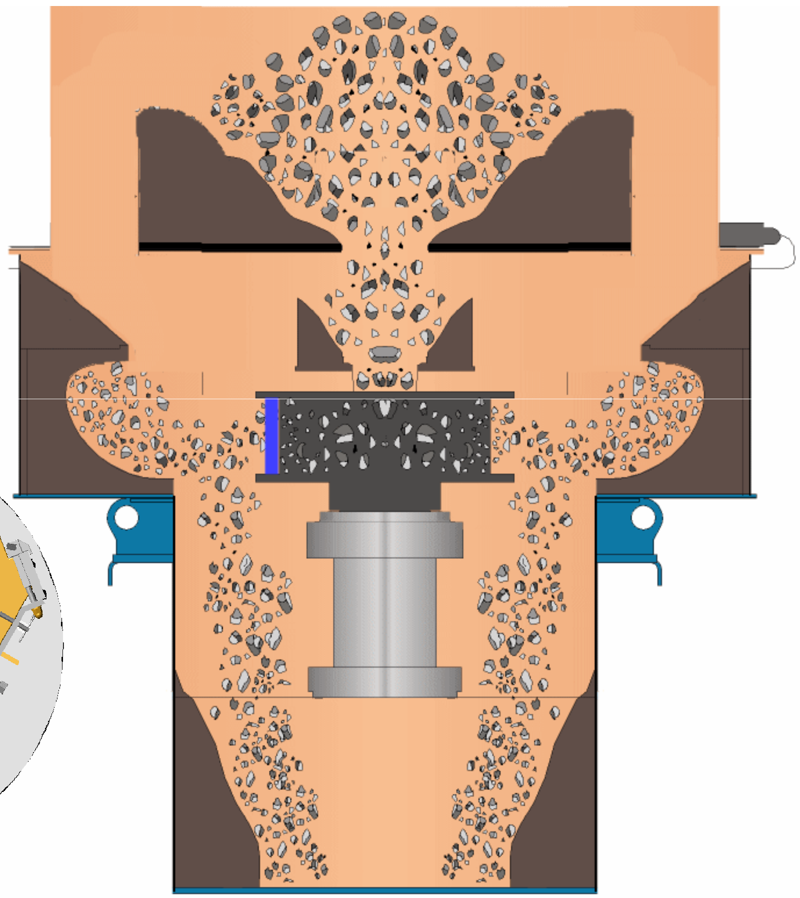
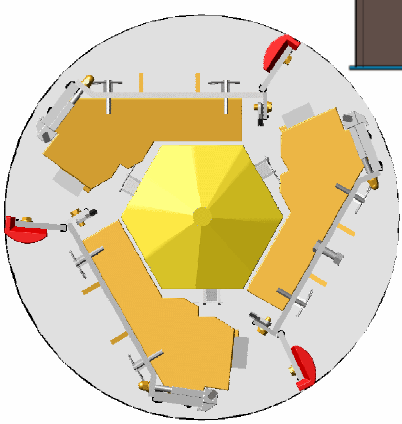
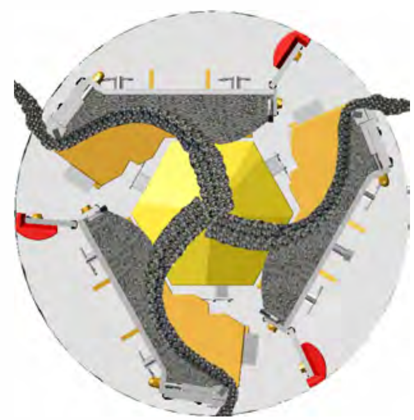
VSI How It Works



Rotor Only Feed





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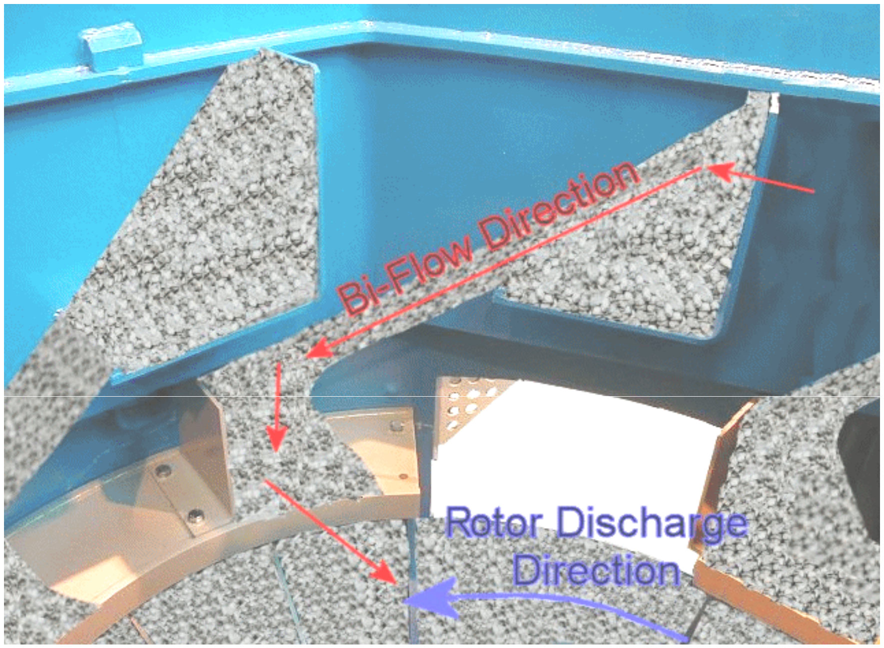
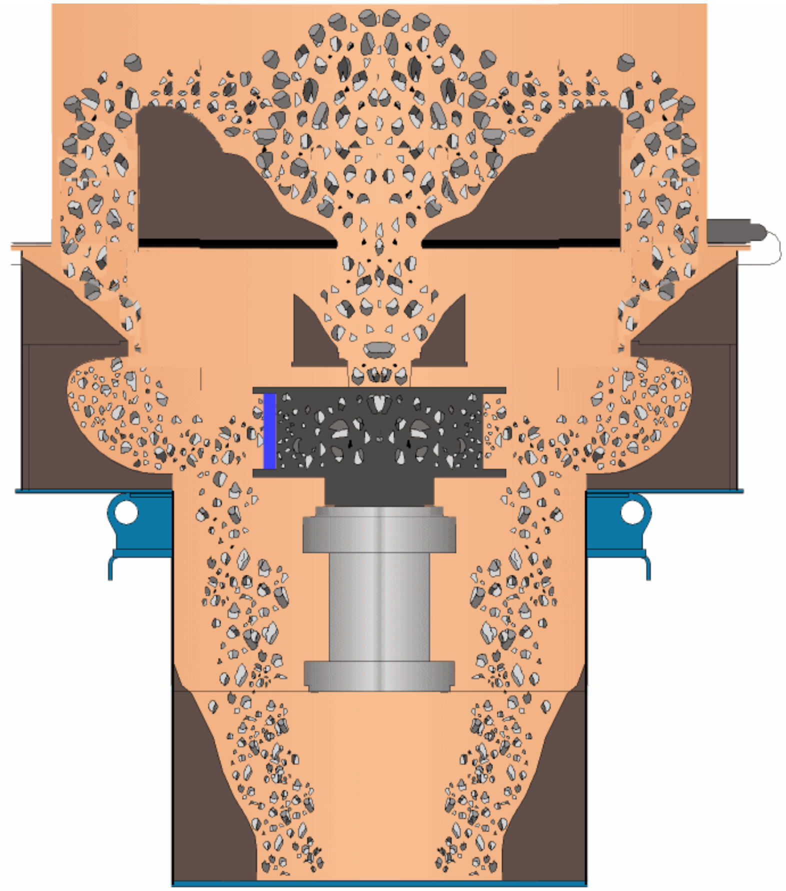
VSI How It Works





Rotor And Bi-Flow Feed

What do we really know about crushing?

- What are the major influences?
- From material factors?
- From equipment/mechanical factors?

What are we about to examine?

- The major influences on crusher performance, which are

- material factors such as

1. toughness,
2. bulk density
3. feed size analysis

- machinery factors such as

1. setting
2. throw (cone crushers)
3. chamber volume
4. speed

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Mechanical & material

Limestone

1” – 3”

0 – $1^{1}/_{4}$ ”

Limestone

1” – 3”

0 – $1^{1}/_{4}$ ”

The same energy is used.

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Material

Limestone

1” – 3”

0 – $1^{1}/_{4}$ ”

Basalt

1” – 3”

0 – $1^{1}/_{4}$ ”

Toughness is a major factor

Mechanical

Limestone

1” – 3”

0 – $1^1/_4$ ”

Limestone

1” – 3”

0 – $1^1/_4$ ”

Volume by throw,chamber profile or material bulk density & feed grading are factors

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Mechanical

Basalt

1” – 3”

0 – $1^{1}/_{4}$ ”

Basalt

1”- 5”

0 – $1^{1}/_{4}$ ”

Reduction ratio-CSS is a factor

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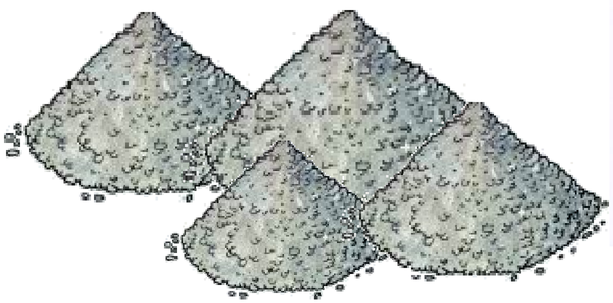
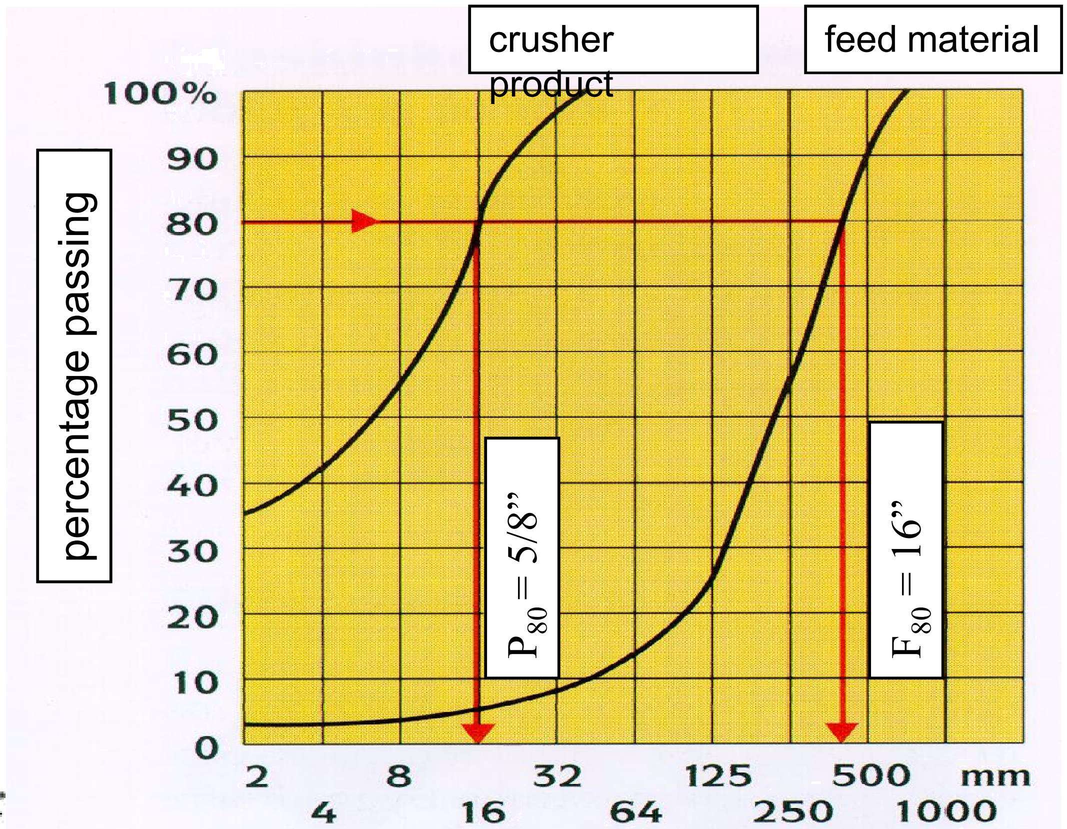
Basic Crushing and Screening Concepts
Reduction Ratio (1)

$$Reduction\ Ratio = \frac{F_{80}}{P_{80}}$$

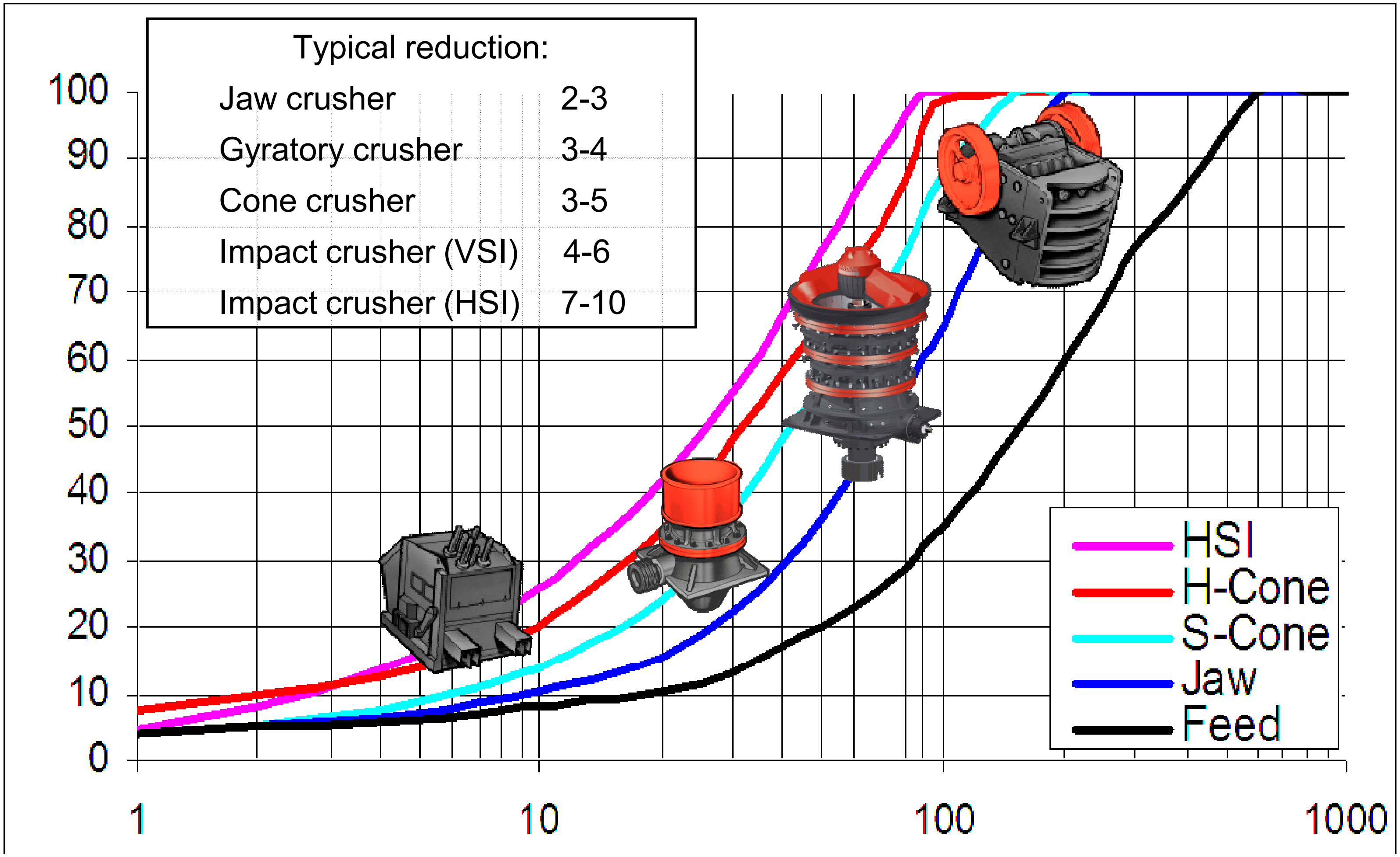
F_{80} = (80 % of feed mtrl)

P_{80} = (80 % of the product)





Basic Crushing Concepts
Reduction Ratio



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Basic Crushing and Screening Concepts
Reduction Ratio (3)

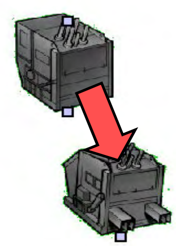
Using reduction ratio to predict required no. of crushing stages

P_{80} Feed: 16”

P_{80} Products: 5/8”

Min. required plant reduction

$16 / {}^{5}/_{8}$ = 25:1



- 2-stage Impact Plant:

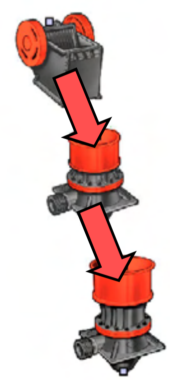
10x7=70

OK, **Only for Ai <0.15**

- 2-stage Jaw/cone Plant:

3x4=12

NOT OK

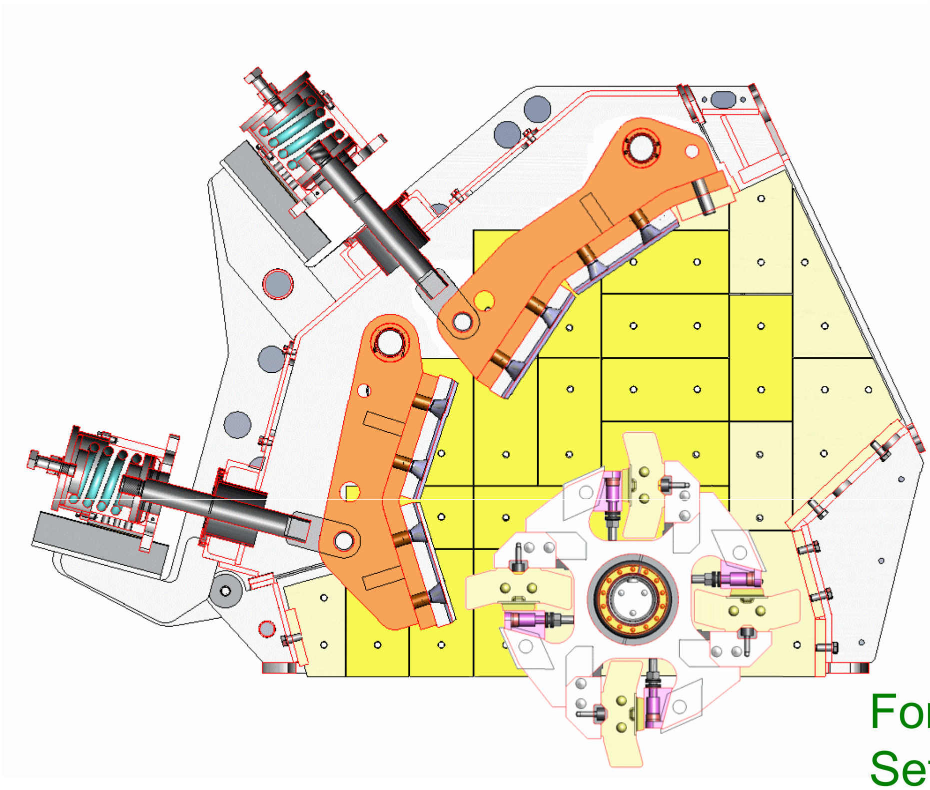


- 3- stage Jaw/cone Plant

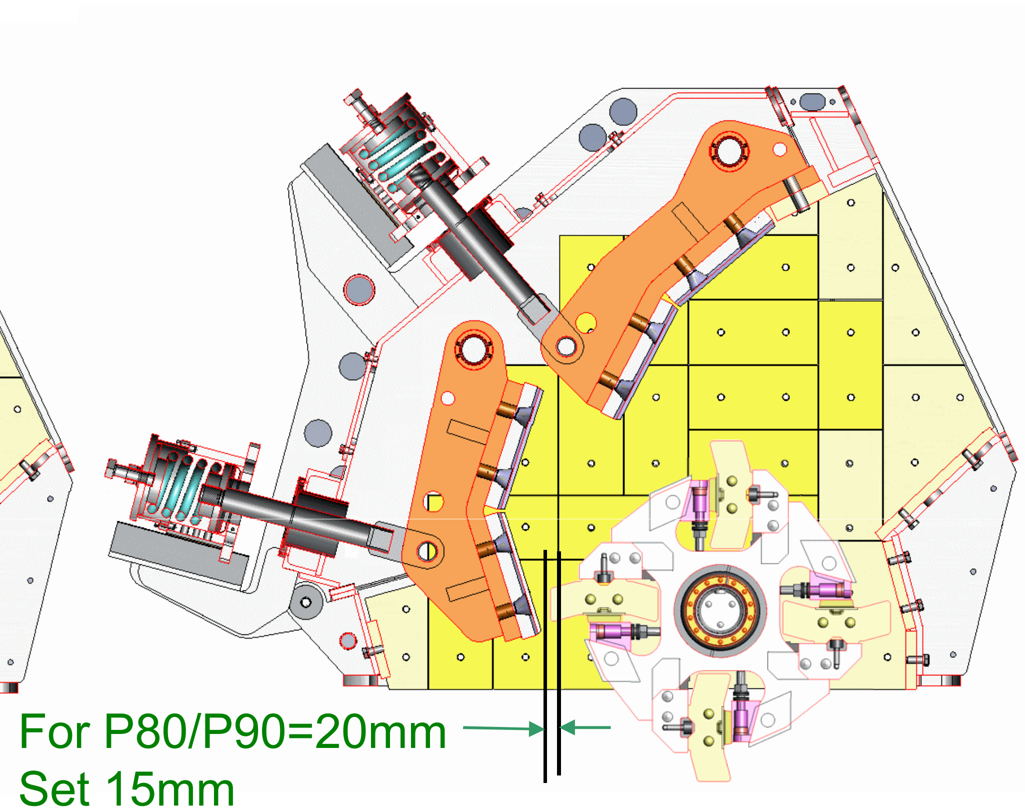
3x3x4=36

OK

Impactor Operation



Volume control by setting of top curtain



Product control by setting of bottom/third curtain

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The crushing chamber in a cone crusher is the most important part

All other parts in the crusher are ”only” there to hold the chamber in place or to create movement of the mantle.

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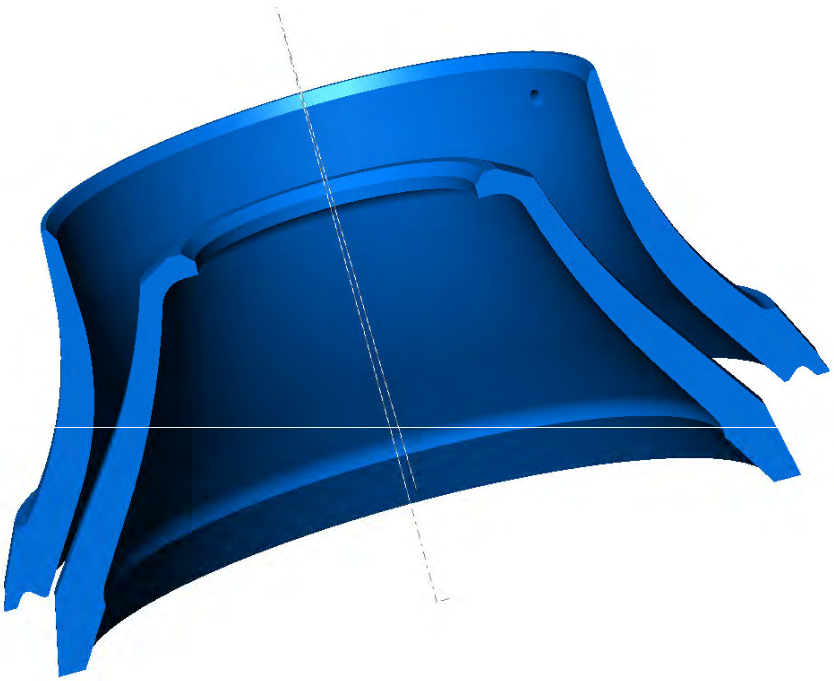
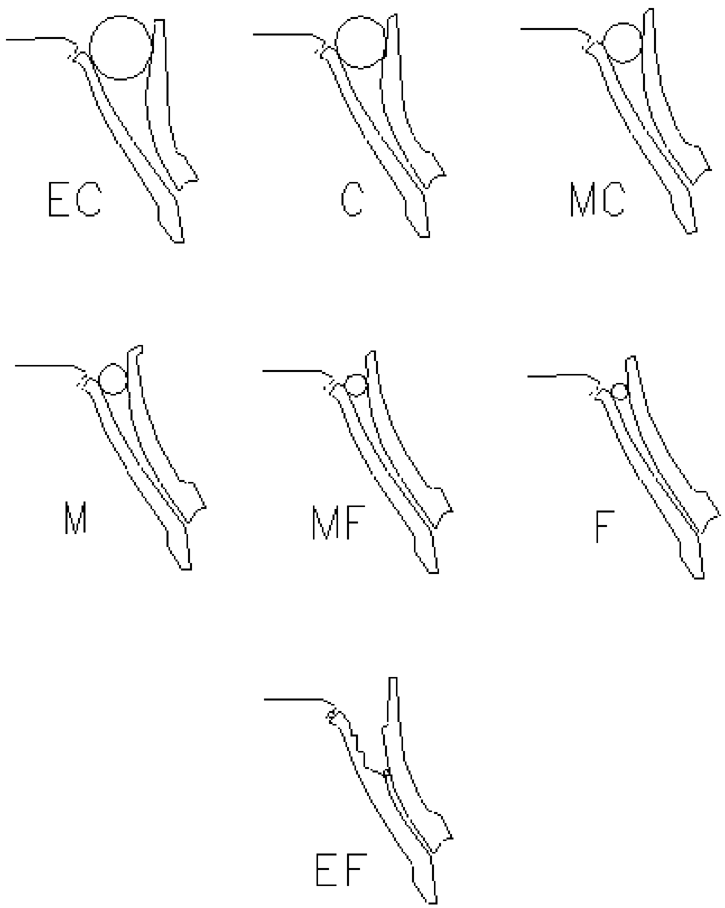
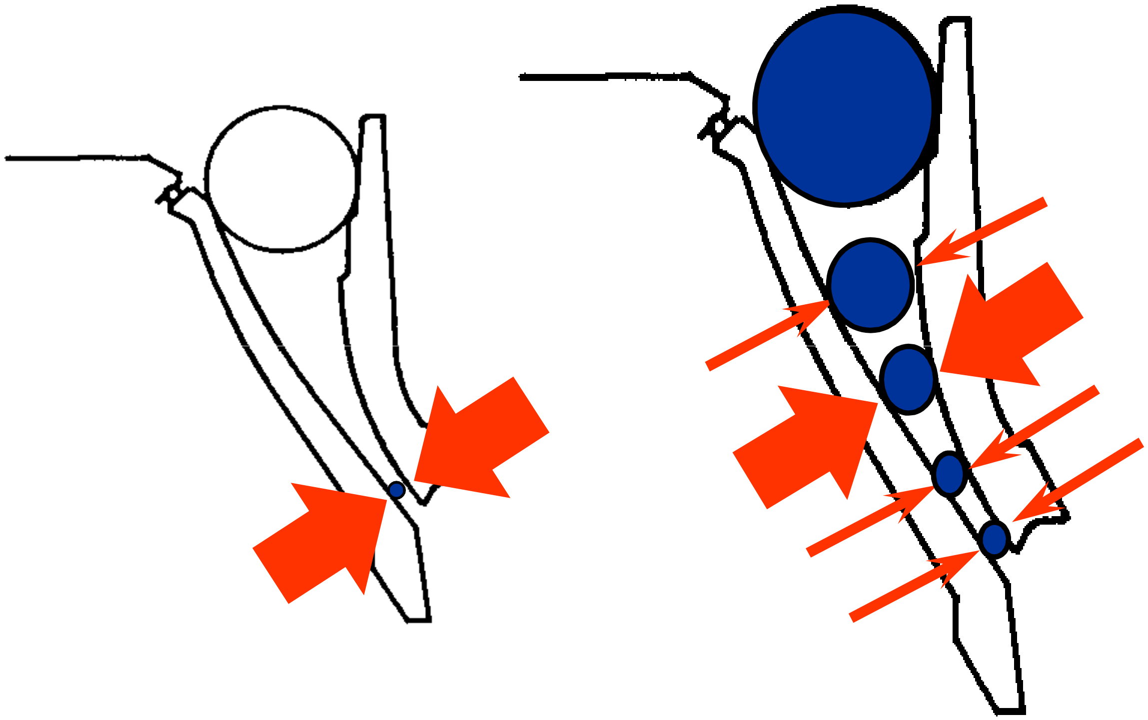
Why so many chambers?





All crushing starts with the chamber!

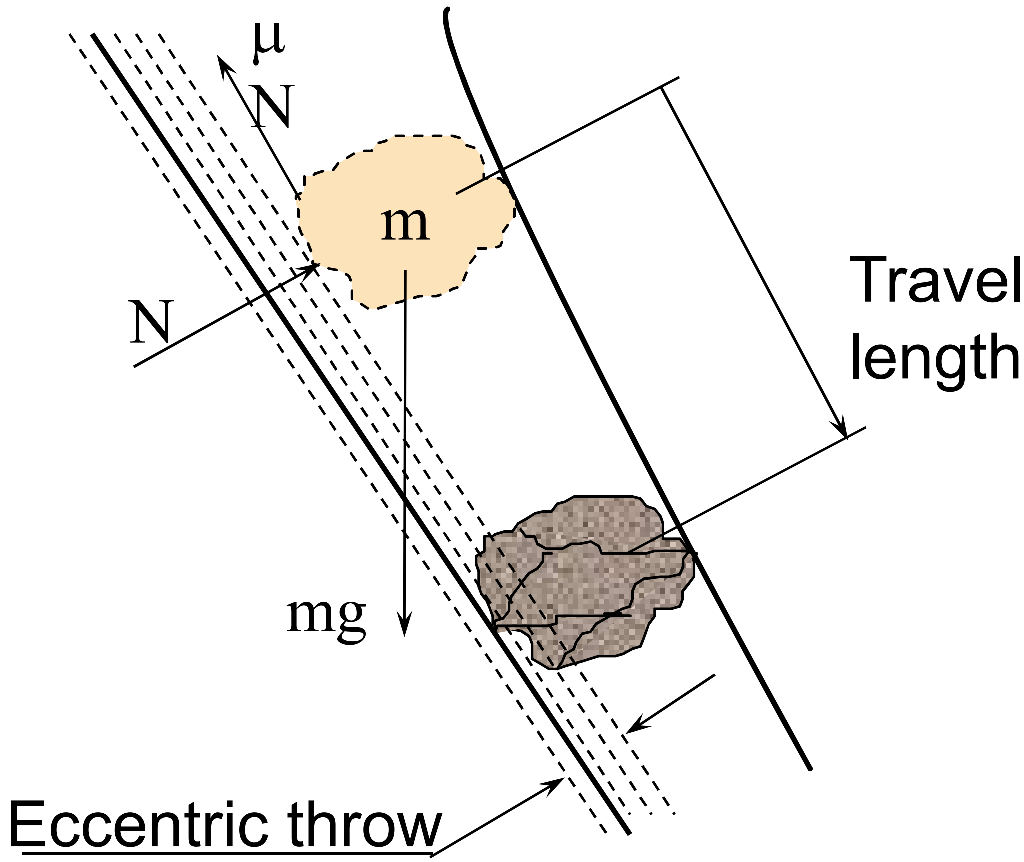
Why different chambers?



- Maximum energy utilisation.
- Avoid load peaks
- Prevent uneven wear

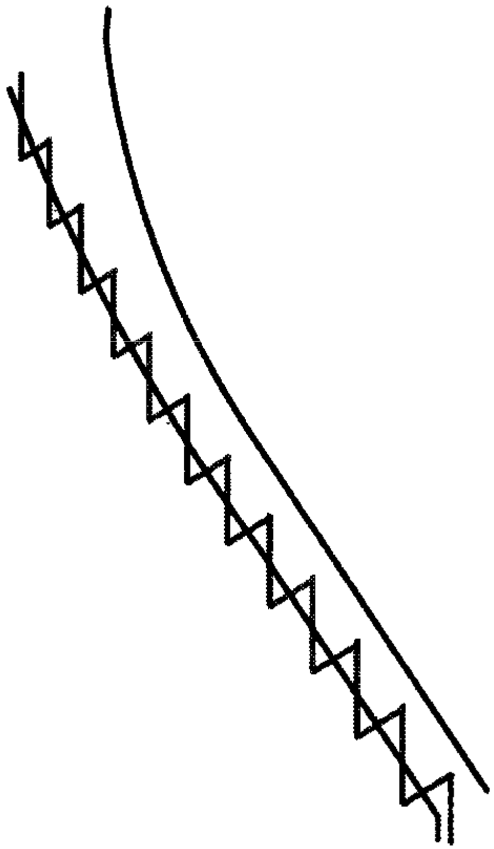
QUARRY ACADEMY

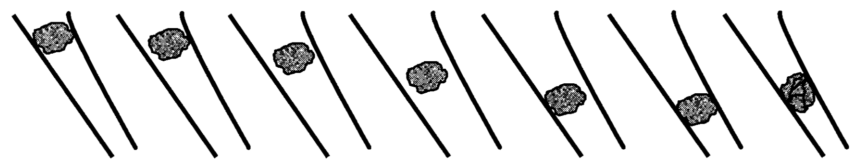
Each eccentric revolution means a crushing stage



Influence of speed

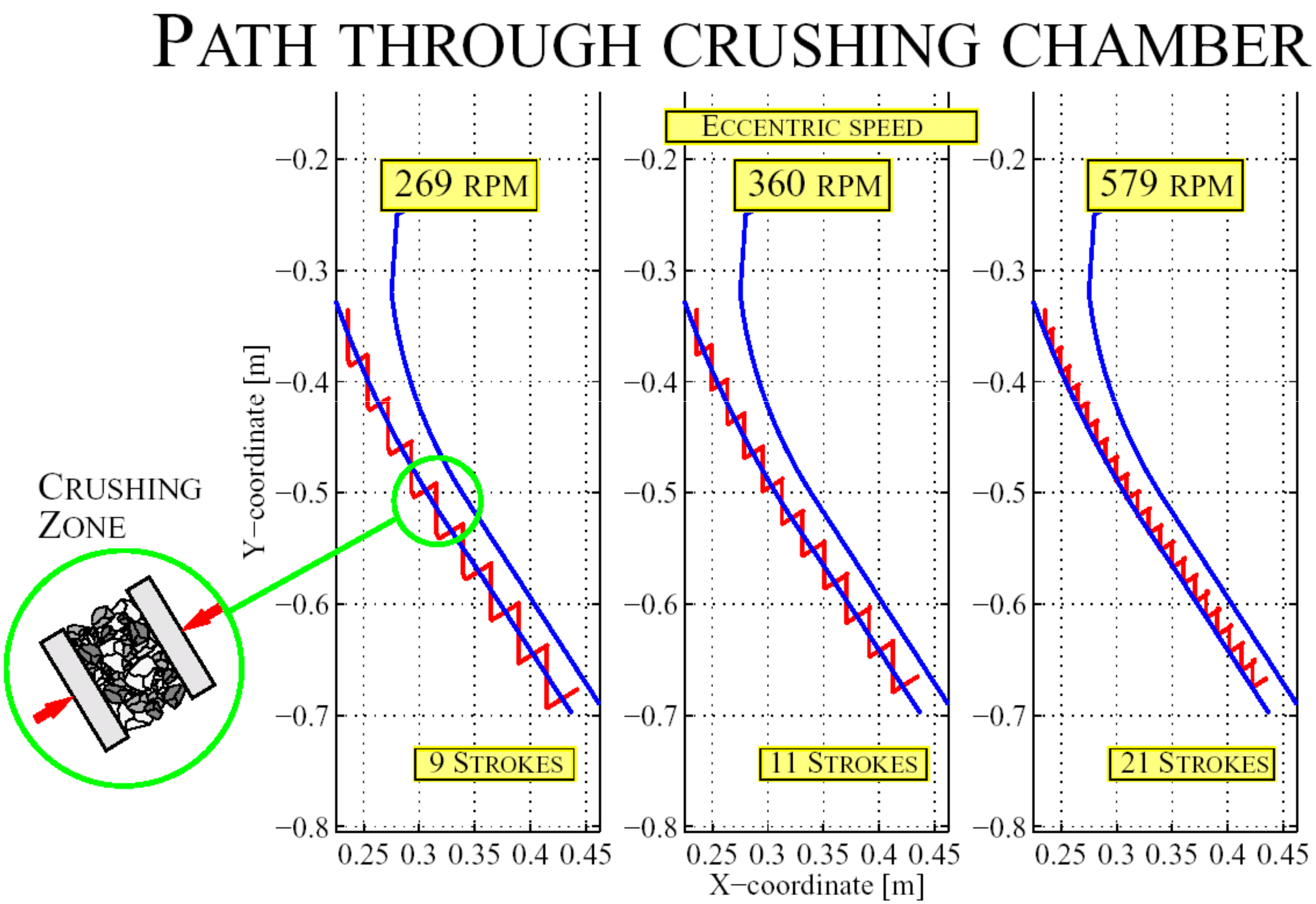
There are several crushing stages in the chamber





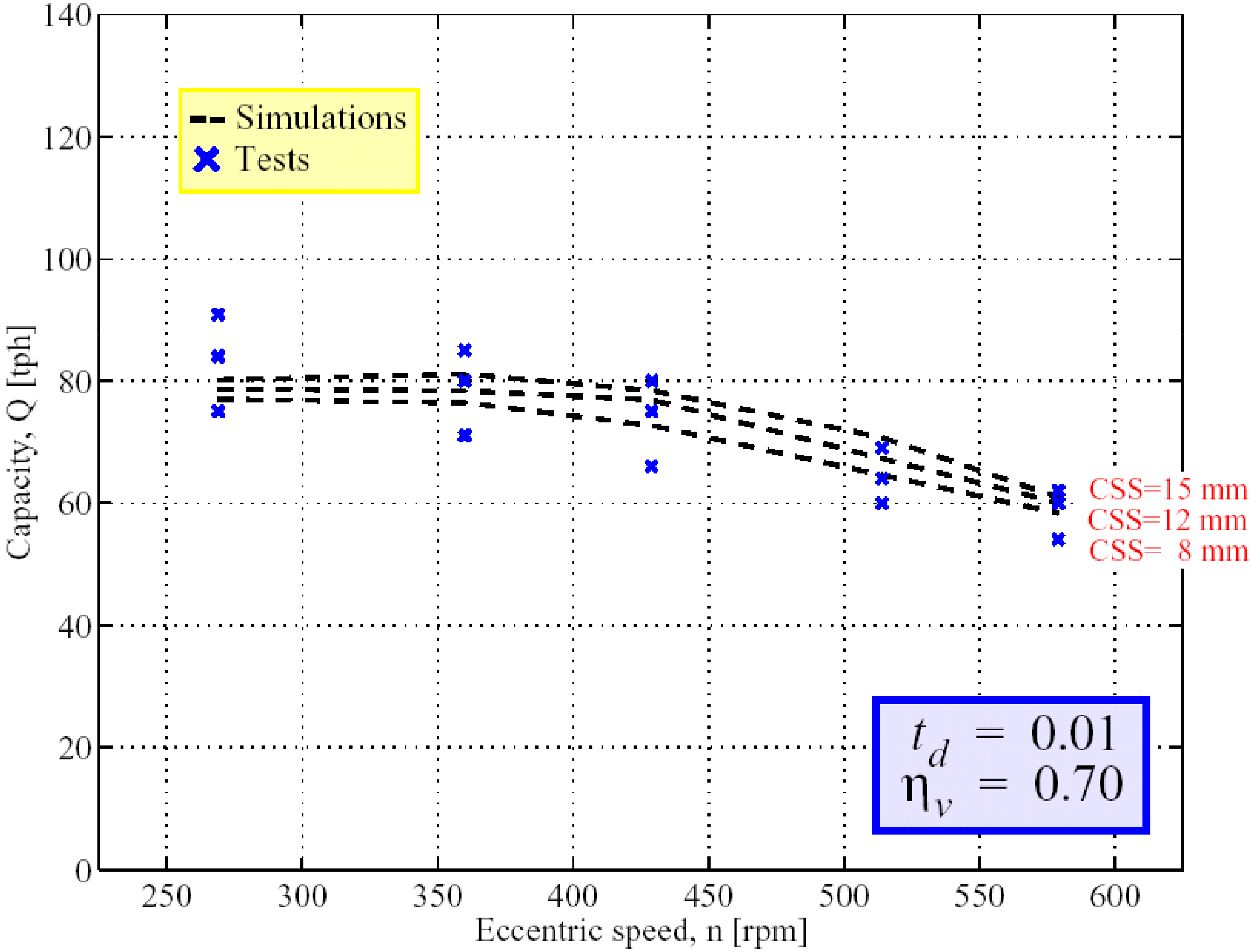
When the falling stone is caught, it is trapped and to some degree pushed upwards.

Influence of speed



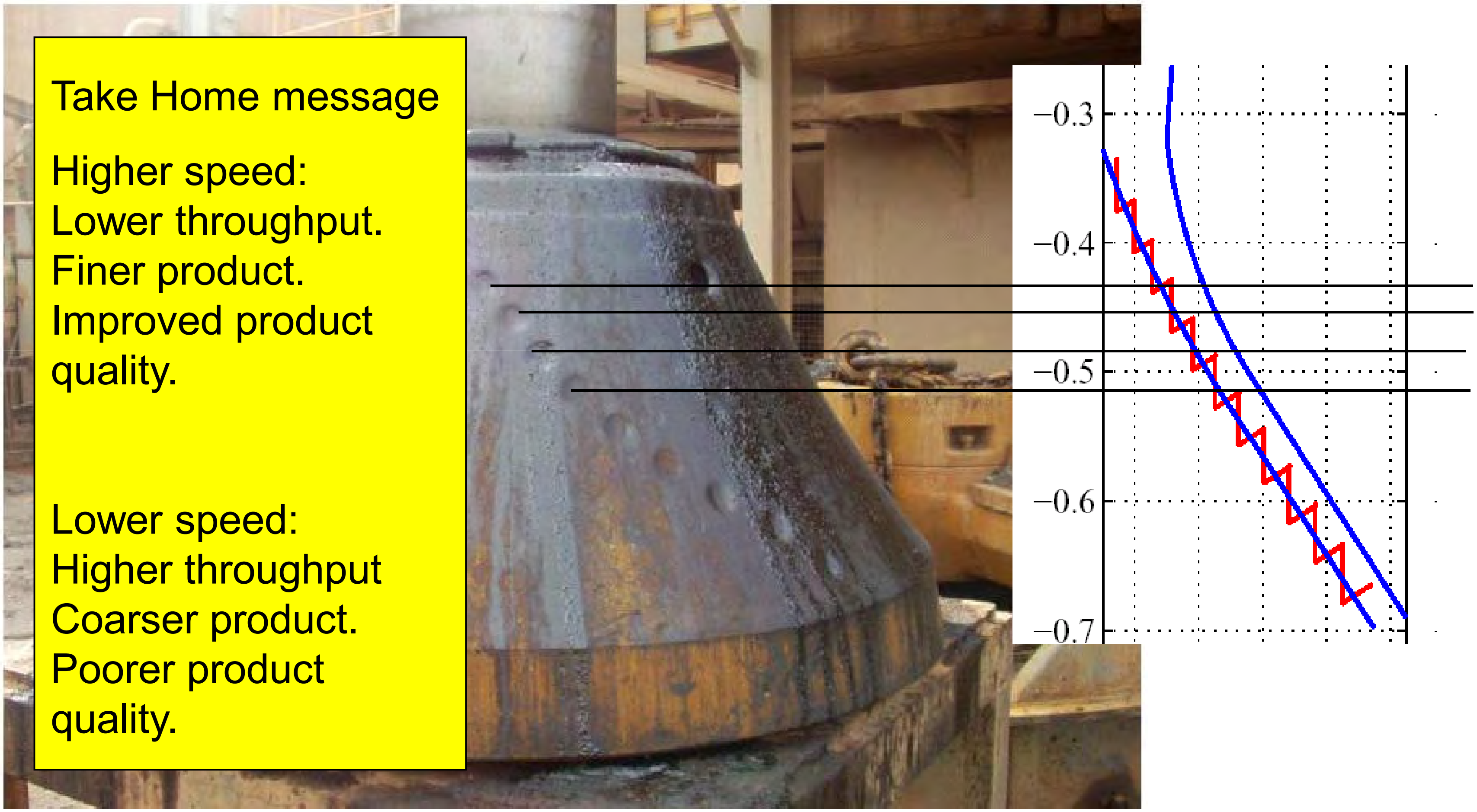
Speed v capacity tests.

CAPACITY



QUARRY ACADEMY

Practice prooves theory!



Take Home message

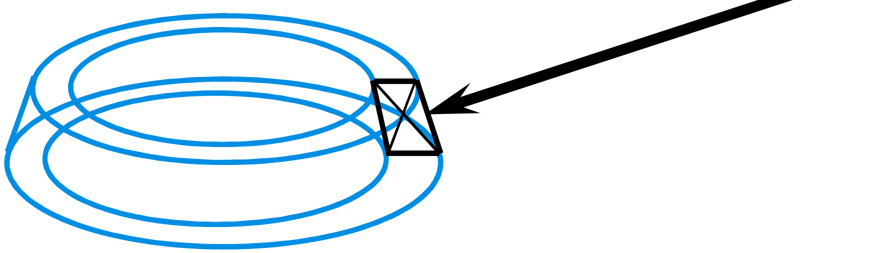
Higher speed:
Lower throughput.
Finer product.
Improved product quality.

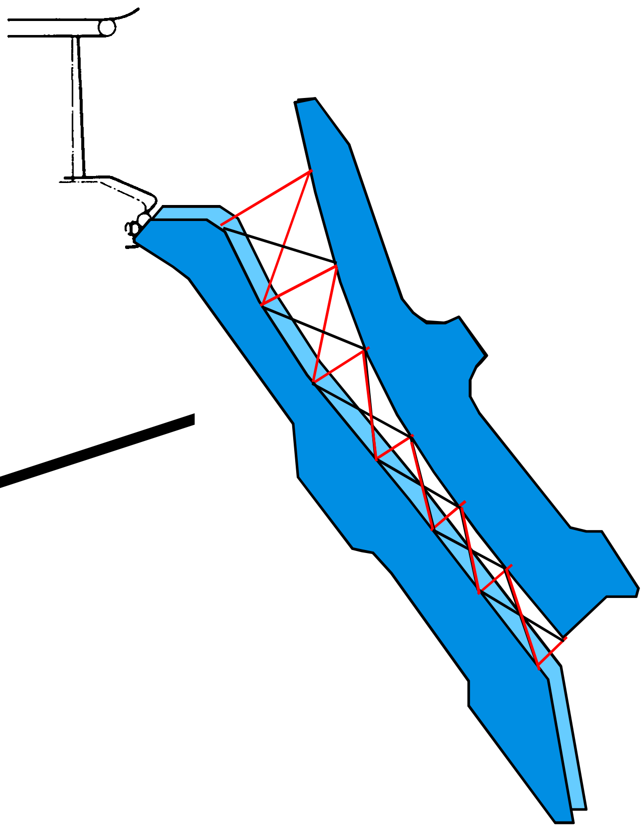
Lower speed:
Higher throughput
Coarser product.
Poorer product quality.

QUARRY ACADEMY

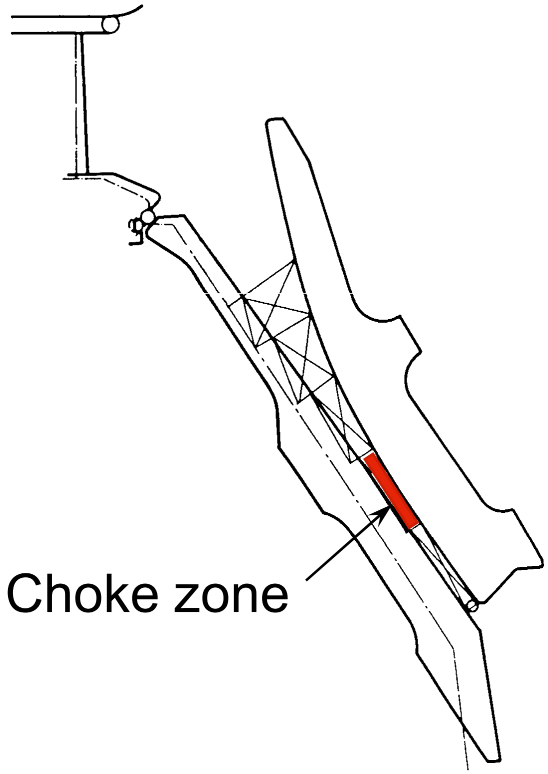
Each stage is represented by a crushing zone

Each ring volume represents the material that is crushed at each eccentric revolution.



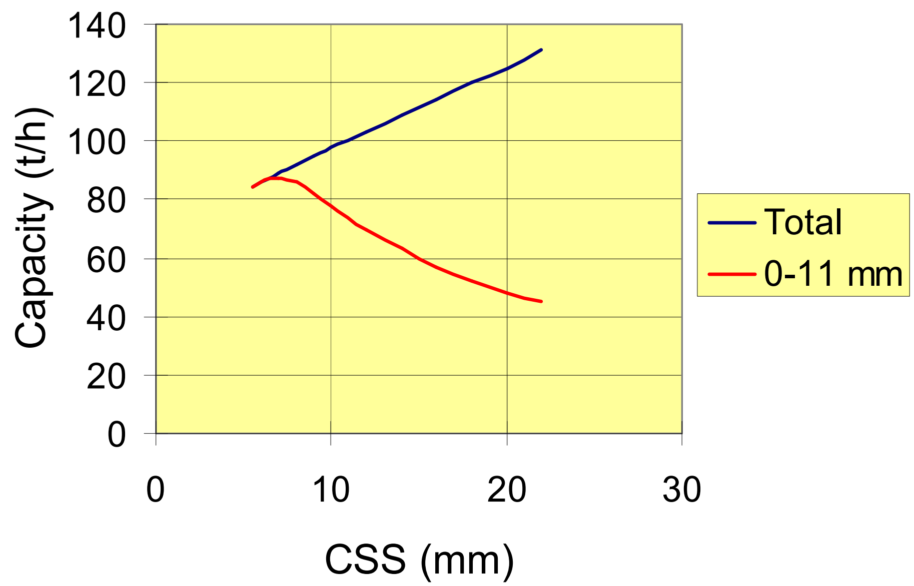


The zone with the smallest volume determines the capacity



The capacity is volumetric

Reduced C.S.S.: Increased net capacity



Small volume reduction in feed zone ➡ small total capacity reduction
Much smaller volume in discharge zone ➡ high size reduction ratio

Note: Capacity - C.S.S. relation is approx. linear

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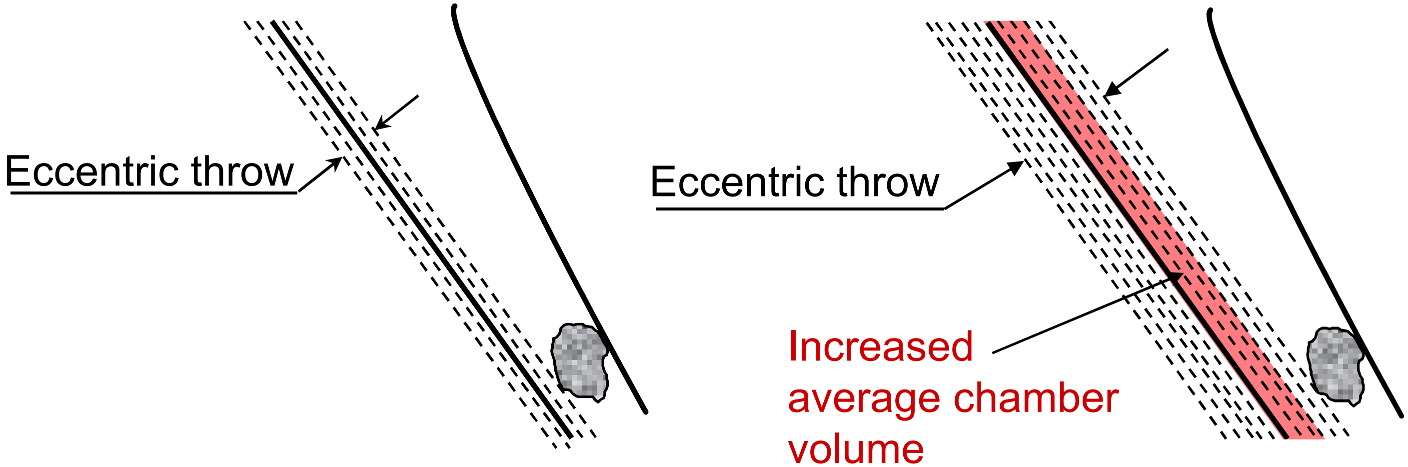
Reduced C.S.S.: Consequence map

C.S.S. reduction

Increased throw: Larger chamber volume



Small throw **Large throw**

Increased throw resulting in increased chamber volume means

- **higher capacity**
- **more stones in the chamber to compress**

QUARRY ACADEMY

Increased throw: Consequence map

Throw increased

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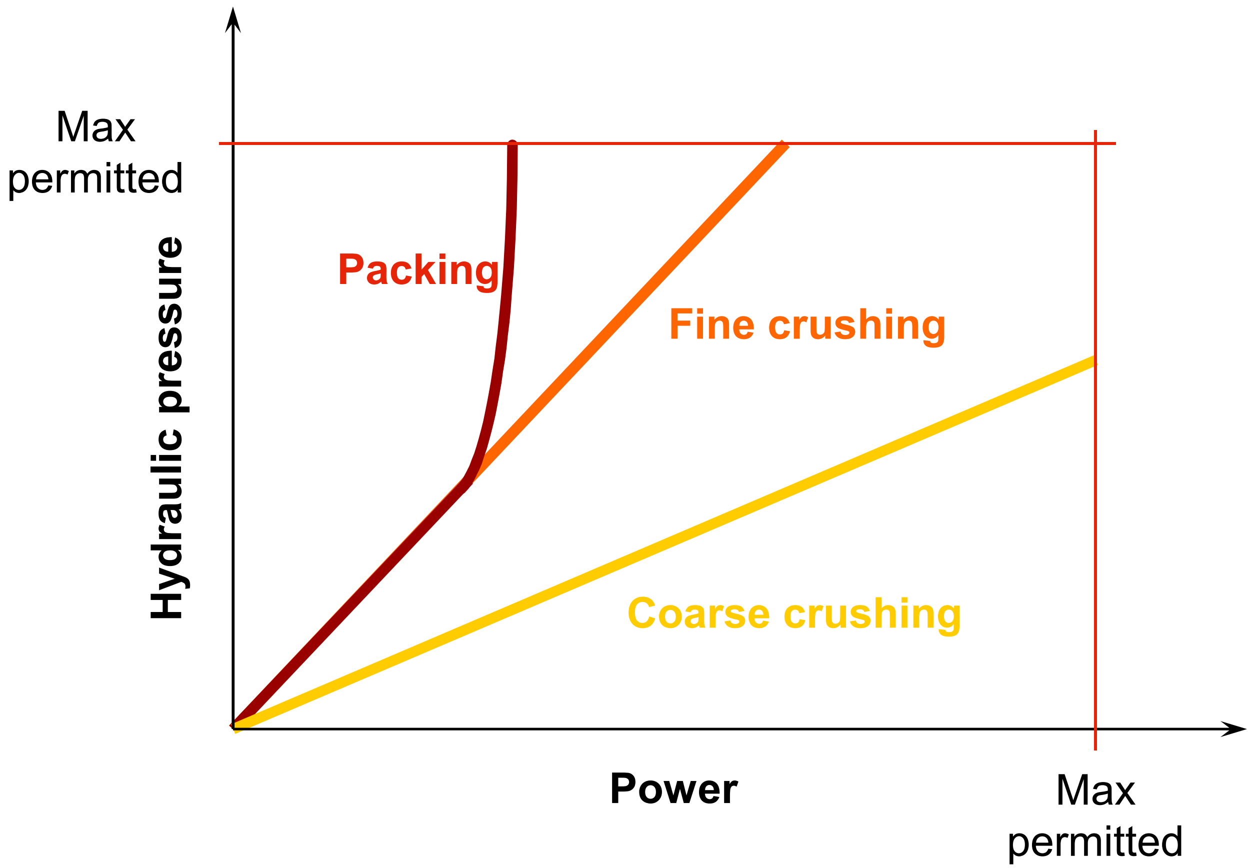
Relation between power and pressure



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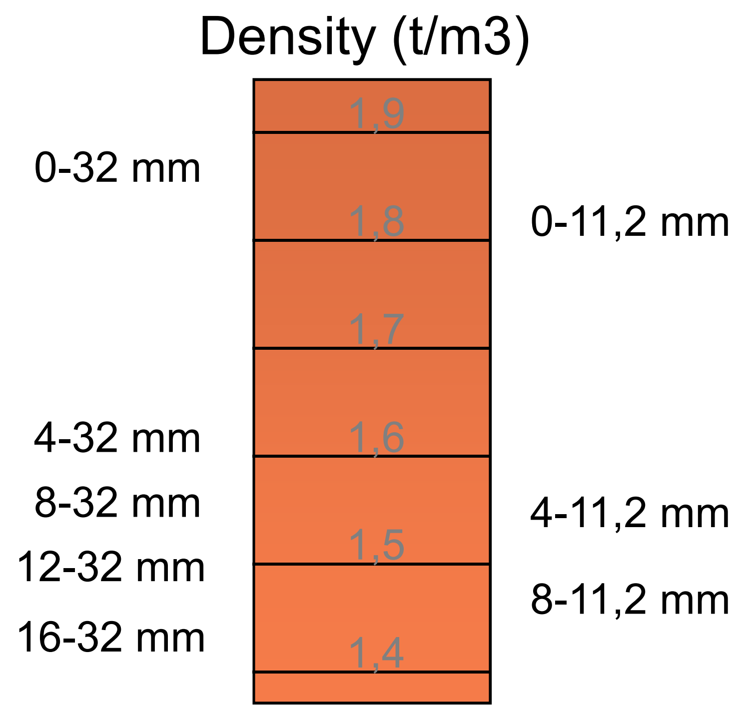
What happens if the feed size changes ?

Smaller feed size → **Capacity up**
Finer product
Better shape

Bulk density increases - higher risk of packing as feed becomes finer.



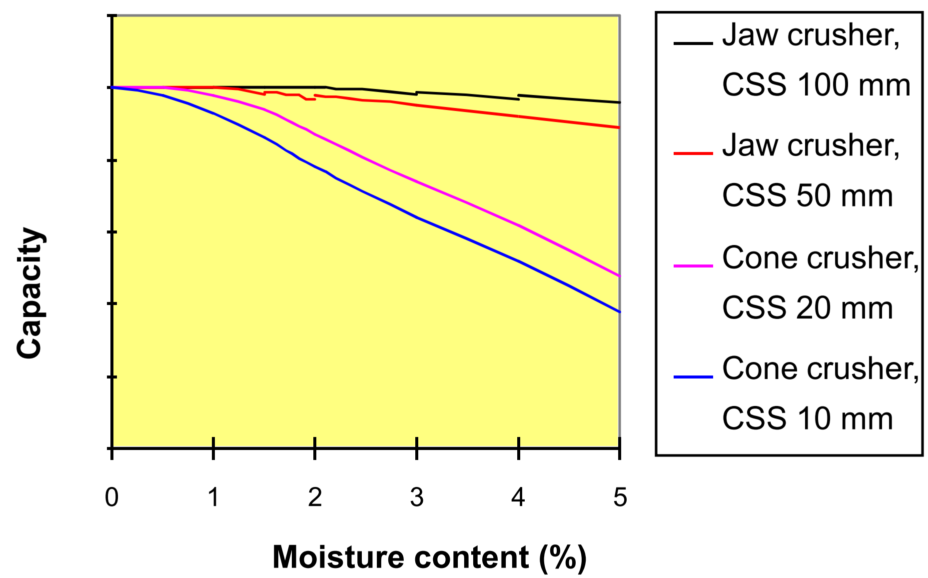
What happens if other feed characteristics change?

Tougher rock

- **Increased crushing force and power draw**
- **Coarser product size**

Increased moisture content

- **Lower capacity**



What happens if other feed characteristics change ?

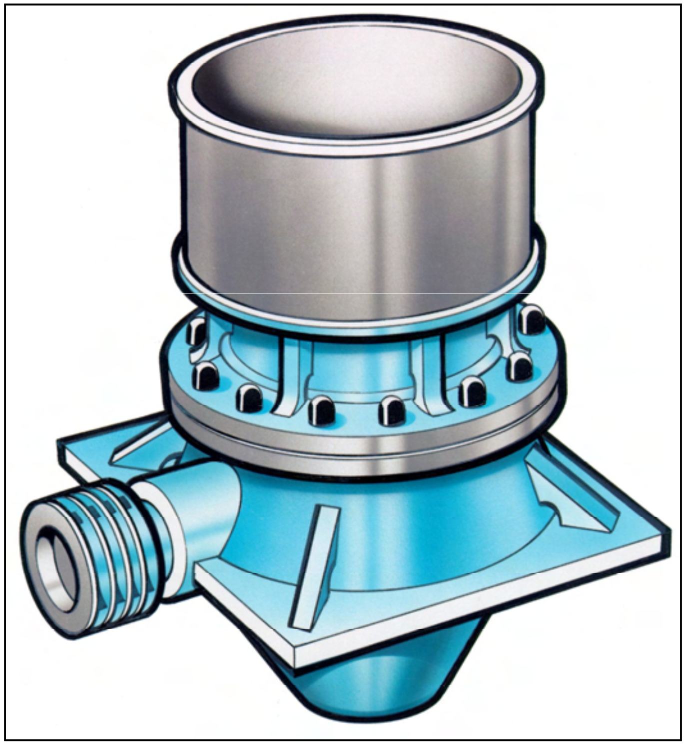
Higher density ➡ Higher capacity

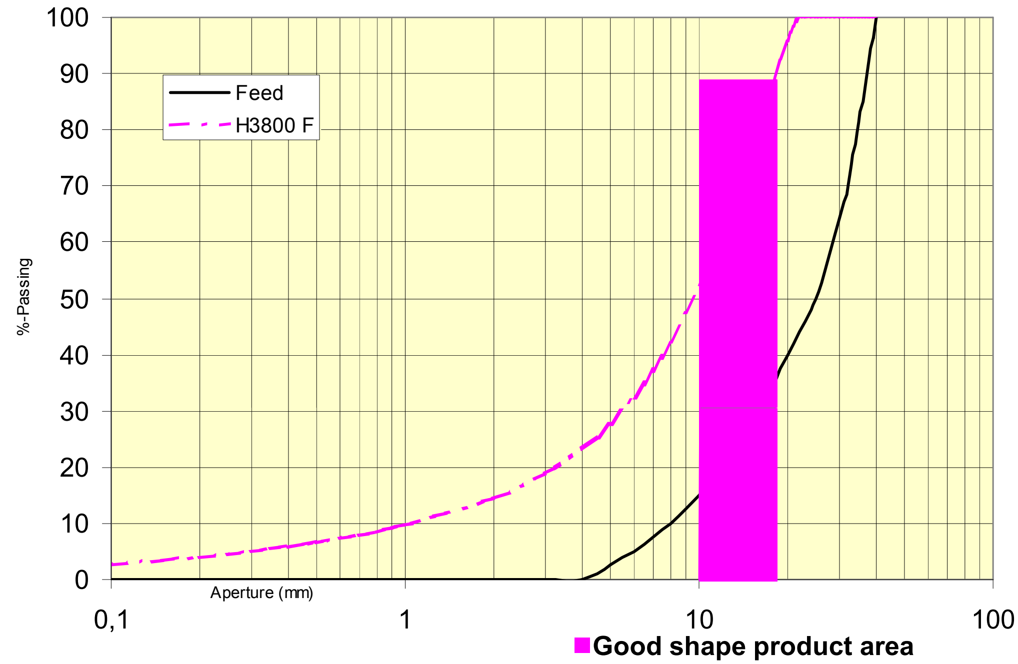
Improved feed particle shape

More cubical
Rounder shape ➡ Faster flow ➡ Higher capacity

QUARRY ACADEMY

Cone Crushers
Product Quality

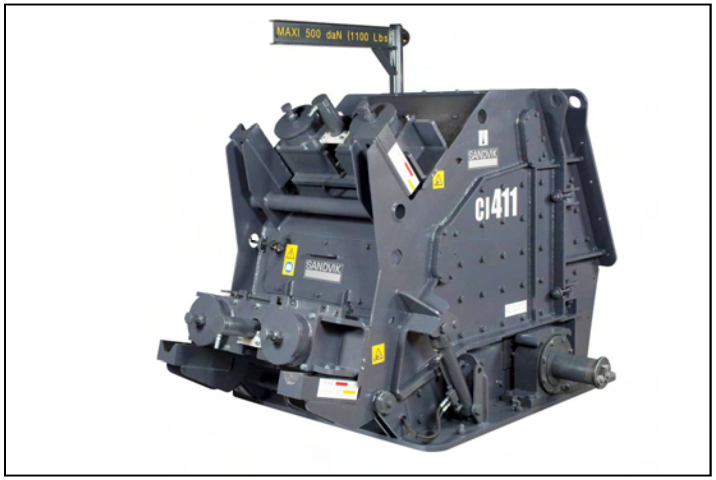


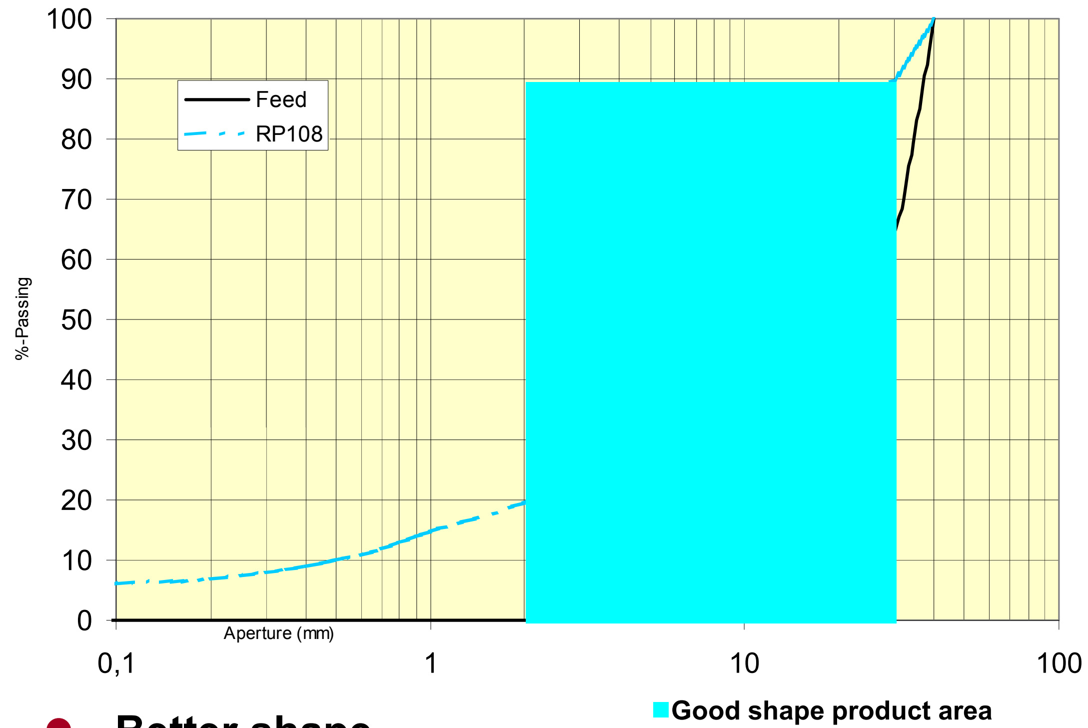


- Good Flexibility
- Higher crushing forces
- Good shape in the 5-80 mm range
- Uniform reduction ratio

QUARRY ACADEMY

Impactors – HSI and VSI
Product quality





- Better shape
- Good shape in the +40 micron range
- Uneven Reduction
- Limited topsize capacity
- High fines production

QUARRY ACADEMY

Crushing General

Take Home Messages

1. **Do you have the optimum chamber fitted to your crusher**

2. **Where available, do you have the optimum throw**

   1&2 are volumetric issues and may well determine the utilisation of the crusher ---remember all crushers work best when continuously choke fed

3. **Do you have the crusher setting optimised.**

4. **Is the feed condition correct—have you removed the risk of packing**

5. **Do you have the optimum speed**

QUARRY ACADEMY

Operating principles
The crushing result is difficult to predict

Input parameters

Crushing result

	Chamber size	Chamber design	Eccentric speed	Eccentric throw	Setting (CSS)	Feed material strength	Feed size	Feed shape	Feed moisture content
Capacity	X	X	X	X	X		X		X
Power consumption	X	X	X	X	X	X	X	X	X
Crushing force	X	X	X	X	X	X	X	X	X
Product size	X	X	X	X	X	X	X	X	X
Product shape		X	X	X	X	X	X	X	
Product strength	X	X	X	X	X	X			

X = Interdependency

Influencing factors

Take Home Message

All crushers have a volumetric and a mechanical limit.

Toughness of material, feed material grading analysis ,volume and reduction ratio all play their part in the ability of the crusher to perform the duty over an acceptable lifecycle.

If any combination of these factors overstress the mechanical capability of the crusher it will be necessary to reduce the influence of another.

EG -The demand for greater throughput at the expense of reduction.

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Conclusions

- the work done in a crusher is dependant on

- material factors such as
1. toughness,
2. bulk density
3. feed size analysis

- machinery factors such as
1. setting
2. throw
3. chamber volume
4. speed

Take Home Message

There are so many variables that to maximise performance it is necessary to understand how these factors and any consequent wear affect the end result.

This can only be done by in-process testing.

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Problems

Some areas of concern which destroy good operation with cone crushers

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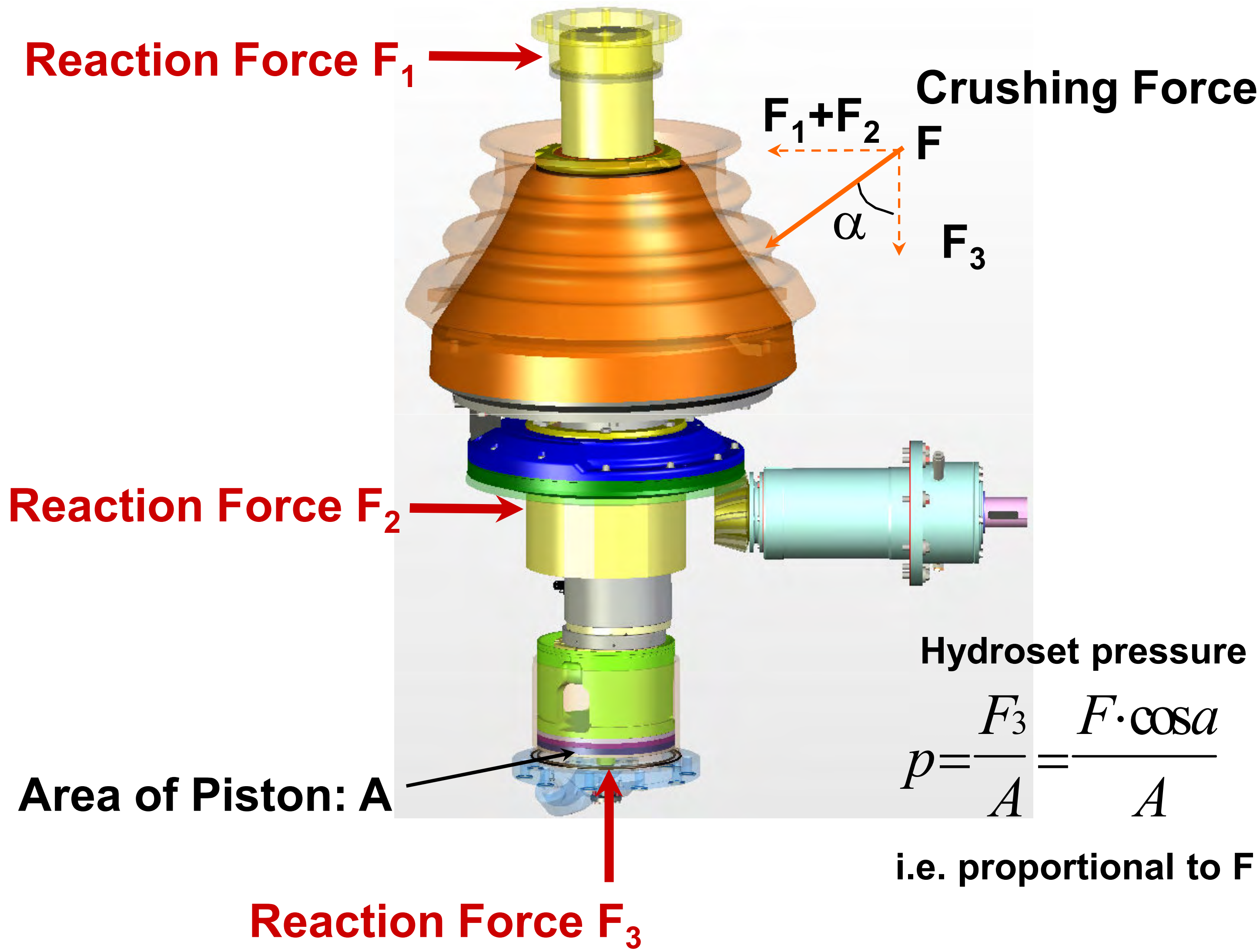
Cone crusher

Pressure Reflects Crushing Force



Hydroset pressure

$$p = \frac{F_3}{A} = \frac{F \cdot \cos a}{A}$$

i.e. proportional to F

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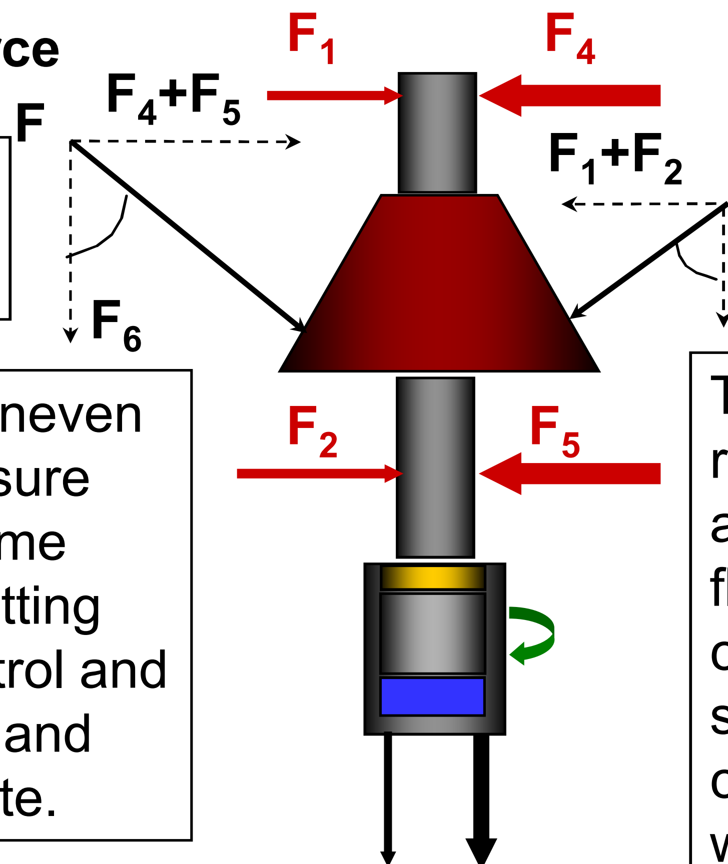
Reaction to uneven, segregated feed

Crushing Force

F4 +F5 > F1+F2

F3 > F6



Crushing Force

F

F_3

As wear becomes uneven the power and pressure fluctuation will become exaggerated, the setting more difficult to control and the product grading and quality will deteriorate.

Throughout every revolution both power and pressure will fluctuate considerably, causing extreme cyclic stress on machine component parts. This will require the setting to be run wider than necessary

Zero reaction at any point during the revolution will suggest a portion of the chamber is empty

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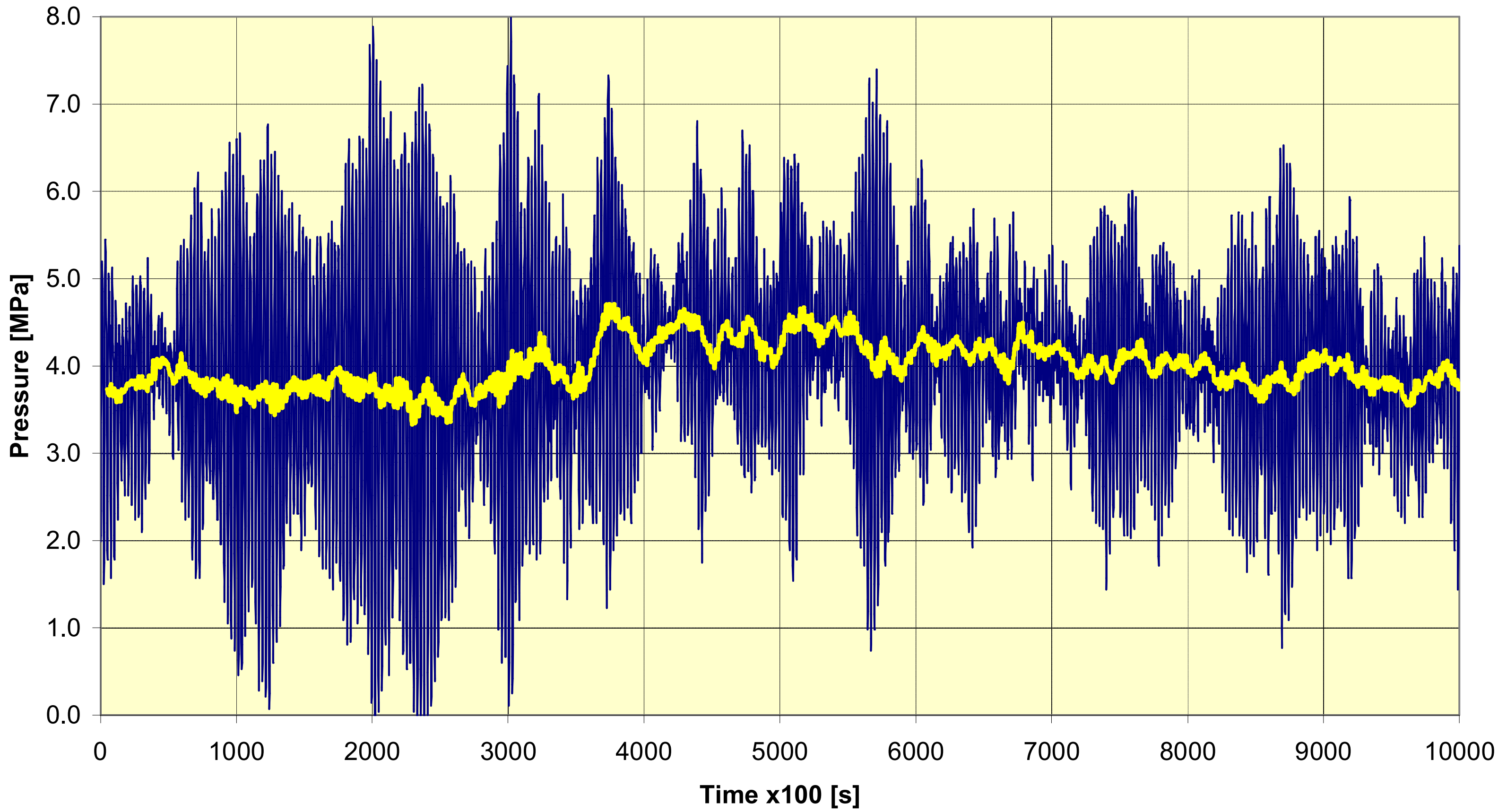
Misaligned feeding at El Teniente,Chile CH880
Tertiary application

Segregated feed- High pressure amplitudes



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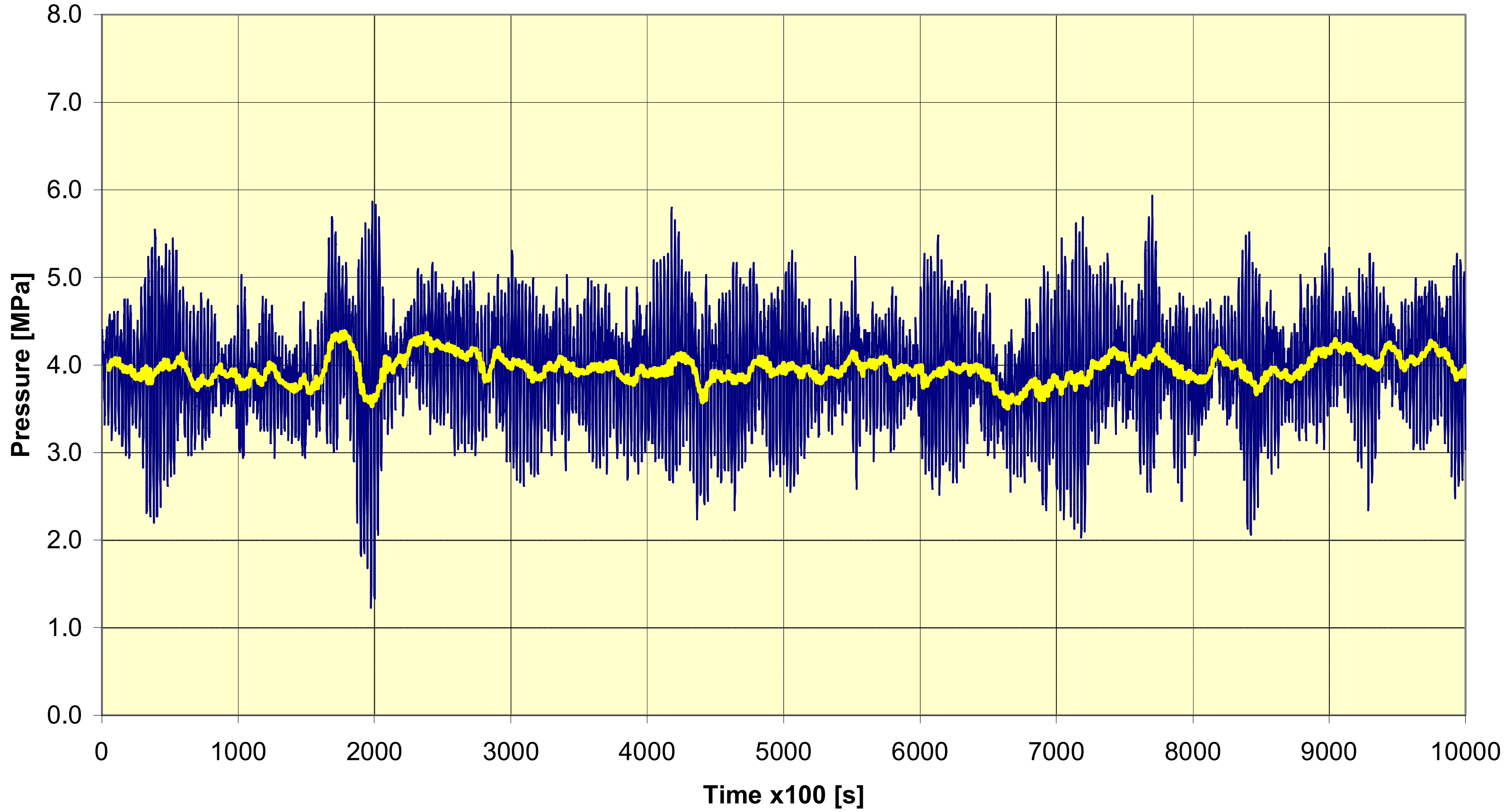
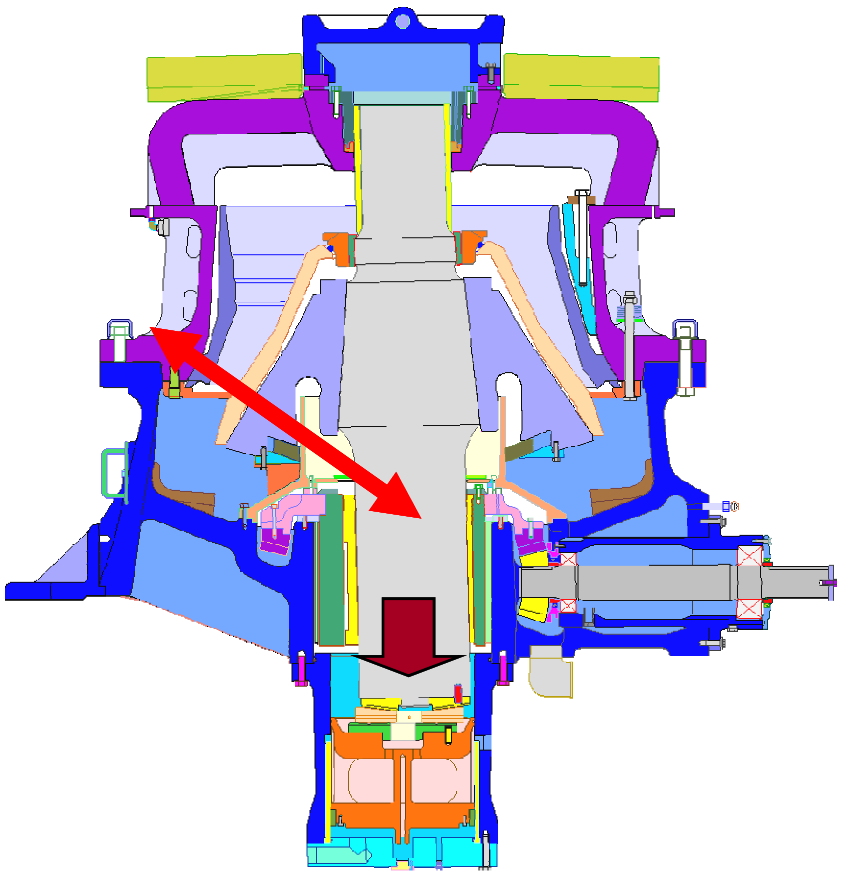
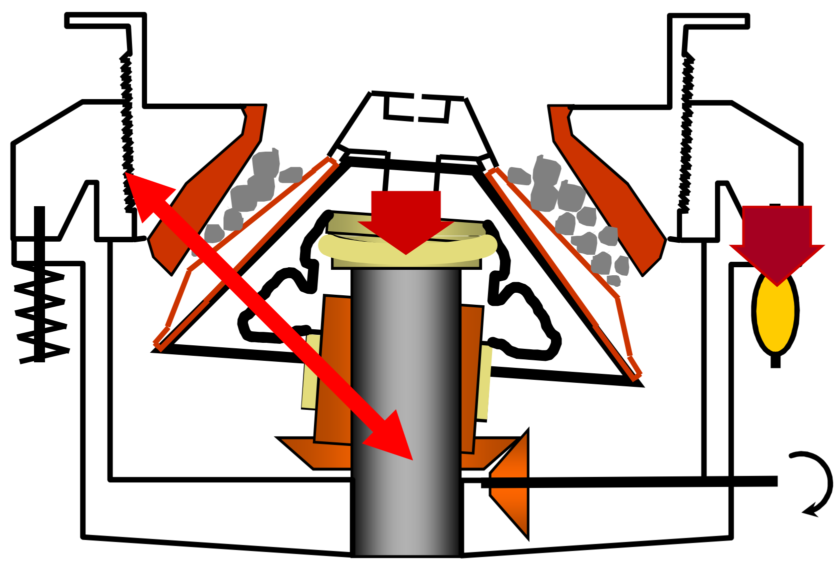
Improved segregation

Unsegregated feed- Low pressure amplitudes



Effects of vertical crushing force





Vertical force taken by single hydraulic cylinder

Vertical force taken by cylinders used to hold topshell to bottomshell

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What are the negative effects?

- High power and pressure will cause the crusher to be run at wider than necessary settings resulting in coarser product producing higher recirculating loads with increased conveying, wear and crushing costs.

- Occasionally the necessity for increased crushing will demand increased capital investment.

- Segregated and poorly distributed feeds will cause the crusher liners to wear unevenly,again with deteriorating performance and associated costs.

- This applies also to poorly fed HSI crushers where hammer wear and curtain liner wear is biased to one side.

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What are the negative effects?

- Product will become coarser and cubicity, often in critical products, will deteriorate. What cost??

- Segregation and uneven wear will cause reduction in liner life through premature exchange. What cost??

- Segregation and uneven wear will cause reduction in mechanical component life, sometimes leading to traumatic failure and the costs of unplanned stoppages.

- THE CUMMULATIVE EFFECT ----- CONSIDERABLE COST TO THE OPERATION.

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Poor feeds-Inclined belt conveyors

A common feed method, but unless considerable care is taken,possibly the most <u>unsatisfactory method</u> of feeding cone crushers.

- Material is segregated by the "tamping" action of the idler sets as material passes over.

- Belt speed.

1. Material leaving the end pulley follows a parabola. The path depends on the speed of the belt.
2. Coarse material, with greater mass, will tend to travel further than finer material.
3. This segregation will become more pronounced the greater the differential size and the higher the conveyor speed.

- Belt width. Improvement in materials and restrictions on capital investment have possibly created a trend towards narrower but higher speed belts. These not only segregate but lack the capability to distribute sufficiently.

- Discharge height.

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