2019 NSSGA AGG1

AGGREGATES ACADEMY & EXPO

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REV YOUR ENGINES!

Optimizing Plant uptime and OPEX

Learn how to improve your plant profitability

AGG1 2019 – Indianapolis, IN

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Metso Minerals Inc.

2019 NSSGA AGG1 AGGREGATES ACADEMY & EXPO

Content

- Crushing plant uptime
- OPEX elements in Crushing plant
- Effects on profitability
- Crushing plant setup effect
- Primary crushing considerations
- Cone crusher considerations
- Factors affecting OPEX

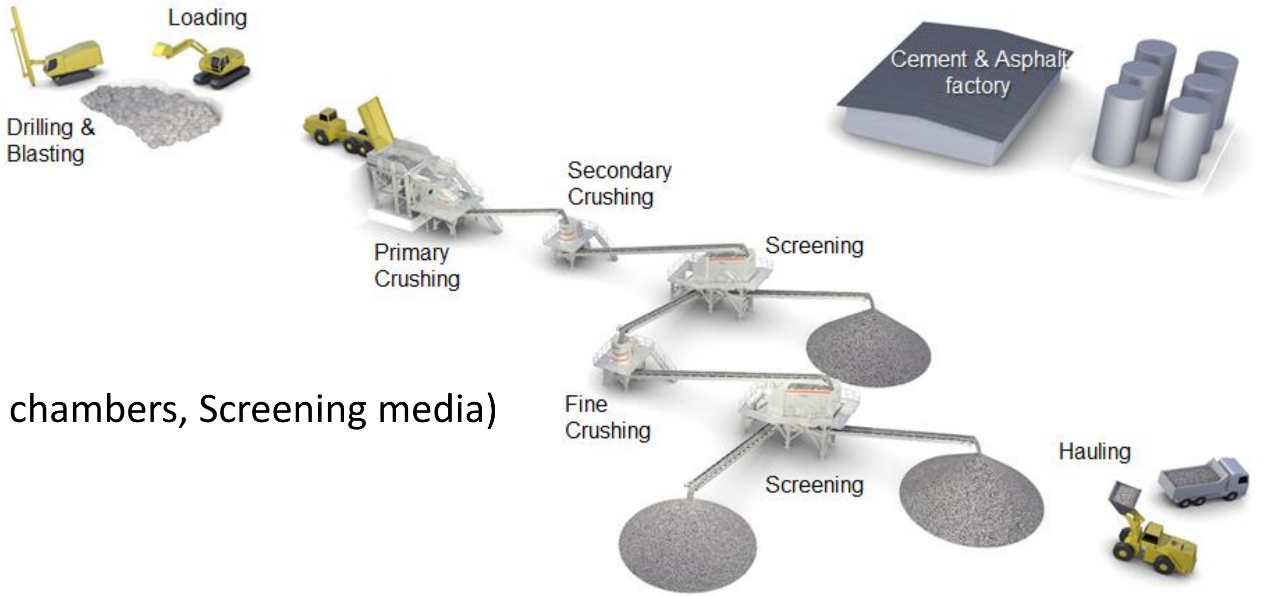
Crushing plant uptime

- Part of active time during which the system is either fully operational or is ready to perform
- Basically uptime is optimized when crushers are running fully loaded all the available time
  - No unplanned maintenance or repairs
  - Crusher performance is utilized well

- Why is the optimized uptime the goal?

Crushing plant OPEX elements

- Rock material
- Drilling & Blasting
- Loading
- Crushing
  - Energy
  - Wear parts (Crushing chambers, Screening media)
  - Spare parts
  - Labor
- Hauling



Operational cost optimization

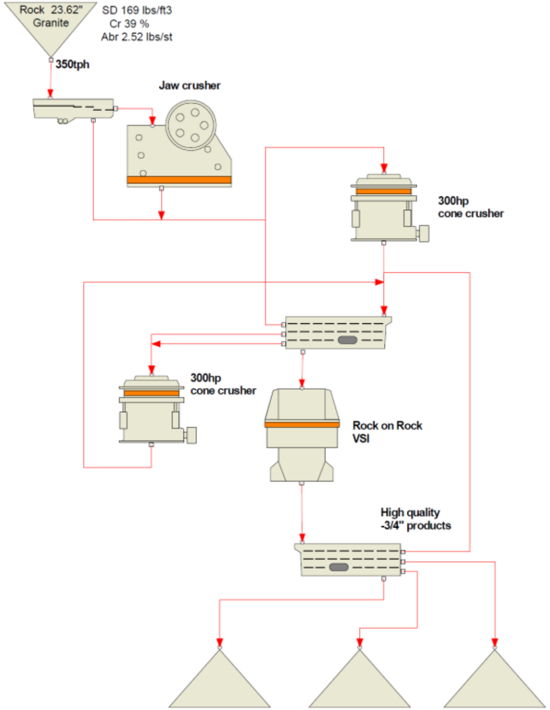
- Some costs are generated anyhow – otherwise plant can't run
- Cost itself – not 100% relevant
- Better measurable: cost allocated to achieved tons of production

- Best value for the money spent is the target!

Cost split of a crushing plant, example

Rock material → Drilling → Blasting → Crushing → Loading → Hauling → Sales, General & Admin

Financial item	kUSD	% of sales	
Sales	4,490		
Cost elements:			
Rock material	260	*6*	
Drilling	470	*10*	
Blasting	660	*15*	
Crushing			
• Energy	220	*5*	
• Wear parts	350	***8***	
• Spare parts	140	*3*	*23*
• Labor	190	*4*	
• Capital cost	110	*3*	
Loading	420	*9*	
Hauling	1,080	*24*	
Sales, General & Admin	270	*6*	
Operating profit	320	***7***	

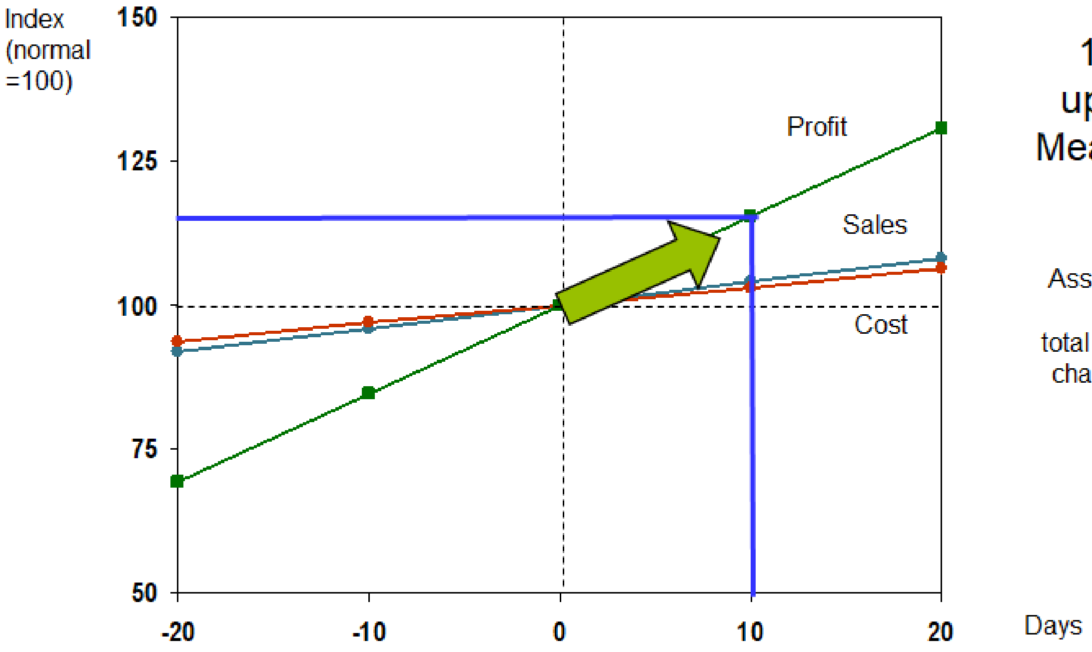


Elements affecting profitability

Profit impact of **lower costs**	Impact on profit
• 1% lower wear part use	1.1%
• 1% lower energy use	0.7%
• 1% lower labor use	0.6%

Profit impact of **higher output**	Impact on profit
• 1% higher capacity with same fixed costs	4.3%
• 1%-point higher process availability	4.3%
• 1 day higher utilization per year	1.5%

Plant uptime has a strong effect on profit



10 Days more uptime Per Year Means >15% more Profit

Assumes labor in crushing and 70%...90% of total costs in other crushing chain steps to be variable

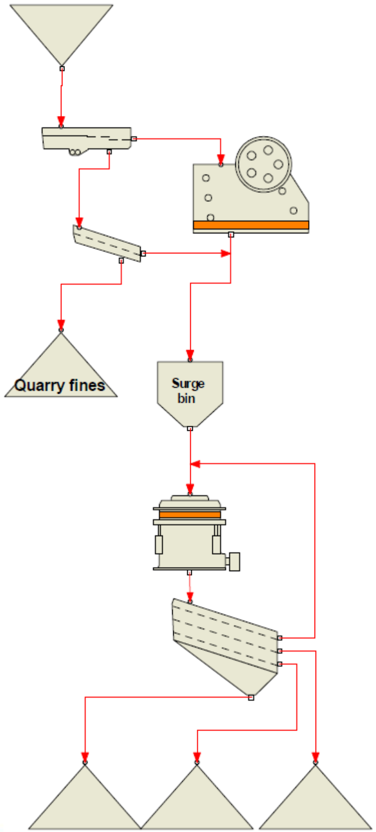
How crushing plant setup and equipment selection affect uptime & plant performance

Main Crushing Plant Considerations

- Simplicity = Availability = High uptime
- Primary stage oversize handling
- Production vs. Operation vs. Maintenance
  - Smaller layout -> easier to get around
  - More access to equipment -> easier maintenance
  - Surge protection and feed control to equipment -> more uptime
- Layouts discussed:
  - Separated crushing stations / stages
  - Screen- to- crusher stations
  - Cascade design

Separated Crushing Stations

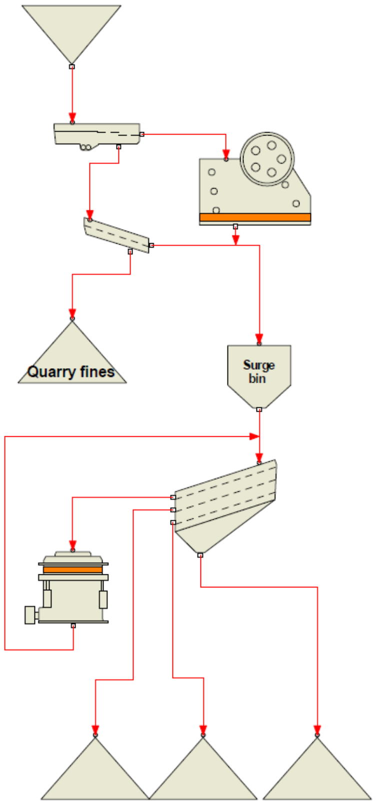
- Crushing stages are separated by use of surge bin(s) or surge pile(s)
- Offers the best utilization of equipment
  - Surge protection before crusher / Controlled feed rate to crusher
- Arguments for:
  - Higher utilization -> higher production
  - Better protection of high $$ equipment (crushers)
  - Easy to design crushing stations for proper feed arrangement
  - Consistent good quality product



Separated Crushing Stations

Screen-to-Crusher Design

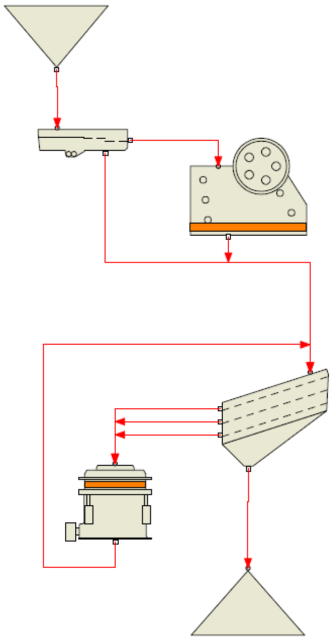
- Each crushing stage contained at their respective station
- Screen feed directly to crusher:
  - No conveyor needed
  - Feed control to crusher is challenging
- Arguments for:
  - High design capacity
- Arguments against:
  - Lowered utilization of crushers
  - Often lowers crusher availability, quality consistency and shape of product due to poor feed arrangement



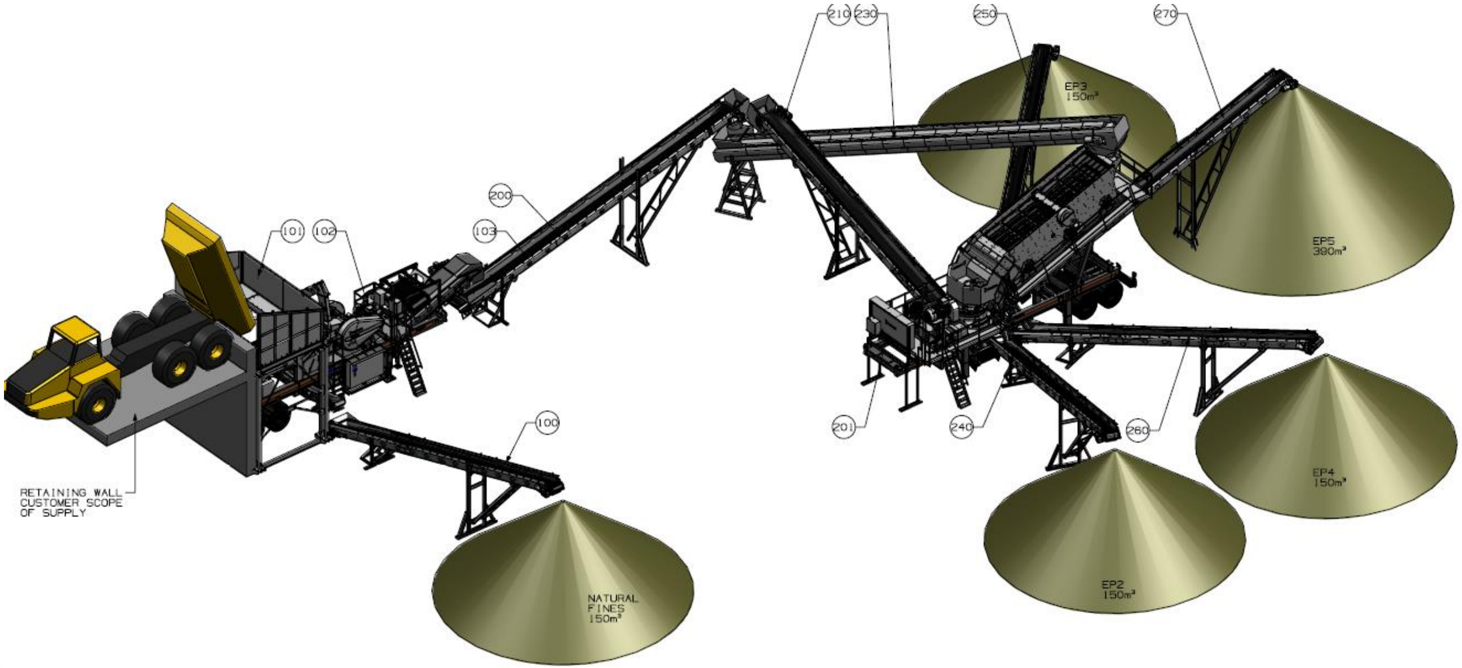
Screen-to-Crusher Design

Cascade Design

- Common in mobile plants where product shape quality is not important
- Process control after initial feed is lost
- Arguments for:
  - High capacity
  - Quarry fines mixed into the product
- Arguments against:
  - Poor process control = poor utilization
  - Product shape and consistency are not perfect



Cascade Design



Availability & Utilization = uptime

- Design capacity (instantaneous): Maximum plant can do at one time
- Nominal design capacity: Estimated throughput of plant over time
- Why not the same?
  - Mechanical availability of equipment
  - Utilization of equipment
    - Natural fluctuations in plant feed
    - Non-uniform flow rates / blockages
    - Inherent changes in equipment performance over time
- Definitions
  - Availability: the mechanical availability of the plant or specific equipment
    - Total time the equipment is available to operate / Total mine operation
  - Utilization: the actual production of equipment in relation to it’s potential
    - Average load on equipment / Maximum design load

Plant availability – Design considerations

- Maximize equipment uptime
  - Maximize life of major wear components
  - Make blockage handling easy
  - Minimize equipment failures through preventative/predictive maintenance, and proper equipment monitoring
  - Minimize tramp events
- Minimize downtime required for maintenance and repairs
  - Easy/quick access to frequent maintenance points
  - Proper maintenance planning
  - Spare equipment for ”cartridge” change outs
  - Spares/wears stored at site (local or supplier consignment stock)

Plant utilization – Design considerations

- Utilization killers
  - No feed or limited feed available
  - Surges in load due to capacity, PSD, or rock properties fluctuations
  - Poor feed control / process control
- Ways to improve utilization
  - Surge protection
  - Separating processes
  - Process and equipment design
  - Feed control systems
  - ”Smart” control systems

Primary Crushing Plants

- Oversize feed material
  - Causes the primary plant to be down to deal with rocks too large for the primary crusher
  - Blocked primary conditions waste valuable uptime and imposes unnecessary loads on equipment which can shorten component life and increase operating cost
  - Simple example
    - In a plant operating 8 hours per day, 5 days per week, 50 weeks per year...
    - 10 minutes of downtime per day to clear oversize blockages = 41 hours per year lost production

Primary Crushing Plants

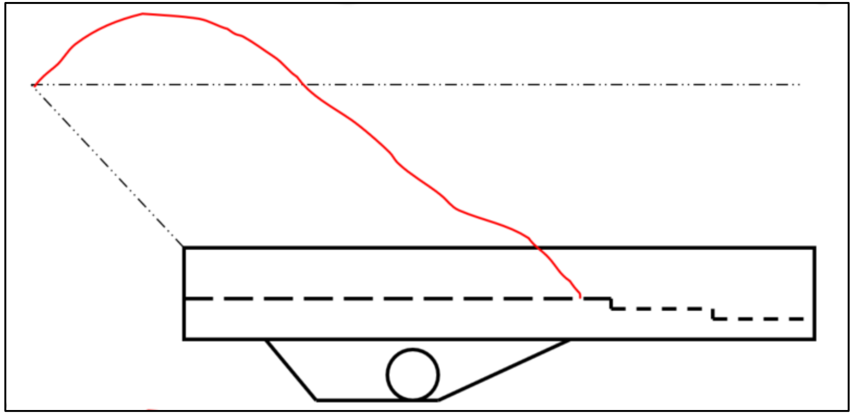
- Oversize feed material
  - Rock breakers can be used to break oversize
    - Can improve primary plant performance by 10-20% (NSSGA Aggregates Handbook)
    - Can be located at the primary plant to deal with oversize material while plant is still in operation
    - Rock breaker can significantly lower or eliminate plant downtime due to oversize feed and recover lost production tonnage
    - Can also be excavator-mounted in the pit to deal with oversize prior to the processing plant
  - Excessive amounts of oversize material may require a review of blasting design and procedures

Primary Plants

- Feed arrangement, operation and scalping
  - Removing fines prior to primary crusher is important
  - Poor scalping contributes to increased operating cost and lower uptime
    - Primary plant with short grizzly feeder
    - Loading with larger equipment than the feeder and hopper are designed for
    - Sticky or round material plugging grizzly bars

Primary Crushing Plants

- Feed arrangement and scalping
  - Benefits to removing fines prior to primary crusher
    - Increase crusher liner life significantly
    - Eliminate downtime for clearing crusher cavities jammed with fines
    - Increase primary plant output and efficiency
    - Increase plant uptime
    - Lower operating cost of primary plant discharge belt as fines that bypass the crusher can cushion larger crusher discharge



Primary Crushing Plants

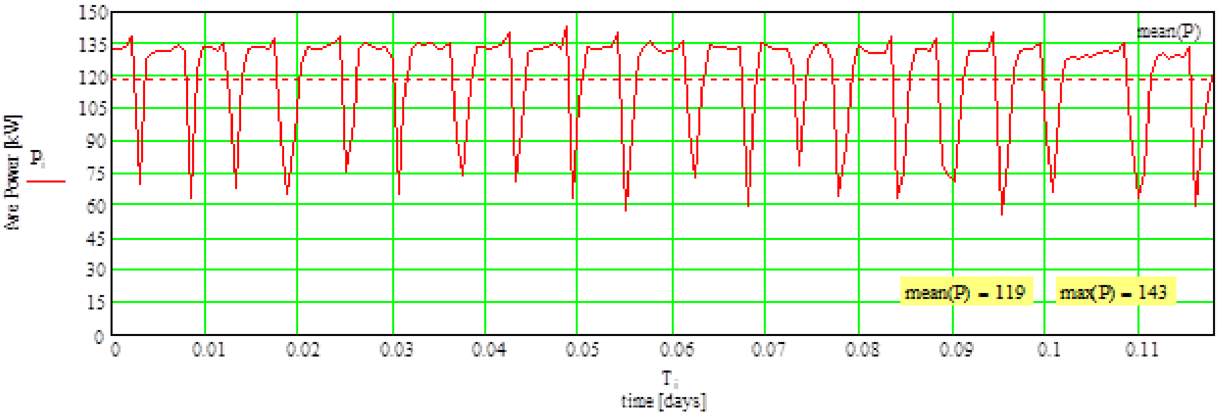
- Availability of the primary plant has drastic effects on the entire operation

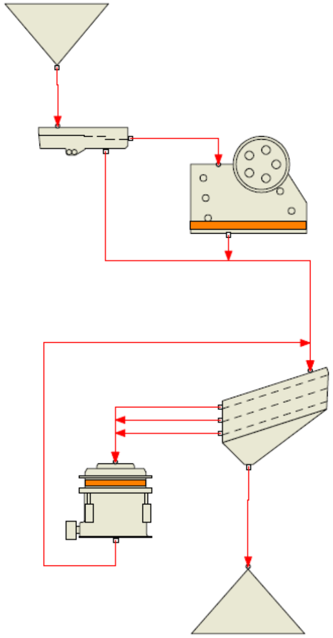
Availability	Avg. Capacity STPH	Production STPD	Production STPY	Average Product Sale Price	Sales per Year
100%	700	5,600	1,400,000	$8/ton	$11,200,000
95%	665	5320	1,330.000	$8/ton	$10,640,000
90%	630	5,040	1,260,000	$8/ton	$10,080,000
85%	595	4,760	1,190,000	$8/ton	$9,520,000
80%	560	4,480	1,120,000	$8/ton	$8,960,000
75%	525	4,200	1,050,000	$8/ton	$8,400,000

- Assumes 2000 hour operating year (8 hours/ day, 5 days/ week, 50 weeks/ year)

Unstabile process

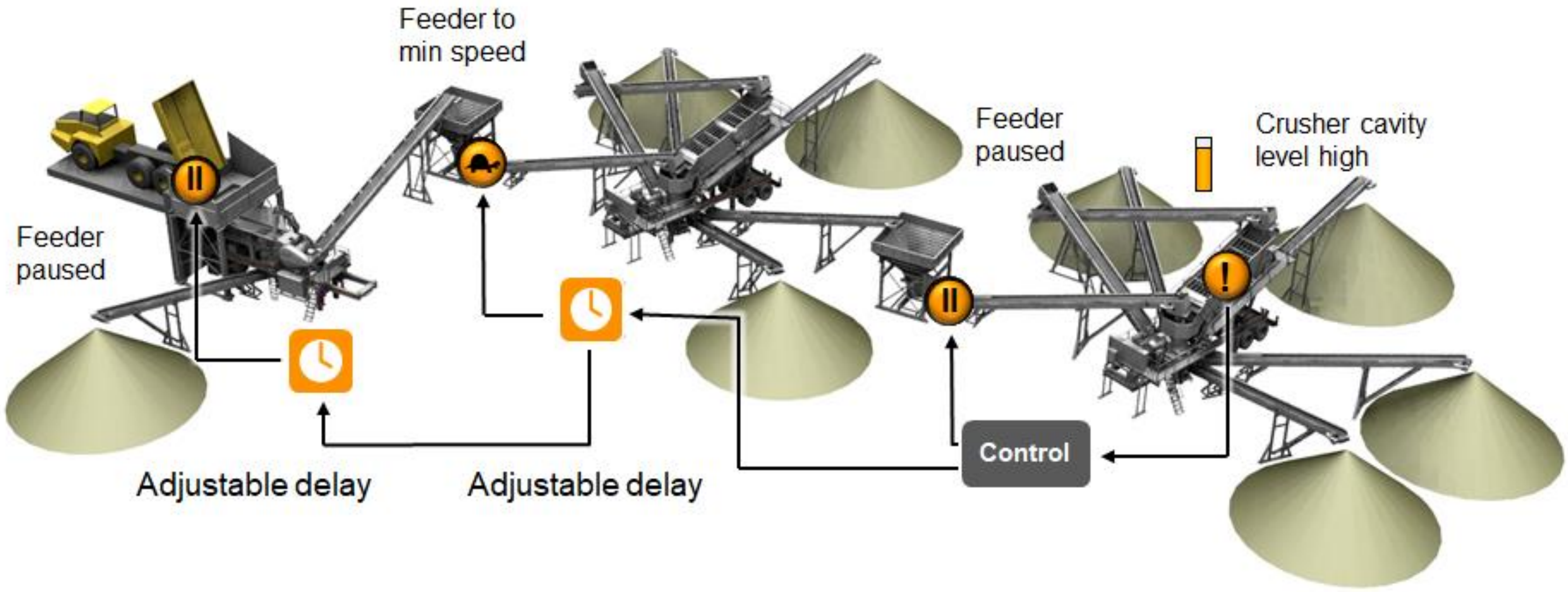
- Crusher feed control not working well
  - Crusher feed level not stabile
  - Crusher performance could be 135kW/119kW= 1.13 = 13% more!





High uptime with proper feed controls

High uptime with proper feed controls



Uptime killers with cone crusher

- CSS calibration
- Crushing chamber lifetime
- Crushing chamber economical lifetime
  - Economical life can be shorter compared to achievable life;
  - When performance dropping >10%, economical life ends
- Crushing chamber relining time

Solutions For increased uptime

- Minimize crusher calibration need; Dynamic wear compensation
  - Automation can take care
- Continue crushing Under load CSS adjustment
  - Especially in abrasive rock cases
- Minimize Crushing chamber change out time
  - Consider spare head / bowl
  - Newest development allows change in 3hours
- Crushing chamber economical wear life
  - Correct crushing chamber for keeping the performance up
  - Utilization ratio of the manganese

Factors affecting OPEX

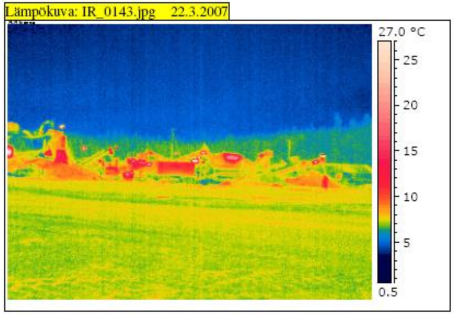
Crushers

Single process equipment technology features reducing OPEX

- Energy efficiency
  - How much energy is utilized for crushing
  - How to improve ?
- Wear part economy
  - Example for wear mechanisms
    - Cone crusher kinematics
    - High Pressure Grinding Rolls
  - How moisture affects wear life
  - How abrasiveness affects wear life
  - Change Your liners on time

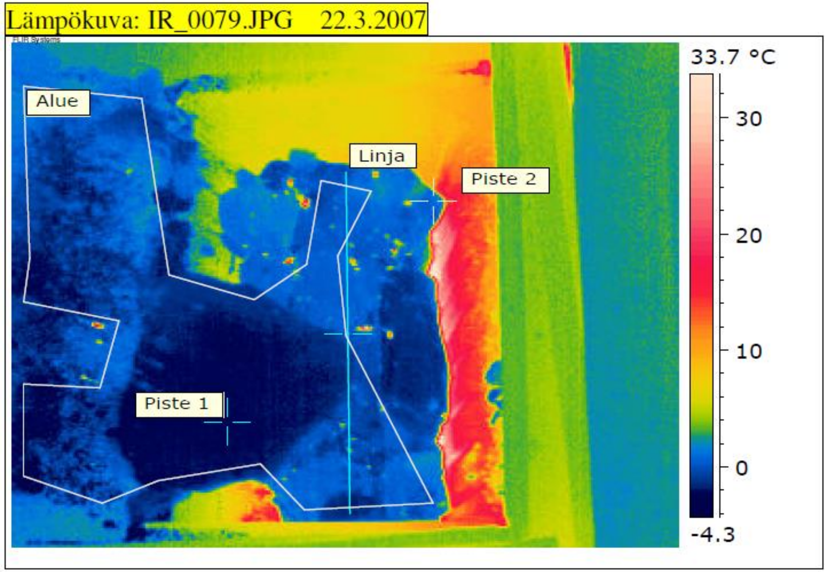
Energy efficiency in crushing

- Crushing process energy efficiency is basically defined by how much of the used energy is converted to heat
- In this test series heat generation in equipment and rock material were measured
- Measurement was made at three stage portable crushing plant



Primary crusher feed

- Rock feed material temperature 2 degrees Celsius



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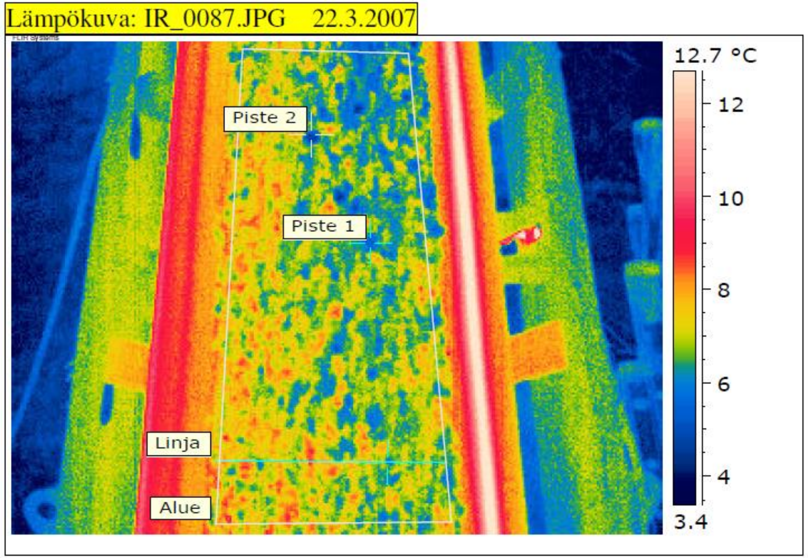
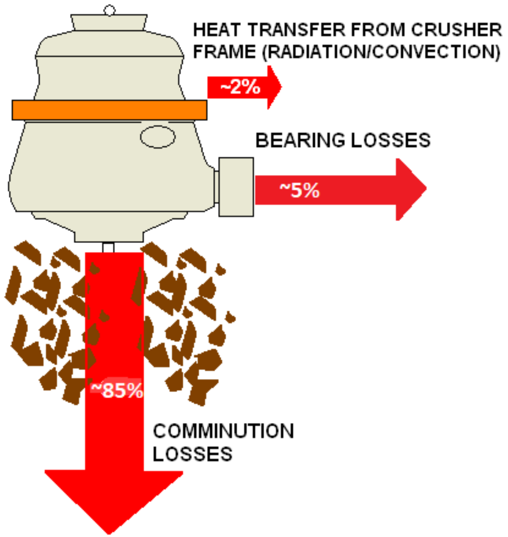
Tertiary crusher product

- Rock product material temperature 6 degrees Celsius



Energy converted to heat: results

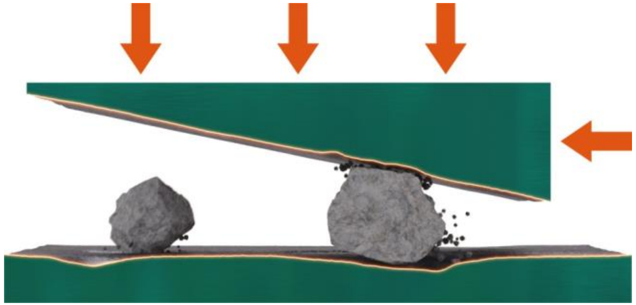
- In fine crushing it is estimated (based on measurements) that less than 5% of the used energy is utilized in generating new surface
- Estimation of the energy losses share is shown in picture 1.



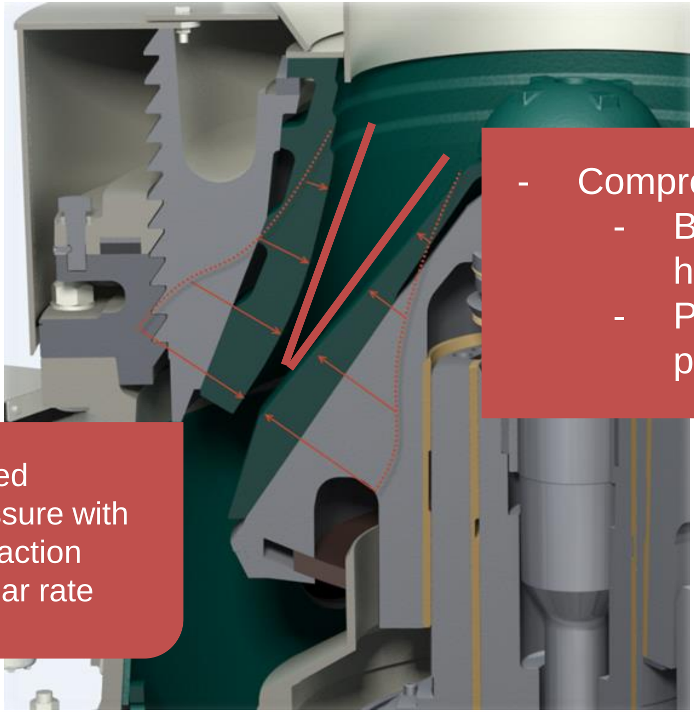
Picture 1. Estimated fine crusher energy losses

How to improve the poor energy efficiency?

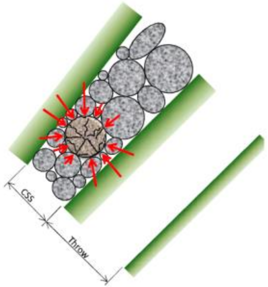
- In ideal conditions rock material is compressed perpendicular without ploughing the wear part
  - Ploughing instead of perpendicular compression causes energy loss
- Together with small enough nipping angle to avoid any slippage / grinding wear mechanism
  - Proven to improve energy efficiency
  - Specific energy reduction of 30% achieved with ideal crusher kinematics and crushing chamber
  - Same time wear speed is reduced with the same magnitude!



Ideal compressive crusher kinematics



- Compression perpendicular to flow
  - Better manganese work hardening
  - Pure compression, no ploughing

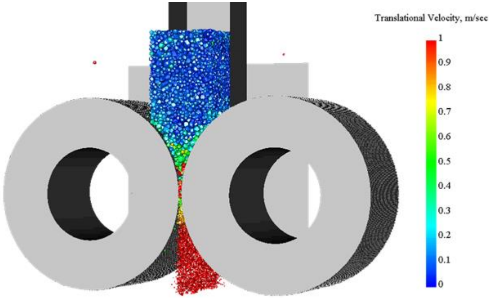


Well distributed crushing pressure with rock-on-rock action minimizes wear rate

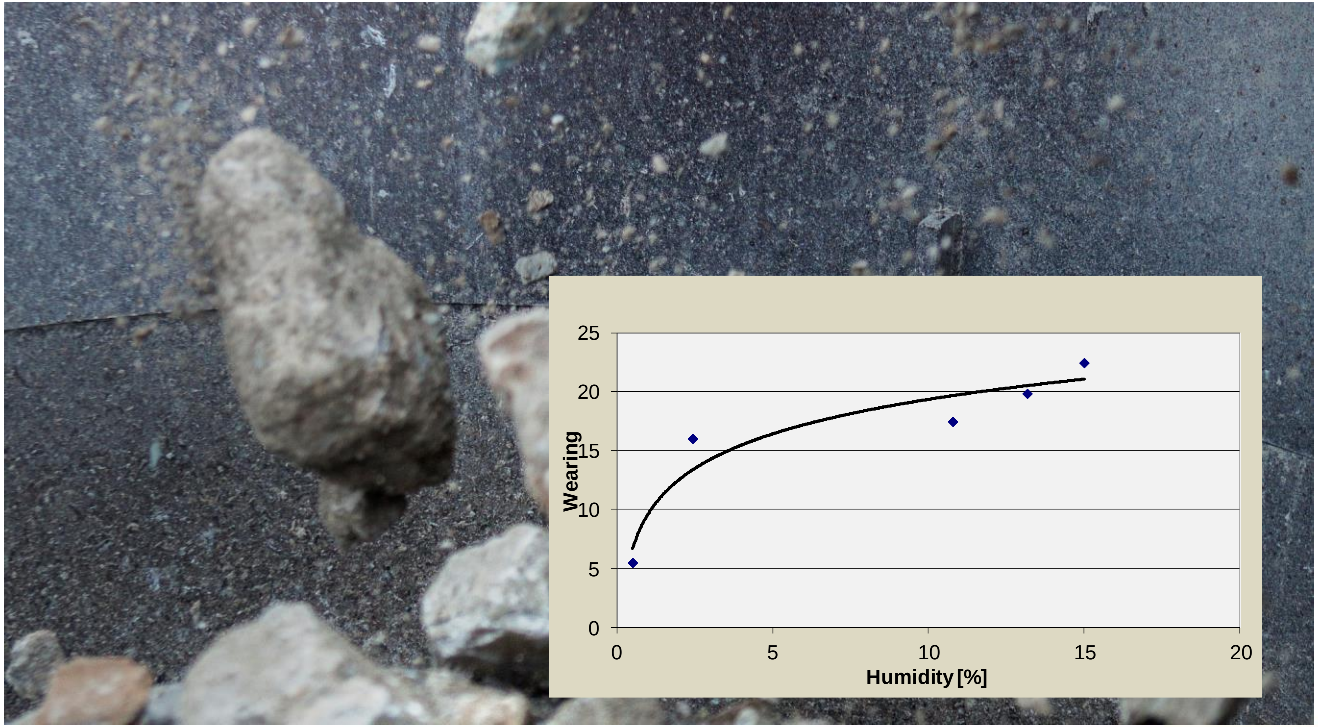
Suitable nip angle for the material being crushed
Crusher speed can be used to assist nipping

High pressure grinding rolls

- HPGR type crushers are nowadays used also among aggregate producers
- Due to ideal packed bed compressive crushing with slow movement:
  - In suitable conditions HPGR can reach 30% slower wear speed compared to a cone crusher
  - Up to 50% lower energy consumption compared to a VSI



How moisture affects wear life?



Aggregate moisture and asphalt

CARBON TRUST
Making business sense of climate change

Industrial Energy Efficiency Accelerator

Guide to the asphalt sector

CARBON TRUST
Making business sense of climate change

The next most significant consumer of energy is the process of drying out the aggregate. Again, asphalt recipes that do not require dry aggregate (such as cold mix) will use significantly less energy. However, energy consumption can also be lowered by reducing the moisture content of the incoming aggregate, whatever the mix. Well-drained aggregates and sand can have a moisture content of 3% or below, but in very wet conditions the moisture content could be as high as 8%. In the examples in the table above, the average moisture of the aggregates was 3.7%.

Structural losses from the plant are relatively low. Provided the dryer's insulation is maintained in good condition, there is little to be gained by improving it.

Twelve per cent of the heat supplied is lost through the stack as hot air (this excludes the latent heat of the water vapour from the aggregate). Some of this heat could be recovered, although its low temperature could limit the extent it can be reused in the process itself. Reducing the air flow through the system will also lower heat loss.

Optimising the burner controls could minimise the energy lost as unburnt fuel. When heavier oils are used and burners are modulated according to the system load, some combustion inefficiencies are inevitable. However, the CO levels recorded on some sites were excessive.

Thermal modelling

Sensitivity analysis on the main production variables was undertaken using a simple thermal model of an asphalt drum heater. This has highlighted the key production parameters that affect energy efficiency:

	Energy saving per tonne of product		
	kWh	$kgCO_2$	£
2% change in moisture content	8.7	2.25	0.52
10°C change in stone exit temperature	2.8	0.72	0.08
10°C change in flue gas temperature	1.7	0.43	0.05
100% change in excess air	1.5	0.39	0.04

If an asphalt plant is thermally efficient (that is, it is well insulated and has little or no unburned fuel from combustion), then the biggest influence on energy use is the moisture content of the incoming aggregate. A 2% improvement in incoming moisture content, implemented throughout the asphalt sector, would save $58,000tCO_2$ and £13 million per year in fuel.

How to affect moisture level?

1 Storing asphalt aggregates under cover and installing drainage

BCG

CARBON TRUST

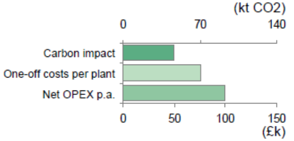
Aggregates Sector Strategy Review
Carbon Reduction Toolbox

July 2009

THE BOSTON CONSULTING GROUP

Description

- Asphalt aggregates are frequently stored in the open air
- Up to 40% of the fuel used by the burner may be consumed in the drying of the aggregate
- 2% reduction in moisture content (eg, 6% to 4%) reduces fuel use by up to 25%; also reducing drying time and increasing throughput
- Coverage ensures moisture content does not increase due to rain
- Drainage removes excess water before introduction into asphalt process

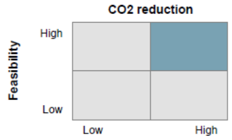


Barriers

- Disruption to operation during construction
- Layout/accessibility of existing site
- Local Authority regulation
  - planning permission
- Scale of project
- Lack of awareness
- Only worthwhile for fine aggregates

Pre-requisites to progress

- Planning permission
- Other areas to store aggregates during construction
- High fuel prices (reducing pay-back time)



Involved Parties & Responsibilities

- **Fund:** Asphalt plants
- **Detail**: Carbon Trust (6-9 FTE months); MPA/BAA – survey of current extent of cover & drainage installations at players
- **Implement**: Players (10-15 FTE months)
- **Operate**: No requirement beyond routine maintenance

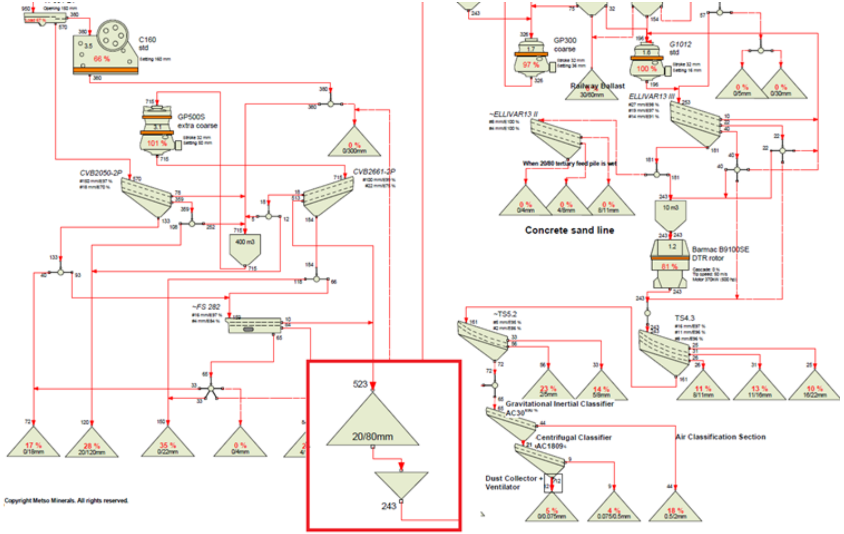
Key activities

- Promote benefits of cover & drainage
- Research and publicize best aggregate loading practices, eg load from top, use FIFO sequence
- Highlight opportunities to avoid planning permission process using delegated powers
- Contact Local Authorities to secure streamlined planning permission process
- Ensure drainage and cover built into new sites

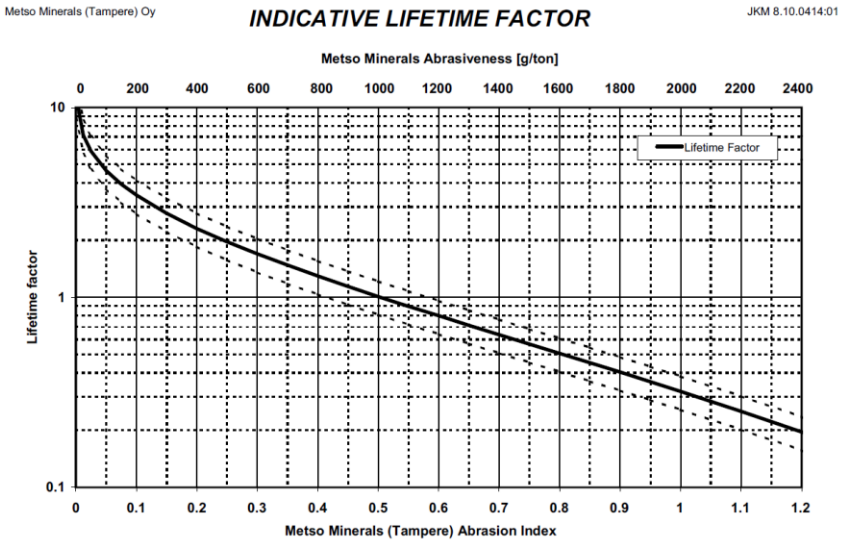
Targets/KPIs/Milestones

- 100% of fine asphalt aggregates stored undercover by 2015
- Average moisture content of aggregates reduced to ~4% in each plant by 2015
- 20% reduction in number of planning permission rejections and length of time per decision

Surge pile considerations



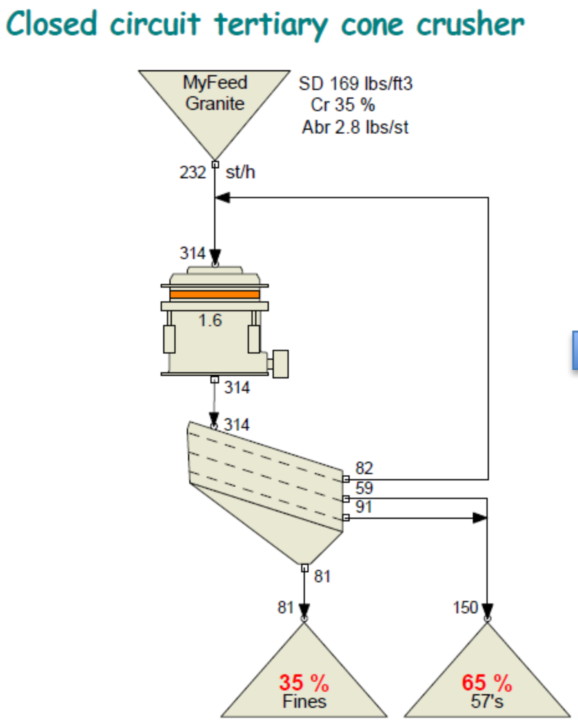
Abrasiveness impact on wear life



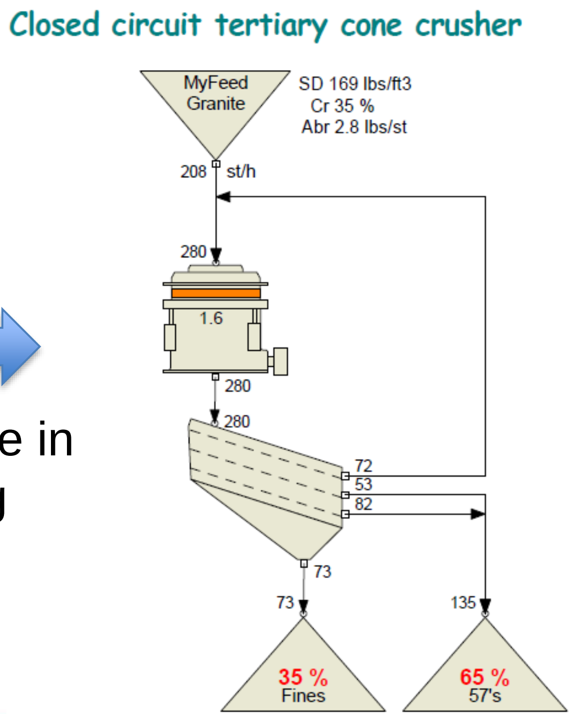
Abrasiveness impact on wear life

- When abrasiveness changes from 1000g/ton to 2000g/ton, the lifetime factor changes from 1 to 0,3. The increase of wear rate is non-linear.
- Example: If yearly consumption is 3 sets of wear parts and abrasiveness goes up from 1000g/ton to 1400g/ton the yearly consumption goes up to 5 sets. If the abrasiveness goes up to 2000g/ton the yearly consumption goes up to 10 sets.

Crusher performance development

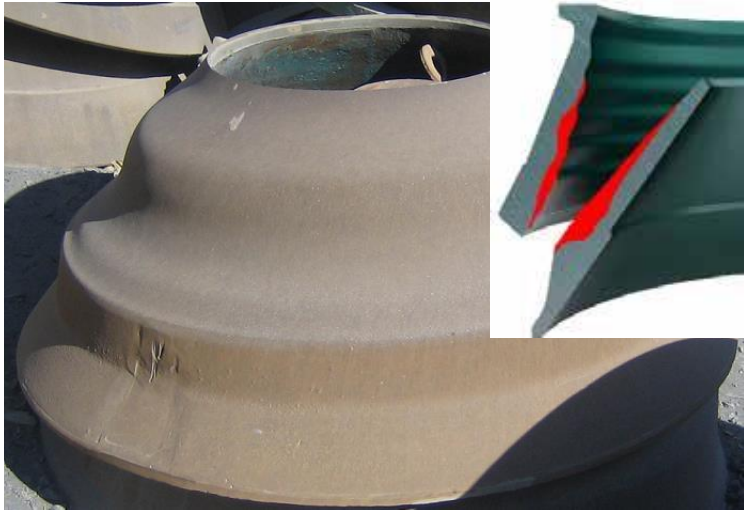


10% decrease in product being produced



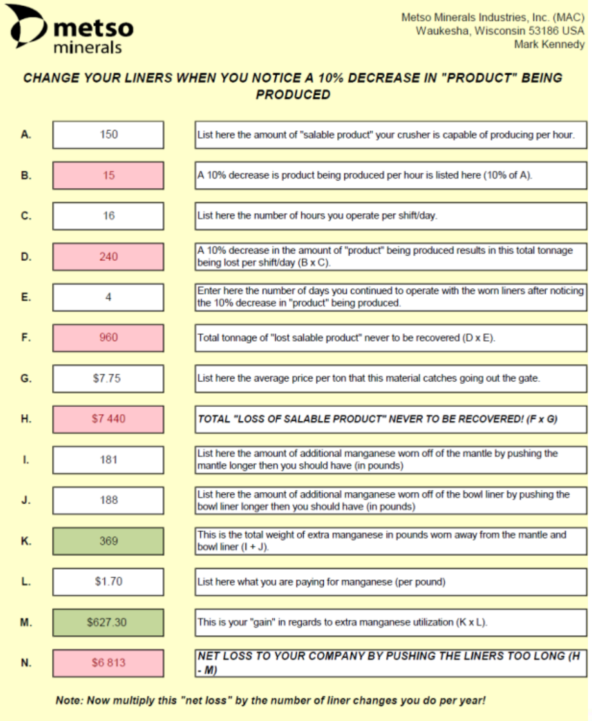
Why crusher performance is dropping?

- Reduced capacity might be due to reduced crushing chamber = lower performance
  - In pedestal type cone crusher stroke increase is somewhat compensating the reducing chamber volume
- One other reason can be poor wear profile
- Need to pay attention on right crushing chamber selection



Effect on profits

- Assumption:
  - During last 20% of liner life, 10% decrease in product being produced
- Calculation (chamber lifetime):
  - 960 tons of valuable product lost
  - 7440$ lost sales
  - 630$ saved by utilizing all available manganese
  - 6810$ lost during one set of liners!



metso minerals

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Mark Kennedy

CHANGE YOUR LINERS WHEN YOU NOTICE A 10% DECREASE IN "PRODUCT" BEING PRODUCED

A.	150	List here the amount of "salable product" your crusher is capable of producing per hour.
B.	15	A 10% decrease is product being produced per hour is listed here (10% of A).
C.	16	List here the number of hours you operate per shift/day.
D.	240	A 10% decrease in the amount of "product" being produced results in this total tonnage being lost per shift/day (B x C).
E.	4	Enter here the number of days you continued to operate with the worn liners after noticing the 10% decrease in "product" being produced.
F.	960	Total tonnage of "lost salable product" never to be recovered (D x E).
G.	$7.75	List here the average price per ton that this material catches going out the gate.
H.	$7 440	TOTAL "LOSS OF SALABLE PRODUCT" NEVER TO BE RECOVERED! (F x G)
I.	181	List here the amount of additional manganese worn off of the mantle by pushing the mantle longer then you should have (in pounds)
J.	188	List here the amount of additional manganese worn off of the bowl liner by pushing the bowl liner longer then you should have (in pounds)
K.	369	This is the total weight of extra manganese in pounds worn away from the mantle and bowl liner (I + J).
L.	$1.70	List here what you are paying for manganese (per pound)
M.	$627.30	This is your "gain" in regards to extra manganese utilization (K x L).
N.	$6 813	NET LOSS TO YOUR COMPANY BY PUSHING THE LINERS TOO LONG (H - M)

Note: Now multiply this "net loss" by the number of liner changes you do per year!


THANK YOU
For Your Attention