Crushing
- Optimizing the Process

Magnus Evertsson

Improving Processes. Instilling Expertise.

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Objectives

- Different levels of optimization
- Different aspects of optimization
- Detailed demonstration of cone crusher yield optimization including economical aspects

QUARRY ACADEMY

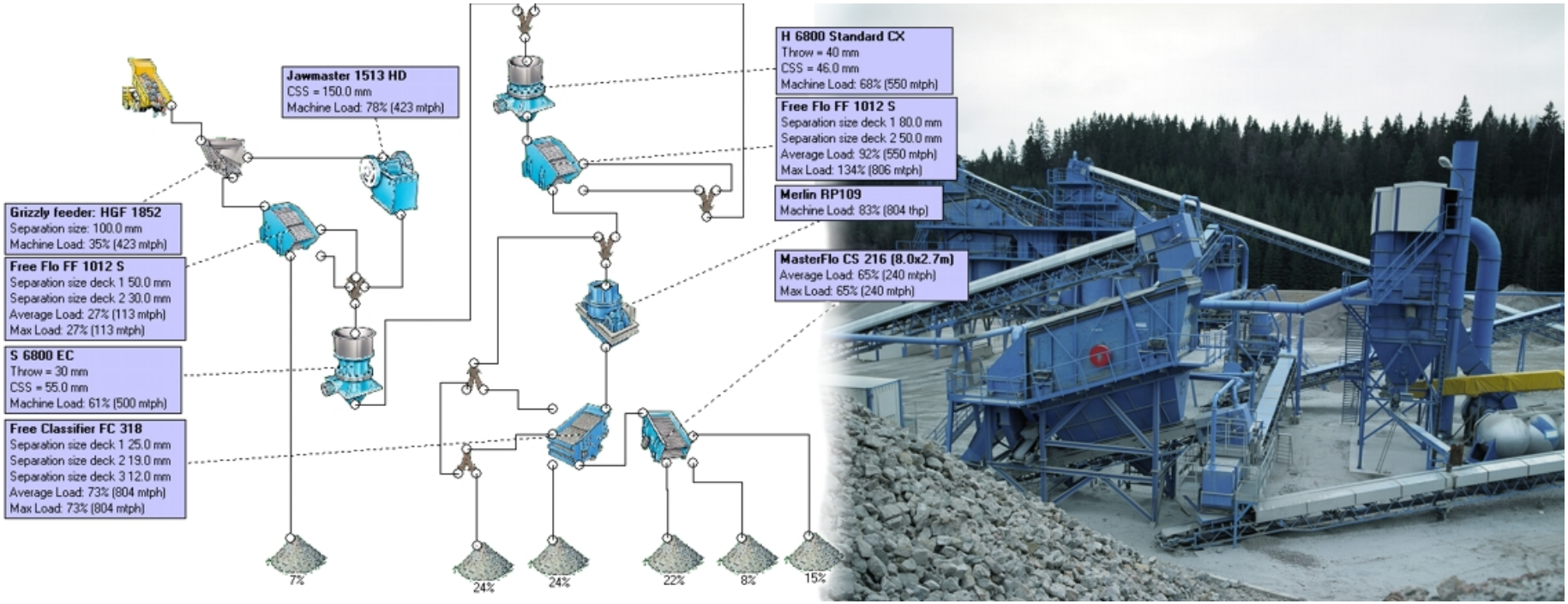
Crushing Plant Optimization

- large scale

QUARRY ACADEMY

Crushing Plant Optimization

- **Technical and economical**



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Crushing Plant Optimization

The effect of wear

- Screen cloths
- Crushing chambers

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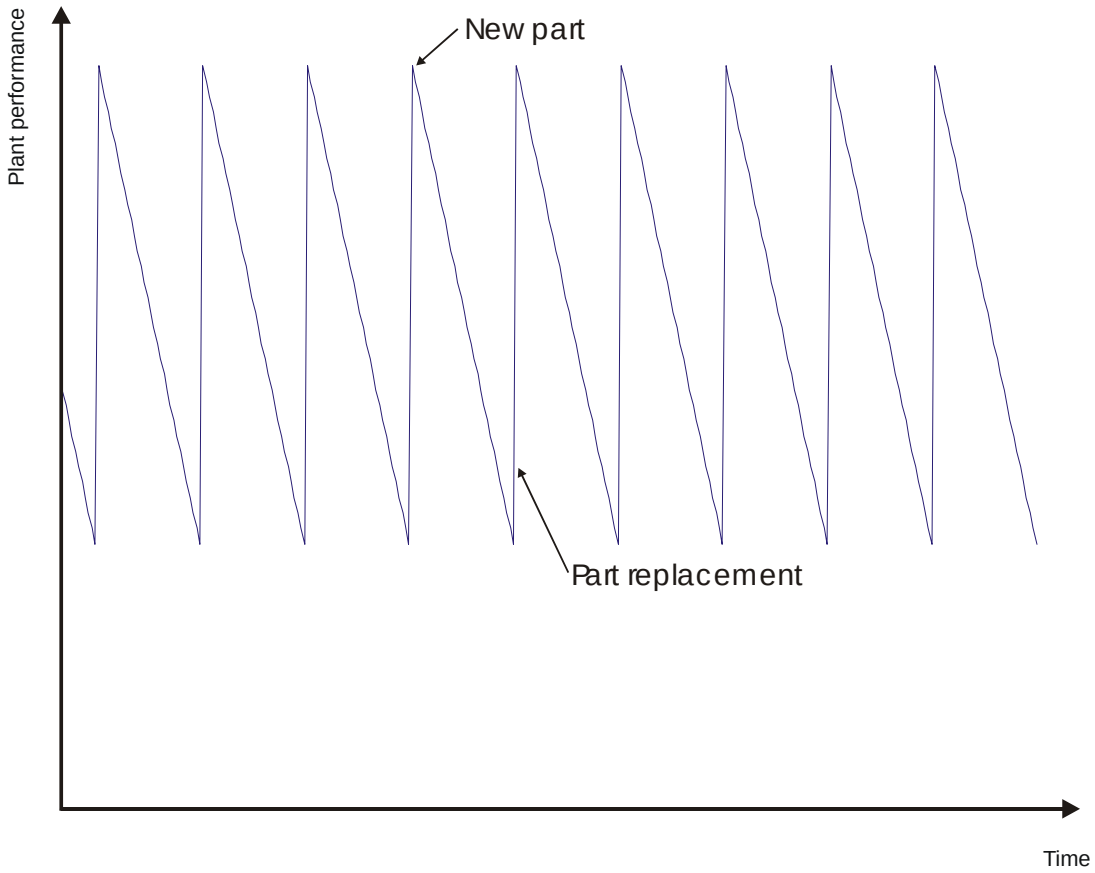
Effect of Wear

The variation due to ONE wear part



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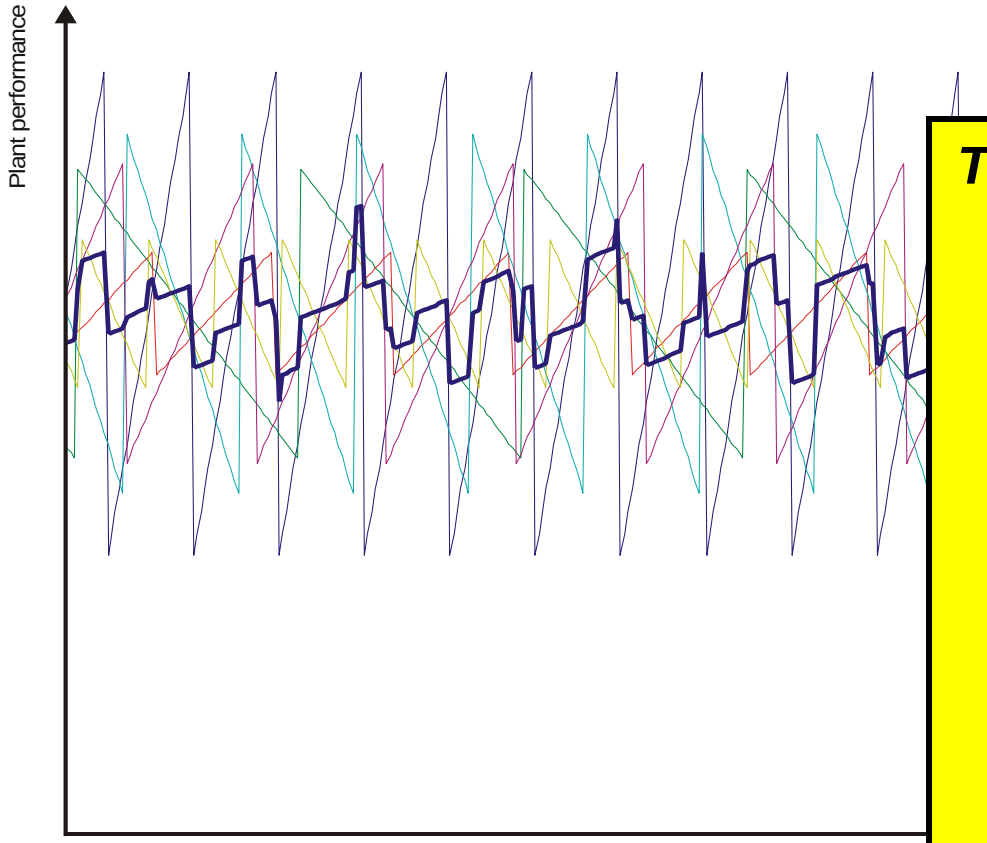
Effect of Wear

The variation due to SIX different wear parts



Take home message:

You can experience strange variations then sampling.

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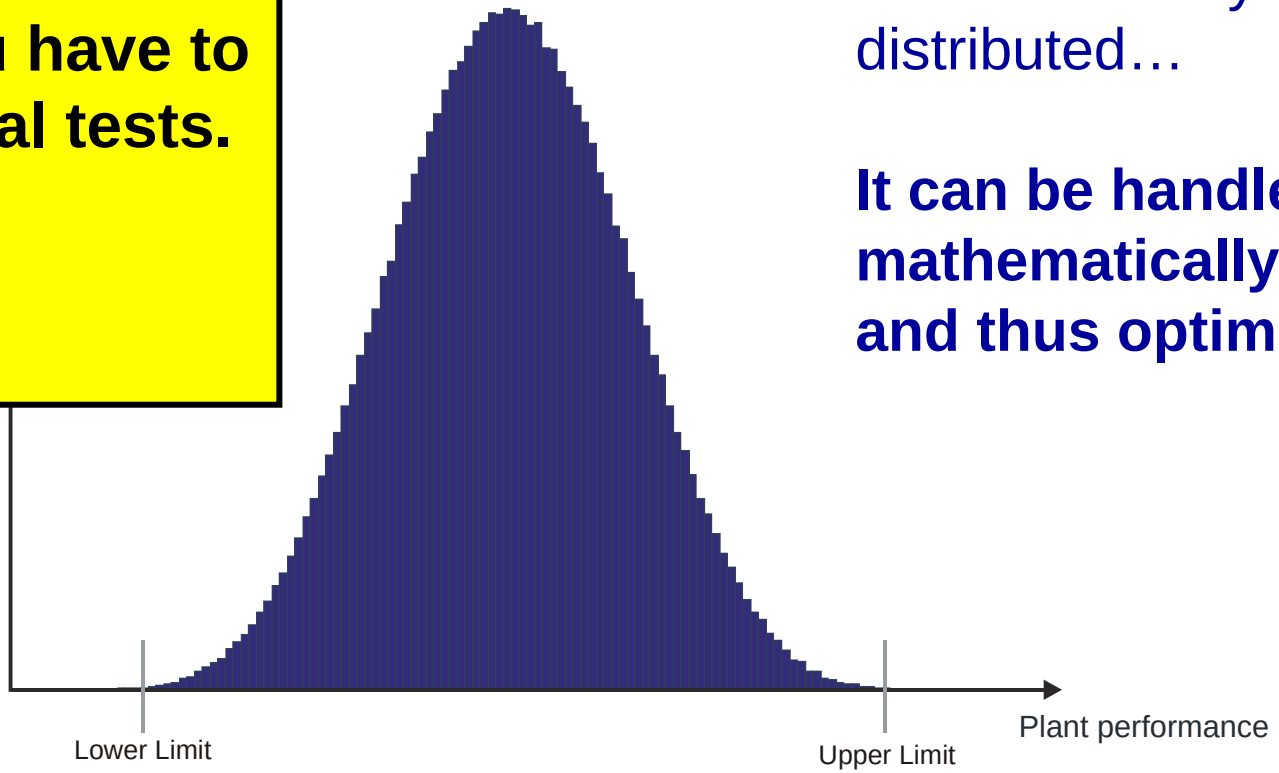
Effect of Wear

Take home message:

To catch the true value you have to do several tests.



The combined effect will be normally distributed…

It can be handled mathematically and thus optimized!

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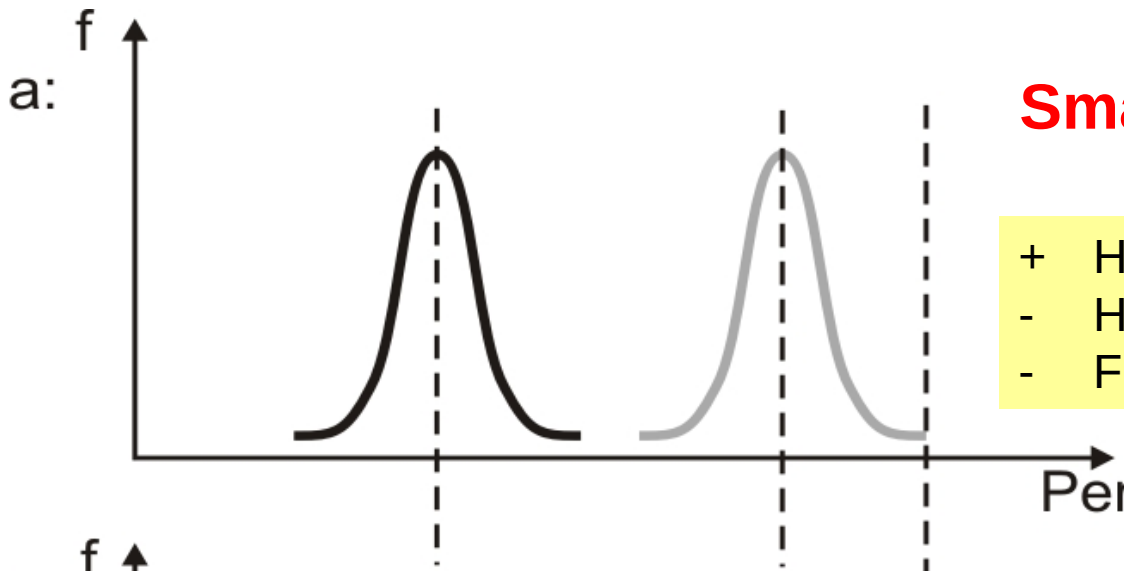
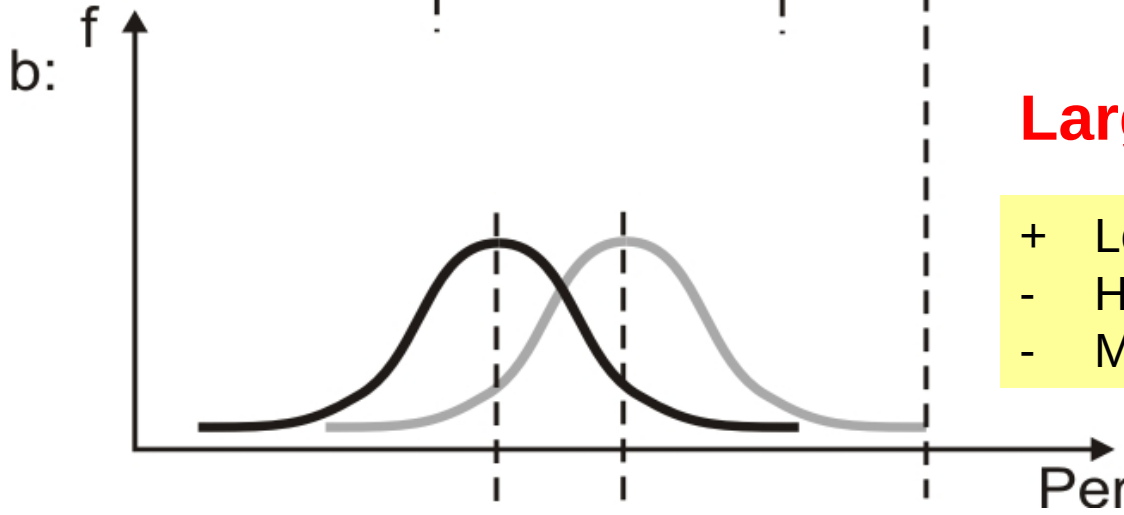
Effect of Wear



Small wear tolerance

+ High average performance
- High replacements costs
- Frequent stops



Large wear tolerance

+ Low average performance
- High utilisation of wear parts
- More production time

QUARRY ACADEMY

Crushing Plant Optimization

- **Concurrent ECONOMICAL and TECHNICAL optimization**
- **Wear management of parts**
  - screen cloths
  - crushing chambers
- **Make the most out of the customer requirements**
  - still fulfilling the quality demands

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Optimization of a Tertiary Crushing Stage

- small scale optimization

QUARRY ACADEMY

Optimization of a Tertiary Crushing Stage

Background

- **Some limestone quarries in the Mid West produce excessive amounts of fines <4# (<4.7mm)**

- **A typical “modern” crusher produces 19-21%**
- **A typical “old” crusher produces 14-15%**

- **Modern crushers have high power input/draw which is achieved by large throws,**
  BUT these machines produce more fines.

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Optimization of a Tertiary Crushing Stage

- The crushers are the last size reduction stage in the value chain.
- Over crushing is common.
- The rock cannot be repaired.
- We need to control the crusher carefully.

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Optimization of a Tertiary Crushing Stage

Combine product yield and economic aspects

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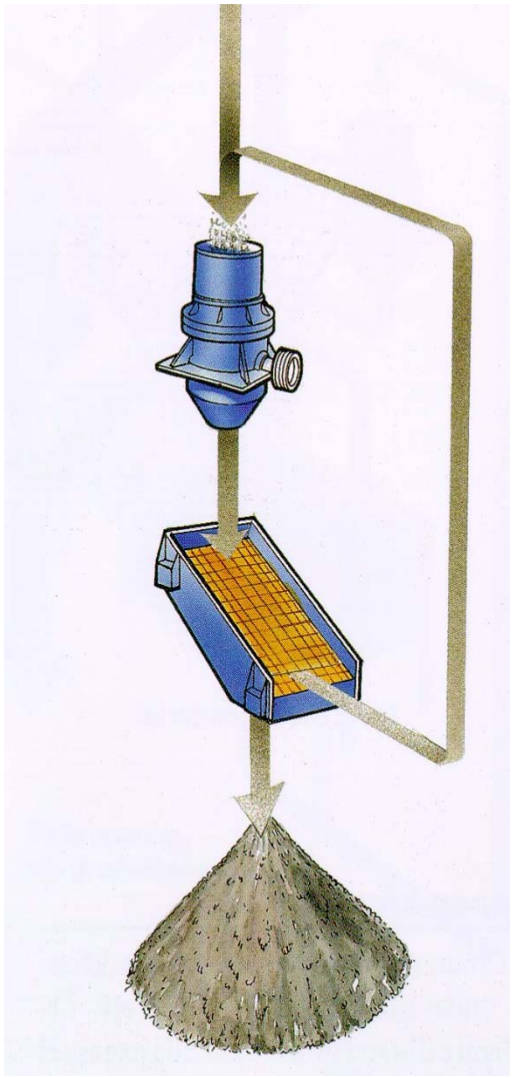
Test Setup and Parameters

- H3800 Hydrocone
- Standard MC and modified chambers
- Eccentric speed 360->288 rpm
- Throw 36->29 mm



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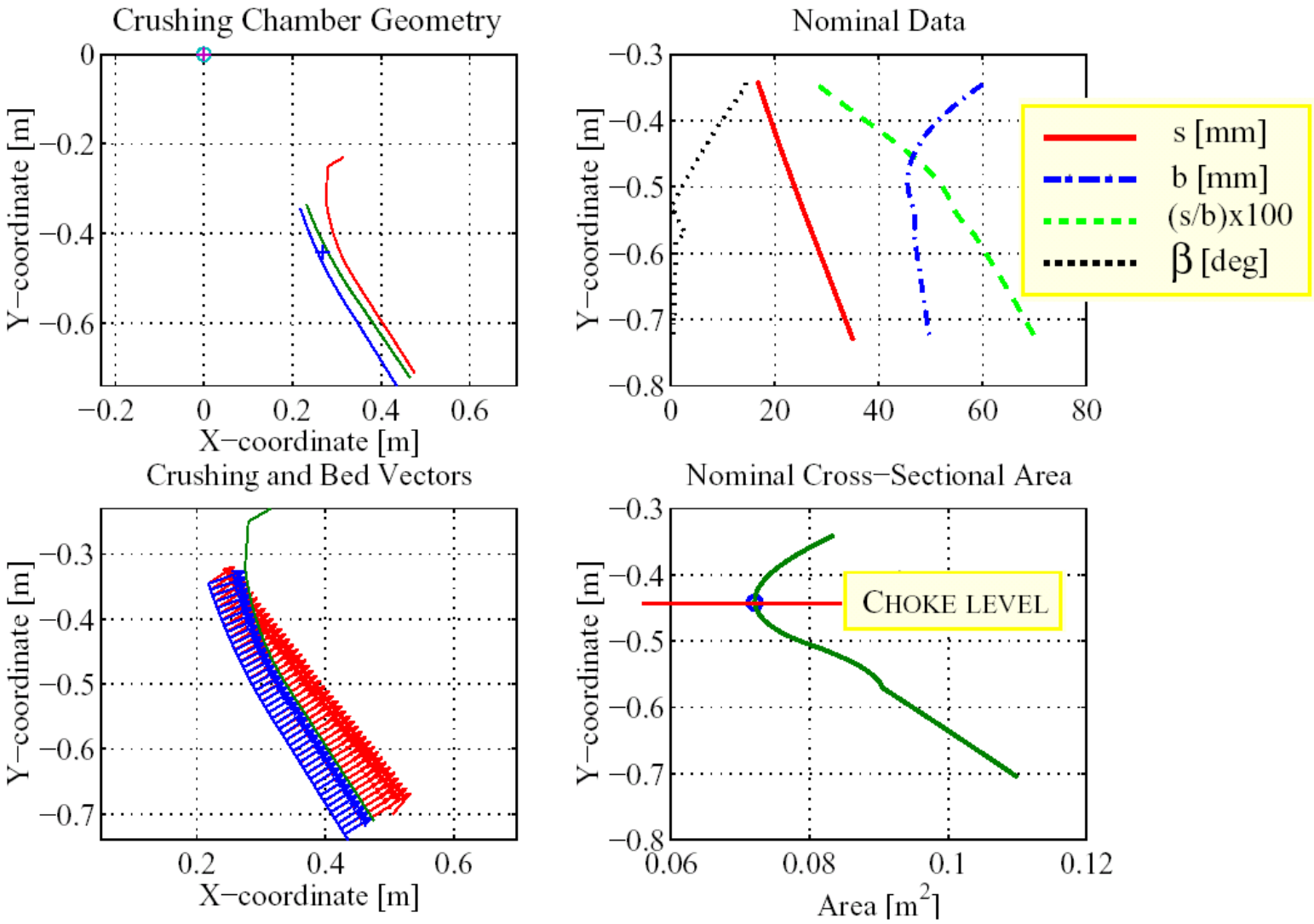
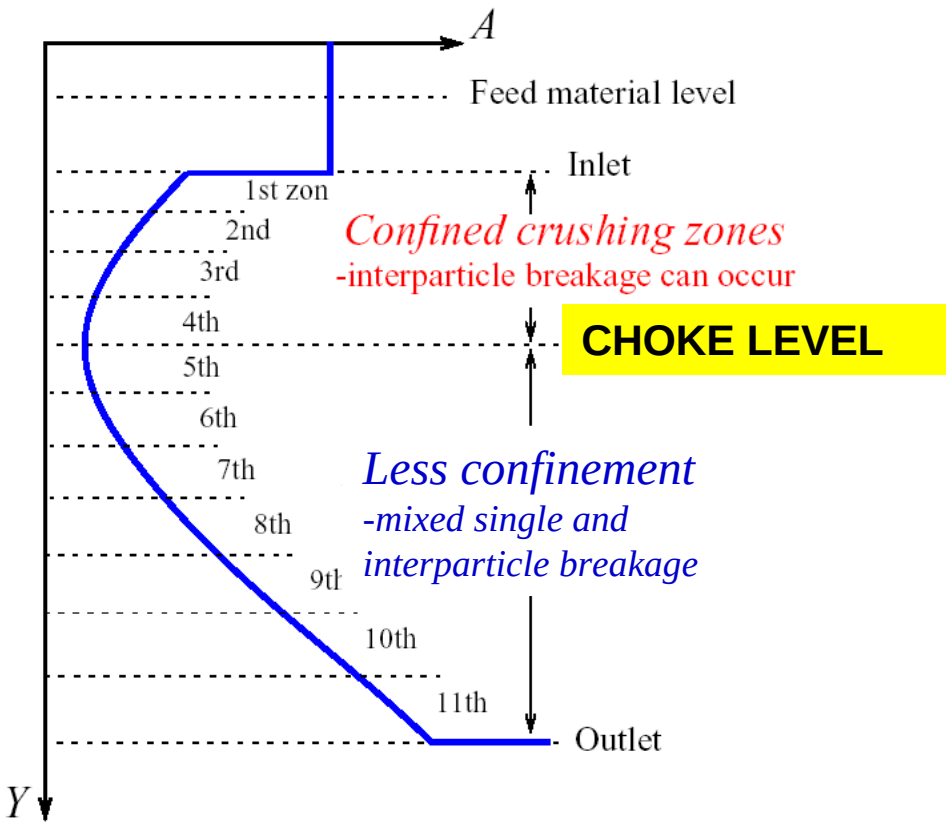
Crusher (Nominal) Geometry

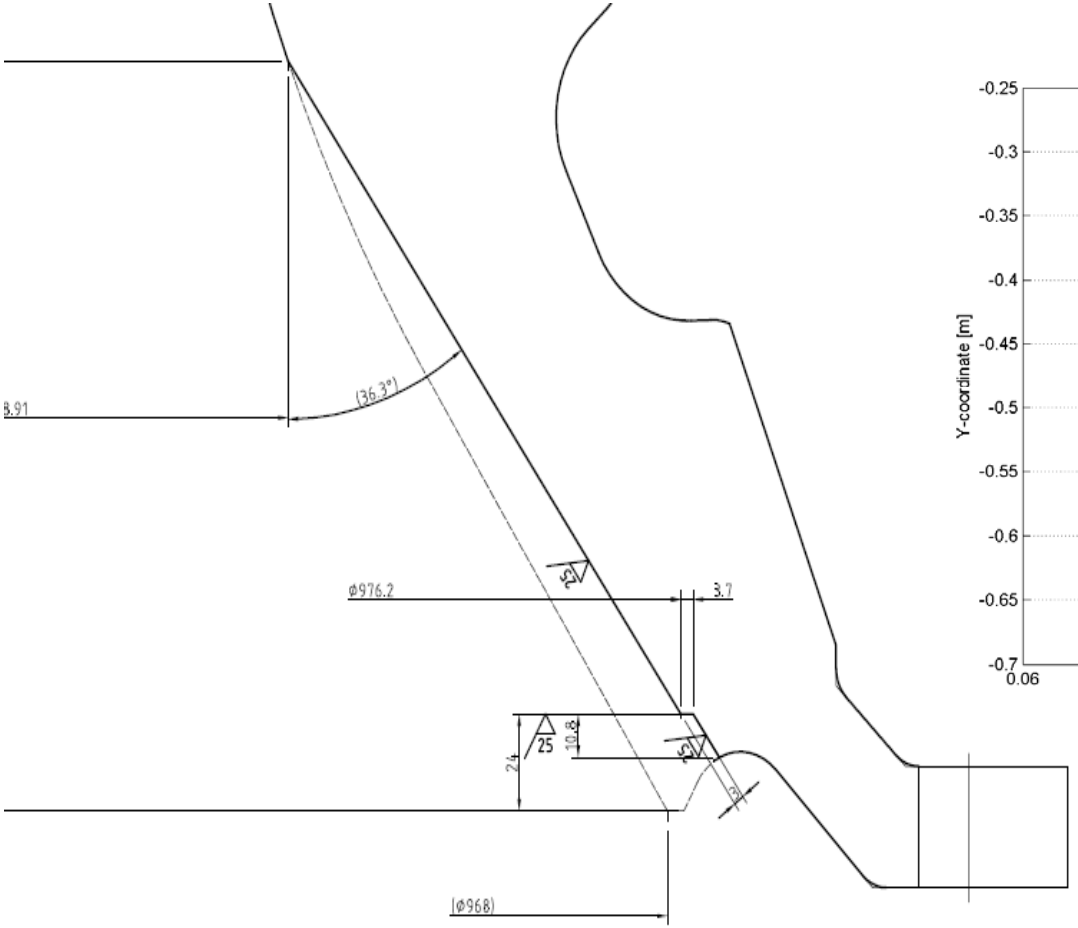


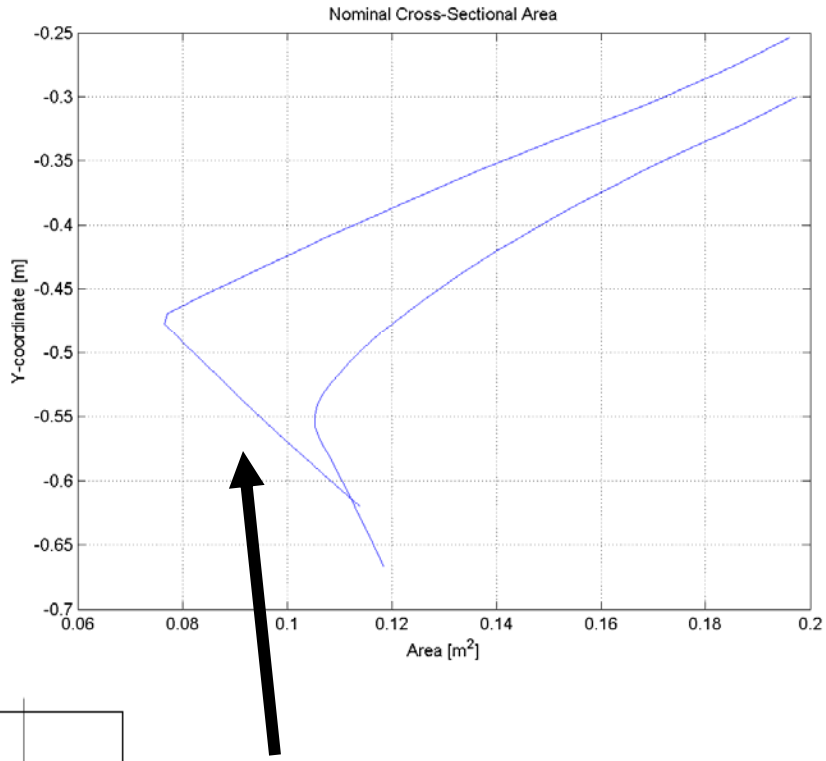
Breakage Modes



- **Interparticle**
- **Single particle**

Chamber Design





Parallel crushing zone with low pressure

-less fines

-top size calibrated

Test Procedure

- **Careful calibration**
- **50 tests**
  - CSS=minimum, …, 14, 15, 16, ...,21 mm
- **Sieving (and shape/flakiness index)**
- **Yield calculations**
- **Cost calculation**
- **Gross profit estimation**

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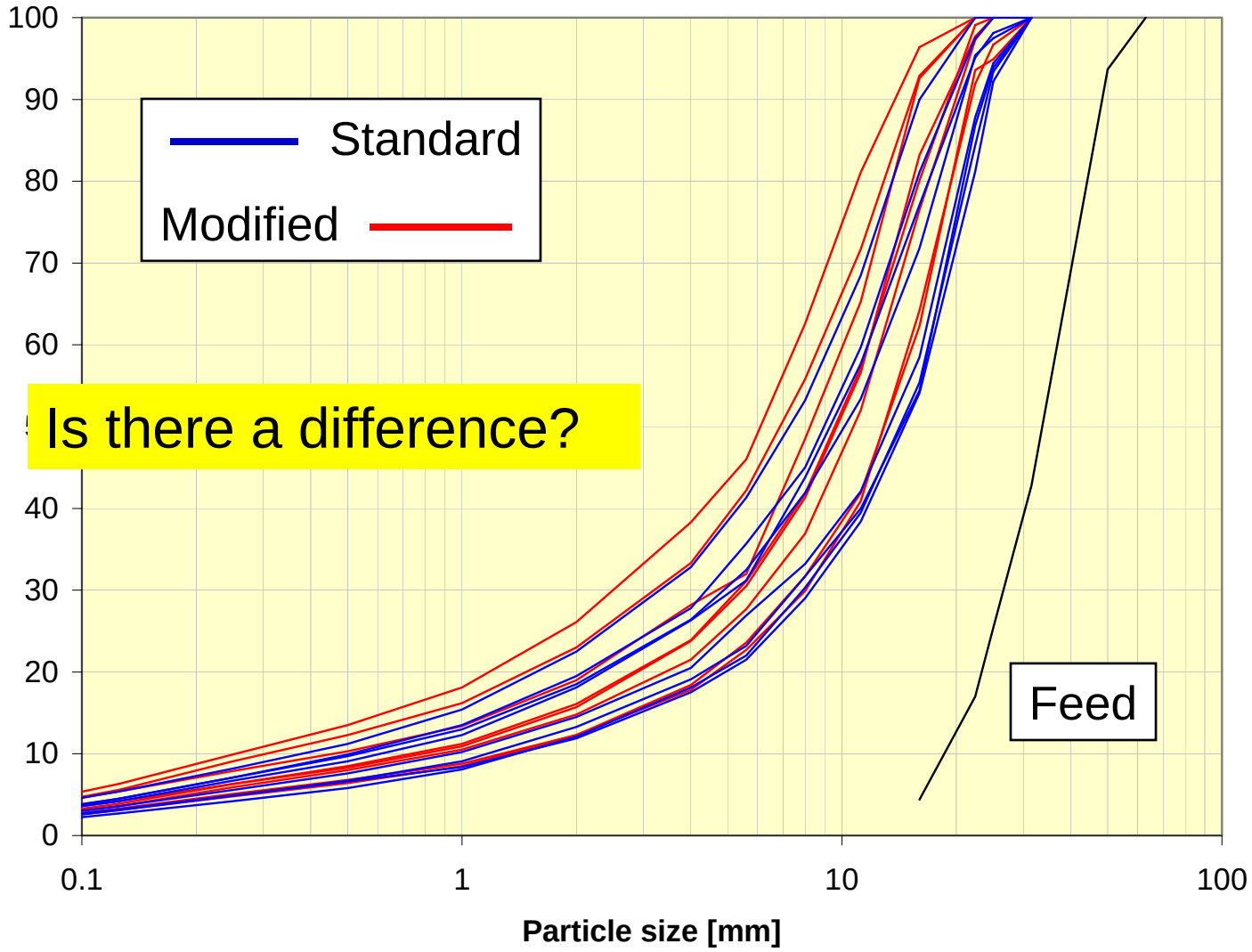
Results from Sieving

	Modified, +25-50 feed (coarse) 29 mm stroke, 288 rpm								Modified, +25-50 feed (coarse) 29 mm stroke, 360 rpm -STD								Modified, +25-50 feed (coarse) 36 mm stroke, 360 rpm -STD							
	26	**27**	**28**	**29**	**30**	**31**	**31**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**49**	**50**
0.063	3.4	3	3.1	2	2.4	1.8	1.7	1.6	3.3	2.6	2.3	2.1	2.2	2	1.7	1.5	3	2.5	2.3	2.3	1.9	1.7	1.3	1.5
0.125	6.3	5.6	5.4	3.9	4.2	3.6	3.3	3.1	6.3	4.9	4.5	4.1	4.3	4.1	3.3	2.9	5.4	4.5	4.2	4.5	3.6	3.2	2.7	3.1
0.25	9.9	9.1	7.9	6.3	6.3	5.9	5.1	4.8	10.1	7.7	7.1	6.5	6.9	6.8	5.2	4.6	8.2	7.1	6.7	7.1	5.6	4.9	4.2	4.9
0.5	13.5	12.3	10.3	8.5	8.3	8	6.8	6.4	13.8	10.5	9.5	8.8	9.3	9.2	7	6.3	11.2	9.9	9.1	9.7	7.6	6.7	5.8	6.6
1	18.1	16.2	13.4	11.2	10.9	10.5	8.8	8.5	18.5	14.1	12.7	11.8	12.2	11.9	9.3	8.5	15.4	13.5	12.3	13	10.2	9.1	8.1	8.4
2	26.1	23	19	16.1	15.7	14.8	12.3	12.3	26.5	20.8	18.2	17.2	17.1	16.1	13.5	12.4	22.5	19.5	18.1	18.5	14.5	13.3	12.1	11.9
4	38.3	33.3	28.2	23.9	23.8	21.5	17.8	18.4	38.5	31	27	25.2	24.6	22.3	20.1	18.7	32.8	27.8	26.3	26.4	20.5	19.1	18.1	17.5
5.6	46	42.2	32	31.1	30.5	27.7	22.7	23.6	45	39.8	32.6	32.3	31.6	26	26.2	24	41.3	35.7	31.2	32.5	26.9	23.2	22	21.5
8	62.6	55.8	48.5	41.8	41.3	36.9	29.9	31.7	60.1	52.4	45.4	43.1	40.9	36.1	35.9	32.9	53.2	45	43.8	41.9	33.2	31.7	30.3	29
11.2	81.1	71.7	65.3	57.2	56.6	52	40.9	41.9	74.7	68.6	60.6	56.3	53.8	48.6	48	45.2	68.5	59.7	57.7	53.4	42.1	40	39.5	38.4
16	96.4	92.9	92.6	80.1	83.2	76.5	64.2	62.3	93.5	87.8	86.7	79.2	77	69.3	68.2	65.8	90	81.1	77.1	71.8	58.5	54.4	55.4	54.1
22.4	100	100	100	99.1	97.7	97.3	91.9	93.6	100	98.5	100	100	96.8	92.6	94.2	93.6	100	97.5	95.1	95.4	87.8	86.8	84.4	81.2
25	100	100	100	100	100	100	96.7	94.9	100	100	100	100	100	95.6	100	100	100	100	98.1	97.5	94.4	93.9	93.4	92.2
31.5	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

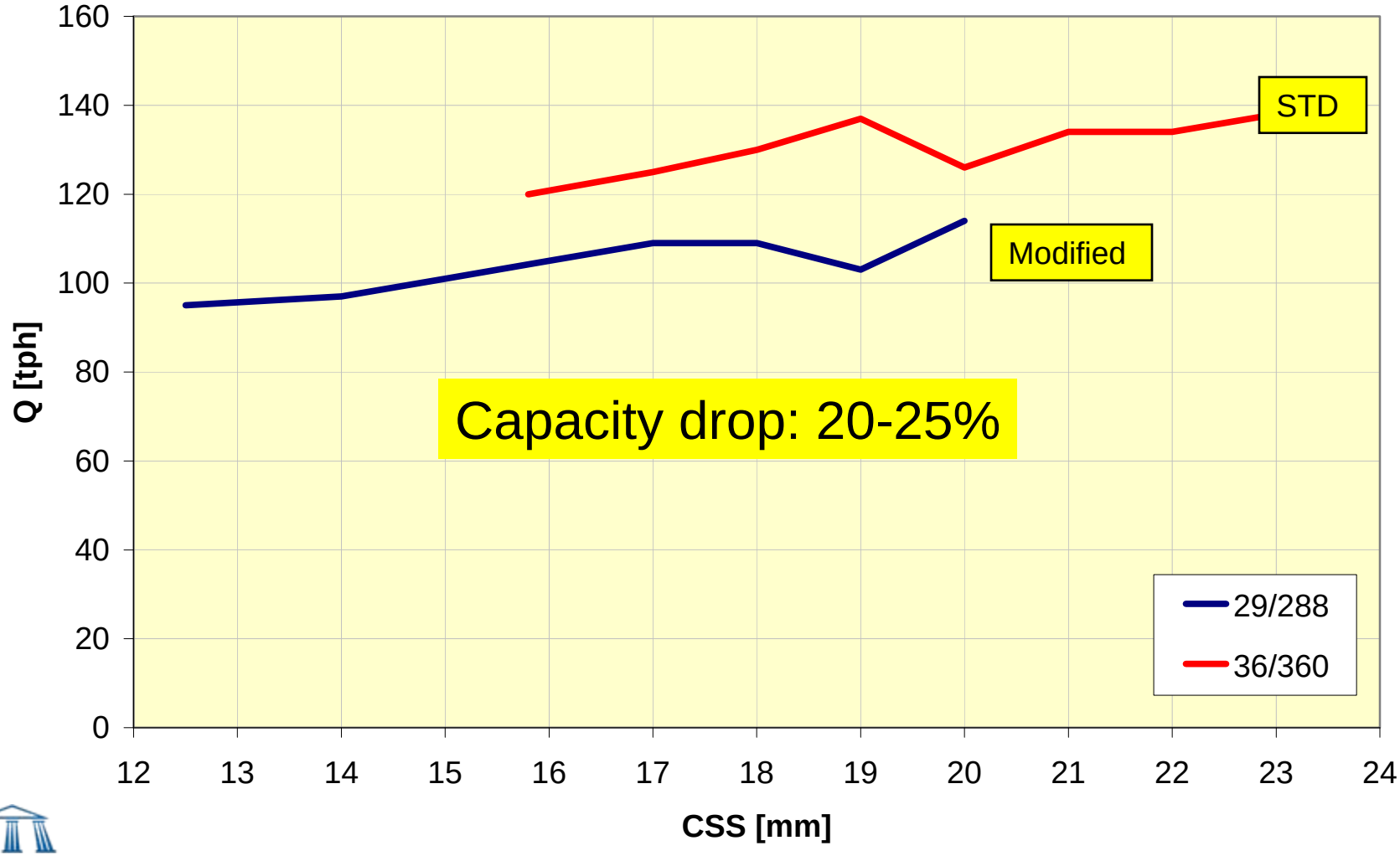
QUARRY ACADEMY

Particle Size Distributions



QUARRY ACADEMY

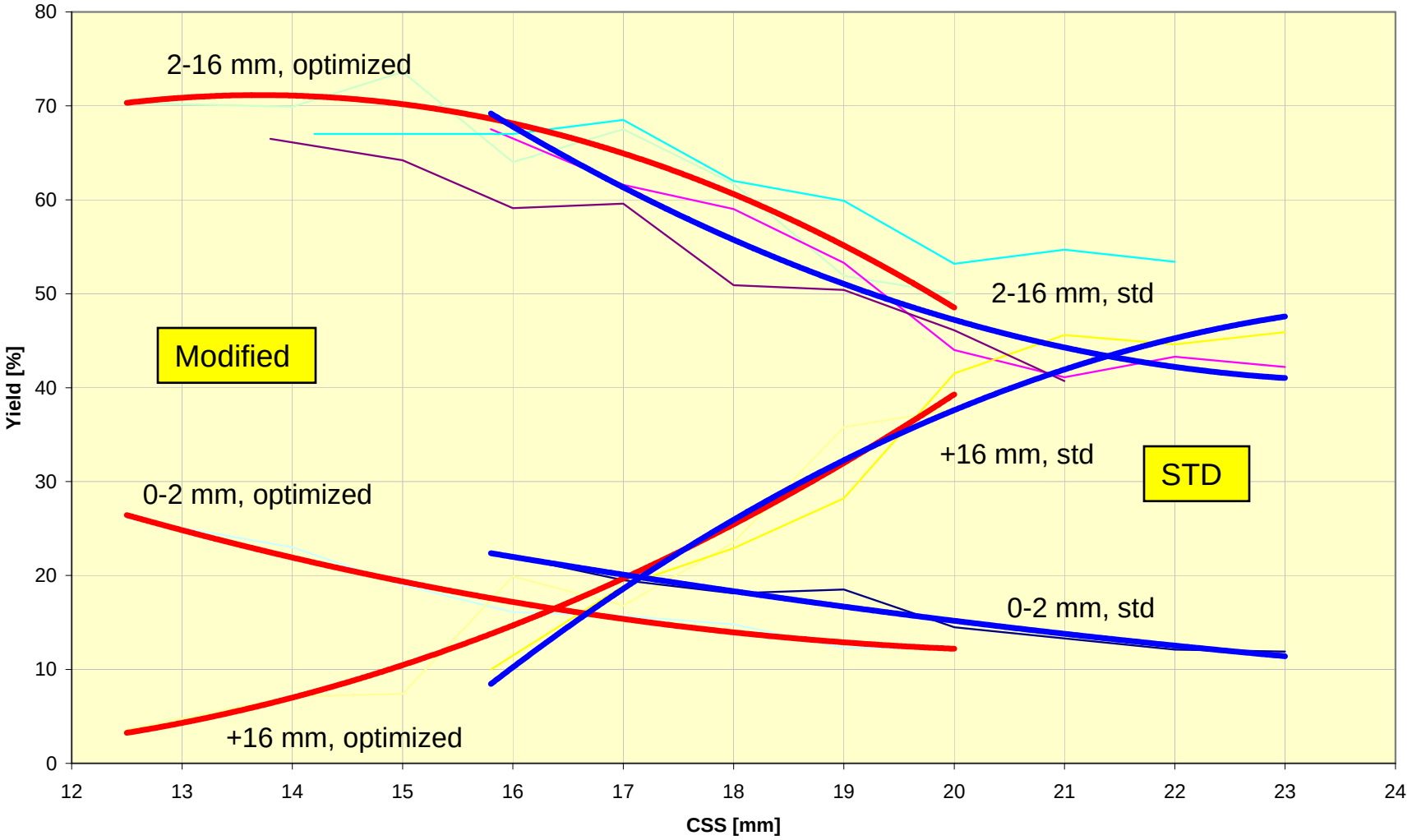
Total Capacity
[tph]



QUARRY ACADEMY

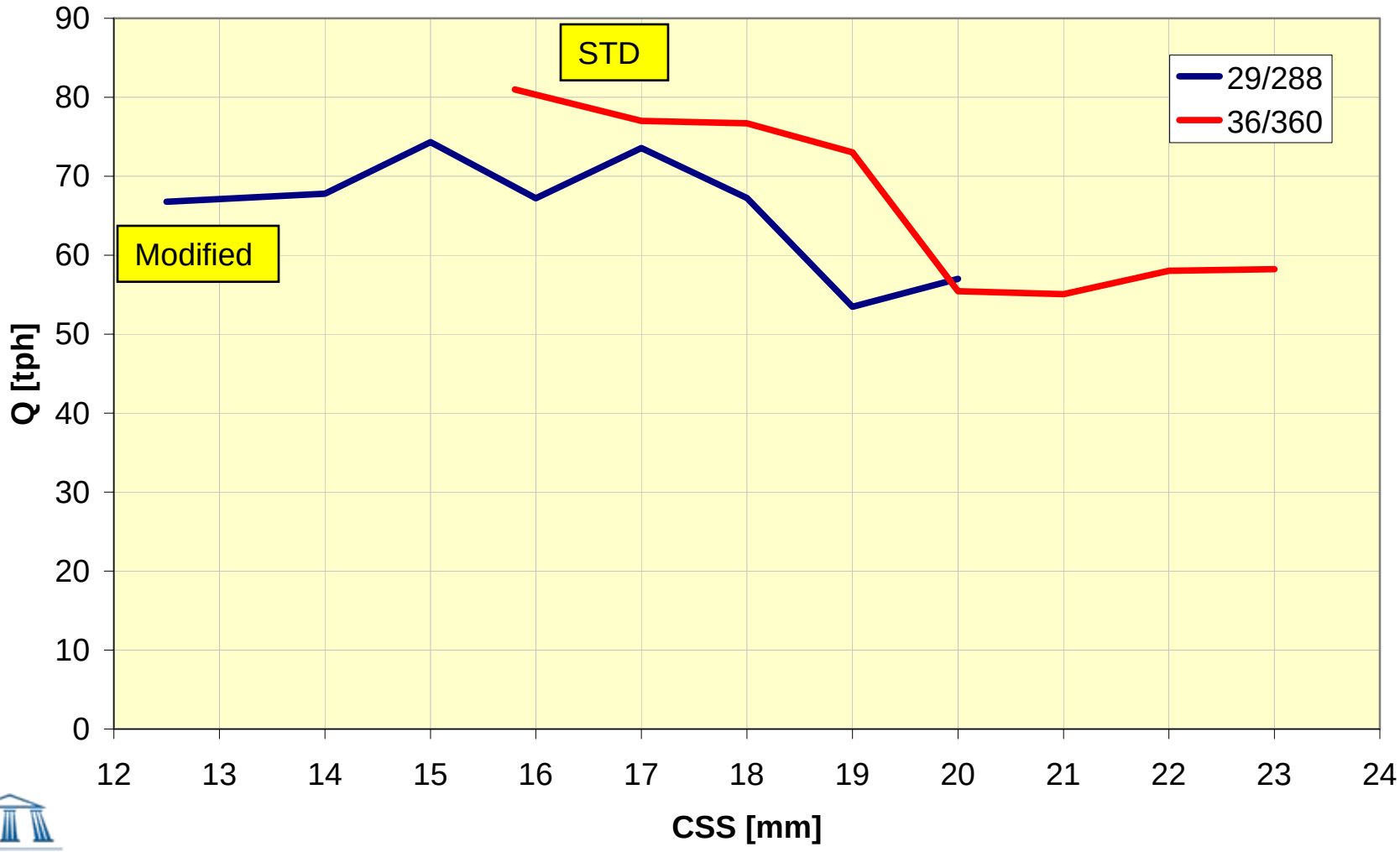
Product Yield

0-2, 2-16 and +16mm, [%]



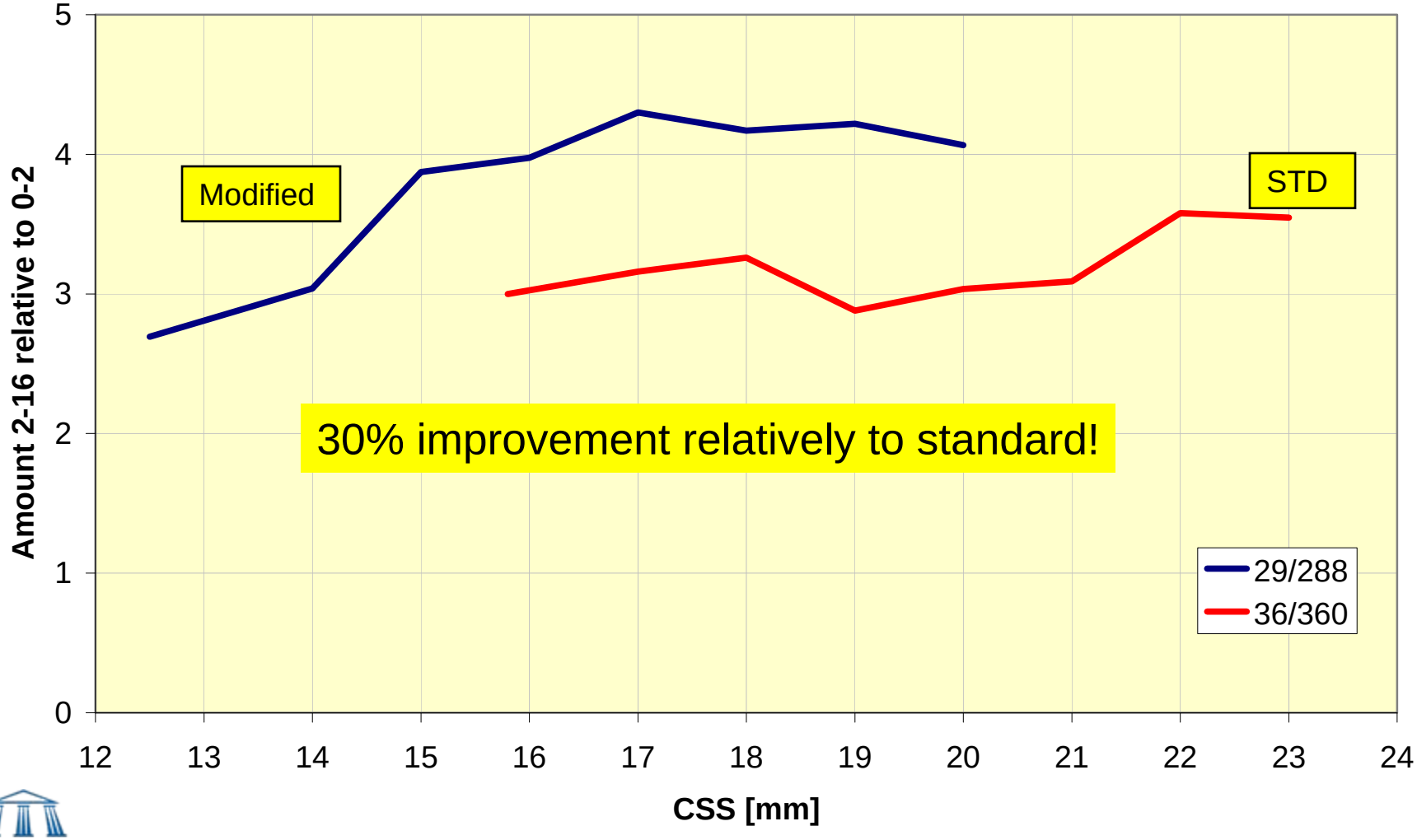
QUARRY ACADEMY

Production of Premium Product
2-16mm [tph]



QUARRY ACADEMY

Relation between Produced Product and Fines



QUARRY ACADEMY

Economical Analysis

- **Allocated cost per ton saleable product**

  = all the cumulated costs (drilling, blasting, hauling, conveying, primary and secondary crushing) divided by the mass of the saleable product

- **Gross profit**

  = potential sales – production costs

QUARRY ACADEMY

Economical Analysis

	Step					
Costs [USD]	**1**	**2**	**3**	**4**	**5**	**6**
Feed material	1.30	1.40	1.50	1.60	1.70	1.80
Crushing cost	0.34	0.37	0.40	0.42	0.45	0.47
Income [USD]						
Typical product	4.00	4.80	5.60	6.40	7.20	8.00
Handling of fines	0.20	0.22	0.24	0.26	0.28	0.30

QUARRY ACADEMY

Economical Analysis

	29/288								36/360							
CSS [mm]	12.5	14	15	16	17	18	19	20	15.8	17	18	19	20	21	22	23
P [kw]	133	111	105	89	92	87	79	74	148	123	126	101	100	91	84	80
p [Mpa]	5.6	4.6	4.0	3.2	3.4	3.0	2.8	2.6	4.6	4.2	3.8	2.7	2.7	2.5	2.2	2.3
Q [tph]	95	97	101	105	109	109	103	114	120	125	130	137	126	134	134	138
Yield [%]																
0-2	26.1	23.0	19.0	16.1	15.7	14.8	12.3	12.3	22.5	19.5	18.1	18.5	14.5	13.3	12.1	11.9
2-16	70.3	69.9	73.6	64.0	67.5	61.7	51.9	50.0	67.5	61.6	59.0	53.3	44.0	41.1	43.3	42.2
+16	3.6	7.1	7.4	19.9	16.8	23.5	35.8	37.7	10.0	18.9	22.9	28.2	41.5	45.6	44.6	45.9
Volumes [tph]																
0-2	25	22	19	17	17	16	13	14	27	24	24	25	18	18	16	16
2-16	67	68	74	67	74	67	53	57	81	77	77	73	55	55	58	58
+16	3	7	7	21	18	26	37	43	12	24	30	39	52	61	60	63

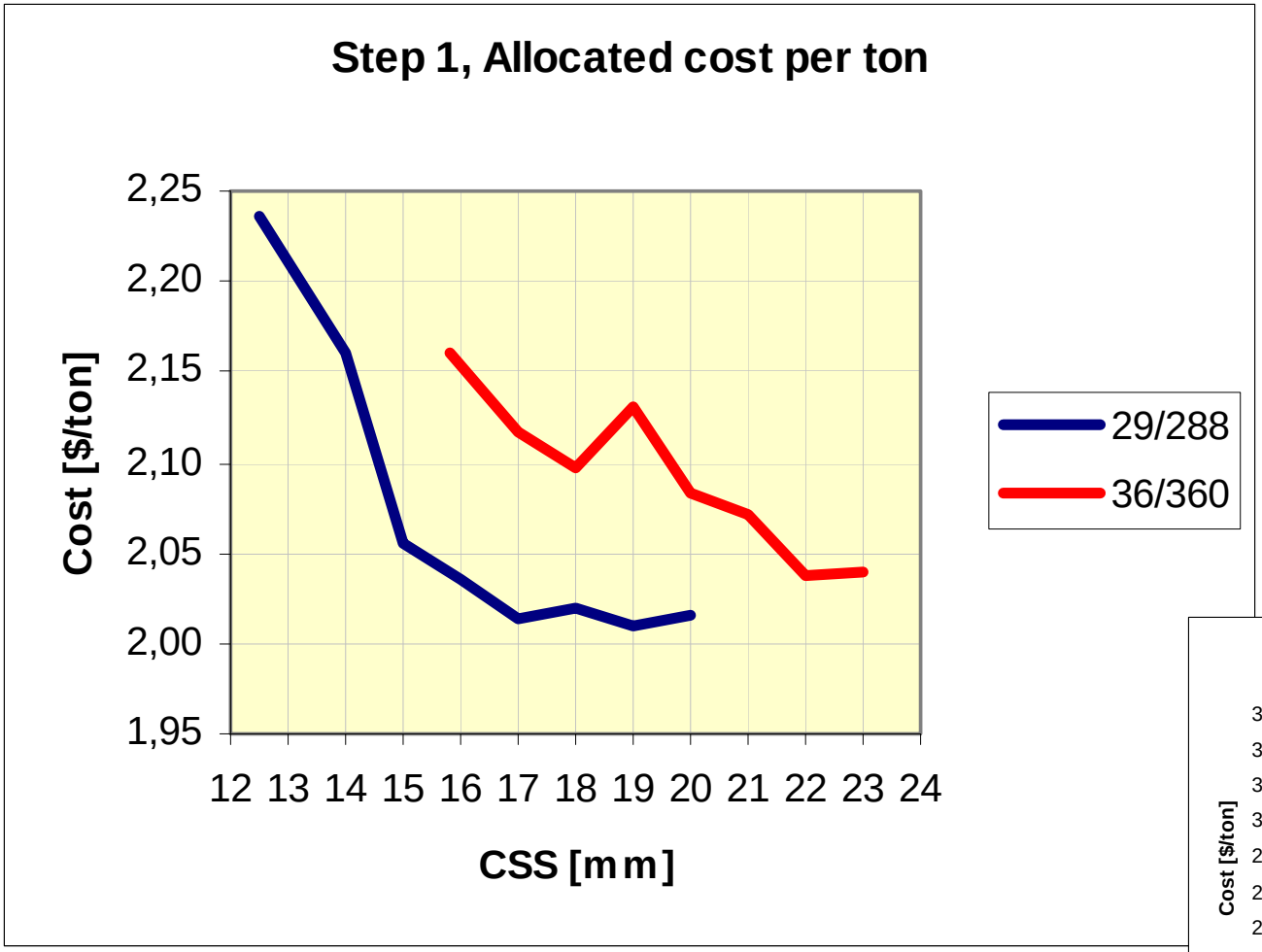
QUARRY ACADEMY

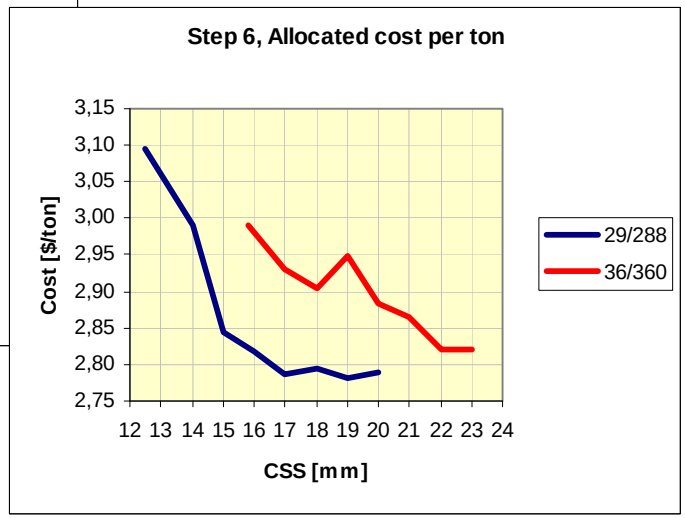
Economical Analysis

Economics	29/288								36/360							
Step 1																
Cost per ton $/ton	2.24	2.16	2.06	2.04	2.01	2.02	2.01	2.02	2.16	2.12	2.10	2.13	2.08	2.07	2.04	2.04
Gross profit $/ton	0.94	1.00	1.15	1.02	1.09	0.99	0.84	0.81	0.97	0.91	0.89	0.78	0.67	0.63	0.68	0.67
Gross profit $/hour	89	97	116	107	119	108	87	92	116	114	116	107	84	84	92	92
Step 2																
Cost per ton $/ton	2.41	2.33	2.21	2.19	2.17	2.17	2.16	2.17	2.32	2.28	2.26	2.29	2.24	2.23	2.19	2.19
Gross profit $/ton	1.50	1.55	1.74	1.53	1.63	1.49	1.25	1.20	1.50	1.40	1.36	1.20	1.02	0.96	1.03	1.00
Gross profit $/hour	142	151	176	160	178	162	129	137	180	175	176	165	128	128	138	138
Step 3																
Cost per ton $/ton	2.59	2.50	2.38	2.36	2.33	2.34	2.33	2.34	2.50	2.45	2.43	2.47	2.42	2.40	2.36	2.37
Gross profit $/ton	2.05	2.11	2.32	2.04	2.17	1.98	1.67	1.60	2.04	1.89	1.83	1.62	1.37	1.28	1.37	1.34
Gross profit $/hour	195	205	235	214	236	215	172	183	244	236	237	222	172	172	184	184
Step 4																
Cost per ton $/ton	2.75	2.66	2.53	2.51	2.48	2.49	2.47	2.48	2.66	2.61	2.58	2.62	2.57	2.55	2.51	2.51
Gross profit $/ton	2.50	2.55	2.80	2.45	2.61	2.38	2.01	1.93	2.47	2.29	2.20	1.96	1.65	1.55	1.65	1.61
Gross profit $/hour	237	248	283	257	284	259	207	220	296	286	287	269	208	207	221	222
Step 5																
Cost per ton $/ton	2.93	2.83	2.70	2.67	2.64	2.65	2.64	2.64	2.83	2.78	2.75	2.79	2.73	2.72	2.67	2.67
Gross profit $/ton	2.93	2.99	3.26	2.85	3.03	2.77	2.33	2.24	2.89	2.67	2.57	2.30	1.92	1.81	1.93	1.88
Gross profit $/hour	278	290	329	300	331	302	240	256	346	334	335	315	243	242	258	259
Step 6																
Cost per ton $/ton	3.09	2.99	2.85	2.82	2.79	2.79	2.78	2.79	2.99	2.93	2.90	2.95	2.88	2.87	2.82	2.82
Gross profit $/ton	3.37	3.43	3.74	3.27	3.47	3.17	2.67	2.57	3.31	3.06	2.95	2.64	2.21	2.07	2.21	2.15
Gross profit $/hour	320	333	377	343	378	345	275	293	398	383	384	361	278	277	296	297

QUARRY ACADEMY

Allocated cost for saleable products $/ton





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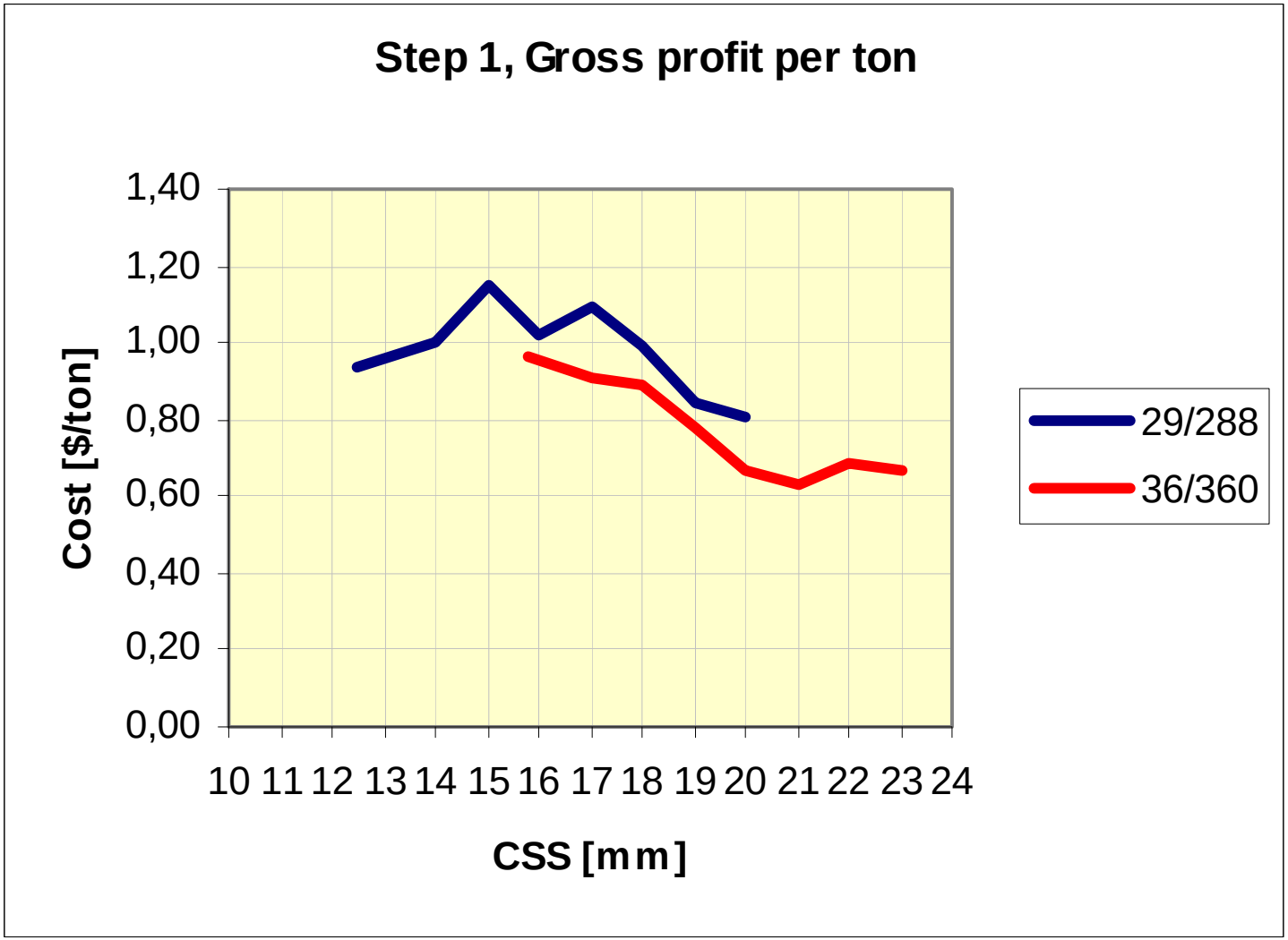
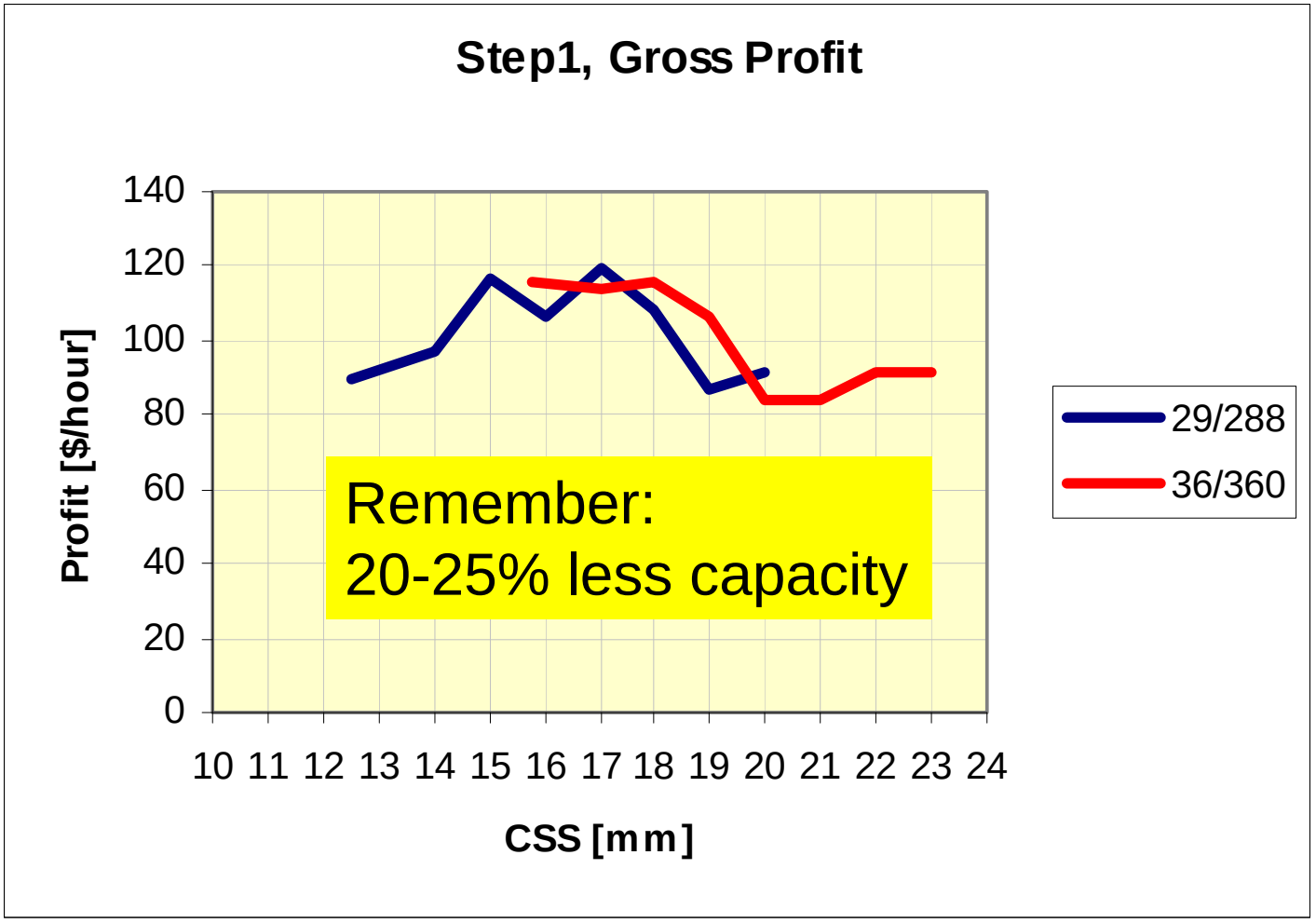
Gross profit - $/ton



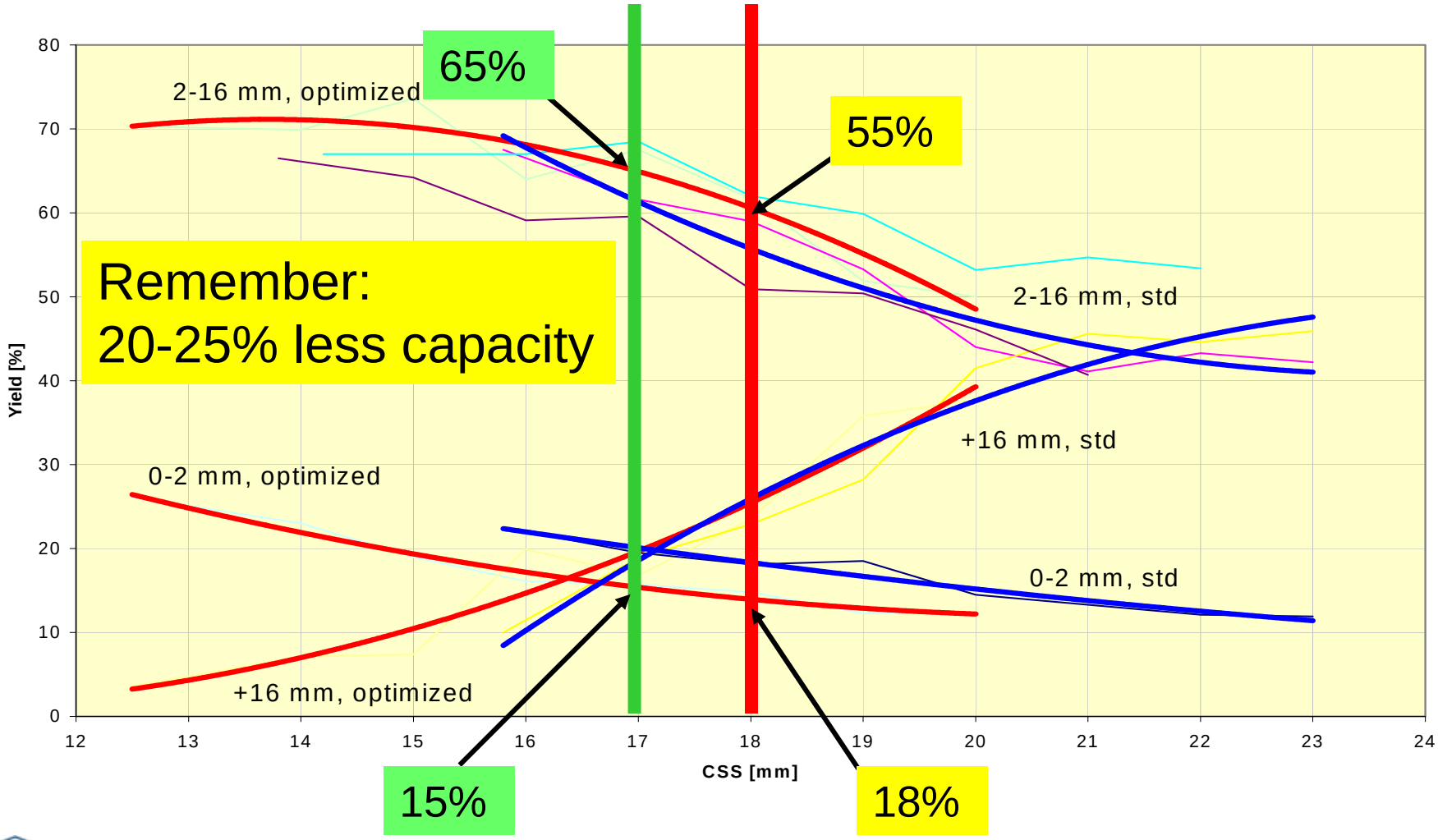
Gross profit - $/hour



QUARRY ACADEMY

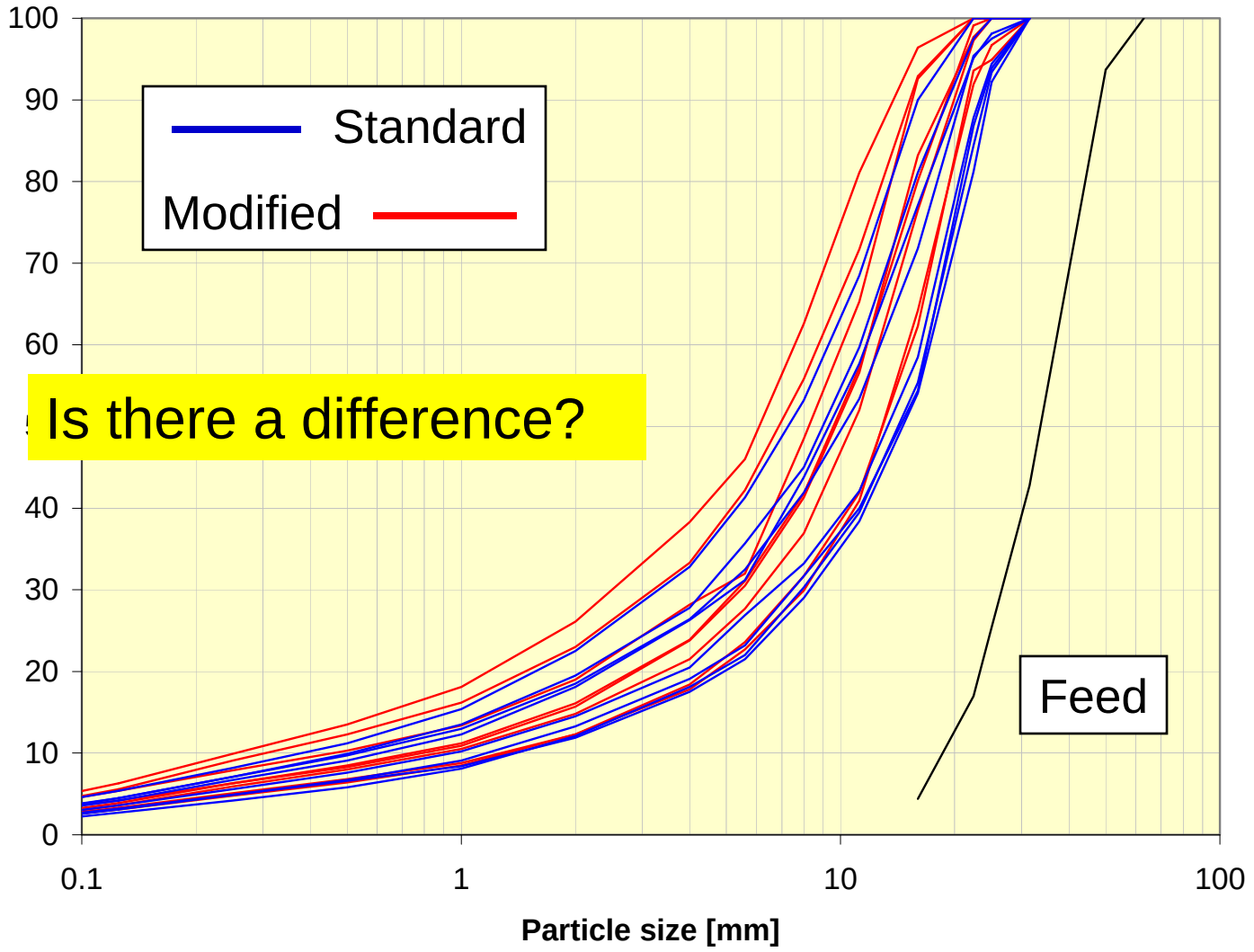
Yield

0-2, 2-16 and +16mm, [%]



QUARRY ACADEMY

Particle Size Distributions



QUARRY ACADEMY

Conclusions
Optimization of a Crushing Stage

- **Difficult to observe the differences from PSD graphs**
- **Careful analyses of yield required**
- **Maximize yield**
  - Get in control of your process!
  - Frequent (=daily) calibration
  - Improved process control
  - Active choice of optimal CSS
- **20-25% decrease in total capacity**
- **30% increase in yield of premium product**
- **Gentle crushing is the key to maximizing the overall yield in a situation where the fines has a low value**

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