Cone Crusher Yield Optimization

Magnus Evertsson

Improving Processes. Instilling Expertise.

Objectives

- Different levels of optimization
- Different aspects of optimization

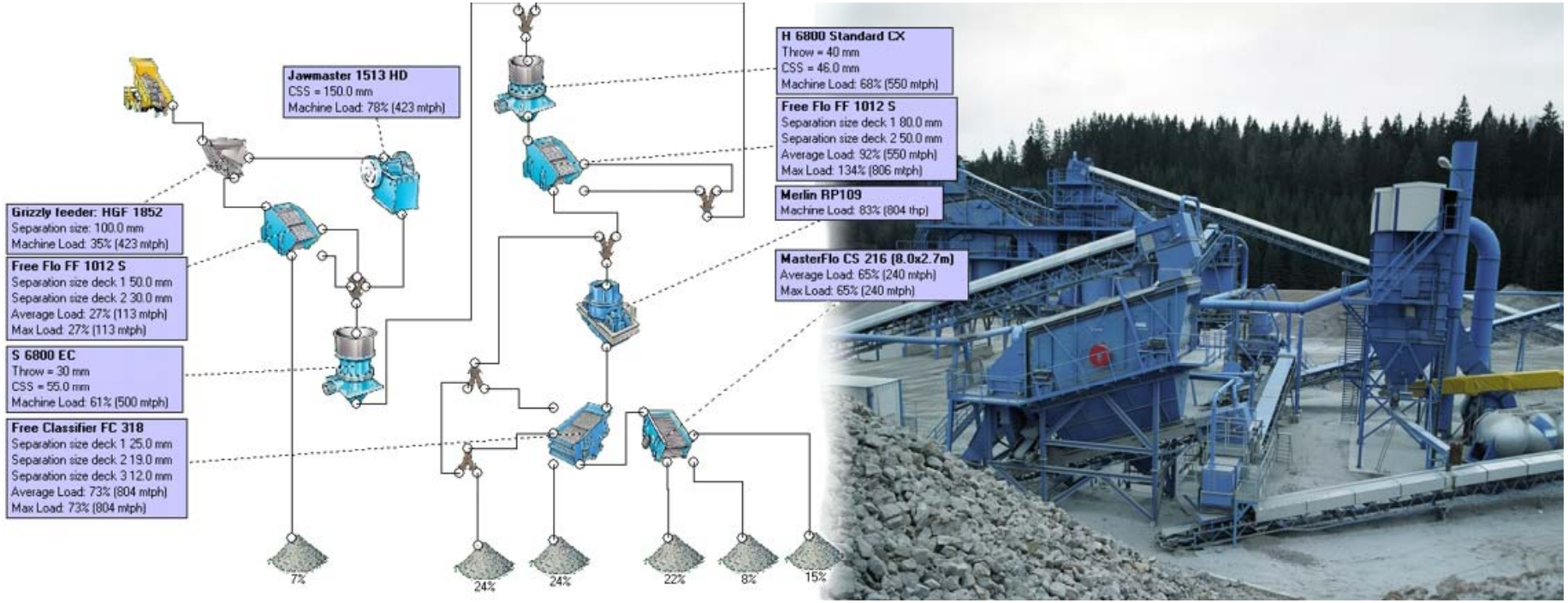
- Detailed demonstration of cone crusher yield optimization including economical aspects

Crushing Plant Optimization

- large scale

Crushing Plant Optimization

- Technical and economical
- Design and operation
- Best possible performance for a given market situation
- Economy, customer requirements, wear and process fluctuations



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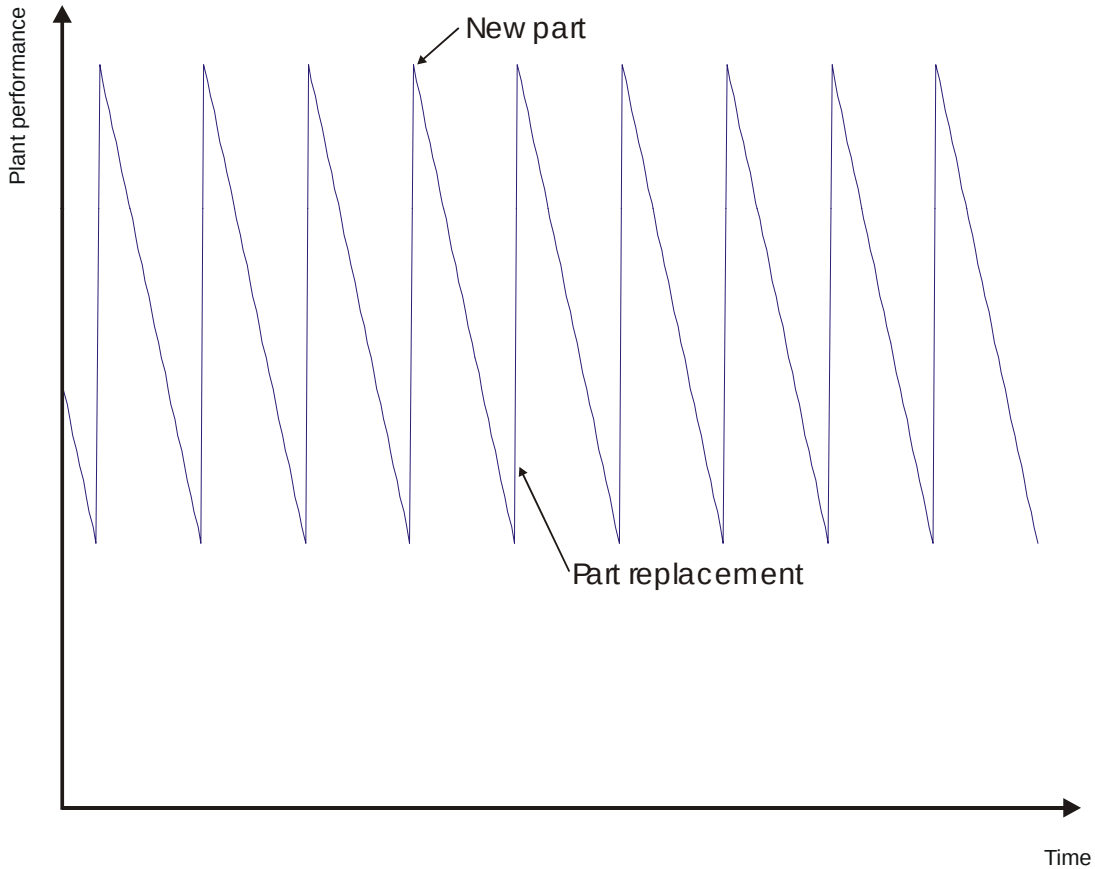
Crushing Plant Optimization

The effect of wear

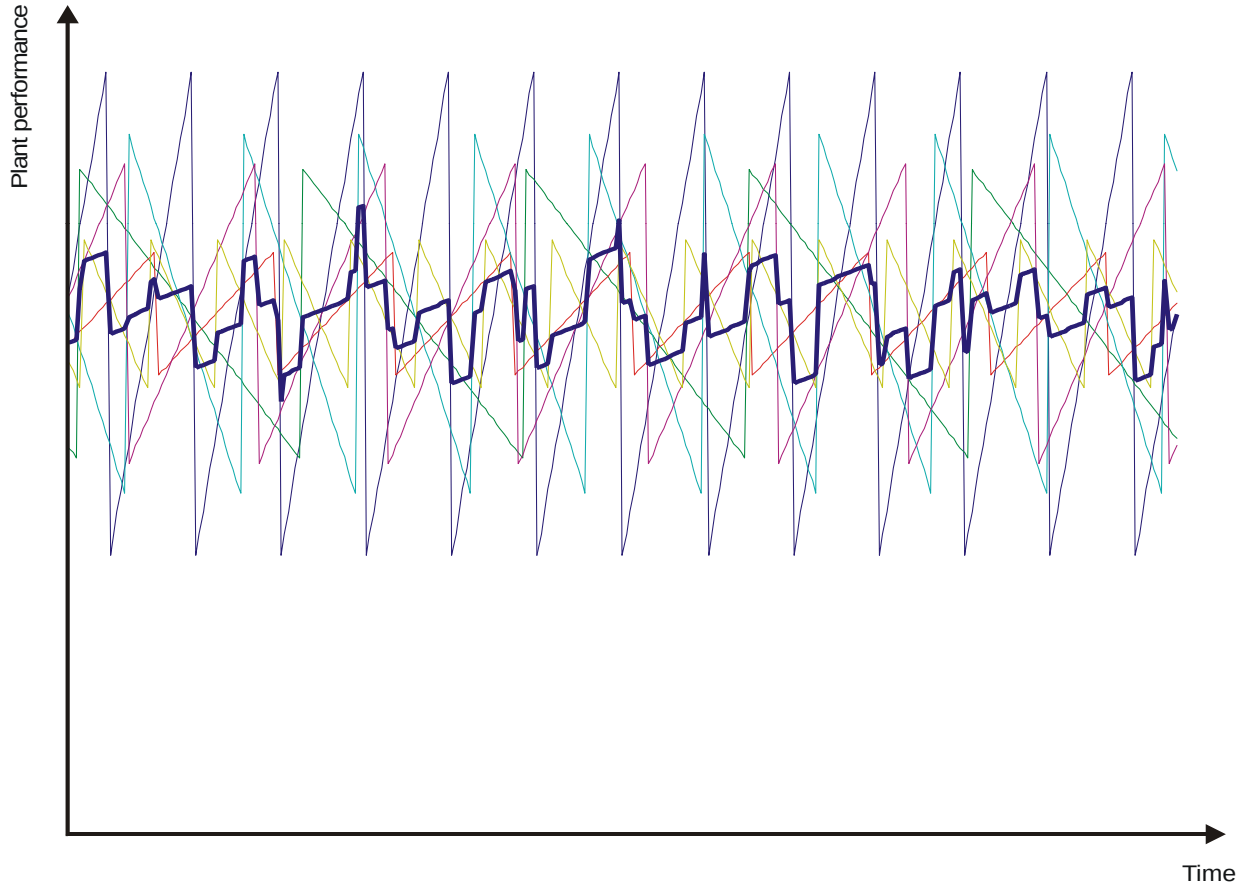
Effect of Wear

The variation due to ONE wear part

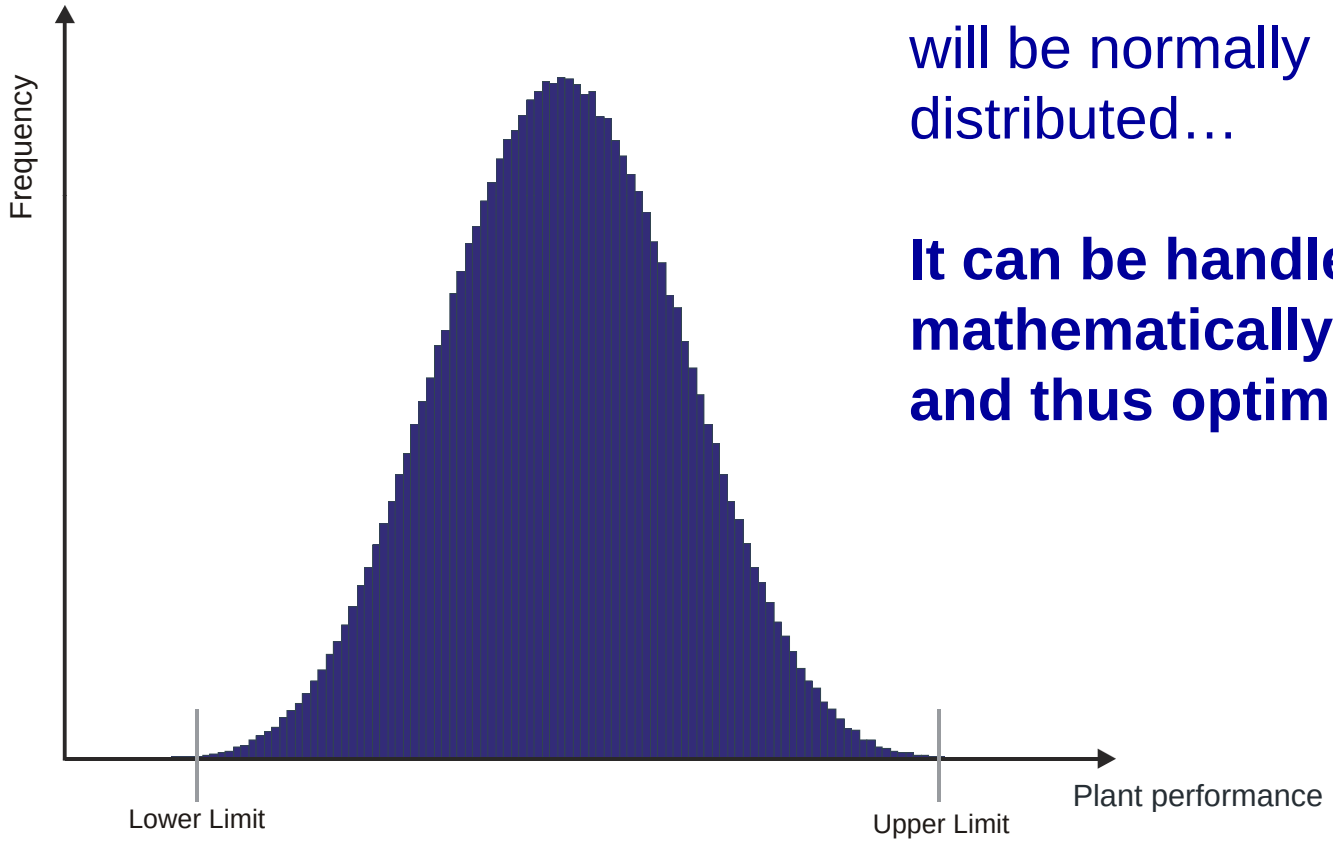


Effect of Wear

The variation due to SIX different wear parts



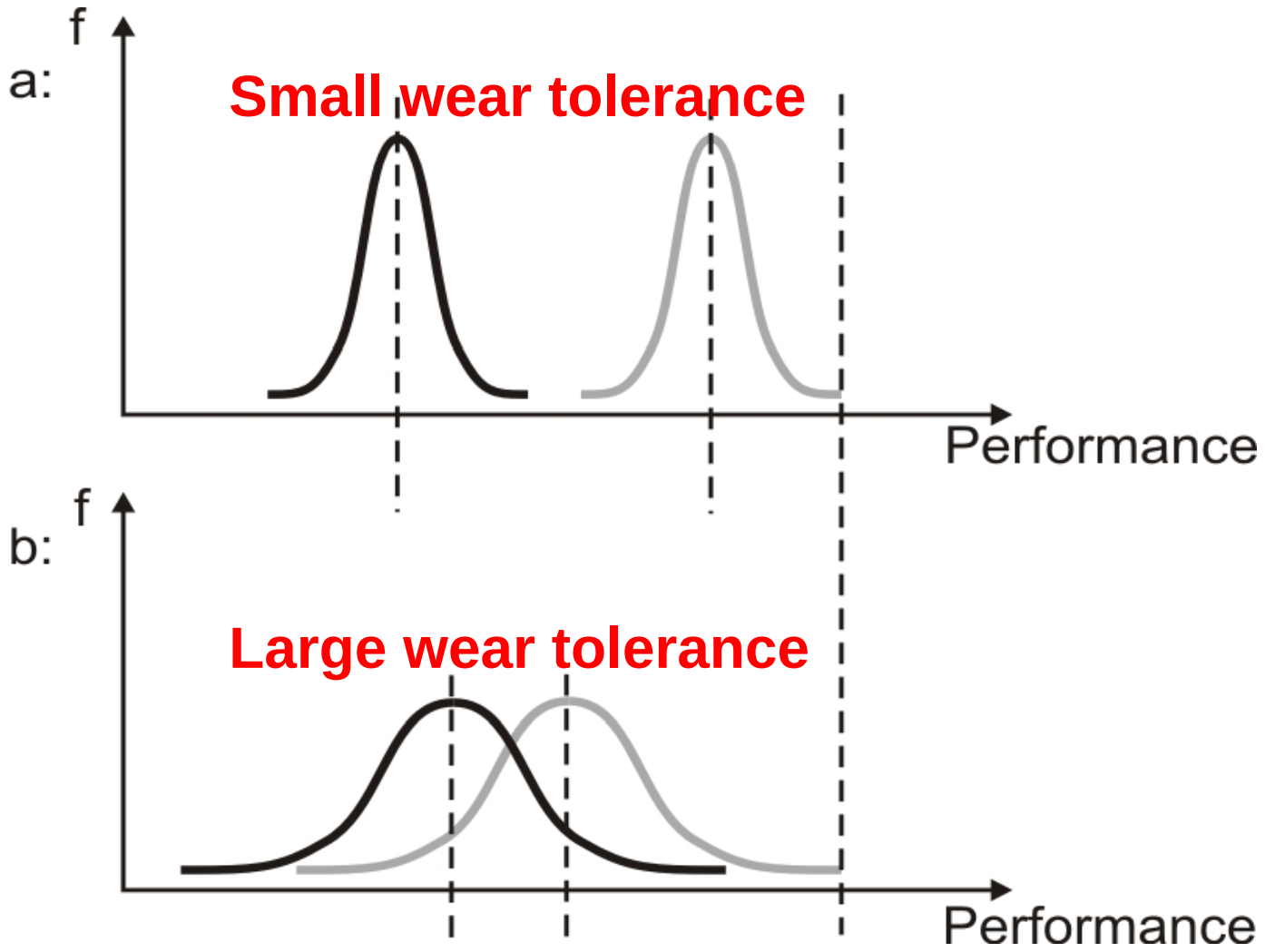
Effect of Wear



The combined effect will be normally distributed…

It can be handled mathematically and thus optimized!

Effect of Wear



Conclusions
Crushing Plant Optimization

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

Optimization of a Tertiary Crushing Stage

- small scale

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 most important production units as these are the primary sources for generating the product gradation
- The rock cannot be repaired…

Optimization of a Tertiary Crushing Stage

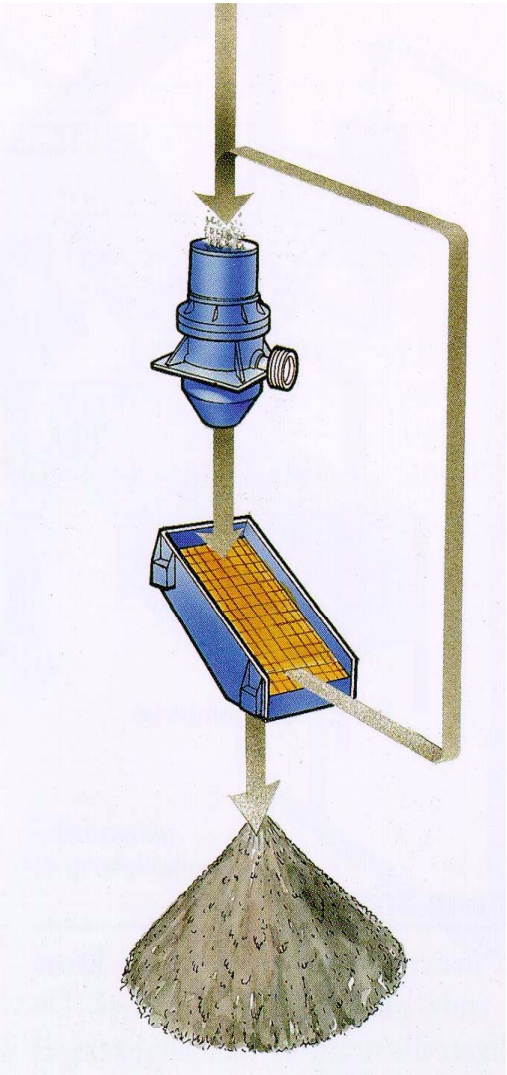
Aspects

- **Optimize total performance**
- **Maximize yield of premium product**
- **Minimize fines production**
- **Minimize circulating load**

- **Capacities**
- **Economics**

Test Setup and Parameters

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



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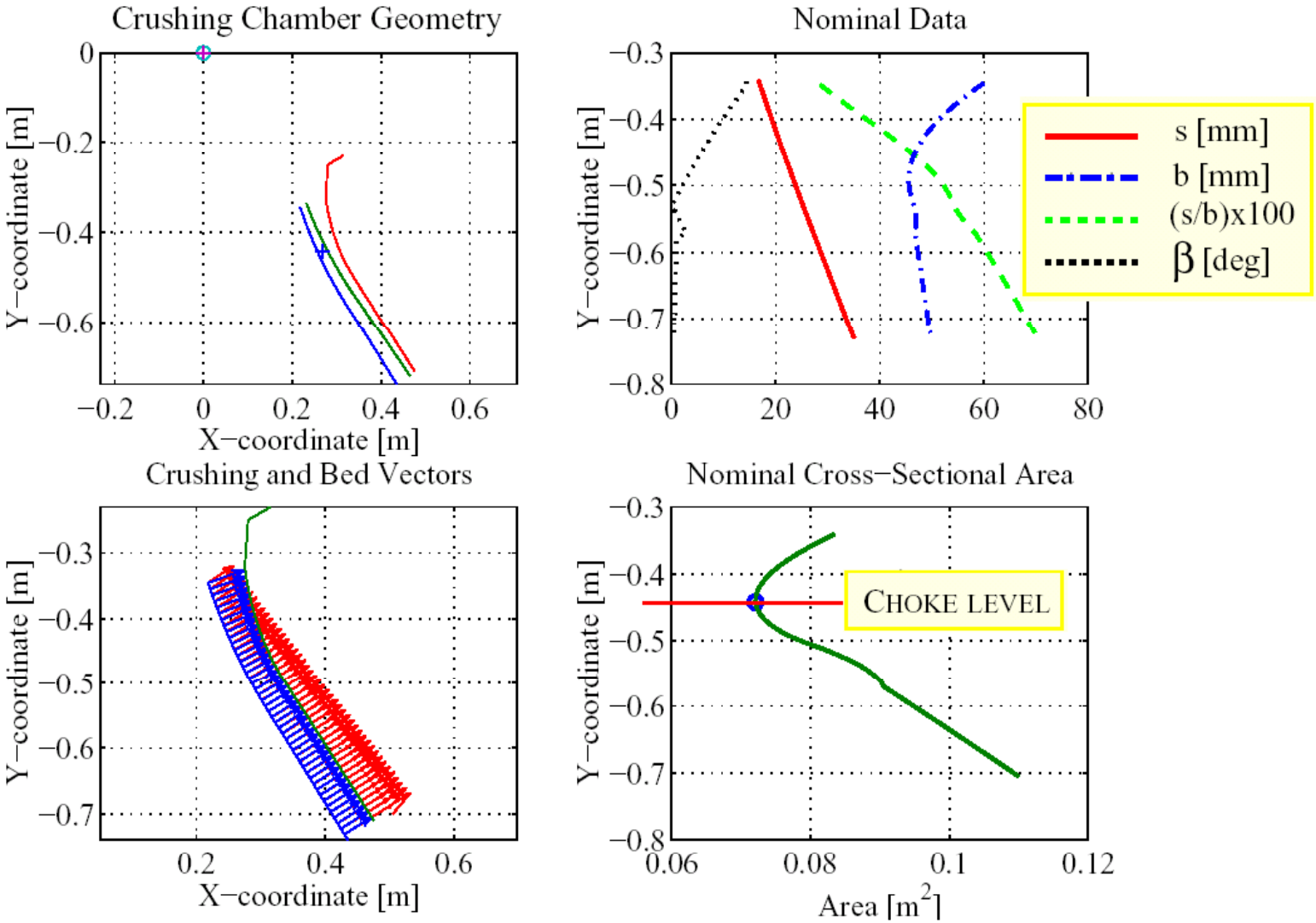
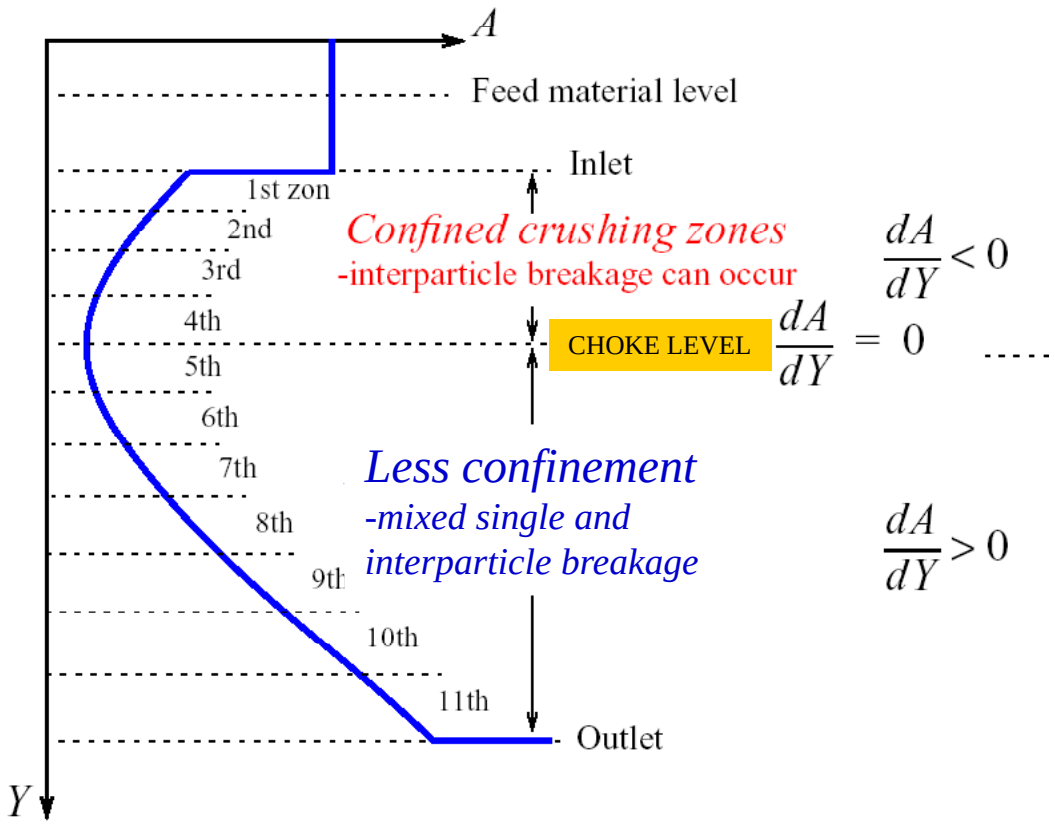
Crusher (Nominal) Geometry

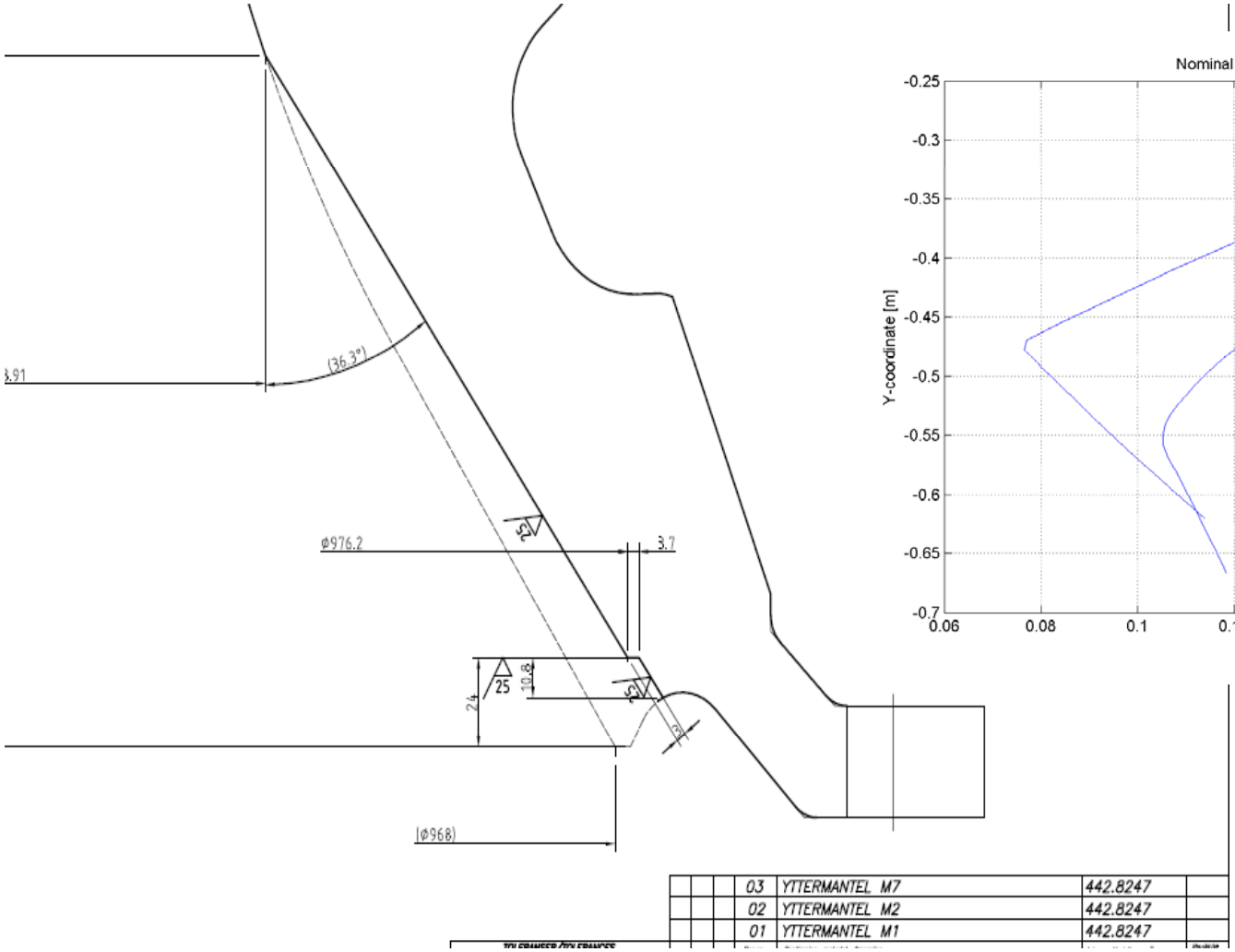


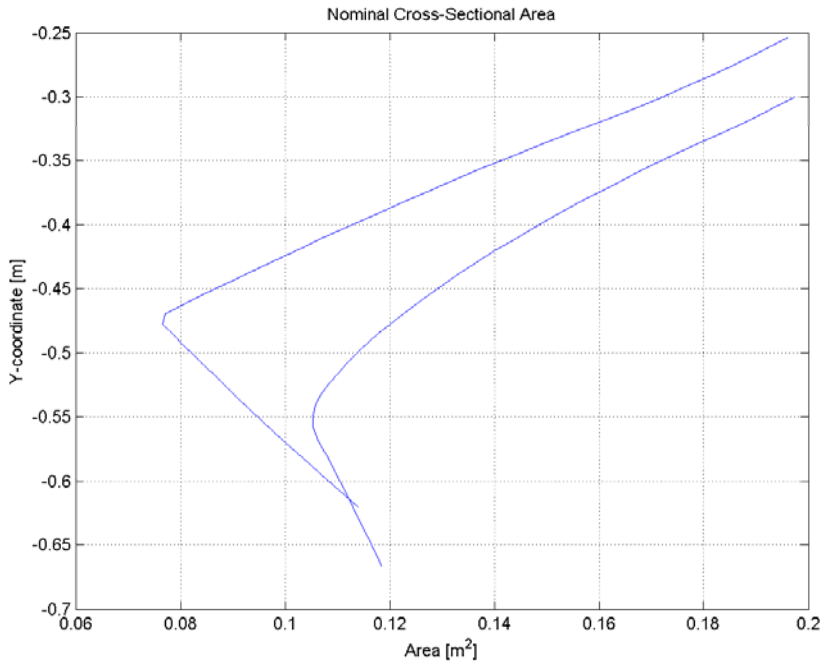
Breakage Modes



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

Chamber Design





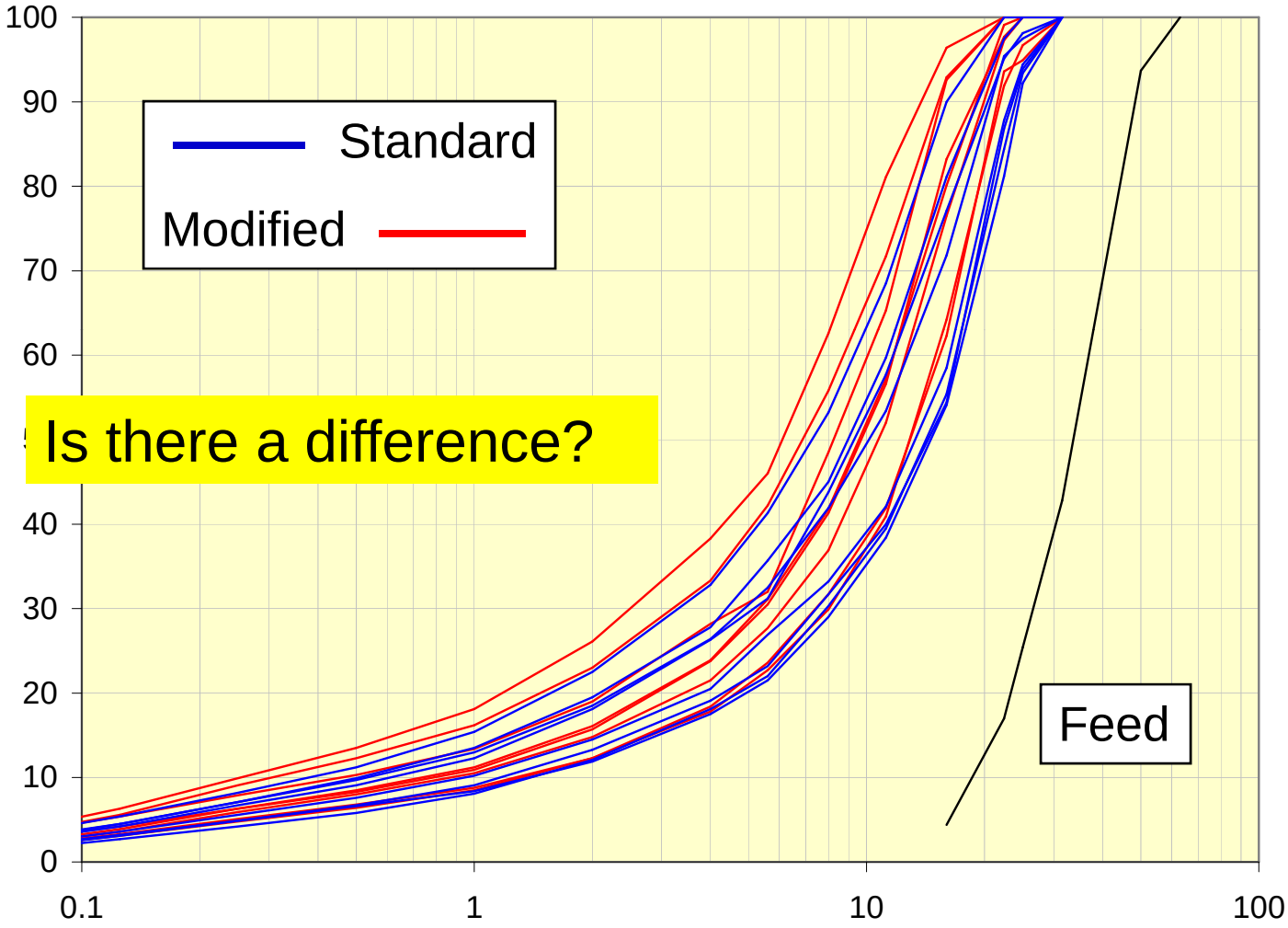
Procedure

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

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

Particle Size Distributions



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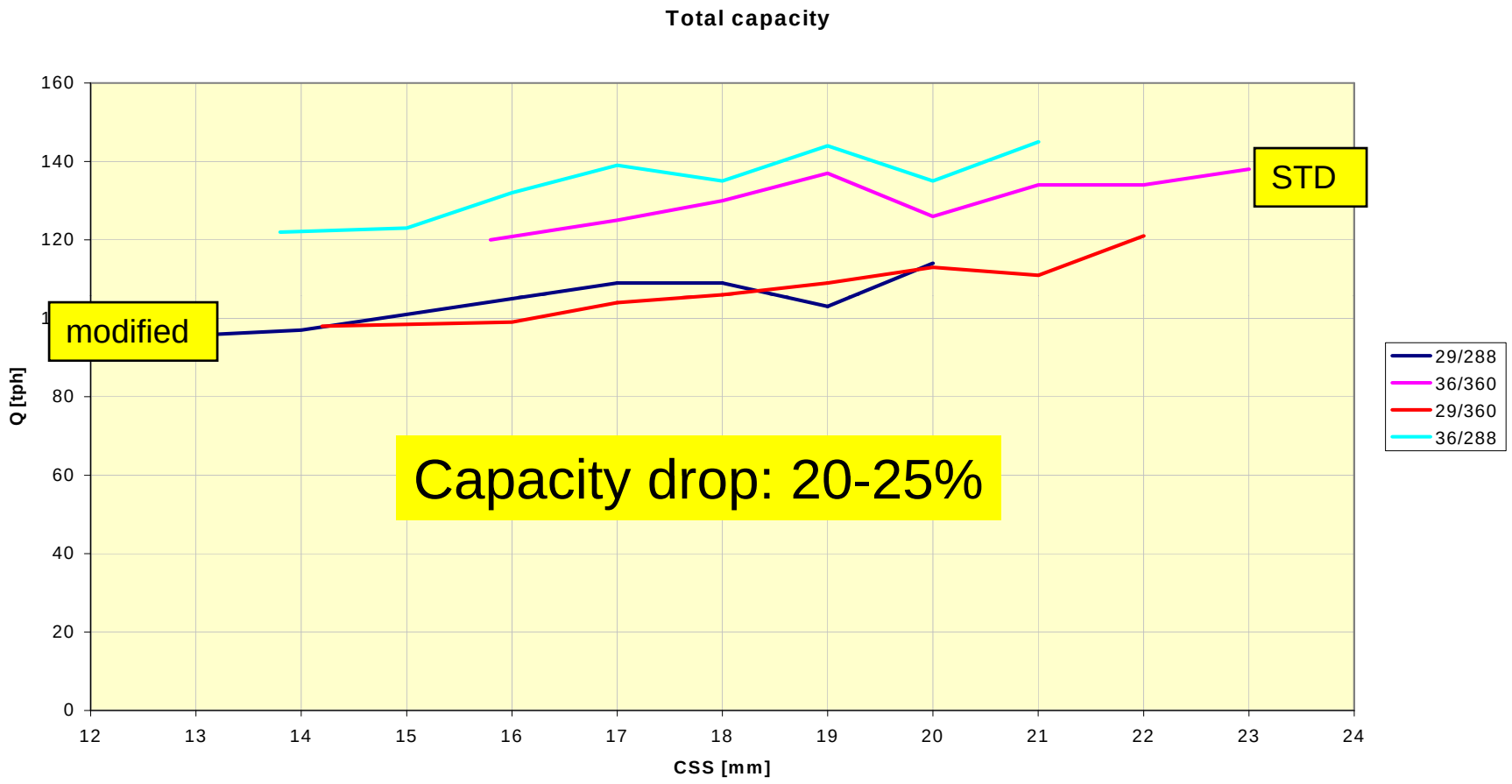
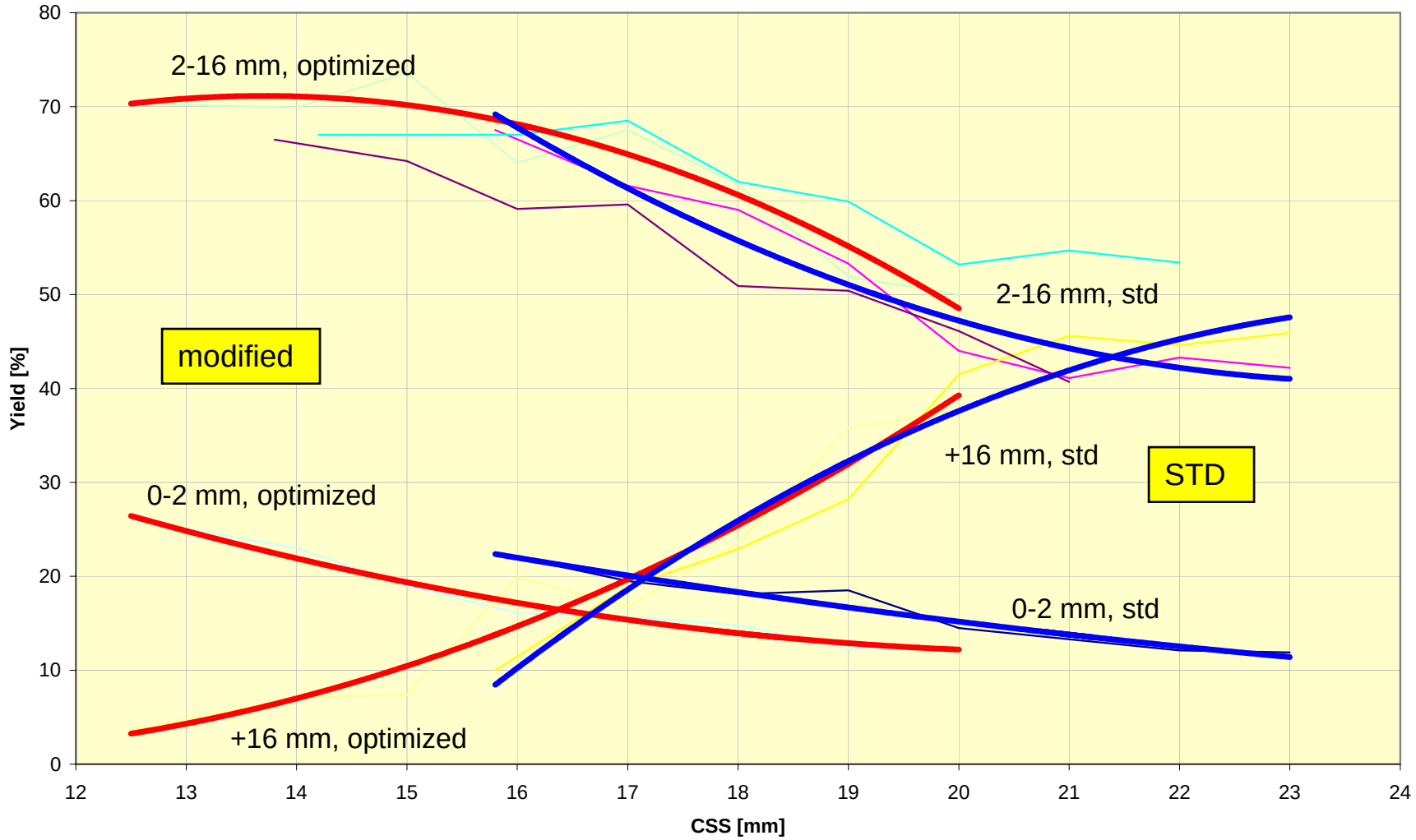
Total Capacity
[tph]

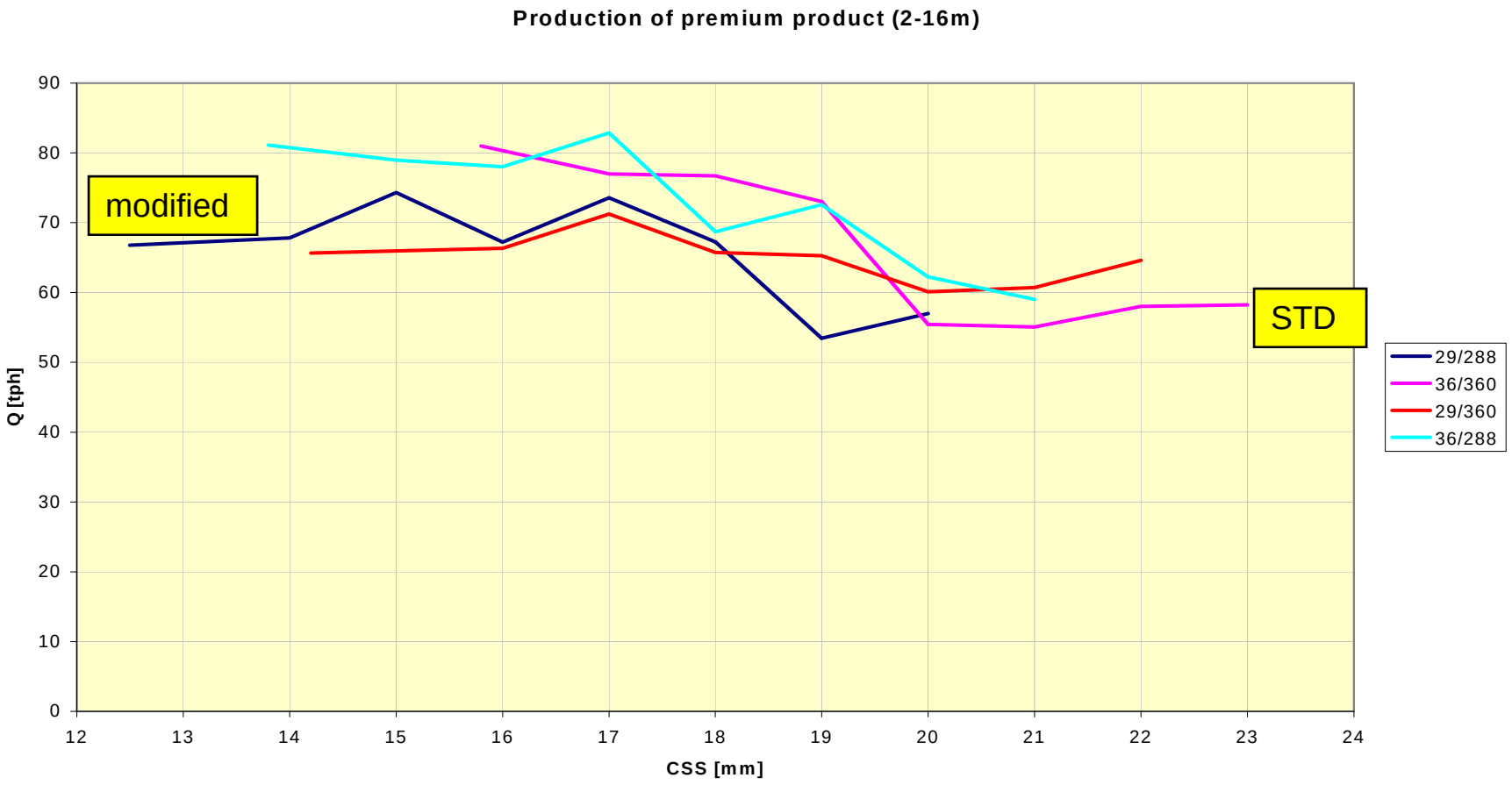


Yield

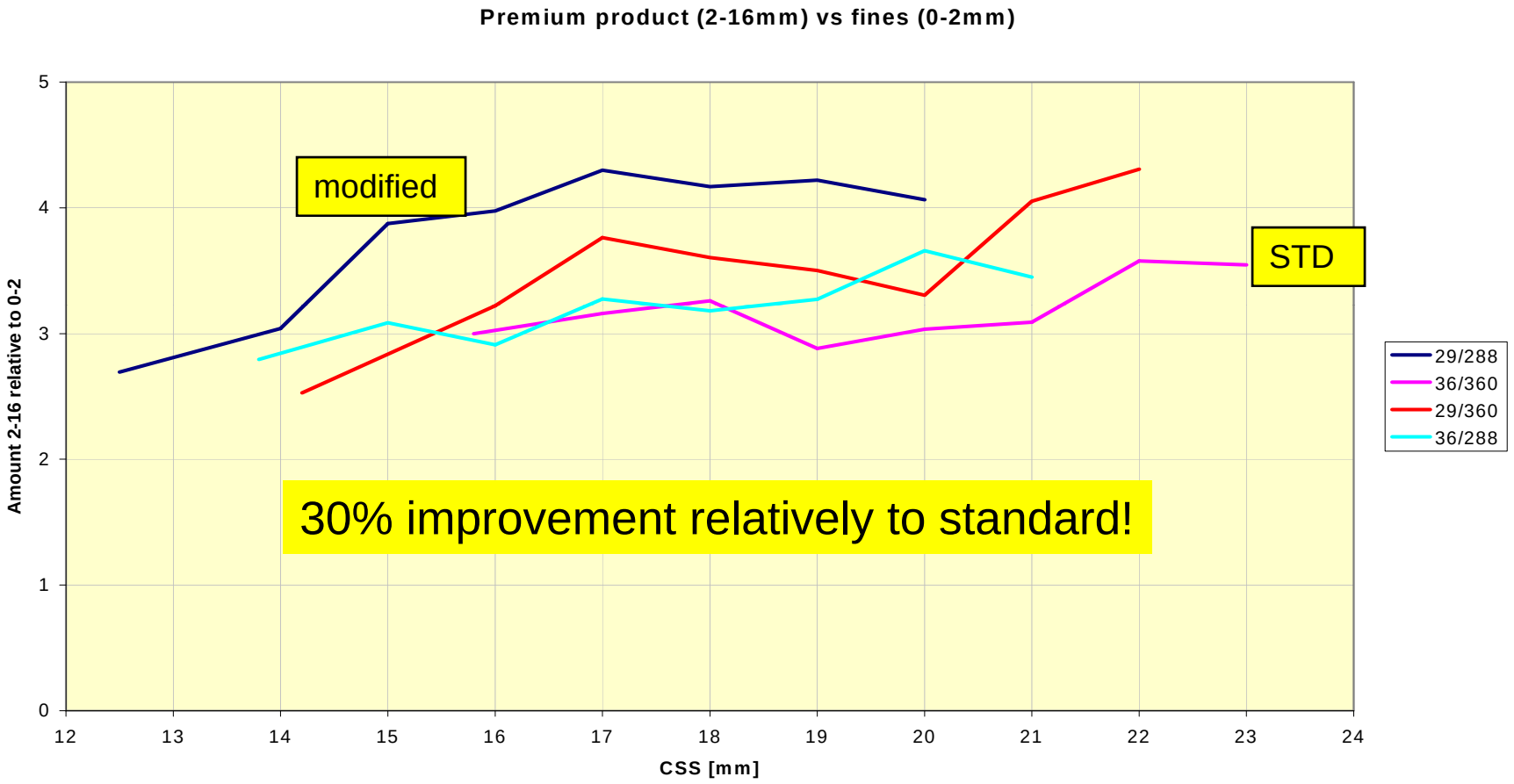
0-2, 2-16 and +16mm, [%]



Production of Premium Product
2-16mm [tph]



Relation between Produced Product and Fines



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Economical Analyses

- **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**

Economical Analyses

- **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

Economical Analyses

	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

Economical Analyses

	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

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Economical Analyses

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

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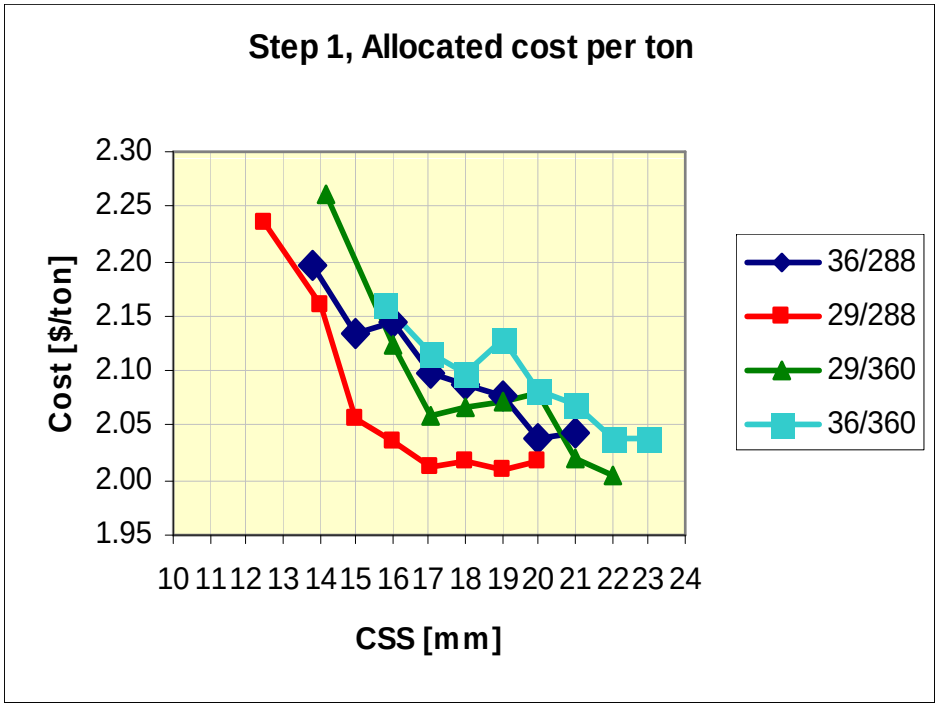
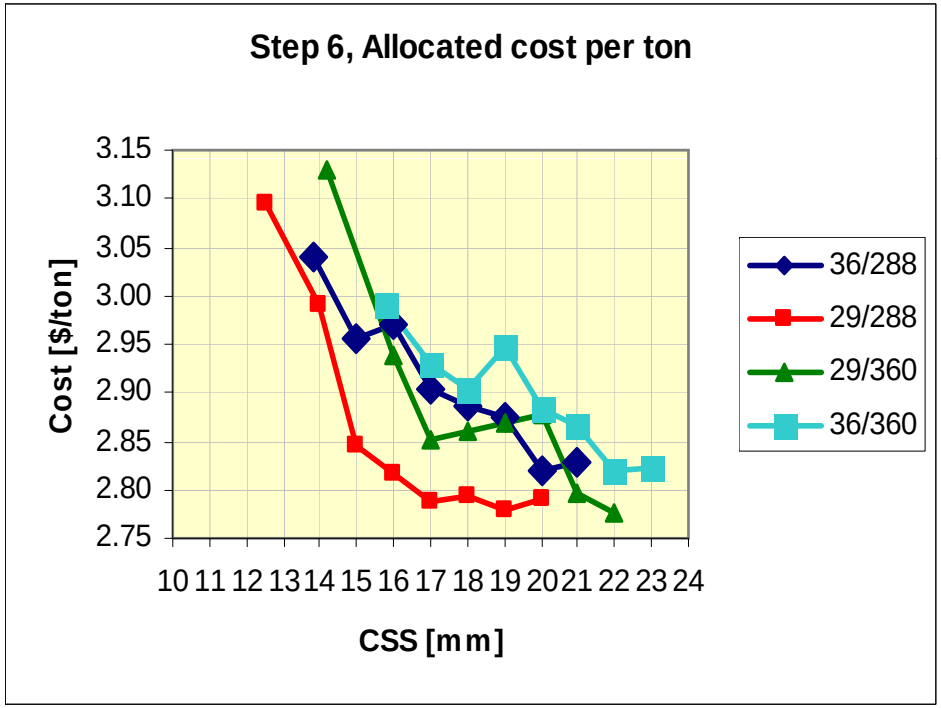
Allocated cost for saleable products





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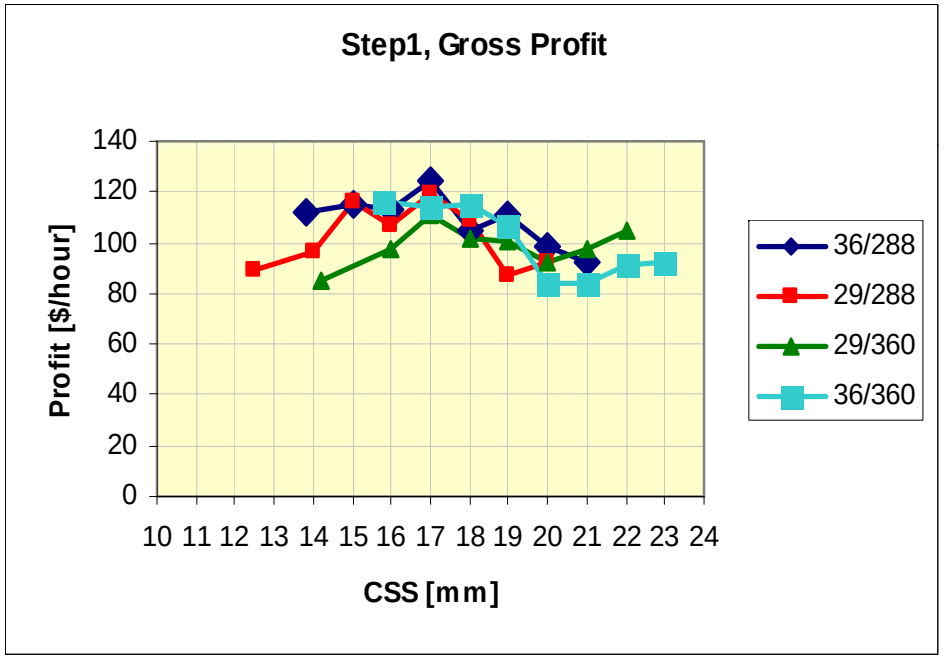
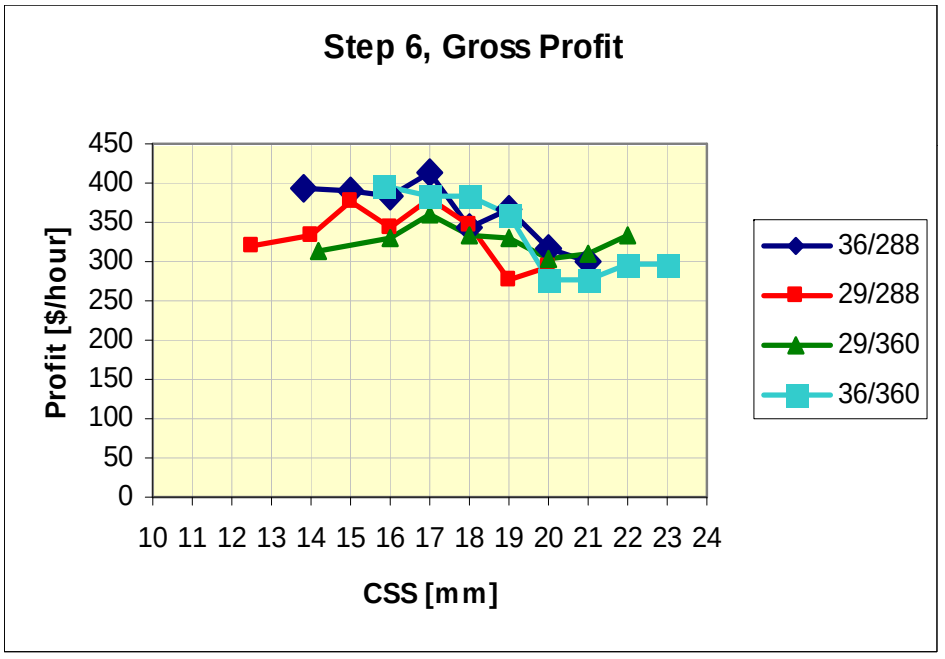
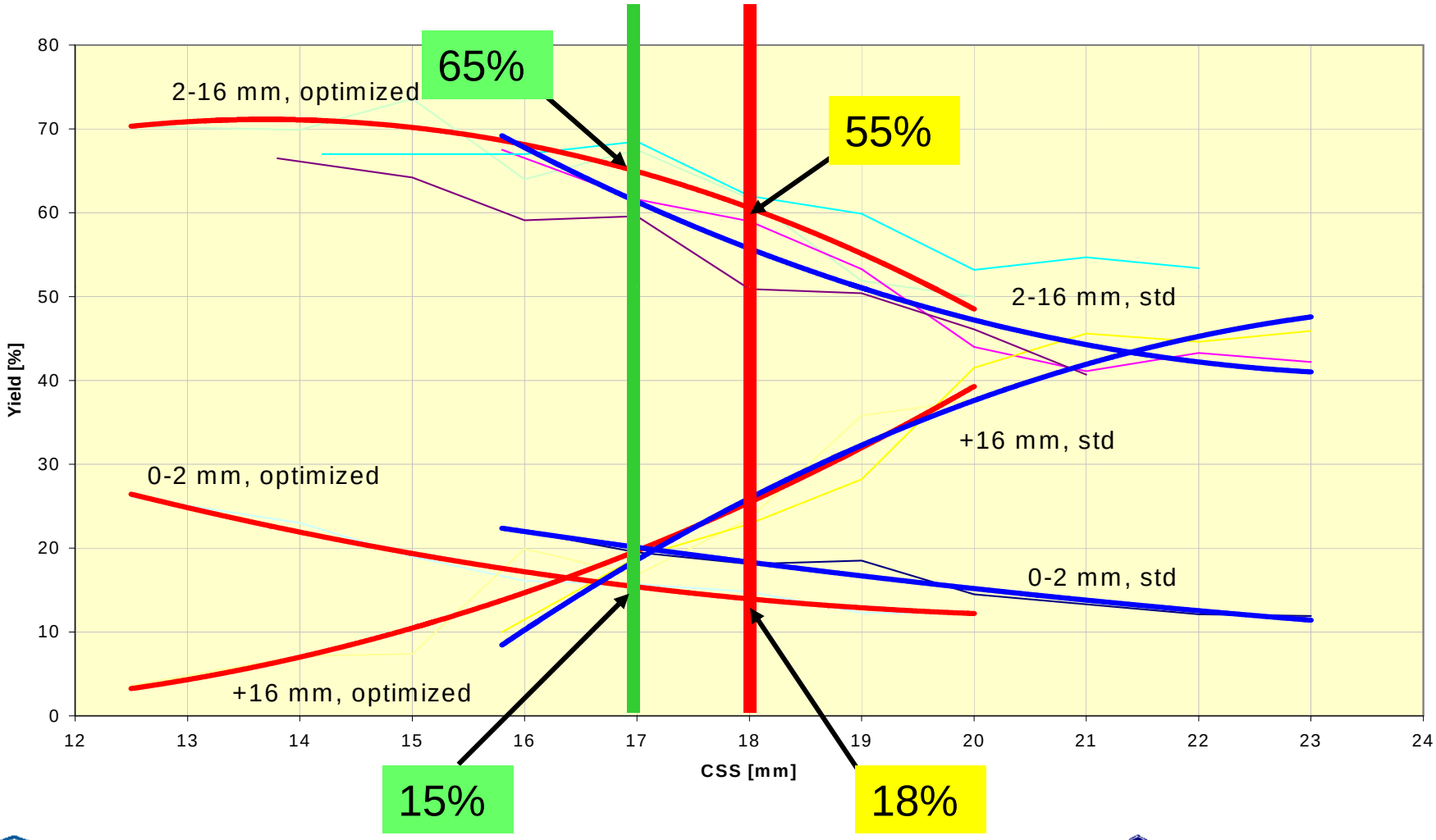
Gross profit



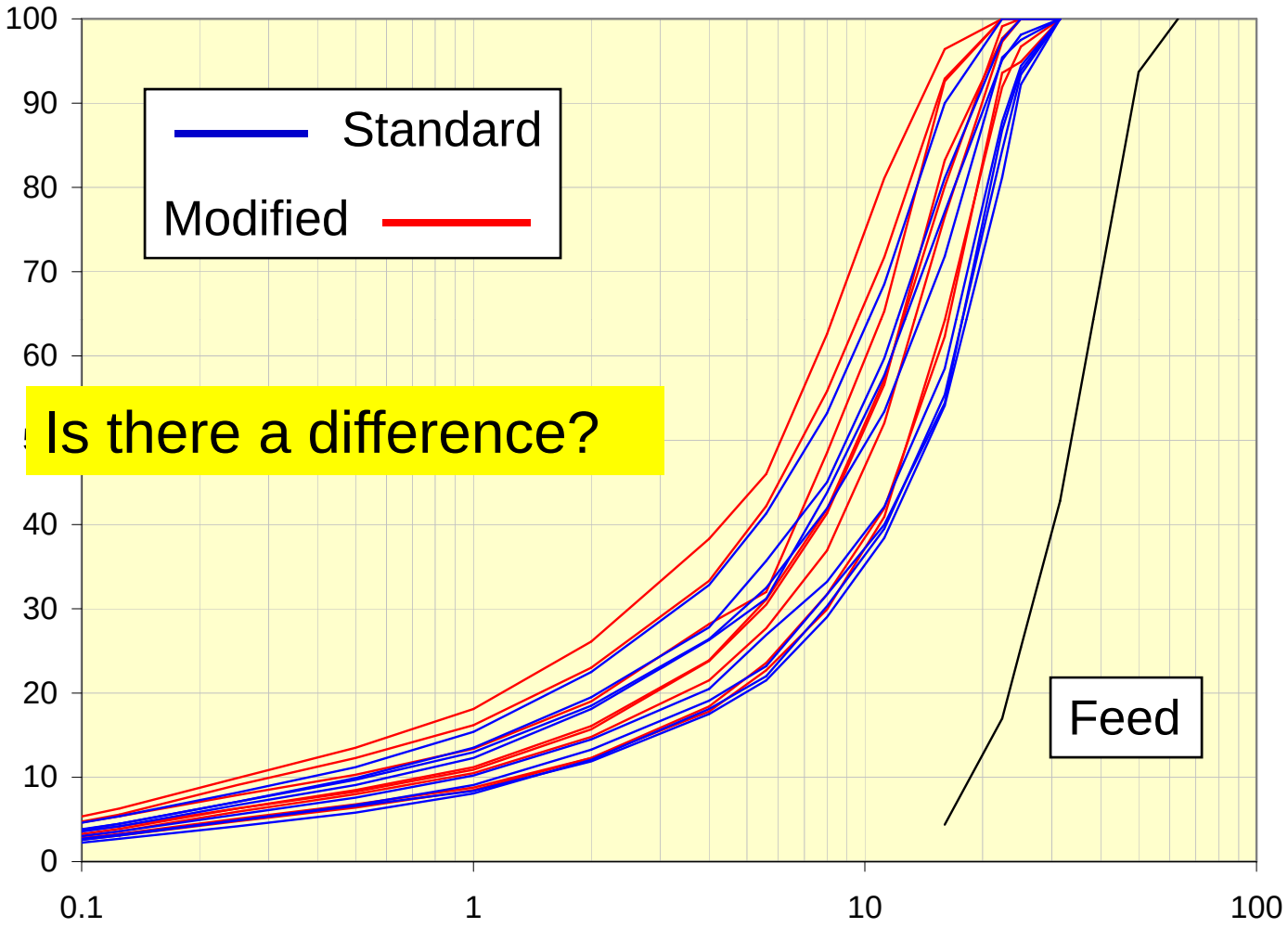


Yield

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



Particle Size Distributions



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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
- **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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