

# Cone Crusher Yield Optimization

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Improving Processes. Instilling Expertise.

**DYNO**  
Dyno Nobel



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# Objectives

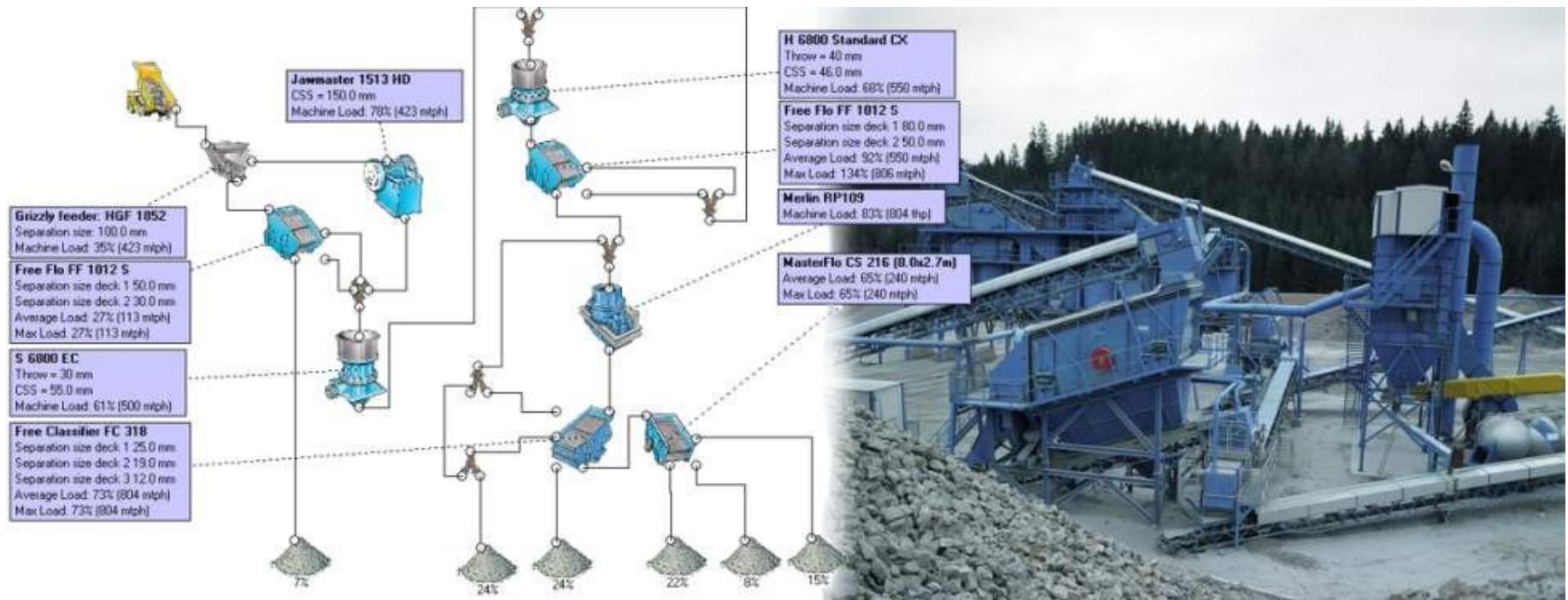
- **Different levels of optimization**
- **Different aspects of optimization**
- **Detailed demonstration of cone crusher yield optimization including economical aspects**

# Crushing Plant Optimization

- large scale

# Crushing Plant Optimization

- Technical and economical



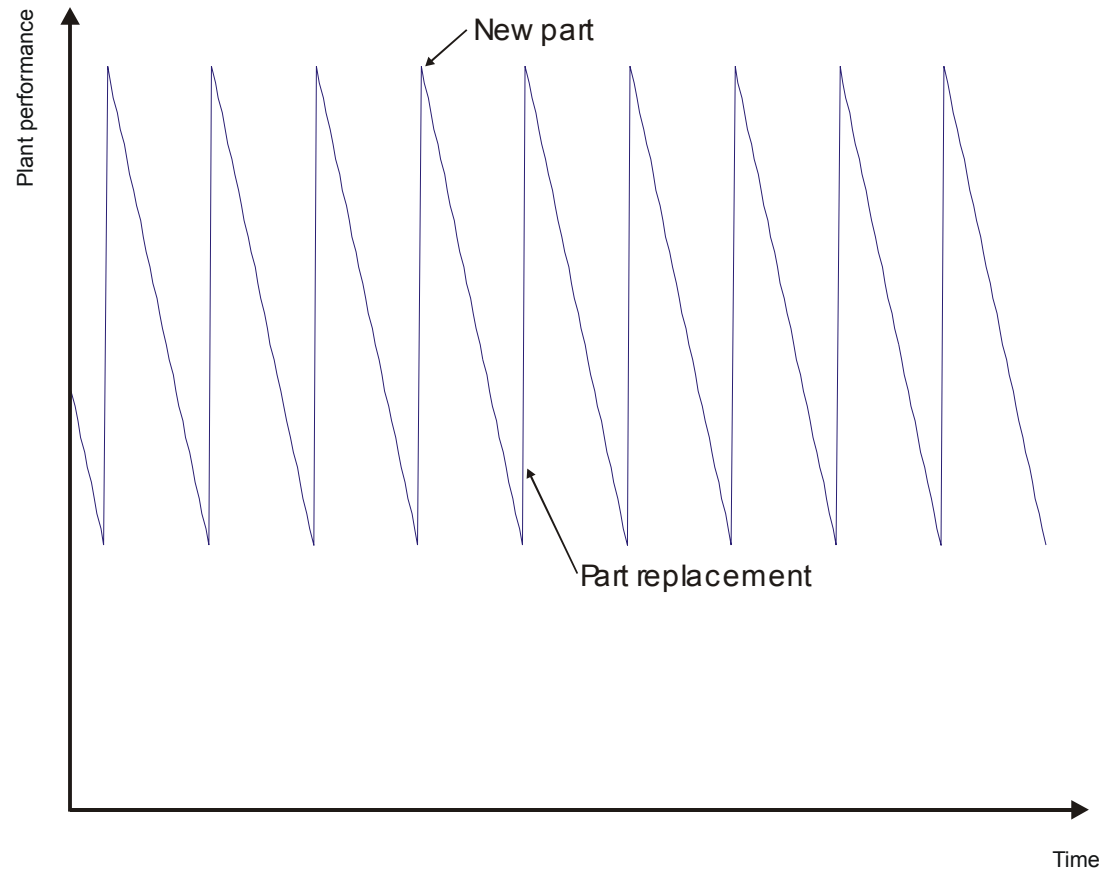
# Crushing Plant Optimization

## The effect of wear

- Screen cloths
- Crushing chambers

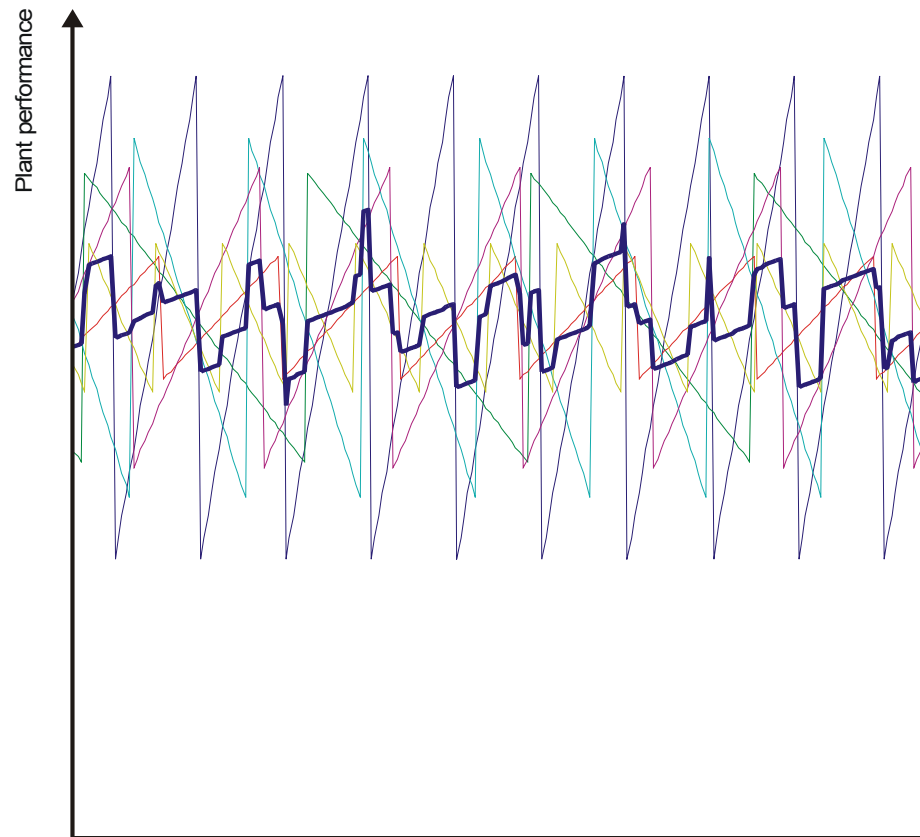
# Effect of Wear

## The variation due to ONE wear part



# Effect of Wear

The variation due to SIX different wear parts



***Take home message:***

**You can  
experience  
strange variations  
then sampling.**

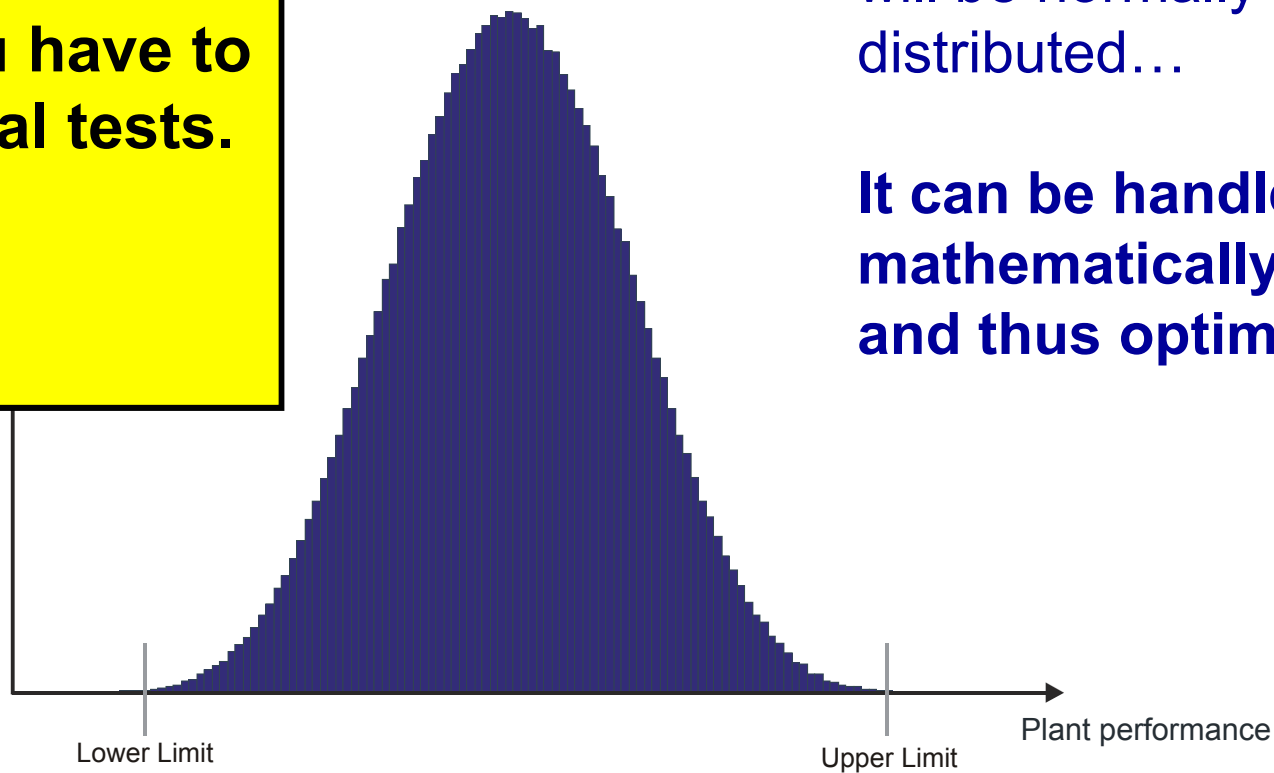
# Effect of Wear

**Take home message:**

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

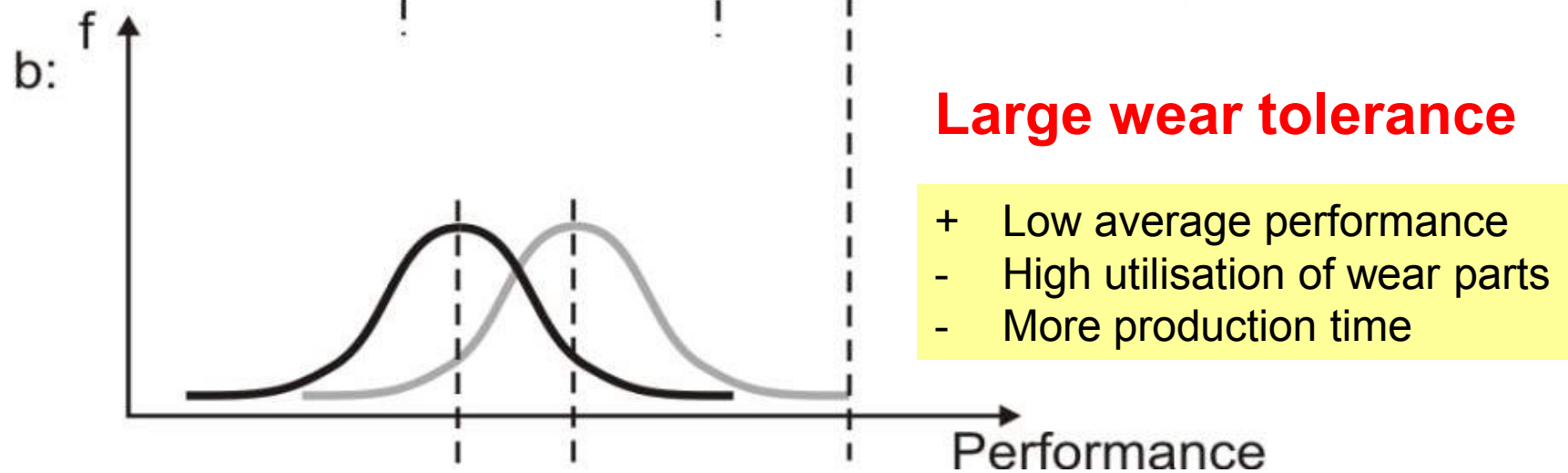
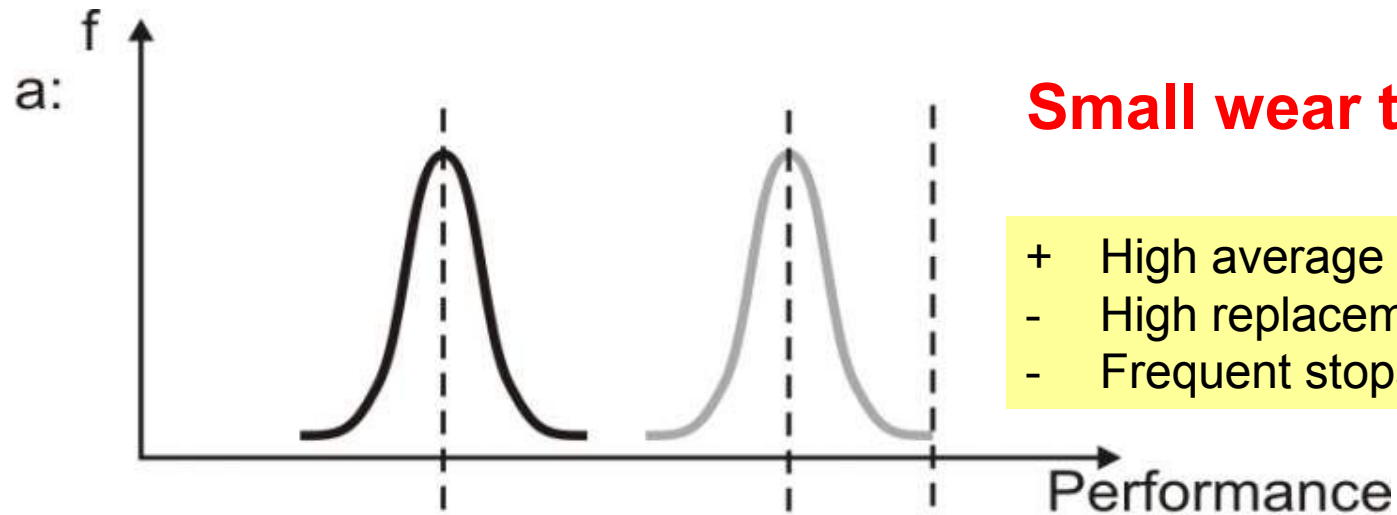
The combined effect will be normally distributed...

**It can be handled mathematically and thus optimized!**





# Effect of Wear



# 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

# Optimization of a Tertiary Crushing Stage

- small scale optimization

# 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.**

# Optimization of a Tertiary Crushing Stage

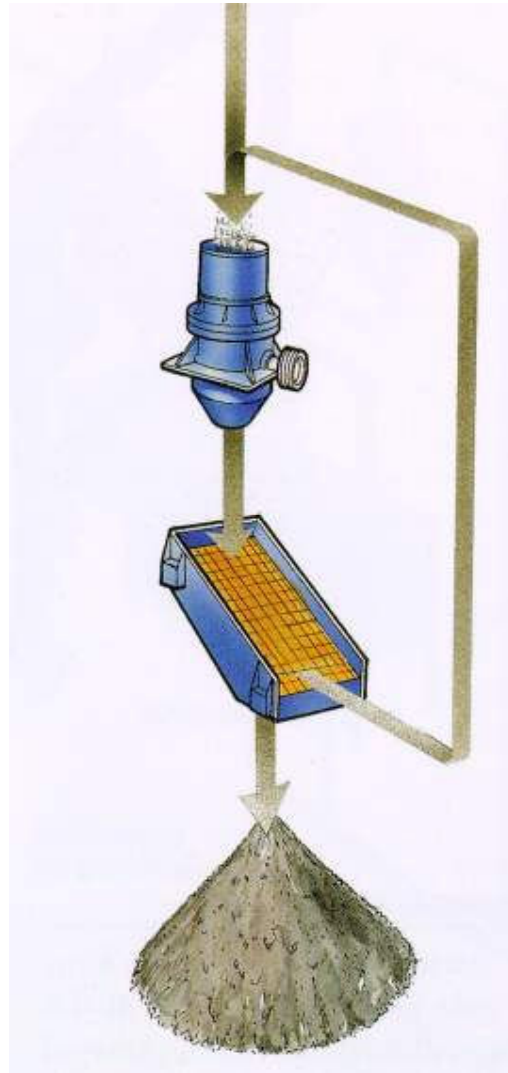
- The crushers are the last size reduction stage in the value chain.
- Over crushing is common.
- The rock cannot be repaired.
- We need to control the crusher carefully.

# Optimization of a Tertiary Crushing Stage

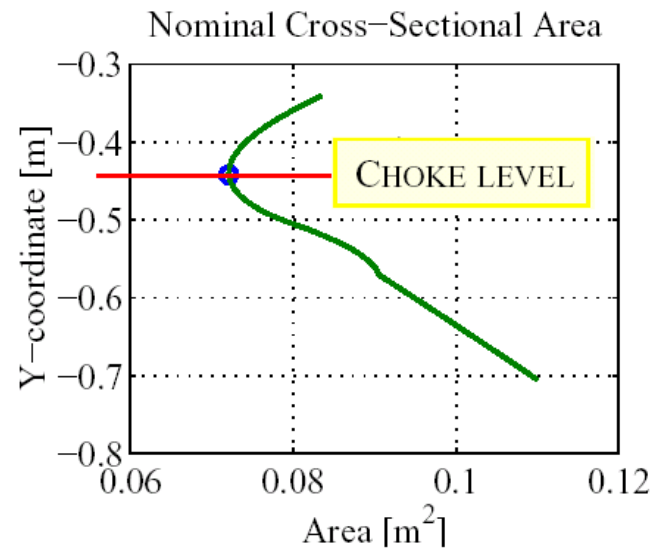
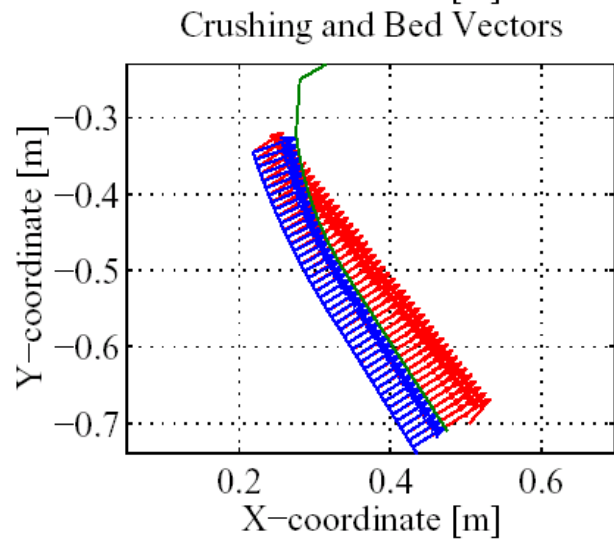
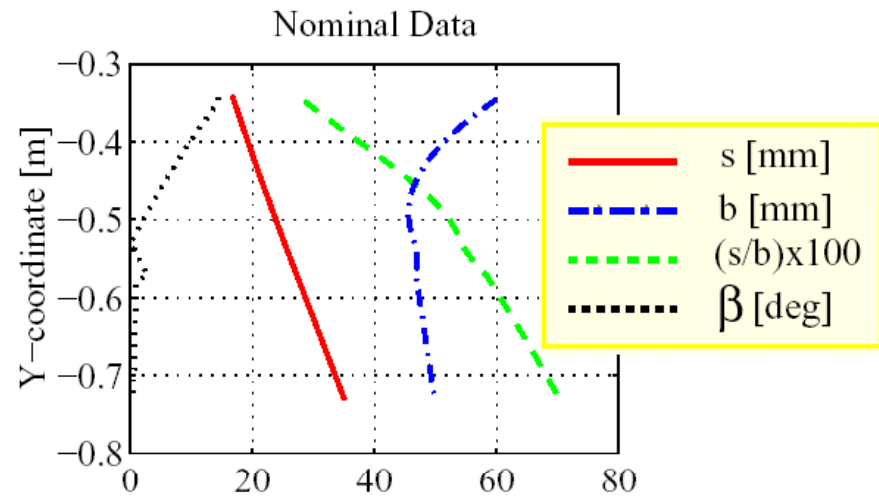
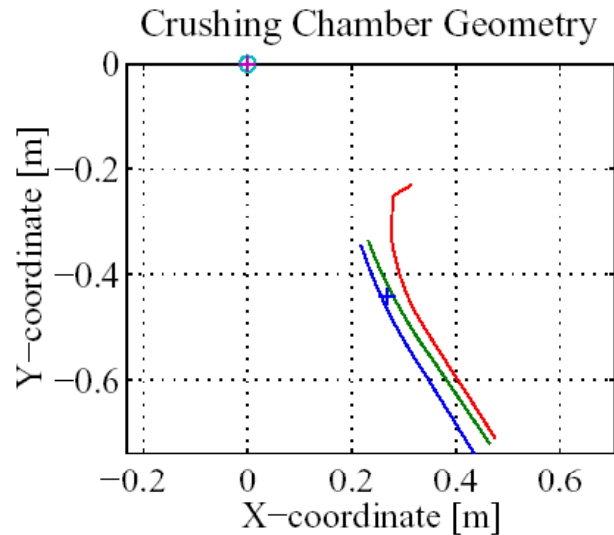
*Combine product yield and economic aspects*

# Test Setup and Parameters

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

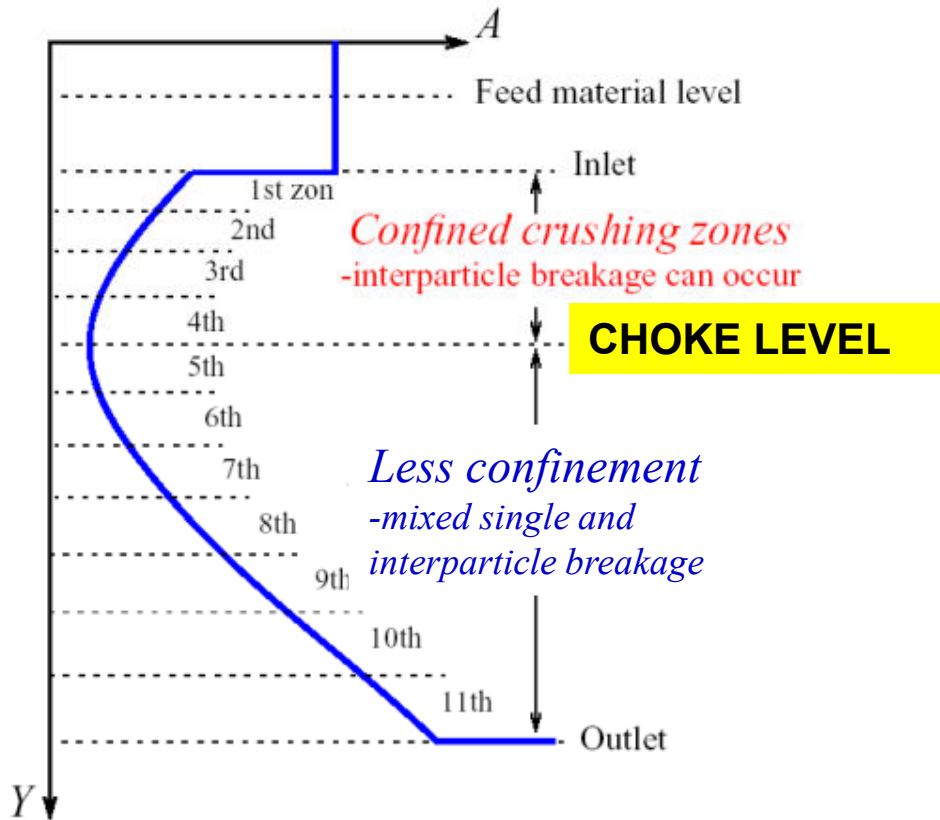


# Crusher (Nominal) Geometry





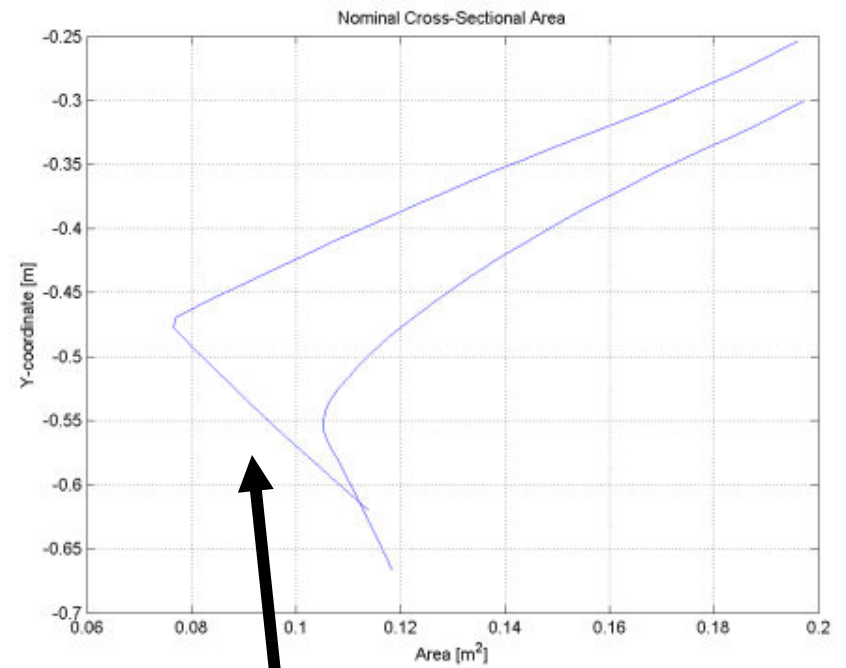
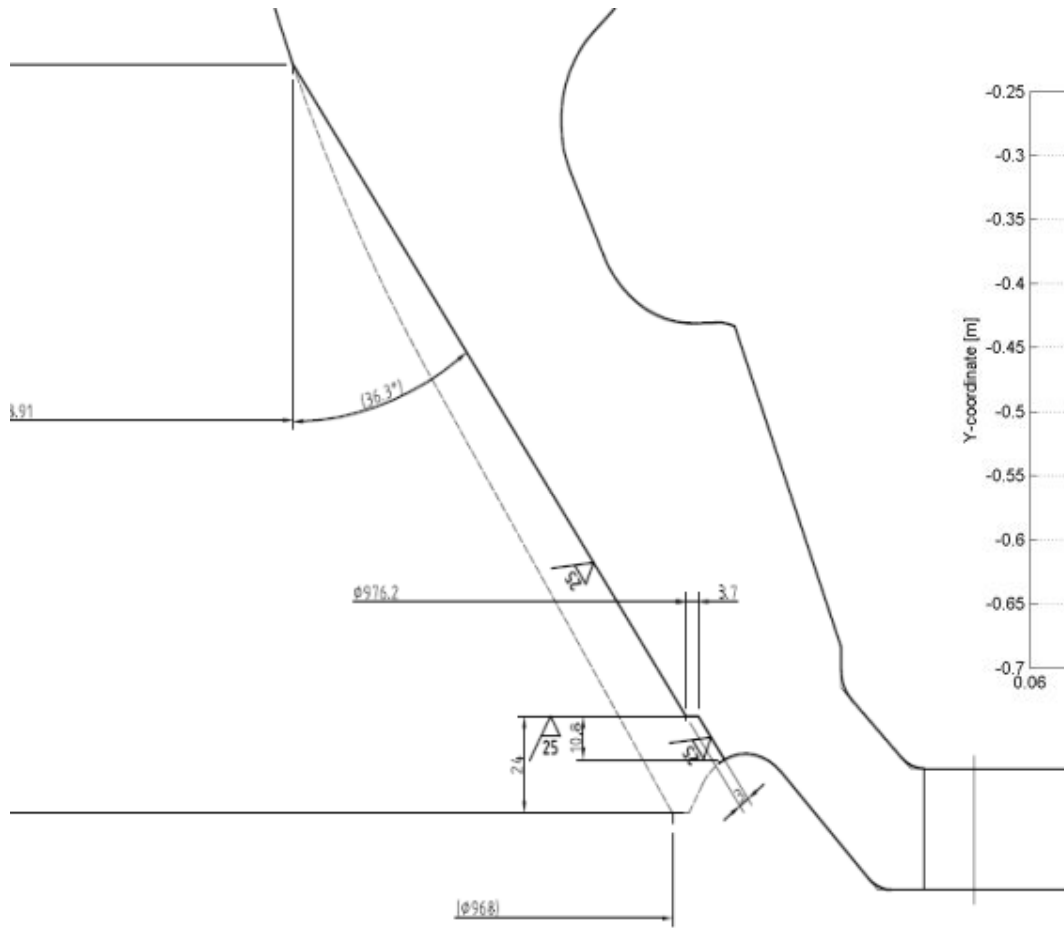
# Breakage Modes



- Interparticle

- Single particle

# Chamber Design



Parallel crushing zone with low pressure

# 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**

# Results from Sieving

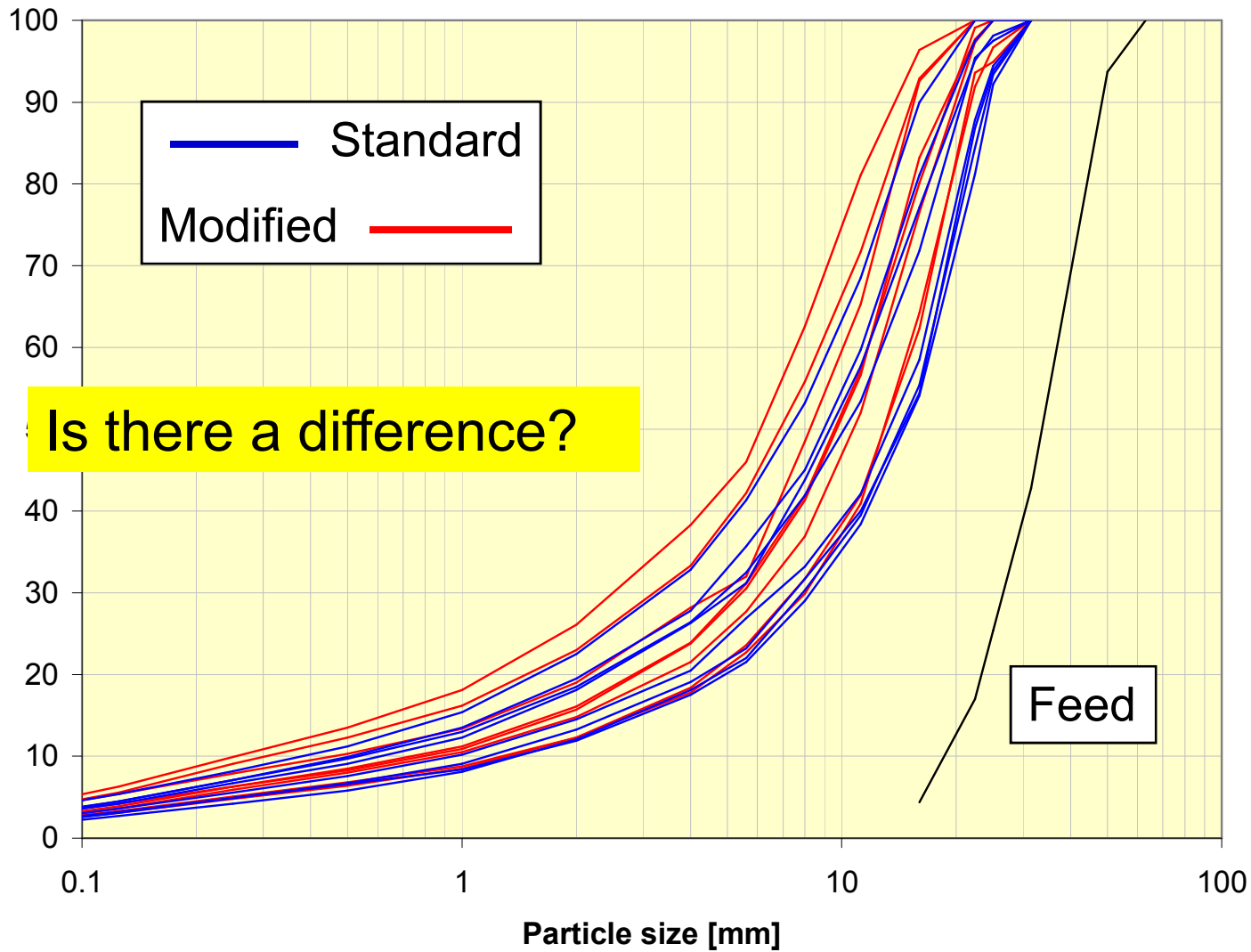
Modified, +25-50 feed (coarse)  
29 mm stroke, 288 rpm

Modified, +25-50 feed (coarse)  
29 mm stroke, 360 rpm -STD

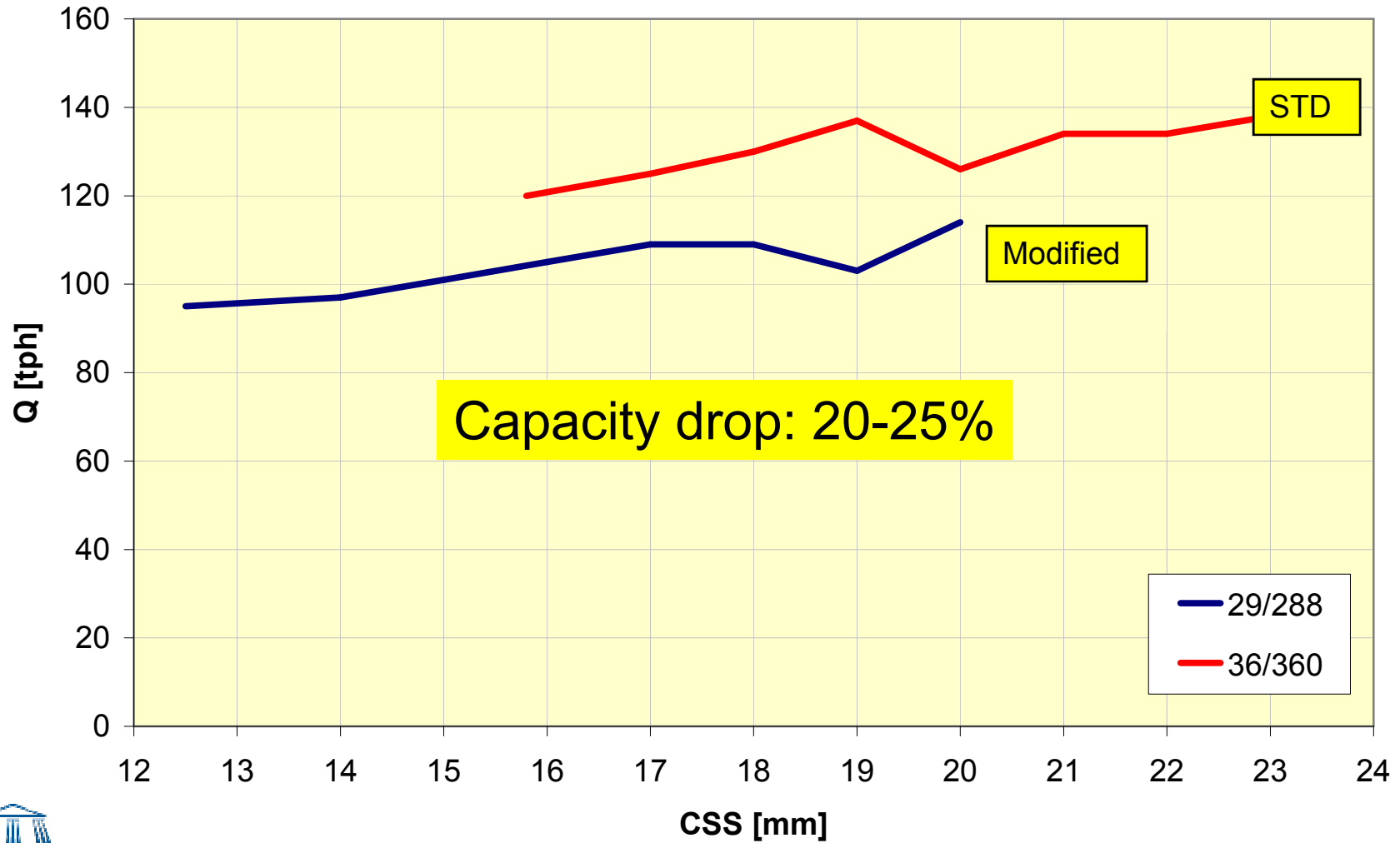
Modified, +25-50 feed (coarse)  
36 mm stroke, 360 rpm -STD

	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

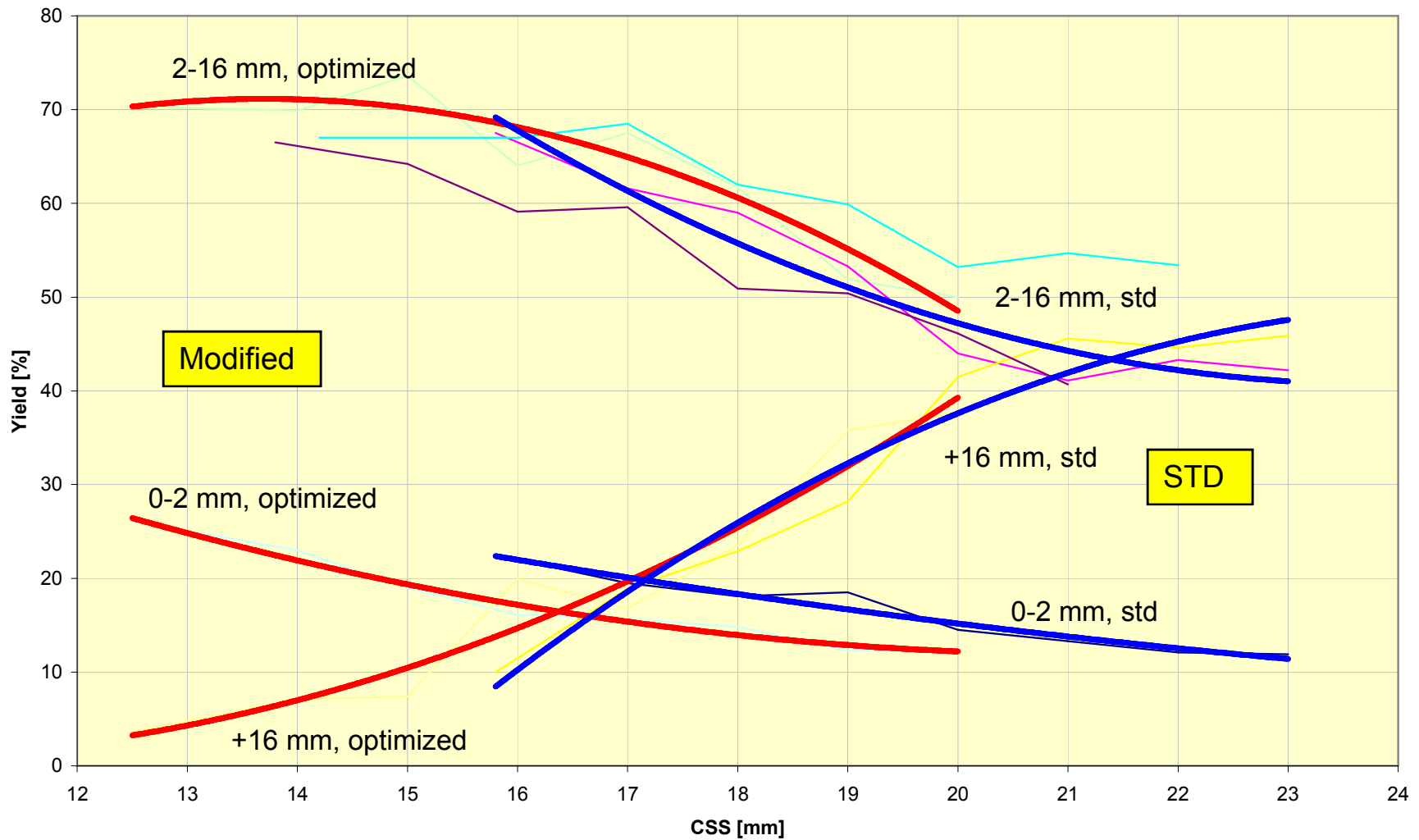


# Total Capacity [tph]



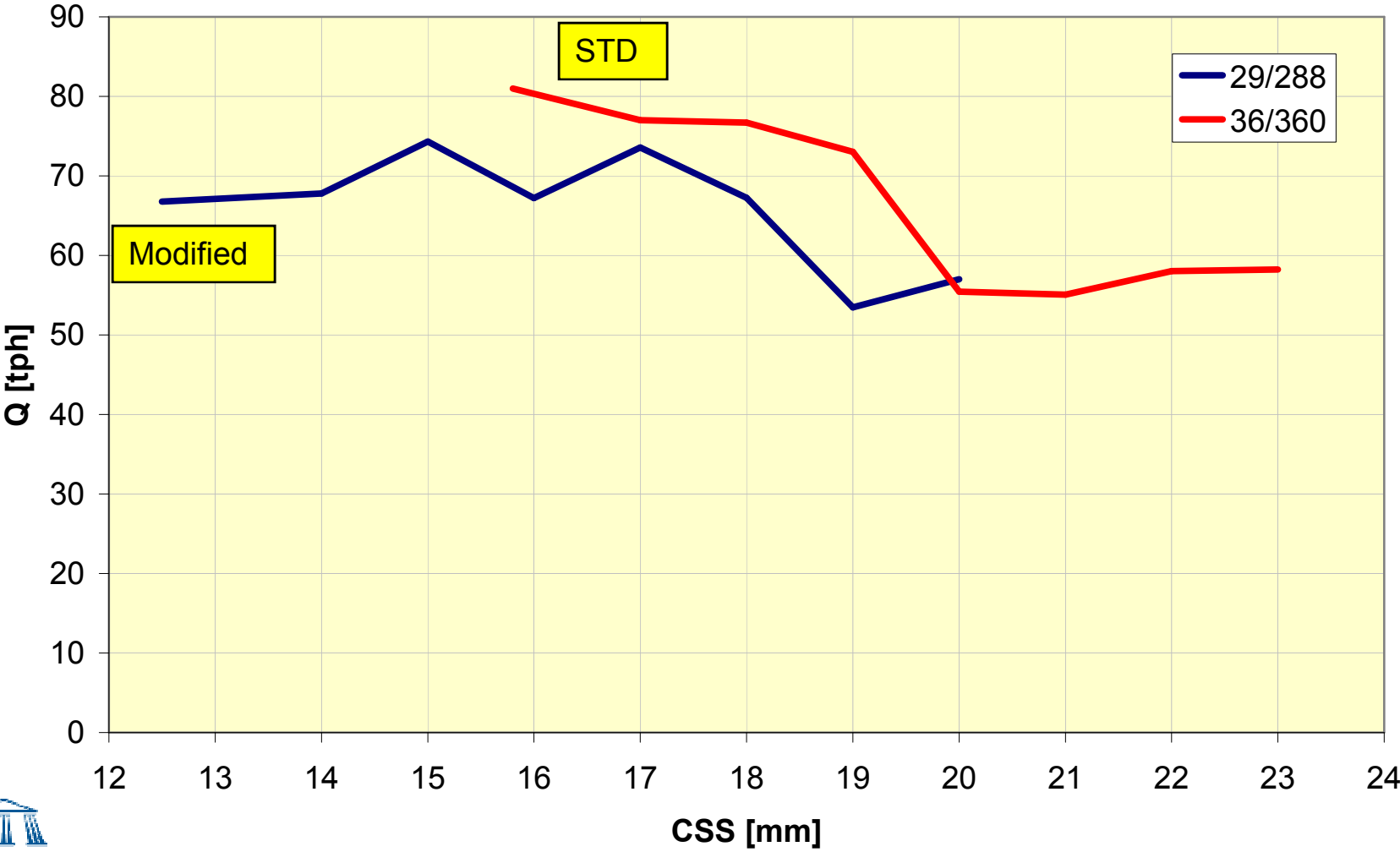
# Product Yield

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



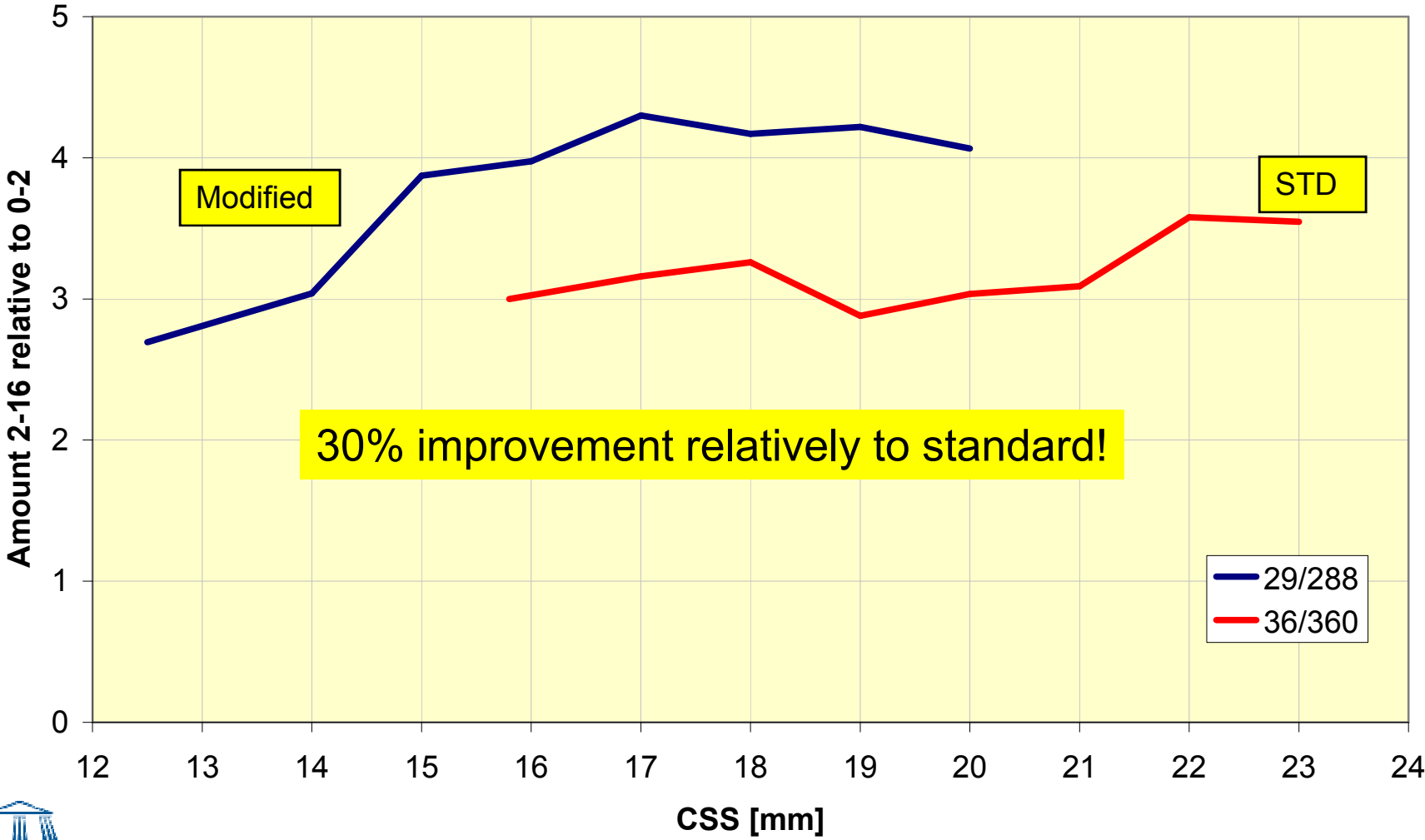
# Production of Premium Product

2-16mm [tph]





# Relation between Produced Product and Fines



# 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

# Economical Analysis

<b>Costs</b>	<b>[USD]</b>	<b>Step</b>					
		<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
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
<b>Income</b>	<b>[USD]</b>						
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 Analysis

**29/288**

**36/360**

<b>CSS [mm]</b>	12.5	14	15	16	17	18	19	20	15.8	17	18	19	20	21	22	23
<b>P [kw]</b>	133	111	105	89	92	87	79	74	148	123	126	101	100	91	84	80
<b>p [Mpa]</b>	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
<b>Q [tph]</b>	95	97	101	105	109	109	103	114	120	125	130	137	126	134	134	138
<b>Yield [%]</b>																
<b>0-2</b>	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
<b>2-16</b>	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
<b>+16</b>	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
<b>Volumes [tph]</b>																
<b>0-2</b>	25	22	19	17	17	16	13	14	27	24	24	25	18	18	16	16
<b>2-16</b>	67	68	74	67	74	67	53	57	81	77	77	73	55	55	58	58
<b>+16</b>	3	7	7	21	18	26	37	43	12	24	30	39	52	61	60	63

# Economical Analysis

29/288

36/360

## Economics

Step 1

<b>Cost per ton \$/ton</b>	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
<b>Gross profit \$/ton</b>	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
<b>Gross profit \$/hour</b>	89	97	116	107	119	108	87	92	116	114	116	107	84	84	92	92

Step 2

<b>Cost per ton \$/ton</b>	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
<b>Gross profit \$/ton</b>	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
<b>Gross profit \$/hour</b>	142	151	176	160	178	162	129	137	180	175	176	165	128	128	138	138

Step 3

<b>Cost per ton \$/ton</b>	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
<b>Gross profit \$/ton</b>	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
<b>Gross profit \$/hour</b>	195	205	235	214	236	215	172	183	244	236	237	222	172	172	184	184

Step 4

<b>Cost per ton \$/ton</b>	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
<b>Gross profit \$/ton</b>	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
<b>Gross profit \$/hour</b>	237	248	283	257	284	259	207	220	296	286	287	269	208	207	221	222

Step 5

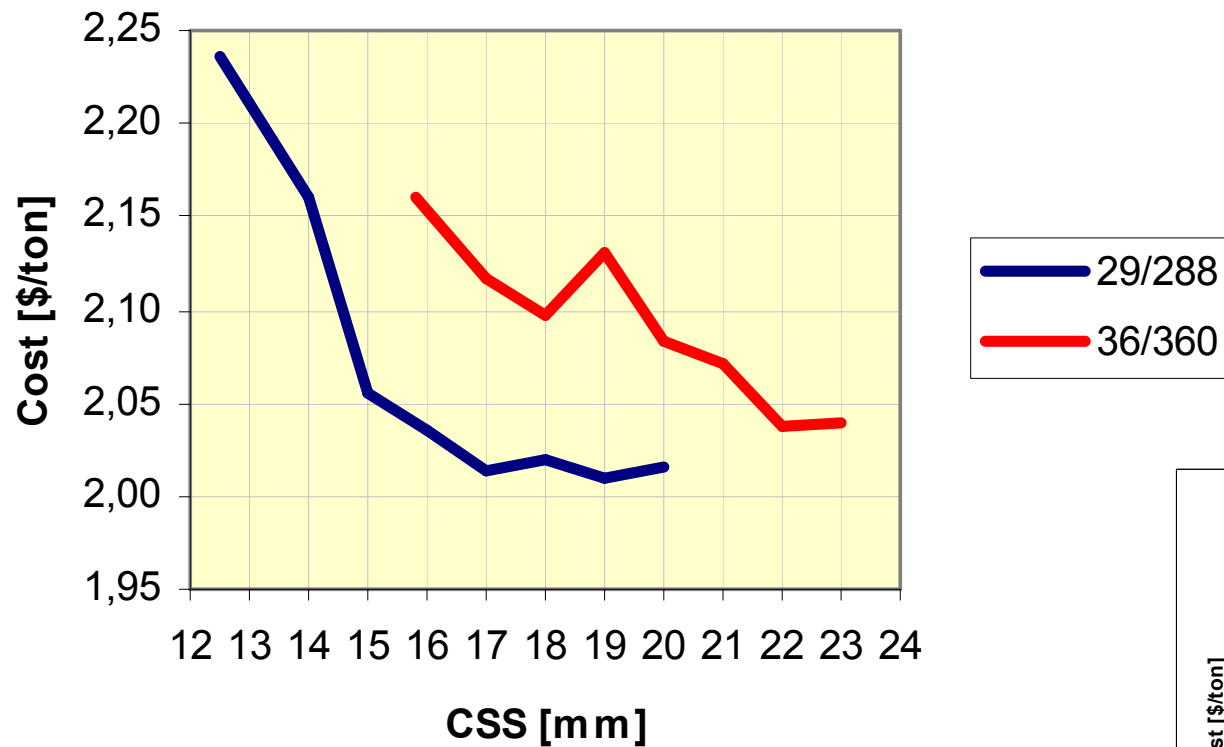
<b>Cost per ton \$/ton</b>	2.93	2.83	2.70	2.67	2.64	2.65	2.64	2.64	2.83	2.78	2.75	2.79	2.73	2.72	2.67	2.67
<b>Gross profit \$/ton</b>	2.93	2.99	3.26	2.85	3.03	2.77	2.33	2.24	2.89	2.67	2.57	2.30	1.92	1.81	1.93	1.88
<b>Gross profit \$/hour</b>	278	290	329	300	331	302	240	256	346	334	335	315	243	242	258	259

Step 6

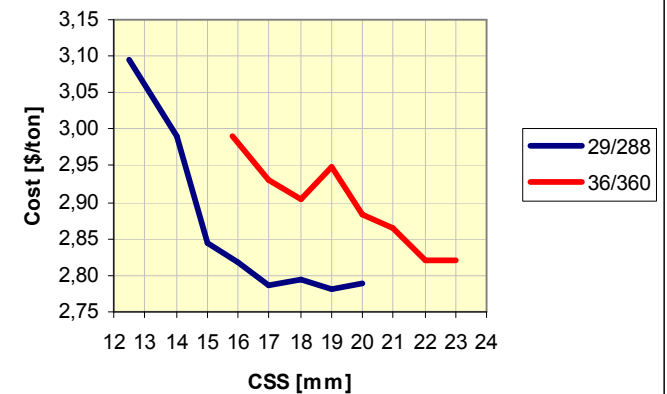
<b>Cost per ton \$/ton</b>	3.09	2.99	2.85	2.82	2.79	2.79	2.78	2.79	2.99	2.93	2.90	2.95	2.88	2.87	2.82	2.82
<b>Gross profit \$/ton</b>	3.37	3.43	3.74	3.27	3.47	3.17	2.67	2.57	3.31	3.06	2.95	2.64	2.21	2.07	2.21	2.15
<b>Gross profit \$/hour</b>	320	333	377	343	378	345	275	293	398	383	384	361	278	277	296	297

# Allocated cost for saleable products \$/ton

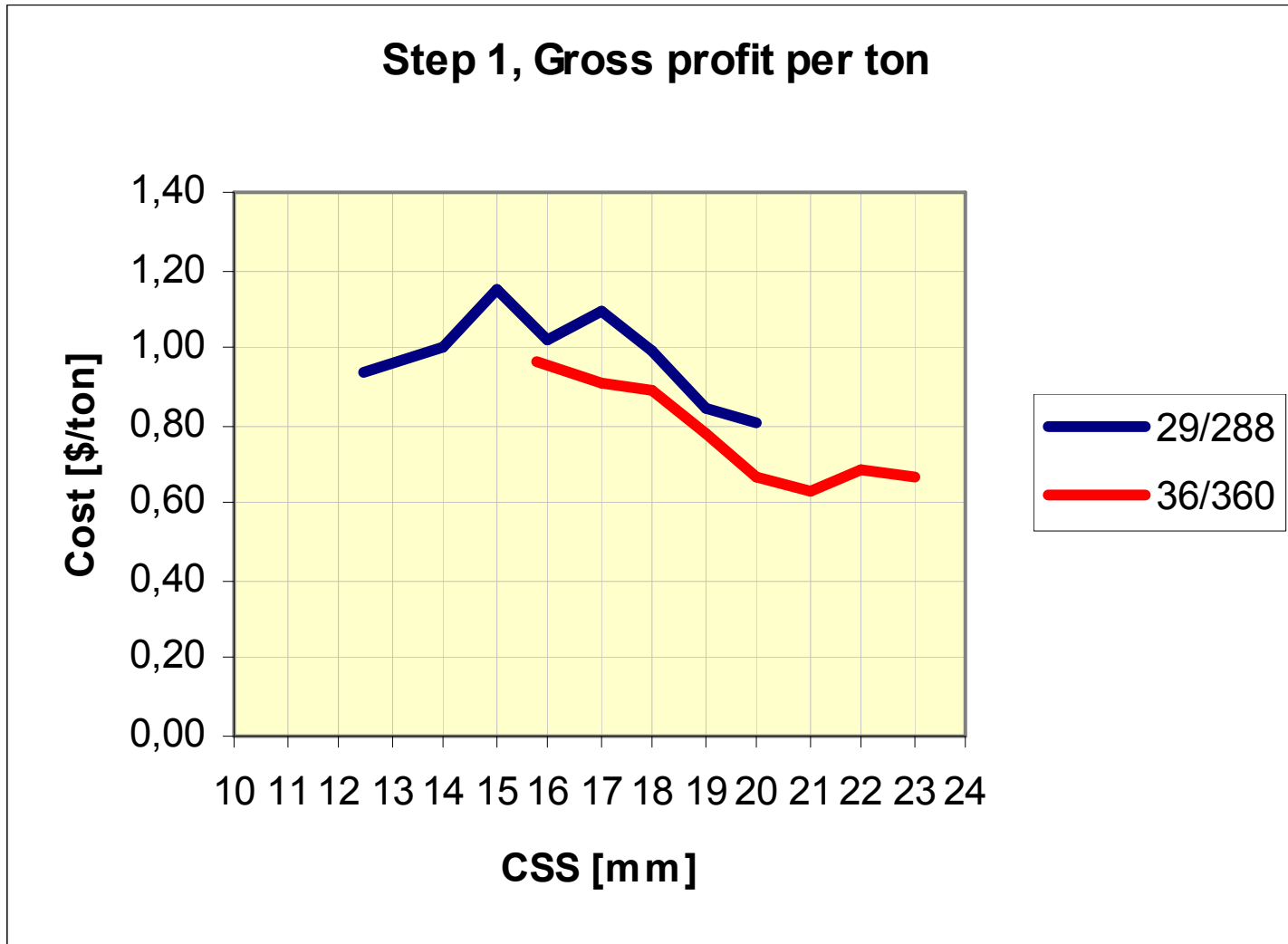
## Step 1, Allocated cost per ton



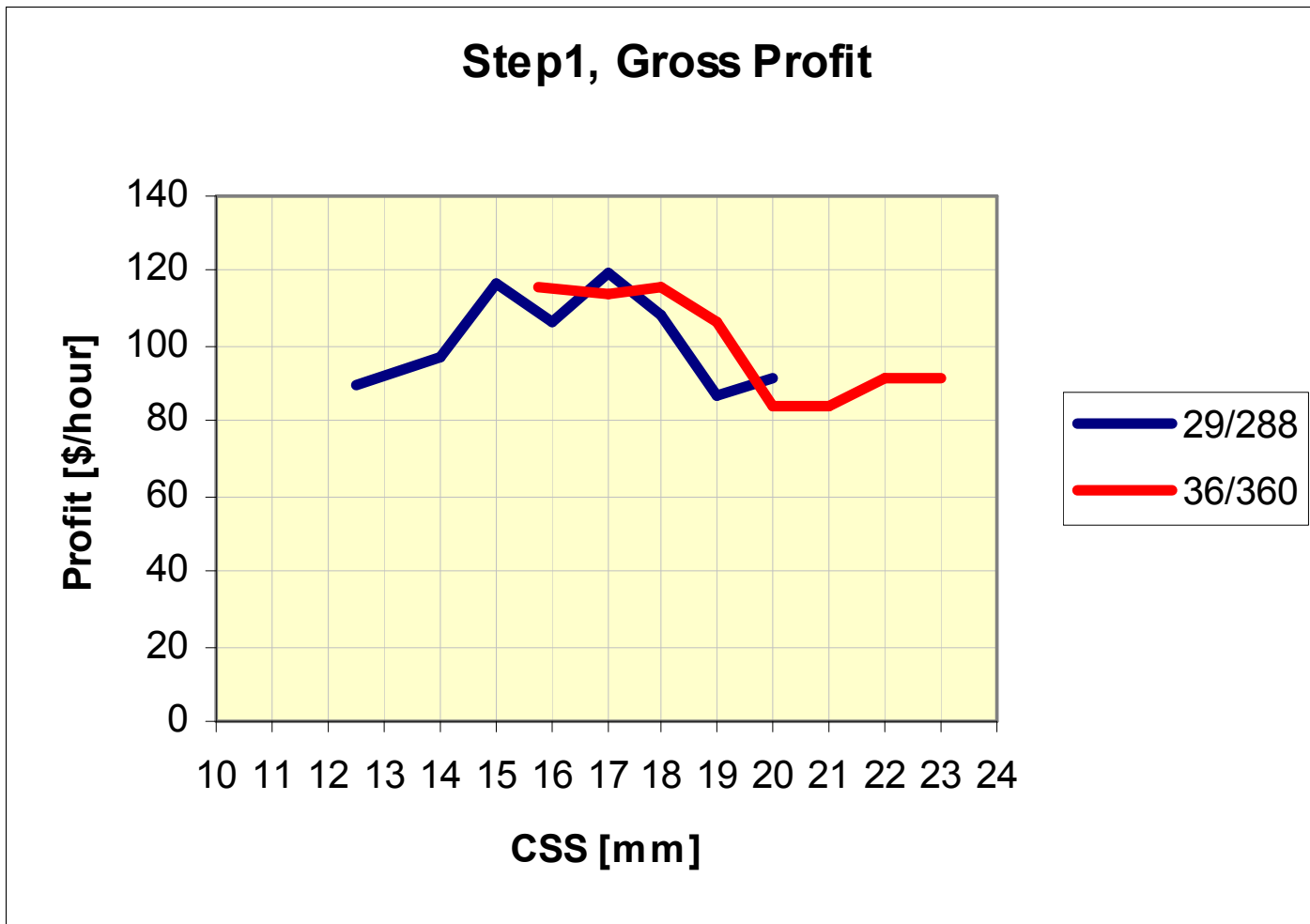
## Step 6, Allocated cost per ton



# Gross profit - \$/ton



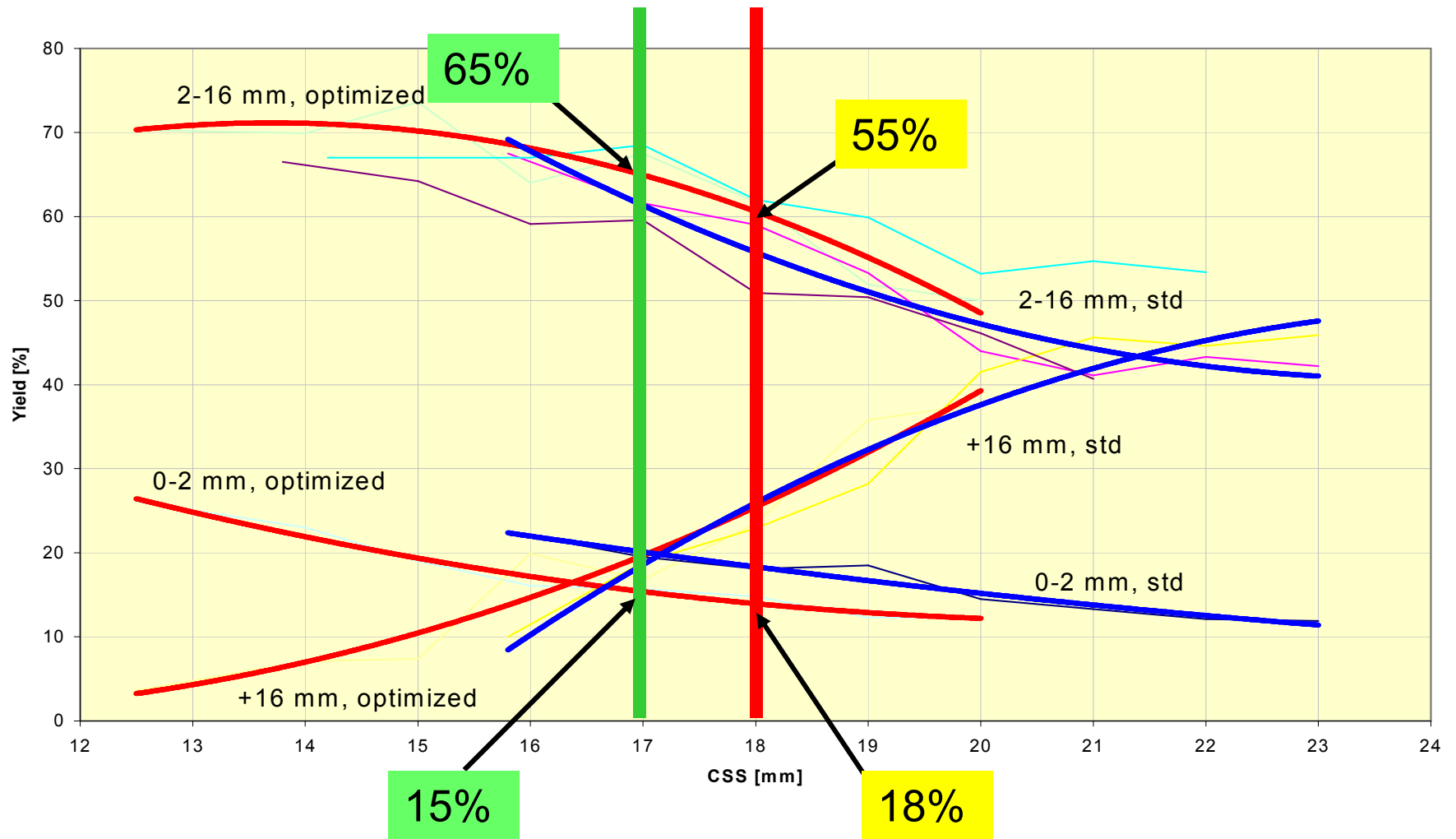
# Gross profit - \$/hour



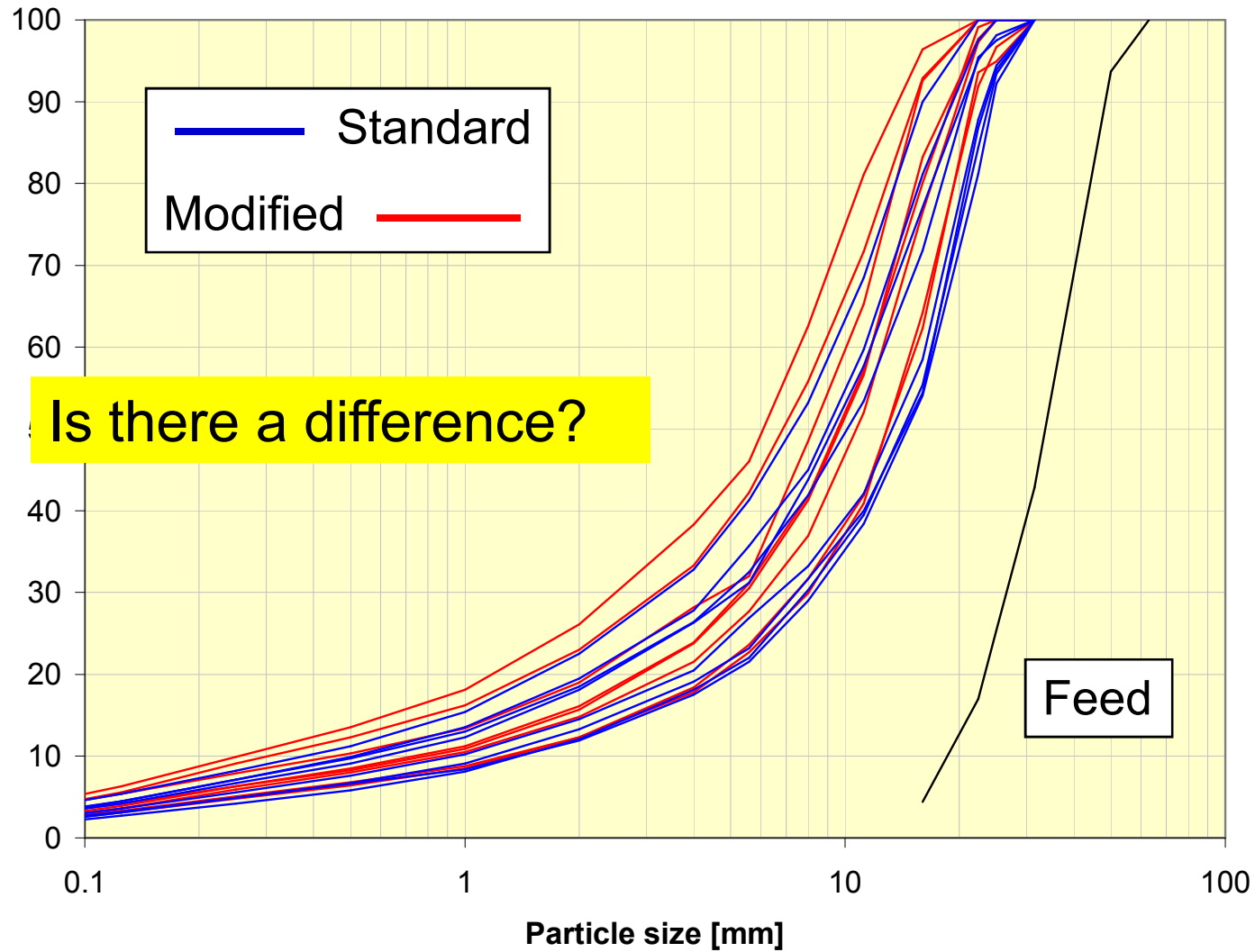


# Yield

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



# Particle Size Distributions



# 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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