Introducing HPGR Crushers into a Russian Magnetite Operation

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Stoylenski GOK

- Based at Stary Oskol in Belgorod region – 600km S of Moscow
- A fully owned subsidiary of NLMK – now Russia's largest steel maker partly based at Novolipetsk.
- SGOK process 32Mtpa of ore producing 14Mtpa of magnetite concentrate at 66.5%Fe

Plans

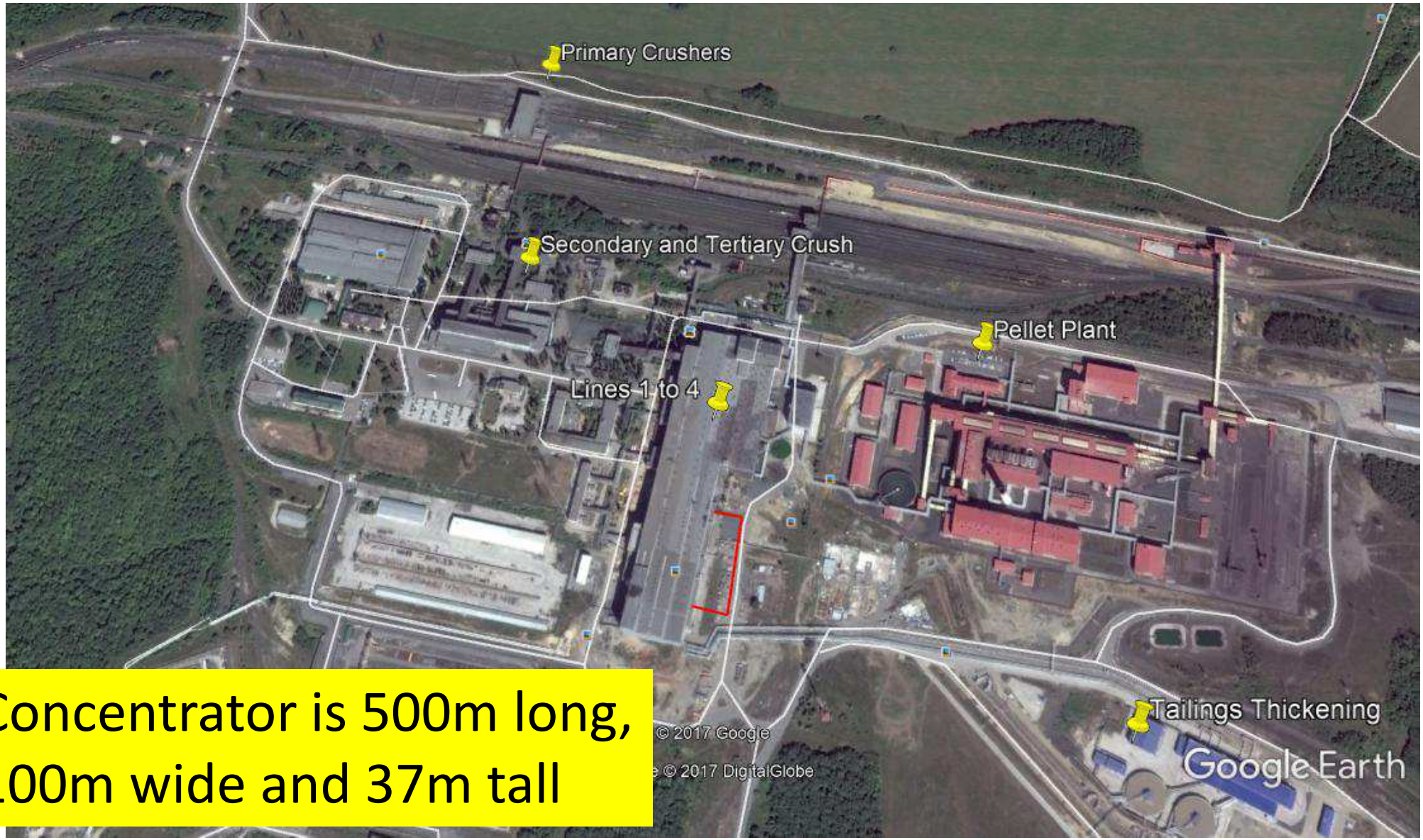
- Original plan 32Mtpa to 42Mtpa by building new 4 railway tracks to double primary crushers, new secondary/tertiary building and line 5. Estimated at $US400m – everything had a standby.
- Estimated that existing primary crushers and rails tracks could reach 52Mtpa – changed concepts
  - HPGR being installed as a cheap +5Mtpa expansion (15%) – approx. $US80m
  - Currently doing a BFS on another +5Mtpa project +$US100m
  - PFS/Scoping - Line 5 - $200m - using either AG mills or tertiary HPGRS and bigger mills +10Mtpa
  - Ie we reach 52Mtpa for the original $400m

An Impressive Pit

Limestone on the top – feeds a cement plant

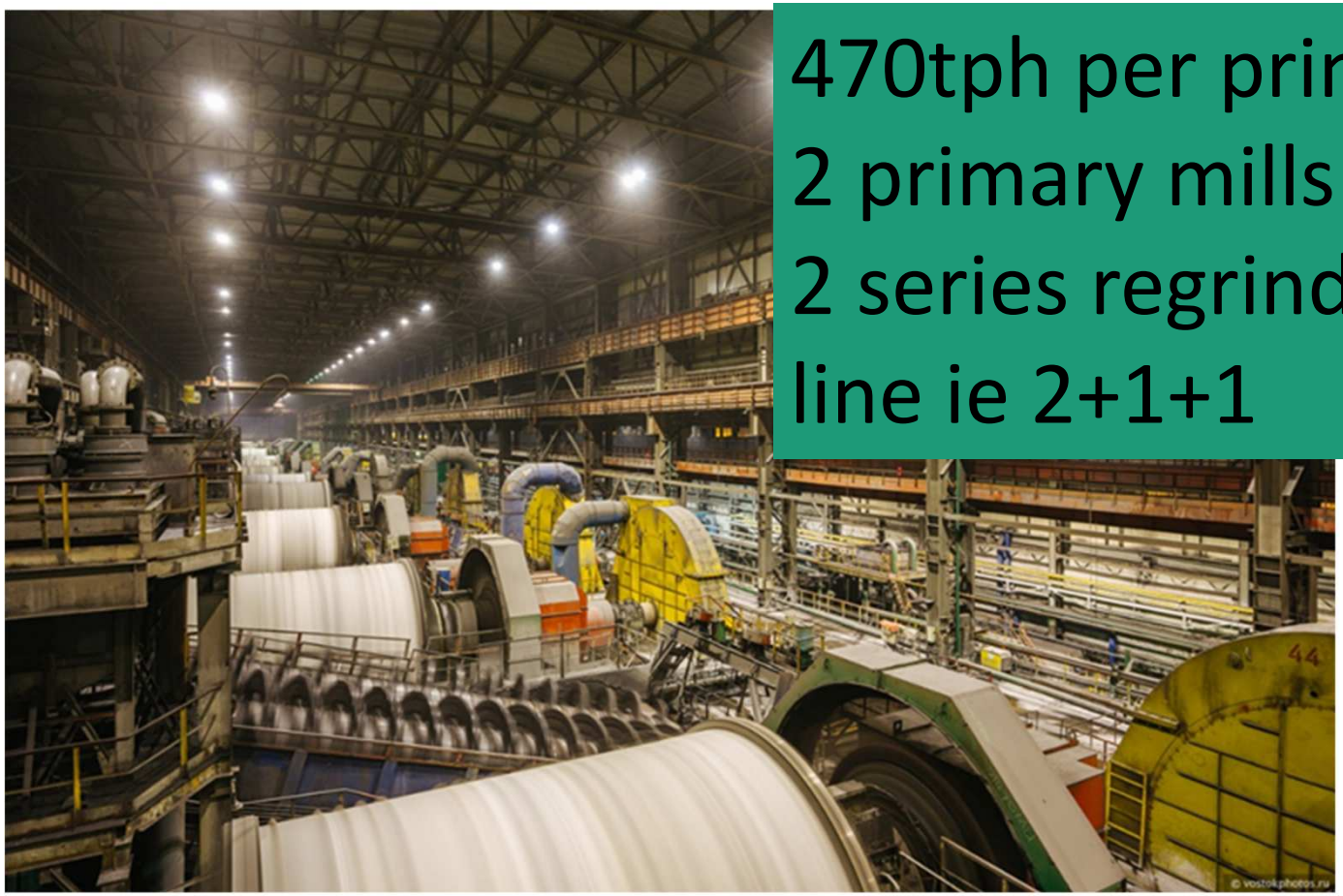
Hematite for 2Mtpa

Magnetite for 42Mtpa



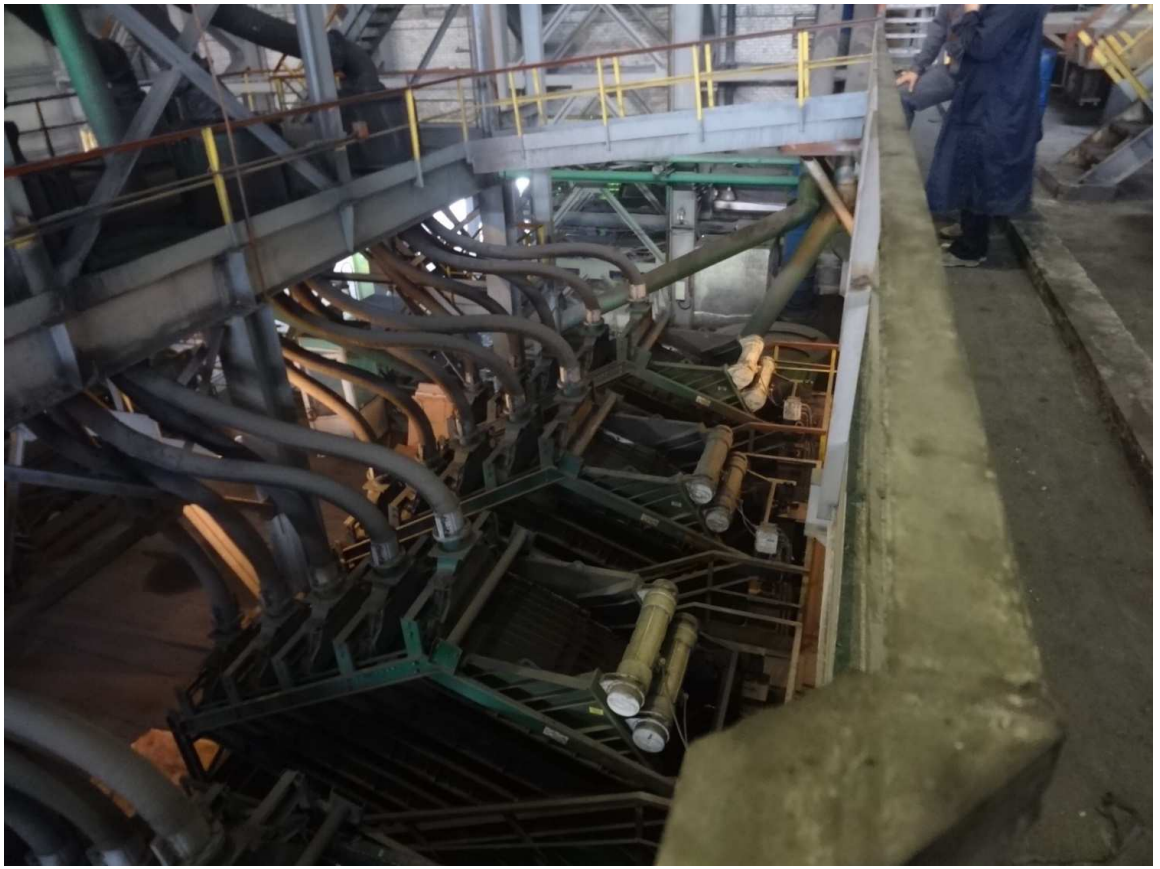
Concentrator is 500m long, 100m wide and 37m tall

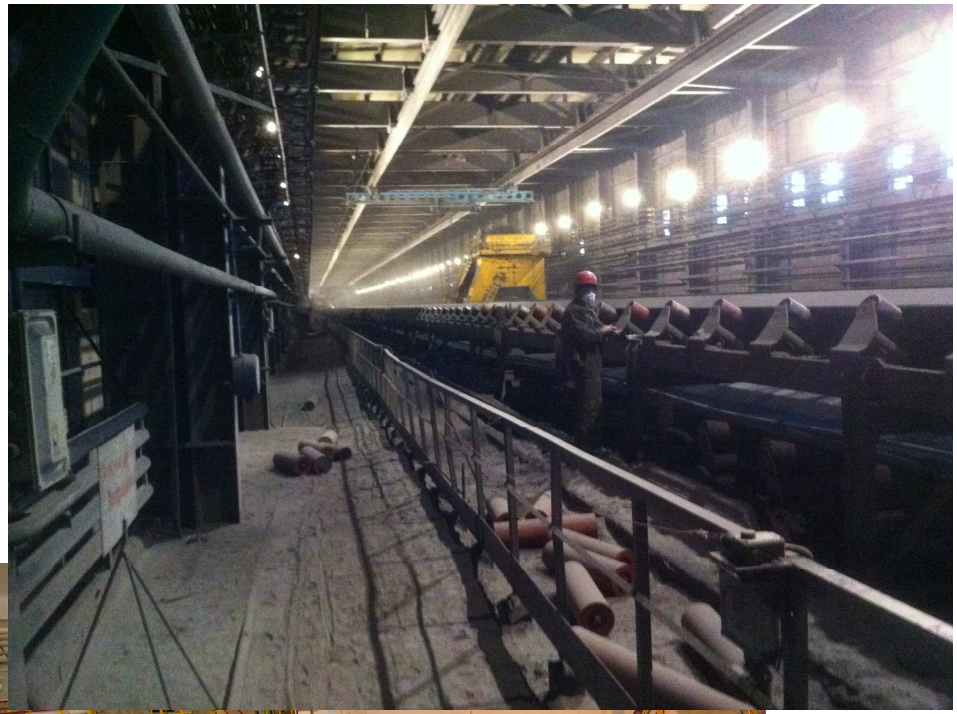
Current Circuit Design Lines 1-3



470tph per primary mill
2 primary mills per line
2 series regrind mills per line ie 2+1+1

Current Design Line 4 – 5 mills plus Derricks 2+2+1





Feed distribution,
Magnetic separators

Process Water pumps
New Thickeners

Introducing HPGR - Based on Classic Bond/Rowlands

- W = 10*Wi(1/$\sqrt{P_{80}}$ - 1/$\sqrt{F_{80}}$) $* Ef1 * Ef2 * Ef3 * Ef4 * Ef5 * Ef6 * Ef7 * Ef8$

- The HPGR
  - affects the Bond Wi
  - The feed size F_{80}
  - The oversized feed factor Ef4

- A fourth impact – a feature of magnetite plants is that as a stage product is ground finer that this reduces the tonnage to the next stage of grinding.

Potential benefits - Weakening the crystals

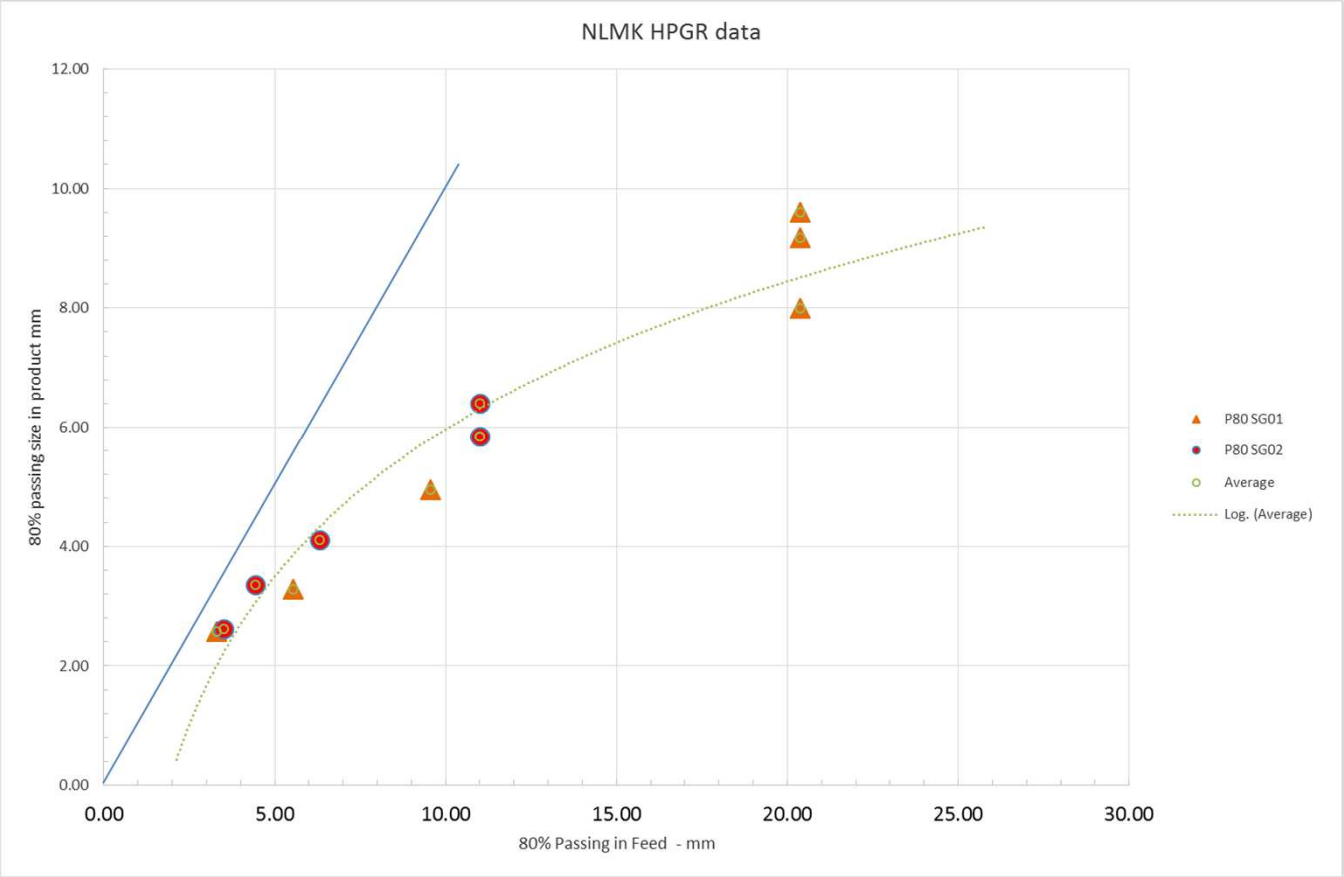
Table 1 Adjusting the data for a common feed size

SG01 Coarse ore		Improvement just due to feed size changes	Measured improvement HPGR Test	Gain due to HPGR weakening
	Feed			
	Feed after HPGR	2%	34.9%	32.6%
SG02 current	Feed			
	Feed after HPGR	11%	30.1%	19.5%

Benefit in the laboratory was more than 19%
For design purposes we used 10%

(Coarse ore SG01 was -32mm and SG02 was current ore at -16mm – 80%-11mm)

Potential Benefits of HPGR – reducing feed size



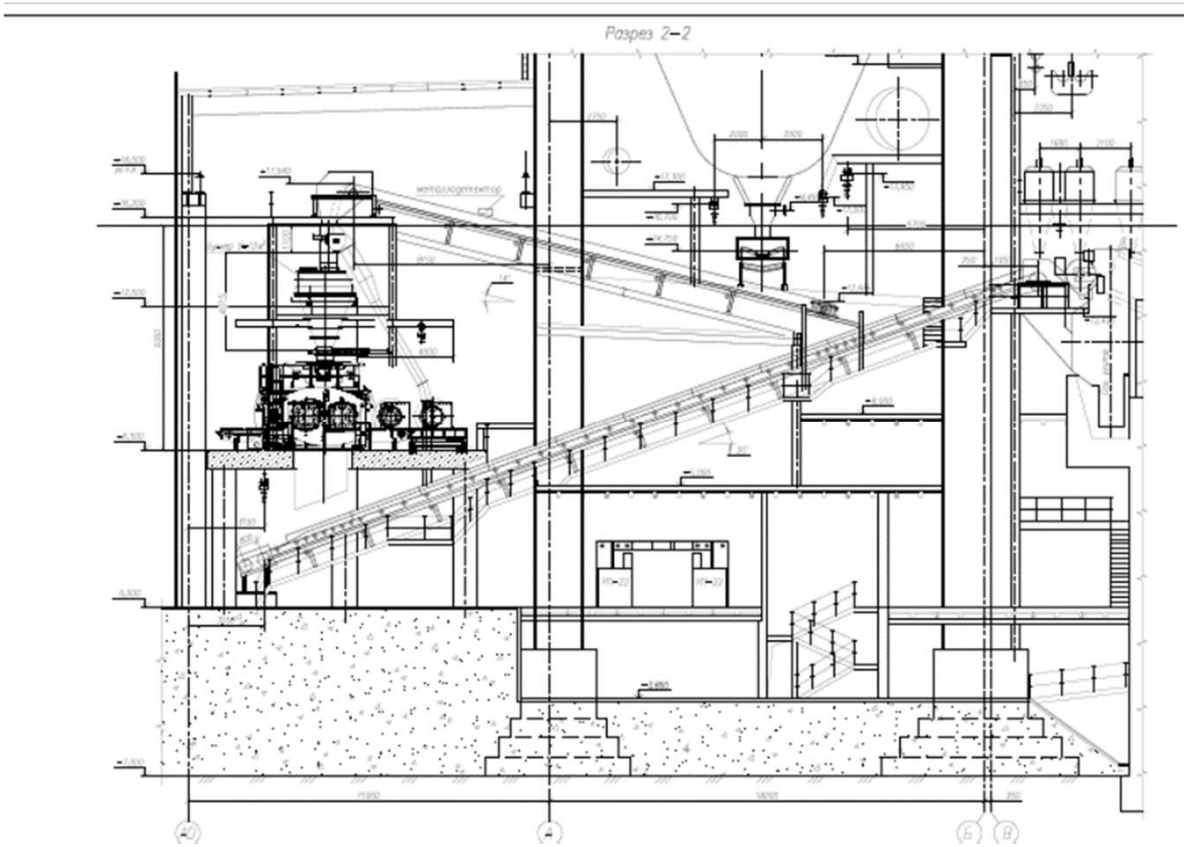
Impact of Each Change

							P80
			KW	% Change	Benefit	Cumul	Micron
tph	945	As Is (grinds to 280 micron	7300				280
		Size to 6.0mm	6797	93%	7%	93%	
		Improved BM efficiency	6240	92%	8%	85%	
		Microcracking	5436	87%	9%	74%	
tph	1068	New Tonnage +13%	6144	113%	-10%	84%	
		New Product (208 micron)	7296	119%	-16%	100%	208
Tonnage	113%						

Another model determines how the rest of the plant operates – and ends up at 13% tonnage But first stage has to produce at finer product size so the rest of the plant has capacity

Installation

- Originally two machines for the whole plant – 4500tph!
- Suggestion that Line 1 and 4 had an unused dry magnetic section (DMS) could that be used. Implied we would have 8 machines
- Height of the 1.5 x 1.0 HPGR and chutes (one in front of each primary mill) was roughly the space of the DMS unit



Design (1)

- Conveyors at 18 to 20 degrees
  - Used Ribbed conveyor
  - Ore is very dry (<1.5%) so quite clean
- No room in the existing building for either a recycle system or a classification system so design is single pass
- Russians not convinced that you can dry screen at 8mm so even lines 2 an 3 are a single pass system (no building restraint). They didn't like edge splitting due to wear issues, and unclassified recycle was too radical!!!

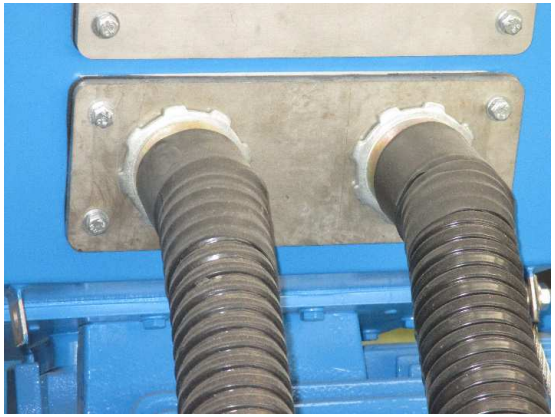
Design 2

- Needed a common machine size though line 4 is 20% higher production than 1-3
- Sized for line 4 and with a 20% conservative design factor meant the normal machine for 1-3 running at 60% of full speed
- Mdot – machine productivity was 450ts/hm^3 while design was 320.

- Meant that the machines were running at <50% of normal speed and the VSDs overheated.
- Eventually had to change the gear boxes to speed up the motors – a recirculating load would have avoided this.

Start up Issues

- Poor appreciation of the time for electrical installation (v mechanical installation). Client used four different electrical contractors for four machines – they are all different!!!
- Different cable size standards 120mm (Russian) v 180mm (Europe) – needed extra cables into motor junction box which was not designed for them



Screwed

Welded

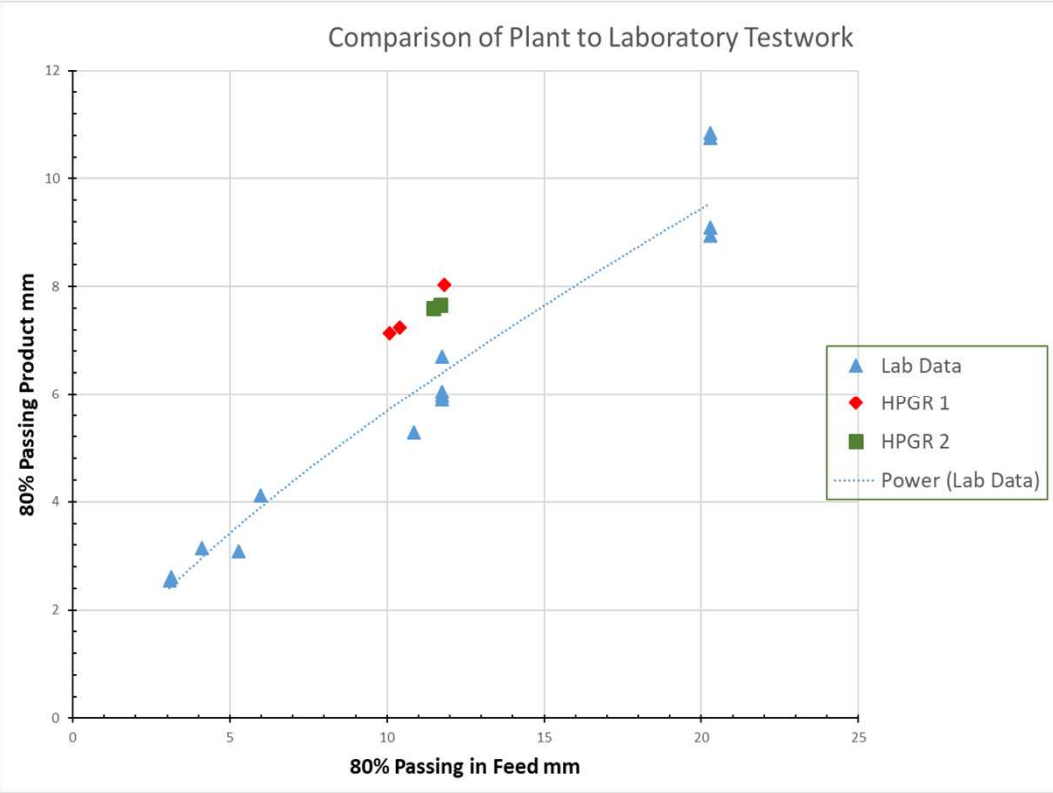
6 cables needed!

Commissioning – no pressure

- Present at the hot commissioning:
  - President NLMK
  - Tech Director NLMK
  - GM SGOK
  - Tech Director SGOK
  - About 20 others
  - Camera crew, interviewer -- appeared on You Tube the next day
- Lasted five minutes – a hatch fell open – and what can you see from 4 m away
- On second run – most obvious sign was drop in recirculating load at the mills

Results

- Simple tests on measuring the product size showed the size was 1mm coarser than laboratory – which was a size in the contract.
- Possibly due to change in ore types
- Impact on the mill product sizes was very hard to measure – grab samples were the order of the day



Can you sample this?

- Tried line sampling but no consistency.
- How do you increase recirculating load – add water or decrease water?

Monthly results – the month of May

Comparing line 1 to lines 2 and 3 – using their normal controls – fixed Fe grade in product adjusted by changing tonnage

	Days	Extra tph relative to lines 2/3	Extra %-45micron - relative to #2 and #3	Tonnage for Same Grind	Benefit
Days of both HPGR (>20hours)	14	55	0.80	71.2	8%
Days of one HPGR	7	39	0.30	45.5	5%
Days no HPGR	10	9	-0.22	4.3	0%

BUT THE ORE CHANGED FOR 10DAYS!!!??? - The days of normal ore are shown below

	Days	Extra tph relative to lines 2/3	Extra %-45micron - relative to #2 and #3	Tonnage for Same Grind	Benefit
Days of both HPGR (>20hours)	5	84	1.20	108.6	12%
(outside 17th to 27th)					

On - Off Testing – 4 hours on, 4 hours off

Adjusted to give the same product grind
OFFICIAL RESULTS!!!

		Mill Line 1 - 1%-45u is 10tph		Mill Line 4 - 1%-45u is 30tph	
		Aver. for 4 h	Aver. for 6 h	Average for 4 hours	Average for 4 hours
		With HPGR	Without HPGR	With HPGR	Without HPGR
Actual mill production	t/hr	572.5	487.5	690	465
Increase in Mill Capacity	%		**17.40%**		**48.39%**
% -45µ in the concentrate	%	72.7	74.88	77.65	82.55
Adjusted capacity - constant grind	t/hr	572.5	510	690	612.1
Increase in Production	%		**12.25%**		**12.73%**
Specific energy consumption	kWh/t	36.1	37.61	37.68	39.94
Increase in SE consumption	kWh/t		**1.51**		2.25

A 12 – 13% tonnage benefit for the same product grind.
This result was the official result – signed by everyone!

Finally comprehensive sampling – over 6 weeks

- Managed to persuade the client to undertake variability of ore sampling – for the future projects
- Designed to measure the true change in Bond WI of the ore by the HPGR – measuring the field Bond WI

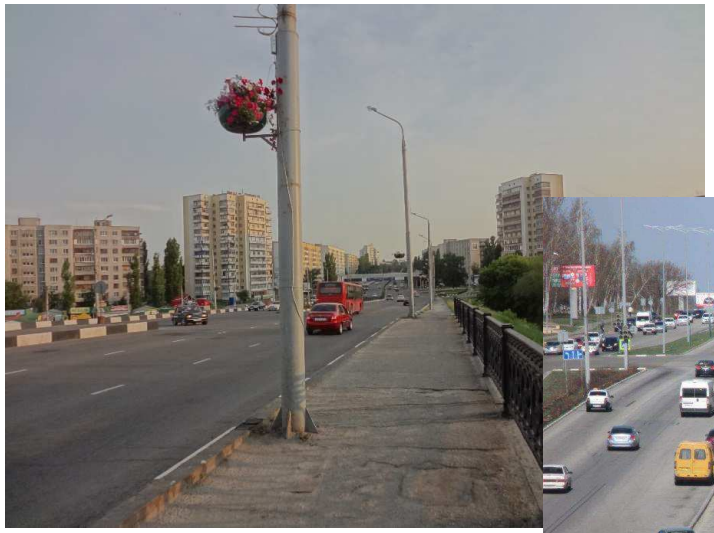
Actual Impact on the Mill Line				
		No HPGR	**HPGR**	**%Change**
Feed Rate	TPH	866	1040	20%
Field Bond WI	kWh/t	11.5	9.1	-21%
Stage Feed 80% passing	*mm*	*10.0*	*7.0*	
Stage Grind 80% passing	*micron*	*176*	*153*	
Total power/t feed (mill and HPGR)	kWh/t	9.02	8.04	

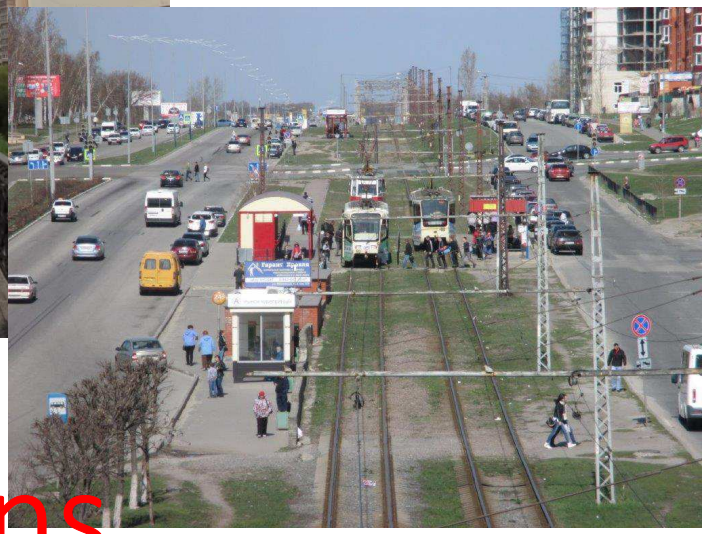
Conclusion

- Ultimately successful with results better than expected
- Lines 2 and 3 now being upgraded with HPGR
- The target 37Mtpa will be achieved
- Now for 42Mtpa – and the HPGRs have the capacity

Recommendations

- The restricted ability of VSDs to adjust speed create issues with the uncertainty of:
  - Mdot
  - Design allowances
- I would recommend a recycle system - preferably screened but random recycle or edge recycle would allow full capacity of the HPGR to be used – regardless of design issues.
- I would confidently recommend HPGRs for the quaternary retrofit application





Questions

Thanks to SGOK and NLMK for permission to publish this paper – and give me the challenge of introducing new technology – and a role in a You Tube video – my smooth English accent swamped by the Russian translation.

Thanks to Worley Parsons for their support and project management

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