An Overview of the HPGR and Fine Grinding Technologies to Characterize Ore Grindability

F.O. Verret

Group Leader Metallurgy – Québec City

SGS Minerals Services, Québec, Qc, Canada.

WHEN YOU NEED TO BE SURE

SGS

Outline

- **Introduction**
- Bench-scale Testing
- Pilot-scale Testing
- Conclusions

Introduction
New Technologies

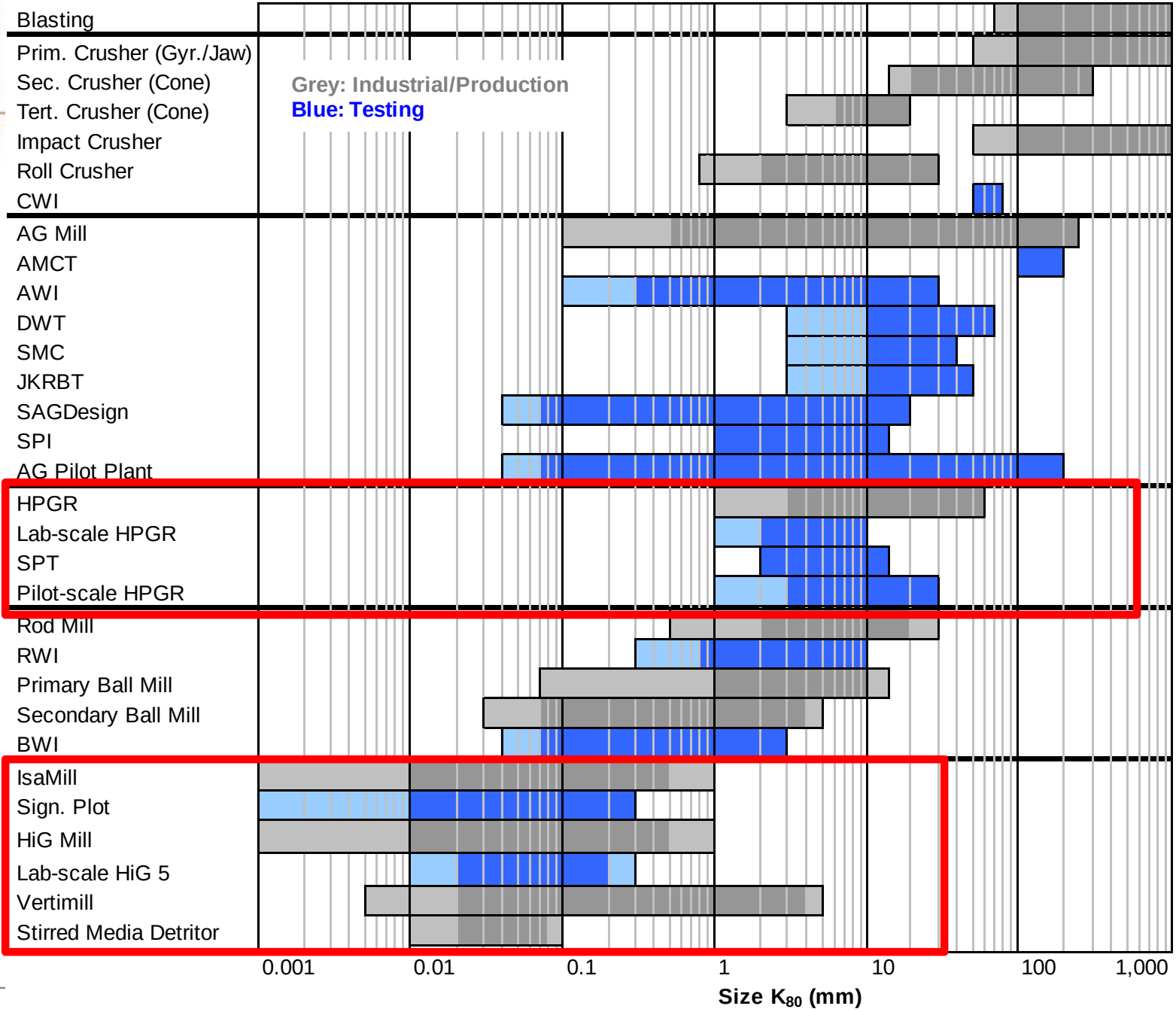
- New technologies… but not that recent:
  - High Pressure Grinding Rolls (HPGR)
    - Cement industry: early 1980's
    - Diamond: mid 1980's
    - Iron ore: mid 1990's
    - Hard rock / Minerals: 2003
  - First IsaMill in operation: 1994 (Mount Isa)
  - HiGmill™:
    - Calcium carbonate industry: mid 1980's
    - Mineral industry: 2013
  - First Vertimill®: 1979

Outline

- Introduction
- **Bench-scale Testing**
  - **Bond Test Recap**
  - **HPGR** (Polysius)
  - **IsaMill** (Glencore)
  - **HiG 5** (Outotec)
  - **Jar Test** (Metso)
- Pilot-scale Testing
- Conclusions

Grindability Tests - Review

	Small-scale Test	Mill Dia.	Top Size		Closing Size	Sample Requested[1]	Sample Consumed[2]	Type	Steady-state
		(m)	(mm)	(Core)	(mm)	(kg)	(kg)		(Y/N)
HPGR	Lab-scale HPGR	0.25	12.7	BQ	3.35	350	300	Locked-cycle	Y
	SPT	N/A	19.1	BQ	3.35	10	7	Locked-cycle	Y
	Pilot-scale HPGR	0.71	35	NQ	Various	150	150	Locked-cycle	Y
	HPGR Pilot Plant	0.9	50	-	Various	>2,000	>2,000	Continuous	Y
Ball Mills	Bond Ball Mill	0.305	3.35	Any	0.149	10	5	Locked-cycle	Y
	Mod Bond	0.305	3.35	Any	N/A	2	1.2	Batch	N
Regrind	Sign. Plot (Isamill)	0.15	0.5	Any	Int. Class.	15	15	Semi-Cont.	Y
	Lab-scale HiG 5	0.1	0.3	Any	Int. Class.	*15*	*15*	Semi-Cont.	Y
	Jar Mill Test (Vertimill)	0.2	0.5	Any	Various	15	15	Batch	N


Blasting
Prim. Crusher (Gyr./Jaw)
Sec. Crusher (Cone)
Tert. Crusher (Cone)
Impact Crusher
Roll Crusher
CWI
AG Mill
AMCT
AWI
DWT
SMC
JKRBT
SAGDesign
SPI
AG Pilot Plant
HPGR
Lab-scale HPGR
SPT
Pilot-scale HPGR
Rod Mill
RWI
Primary Ball Mill
Secondary Ball Mill
BWI
IsaMill
Sign. Plot
HiG Mill
Lab-scale HiG 5
Vertimill
Stirred Media Detritor
Grey: Industrial/Production
Blue: Testing
0.001
0.01
0.1
1
10
100
1,000
Size K80 (mm)

Bench-scale Testing

Bond Ball Mill Grindability Test

Bond Ball Mill

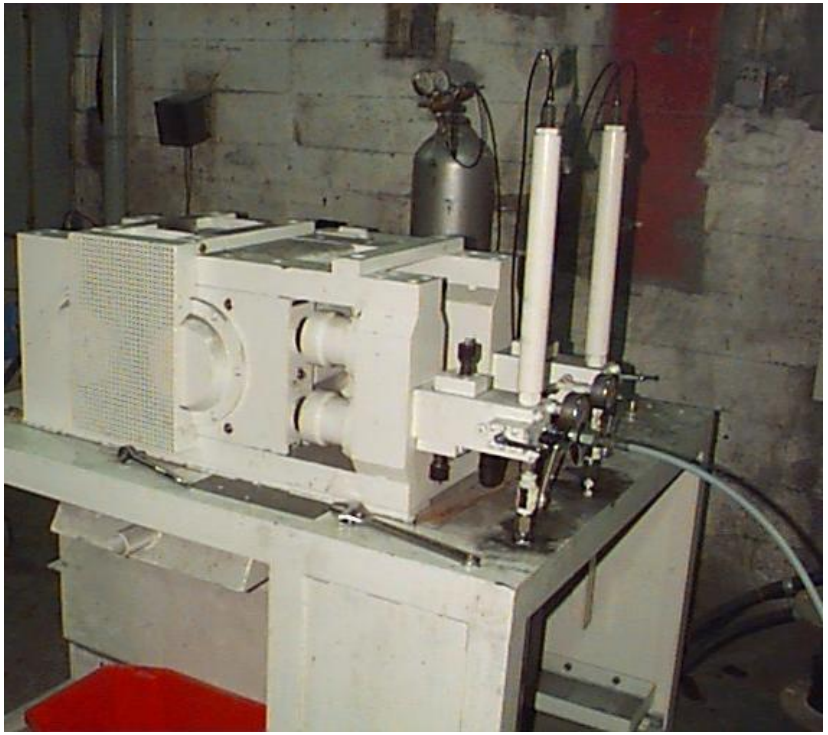
Deliver BWI for BM design in power models

Suitable for variability testing

For lateritic ores, the natural fines are removed prior to the test

Bench-scale Testing

LABWAL HPGR Testing



LABWAL HPGR

- 25 kg of 12.5 mm per test. 350 kg for full program
- Batch / Locked-cycle Test
- Deliver HPGR and BM power
- HPGR vs conventional mill trade off studies
- Preliminary scale-up but need full PP
- Less suitable for variability testing
- Prepare material for float / leaching trade off studies

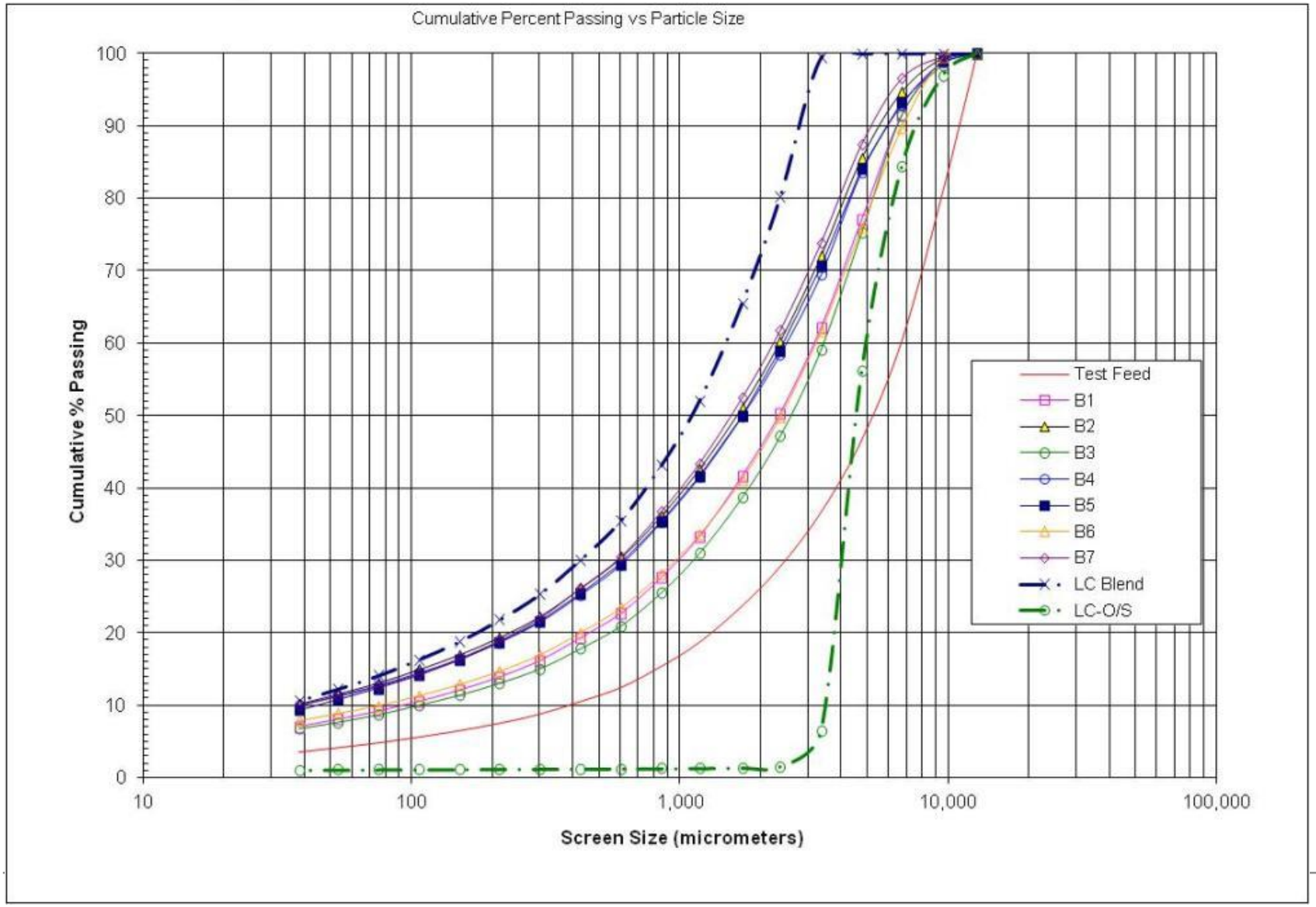
Bench-scale Testing

LABWAL HPGR Testing

- Two procedures:
  - Batch Test
    - 7 batch tests 25kg+ each, for 30sec+ of operating time
    - Investigate impact of moisture and pressure on kWh/t and fineness
  - Locked-cycle Test
    - On optimal performance determined in Batch test
    - Standard closing screen size is 3.35mm (6 mesh), or as per client needs
    - Provide kWh/t for locked-cycle test, and other parameters use for design.
    - Prepare material for BWI testing (micro-cracks and additional fines in the feed)

Bench-scale Testing

LABWAL HPGR Testing



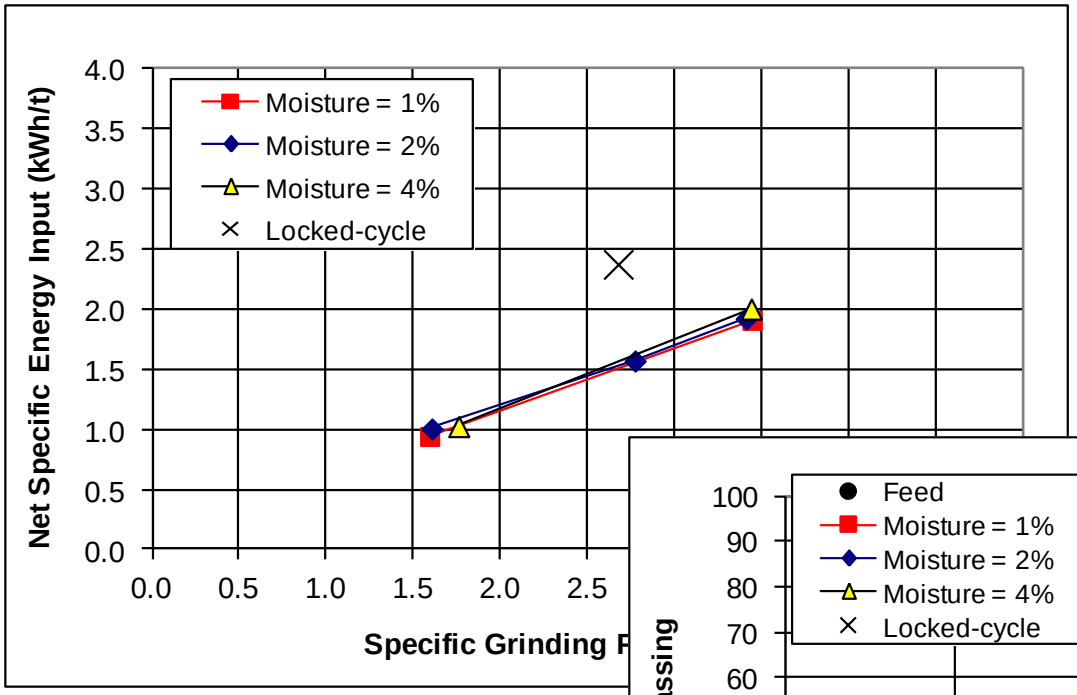
Bench-scale Testing

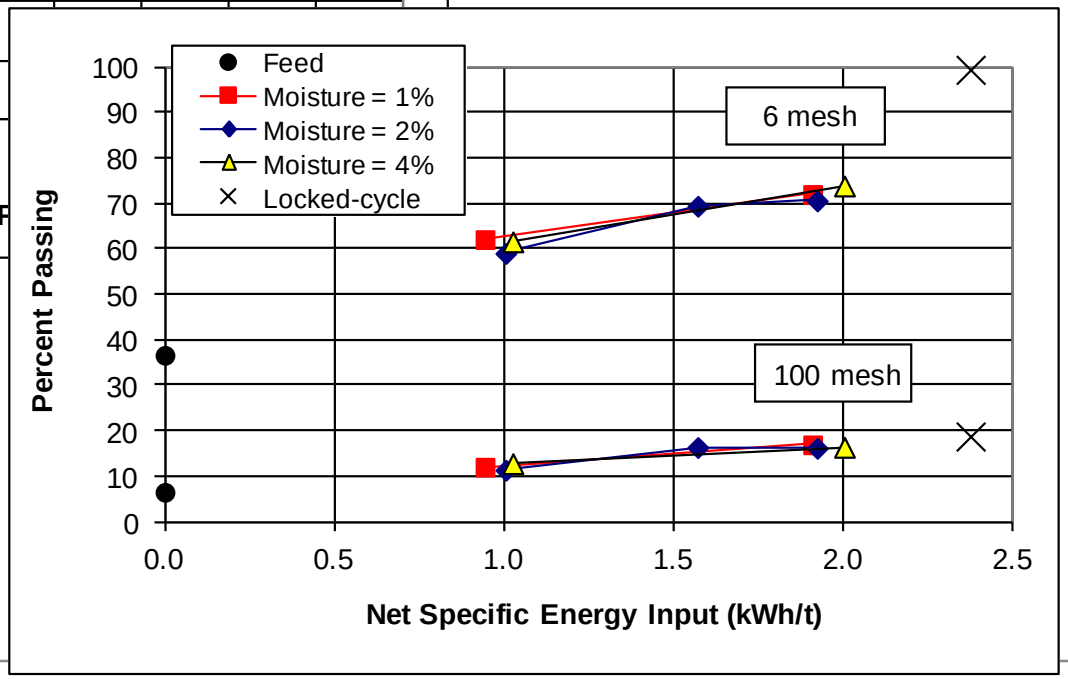
LABWAL HPGR Testing

Test Results Summary								
		Batch Tests						
Test Number		**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**
Date:		06/12/10	06/12/10	06/12/10	06/12/10	06/12/10	06/12/10	06/12/10
Operation								
Pressure of Operation (bar)		32	69	32	56	68	35	69
Moisture (%H_2O)		1.1	1.0	2.0	1.9	1.9	3.7	3.8
Dry Net Throughput (t/h)		2.7	2.6	2.7	2.6	2.5	2.7	2.4
Circulating Load (%)		-	-	-	-	-	-	-
Gross Power (kW)		3.5	5.8	3.7	5.0	5.8	3.7	5.8
Net Power (kW)		2.6	4.9	2.7	4.1	4.9	2.7	4.8
Gross Specific Energy Requirement (kWh/t)		1.30	2.28	1.37	1.93	2.29	1.38	2.39
Net Specific Energy Requirement (kWh/t)		0.94	1.91	1.01	1.57	1.93	1.03	2.01
HPGR Product Analysis								
P_{50} (µm)		2,338	1,628	2,589	1,711	1,706	2,377	1,552
P_{80} (µm)		5,130	4,149	5,298	4,374	4,302	5,292	3,950
Percent Passing 6 mesh		62.1	72.0	59.0	69.4	70.6	61.6	73.9
Percent Passing 100 mesh		12.0	16.9	11.4	16.4	16.2	12.8	16.4
Flake Density (kg/L)		2.3	2.3	2.3	2.3	2.3	2.3	2.3
Flake Thickeness (mm)		6.0	6.0	6.0	6.0	6.0	6.0	6.0
Performance Indicators								
Specific Grinding Force (N/mm^2)		1.59	3.45	1.61	2.77	3.41	1.76	3.44
Specific Throughput (ts/hm^3)-(m_f)		241	227	238	231	225	238	215
Specific Throughput Rate (ts/hm^3)-(m_c)		199	199	199	199	199	199	199
Specific Power (kWs/m^3)		228	433	240	364	433	244	431
New minus 6 Produced (%)		25.4	35.4	22.4	32.8	33.9	24.9	37.2
New minus 100 Produced (%)		5.5	10.4	4.9	9.9	9.7	6.3	9.9

Bench-scale Testing

LABWAL HPGR Testing





Bench-scale Testing

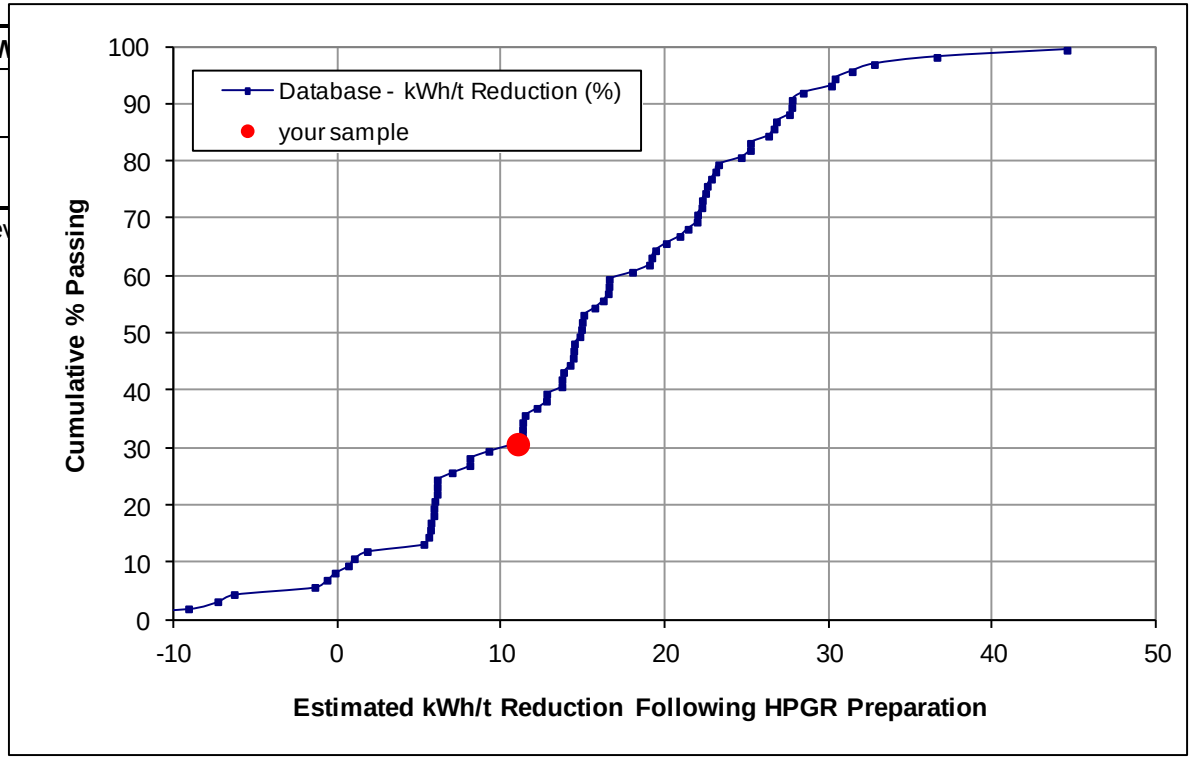
LABWAL HPGR Testing

BWI test on HPGR product when HPGR-Ball mill circuit is contemplated

Sample Name	Mesh of Grind	F_{80} (µm)	P_{80} (µm)	Gram per Revolution	Work Index (kWh/t)	Hardness Percentile
HPGR Feed	120	2,357	93	1.43	14.5	50
HPGR Product	120	2,362	93	1.53	13.7	42

	BWI Balance, % weight		W
Sample Name	Feed	%U/S	to be Ground
HPGR Feed	100	10.9	89.1
HPGR Product	100	15.5	84.5

* kWh/t reduction based on [gross gram per rev



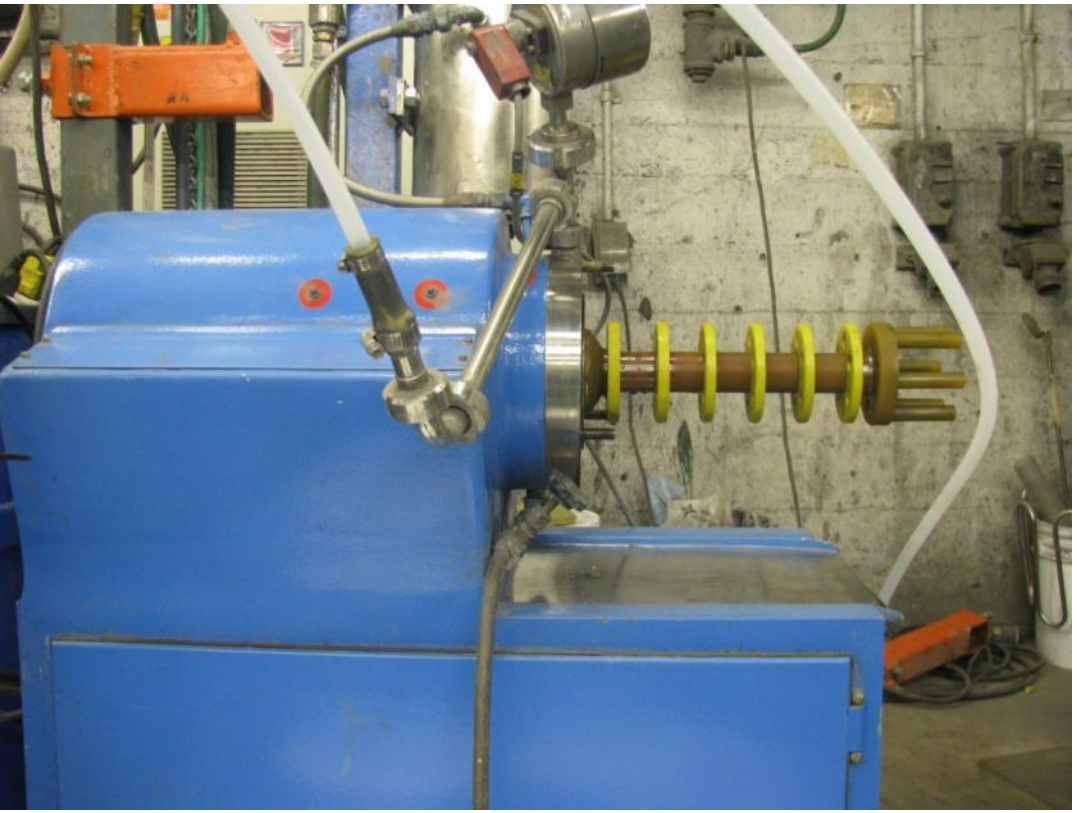
Bench-scale Testing

LABWAL HPGR Testing

- Static Pressure Test (SPT)
  - For variability study
  - Piston with incremental pressure
  - Uses between 3 and10kg
- Ore abrasiveness can be measured through the Atwal test (Polysius)

Bench-scale Testing

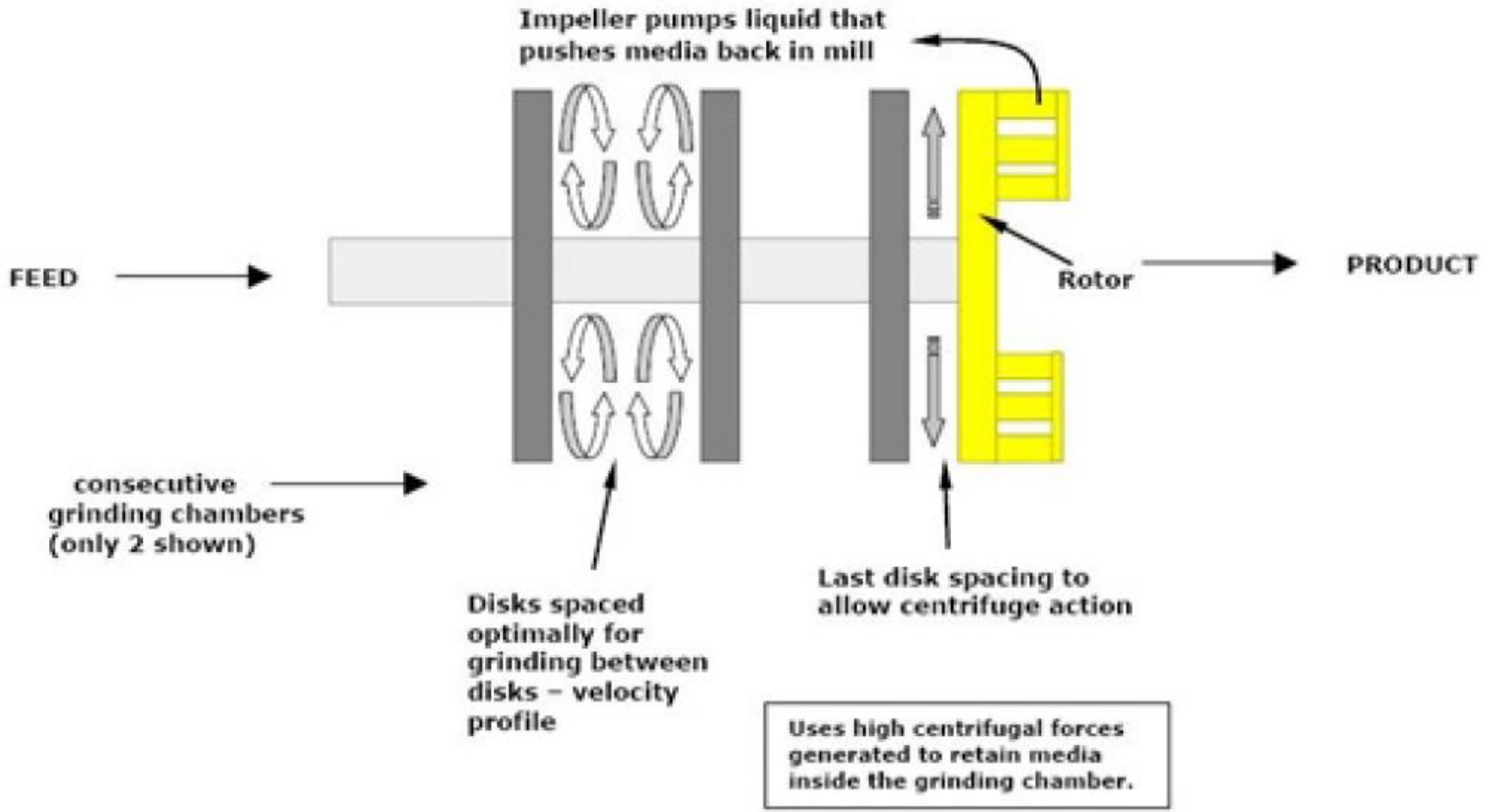
IsaMill Signature Plot



- Requires 15-kg of sample
- From 150 down to ~10 microns (K_{80})
- Generate kWh/t and media consumption
- Internal classification
- Direct scale-up
- Continuous operation for pilot plant testing

Bench-scale Testing

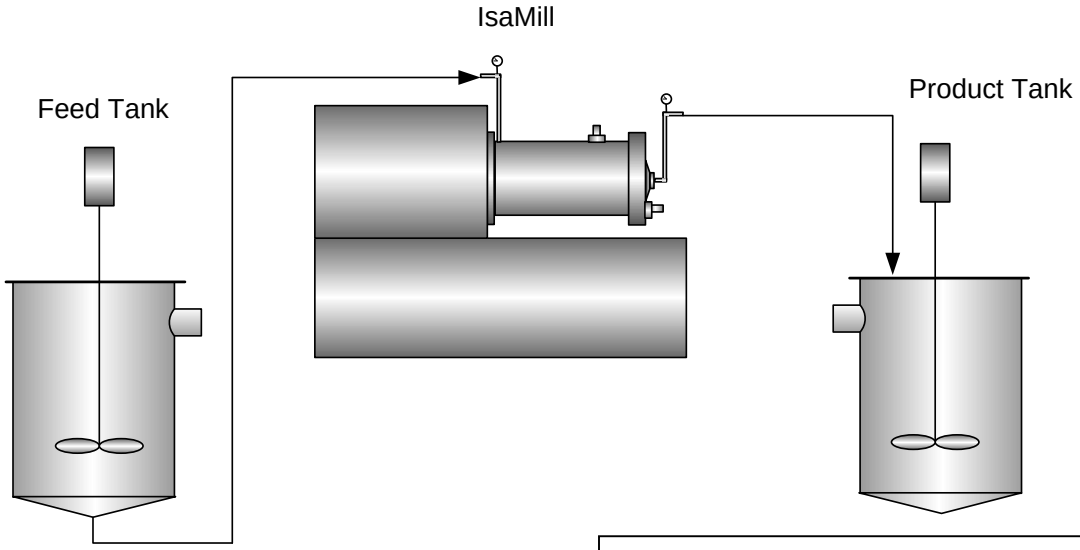
IsaMill Signature Plot



Bench-scale Testing

IsaMill Signature Plot

Setup



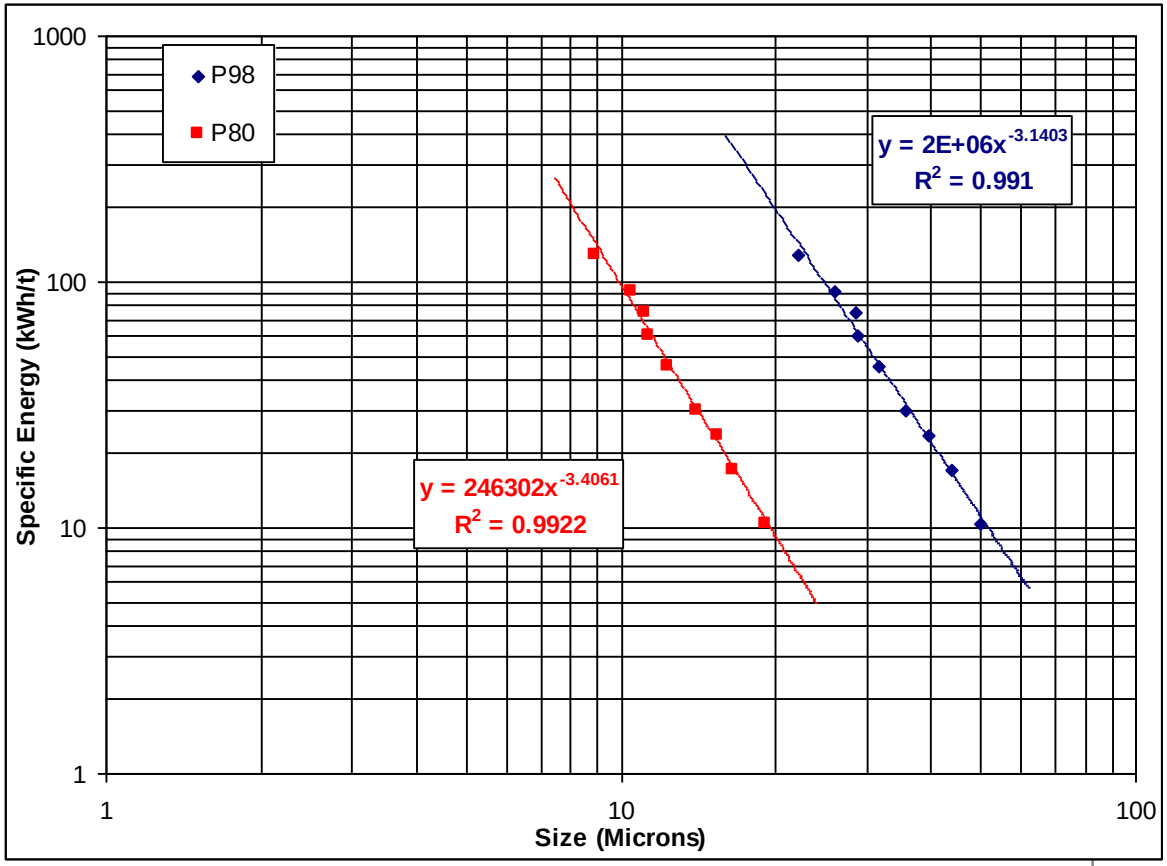
Parameters recorded:

- Feed % solids
- Throughput rate
- Number of passes required
- Media selection
- Feed and product pulp densities and viscosities
- Specific energy input
- Specific energy input vs. P80 curve
- Feed and product particle size analyses
- Media consumption

Viscosity is monitored at every pass, and water added when pulp too thick

Bench-scale Testing

IsaMill Signature Plot



- Test Results
  - Within reasonable reduction ratios, the log of size plotted against the log of energy, produces a straight line.
  - This line can be extrapolated within the limits of media efficiency and viscosity.
  - This plot is referred to as a signature plot, and is unique to the ore, pulp conditions and media selected.

Bench-scale Testing

HiG 5

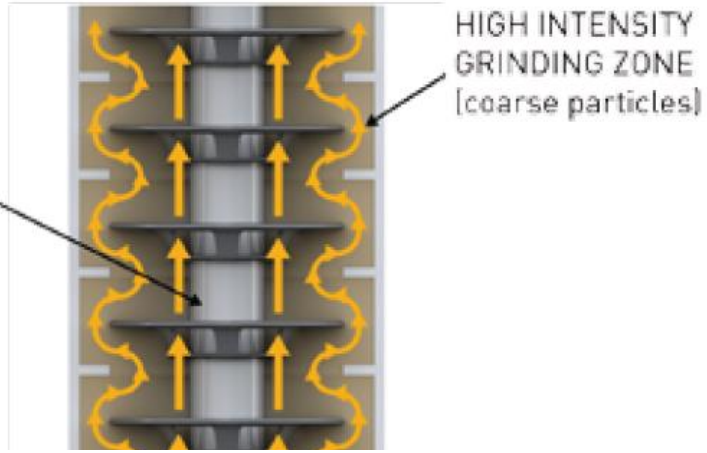
- Requires 15-kg of sample
- From 200 down to ~20 microns (K_{80})
- Generate kWh/t and media consumption
- Internal classification
- Continuous operation for pilot plant testing

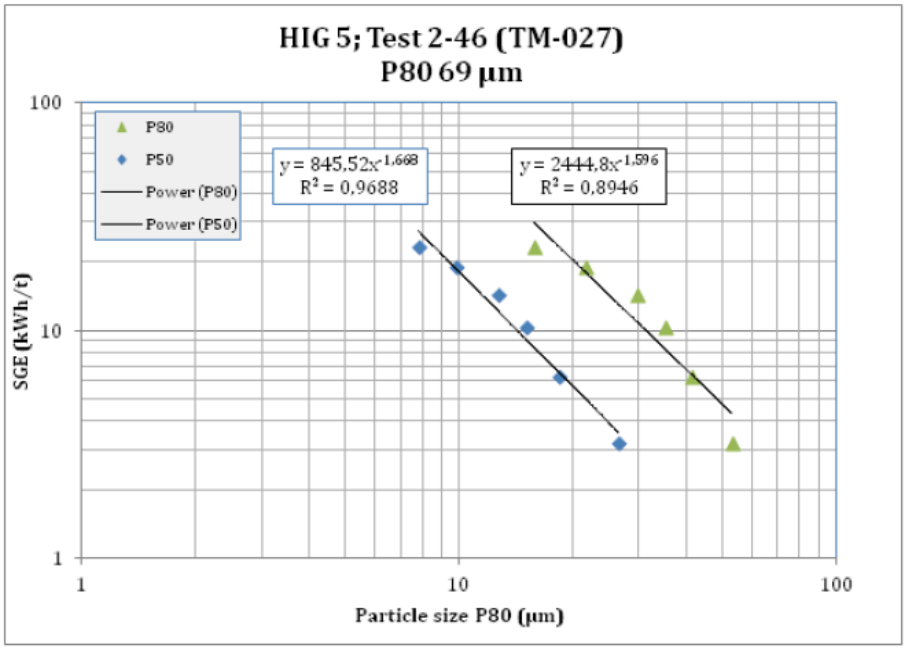
Bench-scale Testing

HiG 5

Variables:

- Feed % solids
- Throughput rate
- Number of passes required
- Shaft speed
- Media selection
- Feed and product pulp densities and viscosities
- Specific energy input
- Specific energy input vs. P80 curve
- Feed and product particle size analyses

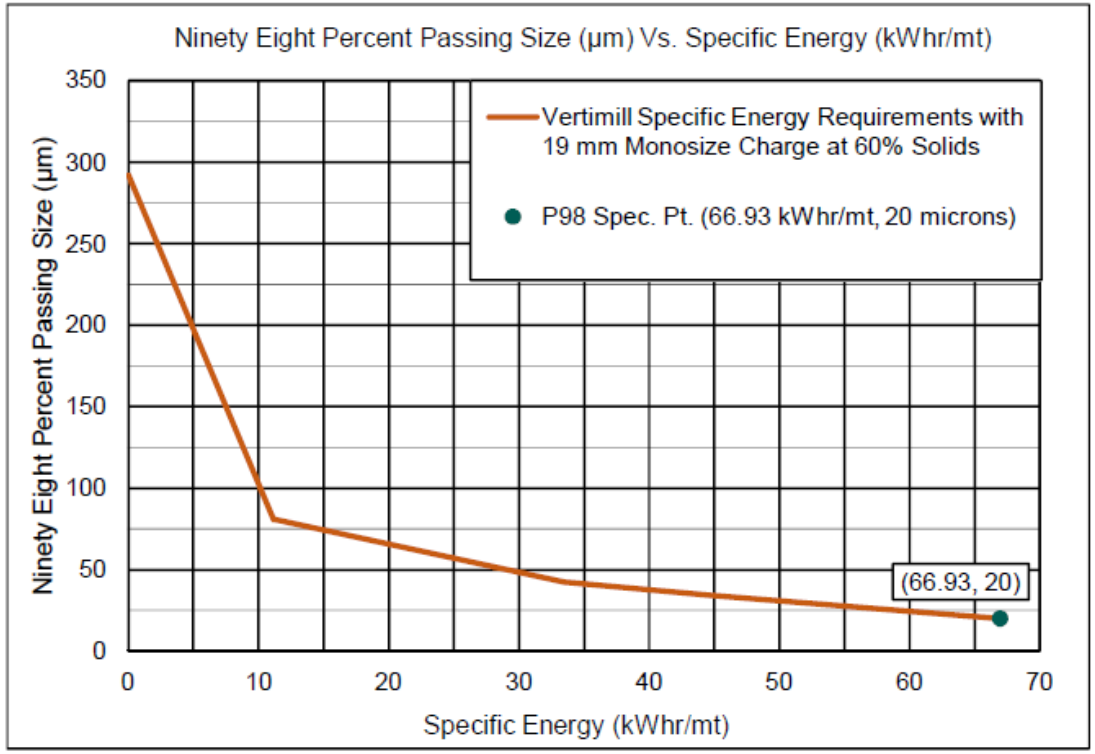




Bench-scale Testing

Jar Mill Test

- Multiple wet batch tumbling grinding test (4-5 per sample)
- Calculations for indicated energy requirements
- Specific energy input vs. P_{98} curve



Outline

- Characterisation Objectives
- Bench-scale Testing
- **Pilot-scale Testing**
- Conclusions

Pilot-scale Testing Consideration

- Integrated Circuit, or Unusual Operating Conditions
  - Introduction of metallurgical separation units, such as coarse magnetic separation
  - HPGR to a fine size, which may causing excessive circulating load
  - Operation conditions falling outside typical range (mill speed, load, ball charge, etc.)
- Unusual Ores
  - Highly heterogeneous ores
  - When ores with significantly different grindability characteristics are to be blended
  - Fall outside ‘normal range’, such as extremely hard ores
  - Other unusual behaviours: ore containing flakes, fibres, or unusual rheology, soluble component, etc.

Pilot-scale Testing Consideration

- Conflicting Results
  - Two methodologies presenting significantly different conclusions
- Should be Conducted when in Doubt

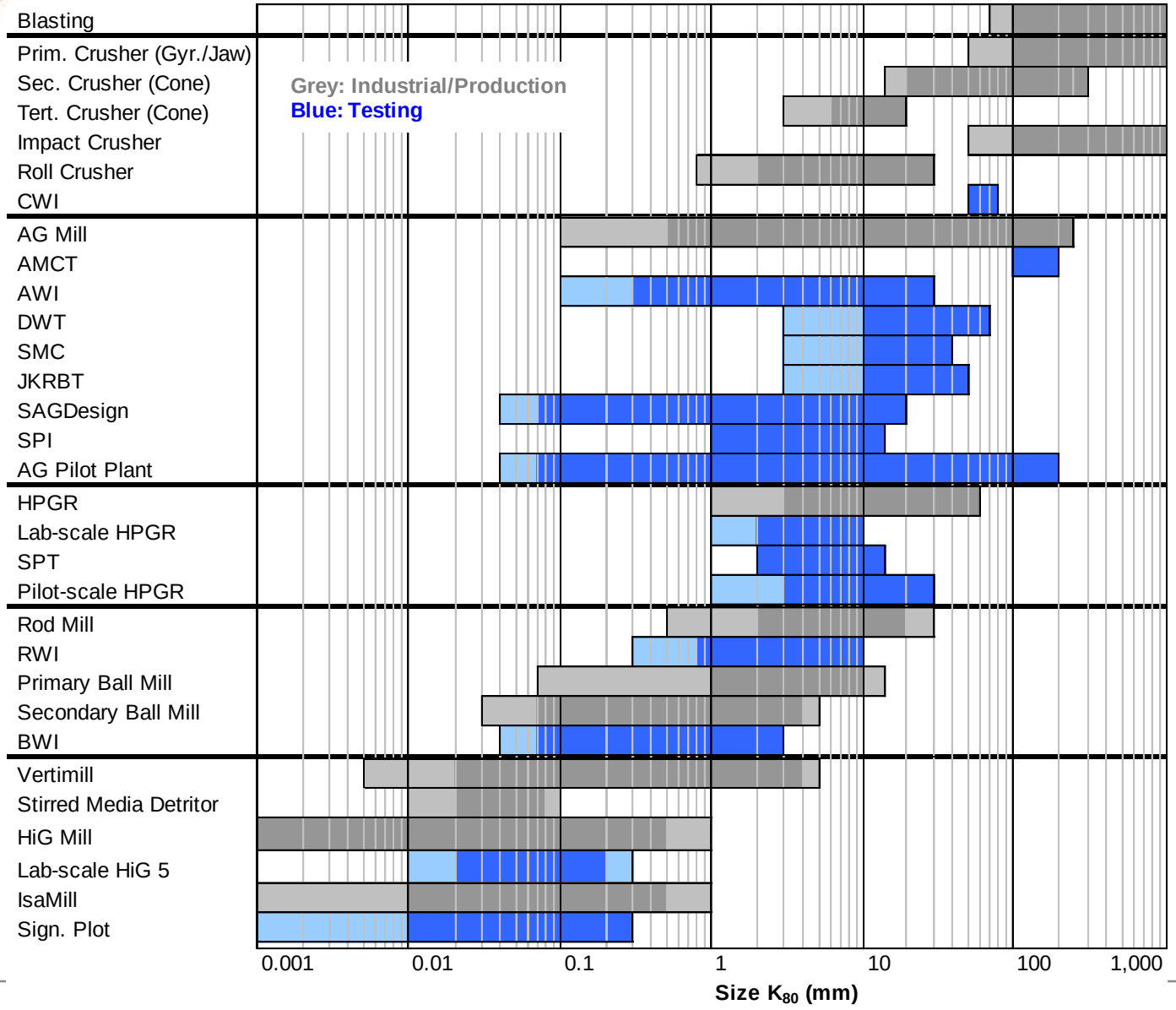
Outline

- Introduction
- Bench-scale Testing
- Pilot-scale Testing
- **Conclusions**

Conclusions

- HPGR and HiGmill™ technologies were not available to the hard rock industry until recently (wear, fear of different technology, etc).
- HPGR should be considered early in the project (not only AG milling)
- Important to do regrind test on proper material, as regrind feed characteristics are significantly different than raw material.
- Confirmation through pilot plant is always desirable

Questions?


Blasting
Prim. Crusher (Gyr./Jaw)
Sec. Crusher (Cone)
Tert. Crusher (Cone)
Impact Crusher
Roll Crusher
CWI
AG Mill
AMCT
AWI
DWT
SMC
JKRBT
SAGDesign
SPI
AG Pilot Plant
HPGR
Lab-scale HPGR
SPT
Pilot-scale HPGR
Rod Mill
RWI
Primary Ball Mill
Secondary Ball Mill
BWI
Vertimill
Stirred Media Detritor
HiG Mill
Lab-scale HiG 5
IsaMill
Sign. Plot
Grey: Industrial/Production
Blue: Testing
0.001
0.01
0.1
1
10
100
1,000
Size K80 (mm)