BIOGRAPHY – John Starkey

BASc Mining - U of T
P.Eng. Consulting Engineer.
12 yrs operations at Kidd Creek, and INCO
12 yrs engineering at Kilborn
15 yrs consulting
President, Starkey & Associates Inc.

- Est'd partners, capabilities, in USA, Russia & Australia
- Added 2 full time engineers in 2009, Oakville office
- International - due diligence study for Polyus Gold 2009
- Lead engineer for the Berezitovy Au mill - 2008 startup
- Provide engineering, consulting and testing services
- 15 year patent agreement for SAGDesign test

Design Performance Realized SAGDesign™ Testing

Starkey & Associates Inc.
SAGDesign and Process Engineering

SELECTION OF GRINDING EQUIPMENT TO MATCH THE ENTIRE ORE BODY USING SAGDESIGN TECHNOLOGY

Mining Magazine Congress
Niagara-on-the-Lake, Ontario
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Agenda

1. ***Where are we today***
2. What is a ‘good’ design
3. SAGDesign Database
4. Mill sizing calculations
5. Conclusion

1. Where are we today

Question - Are we grinding to push tonnage or recover metal?

Some things observed recently

- Various consultants give widely divergent predictions (discuss)
- Consultants think that if a SAG mill works it is overdesigned
- Some use other tests and hope they work (they don't)
- JK cannot size new mills accurately over 15 kWh/t (no data)
- SPI is a scoping test
- SMC does not correlate with SPI
- Full DW test cannot be done deep in the mine (explain)

1.1 The result

Our response as individuals and the industry

- HPGR is looked to as a way out because SAG designers have not got their act together in a consensus mode
- New grads are confused (discuss Tuscon story)
- Experts use flawed assumptions to solve the problem
- Back to basics is required
- A new technology has been introduced
- Only one person is teaching in the Universities
- The lecture includes SAGDesign technology
- Other methods are private, require expensive software or just don’t work very well

1.2 SAGDesign SAG Mill at Dawson in Salt Lake City

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2. What is a 'Good' Design

- Steady feed at design t/h so good metallurgy is possible
- This is 80th percentile not 50th based on entire ore body
- No SAG mill scats
- No ball mill scats
- No spillage during operation
- Way to measure T80
- Way to control T80, screen, trommel, cyclone, or classifier,
- Can grind hardest ores
- Always meet design t/h
- Proper Instrumentation for optimization
- SAG efficiency is equal to lab (benchmark)
- BM efficiency = Bond Wi (including fines and diam corr)

2.1 How to achieve a good SAG and BM design

- Take proper samples considering, geology and mine plan
- Do SAGDesign tests
- Minimum 10 for design guarantee (Outotec's)
- If unfamiliar with SAGDesign use other method(s) for comparison
- Determine:
  - P80 for good metallurgy
  - % availability (considering country)
  - Design t/h
- Calculate the required motor power for 80th percentile data
- Calculate the required mill sizes paying attention to future considerations in selecting the flowsheet and the T80.

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3. SAGDesign Database

- Needed to analyse all SAGDesign test data to date – 5 yrs
- 35 projects, 232 tests
- Trend SAG W = f(Bond Wi). Not accurate
- Compare hard and soft ores to DB
- Study new discoveries
- Present info at CIM Toronto, METSOC Sudbury, SME Tucson

Figure 1 – SAG Pinion Energy Vs Cum. Dist.% of Samples Tested

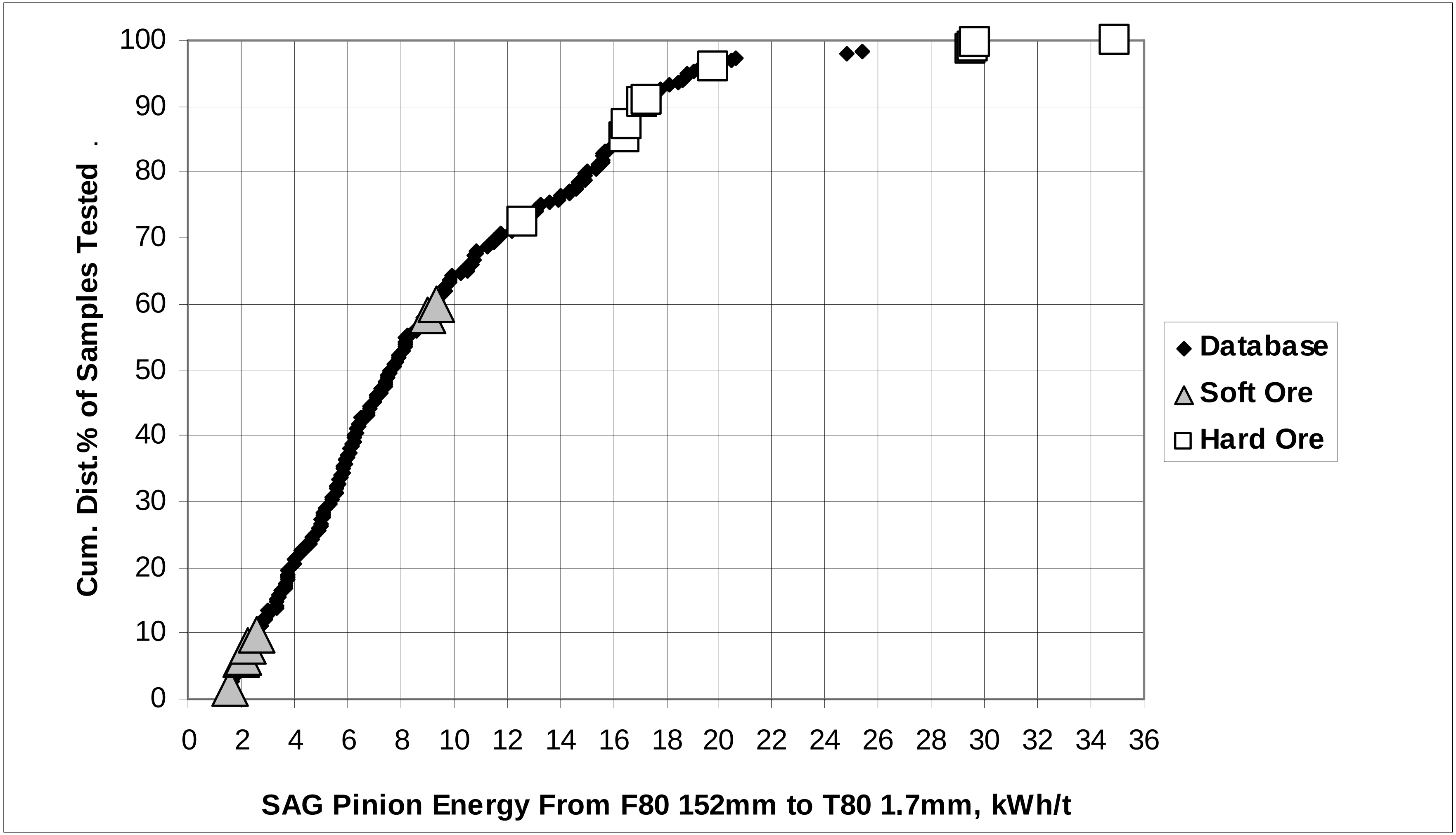


Figure 2 – Bond Ball Mill Work Index Vs Cum. Dist% of Samples Tested

Figure 3 – Database SAG and Bond Data by Year – Including Soft and Hard Ore

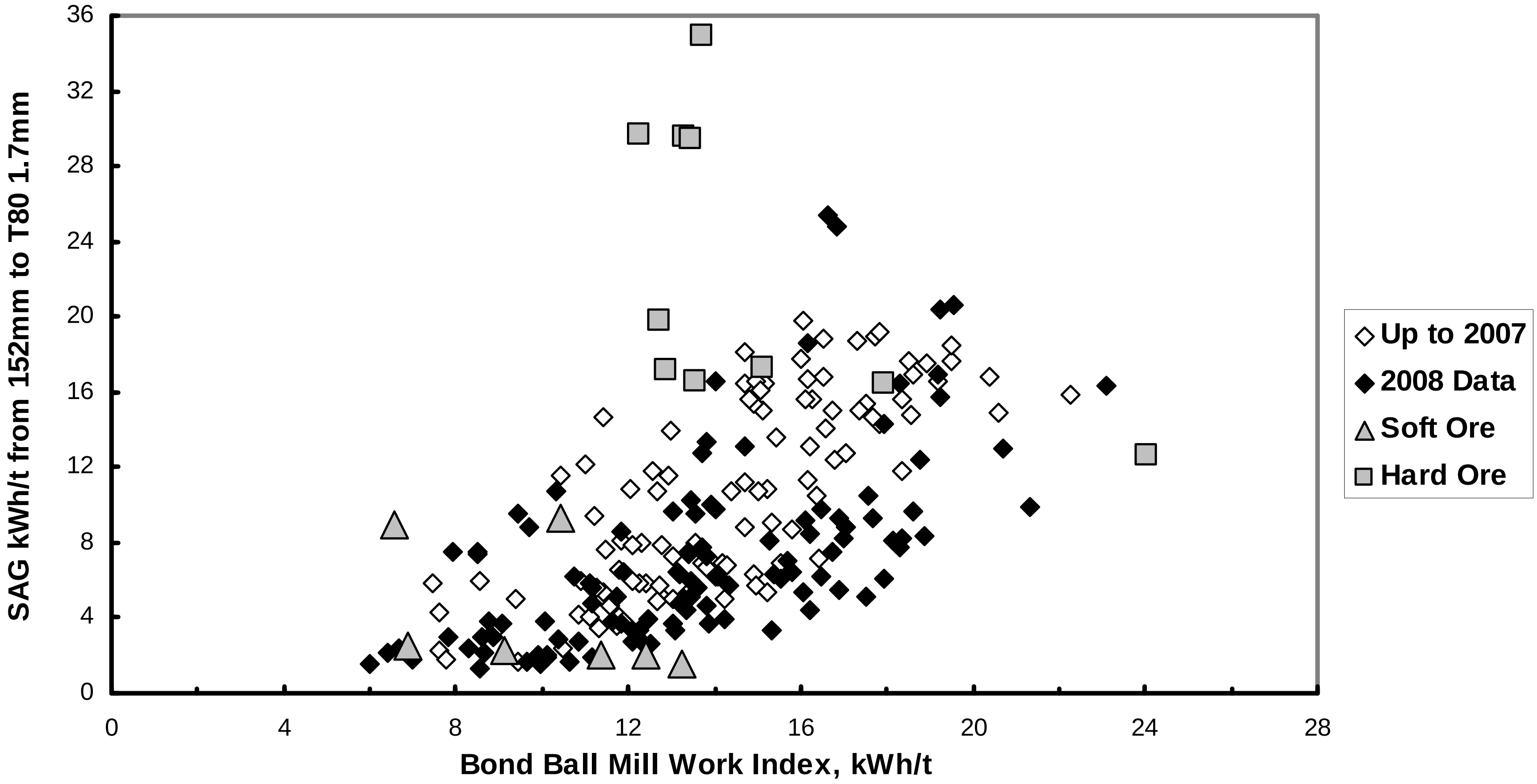


Fig. 4 – SAG Pinion Energy Vs Ratio of SAG/Bond BM Wi Including Soft and Hard Ore

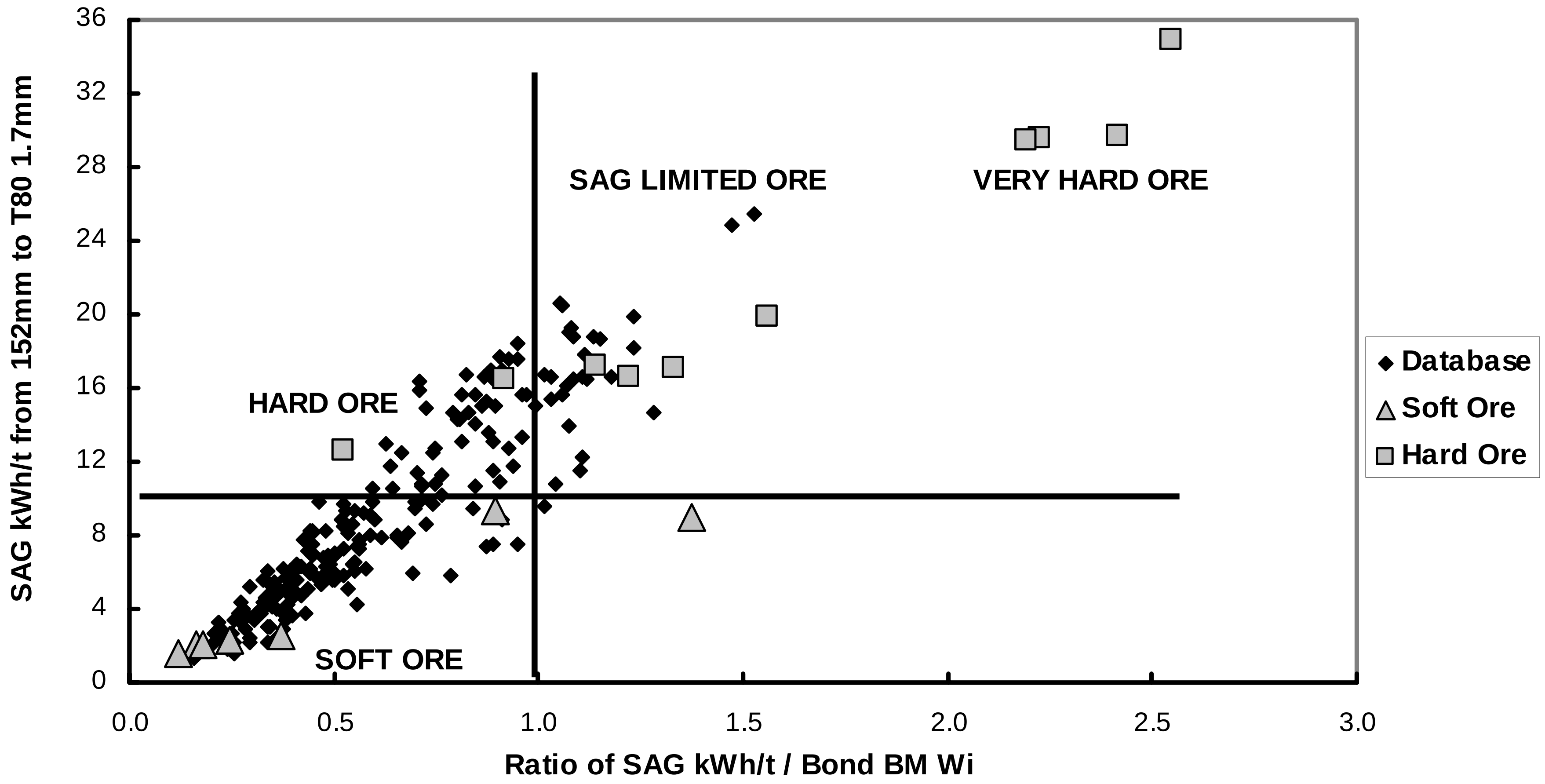
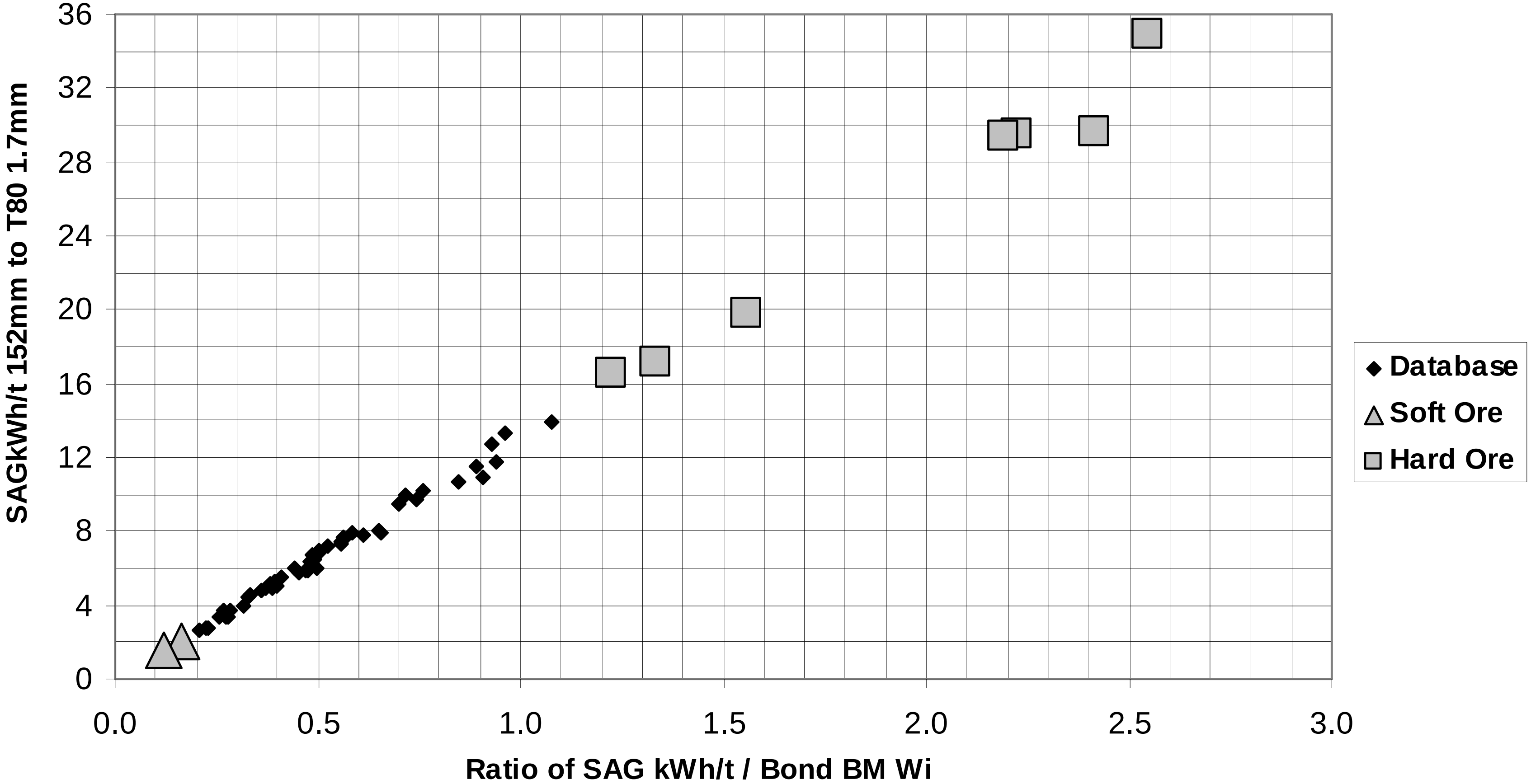


Fig. 5 – SAG kWh/t to 1.7mm Vs Bond BM Wi, 58 Samples with Bond Wi 12 - 14



3.1 New Discoveries

Wide variance in SAG W for constant Bond of 13

Energy shifts occur at 2 mm and over 10 mm

Identified macro/micro ratio as key parameter

Consider ratio in design

Calculate mill sizes

Works on every ore

3.2 Rotating Mill grinding tests using steel

Test	F80	Mill, In.	Sample	Remarks
Bond BM	2	12 x12	10 kg	BM design
Bond RM	10	8 x 20	20 kg	RM design
SPI	12.7	12 x 4	5 kg	Scoping
MacPherson	19	18 x 6	200 kg	Pilot plant
SAGDesign	19	19.2 x 6.4	15 kg	SAG/BM design

Shift in hardness at 2 mm and 10 mm

Tests do a good job for what they were designed to do

SAGDesign most comprehensive

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Typical mill design calculations

CASE 1 - No pebble crusher. Fixed rpm new SAG and ball mills. 80th% ore.

A - Calculation of Unit Pinion Energy for SAG Mill and Ball Mill ***Reduction for pebble crush*** ***0%***

Item	Units			80th%
SAG Mill to 12 mesh US Std.	kWh/t		***design SAG pinion energy***	**29.5**
Adjust SAG Energy to "T80"µ	**1700**	***SAGDesign test T80***		**0.0**
Total SAG Shell Energy	kWh/t			**29.5**
B Mill Pinion Energy to "P80" µ	**74**	***design P80***		**12.3**
SAGDesign Bond BM Wi	*kWh/t*		***design Bond Wi***	***13.4***
Total Grinding Energy	kWh/t			**41.8**
Design SAG Feed - mt/h	**215**	***design t/h***	***Measured Ratio, SAG/BM***	***2.2***

B - Calculation of Unit Motor Energy for Fixed speed SAG Mill and Ball Mill (Metered Energy)

Item	Factors		80th%
SAG Energy kWh/t * @	1.06	** SAG Motor - corrected for efficiency loss with synchronous motor & clutch*	**31.3**
BM Energy kWh/t ** @	1.06	*** BM Motor - corrected for efficiency loss with synchronous motor & clutch*	**13.0**
	0.88	*BM diameter correction factor - see Table F*	**11.4**

C - Calculation of Unit Motor Sizing for Fixed Speed SAG Mill and Ball Mill

Item	Factor***		80th%
SAG Motor kWh/t*@	1.10	*SAG Mill operating allowance factor*	**34.4**
BM Motor kWh/t**@	1.05	*Ball Mill operating allowance factor*	**12.0**
		Installed unit energy	**46.4**

*Note *** Includes for SAG operating margin and for ball mill operating margins.*

D - Motors Required for Fixed Speed SAG Mill and Ball Mill **215 t/h** **80th%**

SAG Mill Motor, kW		**7,394**
Ball Mill Motor, kW		**2,576**

E - Mill Dimensions, Motor Specification, Fixed Speed SAG Mill ***Adjust mill D & L to provide req'd kW***

Mill	Speed	Dia, Ft	A	B	C	EGL	Calculated Motor		Instal	Mill Dimensions	
	% Crit	(ID Shell)	ID - 0.5'	26% Load	75% Crit	Length	HP	kW	HP	Dia, ft	EGL, ft
	fixed			*10% steel*							
SAG Mill	75	32.00	986	4.17	0.1838	13.12	9,916	**7,394**	**10,000**	**32**	**13.1**
Ball Mill	75	16.00	167	5.02	0.1838	22.37	3,454	**2,576**	**3,500**	**16**	**22.4**

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Conclusions

- Take samples that represent the entire ore body
- Design with confidence to achieve t/h stability
- Measure and calculate - is preferred method
- Use the right test
- SAGDesign - for ores over 15 kWh/t (in SAG mill)
- BM Wi can not be used alone for SAG mill design
- SAGDesign - only method that reports in kWh/t at any T80
- The program is affordable…………… and fast…………..

References

Six papers available on SAGDesign.com website

- SAGDesign Testing – What It Is and Why It Works. SAG 2006
- Comparison of Ore Hardness Measurements for Grinding Design for the Tenke Project. CMP 2007
- SAGDesign Testing Review - Case Studies. 2008 IMPC-XXIV
- New Discoveries in the Relationship Between Macro Vs Micro Grindability. CIM 2009
- Impact on Mill Design and Flotation Control of new Discoveries in the Relationship Between Macro and Micro Grindability. METSOC 2009
- Impact on Grinding Mill Design of Recent New Discoveries

Thank you !

Your questions are welcomed.