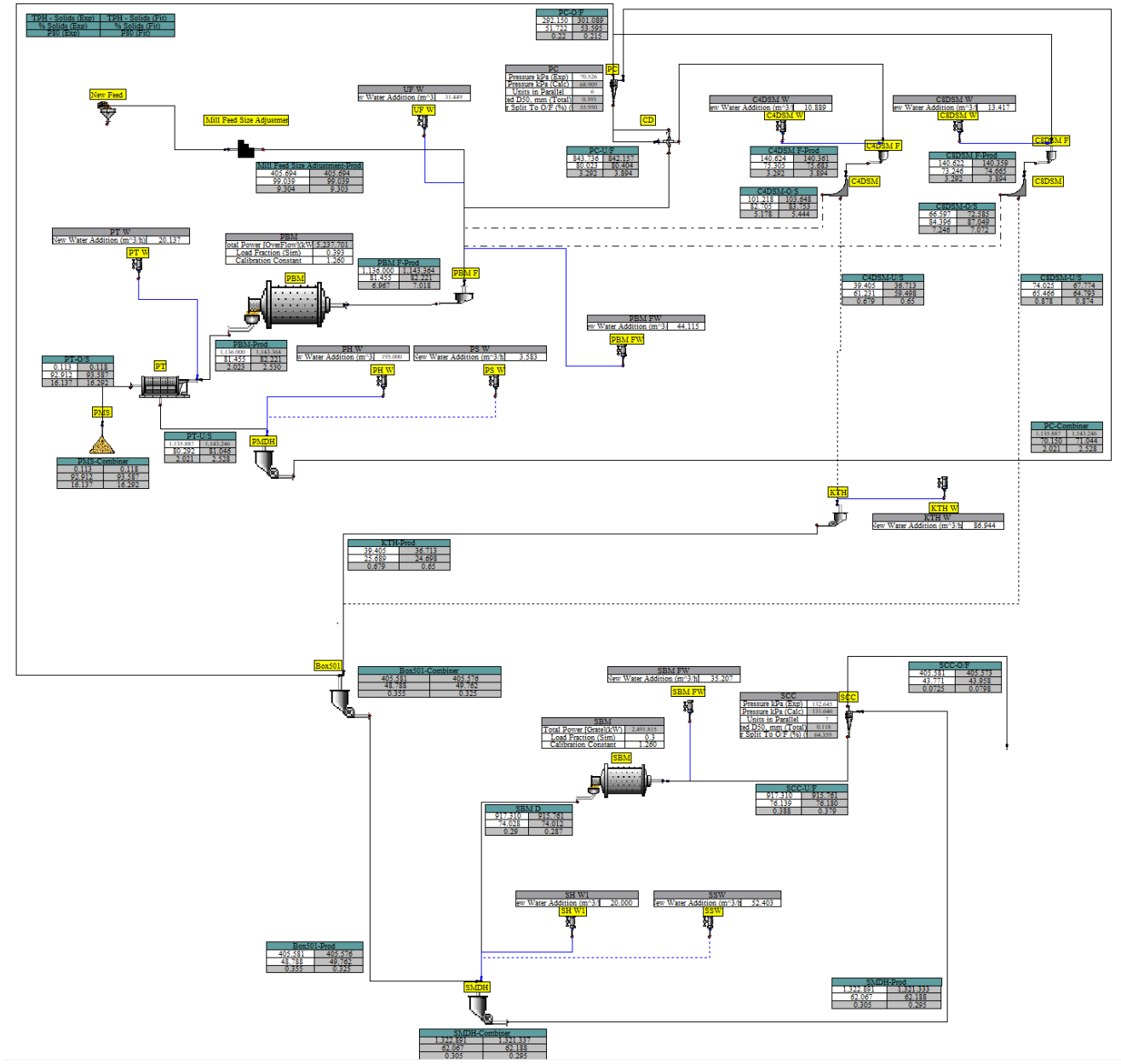

New Feed
Mill Feed Size Adjustmer
Mill Feed Size Adjustment-Prod
UF W
CD
PC
PC-O/F
PC-U/F
C4DSM W
C4DSM F
C4DSM
C4DSM-F-Prod
C4DSM-O/S
C4DSM-U/S
C8DSM W
C8DSM F
C8DSM
C8DSM-F-Prod
C8DSM-O/S
C8DSM-U/S
PT W
PT
PBM
PBM F
PBM-Prod
PBM FW
PH W
PS W
PT-O/S
PT-U/S
PMS
PMS-Combiner
PMDH
PC-Combiner
KTH
KTH W
KTH-Prod
Box501
Box501-Combiner
Box501-Prod
SBM FW
SBM
SCC
SCC-O/F
SCC-U/F
SBM-D
SH W1
SSW
SMDH
SMDH-Prod
SMDH-Combiner

CALCULATION COVER SHEET **Date:** 2026-02-03

Author: Alex Doll **Revision** 1

Project: MetPlant 2026 **Calc No:**

Title: Functional Performance calculation for ball mill circuit

Tanami survey of 2025-08-16, Primary ball mill, Box 501 as transfer size

Purpose:

Calculate the functional performance efficiency of a ball mill circuit using the method of McIvor (Metcom technology technique adapted by Alex Doll).

Basis / Assumptions:

Conduct a grinding circuit survey where the ball mill feed stream (cyclone underflow) and ball mill discharge stream are sampled and the particle size distribution (PSD) is computed. Use this to determine the hydrocyclone efficiency by measuring the proportion of "product" (the desired flotation feed size) that exists in the ball mill feed stream.

Compute the amount of "product" created in the ball mill by comparing the proportion of that size class in the mill feed and discharge, then multiply by the mass flow rate to determine the t/h of "product" created in the mill.

Use the ball power measurement, corrected to the mill shell or pinion, to compute the amount of power consumed to make the "product". (Optional) If a Bond ball mill laboratory grindability test has been conducted, then a benchmark comparison using the Bond test versus the industrial mill may be conducted.

Desired "product" size:	**324** µm
Particle size distribution of mill feed, see calculation:	**attached**
Measured BM discharge percent solids	
Measured cyclone u/f percent solids	

Method: A survey of the primary mill was conducted on 2025-08-16. Particle size distributions were determined for the mill feed and the mill product.

	Measured	Balanced	
Fraction of fresh feed passing 324 µm:	11.8%	11.8%	w/w
Fraction of mill feed passing 324 µm:	20.8%	20.8%	w/w
Fraction of mill discharge passing 324 µm:	45.6%	45.6%	w/w
Fraction of Box 501 passing 324 µm:	80.0%	80.0%	w/w
Circuit classification system efficiency (CSE):	66.8%	66.8%	
Comment:		**poor (target >70%)**	
Mill circuit feed rate, equiv. dry solids		406	tonnes/h

	Measured	Balanced	
Ball mill feed rate, equiv. dry solids	1,113	1,113	tonnes/h
Cyclone feed rate, equiv dry solids			
Circulating load	274%	274%	
Ball mill motor power, at DCS		**4,744**	kW
Electromechanical efficiency		**93.14%**	
Ball mill power at mill shell		4,419	kW

CALCULATION COVER SHEET **Date:** 2026-02-03

Author: Alex Doll **Revision** 1

Project: MetPlant 2026 **Calc No:**

Title: Functional Performance calculation for ball mill circuit

Tanami survey of 2025-08-16, Primary ball mill, Box 501 as transfer size

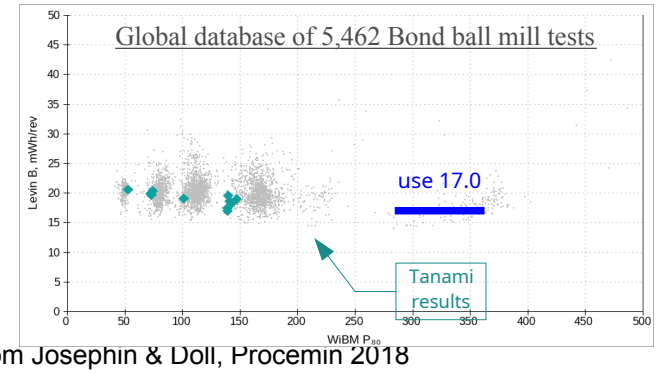
specific energy consumption, BM circuit	10.89 kWh/t
Fines in the circuit feed (primary mill product)	47.86 t/h
Fines generation, new product creation rate	275.97 t/h
Mill grinding rate, new fines per kW of power consumed	0.093 fines t/h per eff kW
Laboratory BM test g/rev for 324 µm P_{80} test	2.04 grams/revolution
Laboratory BM new fines per kW of power consumed	0.120 fines t/h per eff kW
BM grinding efficiency	78%
	reasonable (target >80%)

Results: The amount of oversize material in the cyclone overflow 82 t/h

81 t/h (measured)

The classification system efficiency is poor compared to the surveys published by McIvor (>70% expected).

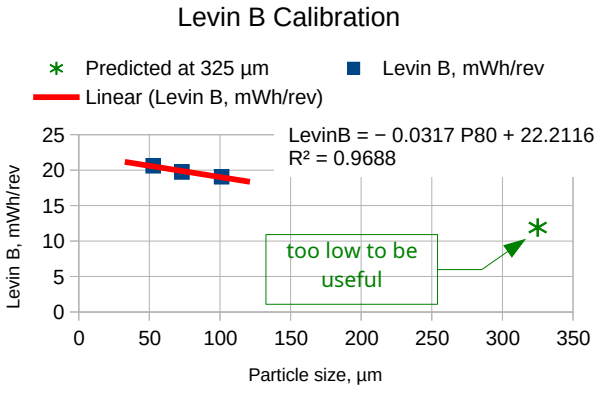
Grinding efficiency is acceptable, the industrial mill is nearly as efficient as an equivalent Bond ball mill apparatus in the laboratory. Note that the computed Levin B value 11.9 mWh/rev is well outside of the normal range of 15–20 mWh/rev @ 325 µm and is not robust, assume a more normal B value of 17.



Conclusions & Recommendations:

Circuit appears to be running at very low efficiency if the Levin B of 11.9 mWh/rev is correct (the A27173 regression). A more normal Levin B value of 17 mWh/rev gives an acceptable 78% efficiency.

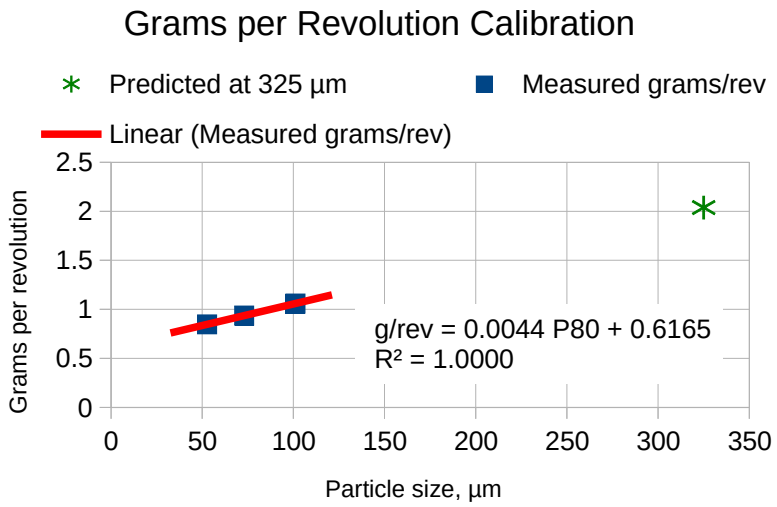
Addendum, Bond mill power consumption from Josephin & Doll, Procemin 2018 using method of Levin, 1989



This curve doesn't extrapolate well to 325 µm. Use the global database (grey points) from the graph above. Assume Levin B of 17 mWh/rev

Use laboratory grinding rate (Levin "B") value of 17.00 mWh/rev

	A	B	C	D	E	F	G	H	I
1	**CALCULATION COVER SHEET**				**Date:**	2026-02-03			
2					**Author:**	Alex Doll		**Revision**	1
3	**Project:**	MetPlant 2026			**Calc No:**				
4	**Title:**	Functional Performance calculation for ball mill circuit							
5		**Tanami survey of 2025-08-16, Primary ball mill, Box 501 as transfer size**							
93		*Grams per revolution*							



Model

Nearest neighbours model

80% = 9.38 mm

Bond √2 model

80% = 9.8 mm

$$\% \text{ Passing} = 0.5 \times \left(\frac{x}{5043}\right)^{\left(\frac{1}{\sqrt{2}}\right)}$$

Gaudin Schuhmann model

80% = 10.52 mm

$$\% \text{ Passing} = \left(\frac{x}{14910}\right)^{0.639}$$

$R^2 = 0.99$

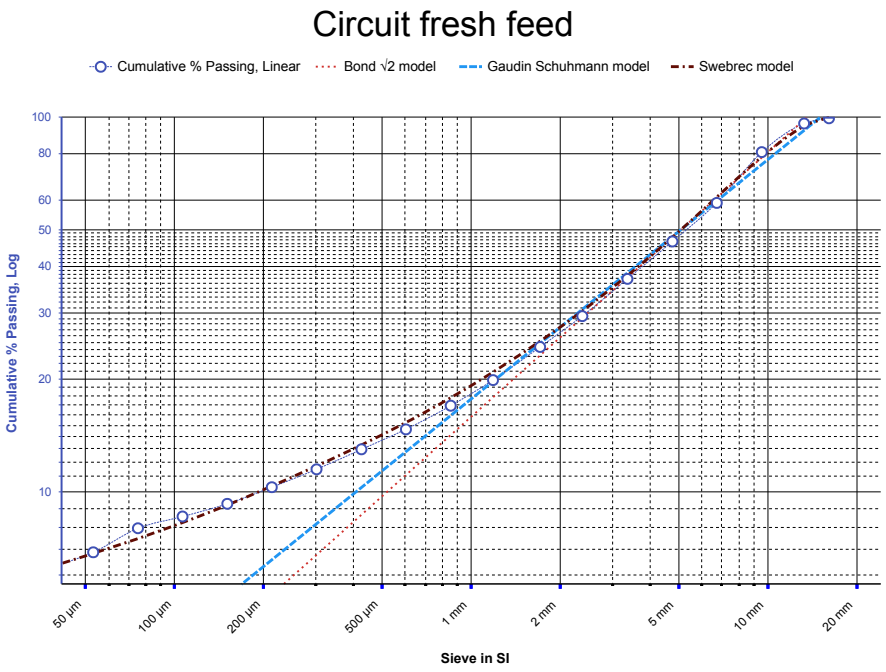
Rosin Rammler model

Swebrec model

80% = 9.76 mm

$$\% \text{ Passing} = \frac{1}{1+\left(\frac{\ln(16000/x)}{\ln(16000/5043)}\right)^{1.634}}$$

$R^2 = 1$



Size, µm	%passing
324	11.8%
193	10.0%
75	8.0%

Model

Nearest neighbours model

80% = 324.22 µm

Bond √2 model

80% = 171.02 µm

$$\% \text{ Passing} = 0.5 \times \left(\frac{x}{88}\right)^{\left(\frac{1}{\sqrt{2}}\right)}$$

Gaudin Schuhmann model

80% = 292.74 µm

$$\% \text{ Passing} = \left(\frac{x}{518}\right)^{0.391}$$
$$R^2 = 1$$

Rosin Rammler model

80% = 329.64 µm

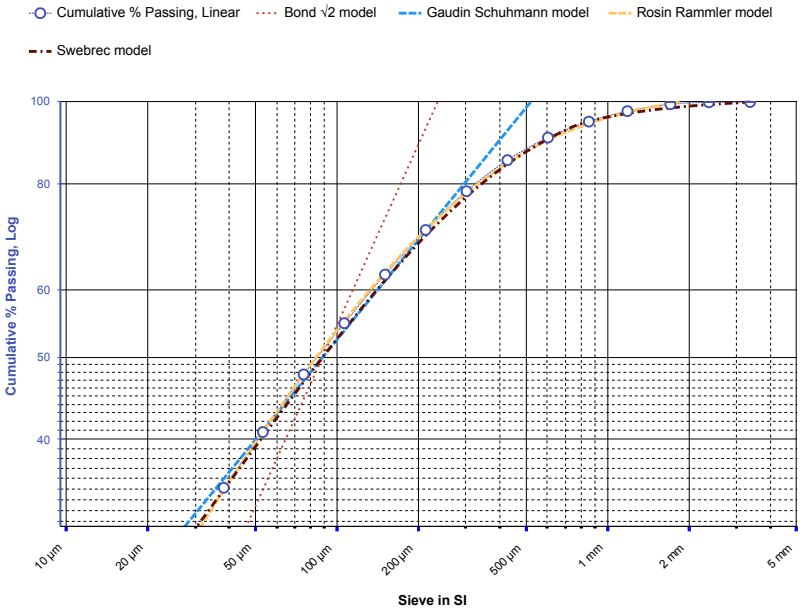
$$\%\text{Retained} = \exp\left[-\left(\frac{x}{152}\right)^{0.612}\right]$$
$$R^2 = 1$$

Swebrec model

80% = 338.82 µm

$$\% \text{ Passing} = \frac{1}{1+\left(\frac{\ln(3350/x)}{\ln(3350/88)}\right)^{2.996}}$$
$$R^2 = 1$$

Box 501 product (transfer size)



Size, µm	%passing
324	80.0%
193	68.0%
75	47.8%

Model

Nearest neighbours model

80% = 7.43 mm

Bond √2 model

80% = 4.17 mm

$$\% \text{ Passing} = 0.5 \times \left(\frac{x}{2147}\right)^{\left(\frac{1}{\sqrt{2}}\right)}$$

Gaudin Schuhmann model

80% = 6.19 mm

$$\% \text{ Passing} = \left(\frac{x}{10227}\right)^{0.444}$$
$$R^2 = 0.99$$

Rosin Rammler model

80% = 8.03 mm

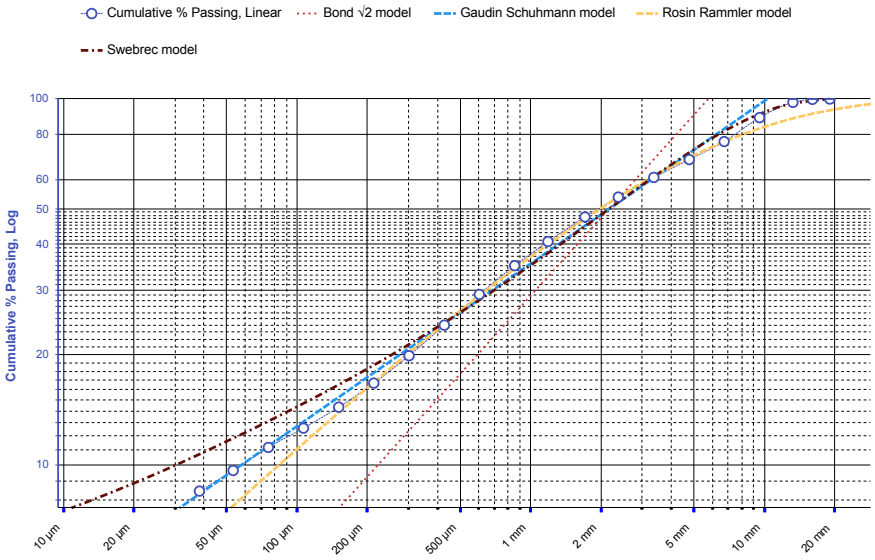
$$\%\text{Retained} = \exp\left[-\left(\frac{x}{3614}\right)^{0.596}\right]$$
$$R^2 = 1$$

Swebrec model

80% = 6.33 mm

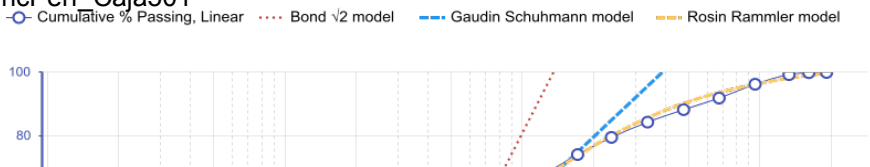
$$\% \text{ Passing} = \frac{1}{1+\left(\frac{\ln(19000/x)}{\ln(19000/2147)}\right)^{2.025}}$$
$$R^2 = 0.99$$

Primary BM Feed



Size, µm	%passing
324	20.8%
193	16.1%

Primary BM product



Model

Nearest neighbours model

80% = 2.44 mm

Bond √2 model

80% = 979.99 µm

$$\% \text{ Passing} = 0.5 \times \left(\frac{x}{504}\right)^{\left(\frac{1}{\sqrt{2}}\right)}$$

Gaudin Schuhmann model

80% = 2 mm

$$\% \text{ Passing} = \left(\frac{x}{3857}\right)^{0.341}$$
$$R^2 = 0.98$$

Rosin Rammler model

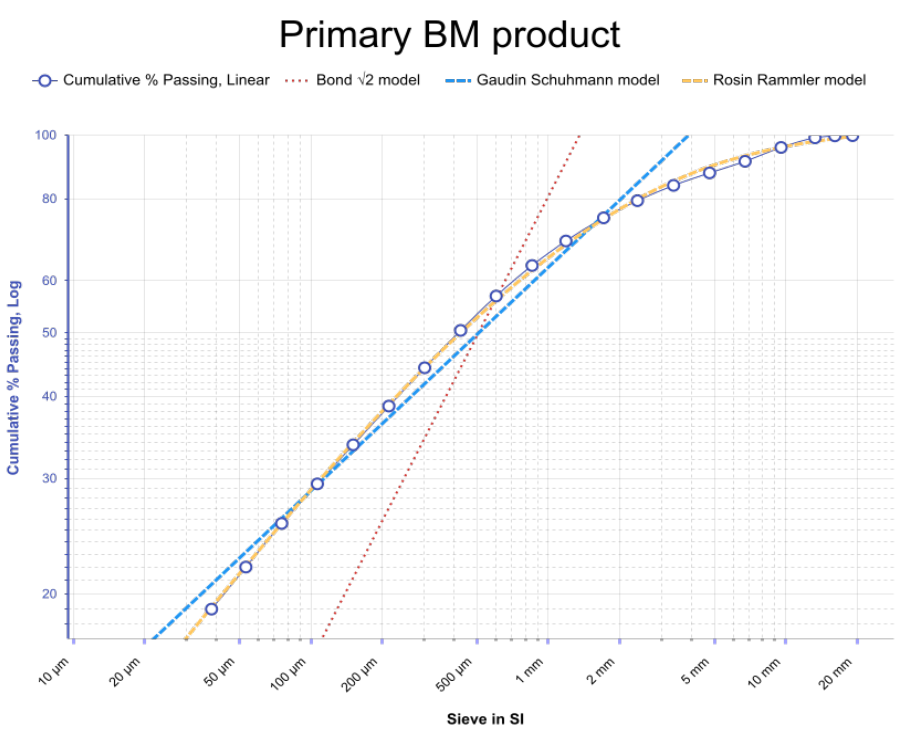
80% = 2.35 mm

$$\%\text{Retained} = \exp\left[-\left(\frac{x}{891}\right)^{0.491}\right]$$
$$R^2 = 1$$

Swebrec model

80% = 2.78 mm

$$\% \text{ Passing} = \frac{1}{1+\left(\frac{\ln(16000/x)}{\ln(16000/504)}\right)^{2.038}}$$
$$R^2 = 0.97$$



Size, µm	%passing
324	45.6%
193	37.3%

CALCULATION COVER SHEET **Date:** 2026-02-03

Author: Alex Doll **Revision** 1

Project: MetPlant 2026 **Calc No:**

Title: Functional Performance calculation for ball mill circuit

Tanami survey of 2025-08-16, Secondary ball mill, Box 501 as transfer size

Purpose:

Calculate the functional performance efficiency of a ball mill circuit using the method of McIvor (Metcom technology technique adapted by Alex Doll).

Basis / Assumptions:

Conduct a grinding circuit survey where the ball mill feed stream (cyclone underflow) and ball mill discharge stream are sampled and the particle size distribution (PSD) is computed. Use this to determine the hydrocyclone efficiency by measuring the proportion of "product" (the desired flotation feed size) that exists in the ball mill feed stream.

Compute the amount of "product" created in the ball mill by comparing the proportion of that size class in the mill feed and discharge, then multiply by the mass flow rate to determine the t/h of "product" created in the mill.

Use the ball power measurement, corrected to the mill shell or pinion, to compute the amount of power consumed to make the "product". (Optional) If a Bond ball mill laboratory grindability test has been conducted, then a benchmark comparison using the Bond test versus the industrial mill may be conducted.

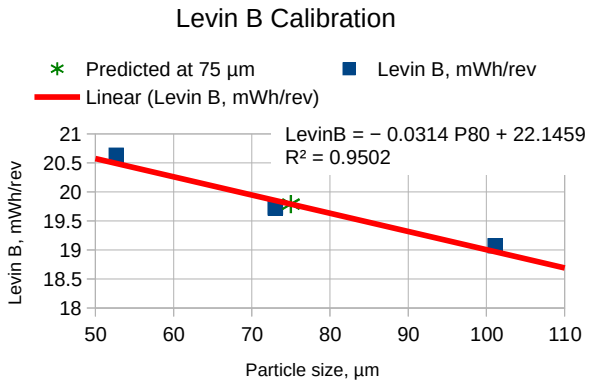
Desired "product" size:	**75** µm
Particle size distribution of mill feed, see calculation:	**attached**
Measured BM discharge percent solids	
Measured cyclone u/f percent solids	

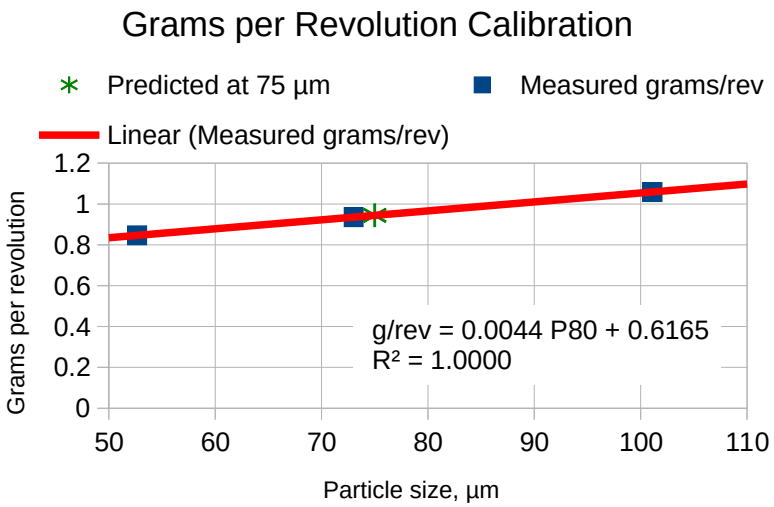
Method: A survey of the secondary mill was conducted on 2025-08-16. Particle size distributions were determined for the mill feed and the mill product.

	Measured	Balanced	
Fraction of box 501 passing 75 µm:	47.8%	47.8%	w/w
Fraction of mill feed passing 75 µm:	20.6%	20.6%	w/w
Fraction of mill discharge passing 75 µm:	34.8%	34.8%	w/w
Fraction of cyclone OF passing 75 µm:	80.0%	80.0%	w/w
Circuit classification system efficiency (CSE):	72.3%	72.3%	
Comment:		**good (target >70%)**	
Mill circuit feed rate, equiv. dry solids		406	tonnes/h

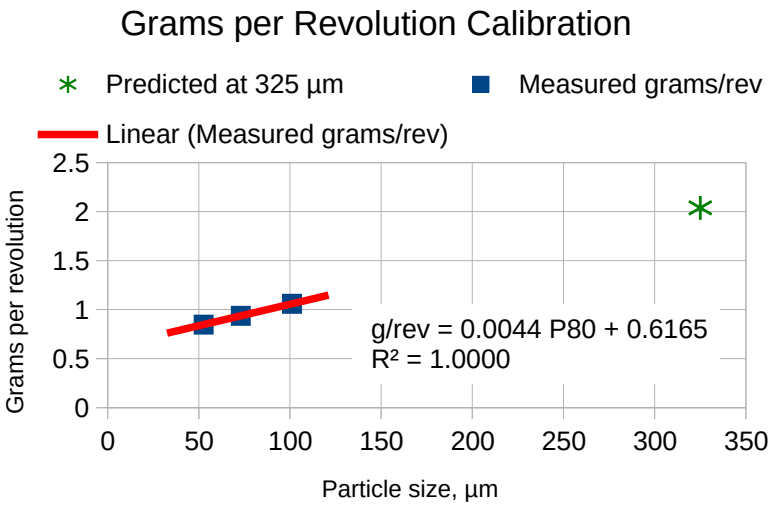
	Measured	Balanced	
Ball mill feed rate, equiv. dry solids	922	922	tonnes/h
Cyclone feed rate, equiv dry solids			
Circulating load	227%	227%	
Ball mill motor power, at DCS		**2,342**	kW
Electromechanical efficiency		**93.14%**	
Ball mill power at mill shell		2,181	kW

	A	B	C	D	E	F	G	H	I
1	**CALCULATION COVER SHEET**				**Date:**	2026-02-03			
2					**Author:**	Alex Doll		**Revision**	1
3	**Project:**	MetPlant 2026			**Calc No:**				
4	**Title:**	Functional Performance calculation for ball mill circuit							
5		**Tanami survey of 2025-08-16, Secondary ball mill, Box 501 as transfer size**							
49		specific energy consumption, BM circuit					5.38	kWh/t	
50		Fines in the circuit feed (primary mill product)					193.76	t/h	
51		Fines generation, new product creation rate					130.51	t/h	
52		Mill grinding rate, new fines per kW of power consumed					0.083	fines t/h per eff kW	
53		Laboratory BM test g/rev for 75 µm P_{80} test					1.75	grams/revolution	
54		Laboratory BM new fines per kW of power consumed					0.089	fines t/h per eff kW	
55		BM grinding efficiency					93%		
56									
57	**Results:**	The amount of oversize material in the cyclone overflow					81	t/h	
58							81	t/h (measured)	
59									
60		The classification efficiency of this system is good compared to the surveys							
61		published by McIvor (>70% expected).							
62									
63		Grinding efficiency is very good when the g/rev is corrected to account for the							
64		difference between a Bond ball mill test feed F_{80} size (2300 µm) and the Box 501							
65		size (325 µm).							
66									
67									
68	**Conclusions & Recommendations:**								
69									
70		The secondary circuit is operating at very high efficiency.							
71									
72									
73									
74									
75									
76	**Addendum**, Bond mill power consumption from Josephin & Doll, Procemin 2018								
77	using method of Levin, 1989								
78									
79									
80									
81									
82									
83									
84									
85									
86									
87									
88									
89									
90									
91	Use laboratory grinding rate (Levin “B”) value of						19.75	mWh/rev	





Curve for 75 µm P_{80}



Curve for 325 µm P_{80}

The Bond ball mill test grams per revolution measurement is based on a "standard" particle size distribution with F_{80} around 2.3 mm. The secondary ball mill feed F_{80} is only 325 µm, so the Bond test g/rev need to be adjusted to remove the number of lab mill revolutions required to achieve a K_{80} of 325 µm. Take one-over the g/rev to get revolutions per gram to a particular product size. These revolutions should be additive, so the mill revolutions to get 75 µm, minus the revolutions to get 325 µm should give the equiv revolutions to go from 325 µm to 75 µm in a laboratory Bond ball mill.

	Feed F_{80}	Product P_{80}	grams/rev	rev/gram
regular Bond F_{80} size to 325	2300	325	2.04 →	0.49
regular Bond F_{80} size to 75	2300	75	0.94 →	1.06
synthetic 325 µm to 75 µm	325	75	**1.75** ←	0.57

Model

Nearest neighbours model

80% = 75.03 µm

Bond √2 model

80% = 48.96 µm

$\% \text{ Passing} = 0.5 \times \left(\frac{x}{25}\right)^{\left(\frac{1}{\sqrt{2}}\right)}$

Gaudin Schuhmann model

80% = 74.77 µm

$\% \text{ Passing} = \left(\frac{x}{125}\right)^{0.432}$
$R^2 = 1$

Rosin Rammler model

80% = 75.63 µm

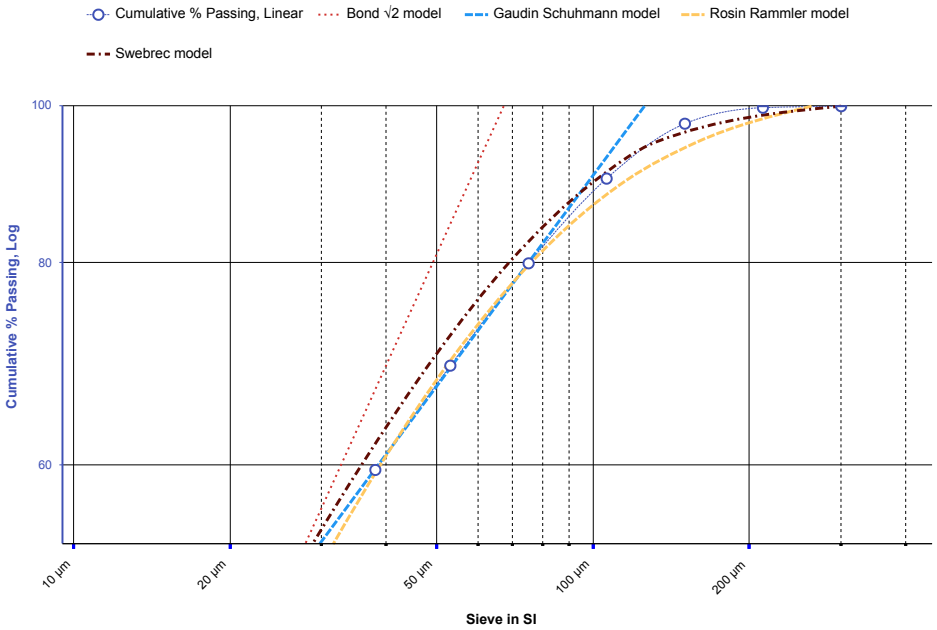
$\%\text{Retained} = \exp\left[-\left(\frac{x}{43}\right)^{0.843}\right]$
$R^2 = 1$

Swebrec model

80% = 68.57 µm

$\% \text{ Passing} = \frac{1}{1+\left(\frac{\ln(300/x)}{\ln(300/25)}\right)^{2.676}}$
$R^2 = 1$

Secondary Cyclone Overflow



Size, µm	%passing
75	80.0%

Model

Nearest neighbours model

80% = 400.33 µm

Bond √2 model

80% = 410.4 µm

$\% \text{ Passing} = 0.5 \times \left(\frac{x}{211}\right)^{\left(\frac{1}{\sqrt{2}}\right)}$

Gaudin Schuhmann model

80% = 375.37 µm

$\% \text{ Passing} = \left(\frac{x}{493}\right)^{0.817}$
$R^2 = 0.99$

Rosin Rammler model

80% = 406.84 µm

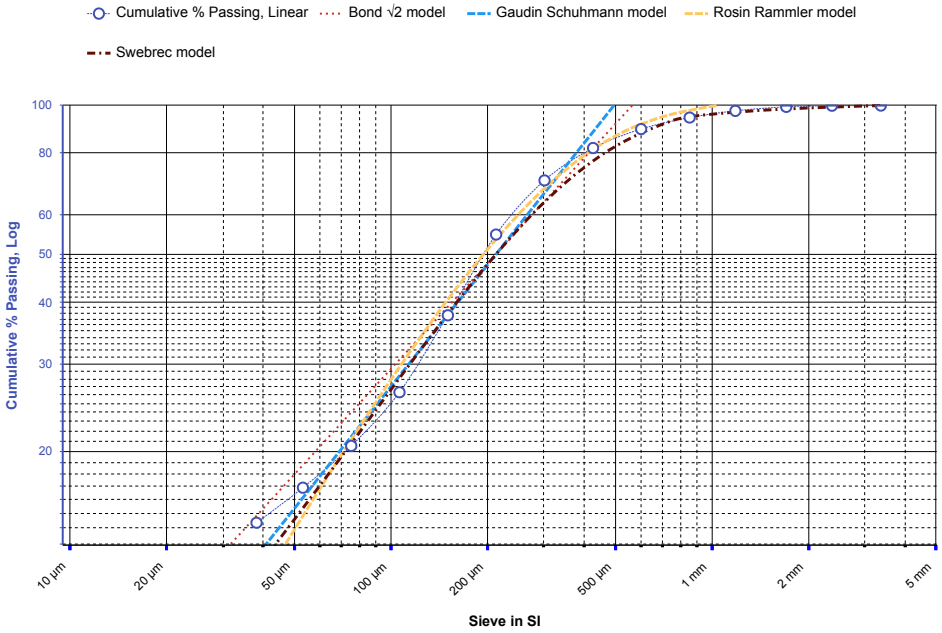
$\%\text{Retained} = \exp\left[-\left(\frac{x}{267}\right)^{1.13}\right]$
$R^2 = 0.99$

Swebrec model

80% = 459 µm

$\% \text{ Passing} = \frac{1}{1+\left(\frac{\ln(3350/x)}{\ln(3350/211)}\right)^{4.203}}$
$R^2 = 0.99$

Secondary BM Feed



Size, µm	%passing
75	20.6%

Nearest neighbours model

80% = 299.38 µm

Bond √2 model

80% = 259.7 µm

$$\% \text{ Passing} = 0.5 \times \left(\frac{x}{134}\right)^{\left(\frac{1}{\sqrt{2}}\right)}$$

Gaudin Schuhmann model

80% = 302.12 µm

$$\% \text{ Passing} = \left(\frac{x}{445}\right)^{0.576}$$
$$R^2 = 0.99$$

Rosin Rammler model

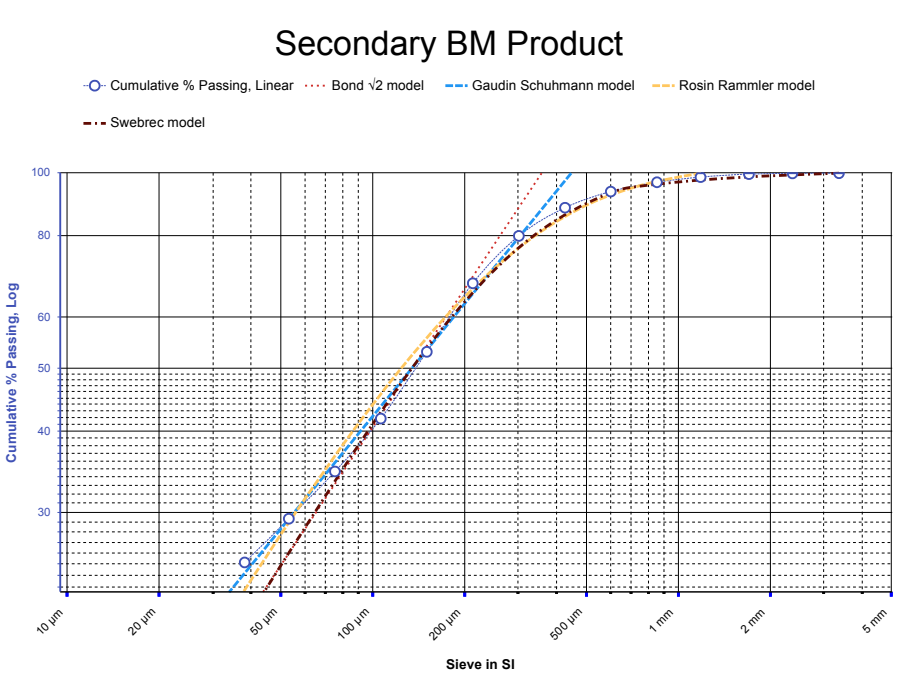
80% = 337.33 µm

$$\%\text{Retained} = \exp\left[-\left(\frac{x}{191}\right)^{0.836}\right]$$
$$R^2 = 0.98$$

Swebrec model

80% = 334.19 µm

$$\% \text{ Passing} = \frac{1}{1+\left(\frac{\ln(3350/x)}{\ln(3350/134)}\right)^{4.14}}$$
$$R^2 = 0.99$$



Size, µm	%passing
75	34.8%