Report to:

PACIFIC BOOKER MINERALS INC.

Morrison Project
HPGR Trade-off Study

Document No. 0652720100-REP-R0004-02

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MORRISON PROJECT
HPGR TRADE-OFF STUDY

MAY 2008

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REVISION HISTORY

REV. NO	ISSUE DATE	PREPARED BY AND DATE	REVIEWED BY AND DATE	APPROVED BY AND DATE	DESCRIPTION OF REVISION
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01	Dec. 21, 07	R.A. Dec. 21, 07	H.G./J.A. Dec. 21, 07	D.S. Dec. 21, 07	Final report to client.
02	May 12, 08	R.A. May 12, 08	H.G. May 12, 08	D.S. May 12, 08	Final report to client revised.

EXECUTIVE SUMMARY

The Morrison porphyry copper/gold deposit is located in Central British Columbia, 35 km north of the village of Granisle. The deposit will be mined by open pit methods, with a 30,000 tonne per day (**t/d**) or 10.95 millions tonnes per year (**Mt/a**) mineral processing plant for production of copper and molybdenum concentrates. The measured/indicated mineral resource is 206,869,000 tonnes (**t**) grading 0.46% Cu equivalent. This consists of 0.39% Cu, 0.20g/t Au, and 0.005% Mo.

This report is a trade-off study to evaluate the application of High Pressure Grinding Rolls (**HPGR**) as an alternative technology to the conventional semi-autogenous grinding (**SAG**) milling process for the Morrison Project.

The processing plant is designed to operate at 30,000 t/d capacity with an availability of 92%.

Results of the trade-off study indicate that the application of HPGR's to the Morrison project would result in significant operational cost savings in the comminution circuit amounting to more than 23%. The accuracy of the trade-off study estimate is in the range ±25% and all costs recorded are in Canadian (**CDN**) currency.

This trade-off study indicates that the introduction of the HPGR as a replacement for the conventional SAG milling process offers significant benefits. It is recommended that a detailed feasibility study be carried out using HPGR in the comminution circuit.

With the HPGR in place of the SAG mill, the power requirements of combined crushing-grinding circuits indicates a gross installed power reduction for the HPGR option of 3.67 megawatts (**MW**). The resulting power savings translates into an operating cost savings of CDN$0.08/t. The savings in power costs is based upon a power unit cost of CDN$0.032/kWh. For consumables, this reduction was estimated to be about CDN$0.59/t. With respect to capital cost, the HPGR option is CDN$9.45 million (**M**) more than the SAG option; however, within the accuracy level of the study, the capital costs for both options can be considered to be similar.

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1.0 INTRODUCTION

Wardrop Engineering Inc. (**Wardrop**) was requested by Pacific Booker Minerals Inc. (**Pacific Booker**) to prepare an order of magnitude trade-off study to evaluate the application of HPGR as an alternative technology to the conventional SAG milling technology for the Morrison Project.

2.0 BACKGROUND

HPGR have been in operation for some time and were originally developed and applied in the cement industry. The technology was introduced into the mining industry in the early 1980s, with the first HPGRs used for the crushing of kimberlite in diamond mines. The application and advantages of using these grinding roles to extract diamonds is well established. HPGR technology was also successfully introduced and applied in the iron ore industry and for the crushing of limestone.

The HPGR consists of a pair of counter rotating rolls, one fixed and the other floating. The feed is introduced to the gap in between the rolls and is crushed by the mechanism of inter-particle breakage. The grinding force applied to the crushing zone is controlled by a hydro-pneumatic spring on the floating roll. Speeds of the rolls are also adjustable to obtain optimum grinding conditions.

There are several benefits to using HPGRs in the mining industry. The benefits are significant when considering HPGRs as a replacement to SAG mills, mainly because of the following:

- large savings in energy costs
- reduced grinding media consumption and operating costs
- faster equipment delivery schedules
- produces a finer product.

While the benefits of HPGR crushing in terms of lower energy costs and superior interparticle crushing are well known, the mining industry was reluctant to embrace this technology due to the problems of high wear. Over the past few years, major advances have been made in wear protection technologies. These advances have been applied to the roll surfaces, which have reduced wear significantly, thereby making this technology more attractive for hard rock mining applications.

The main HPGR manufacturers are Polysius Corporation (Polysius), KHD Humboldt Wedag (KHD), and Koppern Machinery Australia Pty Ltd. (Koppern), all from Germany. Polysius favours a high aspect ratio design (large diameter, small width), while KHD and Koppern prefer a low aspect ratio. The high aspect ratio design provides for a larger operating gap and reduced wear. Koppern's machine, when compared to Polysius and KHD, is smaller with a maximum roll diameter restriction of 1.5 m due to manufacturing constraints and surface wear. All these companies have independently spent considerable time and resources to reduce wear. They have now come up with superior rolls, which include the use of studs, segments, edge protection inserts, and advanced materials of construction.

Mining companies are now beginning to incorporate HPGR technology. Freeport is a mining company that has taken the lead in introducing the HPGR at the Cerro Verde copper mine in Peru. The circuit at Cerro Verde incorporates four HPGR units (2.4 m diameter x 1.7 m wide; 5,000 kW) processing 2,500 tonnes per hour (**t/h**) instead of traditional SAG mill circuit.

In July 2007, Wardrop visited the Cerro Verde mine in Peru and feedback from plant personnel indicated that the HPGRs are performing well and met the specifications.

The Adanac Ruby Creek molybdenum project in Canada as well as Boddingtons and Bendigo gold projects in Australia, which are all nearing completion, have also included HPGR technology. Freeport McMoran uses two HPGR units (2.0 m diameter x 1.8 m wide; 3,600 kW) to process 1,450 t/h at their Grasberg Mine in Irian Jaya, Indonesia.

3.0 TESTWORK

SGS Mineral Services conducted grinding testwork for the Feasibility Study on 82 drill core samples from the Morrison deposit, in order to conduct CEET design study for a comminution circuit in August 2007. The results of the tests are shown in Table 3.1 below.

Table 3.1 Grinding Test Results

	Crusher Index	SPI (minutes)	BWi (kWh/t)
Samples Average	13.7	105.2	16.4

The results show the ore has an average a Crusher Index of 13.7, SAG Power Index (**SPI**) of 105 minutes and Ball Bond Work Index (**BWi**) of 16.4. Results from the testwork indicate that the material sample has a medium hardness from the perspective of semi-autogenous milling.

SGS Mineral Services testwork details are presented in "Ore Grindability Characterization and Feasibility Grinding Circuit Design for Morrison Project, Project 11474-001 Interim Report, August 2007" as part of the feasibility study.

3.1 HPGR TESTWORK

Discussions were held with all HPGR manufacturers and, in September 2007, Polysius Research Centre in Germany was contracted by Pacific Booker to conduct testwork on high pressure comminution. The results show that the specific energy is 2.0 kWh/t with a specific throughput of 220 ts/hm^3.

For the purposes of the Feasibility study, the Polysius 24/17 HPGR model was determined for the circuit. This machine is capable of processing 30,000 t/d and is currently in operation at Cerro Verde.

It is assumed that the HPGR will produce a product with a P_{80} of 3.8 mm.

For more details on the HPGR, see the report by Polysius entitled "High-Pressure Grinding Tests on Copper/Gold/Molybdenum Ore from the Morrison Project – British Columbia, Canada", attached as Appendix E.

4.0 COMMINUTION CIRCUITS

A brief description of the SAG and HPGR circuits is given below. As part of the evaluation, it was decided to focus the trade-off study on replacing the conventional SAG mill in the comminution circuit with an equivalent duty HPGR unit. Other potential circuit configurations utilizing HPGR were not considered in the study.

4.1 ASSUMPTIONS

The following assumptions have been made in this trade-off study:

• Plant feed rate, Mt/a	10.95
• Plant feed rate, t/h	1,359
• Plant availability/running time, %	92
• Product P_{80} (Flotation feed), µm	150
• Budget quotations accuracy, ± %	25
• Power cost, per kWh	CDN$0.032

Detailed process design criteria for both SAG and HPGR options are included in Appendix A.

4.1.1 SAG CIRCUIT

To produce an average 1,359 t/h at a P_{80} of 150 µm, the conventional circuit is comprised of:

- a single SAG mill of 10.36 m diameter and 5.79 m length, which uses a maximum of 10,400 kW
- two ball mills of 6.10 m diameter and 10.21 m length, which uses a maximum of 6,700 kW each
- a 315 kW cone crusher.

The front end of the circuit is comprised of run-of-mine material feeding directly into a gyratory crusher. The product from the crusher feeds the 30,000 t live capacity crushed ore stockpile. Apron feeders are used to feed the conveyors, which transport the crushed material to one SAG mill. The product from the SAG mill feeds the SAG mill screen, with the screen undersize reporting to a ball mill and the oversize going to a pebble crusher. The crushed product is returned to the SAG mill.

The SAG ball mill circuit flowsheet including material balance is given in Appendix A.

4.1.2 HPGR Circuit

The simplified HPGR crushing circuit is shown in the flowsheet entitled "HPGR Option Trade-off Study". From the stockpile, apron feeders will transport the ore to a double-deck screen with the oversize feeding a cone crusher and undersize material reporting to the HPGR surge bin. The crushed material is returned as feed to a second set of double-deck screens. The HPGR unit will be fed from the surge bin using belt feeders. The HPGR product will be screened with oversize returned to the HPGR feed surge bin. Screen undersize from the screen will be fed to the ball mill pump boxes, as shown in Flowsheet No. 3. The ball mills pump box feeds two sets of cyclones for classification with cyclone product reporting as flotation feed material.

The HPGR circuit flowsheets including material balance are available in Appendix A.

Table 4.1 Plant Data

Plant Concept	SAG Circuit	HPGR Circuit
Equipment	1 SAG Mill (10.36 x 5.79 m) 10.4 MW	1 Secondary Crusher 750 kW
	1 Pebble crusher 315 kW	1 HPGR 5.3 MW
	2 Ball Mills (6.1 m x 10.2 m) 6.7 MW each	2 Ball Mills (6.1 m x 10.2 m) 6.7 MW each (installed-actual consumption 10% less)
	Screens, conveyors 0.5 MW	Screens and Conveyors 1.5 MW
Total Drive Capacity Installed	24.62 MW	20.95 MW

Appendix B shows the general layout for both options.

5.0 CAPITAL AND OPERATING COST COMPARISON

Operating costs were determined for both HPGR and SAG options. Details are shown in Appendix C.

Both the HPGR and SAG circuit capital costs are based on budget estimates received from suppliers. A detailed capital cost summary is included in Appendix D.

Estimates for maintenance and consumables costs for each of the options are based on information received from suppliers on similar projects. An estimate for savings in the shipment of mill balls resulting from the replacement of SAG with HPGR is also included.

The cost of power is CDN$0.032/kWh.

Table 5.1 compares the capital and operating costs of an HPGR circuit versus a conventional SAG milling circuit.

This Trade-off Study was based on plant operation with electrical power only. The accuracy of this estimate is in the range ±25%.

The HPGR option, with respect to capital cost, can be considered to be the same as the SAG option within the accuracy level of this study.

The HPGR option indicates significant savings in total operational costs amounting to CDN$0.67/t annually when compared to the SAG mill option.

The detailed operating and capital cost estimates are presented in Appendix C and Appendix D, respectively.

Table 5.1 Capital and Operating Cost Analysis

	SAG				HPGR			
			Operating Cost ($/t)				Operating Cost ($/t)	
	Capital Cost ($)	Power (MW)	Energy	Supplies/Maintenance/Labour	Capital Cost ($)	Power (MW)	Energy	Supplies/Maintenance/Labour
OPERATING COST SUMMARY								
Labour				0.239				0.252
Supplies				2.100				1.498
Power		22.24	0.52			17.91	0.44	
CAPITAL COST SUMMARY								
Direct Costs								
Reclaim Conveyor	592,000				987,000			
Secondary/Tertiary Crushing Equipment (comprised of Cone Crusher, HPGR Crusher, Vibrating Screens - Primary and Secondary, Transfer Conveyors, Steel chutes and bins)	-				23,877,000			
Secondary/Tertiary Crushing Building	-				6,532,000			
Grinding Equipment, comprised of:								
• **HPGR OPTION:** 2 Ball Mills, Pumps, Cyclopacks					23,225,000			
• **SAG OPTION:** SAG Mill, 2 Ball Mills, Pumps, Cyclopac	46,855,000							
Girnding Building	14,789,000				14,221,000			
Total Indirect Costs	20,345,000				21,957,000			
Contingency (15% of Direct costs)	12,387,000				13,620,000			
TOTAL	**$94,968,000**	**22.24**	**0.52**	**2.340**	**$ 104,419,000**	**17.91**	**0.44**	**1.750**
TOTAL - OPERATING COST ($/t)				**2.86**				**2.19**

	HPGR Vs SAG	HPGR Vs SAG	Overall Savings
Power Savings	15.38%	0.08 $/t	$0.88 Million per year
Consumables Savings	25.21%	0.59 $/t	$6.46 Million per year
Total Operating Savings	**23.43%**	**0.67 $/t**	**$7.34 Million per year**
Total Capital Savings	**-9.83%**	**-$-9,451,000**	**-$9.45 Million**

Data	
Throughput Rate (t/a)	10,950,000
Throughput Rate (t/h)	1,359
Availability SAG (%)	92
Availability HPGR (%)	96

Assumption Power Cost
CDN$/kwh **0.032**

ALL FIGURES SHOWN IN CDN$

Details:

SAG Mills:	include 1 mill plus pebble, screens, general spares
SAG Circuit: Ball Mills:	include 2 mill plus general spares
HPGR Unit:	include 1 unit plus general spares
HPGR Circuit – Ball Mills:	include 2 mill plus general spares
HPGR Screens:	include 2 units plus spares
HPGR Circuit – Cone Crusher	includes 1 units plus general spares
HPGR Circuit – Conveyors, etc.	includes conveyors, surge bins and dust collection system

6.0 COMMENTS

Economically, the HPGR circuit option has been determined to be very favourable.

The capital cost increase for the HPGR option has been calculated to be about CDN 10 million compared with that for an equivalently sized SAG mill circuit.

The total operating cost savings due to the introduction of the HPGR versus the SAG option is about CDN 7.34 million per year.

The size of the Morrison Project operation at 10.95 Mt/a throughput rate has resulted in the recommendation that one SAG mill or one HPGR unit be considered for installation in the proposed comminution circuit, each option followed by ball milling. Based on the obtained trade-off study results and HPGR pilot testing, the following objectives were achieved:

- determination of energy requirements
- optimization of the HPGR operating variables
- sizing the HPGR for industrial scale
- determination of wear rate
- determination of HPGR impact on ball mill unit energy consumption.

The power savings offered by HPGR technology, especially for high tonnage applications and even in situations where power is relatively cheap, is one of the primary reasons for this HPGR technology being selected for new projects of this nature. Additional factors include the rapidly developing familiarity and reliability of HPGR technology, the reduced footprint required, reduced associated operating costs, and in some cases, a finer product grind size.

7.0 CONCLUSIONS

A trade-off study has been conducted comparing the capital and operating costs of using HPGR technology and the SAG milling option in the communication circuit for the Morrison porphyry copper/gold project. A significant savings in operating costs indicates that it is favourable to use the HPGR option when compared with the more conventional SAG milling option. In addition, the HPGR option can provide increased revenue due to the increased availability and plant capacity.

Based on the results of this evaluation, it is recommended that the HPGR option be used in the detailed engineering stage.

APPENDIX A

PROCESS DESIGN CRITERIA AND FLOWSHEETS

WARDROP

PROCESS DESIGN CRITERIA - HPGR

PROJECT: Pacific Booker
CLIENT: Morrison Porphyry Copp
PROJECT NUMBER: 06527201.00
DATE: 7-Dec-07
REV: D - WORKING COPY

All values are in metric units.

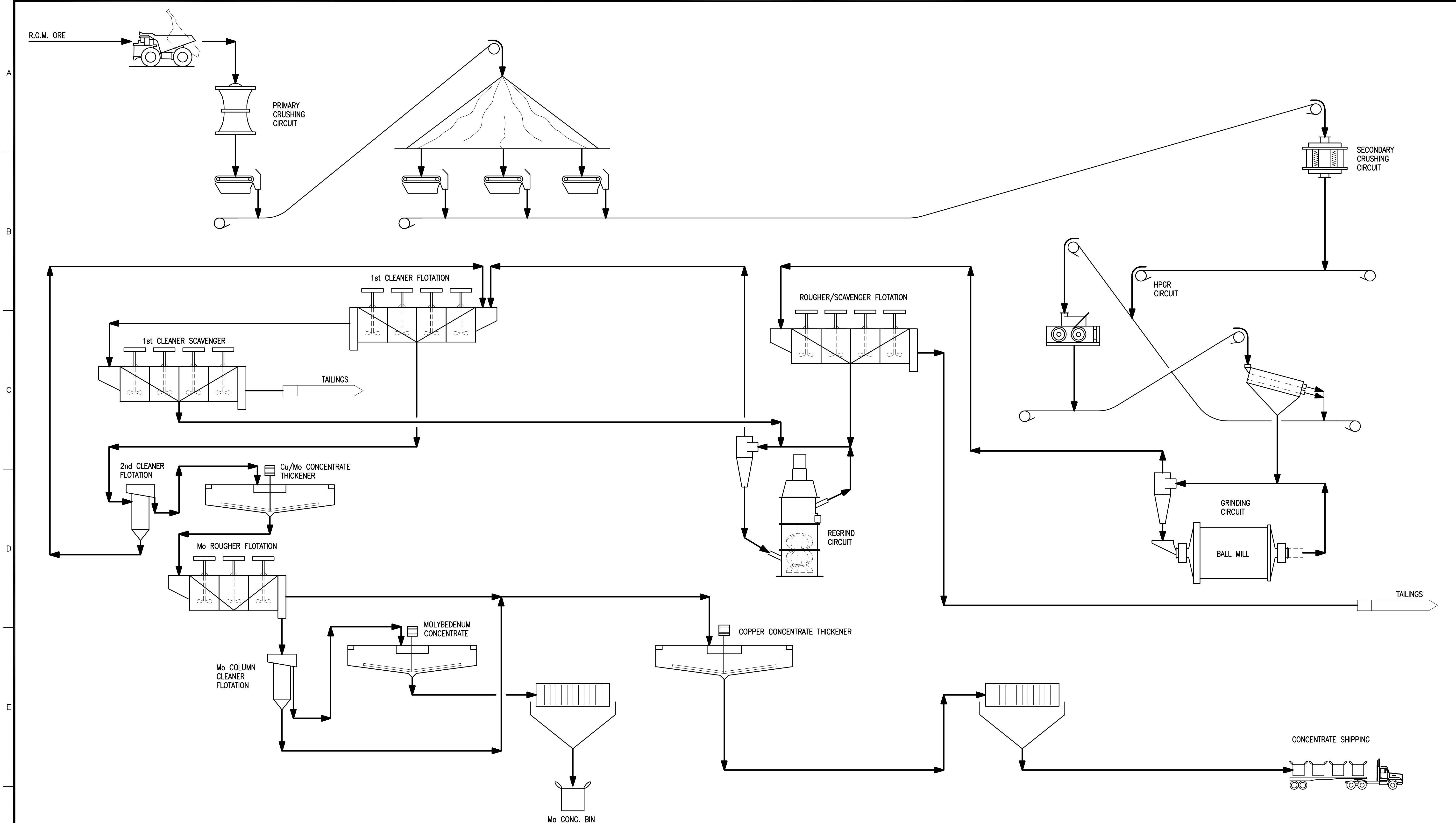
CODES

1 Client
2 Industry / Experience
3 Calculation
4 Mass Balance
5 PRA Met Lab
6 SGS Met Lab
7 Beacon Hill Consultants
8 Suppliers
9 Others

DESCRIPTION	UNIT	VALUE	SOURCES
GENERAL			
Type Of Deposit		Porphyry Copper Gold Ore	
Ore Characteristics			
Specific Gravity	g/cm^3	2.7	6
Bulk Density	t/m^3	1.6	2
Moisture Content	%	3.0	1
Abrasion Index (Average)	g	0.320	6
Operating Schedule			
Shift/Day		2	1
Crusher Plant Hours/Shift	h	8	1
Crusher Plant Hours/Day	h	16	1
Grinding and Flotation Hours/Shift	h	12	1
Grinding and Flotation Hours/Day	h	24	1
Days/Year	days	365	1
Plant Availability/Utilization			
Overall Plant Feed	t/y	10,950,000	2,1
Overall Plant Feed	t/d	30,000	1
Crushing Plant Availability	%	75.0	2
HPGR Availability	%	95.0	
Grinding and Flotation Plant Availability	%	92.0	2
Crushing Rate	t/h	2,500.0	3
HPGR Rate		1,315.8	
Grinding Rate	t/h	1,358.7	3
Flotation Rate	t/h	1,358.7	3
Head Grades	% Cu	0.40	6
	% Mo	0.006	6
	g/t Au	0.19	6
	g/t Ag	1.60	6
Recovery:	Cu %	84.00	5,6
	Mo %	78.00	5,6
	Au %	56.00	5,6
	Ag %	56.00	5,6

DESCRIPTION	UNIT	VALUE	SOURCES
Cu Concentrate Grade	% Cu	26.50	5,6
	% Mo	0.37	5,6
	g/t Au	9.00	5,6
	g/t Ag	75.00	5,6
Mo Concentrate Grade	% Cu	0.83	5,6
	% Mo	53.60	5,6
Cu Concentrate Mass Recovery	%	1.27	3
Mo Concentrate Mass Recovery	%	0.009	3
Cu Concentrate Production	t/y	138,838	3
Mo Concentrate Production	t/y	956	4
CRUSHING			
Primary Crushing Production Parameters			
Feed Particle Size	mm	1,500	2
Crusher Type	type	Gyratory	2
Number of Crushers		1	3
Crushing Rate	t/h	2,500.0	4
Product Size, P_{80}	mm	150	2
Liner Wear Rate	kg/kW·h	0.022	3
Crushed Ore Stockpile Parameters			
Crushed Ore Stockpile (Live Capacity)	t	30,000	2
Crushed Ore Bulk Density	t/m^3	1.6	2
Angle of Repose	degrees	37	2
Angle of Reclaim	degrees	60	2
No of Feeders		3	3
Average Tonnage Rate (Each), Operating	t/h	453	4
Type of Discharge Feeders	type	Apron	2
SECONDARY CRUSHING & SCREENING			
Crusher Type		Cone	
Number of Crushers		1	
Operating Shifts/Day		2	
Operating Hours/Shift		12	
Secondary Crushing and Screening Availability	%	75	
Processing Rate	mtph	1,019.0	
Product Size, P80	mm	45.0	
No of Dishcharge Feeders		1	
Type of Discharge Feeders		Conveyor	
Crushed Ore Bulk Density	t/m^3	1.6	
Screen Type	double deck	Vibratory/Dry	
Number of Screens		2	
Processing Rate		2,377.7	
Screen Appertures	mm	75 and 45	
TERTIARY CRUSHING			
Crusher Type		HPGR	
Number of Units		1	
Tertiary Crushing Plant Availability	%	95	
Processing Rate (Fresh Feed)	t/h	1,315.8	
Type of Feeders		Belt Feeder	

DESCRIPTION	UNIT	VALUE	SOURCES
Number of Feeders		1	
Specific Energy Consumption	kWh/t	2.0	
Average Specific Throughput	ts/hm^3	220	
Feed Size, 80% Passing	mm	45.0	
Product Size, 80% Passing	mm	6.0	
Screen Type	double deck	Vibratory/Wet	
Number of Screens		2	
Screen Availability	%	95	
Processing Rate		1,834.2	
Screen Appertures	mm	20 and 6	
GRINDING			
Mill Type		Ball mill	2
Number of Mills		2	3
Processing Rate	t/h	1,358.7	4
Bond Ball Mill Work Index	kWh/t	16.1	6
Feed Solids	%w/w	72.0	2
Abrasion Index, Ai		0.320	6
Liner Wear Rate	kg/kW·h	0.008	3
Feed Size, P_{80}	mm	6.0	6
Product Size, P_{80}	µm	150	1, 5
Mill Speed	% CS	72	2
Ball Mill Charge	%	35	
Recirculation Load	%	300	2
Classification	type	Cyclones	



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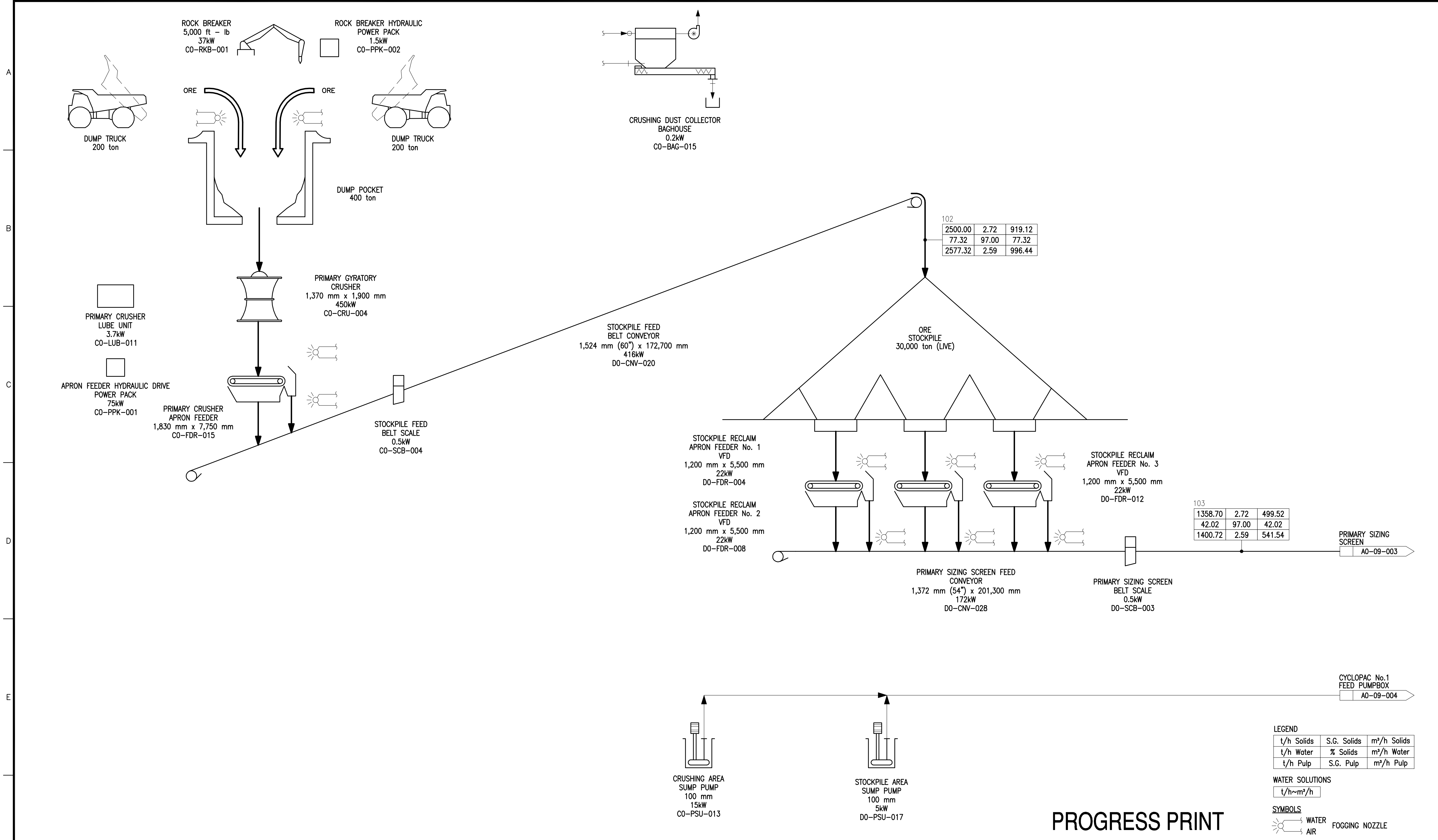

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Stream 103

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LEGEND

t/h Solids	S.G. Solids	m³/h Solids
t/h Water	% Solids	m³/h Water
t/h Pulp	S.G. Pulp	m³/h Pulp

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PACIFIC BOOKER MINERALS INC.

WARDROP Engineering Inc.

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PRIMARY CRUSHER
STOCKPILE & RECLAIM
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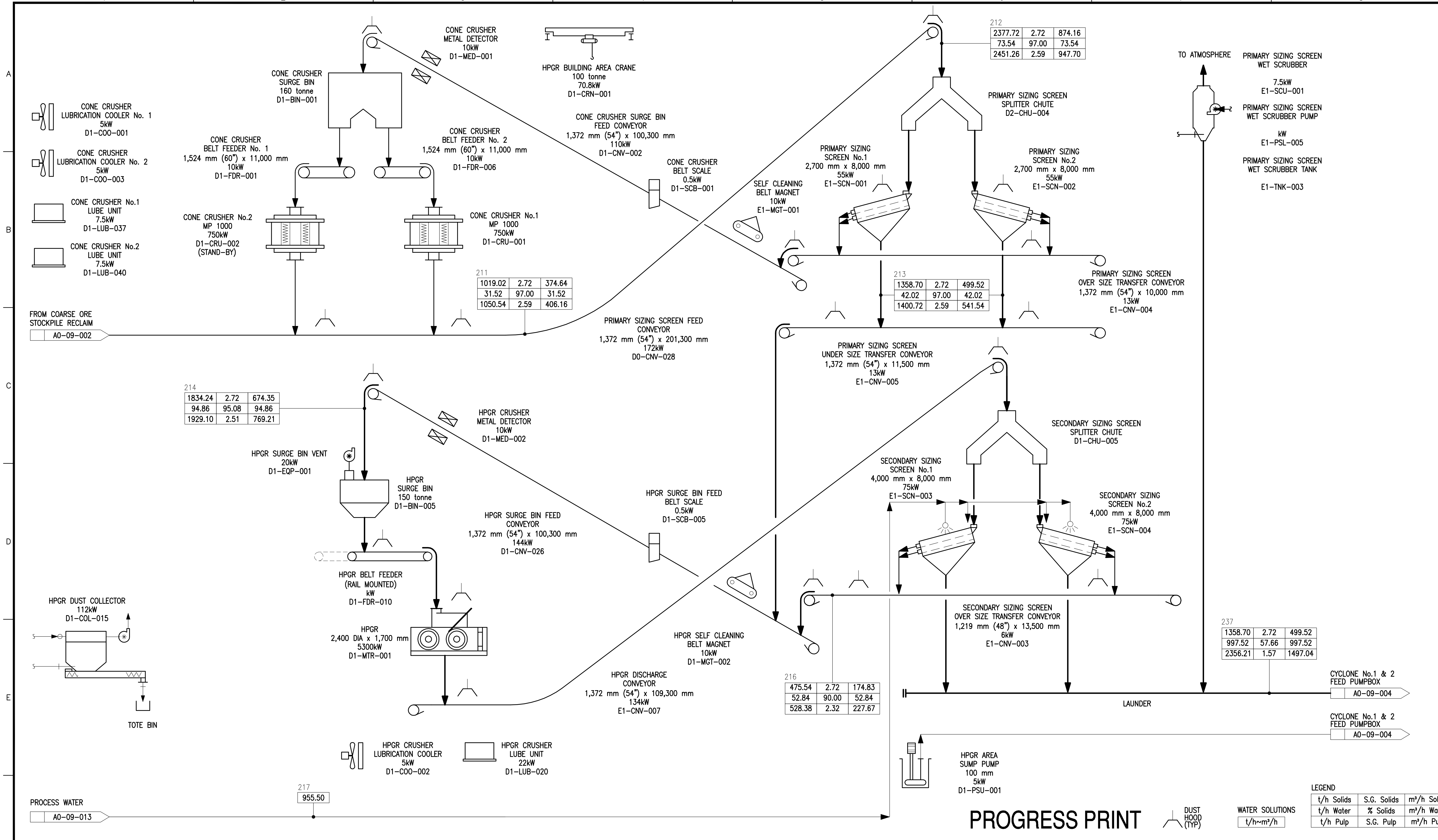

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Stream 212

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Stream 213

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Stream 214

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1929.10	2.51	769.21

Stream 216

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528.38	2.32	227.67

Stream 237

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997.52	57.66	997.52
2356.21	1.57	1497.04

LEGEND

t/h Solids	S.G. Solids	m³/h Solids
t/h Water	% Solids	m³/h Water
t/h Pulp	S.G. Pulp	m³/h Pulp

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WARDROP Engineering Inc.

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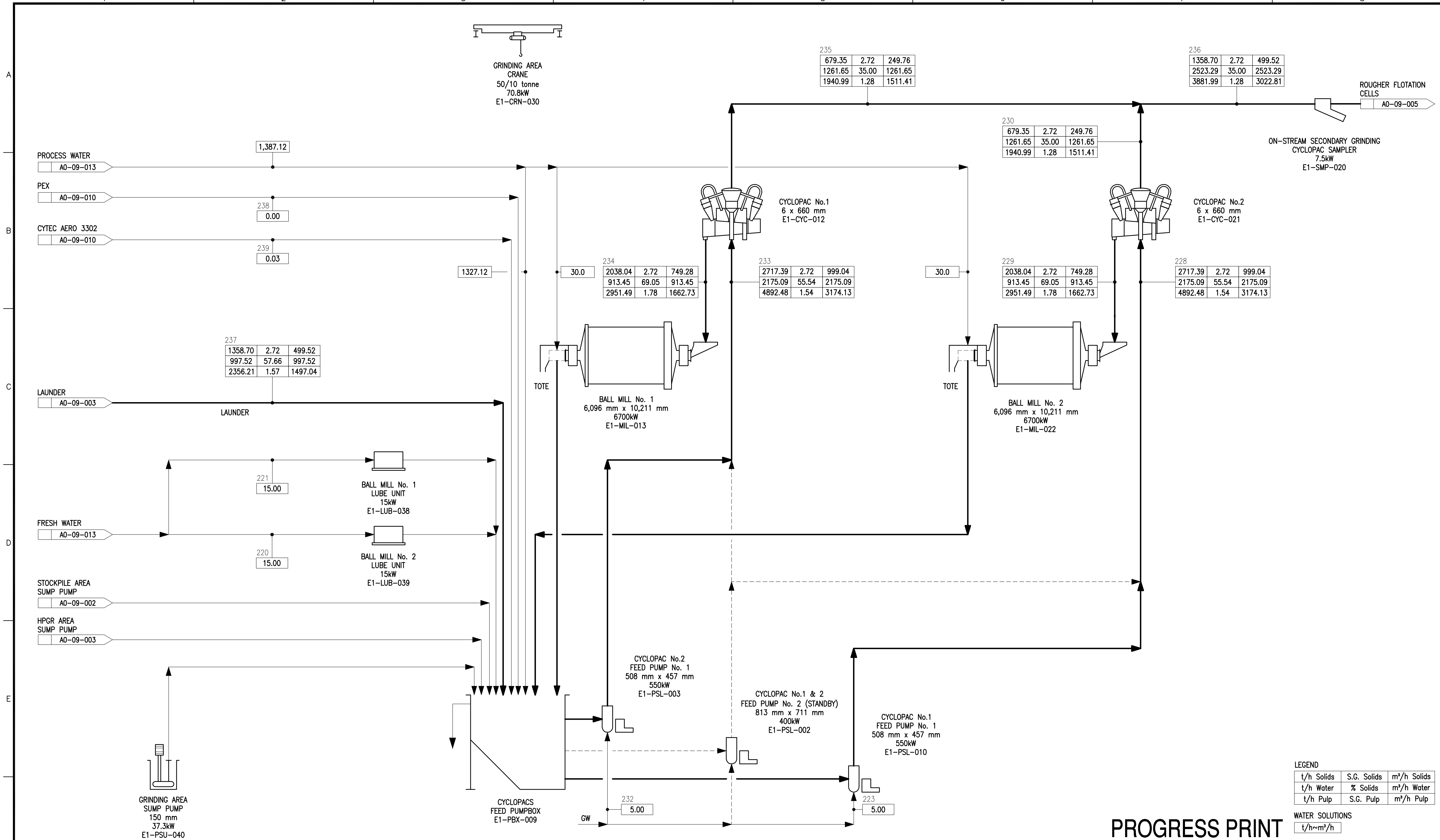

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DWG. NO.	REFERENCE DRAWINGS	CLIENT	PROJ.MAN.	PROJ.ENG.	PROCESS	ELECTR.	INSTR.	PIPING	MECH.	STRUCT.	SERVICES	ARCH.	LAYOUT	REV. No.	ISSUE No.	DESCRIPTION	DATE	BY

SECTION:	PROCESS	
SCALE:	NONE	DATE
DESIGN. BY:	HG	FEB07
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CHECK. BY:		
APP. BY:		

PACIFIC BOOKER MINERALS INC.

WARDROP Engineering Inc.

TITLE MORRISON PORPHYRY COPPER GOLD
GRINDING AREA
PROCESS FLOW DIAGRAM No. 3

FILENAME:	PROJECT NUMBER	DRAWING NUMBER	REV.
A009004.DWG	06527201.00	A0-09-004	A

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WARDROP

PROCESS DESIGN CRITERIA - SAG

PROJECT: Pacific Booker
CLIENT: Morrison Porphyry Copp
PROJECT NUMBER: 06527201.00
DATE: 22-Jun-07
REV: C - WORKING COPY

All values are in metric units.

CODES

1	Client
2	Industry / Experience
3	Calculation
4	Mass Balance
5	PRA Met Lab
6	SGS Met Lab
7	Beacon Hill Consultants
8	Suppliers
9	Others

DESCRIPTION	UNIT	VALUE	SOURCES
GENERAL			
Type Of Deposit		Porphyry Copper Gold Ore	
Ore Characteristics			
Specific Gravity	g/cm^3	2.7	6
Bulk Density	t/m^3	1.6	2
Moisture Content	%	3.0	1
Abrasion Index (Average)	g	0.320	6
Operating Schedule			
Shift/Day		2	1
Crusher Plant Hours/Shift	h	8	1
Crusher Plant Hours/Day	h	16	1
Grinding and Flotation Hours/Shift	h	12	1
Grinding and Flotation Hours/Day	h	24	1
Days/Year	days	365	1
Plant Availability/Utilization			
Overall Plant Feed	t/y	10,950,000	2,1
Overall Plant Feed	t/d	30,000	1
Crusher Plant Availability	%	75.0	2
Grinding and Flotation Plant Availability	%	92.0	2
Crushing Rate	t/h	2,500.0	3
Grinding Rate	t/h	1,358.7	3
Flotation Rate	t/h	1,358.7	3
Head Grades	% Cu	0.40	6
	% Mo	0.006	6
	g/t Au	0.19	6
	g/t Ag	1.60	6
Recovery:	Cu %	84.0	5,6
	Mo %	78.0	5,6
	Au %	56.0	5,6
	Ag %	56.0	5,6
Cu Concentrate Grade	% Cu	26.5	5,6
	% Mo	0.37	5,6

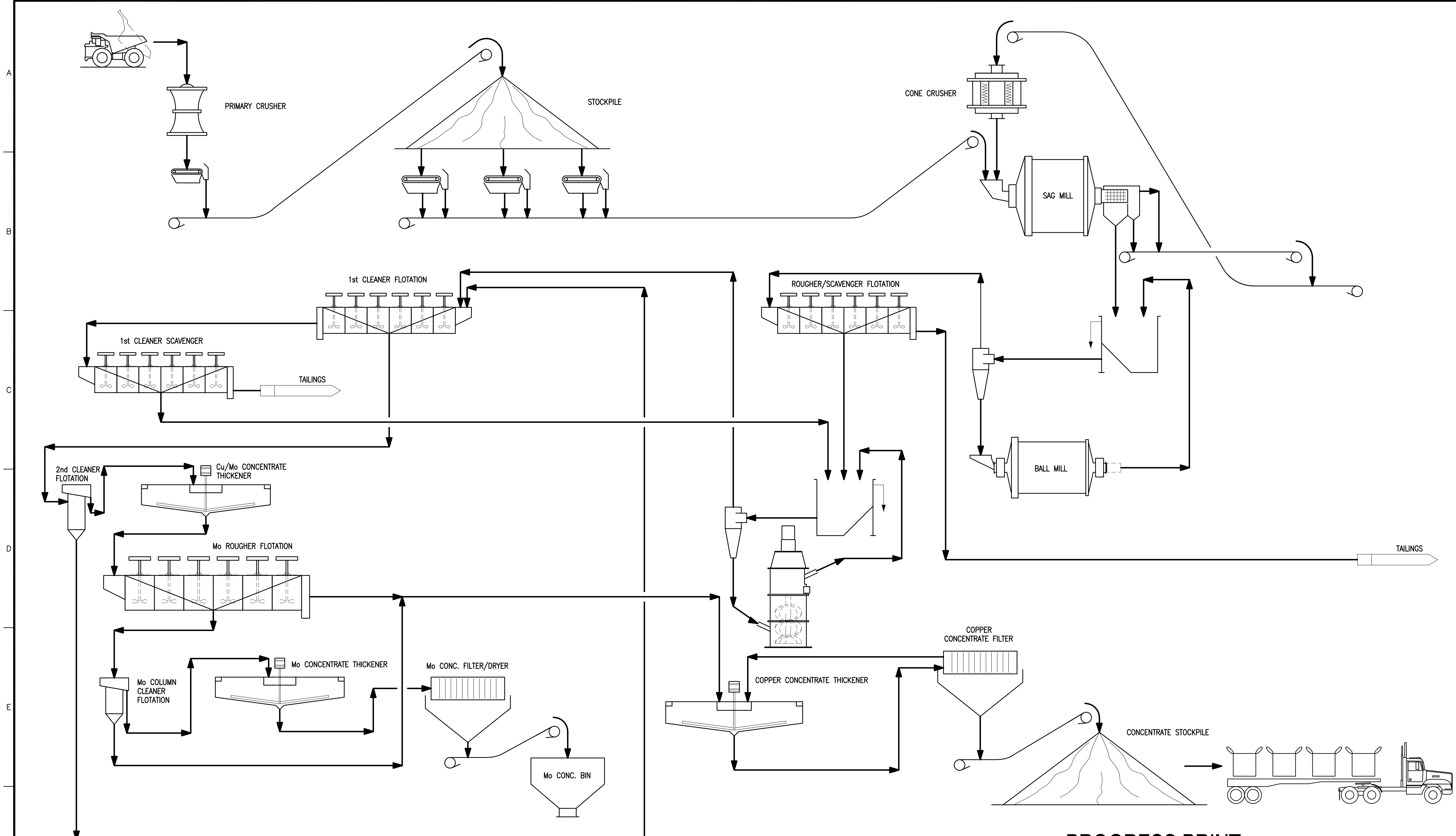
DESCRIPTION	UNIT	VALUE	SOURCES
	g/t Au	9.0	5,6
	g/t Ag	75	5,6
Mo Concentrate Grade	% Cu	0.8	5,6
	% Mo	53.6	5,6
Cu Concentrate Mass Recovery	%	1.27	3
Mo Concentrate Mass Recovery	%	0.02	3
Cu Concentrate Production	t/y	138,838	3
Mo Concentrate Production	t/y	956	4
CRUSHING			
Primary Crushing Production Parameters			
Feed Particle Size	mm	1,500	2
Crusher Type	type	Gyratory	2
Number of Crushers		1	3
Crushing Processing Rate	t/h	2,500.0	4
Product Size, P_{80}	mm	150	2
Liner Wear Rate	kg/kW·h	0.022	3
Crushed Ore Stockpile Parameters			
Crushed Ore Stockpile (Live Capacity)	t	30,000	2
Crushed Ore Bulk Density	t/m^3	1.6	2
Angle of Repose	degrees	37	2
Angle of Reclaim	degrees	60	2
No of Feeders		3	3
Average Tonnage Rate (Each), Operating	t/h	453	4
Type of Discharge Feeders	type	Apron	2
GRINDING			
Production Rate	t/h	1,358.7	4
Bond Ball Mill Work Index	kWh/t	17.0	6
Primary Grinding			
Mill	type	SAG mill	2
Number of Mills		1	3
Feed Solids	%w/w	72	4
Bond Abrasion Index, Ai		0.320	6
Balls Wear Rate	kg/kW·h	0.125	3
Liner Wear Rate	kg/kW·h	0.011	3
Feed Size, F_{80}	µm	150,000	2
Product Size, P_{80}	µm	4,400	6
Mill Speed	% CS	70	2
Grate Size	mm	19	60
Classification	type	Screen	2
Screen Aperture	mm	10-19	2
Screen Oversize Flowrate	t/h	272	2
SAG Circuit Pebble Crusher		Pebble/Cone	2
Circulating Load	%	20	2
Average Tonnage Rate, Pebble Crusher	t/h	272	3
Max. Tonnage Rate, Pebble Crusher	t/h	340	3
Pebble Crusher Discharge, P80	mm	16	2
Pebble Crusher Discharge, P80	mm	10	3
Secondary Grinding			

DESCRIPTION	UNIT	VALUE	SOURCES
Mill	type	Ball mill	2
Number of Mills		2	3
Feed Solids	%w/w	72	2
Abrasion Index, Ai		0.320	6
Liner Wear Rate	kg/kW·h	0.008	3
Primary Bond Work Index	kWh/t	17.0	3
Feed Size, P_{80}	µm	4,400	6
Product Size, P_{80}	µm	150	5
Mill Speed	% CS	72	2
Ball Mill Charge	%	35	
Recirculation Load	%	300	2
Classification	type	Cyclones	

DESCRIPTION	UNIT	VALUE	SOURCES
FLOTATION CIRCUIT			
Copper and Gold Flotation			
Conditioning			
Solids Flow Rate	t/h	1,358.7	4
Pulp Flow Rate	m^3/h	3,022.8	4
Solids/Pulp Density	%	35.0	4
Conditioning Residence Time	min	2.0	3
Pulp pH		9.8	6
Rougher/Scavenger Flotation			
Solids Flow Rate	t/h	1,358.7	4
Pulp Flow Rate	m^3/h	3,022.8	4
Solids/Pulp Density	%	35.0	4
Plant Retention Time	min	30.0	4
Batch Retention Time	min	12.0	2
Flotation Time Scale-up		2.5	6
Pulp pH		9.5	6
Rougher Concentrate Weight Recovery	%	8.0	3
Concentrate Regrind Circuit			
Throughput	t/h	147.6	
Mill Type	type	Tower Mill	
Number of Mills		2	
Ball Mill Bond Work Index	kWh/t	17.0	
Pulp Density	% solids	0.0	
Feed Size, P_{80}	µm	150.0	
Product Size, P_{80}	µm	25.0	
Mill Speed	% CS	72.0	
Mill Ball Charge	%	35.0	
Recirculation Load	%	250	
Classification		Cyclones	
Cyclone Feed Density	%	42.4	2
1st Cleaner Flotation			
Solids/Pulp Density	%	24.4	4
Solids Flow Rate	t/h	158.9	4
Pulp Flow Rate	m^3/h	491.2	4
Plant Retention Time	min	33.6	4
Residence Time Scale-up		2.8	2
Batch Retention Time	min	12.0	6
Flotation pH		11.0	6
1st Cleaner Scavenger Flotation			
Solids/Pulp Density	%	23.5	4
Solids Flow Rate	t/h	130.0	4
Pulp Flow Rate	m^3/h	468.9	4
Plant Retention Time	min	33.6	4
Residence Time Scale-up		2.8	2
Batch Retention Time	min	12.0	6
Flotation pH		11.0	6
2nd Cleaner Flotation			

DESCRIPTION	UNIT	VALUE	SOURCES
Solids/Pulp Density	%	25.7	4
Solids Flow Rate	t/h	28.9	4
Pulp Flow Rate	m^3/h	92.6	4
Plant Retention Time	min	16.8	4
Residence Time Scale-up		2.8	2
Batch Retention Time	min	6.0	6
Flotation pH		11.5	6
Moly Flotation			
Thickening			
Thickener	type	High Rate	
Copper-Moly Concentrate Thickener Feed Solids	t/h	17.6	4
Thickener U/F Density	% solids	50.0	TBA
Thickener Diameter	m	11.4	3
Thickener Unit Area-required	$t/m^2/h$	0.20	TBA
Slurry Storage Tank Capacity	h	12	
Moly Rougher Flotation			
Solids/Pulp Density	%	38.3	4
Solids Flow Rate	t/h	24.0	4
Pulp Flow Rate	m^3/h	45.1	4
Plant Retention Time	min		
Residence Time Scale-up			
Batch Retention Time	min		
Flotation pH			
Moly Cleaner Flotation			
Solids/Pulp Density	%	25.5	4
Solids Flow Rate	t/h	6.8	4
Pulp Flow Rate	m^3/h	21.5	4
Plant Retention Time	min		
Residence Time Scale-up			
Batch Retention Time	min		
Flotation pH			
CONCENTRATE DEWATERING			
Copper Concentrate			
Thickening			
Thickener	type	High Rate	
Copper Concentrate Thickener Feed Solids Flowrate	t/h	17.2	4
Thickener U/F Density	% solids	60.0	4
Thickener Diameter	m	11.3	3
Thickener Unit Area-required	$t/m^2/h$	0.20	TBA
Slurry Storage Tank Capacity	h	12	
Filtration			
Filter	type	Pressure	
Solids Feed Rate	t/h	21.5	4
Slurry Feed Flowrate	m^3/h	18.1	4
Filter Rate	$t/(h{\cdot}m^2)$	0.3	TBA
Filter Unit Area Required	$kg/m^2/h$		TBA
Filter Operating Time	%	85	

DESCRIPTION	UNIT	VALUE	SOURCES
Filter Area	m^2	84.4	3
Filter Cake Moisture	%	8	4
Filtered Copper Concentrate Storage Capacity	t	2,067	3
Filtered Copper Concentrate Storage Capacity	m^3	984	3
Moly Concentrate			
Thickening			
Thickener	type	High Rate	
Moly Concentrate Thickener Feed Solids Flowrate	t/h	0.33	4
Thickener U/F Density	% solids	60.0	4
Thickener Diameter	m	1.6	3
Thickener Unit Area-required	$t/m^2/h$	0.20	TBA
Slurry Storage Tank Capacity	h	12	
Filtration			
Filter	type		
Solids Feed Rate	t/h	0.41	4
Slurry Feed Flowrate	m^3/h	1.22	4
Filter Rate	$t/(h{\cdot}m^2)$	0.3	TBA
Filter Unit Area Required	$kg/m^2/h$		TBA
Filter Operating Time	%	85	
Filter Area	m^2	1.6	3
Filter Cake Moisture	%	20	4
Filtered Copper Concentrate Storage Capacity	t	39	3
Filtered Copper Concentrate Storage Capacity	m^3	19	3
Dryer			
Dryer	type		
Solids Feed Rate	t/h	0.41	4
Concentrate Feed Moisture	%	20	4
Concentrate Product Moisture	%	5	4
REAGENTS			
Lime (Hydrated)	g/t	450	6
Potasium Ethyl Xanthate (PEX)	g/t	90	6
Cytec Aero 3302	g/t	20	6
MIBC	g/t	55	6
Carboxyl Methyl Cellulose (CMC)	g/t	10	
Flocculant	g/t	10	



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PACIFIC BOOKER MINERALS INC.

WARDROP Engineering Inc.

TITLE MORRISON PORPHYRY COPPER GOLD

SIMPLIFIED FLOW DIAGRAM

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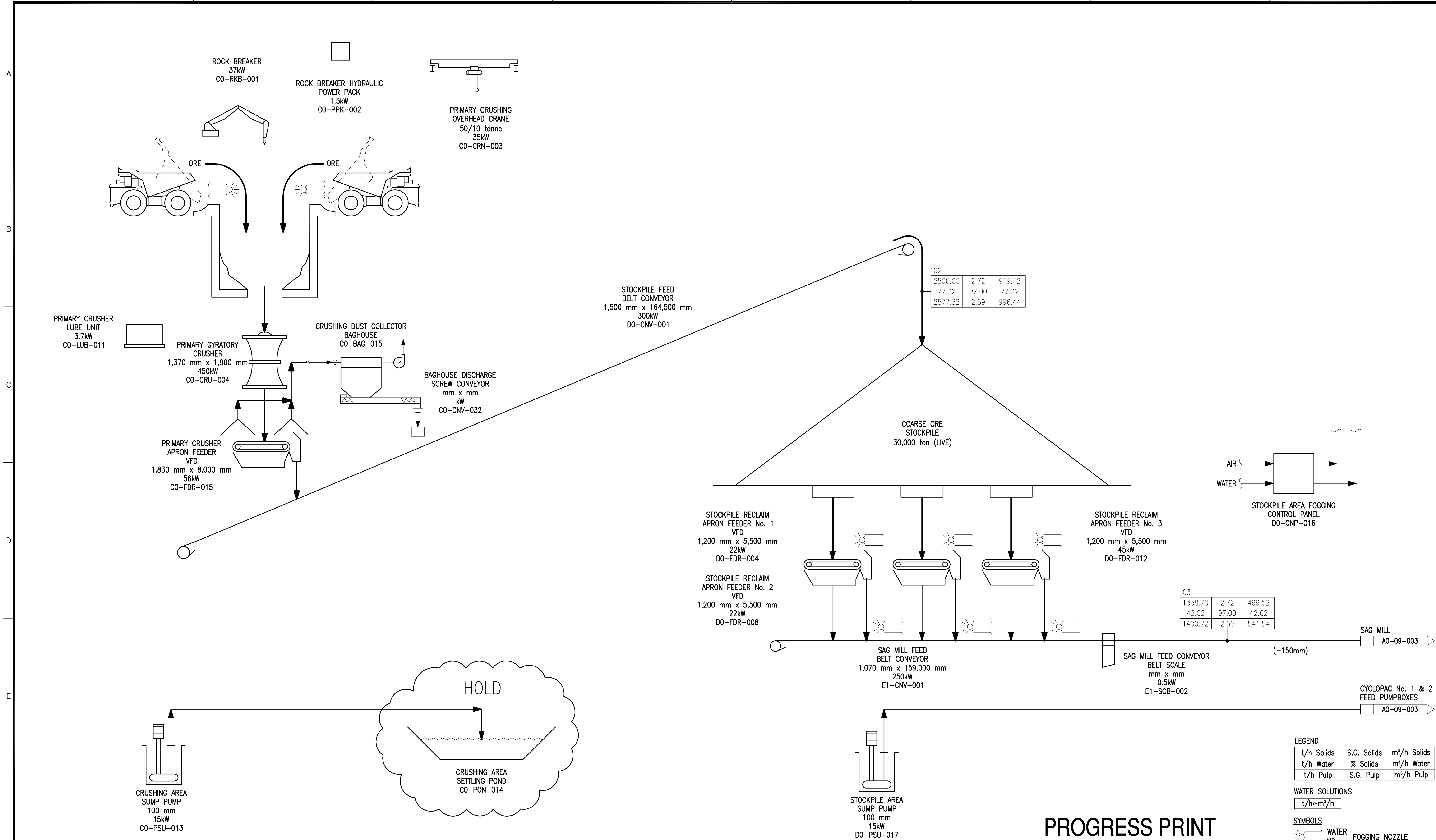

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CLIENT	PRO.MAN.	PRO.ENG.	PROCESS	ELECTR.	INSTR.	PIPING	MECH.	STRUCT.	SERVICES	ARCH.	LAYOUT	REV. No.	ISSUE No.	DESCRIPTION	DATE	BY

SECTION: PROCESS
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PACIFIC BOOKER MINERALS INC.

TITLE MORRISON PORPHYRY COPPER GOLD
CRUSHING & RECLAIM
PROCESS FLOW DIAGRAM No. 1

FILENAME:	PROJECT NUMBER	DRAWING NUMBER	REV.
A009002.DWG	06527201.00	A0-09-002	A

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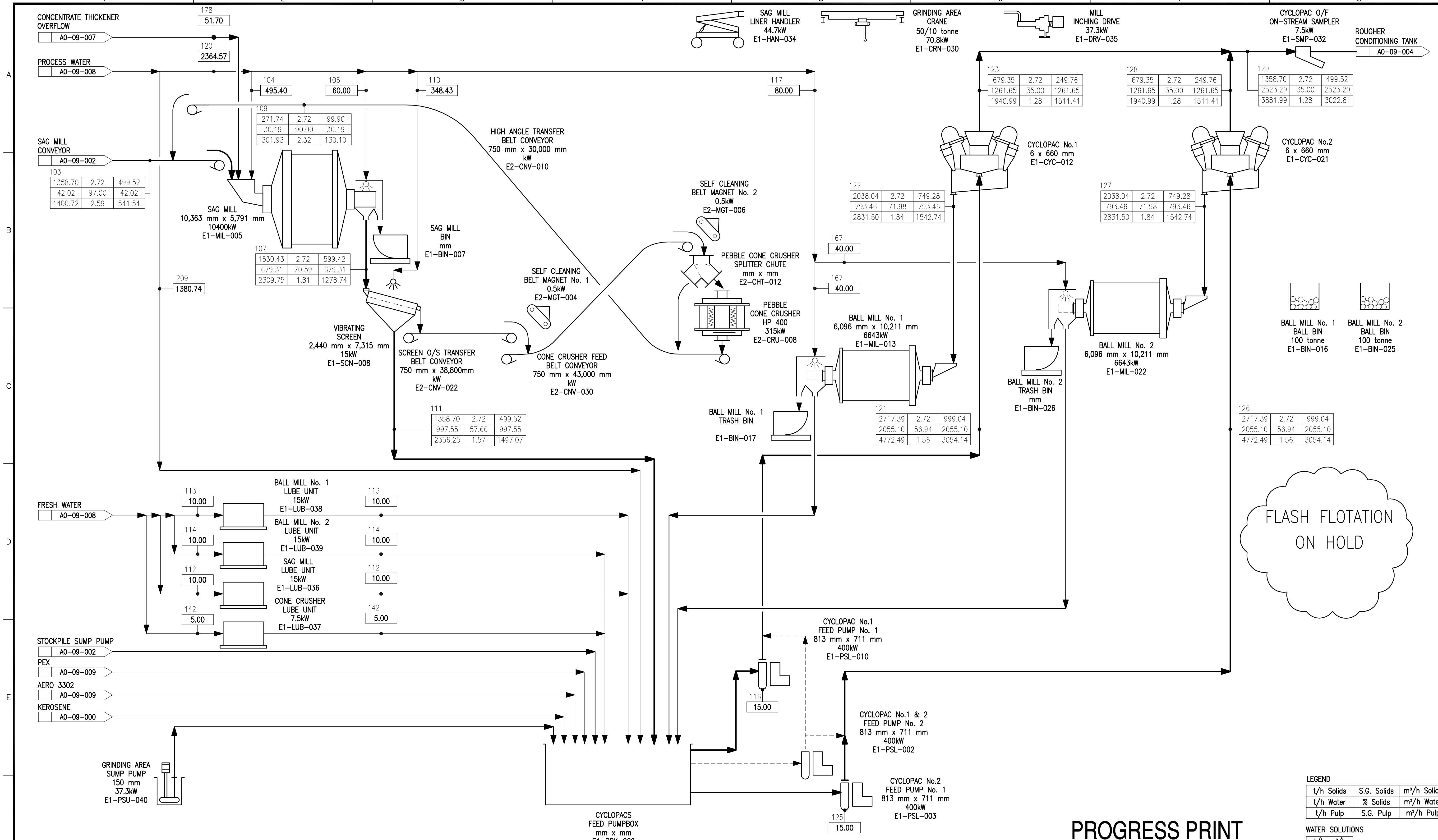

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PACIFIC BOOKER MINERALS INC.

WARDROP Engineering Inc.

TITLE MORRISON PORPHYRY COPPER GOLD
HPGR GRINDING PROCESS FLOW DIAGRAM No. 2

FILENAME:	PROJECT NUMBER	DRAWING NUMBER	REV.
A009003.DWG	06527201.00	A0-09-003	A

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07/08/21

APPENDIX B

LAYOUTS

DWG. NO.	REFERENCE DRAWINGS

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SECTION:	LAYOUT	
SCALE:	1:250	DATE
DESIGN. BY:	J.DIAZ	13DEC07
DRAWN BY:	AR	13DEC07
CHECK. BY:		
APP. BY:		

PACIFIC BOOKER MINERALS INC.

WARDROP Engineering Inc.

TITLE MORRISON PORPHYRY COPPER GOLD

MILL BUILDING
GENERAL ARRANGEMENT
SAG MILL OPTION

FILENAME:	PROJECT NUMBER	DRAWING NUMBER	REV.
E010001opt.DWG	06527201.00	E0-10-001opt	-

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REV. No.	ISSUE No.	DESCRIPTION	DATE	BY
A	1	FOR CLIENT REVIEW	17DEC07	JD

SECTION: LAYOUT
SCALE: 1:200 DATE
DESIGN. BY: J.DIAZ 08AUG07
DRAWN BY: J.DIAZ
CHECK. BY:
APP. BY:

PACIFIC BOOKER MINERALS INC.

WARDROP Engineering Inc.

TITLE MORRISON PORPHYRY COPPER GOLD

HPGR BUILDING GENERAL ARRANGEMENT OPERATING FLOOR PLAN

FILENAME:	PROJECT NUMBER	DRAWING NUMBER	REV.
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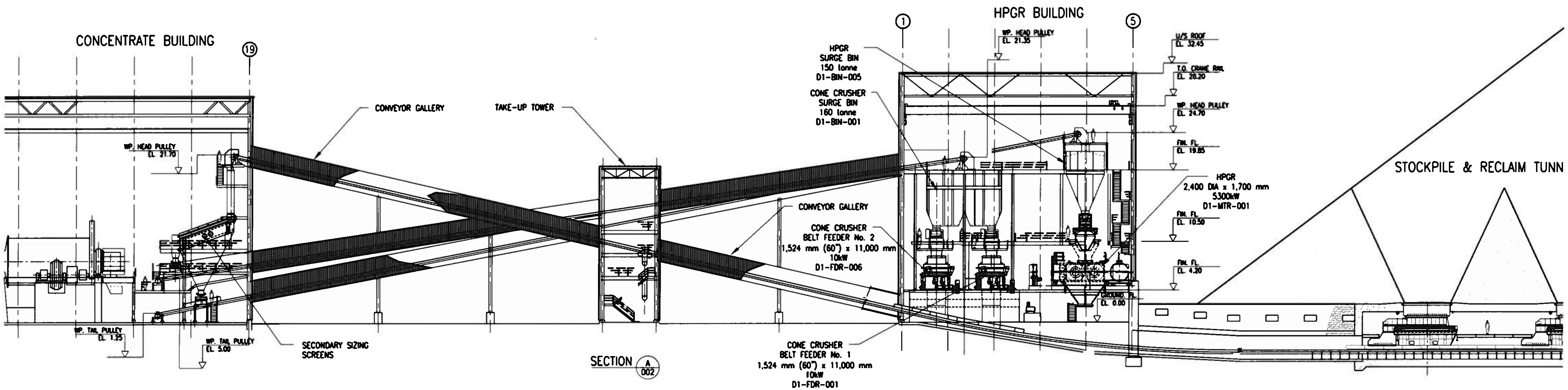
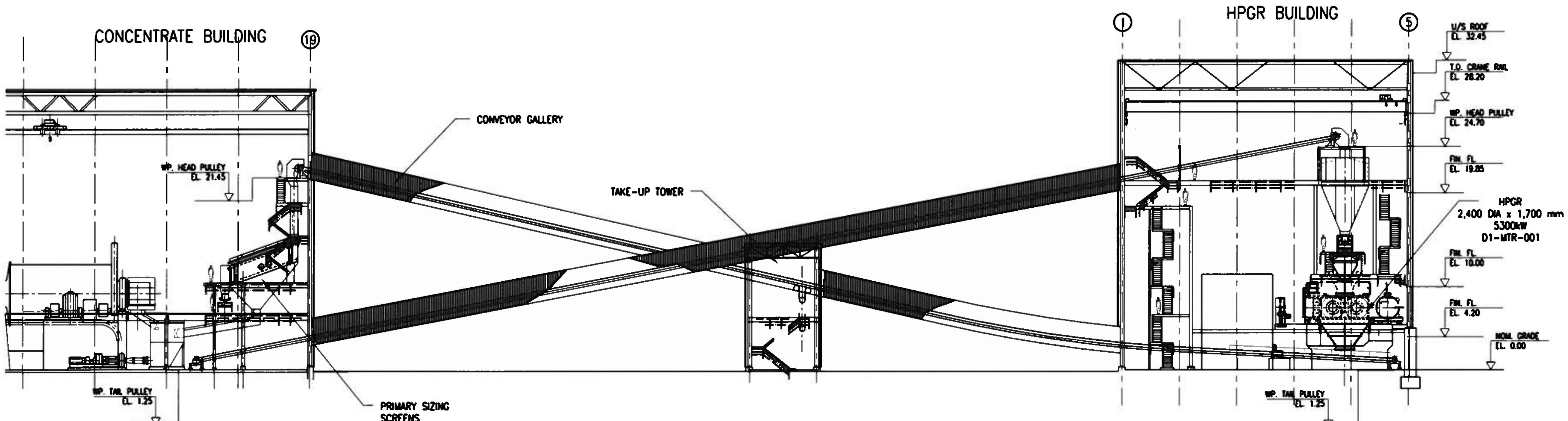


SECTION A 002



SECTION B 002

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SCALE:	1:250	DATE
DESIGN. BY:	J.DIAZ	08AUG07
DRAWN BY:	J.DIAZ	
CHECK. BY:		
APP. BY:		

PACIFIC BOOKER MINERALS INC.

WARDROP Engineering Inc.

TITLE MORRISON PORPHYRY COPPER GOLD

HPGR BUILDING GENERAL ARRANGEMENT SECTIONS

FILENAME:	PROJECT NUMBER	DRAWING NUMBER	REV.
E010004.DWG	06527201.00	E0-10-004	A

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APPENDIX C

OPERATING COSTS

Client: **Pacific Booker Minerals Inc**
Project Name: **Morrison**
Project Number: **6527201**
Date: 17-Oct-07

HPGR

Daily tonnes milled 30,000
Mill Availability 96%
Annual operating days 365

Annual Throughput **10,950,000** t/y

COMMINUTION CIRCUIT OPERATING COST SUMMARY

DESCRIPTION	LABOUR	ANNUAL COST ($)	(UNIT COST CDN$ /tonne ore)
LABOUR			
OPERATING LABOUR	**16**	**$1,142,396**	**0.104**
MAINTENANCE LABOUR	**23**	**$1,617,342**	**0.148**
SUB-TOTAL STAFF	**39**	**$2,759,738**	**0.252**
SUPPLIES			
OPERATING SUPPLIES		**$15,950,276**	**1.457**
MAINTENANCE SUPPLIES		**$450,000**	**0.041**
POWER SUPPLY		**$4,819,710**	**0.440**
SUB-TOTAL SUPPLIES		**$21,219,986**	**1.938**
TOTAL	**39**	**$23,979,725**	**2.190**

Client: Pacific Booker Minerals Inc 12/21/2007
Project Name: Morrison
Project Number: 6527201
Date: 17-Oct-07

HPGR

Daily tonnes milled 30,000
Mill Availability 96%
Annual operating days 365

Annual Throughput 10,950,000 t/y

MILL LABOUR

DESCRIPTION	Labour	Base Salary	Loaded Salary	Annual Cost
		CDN$	CDN$	CDN$
OPERATIONS				
Primary Crusher Operators	2	$54,750	$71,723	$143,445
Cone Crusher and HPGR Operators	2	$54,750	$71,723	$143,445
Control Room Operators	4	$60,225	$78,895	$315,579
Grinding Operators	3	$58,692	$76,887	$230,660
General Labourers	5	$47,216	$61,853	$309,267
SUB-TOTAL OPERATIONS	**16**			**$1,142,396**
SUB-TOTAL OPERATIONS	**16**			**$1,142,396**

Client: **Pacific Booker Minerals Inc** 12/21/2007
Project Name: **Morrison**
Project Number: **6527201**
Date: **17-Oct-07**

HPGR

Daily tonnes milled 30,000
Mill Availability 96%
Annual operating days 365

Annual Throughput **10,950,000 t/y**

MILL MAINTENANCE LABOUR

DESCRIPTION	Labour	Base Salary	Loaded Salary	Annual Cost
PLANT MAINTENANCE				
Mechanics and Electricians	12	$56,612	$74,161	$889,933
Apprentices	9	$48,728	$63,833	$574,497
Instrument Technicians	2	$58,364	$76,456	$152,912
TOTAL MILL MAINTENANCE	**23**			**$1,617,342**

Client:	**Pacific Booker Minerals Inc**	12/12/2007
Project Name:	**Morrison**	
Project Number:	**6527201**	
Date:	**17-Oct-07**	

HPGR

Daily tonnes milled	30,000
Mill Availability	96%
Annual operating days	365

Annual Throughput **10,950,000 t/y**

POWER SUPPLY

Plant Power	kw	17,910
Power Price	$/kwh	0.032

SUPPLIES	KWH	Unit Cost ($/kwh)	Total Cost ($/year)	Unit Cost ($/t ore)
PLANT	150,615,936	0.032	$4,819,710	$0.44
TOTAL POWER SUPPLY	**150,615,936**	**0.032**	**$4,819,710**	**$0.44**

MAINTENANCE SUPPLIES

AREA		Total Cost ($/year)	Unit Cost ($/t ore)
Crushing	allowance	$200,000	0.0183
Grinding	allowance	$100,000	0.0091
Miscellaneous Mill Supplies	allowance	$75,000	0.0068
Misc. Building Complex Supplies	allowance	$75,000	0.0068
TOTAL MTCE. SUPPLIES		**$450,000**	**$0.041**

PLANT OPERATING SUPPLIES

SUPPLIES	Consumption (kg/t ore)	Source	Unit Cost ($/kg)	Source	Unit Cost FOB point	Total Cost ($/year)	Unit Cost ($/t ore)
Gyratory Crusher Liners	0.005	Calculation	3.99	Suppliers	minesite	$232,684	$0.021
Cone Crusher Liners	0.004	Calculation	5.80	Suppliers	minesite	$236,935	$0.022
HPGR Rolls	0.071	Supplier	3.04	Suppliers	minesite	$2,363,448	$0.216
Ball Mill Balls, 3 in.	1.034	Calculation	0.97	Suppliers	minesite	$10,982,862	$1.003
Ball Mill Liners	0.080	Calculation	2.40	Suppliers	minesite	$2,092,348	$0.191
Mill Light Vehicle Operation	allowance	Industry				$24,000	$0.002
Miscellaneous	allowance	Industry				$18,000	$0.002
TOTAL OPERATING SUPPLIES						**$15,950,276**	**$1.457**

12/21/2007

Client: **Pacific Booker Minerals Inc**
Project Name: **Morrison**
Project Number: **6527201**
Date: 17-Oct-07

SAG

Daily tonnes milled	30,000	
Mill Availability	92%	
Annual operating days	365	
Annual Throughput	**10,950,000**	t/y

COMMINUTION CIRCUIT OPERATING COST SUMMARY

DESCRIPTION	LABOUR	ANNUAL COST ($)	(UNIT COST CDN$ /tonne ore)
LABOUR			
OPERATING LABOUR	**15**	**$1,067,625**	**0.098**
MAINTENANCE LABOUR	**22**	**$1,553,509**	**0.142**
SUB-TOTAL STAFF	**37**	**$2,621,134**	**0.239**
SUPPLIES			
OPERATING SUPPLIES		**$22,498,491**	**2.055**
MAINTENANCE SUPPLIES		**$500,000**	**0.046**
POWER SUPPLY		**$5,734,282**	**0.524**
SUB-TOTAL SUPPLIES		**$28,732,773**	**2.624**
TOTAL	**37**	**$31,353,907**	**2.863**

Client:	**Pacific Booker Minerals Inc**	12/21/2007
Project Name:	**Morrison**	
Project Number:	**6527201**	
Date:	17-Oct-07	

SAG

Daily tonnes milled	30,000	
Mill Availability	92%	
Annual operating days	365	
Annual Throughput	**10,950,000**	t/y

MILL LABOUR

DESCRIPTION	Labour	Base Salary	Loaded Salary	Annual Cost
		CDN$	CDN$	CDN$
OPERATIONS				
Crusher Operators	2	$54,750	$71,175.00	$142,350
Control Room Operators	4	$60,225	$78,292.50	$313,170
Grinding Operators	4	$58,692	$76,299.60	$305,198
General Labourers	5	$47,216	$61,381.32	$306,907
SUB-TOTAL OPERATIONS	**15**			**$1,067,625**
TOTAL MILL LABOUR	**15**			**$1,067,625**

Client: **Pacific Booker Minerals Inc** 12/21/2007
Project Name: **Morrison**
Project Number: **6527201**
Date: 17-Oct-07

SAG

Daily tonnes milled 30,000
Mill Availability 92%
Annual operating days 365

Annual Throughput **10,950,000** t/y

MILL MAINTENANCE LABOUR

DESCRIPTION	Labour	Base Salary	Loaded Salary	Annual Cost
PLANT MAINTENANCE				
Mechanics and Electricians	12	$56,612	$74,161	$889,933
Apprentices	8	$48,728	$63,833	$510,664
Instrument Technicians	2	$58,364	$76,456	$152,912
TOTAL MILL MAINTENANCE	**22**			**$1,553,509**

Client:	**Pacific Booker Minerals Inc**	12/12/2007
Project Name:	**Morrison**	
Project Number:	**6527201**	
Date:	17-Oct-07	

SAG

Daily tonnes milled	30,000	
Mill Availability	92%	
Annual operating days	365	
Annual Throughput	**10,950,000**	t/y

POWER SUPPLY

Plant Power	kw	22,235
Power Price	$/kwh	0.032

SUPPLIES	KWH	Unit Cost ($/kwh)	Total Cost ($/year)	Unit Cost ($/t ore)
PLANT	179,196,312	0.032	$5,734,282	$0.52
TOTAL POWER SUPPLY	**179,196,312**	**0.032**	**$5,734,282**	**$0.52**

MAINTENANCE SUPPLIES

AREA		Total Cost ($/year)	Unit Cost ($/t ore)
Crushing	allowance	$100,000	0.0091
Grinding	allowance	$250,000	0.0228
Miscellaneous Mill Supplies	allowance	$75,000	0.0068
Misc. Building Complex Supplies	allowance	$75,000	0.0068
TOTAL MTCE. SUPPLIES		**$500,000**	**0.046**

PLANT OPERATING SUPPLIES

SUPPLIES	Consumption (kg/t ore)	Source	Unit Cost ($/kg)	Source	Unit Cost FOB point	Total Cost ($/year)	Unit Cost ($/t ore)
Gyratory Crusher Liners	0.005	Calculation	3.99	Suppliers	minesite	$232,684	$0.021
Cone Crusher Liners	0.004	Calculation	5.80	Suppliers	minesite	$236,935	$0.022
SAG Mill Balls, 5 in.	0.644	Calculation	1.04	Suppliers	minesite	$7,330,952	$0.669
Ball Mill Balls, 3 in.	1.034	Calculation	0.97	Suppliers	minesite	$10,982,862	$1.003
SAG Mill Liners	0.057	Calculation	2.52	Suppliers	minesite	$1,580,710	$0.144
Ball Mill Liners	0.080	Calculation	2.40	Suppliers	minesite	$2,092,348	$0.191
Mill Light Vehicle Operation	allowance	Industry				$24,000	$0.002
Miscellaneous	allowance	Industry				$18,000	$0.002
TOTAL OPERATING SUPPLIES						**$22,498,491**	**$2.055**

APPENDIX D

CAPITAL COSTS

Pacific Booker Minerals Inc.		Expressed in Canadian Dollars	
Morrison Porphyry Copper Gold Project	30,000 tpd capacity	Location - British Columbia	
WARDROP Engineering Inc	Project # 06527201.00		
	COMMINUTION CIRCUIT CAPITAL COST COMPARISION		

Area Code	Area, Item Description & Equipment Number			HPGR Option	SAG Mill Option	Variance HPGR - SAG Mill
C/D/E	COMMINUTION- DIRECT COST SUMMARY					
CO/DO	RECLAIM CONVEYOR			**$ 986,655**	**$ 592,462**	**$ 394,193**
D1+ D2	SECONDARY/TERTIARY CRUSHING EQUIPMENT COMPRISES OF:			**$ 23,877,316**	**$ -**	**$ 23,877,316**
	Cone Crusher, HPGR Crusher, Vibrating Screens - Primary and Secodnary, Transfer Conveyors, Steel chutes and bins					
D1-O	SECONDARY/TERTIARY CRUSHING BUILDING			**$ 6,532,337**	**$ -**	**$ 6,532,337**
E1	GRINDING EQUIPMENT COMPRISES OF:					**-$ 23,629,629**
	HPGR OPTION: 2 Ball Mills, Pumps, Cyclopacks			**$ 23,225,127**		
	SAG OPTION: SAG Mill, 2 Ball Mills, Pumps, Cyclopac				**$ 46,854,756**	
EO	GIRNDING BUILDING			**$ 14,221,022**	**$ 14,788,707**	**-$ 567,686**
Total	**Sub Total- CamminutionDirect Costs**			**$ 68,842,457**	**$ 62,235,925**	**$ 6,606,532**
	-					
C/D/E	COMMINUTION- INDIRECT COSTS					
	ENGINEERING	8%		**$ 5,507,397**	**$ 4,978,874**	**$ 528,523**
	CONSTRUCTION MANAGEMENT	8%		**$ 5,507,397**	**$ 4,978,874**	**$ 528,523**
	FREIGHT **	8%		**$ 4,631,893**	**$ 4,316,056**	**$ 315,836**
	INDIRECTS	6%		**$ 4,130,547**	**$ 3,734,155**	**$ 396,392**
	FIRST FILL OF MEDIA			**$ 1,026,000**	**$ 1,140,000**	**-$ 114,000**
	SPARES	3%		**$ 1,153,408**	**$ 1,196,792**	**-$ 43,385**
Total	**Sub Total- Comminution Indirect Costs**			**$ 21,956,641**	**$ 20,344,752**	**$ 1,611,889**
-	**SUB TOTAL - DIRECT + INDIRECT COSTS**			**$ 90,799,097**	**$ 82,580,677**	**$ 8,218,420**
-	CONTINGENCY @ 15%			**$ 13,619,865**	**$ 12,387,102**	**$ 1,232,763**
Total	**TOTAL - COSTS**			**$ 104,418,962**	**$ 94,967,779**	**$ 9,451,183**

Note:

** Excluding HPGR and Grinding Mills freight which are included in the equipment cost

APPENDIX E

High-Pressure Grinding Tests on Copper/Gold/Molybdenum Ore from the Morrison Project

A Company of ThyssenKrupp Technologies **Polysius**

December 06, 2007

High-Pressure Grinding Tests

on

Copper/Gold/Molybdenum Ore

from the

Morrison Project
British Columbia, Canada

for Pacific Booker Minerals Inc.

at the

Polysius Research Centre

Project No. 2337 2844 / 2220-7959
WE no. 11815

By: Rene Klymowsky/Holger Plath

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Table of Contents

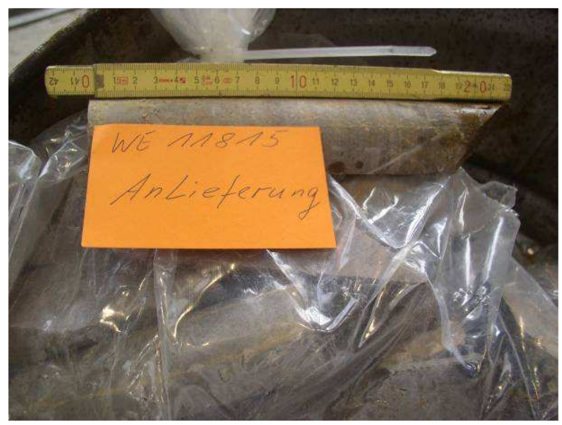
1. Introduction

Pacific Booker Minerals Inc., consulted by Wardrop Engineering, initiated a test program at Polysius AG in Germany to investigate the application of High Pressure Grinding Rolls (HPGR's) at their copper/gold/molybdenum porphyry project in the Morrison Lake area, Northern BC.

Ore samples were received in two shipments, 4 drums each, containing a gross weight of 1720 kg. The samples consisted entirely of drill core, which was crushed to < 1¼" for testing. The tests were carried out in a semi-industrial HPGR at three different pressure levels. Closed-circuit tests were simulated using a 6 mm screen. Standard Bond and POLYSIUS laboratory mill (LABMILL) grinding tests were done on the material before and after pressing to determine the extent of weakening of the material. Furthermore, abrasion tests were carried out at different moisture contents to determine the wear life of the rolls.

Earlier testwork carried out on drill core at SGS Lakefield indicated Bond Work Indices ranging from 11- 23.5 kWh/t, with an average value of 16.4 kWh/t.

Shipment - 2 of 8 drums - 1620 kg net



Drill Core Samples

2. Summary

The feed and product size distributions from open circuit runs in the HPHR on the ore are shown in Figure 1. Increasing pressure had very little effect on the product particle size distributions. Also, moisture content variation had little effect on product PSD's. The main effect of these variables was on the throughput and specific energy consumption. These effects are examined in more detail in the report.

Results from closed-circuit tests with a 6 mm screen are shown in Figure 2. The actual cut size was about 5 mm. The screening was conducted dry, and was quite efficient, resulting in > 90% recovery of the amount of < 5 mm in the HPGR product. The P80 size was about 2.8 mm. It is expected that wet screening would yield very similar results.

The material was of low to medium abrasiveness, with an ATWAL wear index (ATWI) of 9-15 g/t. Wear life for the rolls was estimated at 7000 hours. Bond WI was 17.8 kWh/t before, and 16.1 kWh/t after HPGR, a reduction of 10% in ore hardness.

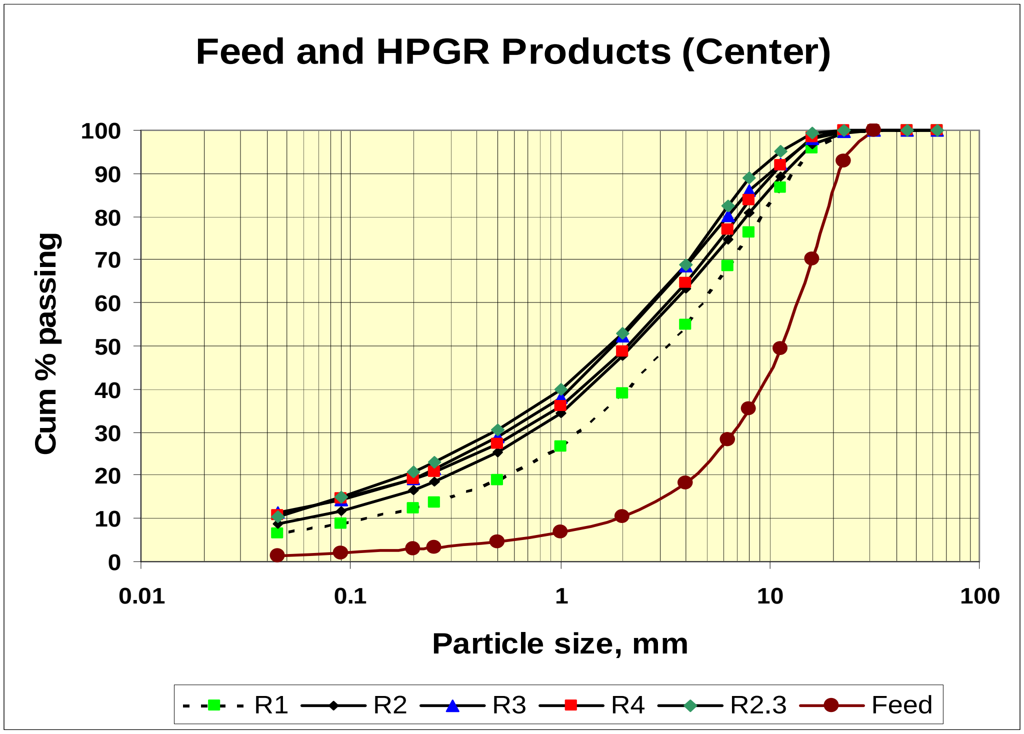


Figure 1. Results of a single pass through the HPGR.

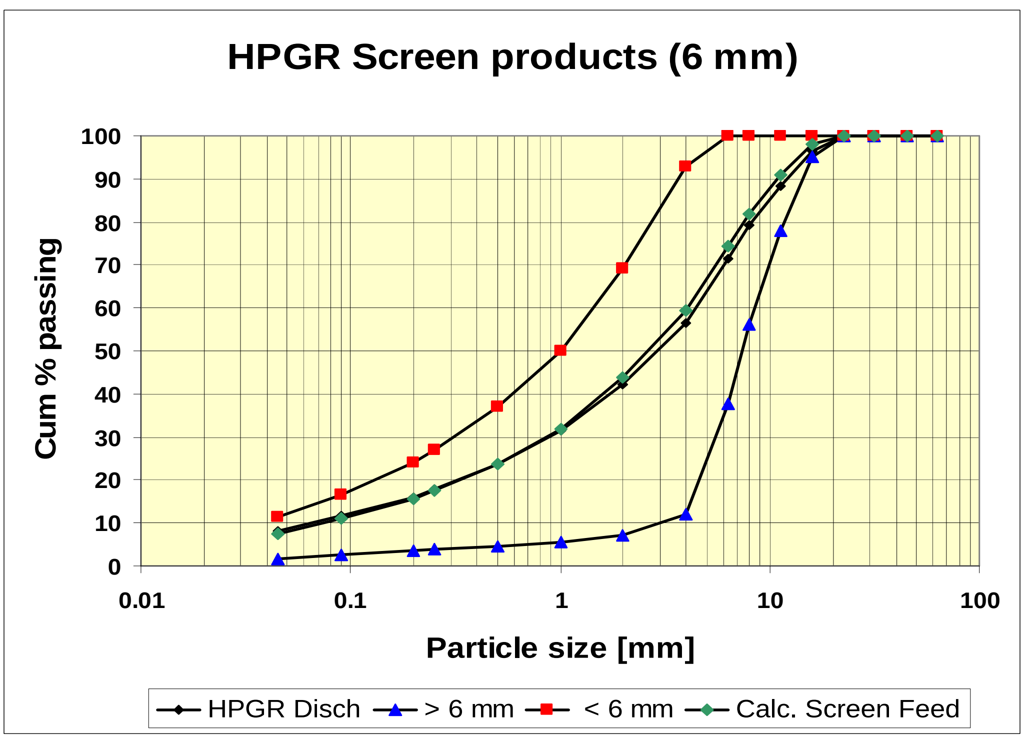


Figure 2. Results of closed-circuit testing in the HPGR.

3. Definition of terms used in testing of High-pressure Grinding Rolls

The key parameters derived from the results of testing in a HPGR are:

- the specific throughput rate
- the specific press force which should be applied to obtain a certain comminution effect
- the specific energy consumption
- the power required for a given throughput and size of rolls.

3.1 Specific Throughput Rate $\dot{m}$

The **specific throughput rate** $\dot{m}$ is defined as the throughput of a given size of machine divided by the projected area and circumferential speed of the rolls:

$$\dot{m} = M / (D * L * u) \quad [ts/hm^3]$$

M	[tph]	:	throughput rate
D	[m]	:	diameter of rolls
L	[m]	:	width of rolls
u	[m/s]	:	circumferential speed of rolls

<u>Note</u>: The **specific throughput rate $\dot{m}$** has units of ts/hm^3, corresponding to the throughput of a HPGR with rolls 1 m in diameter x 1 m wide operating at a roll speed of 1 m/s.

The **specific throughput rate** mainly depends on the <u>properties of the material</u> *(e.g., hardness, the physical density of the material, the particle-size distribution of the feed, and the moisture content);* the <u>grinding pressure</u>, and the <u>type of roll surface</u> employed.

However, the **specific throughput rate** depends only to a limited extent on the diameter and speed of the rolls and is therefore useful for scaling-up from a test unit to a full size industrial unit. HPGRs (and vertical roller mills) are unique among comminution devices in having a specific capacity term which can be assigned to the material and operating conditions.

3.2 Specific Press Force

The **specific press or grinding force** is defined as the total hydraulic force exerted on the rolls divided by the projected area of the rolls in units of N/mm^2 :

$$F_{(sp)} = F / (1000 * L * D) \quad [N/mm^2]$$

$F_{(sp)}$	$[N/mm^2]$	:	specific grinding force
F	[kN]	:	grinding force
L	[m]	:	width of rolls
D	[m]	:	diameter of rolls

This form is useful for comparing pressures on different sizes of HPGR units.

Note: The maximum grinding pressure in the gap between the rolls will be between 40 and 60 times the applied **specific grinding force**, depending on the nip angle. For mineral applications it is sufficient to define the **specific grinding force**.

3.3 Specific Energy Consumption

The **specific energy consumption $W_{(sp)}$** is the energy input which is absorbed per ton of material. It is proportional to the applied specific grinding force.

$$W_{(sp)} \sim c(F_{(sp)}, \dot{m}) * (F_{(sp)} / m) \quad [kWh/t]$$

$W_{(sp)}$	[kWh/t]	:	specific energy input
$F_{(sp)}$	[N/mm²]	:	specific grinding force
m	[(t*s)/(m³*h)]	:	specific throughput rate
$c(F_{(sp)}, \dot{m})$		:	factor (function of $F_{(sp)}$ and $\dot{m}$)

The proportionality is usually linear.

3.4 Power requirements.

The net power required for a given size of rolls is the product of the specific energy input $W_{(sp)}$ and the throughput rate M :

$$P = W_{(sp)} * M \quad [kW]$$

P	[kW]	:	power draw
$W_{(sp)}$	[kWh/t]	:	specific energy input
M	[tph]	:	throughput rate

The minimum motor power required is determined by multiplying the net power by a factor of 1.15 to account for any unevenness in the power draw of each roll. Final motor power is determined by the maximum power that can be transmitted by the gear boxes fitted to a given size of machine.

3.5 Specific Power

The net power required for a given size of rolls may also be derived from the specific power function.

The **specific power P_{SP}** is defined as the power used by a given size of machine divided by the projected area and circumferential speed of the rolls:

$$P_{SP} = P / (D * L * u) \quad [ts/hm^3]$$

P	[kW]	:	power draw
D	[m]	:	diameter of rolls
L	[m]	:	width of rolls
u	[m/s]	:	circumferential speed of rolls

The specific power varies linearly with the specific press force applied, and may be used to determine whether sufficient power has been provided for a unit with a given pressing capacity.

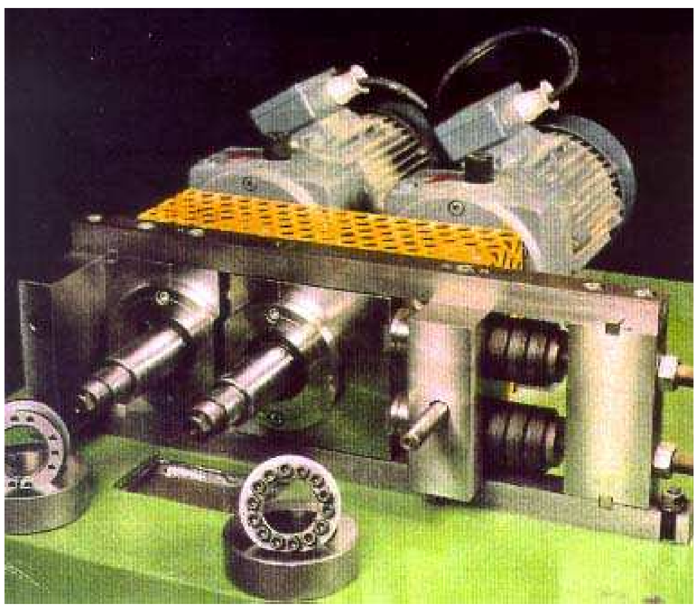
4. Description of Test Facilities

4.1 ATWAL Abrasion Testing High Pressure Grinding Roll

The ATWAL unit is used to determine the wear rates of different ores in High Pressure Grinding Rolls. About 100 kg of material are needed for one test run.

The ATWAL is equipped with smooth solid tyres made of Nihard IV. To ensure nipping of the material between the rolls, the feed is crushed to < 3.15 mm. The rolls are weighed before and after each test, and a specific wear rate is determined from the weight loss divided by the amount of material treated. This specific wear rate is then used to calculate the wear life to be expected on a industrial size HPGR unit.

The ATWAL is choke fed in order to achieve the maximum possible throughput. The grinding force, energy and specific throughput are measured, and the grinding force adjusted, if required.



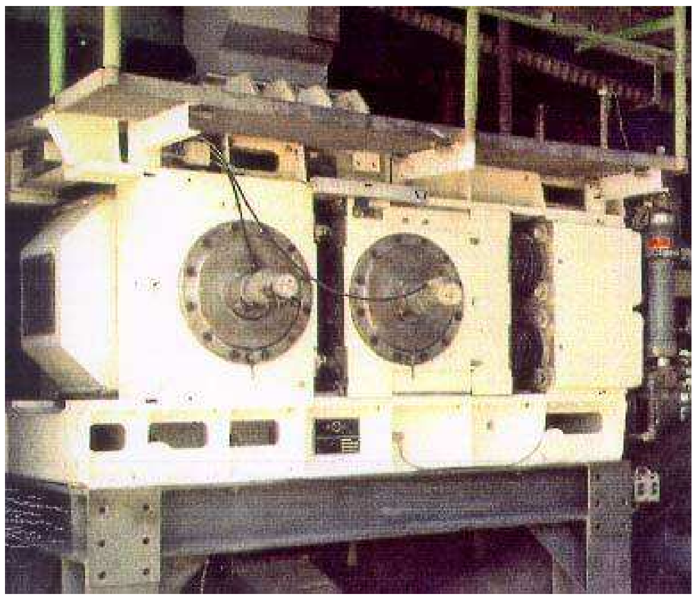
<u>Data of test unit:</u>

Diameter of rolls	: 0.10 m
Width of rolls	: 0.03 m
Speed of rolls	: 0.46 m/s
Top feed size	: 3.15 mm

4.2 REGRO Semi-industrial High Pressure Grinding Roll

Data of test unit:

Diameter of rolls	: 0.71 m	Speed of rolls	: 0.29 - 1.10 m/s
Width of rolls	: 0.21 m	Top feed size	: 16 - 35 mm



The REGRO is equipped with an autogenous wear protection surface in the form of studded liners.

Process data obtained from test work allows the sizing of industrial scale machines.

Data logging: feed rate,
zero gap ,cake thickness
preset nitrogen pressure, zero hydraulic pressure
operating hydraulic pressure
power draw of motors
circumferential speed of rolls

These data allow the calculation of process data such as:

- specific throughput rate
- grinding force and specific energy input
  required for achieving a certain product fineness

5. Test Programme & Results

5.1 Test Programme

The following test programme was approved by Wardrop Engineering. The client, Pacific Booker Minerals, witnessed the tests.

TEST PROGRAMME:

200 KLY
19/09/2007

Project: 2337 2992
WE: 11815

			Analysis
Provided material	< 25 mm 1500 kg		**PSD**, MC, BD, PD
REGRO feed	< 25 mm		PSD, MC, BD
ATWAL feed	< 3.15 mm		Fineness at 90, 250 and 1000 µm

	Test	Feed size	Quantity	Moisture	Pressure	Analysis Centre	Edge	Discharge
ATWAL	A1	< 3.15 mm	100 kg	1%	4 N/mm²			
	A2	< 3.15 mm	100 kg	3%	4 N/mm²			
REGRO	R1	< 25 mm	150 kg	natural	30/25	**PSD**, CD	**PSD**	
	R2	< 25 mm	150 kg	natural	40/30	**PSD**, CD	**PSD**	
	R3	< 25 mm	150 kg	natural	50/40	**PSD**, CD	**PSD**	
	R4	< 25 mm	150 kg	6%	40/30	**PSD**, CD	**PSD**	
Feed preparation: cont'd with product of R2								
Locked-cycle	R2.2	< 25 mm	150 kg	natural	40/30	**PSD**, CD	**PSD**	
with 6 mm screen	R2.3	< 25 mm	150 kg	natural	40/30			
	R2.4	< 25 mm	150 kg	natural	40/30	**PSD**, CD	**PSD**	
Screen products								**PSD**
Bond	B1 (before)	< 3.15 mm	10 kg	dry				**PSD**
	B2 (after)	< 3.15 mm	10 kg	dry		*		**PSD**
LaborMühle	LM1	Crush < 6 m	10 kg	dry				
	LM2	R2.3 < 6 mm	10 kg	dry				

Abbreviations and comments

PSD: Particle size analysis
45, 90, 200, 250 and 500 µm
1, 2, 4, 8, 11.2, 16, 22.4, 31.5 mm, etc.

MC: Moisture content
BD: Bulk density
CD: Cake density
PD: Material density

5.2 ATWAL Wear Test Results

Two ATWAL Wear Tests were carried out on the test material, one on dry material with 1% moisture, and one on wet material with 3% moisture. The results of these tests are given below.

Test	Material	Feed size	Moisture	Specific throughput	Spec. grinding force	Specific wear rate
		[mm]	[%]	[ts/(h m³)]	[N/mm²]	[g/t]
A 1	copper ore	0 x 3.15	1.0	118.4	4.0	9.84
A 2	copper ore	0 x 3.15	3.0	155.8	4.0	15.7

Table 2: ATWAL high pressure grinding wear tests

The tests indicated a low to medium wear rates of 9-15 g/t for the material on the ATWAL testing unit. The wear rates given refer to Nihard IV at the specific conditions on the ATWAL abrasion test unit. They do not reflect the wear rate on full size industrial rolls.

Corresponding wear rates on the ATWAL for other ores are given below:

Other ores	:	very abrasive	> 40 g/t
		medium abrasive	10 to 40 g/t
		low abrasive	< 10 g/t

Scale-up to full size industrial rolls takes into account the final roll diameter and speed of the rolls selected, type and length of the studs employed, as well as the feed characteristics of the material to be treated, i.e. size and moisture. The scale-up is based on a data collected on various ores treated in industrial High Pressure Grinding Rolls.

Preliminary estimates for an industrial size unit would indicate a wear life for the rolls of approx. 7000 h.

5.3 Semi-industrial High-pressure Grinding Tests on the REGRO

Preliminary REGRO tests were run at three different press forces on dry material. Then locked-cycle tests were run with medium pressure in closed-circuit with a 6mm dry screen. The influence of press force and recycle of the oversize on:

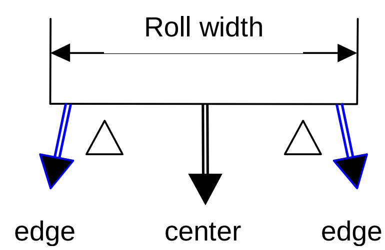
- the specific throughput
- the specific energy input
- the product fineness.

is given in the Table below.

Test no:	Moisture	Specific	Specific	Specific	Specific	Product fineness (center)		
		Press Force	Throughput	Power	Energy	Cumulative % passing		
	[%]	[N/mm²]	[ts/hm³]	[kWs/m³]	[kWh/t]	8 mm	2 mm	0.025 mm
Open- circuit								
R1	1.00	2.59	229.6	320	1.40	76.18	38.80	13.70
R 2/2.1	1.00	3.49	218.0	386	1.77	80.95	47.60	18.40
R3	1.00	4.22	210.6	445	2.11	86.17	52.40	21.60
R4	4.10	3.45	221.8	438	1.97	83.68	48.80	20.70
R2.2	1.00	3.59	220.6	383	1.74	-	-	-
Closed-circuit with 6mm screen								
R2.3	1.00	3.69	225.8	384	1.70	88.87	52.80	23.00

Table 3: Summary of REGRO semi-industrial scale test results.

The feed and product particle size distributions were analysed by dry screening. The discharge of the REGRO was split into a centre and an edge portion. Both portions were analysed separately. Part of the products from the rolls were in the form of compacted flakes, which required de-agglomeration for sizing. The material was de-agglomerated in a rotating drum prior to screen analysis.



The size analysis of the feed and HPGR products are shown in Figures 3-4. The average P80 size achieved in the total discharge was 10 mm; the avg. P80 size in the centre product was 7 mm. The size distributions varied narrowly around these points, indicating that the effect of pressure and recycle on the size reduction was minimal.

The material formed weak flakes, and screening was quite efficient even on a dry basis, Figures 5-6. The circulating load obtained from the dry screening was < 60%, and was expected to be slightly lower from the wet screening.

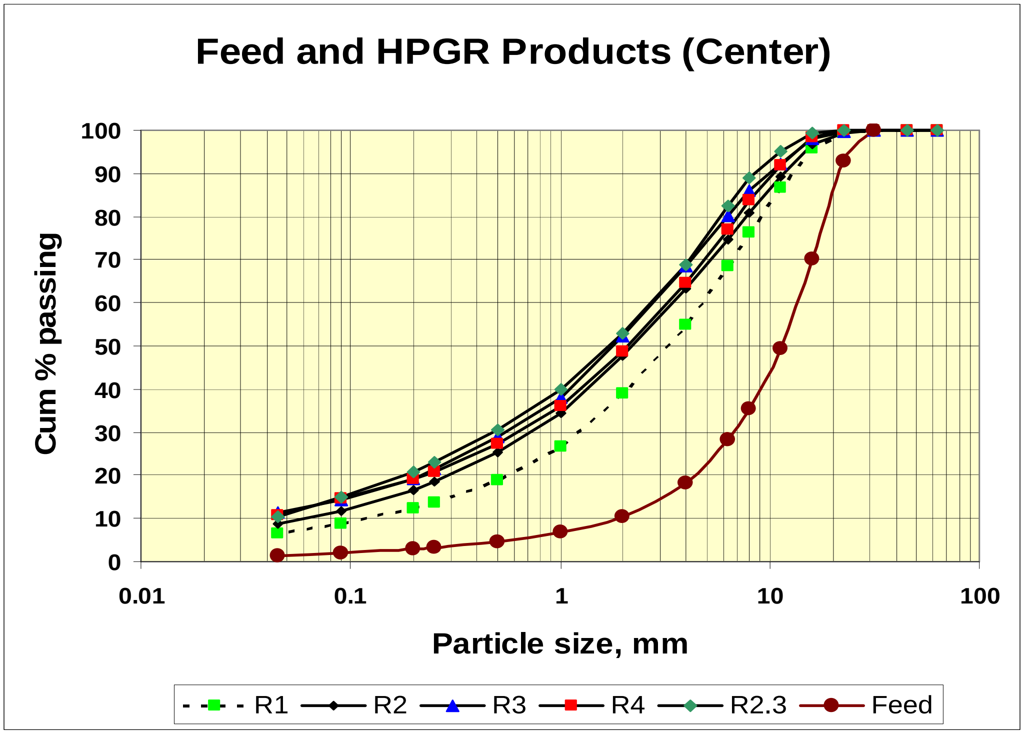


Figure 3. Size distributions feed and center products.

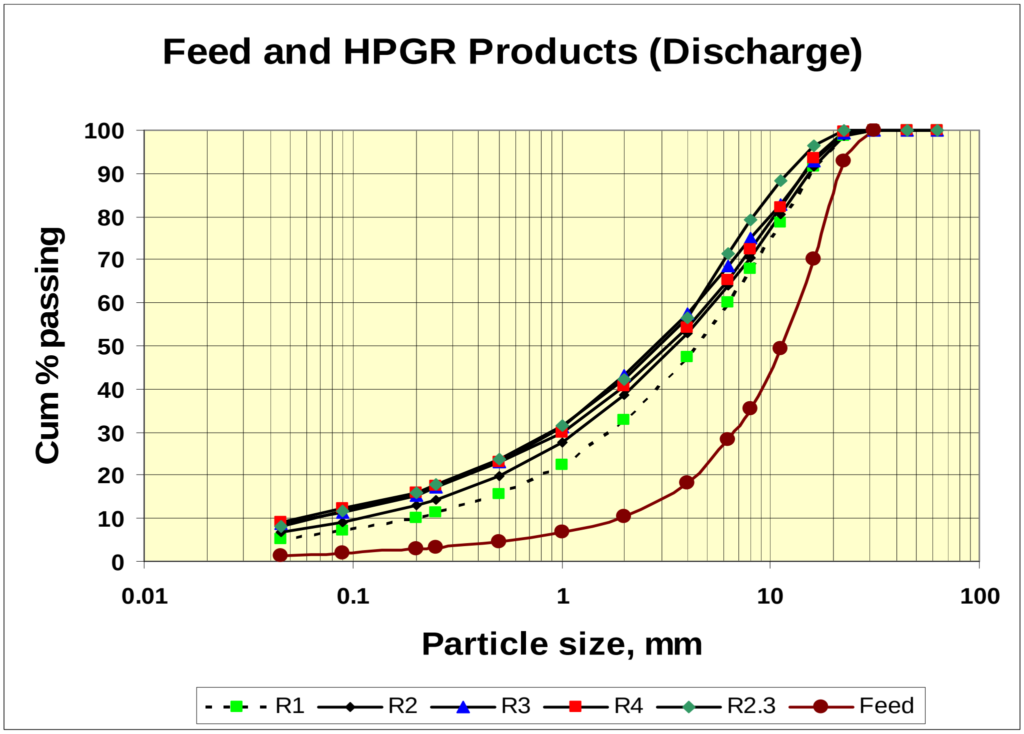


Figure 4. Size distributions feed and total discharge.

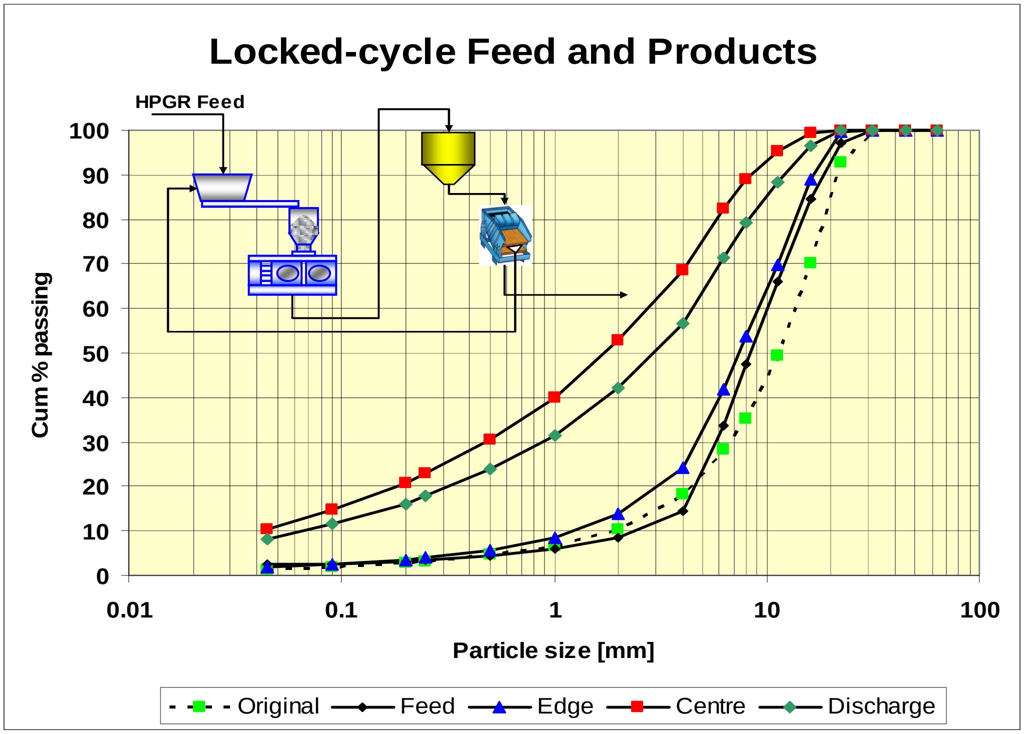


Figure 5. Locked-cycle test results, Test R2.3.

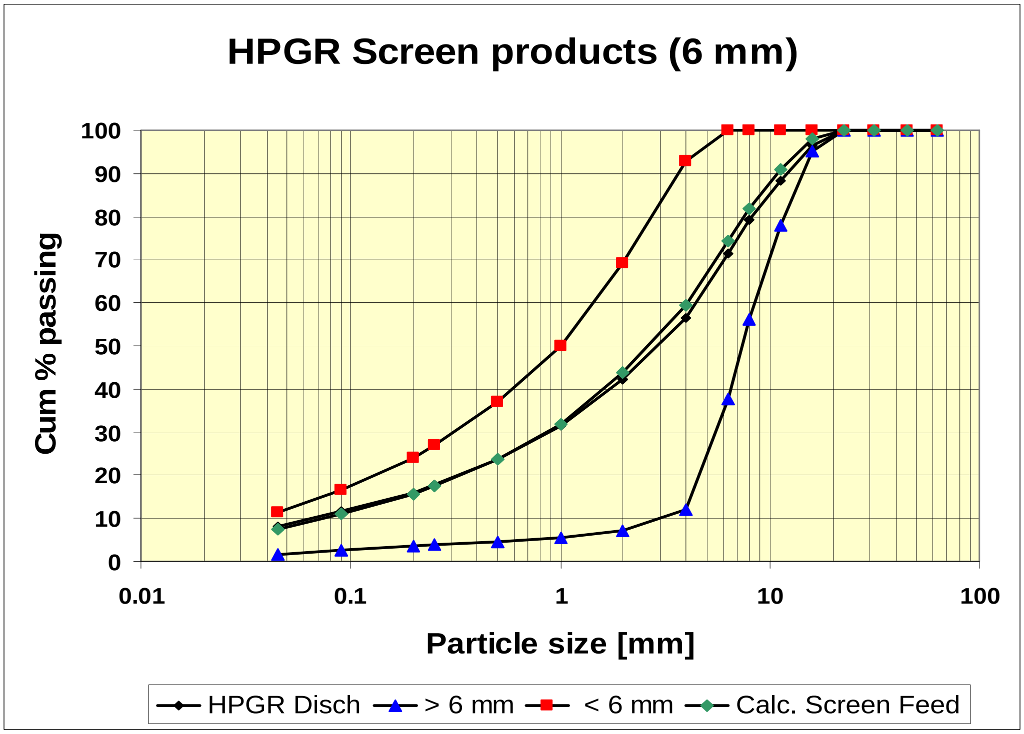
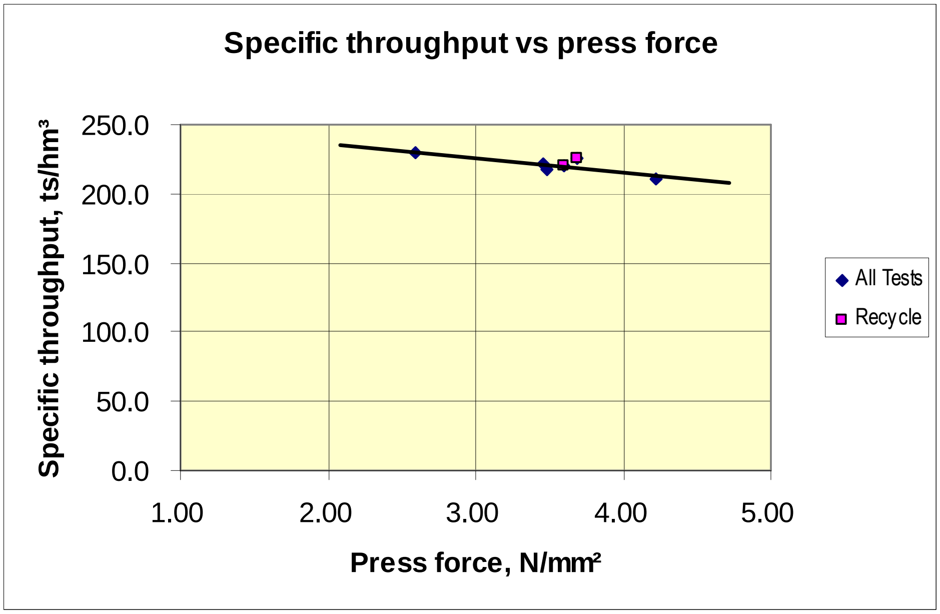


Figure 6. Size distributions dry screen products, Test R2.3.

5.4 Influence of operating conditions.

The influence of the specific press force and moisture on the specific throughput and power draw is shown in Figures 7 and 8. Both press force and moisture had little effect on the throughput. Average specific throughput was 220 ts/hm³ at 3.5 N/mm². However they had a significant effect on the power draw. Fig. 8. Moisture increased the power draw by 20%.



Figures 7. Variation of specific throughput with pressure.

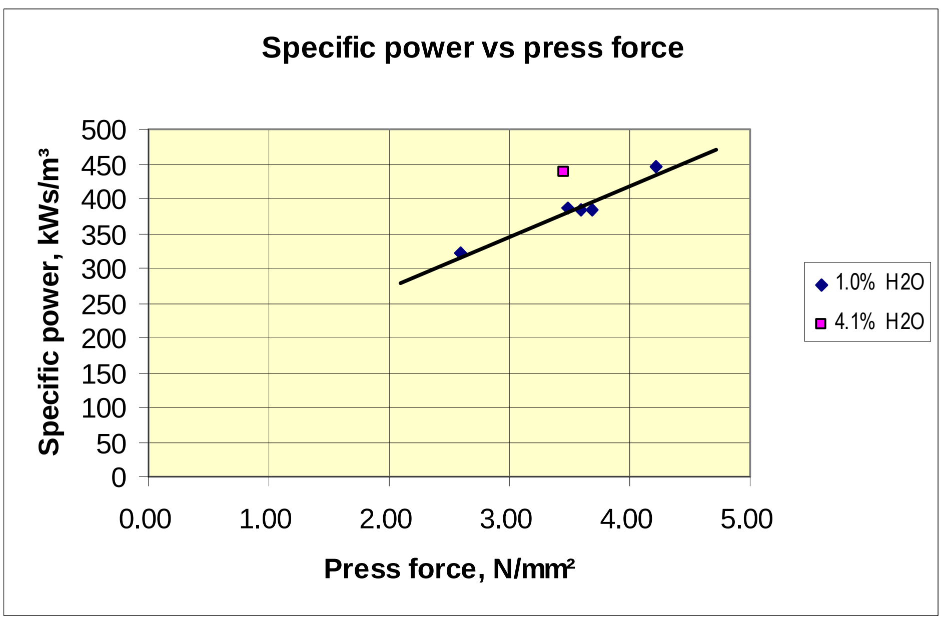


Figure 8. Variation of specific power with pressure.

For dry material, the specific power draw at 3.5 N/mm² was average for copper ores, 380 kWs/m³. Moisture increased this value to about 450 kWs/m³. The specific energy mirrored the specific power trend, resulting in 1.7 kWh/t for dry material and 2.0 kWh/t for wet material at a press force of 3.5 N/mm².

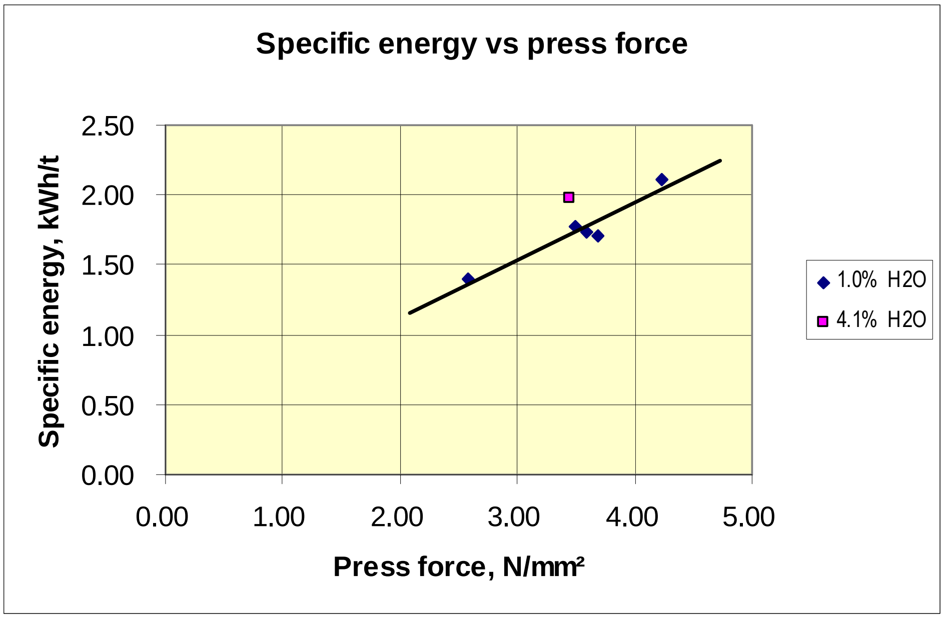


Figure 9. Variation of specific energy with pressure.

Figures 10 and 11 show the effect of grinding pressures on the product fineness. At pressures > 3.5 mm, there was little increase in product fineness, Figure 10. The optimum press force necessary was found to be 3.5 N/mm², see Figure 11.

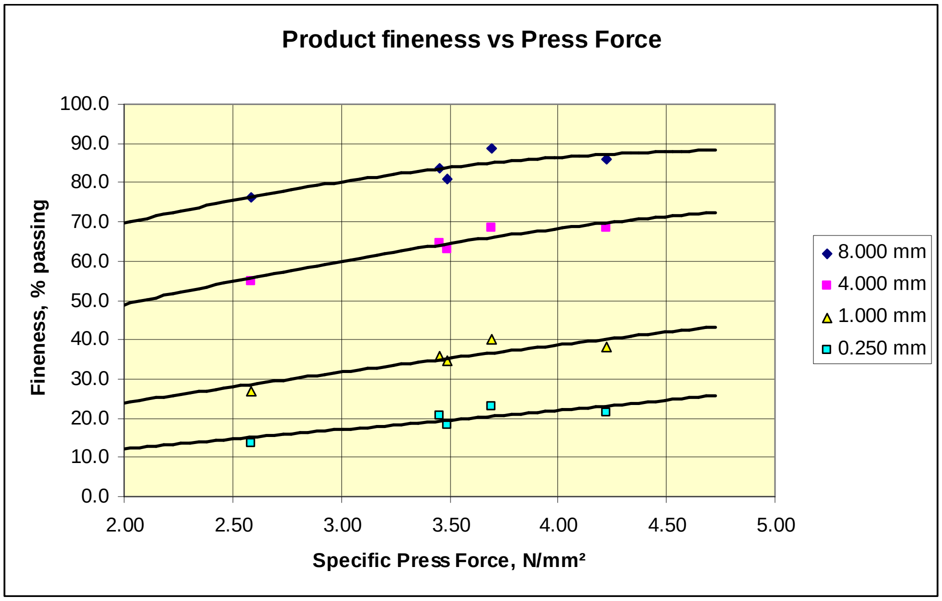


Figure 10. Variation of Product fineness with pressure.

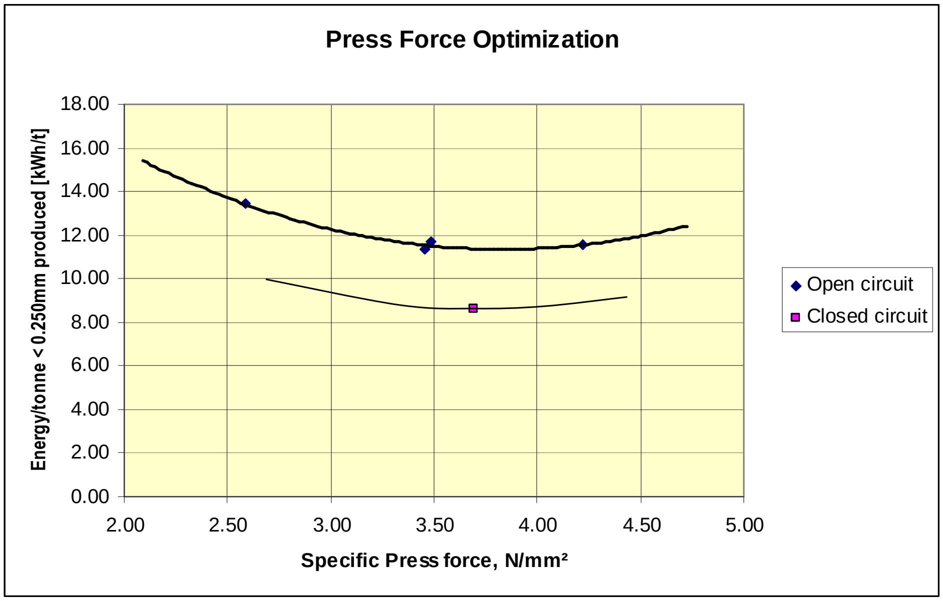


Figure 11. Variation of Product fineness with pressure.

6. Grinding Tests

6.1 Standard Bond Tests

Two standard Bond grinding tests were performed on the material: one on the original feed; the second on product of Test R 2.3 (from closed-circuit with dry screening). The results are given in the Table below. Size analyses of the Bond test feed and products are shown in Figures 12 & 13. The value obtained on the original feed was 17.8 kWh/mt. Treatment in HPGR resulted in a 10% reduction in the WI to 16.1 kWh/t.

Table 4. Summary of Standard Bond Test Results.

	Pi	Gbp	F80	P80	Wi (st)	Wi (mt)
Original ore	90	0.92	2541	64.7	16.2	17.8
R2.3 Product	90	1.06	2108	64.5	14.6	16.1

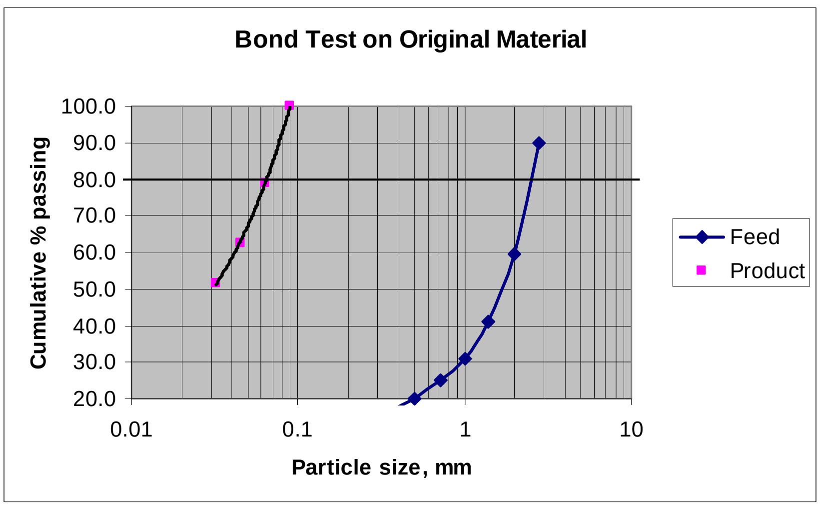


Figure 12.

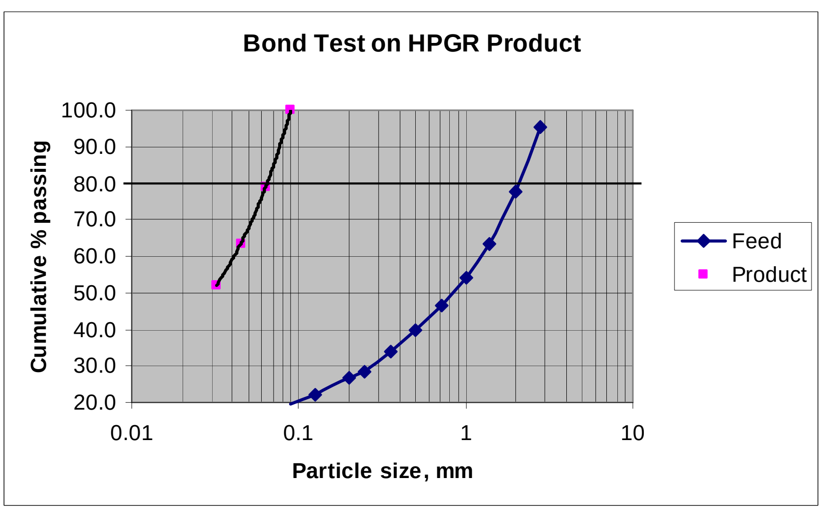
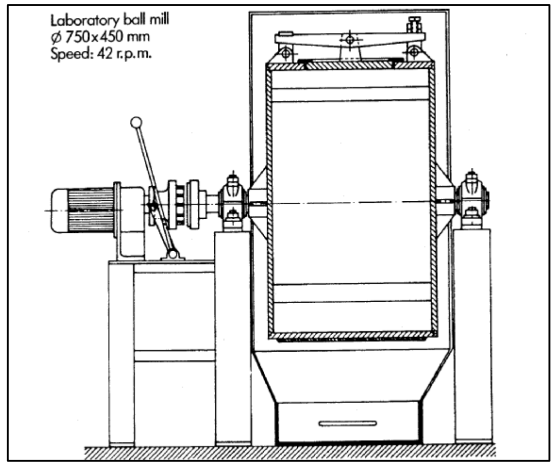


Figure 13.

6.2 POLYSIUS LABMILL Grinding Tests

The LABMILL grinding test was designed specifically for testing HPGR products without pre-crushing of the product for the test. The test is conducted dry in a 750 mm diam. x 450 mm wide ball mill on 7.5 litres of material. The feed, up to 30 mm in size, is ground stepwise using different ball gradings. The ball grading for each step is selected according to the material fineness. The energy consumption and material fineness is determined after each step.

The results are evaluated by plotting the specific energy consumption, in kWh/t, against the product fineness at a given size. Usually two sizes are selected, 90 µm and 200 µm. Linear regression lines are drawn through the points, and estimates are made of the energy required to achieve 80% passing a given size.



A comparison is then made between the energy required for the original feed and for the HPGR product, and the energy savings are calculated from the results. To even up the comparison, the feed was crushed to the top size of the product.

Industrial energy requirements may be calculated from the test results by applying scale-up factors. The LABMILL test is able to provide a realistic comparison of the ball mill energy required for materials with different size distributions. A summary of the LABMILL test results is given in the Table below.

Table 5. Summary LABMILL test results.

	LABMILL Grindability Test Results				
GRIND	**HPGR Feed**		**HPGR Prod.**		**Savings, %**
80% < 200µm	7.07	**kWh/t**	6.06	**kWh/t**	14.2
80% < 90µm	10.62	**kWh/t**	9.27	**kWh/t**	12.7
100% < 90µm	13.76	**kWh/t**	12.28	**kWh/t**	10.8

These indicated a potential energy saving at a P80 of 200 µm of 14% and at a P80 of 90 µm of 12%. Size analyses of the feed size distributions used in the tests are shown in Figure 14.

The energy-size relationships obtained in the tests are shown in Figure 15.

The results indicated higher energy savings than the Bond Tests. The difference in the results is attributable to the larger amount of fines generated in the product by the HPGR, which is not accounted for in the Bond calculations.

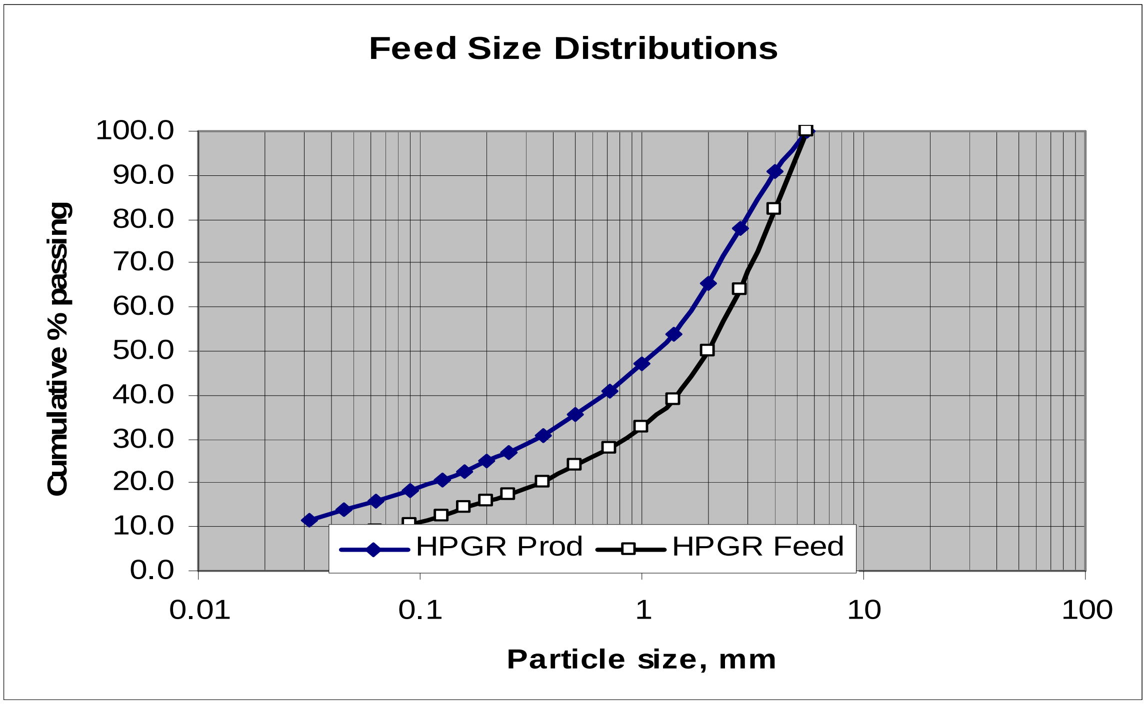


Figure 14. Feed to the LABMILL tests.

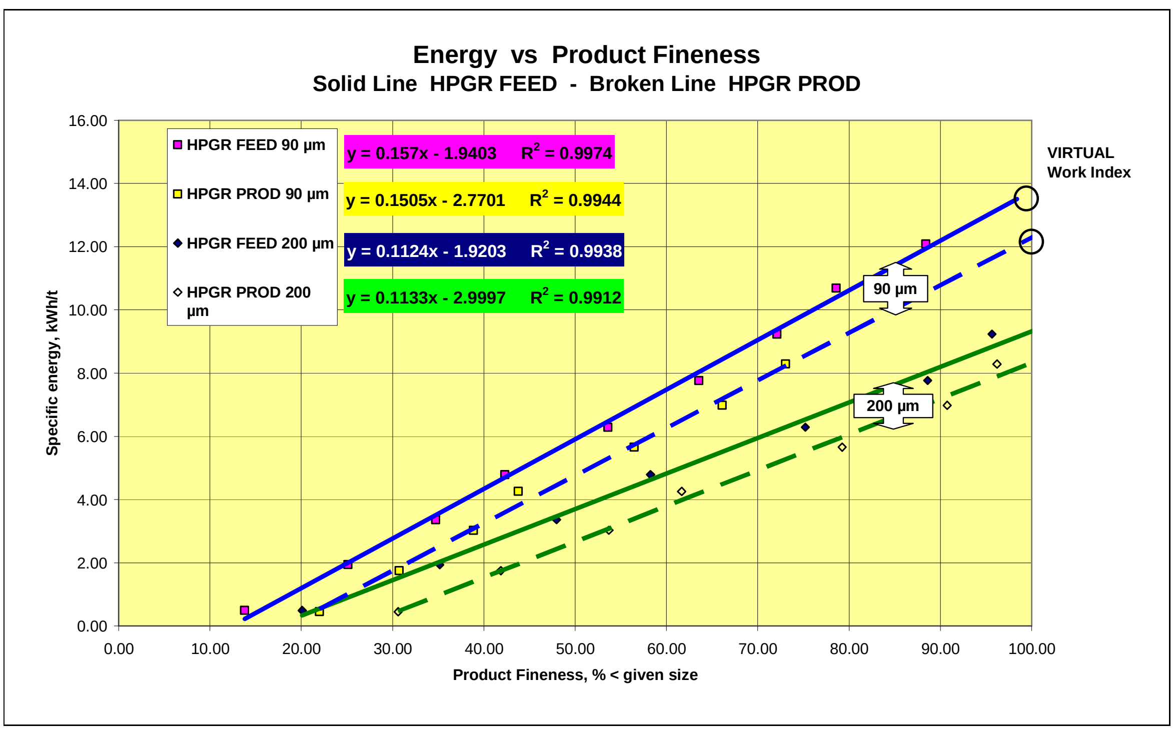


Figure 15. LABMILL energy vs product fineness.

7. Conclusions

1. The material was found to be of low to medium abrasiveness, ATWI index 9-15 g/t. The wear life of the rolls was estimated at 7000 h.

2. The size reduction achieved was better than average for copper ores, > 80% < 8.0 mm, >50% < 2 mm, >20% < 0.2 mm. Increasing pressure had a minimal effect. The max specific press force necessary was 3.5 N/mm².

3. The specific throughput for design purposes was 220 ts/hm³. Recycling of oversize in a closed-circuit operation had no significant effect.

4. The net specific energy consumption was 1.7 kWh/t at a specific press force of 3.5 N/mm² for dry material, and 2.0 kWh/t for wet material with 4-5% moisture content.

5. The material did not form competent flakes on pressing, and could be screened with relatively high efficiency.

6. The Bond Work index of the sample tested was 17.8 kWh/t before and 16.1 kWh/t after HPGR. Pressing in the HPGR resulted in a 10% weakening of the material, through the formation of micro-cracks.

7. LABMILL tests indicated potential energy savings in the order of 14% at a P80 size of 200 µm and 12% at 90 µm from the greater amount of fines created by the HPGR.