SMALL-SCALE CONTINUOUS SAG TESTING USING THE MACPHERSON AUTOGENOUS GRINDABILITY TEST

AUTHORS: ANDRE MCKEN, GUILLAUME CHIASSON - SGS

ABSTRACT

The MacPherson Autogenous Grindability Test is a continuous test performed in an 18” (46cm) semi-autogenous mill, with an 8% ball charge and controlled by sound at 25% mill charge level. At test completion, the products are submitted for particle size analysis, and the mill charge is dumped and analysed to evaluate any coarse and/or heavy material build-up in the mill. Although the importance to achieve a steady state in a grinding test is widely accepted, the MacPherson test remains the only small-scale AG/SAG test that offers this opportunity. It offers a cost-effective alternative to pilot plants for continuous testing of multiple samples.

INTRODUCTION

Fully-autogenous (FAG) and semi-autogenous (SAG) mills were first used on ores in the 1950s, but they were not seriously considered by the mining industry until the 1960s. By the 1970s, most designers of new plants considered AG/SAG grinding, even if it was not used in the final grinding circuit design. In the 1980s, many of the grinding plants that were built used FAG or SAG mills, and to decrease overall operating costs, many operators of older conventional milling plants considered and actually retrofitted their plants with AG/SAG mills.

Historically, the most widely used method to establish the AG/SAG grinding requirements for processing an ore from a deposit was to obtain bulk samples, each weighing 10 to 100 tons, and grind them in a test grinding mill having a minimum diameter of about 5.5 feet. These programs can be very expensive, especially if the ore grindability is variable, and/or if it is buried hundreds of meters underground. The difficulty of obtaining representative samples with 150-200mm top size for pilot plants was often a challenge which called for the development of a small-scale test that could be performed on drill core.

The MacPherson autogenous grindability test [1], which is performed in an 18 inch diameter dry mill, was developed for this purpose, and the results from the test have been used for many years to design commercial grinding plants. The MacPherson Autogenous Grindability test is performed with a light ball charge (8%), so it is actually a SAG mill test, but the results from the test have been used for the analysis of both fully-autogenous (FAG) and semi-autogenous (SAG) circuits (the fine feed size to the mill would not generate sufficient impact energy in FAG model). In this paper, for simplicity sake, the term autogenous grinding refers to both FAG and SAG grinding.

In the last 10 years, smaller-scale tests have been developed to further address the variability of ore types, most notably the MinnovEX SAG Power Index (SPI) test [2], and more recently, the SAG Mill Commination (SMC) test [3], developed by Steve Morrell. These constitute the third generation of increasingly smaller-scale autogenous grindability tests, which are dominating the market nowadays, because of their relatively low costs and sample requirement which makes them ideal for the characterization of widely variable deposits. The advent of these super-small-scale grindability tests, and associated interpretation tools (most notably the CEET software [4]), have largely contributed to increasing the level of knowledge of complex deposits through geometallurgical mapping [5], [6]. Providing that a sufficiently large number of tests are carried out, the test results can be used directly in the block model, supplemented by geostatistics [7].

Due its relatively larger scale, the MacPherson Autogenous Grindability test can only be performed on a limited number of samples, but it remains a cheap alternative to a pilot plant to assess the continuous response of ore samples to autogenous grinding. Over the years, more than 800 tests have been performed on more than 500 deposits, providing a large database for comparison [8].

This paper reviews the test procedure and discusses the deliverables of the test through case studies. The relevance and position of the MacPherson Autogenous Grindability test in modern test programs is also identified.

TEST DESCRIPTION AND DELIVERABLES

The MacPherson autogenous grindability test, as developed by Arthur MacPherson et al [1], is a continuous test performed in an 18” (46cm) semi-autogenous mill, with an 8% ball charge. The test is run until a steady-state is achieved similar to the Bond rod mill and ball mill tests. A draft fan supplies the airflow required to remove the ground material from the mill, and a collection system recovers the ground material from the air stream. This includes a vertical classifier, a cyclone and a dust collector (baghouse). The vertical classifier underflow is classified on a 14-mesh screen with the oversize returning to the mill.

SGS
The test requires material with a top size greater than 1-1/4", and sufficient weight to operate until all the steady-state conditions are met, and for a minimum of six hours. This can normally be achieved with less than 100kg, but typically, a 175kg sample is requested to allow for soft and/or dense ores.

The mill is fed from a hopper by a Syntron feeder actuated automatically by a Milltronics control system. This control system continuously regulates the feed rate by maintaining a pre-set sound level with a microphone located underneath the mill shell, controlling the mill level to 25% charge by volume. The circulating load is controlled to 5% by adjusting the airflow through the mill. The MacPherson mill is presented in Figure 1.

The test is run continuously, similar to a small pilot plant, for a minimum of six hours and until steady state is achieved. Every 15 minutes the test outputs, including the screen undersize, screen oversize, and cyclone underflow are collected and weighed separately. The screen oversize is returned to the feed tray as a circulating load, and the product weights and control settings are recorded. After five hours of operation, providing the throughput rate and the circulating load are stable, the sampling period can commence. The sampling is performed over a 1-hour period, at the frequency of every 15 minutes. The throughput rate and circulating load are maintained constant over the sampling period and two conditions must be satisfied for test closure, as follows (both conditions apply to the total mill output):

1. The difference between the highest and lowest values in the final hour must fall within 10%.
2. Values must vary either down/up/down or up/down/up in the last 45 minutes.

If these conditions are not satisfied, the first 15-minute interval is discarded and the sampling is continued for an additional 15 minutes, and so on until closure is achieved. After the sampling period, the mill is emptied and the charge level is measured. The level must fall within 11.6 and 12.2L, which corresponds to 25% volumetric charge, ±2.5%. If this criterion is not met, the entire mill load is returned to the mill, the set-point is adjusted to increase or decrease the mill load volume, and the test is extended for another 15 to 30 minutes. Once the load level has stabilized again, another one-hour sampling period is started. This procedure is repeated until all the conditions are met.

At test completion, the products are submitted for particle size analysis (PSA) determinations, and the mill charge is dumped and observed. The mill charge is also submitted to a PSA, and size-by-size specific gravity (S.G.) determinations. This allows the evaluation of any coarse material in the mill, or any mineral S.G. concentration. The final product consists of a blend of three streams: the 14 mesh screen undersize, the cyclone underflow, as well as the dust collected in the baghouse. A particle size analysis is performed on each stream and the final product PSA is recalculated from the flow rates and PSAs of the three products.

Because the test is run continuously, an actual steady-state throughput rate (kg/h) and a specific energy input (kWh/t) are obtained, which is unique to this test and desirable for autogenous milling, where the ability to control the product size is very limited. For a given power draw (kW), the specific energy input in kWh/t input is purely driven by the AG/SAG mill throughput, which in turn is driven by the dynamic of the ore. The traditional approach to measure the specific energy requirement was to run a pilot plant, in which the mill feed rate is controlled to maintain a constant mill charge set-point. The MacPherson mill is operated exactly the same way, so it offers a cost-effective alternative to compare kWh/t requirements on numerous samples.

The frequency distribution of MacPherson mill throughput rate and specific energy input are recorded in a database and are reported for comparison purposes. These are being presented in a separate paper presented at this conference [8]. The $P_{10}$ achieved in the MacPherson test, which is ore-dependent and indicative of the actual $P_{10}$ that can be obtained in industrial-scale mills, is also reported in a similar manner.

The mill charge PSA is compared to that of the feed to identify any coarse build-up. The size-by-size density of the rocks constituting the mill charge is also measured, as it can be significantly different from the feed, which could affect the power draw predictions, especially in fully autogenous or low ball charge applications. The mill charge analysis can also provide preliminary indications of pebble composition for pebble milling applications. Photos of the mill charges sized fractions are displayed in the report.

The mill power draw, throughput and product size distribution are used to compute a specific energy input and the MacPherson autogenous work index (AWI). A correlation factor is applied to arrive at the index used in the grinding circuit design, when the gross autogenous index is greater than 10.0 kWh/st, because the MacPherson mill becomes less efficient as the ore becomes harder.

Figure 1: MacPherson Autogenous Grindability Test Apparatus
An example of typical test results is presented for four ore types depicting different levels of friability and ball mill hardness in Table 1.

Competent ores (Bold) typically achieve low throughput rates in the MacPherson mill (6-7kg/ha, in this example), while friable ores normally exhibit significantly higher production rates (12-20kg/ha). Ore A, which has a high ball mill work index, delivered an average size product $P_{80}$ for the test, while Ore B produced a fine $P_{80}$. The fine product is typical of ores depicting a combination of high competency and low ball mill work index. These ores should be treated with a pebble crusher.

Friable ores typically deliver a coarser product, which is coherent with industrial experience. Ore C, which has a high ball mill work index (23.1 kWh/t) produced a much coarser product than Ore D, which generated high grinding rates at fine size due to its low ball mill work index (8.7 kWh/t).

The steady-state mill charge PSAs for these four tests are presented in Figure 2. It can be seen that Ore A, which depicts a consistently high level of hardness at coarse and fine sizes, also produced a consistent mill charge size PSA, similar to that of the feed. The other competent ore (Ore B), which had a low ball mill work index, produced a coarser steady-state mill charge PSA, with little intermediate material. Both competent ores depicted a slight build-up of coarse material greater than 9.5mm. Despite a relatively low A x b value of 64, Ore C was fairly friable and depicted high disappearance rates in the coarse sizes, resulting in a fine steady-state mill charge PSA. This was accompanied with a build-up of hard material in the intermediate fractions, a consequence of the very high ball mill work index (23.1 kWh/t). Ore D, which had the highest A x b value, also generated a fine charge, with less intermediate material, which is coherent with the low ball mill work index (8.7 kWh/t).

Note that the autogenous work index is not a good indicator of the autogenous mill performance in terms of production rate, because it is strongly affected by the product $P_{80}$. For example, the autogenous work index of Ore C was about 20% higher than that of Ore B, although it achieved a much higher throughput rate (70% higher). The MacPherson mill throughput rate or kWh/t should always be used to evaluate production rate performance, while the autogenous work index can be used to project the resulting size reduction. This subtlety has not always been understood by mill designers who often used the transfer size as a design criterion, although this parameter cannot be controlled in practice. Unlike rod and ball mills, it is very difficult to trade a coarser grind for an increased throughput rate with an autogenous mill.

WHEN SHOULD THE MACPHERSON TEST BE PERFORMED?

The MacPherson procedure is very robust, but the power-based interpretation has been gradually supplanted by more versatile computer-based models such as JKSimMet [9], [10] and CEET [4], which attempt to predict the effect of operating parameters on autogenous milling performance. These models, which rely on batch tests, do not provide any direct evidence of the ore’s capability to sustain performance over a long period in a continuous environment. Although most mineral processors will acknowledge the importance of steady-state testing (e.g. Bond rod mill and ball mill, or flotation locked-cycle test) in a test program, the MacPherson test remains the only small-scale autogenous mill procedure that offers this feature.

An autogenous circuit design should always be accompanied with some sort of steady-state validation, but the MacPherson grindability test will be especially essential in the evaluation of the following:

1. Heterogenous ores, or ores comprising a hard component
2. Effect of blends
3. Design of FAG, low ball charge SAG and pebble mills.

HETEROGENOUS ORES, OR ORE COMPRISING A HARD COMPONENT

Highly heterogenous ores, made of minerals of various S.G. and hardness compositions cannot always be appropriately evaluated with batch tests. The harder component of the ore is likely to dominate the mill charge and control the mill performance. The rock density of the mill charge can be significantly different than that predicted from the feed, which can result in power prediction problems in the design.
A heavy minerals concentration will be somewhat desirable as it will increase the power draw of the autogenous mill, but it may call for the installation of a larger motor to sustain the heavier load. On the other hand, a concentration of light minerals will be more problematic, as it will decrease the power draw, which may result in insufficient capacity. In that case, a larger shell will be required to achieve the design power. This potential problem will be especially important for design at low ball charge, where the ore contribution to the power draw will be greater. This is discussed further, later in this document.

Steady-state confirmation is particularly important when a hard component is present in the ore, which may or may not be known ahead of time. The hard component (which sometimes represents only a small fraction of the feed) can build up over time, and significantly hinder the mill performance, as presented in Figure 3, which shows the variation of MacPherson throughput and specific energy requirement over time for a gold project.

The throughput rate for this relatively soft ore (BWI = 13.6 kWh/t) gradually decreased over the test period from an original 7kg/h down to 4.4kg/h at steady-state, which was within the 3% lowest throughput rates of our database. A very significant build-up of coarse material was observed at test completion, as presented in Figure 4. The steadystate mill charge contained more than 47% plus 19mm rocks in the form of well rounded pebbles, compared to 26% in the feed.

It was concluded that this ore would produce a large quantity of pebbles in an industrial autogenous mill, which would ultimately turn into a critical size build-up. Because the ore was soft at finer size, the intermediate material was ground fairly rapidly, resulting in an imbalance in the SAG charge, which was principally composed of coarse material, and a very fine grind was produced ($P_{80}$ of 152 μm), within the 1% finest of our database. A pebble crusher was recommended in the design, to control this imbalance, by taking a fraction of the pebbles down to fine size (12mm), so it can be effectively returned to the mill and get ground by the remaining pebbles.

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>CWI (KWH/T)</th>
<th>RWI (KWH/T)</th>
<th>BWI (KWH/T)</th>
<th>MACPHERSON (KG/H)</th>
<th>AWI (KWH/T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.42</td>
<td>11.1</td>
<td>8.7</td>
<td>18.7</td>
<td>4.2</td>
</tr>
<tr>
<td>B</td>
<td>3.14</td>
<td>13.6</td>
<td>9.8</td>
<td>9.6</td>
<td>8.4</td>
</tr>
</tbody>
</table>

Table 2: Grindability Test Summary

An oxidized gold/silver ore provided another very interesting case study. Two composites, representing different zones (A and B), were submitted to the MacPherson Autogenous Grindability test, as well as the Bond series (low-energy impact, rod mill and ball mill). The grindability test results are summarized in Table 2. Both samples had consistent grindability characteristics over the Bond range (CWI, RWI and BWI) and were categorized as soft to very soft. They were therefore expected to exhibit similar performance in the MacPherson mill. Both samples were tested and, at steady-state, the throughput rate of Sample B (9.6kg/h) was only half that of Sample A (18.7kg/h), while the specific energy requirement was twice as high. As for the previous case, Sample B showed a significant decrease in throughput rate over the test period, while Sample A depicted a steady flow rate over the entire test period.
The explanation of this was found in the analysis of the mill charges obtained from both tests. The two feed samples were highly oxidized giving them a reddish color, but, interestingly, the steady-state ore charge of Sample B was mainly dominated by a grey (non-altered) harder component. This hard component, which was not readily identifiable from the feed or the work index results, built up over time and ended up controlling the throughput rate to the mill.

As a result, a third composite (Sample C), representing principally the grey component of the ore (or the worst-case scenario), was submitted to the test. This sample was definitely greyer than A and B, so a very low throughput rate was anticipated. Interestingly, this did not happen. The steady-state throughput rate stabilized at 10.2kg/h, roughly identical to Sample B, and remained consistent over the entire test period. The relative quantity of grey rocks in the feed did not make a significant difference on the steady-state mill charge or the mill production. This example was very eloquent, as the hard and soft components of the ore had distinct colors. Sample A and B were reddish, while Sample C was grey, but the grey material dominated the steady-state mill charge of both Sample B and C. This clearly showed how a hard component (small or large) can control autogenous mill performance.

EFFECT OF BLENDS

It is common to design an autogenous mill circuit based on a blend representing different ore zones of different hardness and mineral composition. This is somewhat equivalent to testing a heterogenous ore, as previously described. The performance of autogenous milling on a blend sample may be unpredictable, because again, the hardest of the components may dominate the mill charge and control production.

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>S.G.</th>
<th>DWT</th>
<th>RWI</th>
<th>BWI</th>
<th>EXPECTED MACPHERSON</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(G/CM3)</td>
<td>A X B</td>
<td>(KWH/T)</td>
<td>(KWH/T)</td>
<td>THROUGHPUT (KG/H)</td>
</tr>
<tr>
<td>Ore 1</td>
<td>4.49</td>
<td>174</td>
<td>5.3</td>
<td>9.0</td>
<td>39</td>
</tr>
<tr>
<td>Ore 2</td>
<td>3.24</td>
<td>32.9</td>
<td>15.9</td>
<td>12.8</td>
<td>5</td>
</tr>
<tr>
<td>Ore 3</td>
<td>3.04</td>
<td>27.9</td>
<td>21.6</td>
<td>23.3</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 3: Grindability Test Summary for three Ore types

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>RWI</th>
<th>BWI</th>
<th>MACPHERSON TEST</th>
<th>S.G. (G/CM3)</th>
<th>AWI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(KWH/T)</td>
<td>(KWH/T)</td>
<td>(KG/H)</td>
<td>(KWH/T)</td>
<td>P&lt;sub&gt;80&lt;/sub&gt; (M)</td>
</tr>
<tr>
<td>Blend 1</td>
<td>11.5</td>
<td>10.5</td>
<td>13.4</td>
<td>6.5</td>
<td>166</td>
</tr>
<tr>
<td>Blend 2</td>
<td>18.8</td>
<td>18.2</td>
<td>4.1</td>
<td>20.7</td>
<td>144</td>
</tr>
</tbody>
</table>

Table 4: Grindability Test Summary on the Blends

To illustrate the problem, let’s consider three ore types, with the hardness characteristics presented in Table 3. Ore 1 was a heavy Massive Sulphide, with a very high A x b and low work indices. Ore 2 was a relatively competent disseminated ore, with relatively low work indices. Ore 3 was somewhat similar to Ore 2 in terms of competency (A x b), but it had much higher work indices. Because there is a good correlation between the drop-weight test A x b value and the MacPherson throughput rate [8], the throughput rate presented in Table 3 were expected. Projections varied from 4kg/h for Ore 3 to 39kg/h for Ore 1. The test program and circuit design had to reflect the fact that these three very different ores would be blended in the plant.

Two different design scenarios were considered. The first scenario considered treating 46% of Ore 1 with 54% of Ore 2. Scenario 2 included a blend of all three ores, in the ratio 18:22:60.

The two blends were submitted to work index determinations, as well as the MacPherson test, which was the most appropriate way of evaluating the autogenous grindability characteristics of the blends. The results are presented in Table 4. The rod and ball mill work indices of the blends were very close to the weighted average that can be calculated from the blend ratios, but the MacPherson throughput rates were not. Blend 2 produced only 4.1kg/h, which is equivalent to what would be expected of Ore 3 if it was treated all by itself. The S.G. of the steady-state mill charge was strongly dominated by light rocks (S.G. = 3.00g/cm³) with very few metallic rocks.

The performance of the MacPherson mill was strongly affected by the presence of lighter/harder rocks, which built up in the charge, resulting in a low throughput rate. The presence of Ore 1 did not significantly contribute to a higher throughput rate. Instead, a very fine grind was produced, within the 1% finest of our database.

This illustrates how unpredictable the reaction of an autogenous mill can be to heterogenous blends. Blending soft with hard ores will not necessarily result in proportionally higher production rates.

DESIGN OF FAG, LOW BALL CHARGE SAG AND PEBBLE MILLS

The design of a fully-autogenous, or a low ball charge SAG and pebble mills, requires a good understanding of the mill charge dynamics. The mill must be capable of supplying grinding media in the form of coarse (and preferably heavy) pebbles at an appropriate rate. If the ore is too friable, a fine charge will develop and will be incapable of supplying adequate grinding rates. If the ore is too competent, the built-up of such pebbles may hinder the production rate of the autogenous mill. The MacPherson Autogenous Mill test offers a cheap alternative to a pilot plant for the evaluation of the autogenous mill charge.
The low ball charge option was considered for a base metal project consisting of sulphide and oxide zones, which were to be mined successively. The design strategy consisted of treating the hardest oxide ore with a low ball charge SAG mill, and potentially processing the sulphide ores fully-autogenously. The three ores were fairly dense, which is desirable for fully-autogenous milling, but the oxide depicted a bimodal distribution of light (2.6g/cm³) and heavy (3.8g/cm³) rocks, as presented in Figure 5, which made it difficult to predict the steady-state density of the mill charge.

The three ores were processed in the MacPherson mill with the objective of confirming their response to autogenous mill and evaluating the steady-state mill charge with respect to density and PSA. The grindability test results are presented in Table 5. The three ores were soft with respect to impact breakage, as indicated by the A x b values from the drop-weight test. Consequently, all three samples achieved very fast throughput rate in the MacPherson Mill, between 20 and 38kg/h, which represents the top 10% of the database. The three samples generated a fair quantity of coarse material as depicted in Figure 6, but nothing critical. Pictures of the ‘pebbles’ observed in the plus 25mm fraction of the three samples are presented in Figure 7. These were generally heavy, so they could, at larger scale, constitute good grinding media to supplement or even replace the steel charge in the autogenous mill. The oxide ore, preferentially built up a charge of heavier, darker and harder pebbles, which was desirable.

This exercise confirmed the amenability of this project fully-autogenous milling. The three ores achieved high throughput rates and generated an adequate quantity of heavy pebbles. It also confirmed the tendency of the oxide ore to generate heavy pebbles, from a bimodal feed density distribution. It was recommended to proceed with the design.

![Figure 5: Relative Density of Rock Particles](image)

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>NAME</th>
<th>A X B</th>
<th>KWH/T</th>
<th>KG/H</th>
<th>KWH/T</th>
<th>Pₘₐₜ (M)</th>
<th>FEED</th>
<th>S.G. (G/CM³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sulphide 1</td>
<td>107</td>
<td>4.8</td>
<td>7.4</td>
<td>38.2</td>
<td>2.8</td>
<td>189</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>Sulphide 2</td>
<td>160</td>
<td>5.5</td>
<td>10.0</td>
<td>37.1</td>
<td>3.0</td>
<td>319</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>Oxide</td>
<td>109</td>
<td>12.7</td>
<td>17.4</td>
<td>20.4</td>
<td>4.1</td>
<td>232</td>
<td>8.4</td>
</tr>
</tbody>
</table>

![Table 5: Grindability Test Summary](image)

![Figure 6: MacPherson Mill Charge Analysis](image)

![Figure 7: Plus 25mm Size Fraction in the MacPherson Mill Charge](image)
CONCLUSION

The MacPherson Autogenous Grindability test has been presented as a cheap alternative to pilot plant to obtain preliminary assessment of autogenous milling performance in a continuous environment. The test requires 175kg of rocks or drill core samples with a top size of 38mm, which is generally sufficient to operate the mill for 6 hours and until steady-state is achieved. The test produces the following deliverables:

1. A steady-state throughput rate and a kWh/t requirement, which are key components in the evaluation of autogenous mill production.
2. An autogenous mill product size distribution, which is indicative of the actual distribution that can be obtained in industrial mills.
3. An autogenous work index which quantifies size reduction in a continuous environment.
4. A steady-state mill charge, which is analyzed for particle size distribution and size-by-size rock densities.

The analyses of the mill charge can be used to evaluate pebble production for the selection of the circuit configuration. The rock charge density can be used to better predict the power draw of an autogenous mill, or any downstream pebble mills. Although it is not part of the standard deliverables, additional useful information may be obtained from the pebbles in the rock charge, which concentrate the hardest material in the ore. These pebbles can be impact-tested to evaluate worst-case scenarios or pebble crusher requirements. Pebble rejection could also be evaluated through assays and/or metallurgical testing.

This paper demonstrated the MacPherson Autogenous Grindability Test as a valuable tool to evaluate the continuous response of ores to autogenous grinding and the long-term negative effect of hard mineral components, which can sometimes be unpredictable. In the absence of a pilot plant confirmation, the MacPherson Autogenous Grindability test constitutes the most appropriate alternative to eliminate surprises, and reduce the overall risk of a project. This will be especially important for heterogenous ores, or blends which cannot adequately be evaluated with batch tests.

Although the importance of steady-state testing is acknowledged by most mineral processors, the MacPherson Autogenous Grindability test currently remains the only widely used autogenous bench-scale procedure that has this capability.

The MacPherson autogenous grindability test does not attempt to replace pilot testing, nor is it a substitute for other grindability testing procedures, which have their own strengths [11], [12], but it should be included in a modern test program.

REFERENCES


CONTACT INFORMATION

Email us at minerals@sgs.com
www.sgs.com/mining