

DEVELOPMENT PLANNING FOR SAG MILL DESIGN

Progress Bulletin

Starkey & Associates (“Starkey”) was established in 2000 and is recognized as a world-class leader in SAG mill and SAG grinding circuit design. In 2002, John Starkey invented the SAGDesign Test which accurately and consistently quantifies macro-ore hardness (over 3mm), and micro-ore hardness, done on SAG ground ore, as the basis of SAG mill design. The test consists of a robust bench scale laboratory batch SAG test followed by a Bond Ball Mill Work Index test on SAG ground ore. SAGDesign is the only bench-scale test that accurately measures hard ores (exceeding 15 kWh/t to grind the ore from F80 152 mm to T80 1.7 mm).

The SAGDesign laboratory network, comprises 15 independent laboratories, and is managed by Starkey, to direct and provide SAG mill grinding tests and mill design services to clients worldwide. Starkey also offers a wide range of consulting services including plant start-up assistance and overall concentrator process design. It also reviews existing operations, performs due diligence studies and conducts grinding design seminars at international mineral processing conferences. In 2020 Starkey patented the Lab-Scale Continuous Starkey SAGDesign Wet SAG Mill (Mini Pilot SAG Mill) to fulfill a need in the mining industry to economically pilot test the grinding and beneficiation of every mining project, whether for a new open pit or underground mine, or for re-evaluation of producing properties, using standard commercial diamond drill core for this pilot plant research testing.

The tie-in of pilot plant SAG mill results to commercial comminution, using minus 1-inch crushed diamond drill core for feed, is the breakthrough discovery that has allowed pilot plant beneficiation results to be done on a small scale, using 100% minus 1 inch SAG mill feed. Pre-crushing mined ore to ~1 inch is known to reduce commercial SAG energy by about 25%, so the laboratory SAG test must therefore provide 75% of the energy that is required by a commercial SAG mill (measured in kWh/t). That is why the SAGDesign test is so accurate. It also will be the reason that the Mini Pilot SAG Mill will produce representative metallurgical results for beneficiation testing, when considering breakage, mineral liberation and slurry chemistry.

Readers are encouraged to look at the Starkey web site <https://www.sagdesign.com> and the many papers and articles on SAG mill design. Starkey is unbiased in SAG mill design as it has no relationships, tie-ins or agreements with comminution equipment manufacturers. Starkey recommends that mine owners find out the correct size of the SAG mill required for a project using SAGDesign technology, before requesting a quote from a mill manufacturer who must then bid to the specified mill size. Alternate sizes can be bid, but accepted bids for new mills must include the correct specified mill size and power.

Since 2019 Starkey has focused its efforts on the development of its new Mini Pilot SAG Mill but has been held back by COVID-19 in starting-up the Mini Pilot SAG Mill and marketing this new capability. Moving forward, Mr. Starkey will be turning over control of his company to new skilled managers over a period of several years. To help market its new products and promote controlled growth of the company, Starkey is considering creating up to 12 Master Licenses for major mining companies, through an agreement whereby for a one-time fee, the licensee will gain the use of all Starkey laboratory test services on a discounted cost basis with no royalty component. This will allow more lower cost laboratory tests to be done which may include timely and more detailed re-evaluations of ore bodies for better control of operating SAG mills. Starkey invites those companies which have a preference for using other testing methods, to parallel those practices with Starkey's accurate, yet inexpensive design methodology as "production insurance" when new mills are being purchased. Case studies show that Starkey's analysis can significantly alter design parameters of new SAG mills. That is why Starkey designed mills work as intended and are capable to produce design tonnage at start-up with no extra capital expense or lost production during the first two years.

Starkey's patented continuous lab scale SAG mill allows for full metallurgical process design research and testing to be done on small ore samples, including standard drill core taken from deposits that will be future underground mines. Starkey believes that some international mining firms will take advantage of this Master License offer, and some of these will be new clients for Starkey. The resulting increased laboratory work will benefit all of Starkey's independent lab associates who have full supporting knowledge and expertise for conducting SAGDesign tests.

These labs will, of course, continue to serve the mining and exploration markets-at-large (non-licensees), but on the normal combined fee and royalty basis. Royalty fees assure Starkey's growth, oversight of projects, and further development of its patents.

In summary, creating Master Licenses will benefit the mining industry in several ways:

- For large Mining Companies, Laboratory SAG testing will be more economical as it will have no laboratory royalty fee, when ordered through Starkey directly.
- This will set a leadership guideline for smaller companies, that SAGDesign testing is not only acceptable, but preferable, and widely used.
- More tests will be run, including ore hardness re-evaluations for finer process tuning in existing comminution operations.
- Mill designs and mine planning can be paralleled with expert expanded input because SAGDesign SAG test results can be kriged in a mine plan.
- By having SAGDesign technology in-house as "insurance", any erroneous outside input can be rationalized, and corrected before the purchase of an incorrectly sized SAG mill.
- Starkey provides in-house audit capability which may be non-existent at a given plant due to limited continuing internal resources in project centered corporations.
- Reliance on consultants' or equipment manufacturers' biases or hidden conflicts of interest can be eliminated.
- Ore bodies mined from underground workings can, for the first time, be properly tested using drill core for pilot plant SAG mill feed, to optimize and identify the recovery that can be expected. Ores with SAG hardness exceeding 15 kWh/t (to grind from F80 152 mm to T80 1.7 mm), can be accurately tested, where all other technologies fail badly to measure the real hardness which can vary up to 30 kWh/t in rare cases.
- Autogenous grinding is included in SAGDesign technology because zero percent steel in a SAG mill is in fact, fully autogenous grinding.

Smaller mining firms can always rely on hiring Starkey to provide and manage a full comminution testing program (mill design and/or geo-metallurgy) and needed front end project design skills. Starkey's goal here is to introduce its capabilities to a broader market, while not disrupting its

base markets and relationships. Expanding the usage of SAGDesign technology will benefit the mining industry as noted above, and at the same time assure Starkey's growth.

Starkey has published results of a number of design case failures where undersized SAG mills were used to save a few million dollars in the price of the SAG mill, leading to production losses of \$100's of millions after start up. Also, mill design testing with 2 competitive methods in one project cost over \$500,000, leading to conflicting design parameters which Starkey resolved for about \$30,000 using SAGDesign test results. Starkey has a history of providing throughput solutions which deliver t/h from a SAG mill as promised. Accuracy of the SAGDesign SAG test energy result has been shown, in round robin testing at 8 labs in 2012, to be less than +/- 5%.

Interested Master Licensee eligible mines are invited to follow up with Starkey to examine what is offered in detail. That may include a Licensee acquiring its own in-house batch-laboratory scale test equipment, but Starkey strongly suggests that such work be left to the current commercial labs as the most economical testing option in most cases. Starkey assures that Master Licensees' data and projects will receive 100% confidentiality through what has been proposed herein, much in the same way that Lakefield Research, owned by Falconbridge, worked together, yet with confidentiality, more than 60 years ago.

John Starkey is a professional mining engineer (University of Toronto 1961) with an impressive resume. Each line describes production, design, or consulting jobs over a 60-year career with much of John's experience pulled into his 39 publications, all accessible on the Starkey web site. John Starkey, his company, and SAG mills are synonymous.