Biography: Norman O. Lotter

Norman Lotter is President and Consulting Engineer of Flowsheets Metallurgical Consulting Incorporated, based in Sudbury, North Ontario, since January 2016. Flowsheets Inc. offer specialist technical services to the mineral processing industry (www.flowsheets.ca). He earned his bachelor's degree in pure and applied science at the University of Natal, South Africa, his M.Sc.in chemical engineering from the University of Cape Town, South Africa, and his Ph.D. in metallurgical engineering at McGill University, Canada. He is a designated Consulting Engineer with the Professional Engineers of Ontario, as well as a licenced Professional Engineer in South Africa, and a Chartered Engineer with the Engineering Council of the United Kingdom. He has spent most of his career of 44 years focussed on the identification of gaps in procedures and methodologies in the mineral processing discipline where sampling and measurement errors have historically hindered the attainment of clear observations and conclusions. One of his specialist areas is in flowsheet development. Another is in sampling. In recent years, he has developed an interest in flotation electrochemistry.

In the earlier years of his career he worked with Rustenburg Platinum Mines, South Africa, as Manager, Divisional Metallurgical Laboratory. In this role he led a team in the pursuit of more reproducible flotation testing, and developed High Confidence Flotation Testing between 1986 and 1995 to improve the representativity of the ore samples brought for testing, as well as a replicate flotation testing system with appropriate quality controls to assure a 95% level of confidence in the test data. The first prototype of this model was published with the South African Mine Metallurgical Managers' Association in 1994, and was presented with a gold award for the contribution to practice. It was later presented in its final form to the SME in Denver at their 1995 meeting. This model was put to work in the operating concentrators of Rustenburg Platinum Mines Limited, and successfully focussed on improved grinding and flotation circuit layout and reagent strategies. This model was also used during the sampling and testwork for the design of the Potgietersrust Platinum concentrator, the first Platreef ore treatment operation in the world, which commissioned successfully on designed grade and recovery.

He was recruited to Canada by Falconbridge in 1997, where he started up a hybrid Process Mineralogy group to develop more advanced methods in sampling, quality control and flowsheet development. This group contains geologists, mineralogists, samplers and mineral processors. In this role, he developed – together with his team - Statistical Benchmark Surveying, a sampling protocol designed to deliver representative survey samples from an operating concentrator for mineralogical study. This work was presented to the MEI conference Nickel '05 in Cape Town, South Africa, and was published in the Minerals Engineering journal in 2007

He has spent a significant amount of his time in his career on training and mentoring young engineers, and derives much pleasure in seeing their careers grow. He is a supporter of the concept of inter-disciplinary training, where he sees synergies in the project work.

He was awarded Distinguished Lecturer by the CIM in 2010 in recognition of his contributions to advanced flowsheet development.

Norm Lotter has earned the respect of the Mineral Processing community worldwide

by

Michael G. King, C.Sci., C.Chem., FRSC (UK)

I have known Norm since 1998 when I joined Falconbridge (now Glencore)) as Director of Metallurgical Technology one year after he arrived in Canada from South Africa in 1997. I am fully familiar with Norm's work since that time and I can testify that he has established an outstanding record of introducing new methodologies and technologies for the betterment of Process Mineralogy worldwide.

Details of these achievements which are presented below, along with key references, demonstrate his contribution and show that Norm operates at the cutting edge of his profession. His work has been recognized by both his peers in Canada and around the Process Mineralogy world. When reviewed in its entirety it is clear that Norm's professional achievements have made the Mineral Processing industry much more productive in metal recovery and operational efficiency. He has had and continues to have a remarkable record of success in bringing new applied technologies to Mineral Processing operations.

Shortly after starting at Falconbridge Norm was able to institute the concept of **Statistical Benchmark Surveying** at the company's mills – Strathcona ON and Raglan QC. The concept uses the Central Limit Theorem (CLT) to establish Internal and External Reference Distribution Criteria from multiple sample surveys. The methodology requires that both the short term and long term performance of the mill must first pass the confidence limits imposed by the CLT. Replicate samples from the actual mill survey must then, in turn, meet the same criteria as the reference distributions before the samples are presented for analysis. This means that when the data are analysed and potential process improvements are identified, these improvements can be evaluated in the knowledge that they have passed 95% confidence limits for success. Simply stated, operators in the mills are presented with process improvements which will be sustainable in the long term when implemented. Norm has received Masters and Ph. D degrees for his work in the area of plant sampling and quality assurance.

The concept of Statistical Benchmark Surveying is detailed in its entirety as the Ph. D. dissertation that Norm wrote in 2005 under the supervision of Prof. Andre Laplante at McGill University. The key parts of this dissertation were first presented at the Canadian Mineral Processors Meeting (CMP) in 2005[1]. Using the Raglan mill as the example the thesis outlines two types of survey model. The Benchmark model is used for typical operations and the Campaign model is used for specific ore types being milled for a specified period.

At the same time the effectiveness of Statistical Benchmark Surveys was further enhanced by new technology which Norm introduced. Following the sorting of mill process feed by spinning rifflers the samples were forwarded for detailed analysis by QEMSCAN (formerly QEM*SEM) technology. The QEM*SEM unit installed at the Falconbridge Technology Centre in 1998 was the first of its kind in North America. The result of this approach was that process improvements at Strathcona and Raglan were achieved on an ongoing basis. In particular, the success at Raglan is documented in papers presented at CMP meetings by P.Langlois[2] in 2001 and N.Lotter[3] in 2002.

Norm had the vision and foresight to champion the purchase and installation in 2004 of the first Canadian Process Technologies **Mini Plot Plant (MPP)** in Canada. This technology is unique in its use of a small primary sample mass to run integrated and continuous flotation pilot plant tests for both plant optimization and plant design. Since installation dozens of different

flowsheet/ore combinations have been tested including validations of scale up to existing industrial plants.

Norm has also introduced the concept of **High Confidence Flotation Testing**. Again using advanced statistical criteria, High Confidence Flotation Testing utilizes the rigorous concept to prove reproducibility and sustainable process change. Since its introduction in 2004 High Confidence Flotation Testing has become the standard way of evaluating flowsheets for new ore bodies within the Glencore (formerly Falconbridge) organization, beginning with the Montcalm ON mine in 2004 and the Nickel Rim ON mine in 2009. The technology centre where this concept was introduced has been renamed XPS and is now an open commercial facility. This technology is available and successfully delivered to all clients of XPS. The impact of High Confidence Flotation Testing is reported in detail in a paper presented in 2010[4].

Norm has combined the success of statistical methods and new technologies into an overall predictive grind – recovery model for milling processes. This concept is given the name of **Virtual Flowsheeting** in which the following sequence is used to develop optimum flowsheets for both established and new ore bodies. This approach involves the integration of quantitative mineralogical data into the definition of process requirements. First ore grinding targets are predicted from detailed coarse composite and/or thin section analysis of the geometallurgical units on the QEMSCAN, second virtual flowsheets are proposed from this data, third ore samples are ground and subjected to high confidence flotation testing and then finally the flowsheets are validated on the Mini Pilot Plant. This approach leads to the development of unique flowsheets customized for each ore body and allows for the optimum recovery of each pay metal in the ore body.

More recently Norm has been involved with Prof. Dee Bradshaw of the University of Cape Town, South Africa in the development of Mixed Collector reagent schemes for the flotation of sulphide minerals, but has taken her early work to a whole new level. He has coined a new term **'Reagent Sudoku'** and relates the collector chemistries to the mineralogy of the ore including values and gangue, developing unique combinations. The use of these novel reagent mixtures have resulted in measureable gains in plant performance and have resulted in great economic returns for a number of companies. Where appropriate and permitted, the work has been presented including at the Minerals Engineering International conferences and at the 2011 CMP meeting[5].

All of this has resulted in Norm and the group he established and directed in Sudbury producing a body of work which keeps XPS at the forefront of Process Mineralogy technology. Norm's singular achievement has been to improve the performance of mills by working back to the ore body – either being mined or available from drill core – and integrating the information gleaned from the mineralogy into performance improvements in areas such as optimal crushing, breakage, flotation for grade and recovery. All of this is done with high statistical confidence. The ability to use his fundamental research and integrate it into practical tools has become a hallmark of Norm's work. Until the end of 2015 Norm was an employee of XPS but on retirement he has formed his own company, Flowsheets Consulting Inc. and he will continue to make his expertise available to the Mineral Processing industry worldwide.

A short list of Norm's publications – both technical presentations and refereed papers is attached for additional reference. The advances in Process Mineralogy detailed in this work are unique in that they have led to immediate operational and financial benefits (typically many millions of dollars each year) to the mills where they have been applied.

Finally, I commend to you that in accomplishing all of the above – **Statistical Benchmark Surveying, Mini Pilot Plant Validation, High Confidence Flotation Testing, Virtual Flowsheeting and Reagent Sudoku -** Norm has earned the respect of the Mineral Processing

community worldwide. His contributions were recognized in 2010 when he was appointed a CIM Distinguished Lecturer and CMP has asked Norm to practically demonstrate his complex sampling theories in short courses. In addition, his relations with mill operators, university collaborators and his fellow engineers in mineral process development have led to a very high level of mutual respect and trust.

Yours sincerely,

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