IMPROVING THE PROCESS OF BLENDING CONSISTENT AND PREDICTABLE FEED IN THE NICKEL SMELTING PROCESS USING PGNAA TECHNOLOGY

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ABSTRACT

The process of blending consistent and predictable feed for the roasters is critical to optimizing product quality and controlling production costs. To assist in this process, Online PGNAA Slurry Analyzers have been installed and evaluated at a Sudbury Ontario smelter. They are used to measure 100% of the full process stream to obtain elemental composition data in real time. This paper explains the application details at Sudbury and the benefits achieved from their Full Stream, Elemental Slurry Analyzers.

KEYWORDS

Californium 252 (Cf-252), Prompt Gamma Neutron Activation Analysis (PGNAA)

INTRODUCTION

Sudbury Integrated Nickel Operations (Sudbury INO), a Glencore Company consists of two underground nickel/copper mines in Sudbury, Nickel Rim South and, Fraser, along with the Strathcona mill and the Sudbury smelter. The facilities are spread throughout the 60 kilometer-long, oval-shaped geological formation known as the Sudbury Basin (Figure 1). The company has been mining nickel-copper ores in the Sudbury area since 1929. Nickel and copper are the primary focus of operations at Nickel Rim South and Fraser. Other base metals such as cobalt and precious metals are also produced.

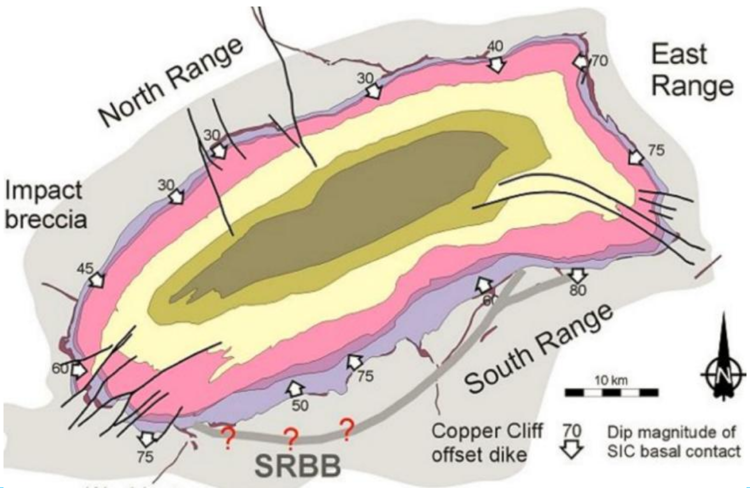

Figure 1 – Sudbury Basin (Geology Museum Guides)

The Strathcona Mill receives ore from Nickel Rim South, Fraser, and third-party miners to produce two concentrate streams. One is a nickel-copper concentrate for use by the Sudbury Smelter; the other is a copper concentrate which goes to other Glencore operations for smelting and refining. The Sudbury Smelter converts the mineral concentrate into a high grade matte containing nickel, copper, cobalt and platinum group metals. This matte product is shipped to Glencore's Nikkelverk refinery in Norway for further processing.

In 2015, the Sudbury INO Smelter completed the first phase of the Process Gas Project (PGP); a series of process changes and capital investments designed to reduce Sulphur Dioxide (SO_2) emissions in accordance with Ontario Regulations 194. A critical element of the planned emissions reduction was the elimination of a higher percentage of sulphur contained in input concentrate streams, which can then be captured and converted to Sulphuric Acid.

The higher requirement to achieve a higher degree of sulphur elimination and the resulting impacts on metallurgical conditions in the electric arc furnace and converter aisle vessels necessitated a higher degree of process control on input concentrate streams. As the feed for the smelter process is variable and comes from different sources, a strategy of feed blending was implemented. The Sudbury INO process team proposed that an online analyzer capable of measuring the sulphur and iron content in their slurry streams would allow real-time control of feed ratios required for concentrate blends, resulting in more consistent and predictable sulphur and iron contents.

In order to find a suitable technology for this application the processing team took a three phased approach for evaluation and implementation.

Phase 1 –Research the suitability of available analyzer technologies for elements of interest contained in slurry. The following characteristics were assessed in the analyzer system:

- Ability to measure material in slurry form
- Stability over time with feeds of varying mineral composition
- Capable of measuring light elements such as Mg, Al, and S
- Capable of measuring heavier elements such as Ni, Cu, Co, and Fe
- Ease in maintenance
- Accuracy and precision over a wide range of mineral composition
- Ability to measure 100% of the slurry in process

Phase 2 - Conduct an in-plant trial of the most suitable technology

Phase 3 – Install a full scale version of the technology.

TECHNOLOGY

The analyzer uses a process known as Prompt Gamma Neutron Activation Analysis (PGNAA) to obtain information on the composition of any process stream. In the PGNAA process, Californium 252 (CF-252) is used to bombard the target material with neutrons. This causes the individual atoms within the target material to release both prompt and delayed gamma rays, as shown in Figure 2.

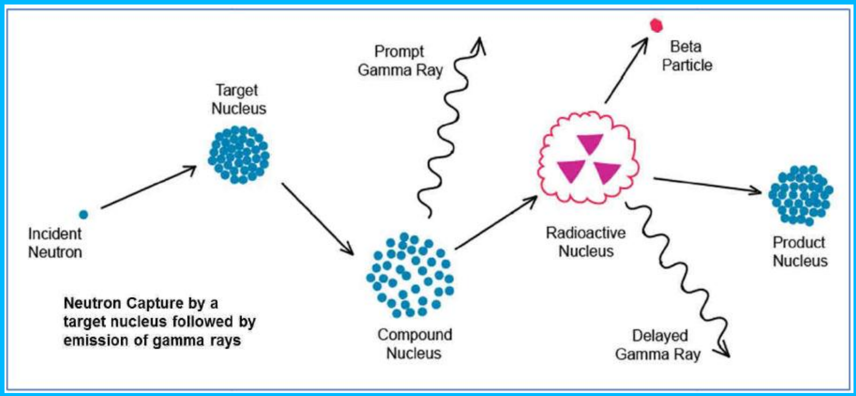

Figure 2 – PGNAA Process (North Carolina State University, 2010)

The emitted prompt gamma rays are detected by scintillation crystals, converting the energy into light. This light is then sent through a photomultiplier to convert it to an electrical pulse and further processing equipment to convert the analog pulse to a digital signal, as shown in Figure 3.

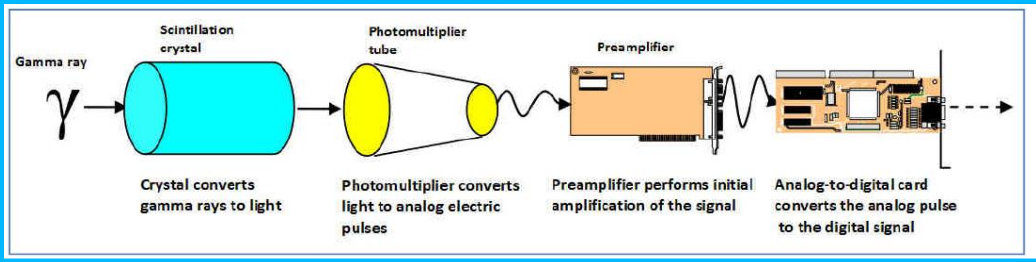

Figure 3 – PGNAA Signal Path (SABIA Inc., 2009)

The analyzer can be configured to measure and display specific elements and parameters of interest such as Ni, Cu, Co, Fe, S, MgO, Al2O3, SiO2, CaO, and Pb.

APPLICATION

In 2009 Glencore and SABIA began discussions on the application of SABIA's PGNAA technology in the Sudbury Integrated Nickel Operations Smelter. This resulted in several proposals by SABIA. As this discussion continued, the Sudbury INO team developed a well thought out "crawl, walk, run" strategy for the implementation of PGNAA to gain greater visibility and control of input slurry composition, with the goals of improved process quality, reduced metallurgical upsets, and reduced production costs. Sudbury INO decided that the greatest opportunity for improved process control would be the use of on-line elemental measurement at the exit of the filter feed tanks, in the front end of the nickel production process. This would allow the slurry pumped from the three filter feed tanks which contain both concentrates from the Strathcona mill along with Custom Feed concentrates to be blended to create optimal feed qualities for the fluid bed roasters (see Figure 4).

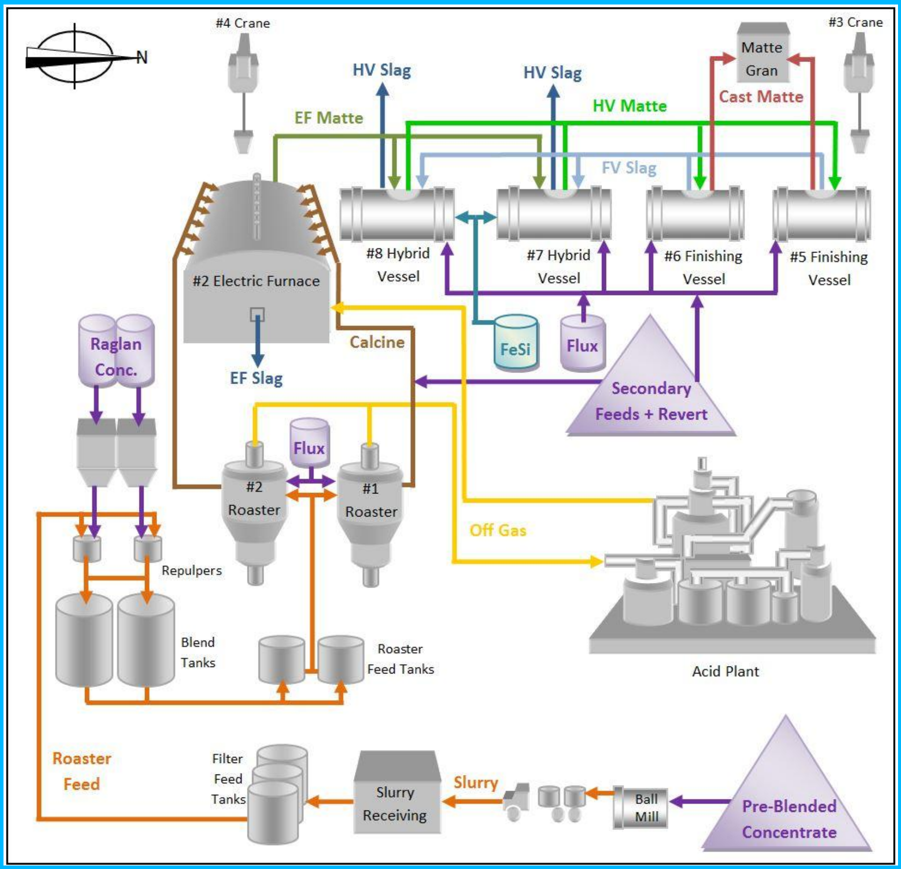

Figure 4 – The Glencore Sudbury Smelter Process

The first step ("crawl") in this overall strategy was to lease a unit from SABIA for a trial period and to thoroughly test the unit and complete a full scientific report. With a successful first step, the second step ("walk") was to purchase this first "trial" analyzer along with two more units, giving complete visibility of the output of each of three filter feed tanks shown in Figure 4.

With the three analyzers in place, the Sudbury team began using the online results to improve process control and roaster output (calcine) quality. The third step ("run") in the program was to use the analyzer results in closed loop process control for significant reduction in process variability, minimization of production costs, and optimization of product quality. Sudbury has completed step 1, is well into step 2, and is now looking to implement closed loop process control in the months to come.

TEST RESULTS

Calibration

Using thirty (30) samples from the combined concentrate feeds, the analyzer was initially calibrated. The calibration represented a wide range of feed types typical of Glencore concentrates and custom feed concentrates sourced from third parties. The sample lab results were obtained using Inductively Coupled Mass Spectrometry. Analyzer calibration was conducted in the first half of 2014, selecting samples to give as much range as possible for a robust calibration. Results were excellent as indicated by the Sulfur, Iron, Nickel and Copper graphs shown below in Figure 5.

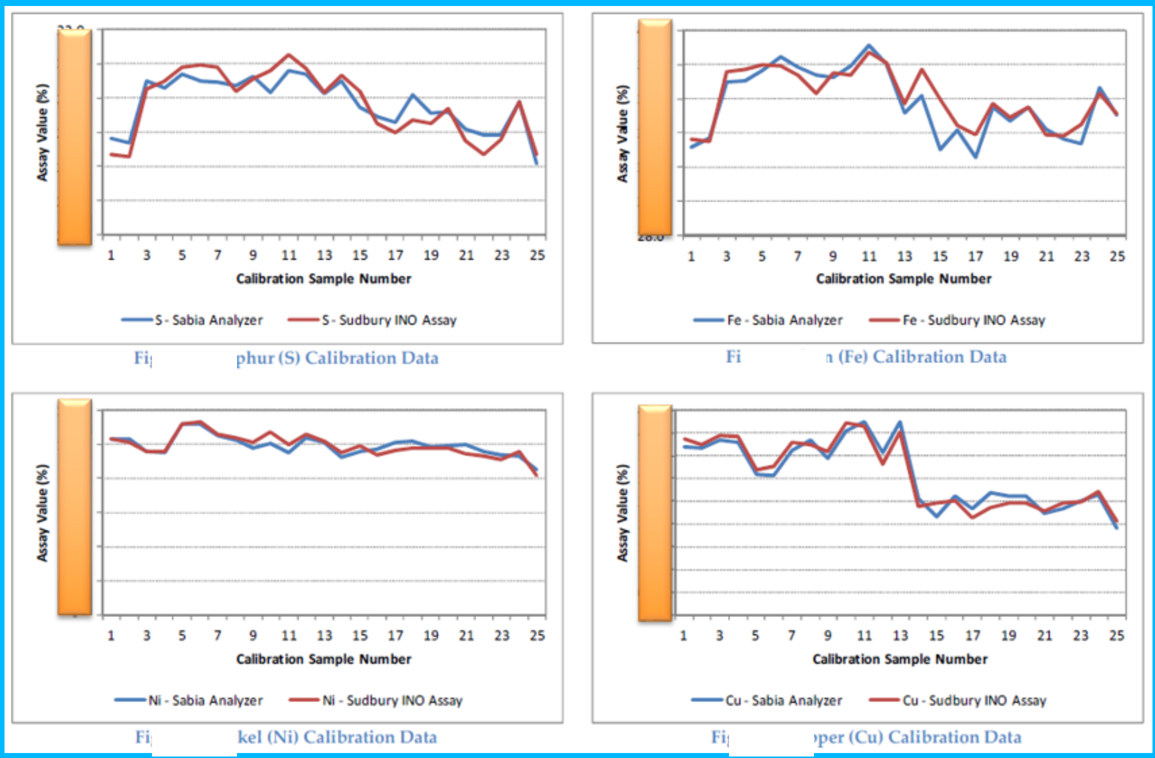

Figure 5 – Calibration Results

With an encouraging calibration implemented, additional samples were collected to validate the performance of the calibrated analyzer.

Validation

To perform a validation of the sampling system's performance, an additional 20 samples were collected. The trend plots on this data set were consistent with the original calibration set. Additionally, the data was examined to ensure that the results conformed to a normal distribution (Figure 6). The results were good, confirming that the data was Gaussian, thus permitting a statistical "t" test to confirm that both the analyzer and the lab were looking at the same population.

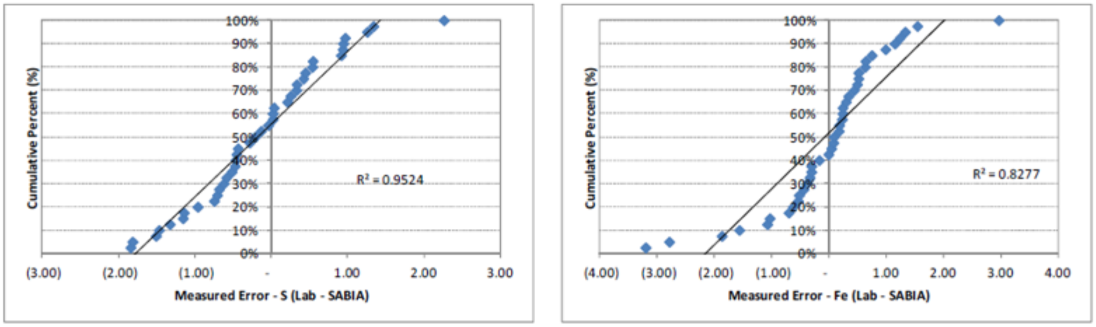

Figure 13: Sulphur (S) Probability Plot

Figure 14: Iron (Fe) Probability Plot

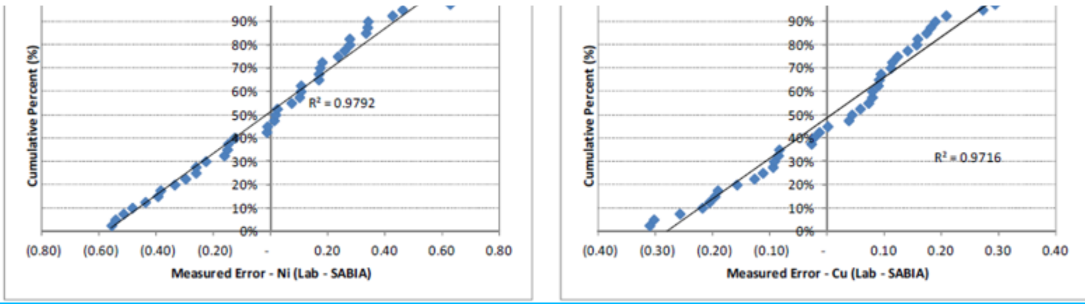

Figure 6 – Assumption Check Normal Distribution

The purpose of the t-test is to quantify the difference between the means of two different normal distributions, in this case the results obtained from the analytical lab and the SABIA analyzer. If the calculated test statistic is less than the reference t-value, then it can safely be assumed that the mean values of the analyzer results and the lab data are equal within a 95% confidence interval. For Ni, Cu, Co, Fe, S, MgO, CaO, and Pb this was the case for the 95% level as shown in Table 1. Tests were also conducted on Density Effects, Concentration Effects, and Interactive Effects. No correlation was found on any of these.

Table 1 – Validation Data T-test

Calculated Value	Ni (%)	Cu (%)	Co (%)	Fe (%)	S (%)	MgO (%)	Al2O3 (%)	SiO2 (%)	Cr (%)	CaO (%)	Cd (ppm)	Pb (ppm)
Average Difference (d)	(0.00)	0.03	(0.02)	(0.52)	(0.36)	0.32	(0.26)	1.06	(0.10)	0.16	(10.44)	(0.35)
Average Lab Value												
Analyzer Bias (%)	0.0%	1.1%	-4.5%	-1.6%	-1.4%	5.7%	-20.7%	8.2%	-133.5%	10.3%	-156.7%	-0.4%
Pooled Standard Deviation (S_d^2)	0.13	0.03	0.00	1.83	1.32	0.73	0.16	1.34	0.01	0.11	42.74	664.85
Test Statistic (t_0)	(0.03)	0.59	(1.32)	(1.50)	(1.22)	1.43	(2.47)	3.53	(4.36)	1.89	(6.19)	(0.04)
T Value - 99% Confidence	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	3.25
99% Confidence Limit Test	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	FALSE	TRUE	FALSE	TRUE
Confidence Limit Value (+/-)	0.27	0.13	0.04	1.03	0.87	0.65	0.30	0.88	0.07	0.25	4.97	27.93
T Value - 95% Confidence	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.26
95% Confidence Limit Test	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE
Confidence Limit Value (+/-)	0.003	0.03	0.02	0.52	0.36	0.32	0.26	1.06	0.10	0.16	10.44	0.35

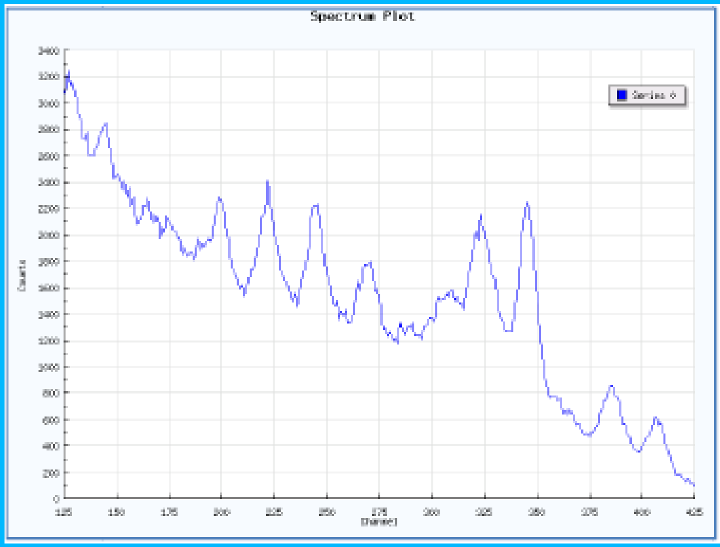

Figure 7 – A Typical Analyzer Spectrum Plot (August 2014)

Table 2 shows the theoretical range of sensitivity for each of the elements in the periodic table for a PGNAA instrument.

Table 2 – Expected PGNAA Sensitivity to Elements of Interest*

Sensitivity in Weight % **	Elements
<0.01%	Cl,Sc,Ti,Ni,Cd,Hg,Sm,Gd,Dy,Ho
0.01-0.1%	S,V,Cr,Mn,Fe,Co,Cu,Rh,Ag,In,Hf,Ir,Au,Nd,Eu,Er,Yb,H
0.1-0.3%	N,Na,Al,Si,K,Ca,Ga,Se,Y,Cs,La,W,Re,Os,Pt,Pr,Tm
0.3-1.0%	Li,Be,Mg,P,Zn,As,Mo,Te,I,Ta,Pb,Ce,Tb,Lu,Th,U
1.0-3.0%	C,Ge,Br,Sr,Zr,Ru,Pd,Sb,Tl
>3.0%	Other Elements

* Note: Table taken from "On-Line Prompt Gamma Neutron Activation Analyzers, Published in the Process/Industrial Instrument and Controls Handbook, Editor-Gregory K. McMillan, Fifth Edition, McGraw Hill, 1999.

** Three sigma detection limit in 10 minutes within an elementary simple rock matrix, ≥150mm thick

CONCLUSIONS

Using sophisticated tools like a test for normal distributions and a t-test to detect any differences between the lab and the analyzer it was determined that for the Sudbury slurry measurements for S, Fe, Ni, Cu, MgO, Co, CaO and Pb were proven to be statistically equivalent to the lab results. The analyzer accuracy at a 95% confidence level was calculated as S = +/- 0.35%, Fe = +/- 0.52%, Ni = +/- 0.003% and Cu = +/- 0.03%. As a result of this successful test Sudbury purchased two more analyzers resulting in on-line, full-stream, real-time, elemental analysis on each of the exit lines from the three filter feed tanks. This enabled manual control of the process leading to the roaster feed tanks. The third step ("run"), using closed loop automated process control will be completed next.

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REFERENCES

Canadian Business Resource, Retrieved from www.cbr.ca

Loken, Michael, P. Eng, “Sudbury Integrated Nickel Operations – a Glencore Company, SABIA Slurry Analyzer – Commissioning and Validation Report”, Final Report September 2014.http://web.cim.org/COM2014/

North Carolina State University, Department of Nuclear Engineering. (2010). Neutron Activation Analysis, Raleigh NC. Retrieved from http://www.ne.ncsu.edu/nrp/naa.html

Thwaites, Phillip, “Process Control in Metallurgical Plants: Towards “Operational Performance Excellence”, Plenary talk at the Automining 2008: International Congress in Automation in Mine Industry, Santiago, Chile

Thwaites, Phillip,”Difference?”, Conference of Metallurgists, Vancouver, BC, Canada 2014