Measuring bath properties using the STARprobe^{TM}

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Abstract

Since the beginning of 2012, STAS is the world distributor of the STARprobe^{TM} developed by Alcoa [1, 2]. Demonstration measurement campaigns have been conducted in different smelters around the world.

During those campaigns, the STARprobe^{TM} bath properties measurements have been compared with standard bath properties measurements regularly carried out in those smelters operated by different aluminium producers.

Those independent comparative measurements all confirmed the capacity of the STARprobe^{TM} to instantaneously and accurately measure <u>S</u>uperheat, <u>T</u>emperature, <u>A</u>lumina concentration and bath <u>R</u>atio for cell control purposes.

Keywords: STARprobe^{TM}, cell control, XRD bath analysis, alumina concentration, superheat, temperature, bath ratio, measurements

1. Introduction

The STARprobe^{TM} is a portable device that takes real−time measurements of bath properties, such as Superheat, Temperature, Alumina concentration and bath Ratio or acidity (STAR), in electrolysis cells. This synchronicity of measurements is a most important step forward in improving the control and efficiency of electrolysis cells. It unites the conventional processes of temperature measurement and bath sampling-analysis into one online measurement, simplifies and greatly shortens the process and time space from measurement/sampling to pot control decision. The pot control decision can therefore be based on the real time cell conditions rather than those from few hours ago or from as long as 24 hours ago.

This integrated real-time measurement system consists of four major components:

- Reusable probe tip
- Portable stand to fit various pot configurations
- Electronics for data acquisition and analysis, and wireless communications for data transfer
- Tablet PC with programs to perform all necessary tasks during measurements.

Considering the great advantages of the STARprobe^{TM}, Alcoa has decided to share the technology with the rest of the aluminium industry starting from 2012. In this regard, Alcoa has just appointed STAS, a well recognized leader in the aluminium industry (www.stas.com), to commercialize the new STARprobe^{TM} analyzing system.

2. First measurement campaign

The main objective of the first measurement campaign was to get familiar with the STARprobe^{TM} measurement technique. Since that measurement technique turned out to be fairly easy to master, we were quickly in position to take advantage of the time set aside to carry out measurements and try to learn from them.

2.1. First repetitivity test

One big question that is typically set aside when bath samples are taken for bath chemistry control purposes is how homogeneous is the bath and hence how representative is a small localized bath sample of the average composition of the bath. Considering the way that the alumina is discretely added to the bath in one region of the cell and consumed in another region, there is no reason to expect that the dissolved alumina concentration in the bath should be relatively homogeneous.

For the first time, using the STARprobe™, it is possible to quickly measure the dissolved alumina concentration in the bath in order to try to assess how homogeneous it is in the bath. For that purpose, 15 consecutive STARprobe™ measurements were carried out in the tap hole of the same pot over a period of 90 minutes averaging one measurement every 6 minutes. The obtained results are presented in the Table 1. Figures 1 to 4 highlight the relative variability or lack of strict repetitivity of the measurements which in turn highlight the lack of homogeneity of the bath. This is particularly true for the dissolved alumina concentration and the bath superheat which is directly affected by the dissolved alumina concentration in the bath sample analyzed by the STARprobe™. Nevertheless, the averaged results give a very consistent picture of the cell conditions as the average measured excess AlF_3 concentration of 10.69%, the average measured dissolved alumina concentration of 2.6%, the line average CaF_2 concentration of 4.9% and the measured average bath temperature of 968.72 °C can be used to calculate a bath superheat of 4.97 °C using the Solheim equation [3] while the measured average bath superheat is 4.94 °C.

Position	Excess	Al_2O_3	Temp	Super
tap	10.25	2.93	969.18	6.21
tap	9.67	2.53	971.02	2.05
tap	10.78	2.85	966.68	6.35
tap	10.51	2.6	970.72	8.8
tap	10.89	2.49	970.16	5.87
tap	10.38	2.13	969.98	2
tap	11.31	2.4	971.18	6.72
tap	10.55	2.76	966.51	5.6
tap	10.2	2.5	970.34	3.8
tap	10.48	2.86	968.13	4.9
tap	11.81	2.12	972.61	5.54
tap	11.37	2.08	967.42	2.67
tap	11.27	2.72	963.65	4.24
tap	9.69	3.21	967.3	4.44
tap	11.26	2.7	965.93	4.98
Mean	10.69466667	2.592	968.7206667	4.944667
Std Dev	0.625446888	0.321696396	2.443067354	1.84237

Table 1: Raw data from the first repetitivity test

Figure 1 to 4 present the raw distributions (histograms) of the 15 measurements and the corresponding normal distributions (curves) having the same mean and standard deviation as the raw distributions.

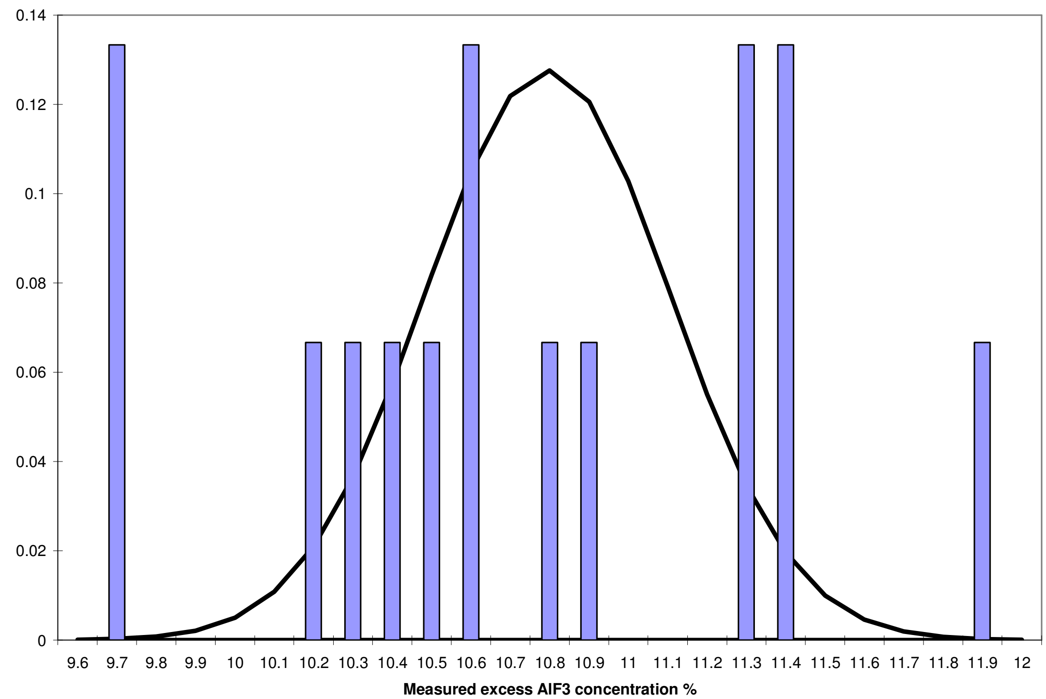

Figure 1: Distribution of the 15 measured excess AlF_3 concentration

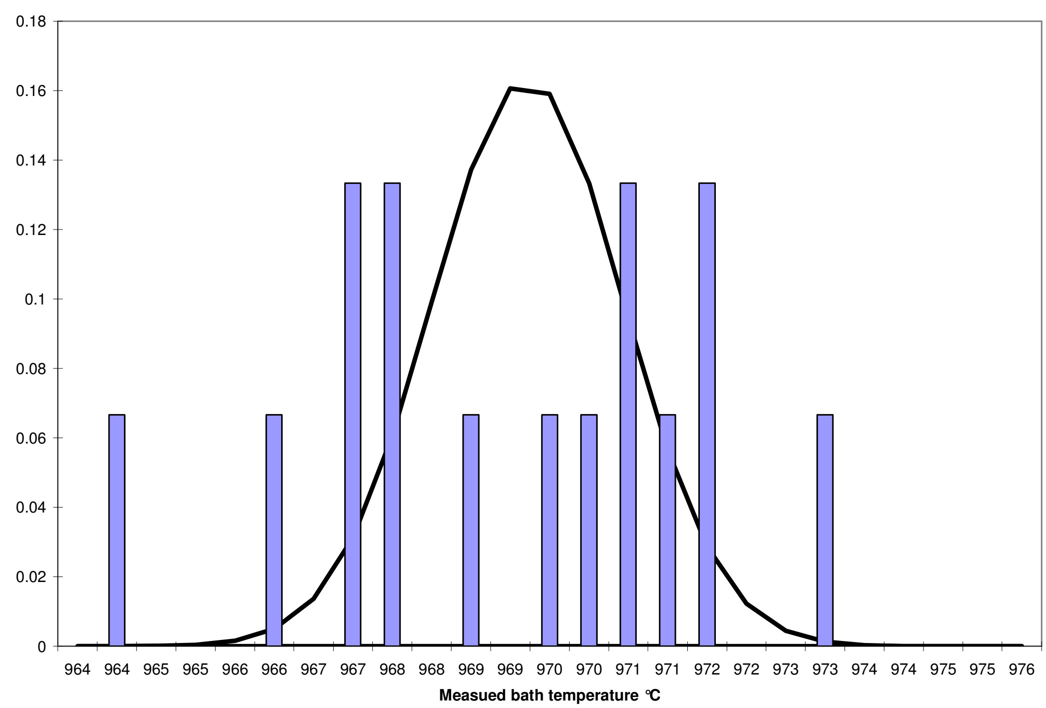

Figure 2: Distribution of the 15 measured bath temperature

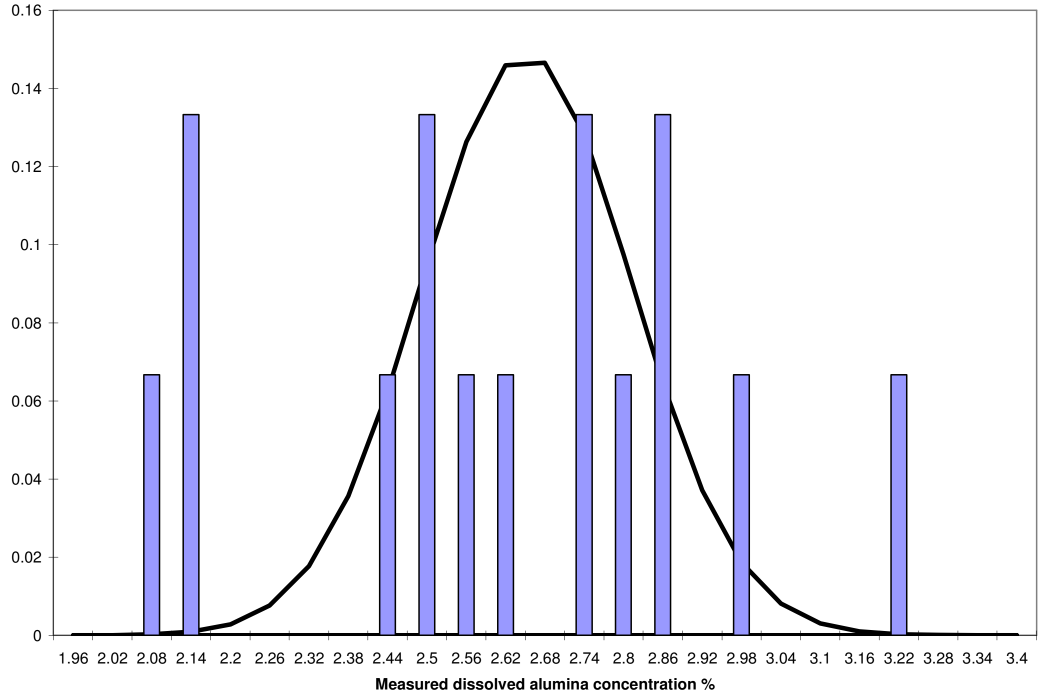

Figure 3: Distribution of the 15 measured dissolved alumina concentration

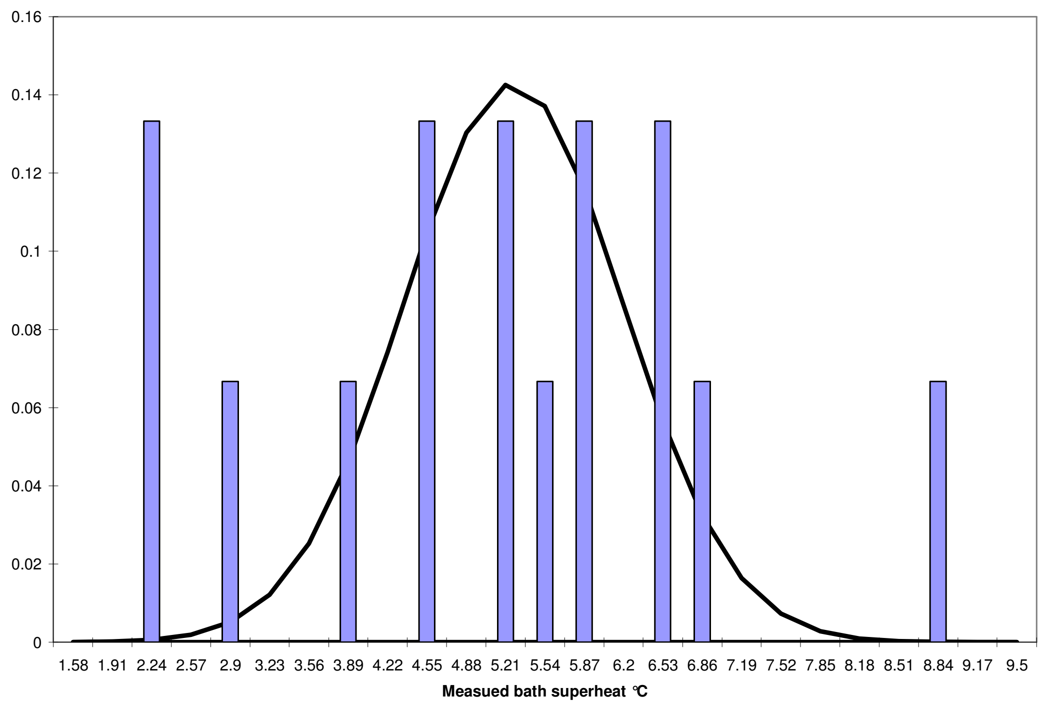

Figure 4: Distribution of the 15 measured bath superheat

2.2. Second repetitivity test

In order to ensure that the above results are really typical, a second repetitivity test was performed the next day again repeating STARprobe^{TM} measurements in a single cell. In total, 22 measurements were obtained over the same period of 90 minutes averaging 4 minutes per measurement. The bath samples were taken this time in two different locations, the taping hole and in a hole opened for that purpose in the side channel quite far from the tapping hole.

The obtained results are presented in Table 2. Figures 5 to 8 present the corresponding distributions. As we can see, Figures 5 to 8 are very similar to Figures 1 to 4 again highlighting the lack of homogeneity of the bath. The tapping hole seems to be as good a location as anywhere else to take bath samples. Again the averaged results give a very consistent picture of the cell conditions as the average measured excess AlF_3 concentration of 11.04%, the average measured dissolved alumina concentration of 3.1%, the line average CaF_2 concentration of 4.9% and the measured average bath temperature of 971.18 °C can be used to calculate a bath superheat of 11.88 °C using the Solheim equation [3] while the measured average bath superheat is 11.56 °C.

Yet, it is clear that the non homogeneity of the bath creates a sampling noise problem that has never been addressed. That bath sampling noise could easily be identified by STARprobe^{TM} measurements. But on its own, replacing standard bath sampling by STARprobe^{TM} measurements at the same frequency, even if extra information is obtained and that information is known without delay, is not addressing the fact that the measured information is noisy. One way to address that sampling noise problem is to measure more frequently and to apply some kind of filter on the measured data before taking feedback control action on it, but discussing this was not in the scope of the present paper.

Position	Excess	Al_2O_3	Temp	Super
tap	11.28	3.7	965.91	12.43
tap	11.39	3.61	968.02	12.23
tap	11.08	3.24	968.83	14.98
tap	10.81	3.65	968.59	13.53
tap	11.06	3.4	968.82	13.55
tap	11.19	3.92	969.65	16.66
side	10.98	3.32	973.66	18.25
tap	11.43	3.09	970.89	11.65
side	10.38	3.14	973.92	9.64
tap	10.51	2.16	972.09	2.69
tap	11.06	2.51	971.22	8.64
side	10.37	2.69	973.77	7.54
tap	11.12	2.72	971.63	9.91
side	11.3	3.13	974.09	12.52
tap	10.59	3.45	969.7	12.92
side	11.06	2.16	973.93	8.59
side	11.28	2.7	974.31	11.47
tap	10.71	3.71	968.89	11.84
side	11.35	2.7	974.36	11.02
tap	10.88	3.23	971.26	12.78
side	11.34	2.7	973.14	10.83
tap	11.75	3.26	969.2	10.68
Mean	11.04181818	3.099545455	971.1763636	11.56136
Std Dev	0.361091419	0.497637057	2.493080988	3.20755

Table 2: Raw data from the second repetitivity test

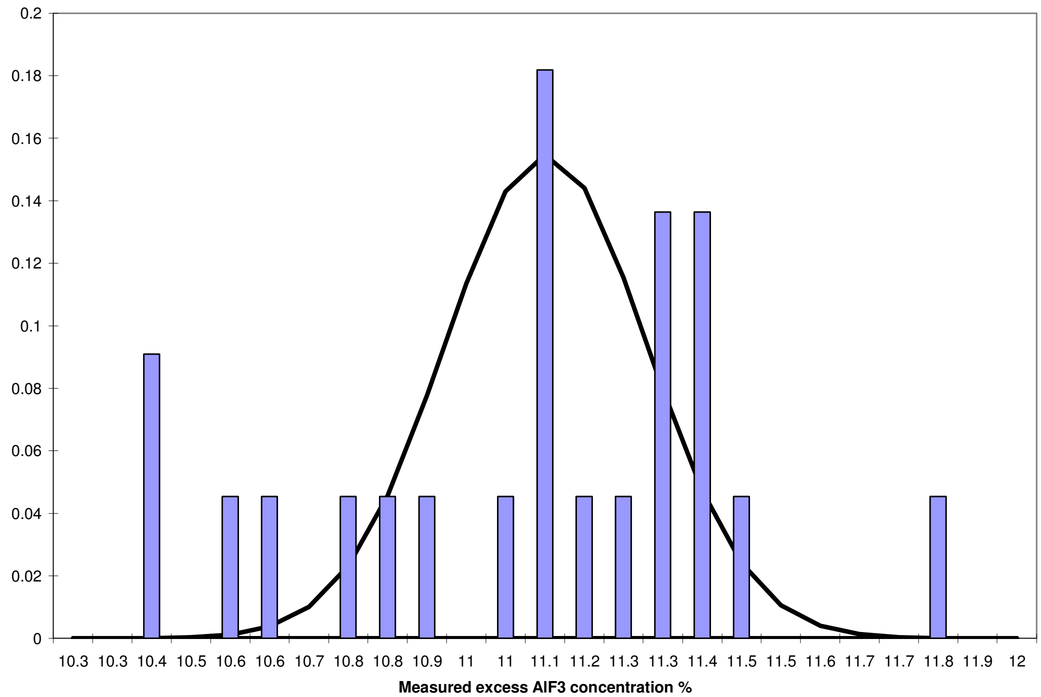

Figure 5: Distribution of the 22 measured excess AlF_3 concentration

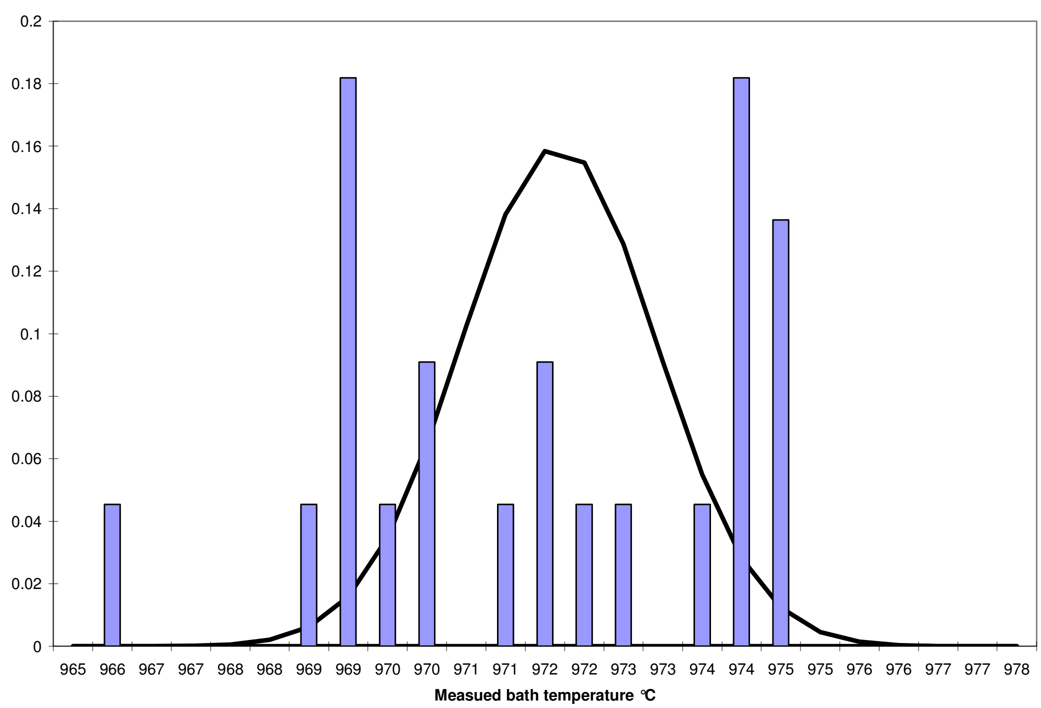

Figure 6: Distribution of the 22 measured bath temperature

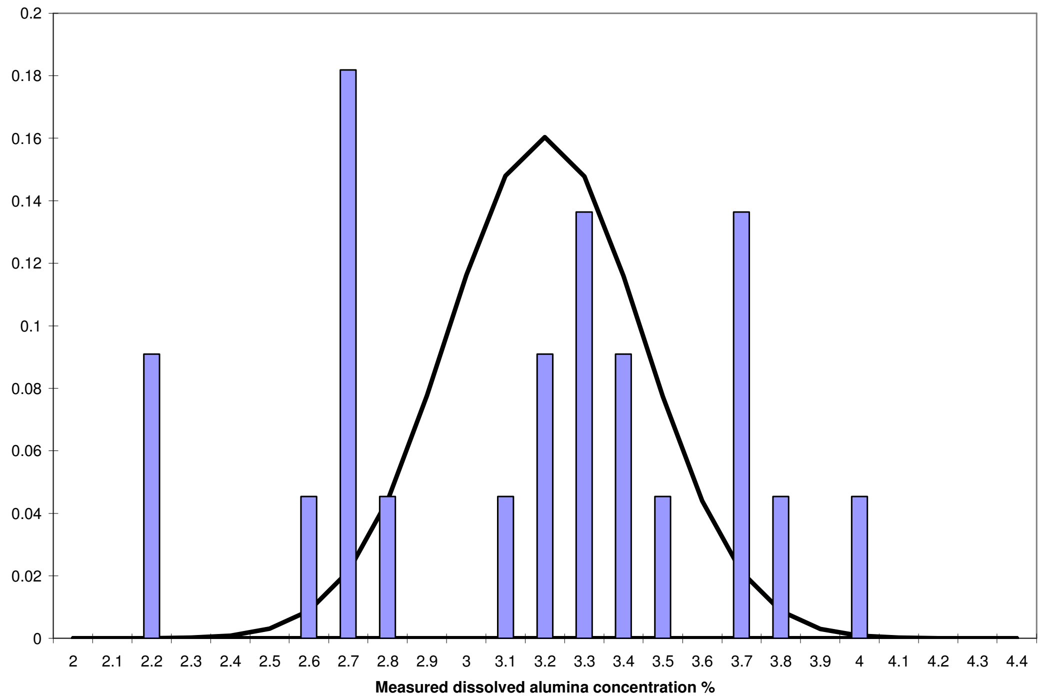

Figure 7: Distribution of the 22 measured dissolved alumina concentration

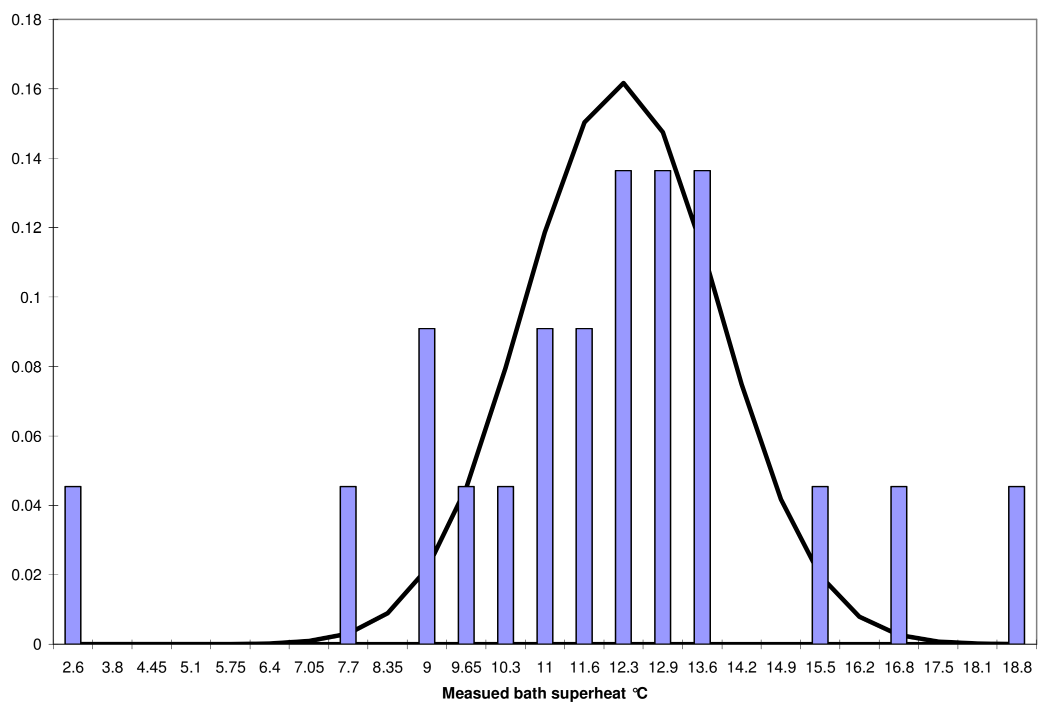

Figure 8: Distribution of the 22 measured bath superheat

3. Second measurement campaign

The second measurement campaign was carried out in another smelter operated by another aluminium producer in order to demonstrate the STARprobe™ technology. So the aim of that very short measurement campaign was to quickly verify that the STARprobe™ can replace the bath sampling/XRD lab analysis of the excess AlF_3 concentration and can measure the bath superheat as well as the other commercial method available. Figure 9 presents the results obtained for the parallel measurement of the excess AlF_3 in 2 different cells so in addition of the comparison between the 2 methods, the issue of the lack of strict repetitivity of the measurements can also be observed in both methods of analysis.

It is important to notice that the default STARprobe™ calibration parameters have been used in that measurement campaign, per example, the average CaF_2 concentration of the cells in that smelter did not match, so the STARprobe™ measured excess AlF_3 concentration is slightly offset for that reason. The next step would have been to carry out a STARprobe™ calibration exercise in order to eliminate the offset between the STARprobe™ and the XRD calculation of the excess AlF_3 concentration, but that would have required more time than was available in that short demonstration measurement campaign. That STARprobe™ calibration exercise has been successfully carried out in a third measurement campaign not presented here.

Figure 10 presents the results obtained for the parallel measurement of the bath superheat in 2 different cells. Again enough measurements have been taken to highlight the lack of strict repetitivity of the measurements regardless of the method used.

There were no attempts to try to compare the STARprobe™ measurement of the dissolved alumina concentration with another method in that second measurement campaign.

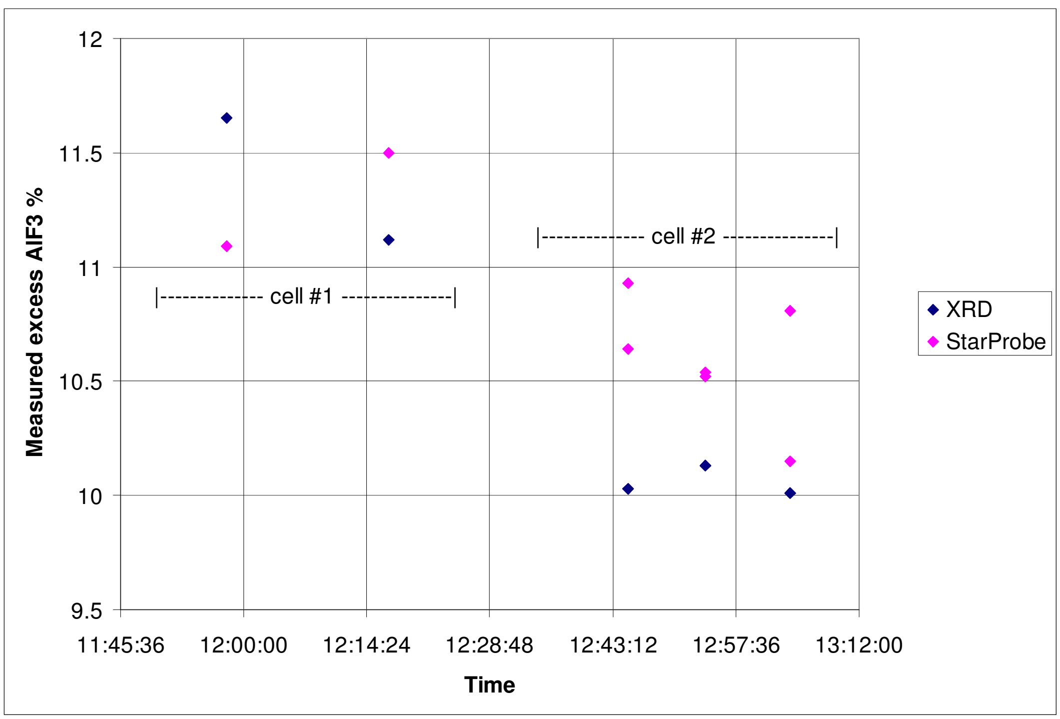

Figure 9: Measured excess AlF_3 concentration

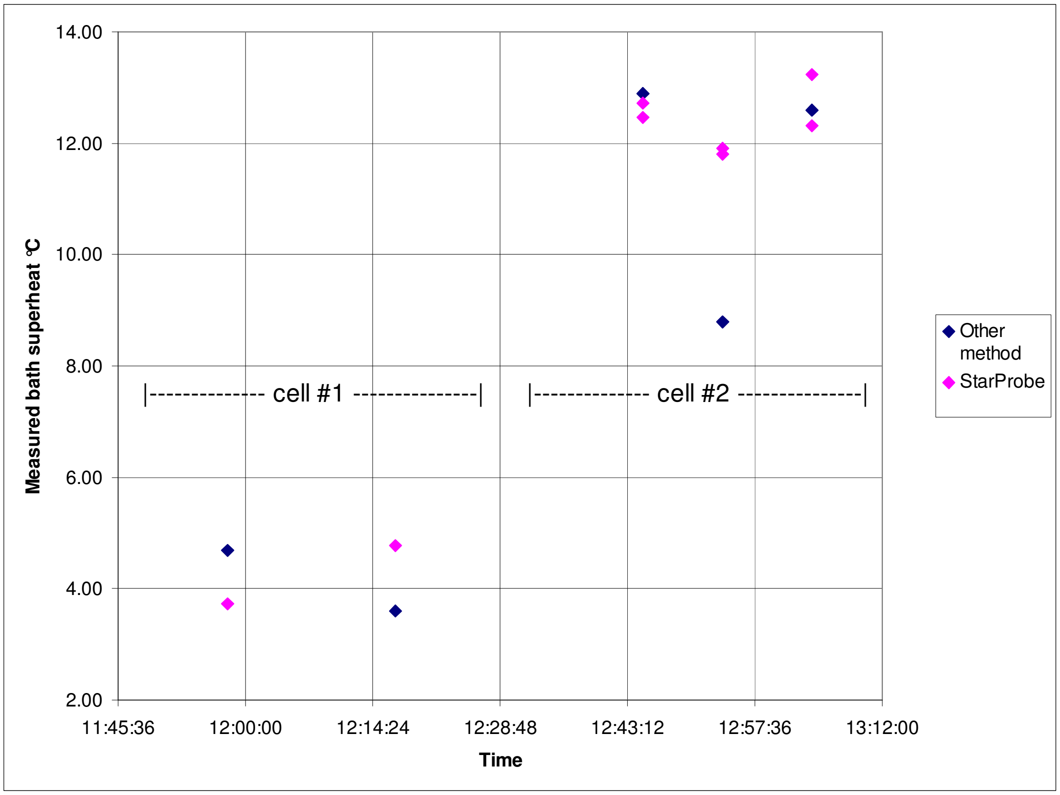

Figure 10: Measured bath superheat

4. Conclusions

Familiarization and demonstration STARprobe™ measurement campaigns have been successfully carried out by STAS since January 2012 in different smelters around the world. Some results from two of them have been presented here.

Comparison with other methods have been carried out independently of Alcoa and are confirming Alcoa's claims on the capabilities of the STARprobe™ to get instantaneous measurement of bath properties for feedback process control purposes.

Measurement repetitivity tests highlight the relative variability or lack of strict repetitivity of the measurements which in turn highlight the lack of homogeneity of the bath. This is particularly true for the dissolved alumina concentration and the bath superheat which is directly affected by the dissolved alumina concentration in the bath sample.

One way to address that sampling noise problem is to measure more frequently and to apply some kind of filter on the measured data before taking feedback control action on it, but that discussion was not in the scope of the present paper.

5. References

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