SPECTRAFLOW
ANALYTICS SWITZERLAND
measure online safe

THE ACCURACY OF A SPECTRAFLOW ANALYZER

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Content

Abstract

SpectraFlow is the only online analyzer on the market free of any radioactive components, neutron generators or lasers. Therefore SpectraFlow is completely safe to operate and no licenses or permits are needed to import, operate and maintain the online analyzer system. This report evaluates at nine different locations the accuracy of the SpectraFlow Analyzer with dynamic comparisons of the XRF at the airslide of raw mills, as well as an absolute comparison of the XRF of crossbelt analyzers after crushers of cement plants. Additionally a dynamic comparison of the results of a Prompt Neutron Activation Analyzer (PGNAA) after a limestone crusher of a cement plant was done. The results of this report show, that SpectraFlow is measuring compared to the XRF reference all constituents very accurately and compared to the PGNAA more accurate. For the process control at the Raw Mill it is essential, that the analyzer delivers very accurate measurement values, as the constituent ranges are very small (e.g. CaO 41% - 45%) compared to an application after the raw material crusher (e.g. CaO 30% - 55%). To control the weight feeders of the additives the measurement results have to be very accurate, real-time (no running averages) and noise-free. A measurement on a belt conveyor is always less accurate than a measurement of raw material on an airslide, due to the consistent grain size and homogeneity of the raw material. Therefore PGNAAs installed before the raw mill are not very efficient to reach very low standard deviations of the Raw Meal, because they have to be installed always on the belt conveyor before the raw mill rather than on the airslide after the mill. SpectraFlow is therefore the most efficient online analyzer for raw mill control.

1. Introduction

This report shows the result of the SpectraFlow Analyzer compared to the conventional offline method XRF, as well as to Prompt Neutron Activation Analyzer (PGNAA). PGNAAs are highly toxic and dangerous and with the availability of SpectraFlow no longer necessary to operate. All the data in this report is collected over representative time frames and from nine different customer installations.

As the results show SpectraFlow is a highly accurate measurement device. The reason for this is:

- Near Infrared is a very sensible analytical method and the ABB Bomem FTIR Spectrometer used in the SpectraFlow Analyzer is the best available on the market, with a very high resolution and an exceptional high precision.
- SpectraFlow is scanning the raw material surface continuously and delivers an interferogram every 425 milliseconds. These interferograms will be averaged over one minute and a spectra is created. In case of a belt speed of 4 m/s and a belt diameter of 2 meters a single minute result covers an area 480m^2 of raw material.
- After a crusher the raw material is statistically mixed. In case certain constituents are partially segregated to the bottom of the belt, the relation of their occurrence on the top and bottom of the conveyor belt is always linear and with an offset correction this is compensated. On an airslide the raw material is very homogeneous and therefore normally no offset correction is needed. This offsets don't have to be adjusted and are extremely accurate and stable.
- A big advantage of the SpectraFlow Analyzer is its surface measurement. Therefore the system is completely independent of belt load and belt speed. No offset corrections have to be done because of changing belt loads.

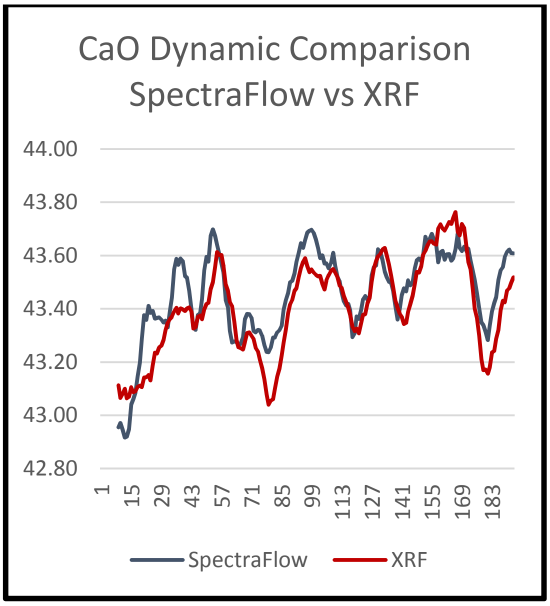
- SpectraFlow is measuring the moisture content of the raw material. In case of the belt conveyor application changing moisture contents in the raw material make it necessary to have a highly accurate moisture measurement. SpectraFlow is measuring the moisture content and is correcting the chemical values directly with the corresponding moisture content. These dry values can be compared over days, weeks or years. Therefore the chemical data delivered by the SpectraFlow Analyzer can be perfectly used for optimizing stockpiles built up over several days.

2. Dynamic Comparison

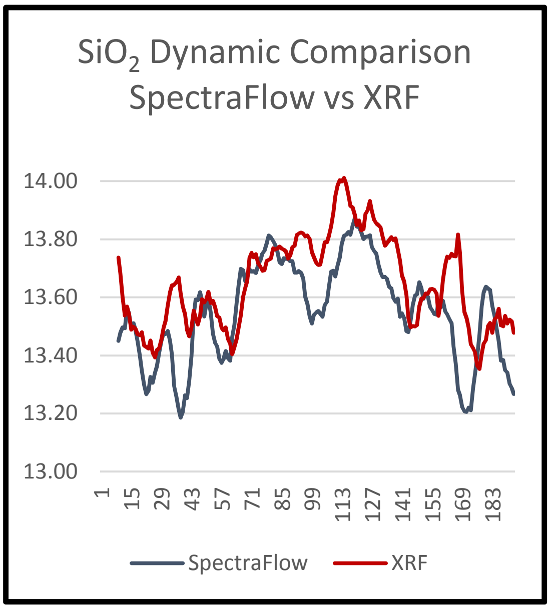
2.1. Comparison of SpectraFlow and XRF

As SpectraFlow can be installed on the airslide it is perfectly possible to compare the analytical results of the analyzer with the XRF as the sampling station is directly behind the analyzer. The sampling stations in these comparisons (Tab.1 to Tab.5) are taking composite samples over one hour with a new sampling system. With all these comparisons the very small range of each constituent has to be considered (e.g. CaO 43.1 to 43.6, SiO_2 13.2 to 13.9, Al_2O_3 3.2 to 3.6, Fe_2O_3 2.15 to 2.45). The charts show, that the SpectraFlow Analyzer measures very accurate and can be therefore perfectly used to control also constituents with very small ranges. This is necessary at the Raw Mill in a cement plant.

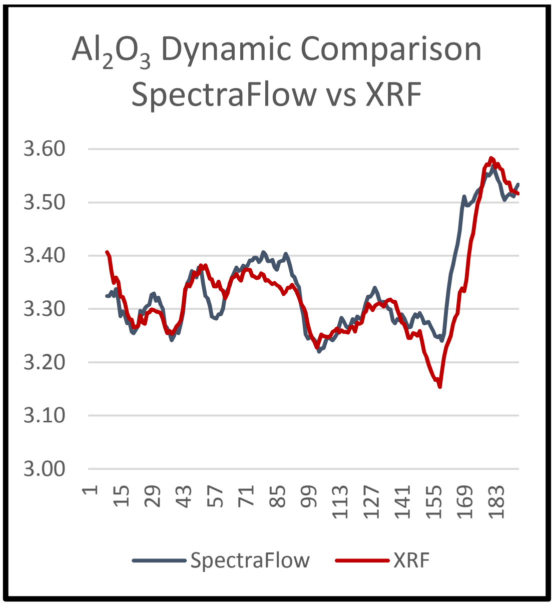
The comparisons were done over a time period of 10 days, where the raw mill was running continuously. The time delay in the XRF measurement is also clearly visible, as the peaks are always delayed for a short time. It also gets obvious, that the sampling system resp. the XRF press pills have problems with the correct sampling resp. an accurate measurement of the SiO_2, due to the behavior of SiO_2 in the sampling screw and matrix effects in the sample, when measuring in the XRF machine. The SpectraFlow results are more reliable, as seen when preparing fused-bed samples for data cross checks.

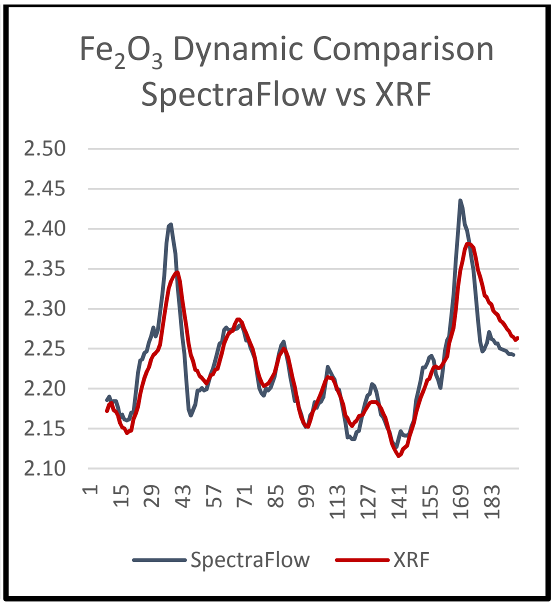


Tab.1 Dynamic Comparison of CaO between XRF and SpectraFlow over 10 days raw mill operation



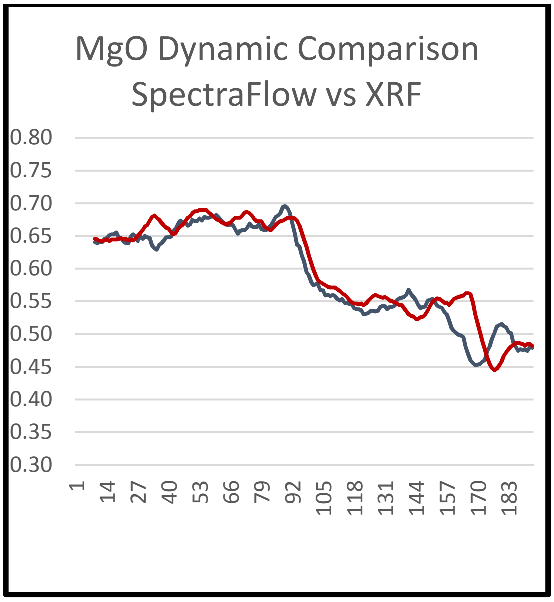
Tab.2 Dynamic Comparison of SiO_2 between XRF and SpectraFlow over 10 days raw mill operation





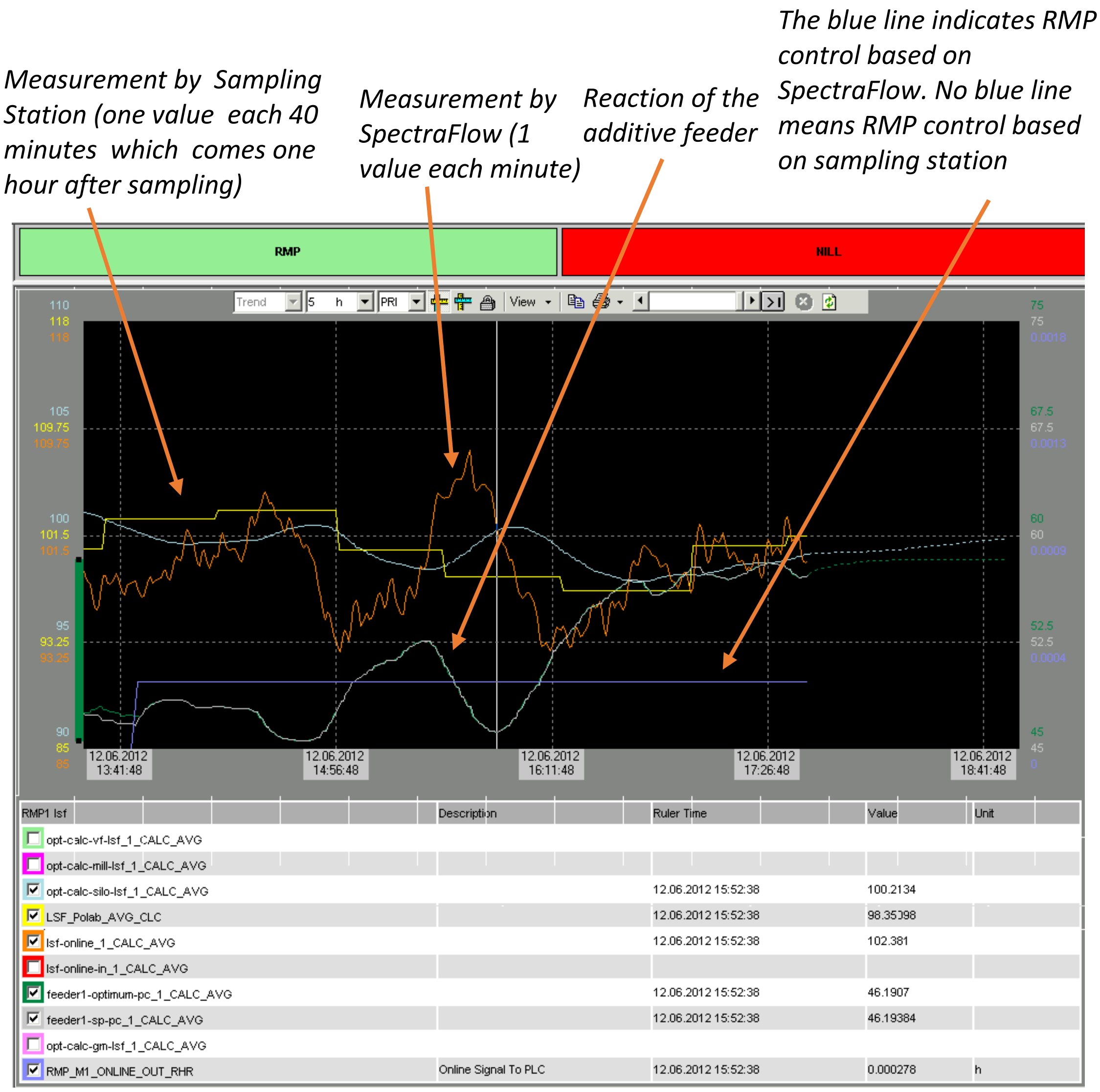
Tab.3 Dynamic Comparison of Al_2O_3 between XRF and SpectraFlow over 10 days raw mill operation

Tab.4 Dynamic Comparison of Fe_2O_3 between XRF and SpectraFlow over 10 days raw mill operation



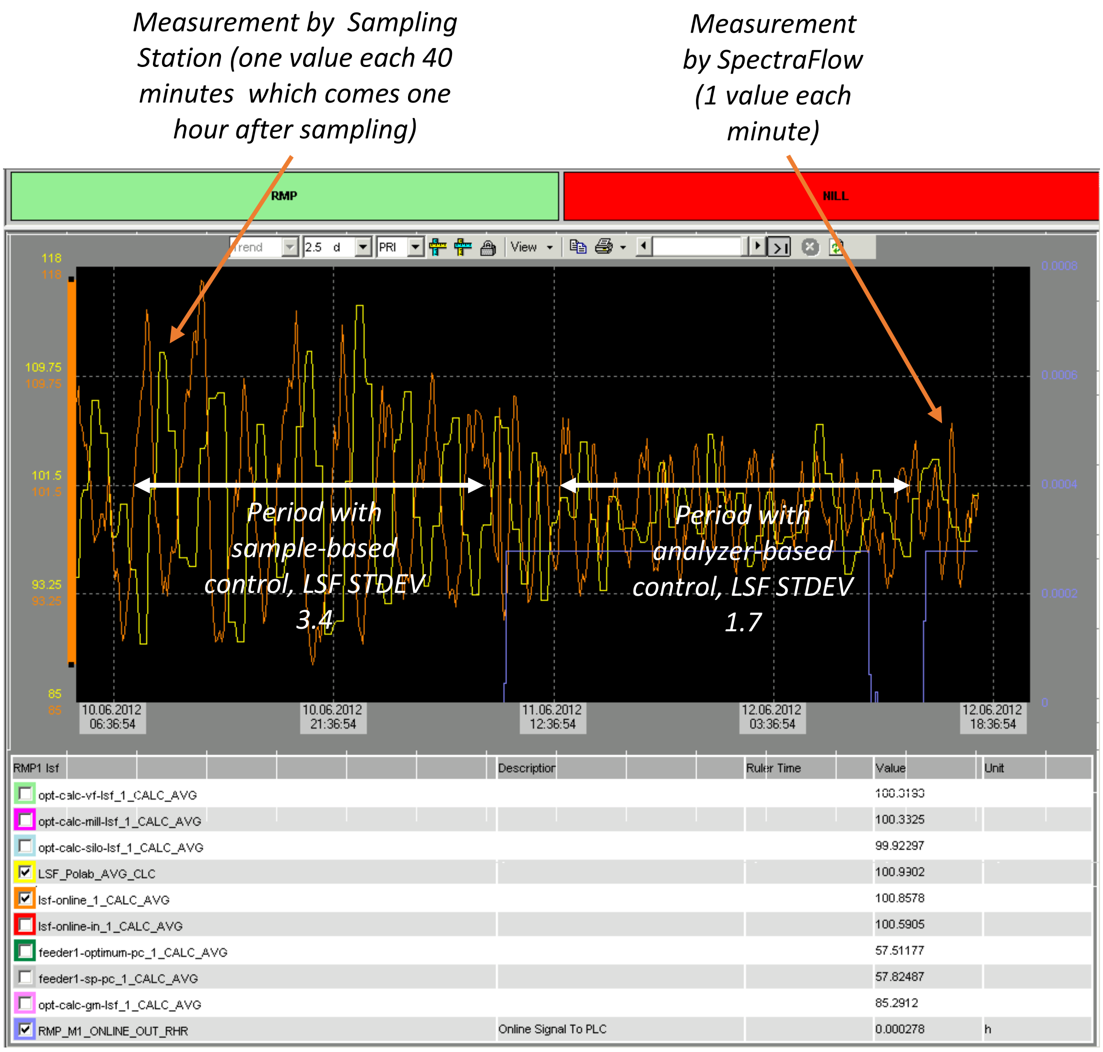
Tab.5 Dynamic Comparison of Al_2O_3 between XRF and SpectraFlow over 10 days raw mill operation

With these accurate measurement results the additive feeders of the raw mill can be optimized very efficiently. This is done by a powerful control software, in Tab.6 the customer has an ABB Raw Mix Proportioning (RMP) software installed and the adjustments of the additive feeders are done on the base of the SpectraFlow Analyzer measurements. Especially when starting a new pile the variations of the stockpile raw material used on the raw mill are very high. In Tab.6 it gets obvious how fast SpectraFlow is identifying the variations and RMP can reacts on these changes immediately. Although the raw material is very variable SpectraFlow and RMP can maintain a very stable LSF of the Raw Meal between 97 and 102 by changing the additive feeder setpoints frequently.



Tab.6 ABB RMP Operator Screen showing the LSF (Lime Saturation Factor) Data of the SpectraFlow Analyzer and the XRF and the feeder adjustments based on the SpectraFlow Analyzer results.

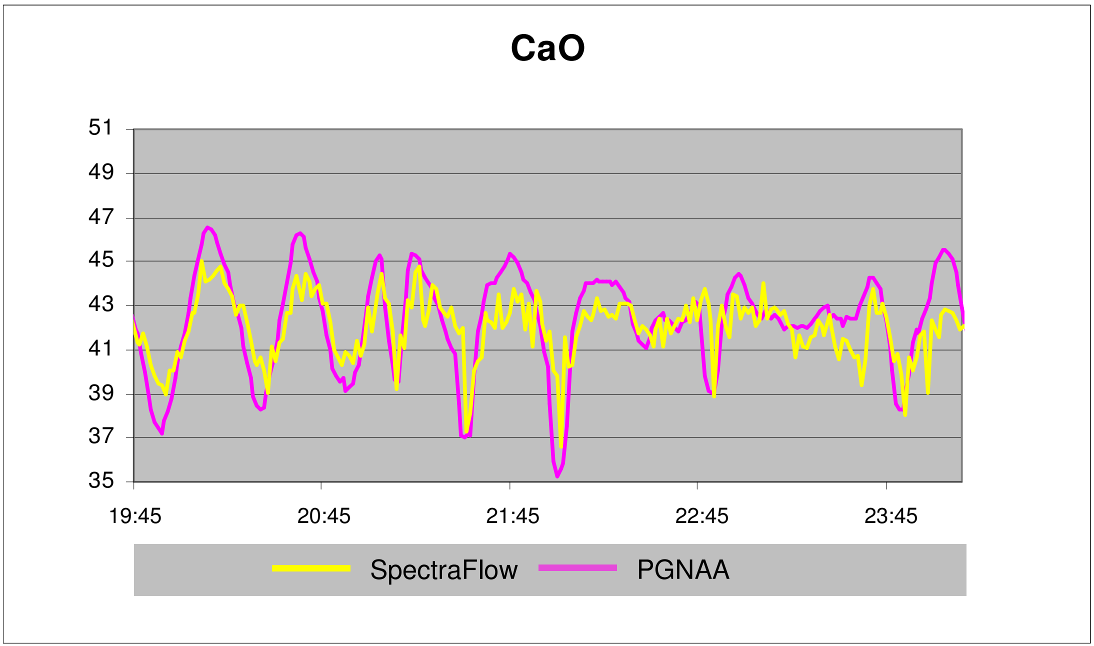
By comparing the performance of the sampled based control and the online analyzer based control the benefit of the accurate high frequent measurement gets especially visible. In Tab.7 the RMP control software was using the 40-minute XRF values during the first 1.5 days of the comparison, while in the second 1.5 days the minute values of the SpectraFlow Analyzers were used to optimize the additive weight feeders. The reduction of the LSF standard deviation was from 3.4 down to 1.7.



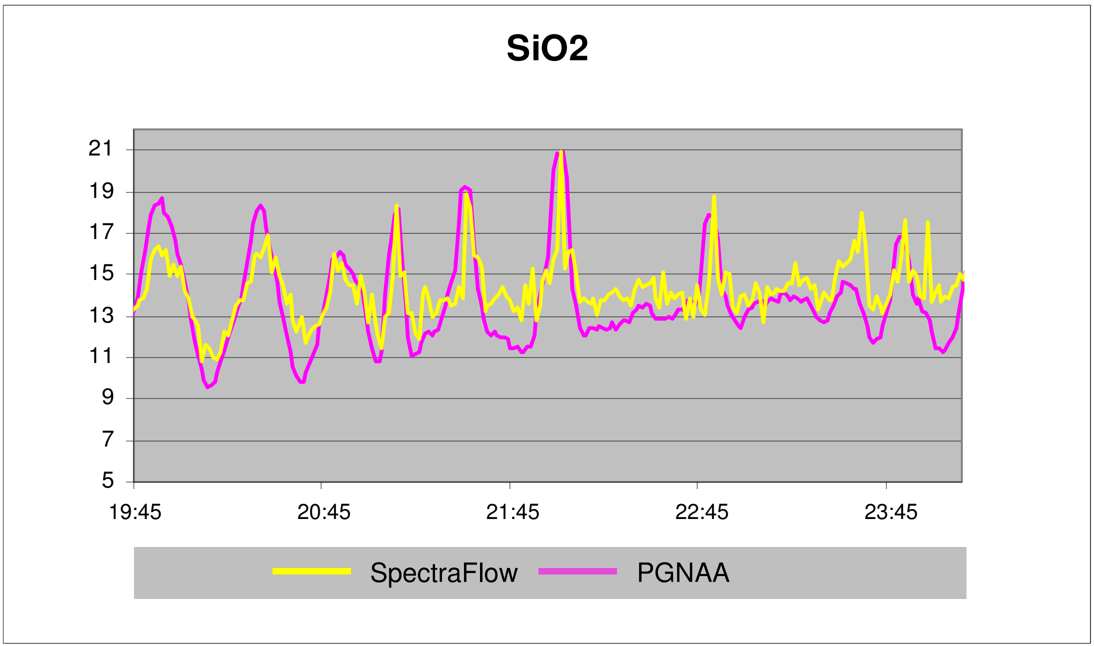
Tab.7 ABB Operator Screen showing the comparison of LSF variation of sample based control and analyzer based control.

2.2. Comparison of SpectraFlow and PGNAA (Prompt Neutron Activation Analyzer)

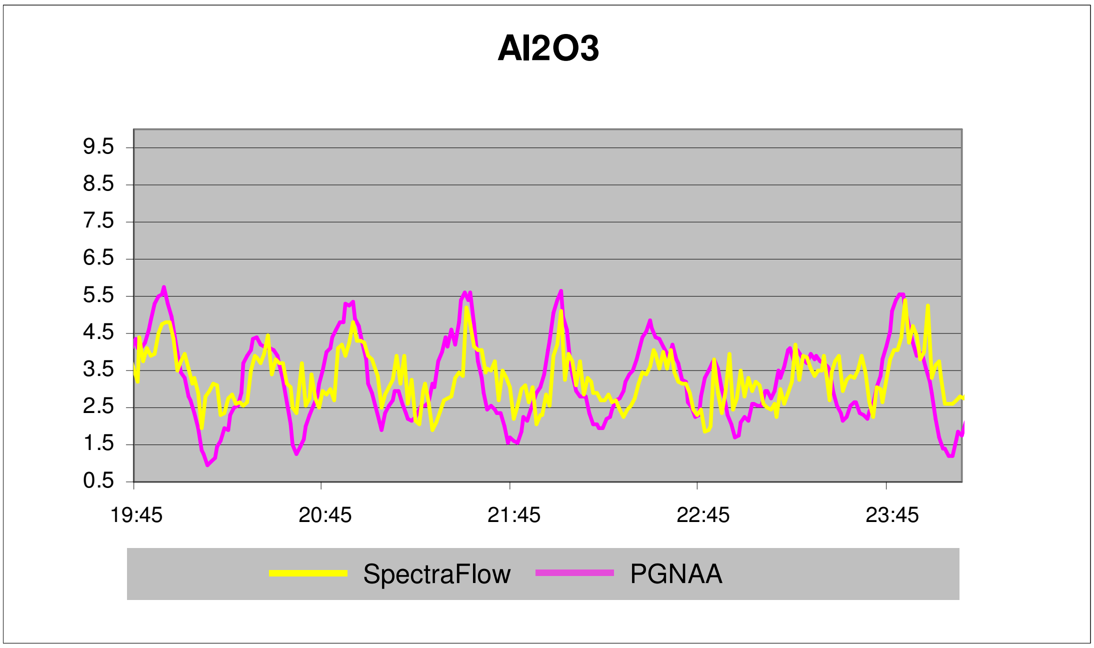
A customer was replacing the PGNAA with the SpectraFlow Analyzer and due to the short delivery times of the SpectraFlow Analyzer the source of the existing PGNAA was still strong and the analyzer was in operation. During this time it was possible to compare the performance of both analyzers extensively, as both analyzers were installed on the same conveyor belt. In a dynamic test over 4.5 hours different raw materials, from high quality limestone to marl was fed to the crusher to cause huge variations with the most important constituents CaO, SiO_2, Al_2O_3 and Fe_2O_3. The results show, that the SpectraFlow Analyzer was following very accurately the dynamics of the PGNAA. The absolute comparison with the XRF over several complete piles show, that SpectraFlow is measuring more accurate than the PGNAA (see Tab.17).



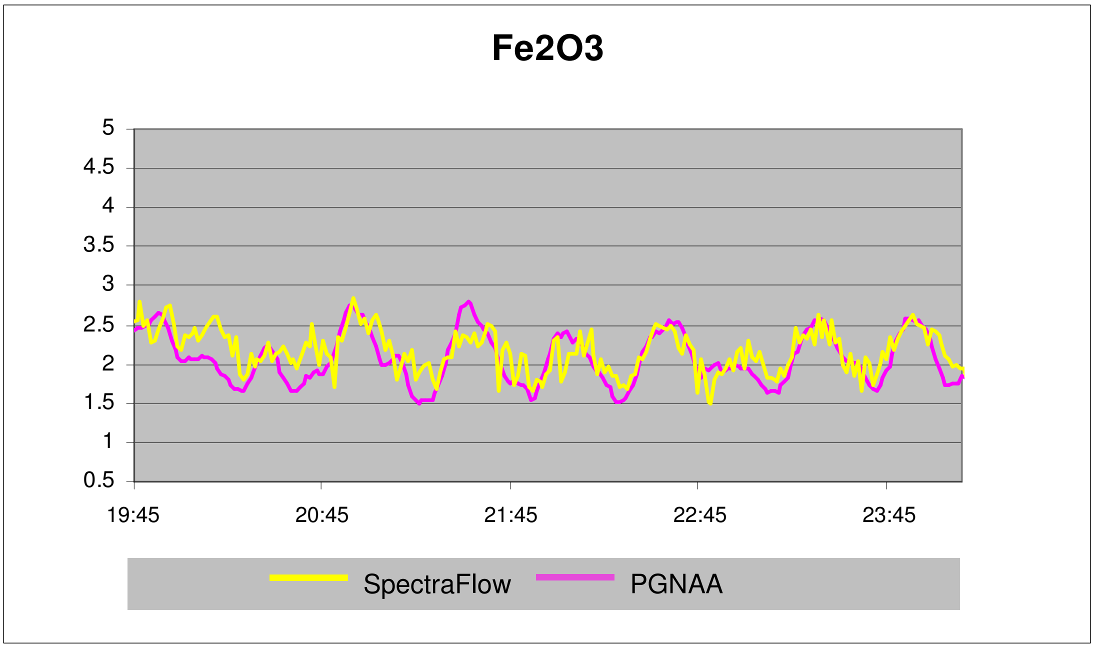
Tab.8 CaO dynamic comparison of PGNAA results with SpectraFlow during a dynamic performance test over 4.5 hours



Tab.9 SiO_2 dynamic comparison of PGNAA results with SpectraFlow during a dynamic performance test over 4.5 hours



Tab.10 Al_2O_3 dynamic comparison of PGNAA results with SpectraFlow during a dynamic performance test over 4.5 hours

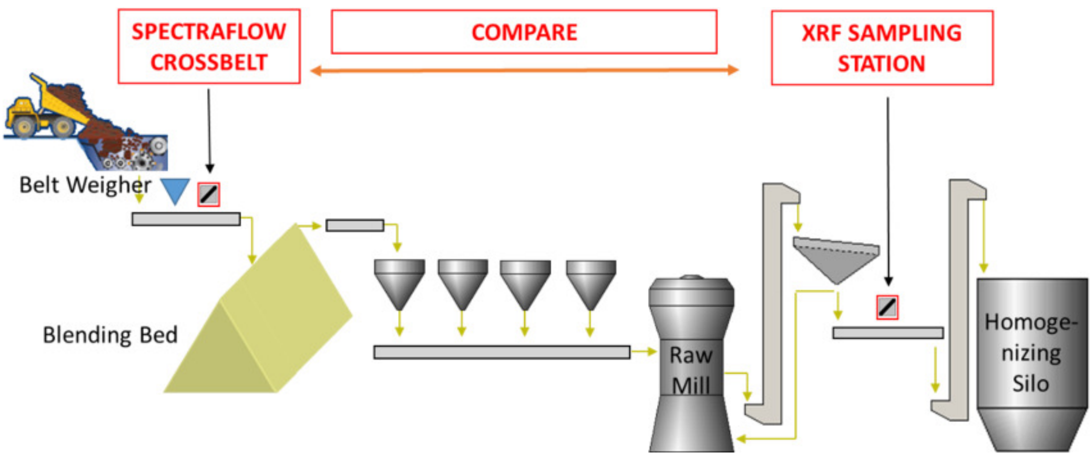


Tab.11 Fe_2O_3 dynamic comparison of PGNAA results with SpectraFlow during a dynamic performance test over 4.5 hours

3. Absolute Comparison

3.1. Comparison of SpectraFlow and XRF

Every performance evaluation of a Crossbelt Analyzer has to be done with a Backcalculation of the XRF Raw Mill values. As the Stockpile is between the Analyzer and the Raw Mill only a comparison of the average chemical composition of the Analyzer values during the stacking of the pile and the average chemical composition of the XRF values after the Raw Mill is meaningful. As this comparison is considering a huge amount of values the comparison is solid. Important is, that from the XRF or SpectraFlow values the additive amount and the chemical composition of each additive has to be subtracted. The accuracy of the backcalculation of each constituent therefore strongly depends on the concentration either in the stockpile or the additives (e.g. if the stockpile mainly contains limestone and the silica is added via the additive feeders the backcalculation will be accurate for CaO but rather difficult for SiO_2. The reason is, that most CaO is added via the stockpile and is measured by the analyzer, while most of the SiO_2 is added via the additive feeders and is not measured by the analyzer and therefore most variations of the SiO_2 are coming from the additives). Another important point is, how much additives are added to the raw mill feed and the chemical variation. As more additives are added with a higher variability less accurate the backcalculation gets.



Tab. 12 Principle of the Backcalculation. To compare the XRF values with the SpectraFlow values the average over a complete pile has to be calculated and the additive addition has to be subtracted from the XRF values or the SpectraFlow values.

In Tab. 13 the additives were subtracted from the SpectraFlow values. About 90% of the raw mill feed is coming from the stockpile and the backcalculation shows, that the SpectraFlow Analyzer is measuring very accurately compared to the XRF reference values. This backcalculation was done over a pile of 10’000 t. The slightly higher deviation of the SiO_2 and Al_2O_3 values is mainly coming from the additive addition. Significant amounts of Silica and Alumina are added via the additive Shale, which is added to the mill approx. 7-9 % (60-70% SiO_2, 10-14% Al_2O_3). Iron is only added between 1 - 3% (38% SiO_2 and 12-15 % Al_2O_3). CaO is exclusively added via the stockpile and the backcalculation therefore is very solid. The iron content in the Iron additive is very stable, therefore also the Fe_2O_3 backcalculated values are very solid.

		CaO		SiO2		Al2O3		Fe2O3	
STOCKPILE 1		SF	XRF	SF	XRF	SF	XRF	SF	XRF
	%	42.31	42.26	14.20	14.95	2.55	2.84	2.52	2.46
		0.05		0.74		0.29		0.06	
STOCKPILE 2		SF	XRF	SF	XRF	SF	XRF	SF	XRF
	%	42.19	42.43	14.62	14.87	2.63	2.83	2.41	2.46
		0.24		0.25		0.20		0.05	
STOCKPILE 3		SF	XRF	SF	XRF	SF	XRF	SF	XRF
	%	42.27	42.44	14.56	14.89	2.65	2.79	2.44	2.51
		0.17		0.33		0.14		0.08	
STOCKPILE 4		SF	XRF	SF	XRF	SF	XRF	SF	XRF
	%	42.20	42.59	14.48	14.82	2.65	2.75	2.46	2.46
		0.39		0.34		0.11		0.00	
STOCKPILE 5		SF	XRF	SF	XRF	SF	XRF	SF	XRF
	%	41.88	42.42	14.98	14.94	2.64	2.87	2.53	2.38
		0.54		0.04		0.23		0.15	
STOCKPILE 6		SF	XRF	SF	XRF	SF	XRF	SF	XRF
	%	41.95	42.41	14.77	14.84	2.61	2.87	2.50	2.45
		0.46		0.07		0.27		0.04	

Tab. 13 Backcalculated XRF values compared to the SpectraFlow values. All values are averages of a complete stockpile of 10'000t.

The customer in Tab. 14 is feeding the raw mill with only around 85% raw material from the stockpile, therefore the backcalculation is less accurate as 15% of the raw mill feed is coming from additives. Parallel to the SpectraFlow a limestone sampler is in operation and the results show, that the limestone sampler is not taking representative samples, as the silicia content is more than 4% too low. Only SpectraFlow is used to control the pile stacking and therefore the pile chemical composition is very stable, especially as the raw material is not very constant. The backcalculation is done over a pile size of more than 50'000 and as the additive addition is around 15% the differences of the XRF and SF are slightly higher as with the customer in Tab. 13, where the pile size is only 10'000 and the additive addition around 10%.

Pile	CaO			SiO2			Al2O3			Fe2O3			MgO			K2O			Cl		
	XRF	SF	LS	XRF	SF	LS	XRF	SF	LS	XRF	SF	LS	XRF	SF	LS	XRF	SF	LS	XRF	SF	LS
1	48.39	48.35	48.71	9.55	9.86	7.49	2.04	2.14	1.72	1.06	1.03	0.63	0.67	0.61	0.78	0.31	0.31	0.19	0.20	0.21	0.28
2	48.03	47.80	48.57	9.84	10.00	7.59	2.22	2.15	1.76	1.05	1.05	0.65	0.71	0.67	0.78	0.33	0.34	0.19	0.20	0.20	0.20
3	47.82	48.23	48.47	10.31	9.99	7.89	2.24	2.07	1.73	1.02	0.97	0.61	0.39	0.38	0.74	0.33	0.33	0.18	0.20	0.21	0.21
4	47.75	48.55	48.39	10.39	9.19	7.98	2.13	2.66	1.80	1.07	1.00	0.64	0.62	0.53	0.77	0.33	0.31	0.20	0.20	0.23	0.20
5	48.20	47.96	48.56	9.98	9.66	7.30	1.95	2.06	1.55	1.13	1.01	0.58	0.72	0.75	0.74	0.30	0.33	0.18	0.21	0.20	0.18
6	47.68	47.90	47.02	10.51	10.38	7.39	2.15	2.21	1.69	1.10	1.03	0.61	0.72	0.76	0.77	0.32	0.33	0.17	0.21	0.20	0.21
7	48.07	47.75	48.43	11.11	11.31	7.77	2.05	2.13	1.74	1.10	0.96	0.62	0.70	0.73	0.75	0.31	0.37	0.19	0.21	0.18	0.29
8	48.07	47.81	48.60	11.15	10.70	7.65	2.04	2.04	1.72	1.12	0.96	0.62	0.71	0.84	0.76	0.31	0.37	0.19	0.20	0.18	0.29
9	48.17	47.97	48.55	10.82	10.84	7.80	2.03	2.10	1.76	1.15	1.02	0.62	0.78	0.84	0.87	0.31	0.37	0.20	0.20	0.16	0.28
10	48.05	47.98	48.42	11.09	11.44	8.17	2.18	2.03	1.88	1.03	0.93	0.65	0.51	0.54	0.76	0.32	0.37	0.20	0.19	0.20	0.25
11	48.29	47.65	48.55	10.56	11.27	7.59	2.04	2.11	1.75	1.00	0.97	0.62	0.81	0.86	0.91	0.30	0.37	0.19	0.20	0.20	0.28
12	48.29	47.73	48.69	10.68	11.88	8.20	2.11	2.17	1.71	0.98	0.93	0.58	0.48	0.47	0.71	0.29	0.36	0.18	0.19	0.14	0.21
13	48.20	48.06	48.44	10.50	11.52	7.96	2.14	2.17	1.85	1.11	1.05	0.65	0.56	0.54	0.74	0.31	0.35	0.19	0.19	0.17	0.24
14	47.02	47.42	48.41	11.67	11.97	8.18	2.35	2.26	1.73	1.23	1.04	0.60	0.86	0.78	0.86	0.36	0.35	0.19	0.19	0.15	0.24
15	48.12	47.87	48.40	10.66	11.25	8.05	2.20	2.15	1.78	1.14	1.06	0.65	0.76	0.66	0.79	0.32	0.34	0.19	0.18	0.14	0.22

Tab. 14 Backcalculated XRF values compared with SpectraFlow (SF) and a Limestone Sampler (LS). The results over 15 stockpiles show, that a limestone sampler can't be used to efficiently control the stockpile stacking. The pile size is more than 50'000t and approx. 85% of the raw material at the mill was coming from the stockpile.

The best comparison of the SpectraFlow and XRF analytical values was possible at a customer, who is using more than 90 % of the raw mill feed from the stockpile and very stable additives. This evaluation (Tab. 15) shows an exceptional stable stockpile, what results in a very low standard deviation of the LSF of around 1.5 at the raw mill. The main reason for this excellent performance is the setup at the crusher, where from 2 feeder belts clay and limestone is separately fed into the crusher according the chemical composition measured by SpectraFlow. As the operation is independent of the trucks a very stable and homogeneous stockpile close at the LSF setpoint of the raw mill is the result. Additionally the weight feeders into the crusher are controlled by a software, which is reading the values of the analyzer and adjusts the feeders into the crusher automatically.

			STDEV[4]	SpectraFlow	XRF	Deviation
PILE 1	RM 2[2]	LSF	1.32	133.70	133.17	0.53
PILE 2	RM 1[1]		1.61	137.05	137.21	-0.16
	RM 2[2]		0.97			
PILE 1	RM 2[2]	CaO	0.20	45.71	45.75	-0.04
PILE 2	RM 1[1]		0.21	45.91	45.83	0.09
	RM 2[2]		0.17			
PILE 1	RM 2[2]	SiO2	0.17	10.70	10.79	-0.10
PILE 2	RM 1[1]		0.20	10.53	10.44	0.09
	RM 2[2]		0.11			
PILE 1	RM 2[2]	Al2O3	0.07	2.83	2.78	0.05
PILE 2	RM 1[1]		0.09	2.68	2.74	-0.06
	RM 2[2]		0.06			
PILE 1	RM 2[2]	Fe2O3	0.11	1.30	1.23	0.07
PILE 2	RM 1[1]		0.08	1.23	1.37	-0.14
	RM 2[2]		0.05			
PILE 1	RM 2[2]	MgO	0.04	1.28	1.28	-0.01
PILE 2	RM 1[1]		0.03	1.30	1.32	-0.01
	RM 2[2]		0.03			
PILE 1	RM 2[2]	K2O	0.01	0.39	0.38	0.01
PILE 2	RM 1[1]		0.01	0.38	0.38	0.00
	RM 2[2]		0.01			

Consumption of				
PILE 1				
MIX[3]	CLAY	LATERITE	TOTAL	
53084	2901	1450	57435	t
92.42	5.05	2.53	100.00	%
PILE 2				
MIX[3]	CLAY	LATERITE	TOTAL	
48509	3431	1004	52944	t
91.01	7.00	1.99	100.00	%
RAW MILL 1[1] / LINE 1				
23234	2109	479	25821	t
89.94	8.20	1.86	100.00	%
RAW MILL 2[2] / LINE 2				
25275	1322	605	27203	t
92.91	4.85	2.23	100.00	%

1) RM 1 is without additive feeder control
2) RM 2 is with additive feeder control
3) Raw Material from Stockpile
4) STDEV from hourly XRF Raw Mill values

Tab.15 Comparison of XRF and SpectraFlow, where over 90% of the raw mill feed was used from the stockpile. The total amount of compared raw material was more than 110'000 t from 2 complete stockpiles.

One customer has two ball mills at a rather small capacity and a big homogenization silo. Therefore it was possible to stop at one raw mill the additives completely for 4 hours each day for a period of 17 days. The circular stockpile was stacked at an average LSF of 80 with the SpectraFlow Analyzer and during the 4 hours daily stoppage of the additive the XRF had to show an LSF of approx. 80. The first sample after the stoppage was not considered and then average of the next 3 samples was made. All sectors were very close to LSF 80 and this results also clearly shows the accuracy of the SpectraFlow measurement. The complete test was made over about 34'000t of raw material and the feeding of the crusher was directly with trucks.

Day	Time	Raw Mill	Additive	LSF		Day	Time	Raw Mill	Additive	LSF	
1	10:58	OM2	OFF	114.00		10	08:17	OM2	OFF	93.1	
	11:58	OM2	OFF	81.40			09:26	OM2	OFF	93.7	
	13:10	OM2	OFF	78.80			10:18	OM2	OFF	80	
	13:59	OM2	OFF	85.60			11:22	OM2	OFF	78.2	
	13:59	OM2	ON	82.20	Average 82.20 SEKTOR01		11:22	OM2	ON	79.10	Average 79.10 SEKTOR10
2	09:09	OM2	OFF	108.00		11	10:17	OM2	OFF	97.7	
	10:08	OM2	OFF	80.30			11:17	OM2	OFF	76.2	
	11:12	OM2	OFF	82.40			12:24	OM2	OFF	76.8	
	12:07	OM2	OFF	73.50			13:16	OM2	OFF	77.6	
	12:07	OM2	ON	77.95	Average 77.95 SEKTOR02		13:16	OM2	ON	77.20	Average 77.20 SEKTOR11
3	09:00	OM2	OFF	105.00		12	09:25	OM2	OFF	97.1	
	10:05	OM2	OFF	74.00			10:20	OM2	OFF	97.1	
	11:09	OM2	OFF	78.70			11:24	OM2	OFF	80.4	
	12:04	OM2	OFF	73.10			12:16	OM2	OFF	93.1	
	12:04	OM2	ON	75.90	Average 75.90 SEKTOR03		12:16	OM2	ON	86.75	Average 86.75 SEKTOR12
4	08:12	OM2	OFF	98.40		13	08:16	OM2	OFF	115	
	09:25	OM2	OFF	105.00			09:20	OM2	OFF	80.4	
	10:24	OM2	OFF	84.70			10:11	OM2	OFF	82.9	
	11:24	OM2	OFF	83.90			11:09	OM2	OFF	79.2	
	11:24	OM2	ON	84.30	Average 84.30 SEKTOR04		11:09	OM2	ON	81.05	Average 81.05 SEKTOR13
5	10:23	OM2	OFF	95.90		14	12:19	OM2	OFF	101	
	11:14	OM2	OFF	90.90			13:13	OM2	OFF	98.2	
	12:10	OM2	OFF	86.40			14:14	OM2	OFF	80	
	13:13	OM2	OFF	82.50			15:22	OM2	OFF	83.3	
	13:13	OM2	ON	84.45	Average 84.45 SEKTOR05		15:22	OM2	ON	81.65	Average 81.65 SEKTOR14
6	10:12	OM2	OFF	94.2		15	08:26	OM2	OFF	79.2	
	11:15	OM2	OFF	98.3			09:23	OM2	OFF	113	
	12:10	OM2	OFF	82.9			10:27	OM2	OFF	68.7	
	13:12	OM2	OFF	76.1			11:23	OM2	OFF	62.8	
	13:12	OM2	ON	79.50	Average 79.50 SEKTOR06		11:23	OM2	ON	65.75	Average 65.75 SEKTOR15
7	10:17	OM2	OFF	93.8		16	17:00	OM1	OFF	113	
	11:15	OM2	OFF	95.7			18:00	OM1	OFF	111	
	12:20	OM2	OFF	75.2			19:00	OM1	OFF	84.7	
	13:14	OM2	OFF	80.2			20:00	OM1	OFF	75.6	
	13:14	OM2	ON	77.70	Average 77.70 SEKTOR07		20:00	OM1	ON	80.15	Average 80.15 SEKTOR16
8	09:16	OM2	OFF	93		17	17:00	OM1	OFF	113	
	10:18	OM2	OFF	84.3			18:00	OM1	OFF	91.8	
	11:14	OM2	OFF	88.2			19:00	OM1	OFF	82.9	
	12:18	OM2	OFF	74.4			20:00	OM1	OFF	73.3	
	12:18	OM2	ON	81.30	Average 81.30 SEKTOR08		20:00	OM1	ON	78.10	Average 78.10 SEKTOR17
9	08:19	OM2	OFF	91.8							
	09:22	OM2	OFF	84.5							
	10:18	OM2	OFF	75							
	11:22	OM2	OFF	75.5							
	11:22	OM2	ON	75.25	Average 75.25 SEKTOR09						

Tab.16 Comparison of SpectraFlow results with the XRF after the raw mill with the stopping of the additive feeders for 4 hours. The pile was stacked at an approx. LSF of 80, which confirmed the XRF when the additives were stopped.

3.2. Comparison of SpectraFlow and PGNAA (Prompt Neutron Activation Analyzer)

Comparing the average stockpile values of both analyzers with the backcalculated XRF values over 10 piles of each approx. 35'000 tons it shows, that SpectraFlow is measuring more accurately all constituents. The SiO_2 is the only constituent, where the PGNAA has a lower RMSD to the XRF, however by observing the data of the Raw Meal the SiO_2 content is around 14.0%, while the backcalculated contribution of SiO_2 from the stockpile is below 3%. More than 80% of the SiO_2 content is added with Sandstone and Clay and the variations of SiO_2 are therefore mostly coming from the additives, which are not measured by the analyzers. A backcalculation of the SiO_2 is therefore not very meaningful. In contrary CaO is only fed to the mill from the stockpile and therefore the backcalculation is very solid. The SpectraFlow Analyzer has an RMSD of 0.47, while the PGNAA has a RMSD more than double of 1.28. This difference is also visible with all other constituents and especially the MgO results of the PGNAA are very unreliable, which was always a concern of the customer, as the quarry contains sections with higher MgO.

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	RMSD
Tons	XRF	34425	33224	35501	31855	34964	33394	32305	32055	35858	32124	
	SF	35226	33344	36298	33272	35234	32850	32936	33092	37042	32364	
	PGNAA	34688	32756	35719	29052	35097	32993	32940	33024	36681	34688	
CaO	XRF	50.81	51.36	51.34	50.84	51.08	51.35	51.40	50.99	51.53	51.40	
	SF	51.65	51.68	50.99	51.26	51.41	51.13	50.73	50.83	50.96	51.05	0.47
	PGNAA	49.80	50.21	50.42	49.56	50.08	50.12	49.96	49.56	50.01	49.80	1.28
SiO2	XRF	3.79	2.79	2.74	3.66	2.98	2.34	2.53	3.04	2.69	2.92	
	SF	2.80	2.54	2.50	2.80	1.90	2.70	3.00	2.73	2.87	3.62	0.63
	PGNAA	3.33	2.30	2.40	3.60	2.62	2.32	2.67	3.35	2.67	3.33	0.31
Al2O3	XRF	1.12	0.83	0.72	0.76	0.77	0.81	1.01	0.91	0.91	1.05	
	SF	0.91	0.85	0.94	0.97	0.92	0.85	0.94	0.94	0.92	1.05	0.13
	PGNAA	0.69	0.67	0.63	0.71	0.67	0.70	0.67	0.74	0.63	0.69	0.24
Fe2O3	XRF	1.44	1.30	1.41	1.33	1.27	1.37	1.29	1.24	1.24	1.15	
	SF	1.33	1.31	1.39	1.33	1.25	1.24	1.31	1.32	1.33	1.31	0.08
	PGNAA	1.26	1.20	1.23	1.23	1.19	1.16	1.17	1.25	1.19	1.26	0.13
MgO	XRF	2.32	2.33	2.36	2.34	2.41	2.38	2.56	2.49	2.53	2.31	
	SF	2.60	2.67	2.57	2.61	2.57	2.69	2.59	2.64	2.68	2.33	0.22
	PGNAA	2.77	2.99	2.78	2.87	2.93	3.08	3.05	3.01	3.01	2.77	0.53
K2O	XRF	0.12	0.08	0.09	0.07	0.07	0.08	0.10	0.09	0.11	0.07	
	SF	0.13	0.11	0.11	0.13	0.11	0.11	0.12	0.12	0.12	0.12	0.03
	PGNAA	0.13	0.11	0.13	0.13	0.11	0.10	0.12	0.13	0.14	0.13	0.04
SO3	XRF	-0.07	-0.03	-0.03	-0.02	-0.04	-0.05	-0.06	-0.02	-0.05	-0.08	
	SF	0.27	0.18	0.05	0.15	0.09	0.39	0.15	0.16	0.11	0.15	0.24
	PGNAA	0.24	0.18	0.11	0.13	0.08	0.27	0.18	0.17	0.17	0.24	0.23
Na2O	XRF	0.05	0.06	0.05	0.06	0.06	0.07	0.06	0.06	0.07	0.07	
	SF	0.09	0.09	0.10	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.03
	PGNAA	-0.04	-0.09	-0.06	-0.08	-0.05	-0.09	-0.07	-0.10	-0.09	-0.04	0.13

Tab. 17 RMSD comparison of SpectraFlow and PGNAA with the backcalculated XRF pile averages over 10 piles of approx. 35’000 tons each.