



X-RAY FLUORESCENCE

## S2 PUMA Series 2 for Slag Analysis

Process Control in EAF and LMF Steel Making Made Quick,  
Easy and Cost Effective

Innovation with Integrity

# Enhance efficiency in steelmaking!

## Precisely Access the Slag Furnace Condition with the S2 PUMA Series 2!

For Steelmakers seeking to manufacture steel more profitably, it is essential to adopt technologies and processes that allow for monitoring and sampling slag more efficiently and cost effectively. Because of the highly integral role of slag in steel manufacturing, it is critical that these prospective technologies and processes are at a minimum: reliable, repeatable, accurate, and that the instrument functions properly in difficult manufacturing environments.

Slag is an important agent in high temperature metallurgical processes and is tuned to an equilibrium condition for maximum action on the metal purity, least attack on the refractory lining, and optimal physical properties. Dosage of slag enhancing additives such as lime, dolomite, or other additives is performed based on the chemical composition of the slag and determines the subsequent by-product sale, creating an additional revenue generating product.

## The Perfect Fit – S2 PUMA Slag Analyzer

The S2 PUMA is a ruggedized benchtop energy dispersive X-ray fluorescence (EDXRF) analyzer developed for tight process control in industrial applications. It is the optimal tool to measure the composition of slags on the shop floor, enabling plant operators to make critical decision within 10 minutes after sampling (including sample preparation) and, thus, in time to ensure optimum dosing of additives (e.g. lime). State-of-the-art X-ray technology enables the S2 PUMA to quickly achieve the analytical accuracy and precision required at the steel plant, helping to reduce costs and improve production efficiency.

Slag processing in steel making



Slag transportation in steel making



# Sample preparation: the key to optimal results

## Sample Preparation

The slag samples were prepared as pressed powder pellets with the aid of a binding agent. 15 g of sample and 1 g of grinding aid tablet were ground together in a tungsten carbide grinding vessel. A magnet was passed over the sample to remove any metal prills that remained in the sample. The powder was then pressed in an aluminum cup (40 mm in diameter) at 30 tons of pressure for 30 s.

## Analytical Procedure

Measurements were performed on a S2 PUMA in vacuum mode. Equipped with Bruker's HighSense XP detector and the 50 W HighSense X-ray Tube with Ag target, the S2 PUMA achieves excellent data quality in just 2 minutes counting time and using the same conditions for all elements of interest. Table 1 lists the applied measurement conditions. The overall time-to-result per sample was ~5 minutes; including sample loading and unloading.

**Table 1** Optimal measurement conditions for slags on the S2 PUMA

Voltage [kV]	Current	Beam filter	Mode	Measurement time [s]	Elements analyzed
20	Automatic	No Filter	Vacuum	120	F, Mg, Al, Si, P, S, Ca, Ti, Cr, Mn, Fe

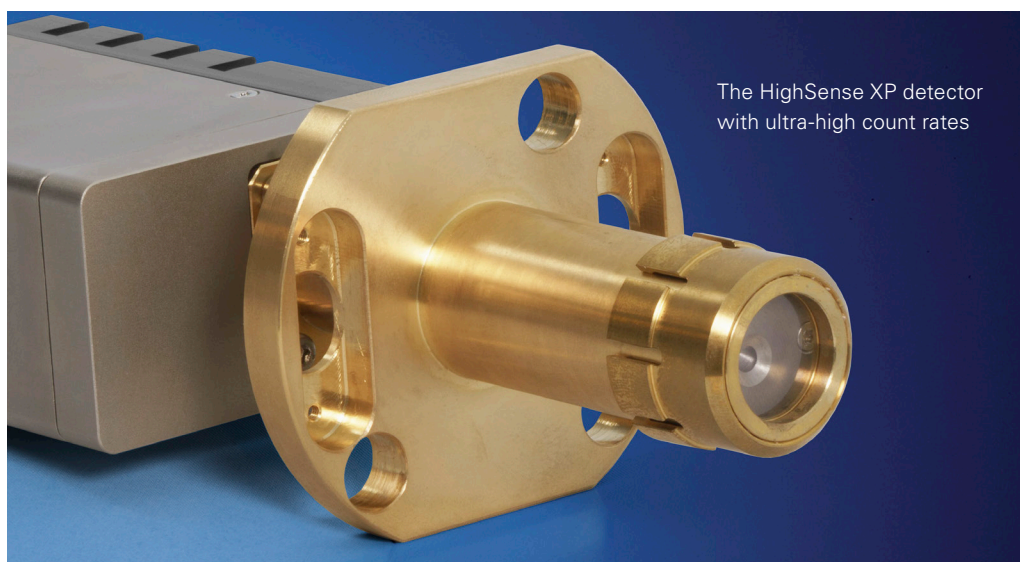
S2 PUMA Single for quick process control of slags



# High Precision and Accuracy with HighSense™ Technology

A set of 30 certified and secondary electric arc furnace (EAF) reference materials and a set of 33 certified and secondary ladle metallurgy furnace (LMF) reference materials were used for two calibrations covering the different concentrations ranges relevant for these two slag types. Elements covered: MgO, Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, S, CaO, TiO<sub>2</sub>, Cr<sub>2</sub>O<sub>3</sub>, MnO, and FeO. Fluorine is only included in the LMF calibration since it is irrelevant for EAF slag monitoring. Similarly, Cr is part of the EAF calibration but not monitored in LMF slags (see Tables 2 and 3). The purpose of adding secondary standards is to help extend the calibration ranges and to compensate for the different particle size between certified reference materials and unknown samples, especially for the lighter elements like MgO and Al<sub>2</sub>O<sub>3</sub>.

The calibration was performed with the powerful and intuitive analytical software SPECTRA.ELEMENTS. This integrated XRF spectroscopy package offers a wide range of matrix and interference corrections.



**Table 2** Calibration range for electric arc furnace (EAF) slags

Compound	EAF Slags [wt%]
MgO	2.4 – 23.5
Al <sub>2</sub> O <sub>3</sub>	0.5 – 10.2
SiO <sub>2</sub>	4.7 – 48.7
P <sub>2</sub> O <sub>5</sub>	0.01 – 16.7
S	0.03 – 0.2
CaO	1.2 – 42.9
TiO <sub>2</sub>	0.15 – 2.3
Cr <sub>2</sub> O <sub>3</sub>	0.5 – 53.8
MnO	2.0 – 28
FeO	9.1 – 48.1

**Table 3** Calibration range for ladle metallurgy furnace (LMF) slags

Compound	LMF Slags [wt%]
F	0.03 – 7.9
MgO	0.2 – 21.2
Al <sub>2</sub> O <sub>3</sub>	1.8 – 38.6
SiO <sub>2</sub>	7.4 – 51.4
P <sub>2</sub> O <sub>5</sub>	0 – 1.6
S	0 – 1.2
CaO	0.6 – 60.4
TiO <sub>2</sub>	0.01 – 2.2
MnO	0.06 – 14.9
FeO	0.1 – 17.2

# S2 PUMA Guarantees Precision and Accuracy!

## Measurement Accuracy and Precision

Replicate analysis were performed for one EAF and one LMF slag pellet. The samples were unloaded and reloaded between measurements. Tables 4 and 5 demonstrate the impressive accuracy and stability of the results obtained with the S2 PUMA. The precision is well within the expected range for the analysis of slag material.

**Table 4** EAF Slags – Stability, Precision, and Accuracy

[wt.%]	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	S	CaO	TiO <sub>2</sub>	Cr <sub>2</sub> O	MnO	FeO	V-Ratio	B3-Ratio
<b>Rep-1</b>	13.53	6.36	14.20	0.240	0.130	26.97	0.36	2.16	5.59	29.84	1.90	1.29
<b>Rep-2</b>	13.61	6.38	14.20	0.240	0.130	26.97	0.37	2.16	5.59	29.84	1.90	1.29
<b>Rep-3</b>	13.63	6.37	14.27	0.240	0.130	27.01	0.37	2.16	5.59	29.78	1.89	1.29
<b>Rep-4-101</b>	...	...	...	...	...	...	...	...	...	...	...	...
<b>Rep-102</b>	13.75	6.54	14.41	0.240	0.130	27.03	0.37	2.17	5.56	29.62	1.88	1.26
<b>Average [wt.%]</b>	13.69	6.44	14.34	0.244	0.126	27.02	0.37	2.17	5.57	29.70	1.89	1.28
<b>Abs. Std. Dev. [wt.%]</b>	0.10	0.05	0.07	0.005	0.005	0.03	<0.01	0.01	0.01	0.07	0.01	0.01
<b>Rel. Std. Dev. [%]</b>	0.7	0.7	0.5	2.3	3.8	0.1	0.9	0.3	0.2	0.2	0.5	0.5
<b>Certified</b>	13.40	6.58	14.24	0.250	0.13	26.66	0.35	2.17	5.63	29.49	1.87	1.26
<b>Difference</b>	0.29	0.14	0.10	0.006	0.004	0.36	0.02	<0.01	0.06	0.213	0.012	0.018

**Table 5** LMF Slags – Stability, Precision, and Accuracy

[wt.%]	F	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	S	CaO	TiO <sub>2</sub>	MnO	FeO	V-Ratio	B3-Ratio
<b>Rep-1</b>	4.58	7.79	2.07	29.93	0.222	1.040	53.19	0.046	0.269	0.502	1.78	1.49
<b>Rep-2</b>	4.63	7.68	2.06	29.88	0.224	1.038	53.22	0.046	0.272	0.502	1.78	1.49
<b>Rep-3</b>	5.33	7.78	2.07	29.97	0.229	1.040	52.86	0.048	0.264	0.499	1.76	1.44
<b>Rep-4-23</b>	...	...	...	...	...	...	...	...	...	...	...	...
<b>Rep-24</b>	5.15	7.82	2.08	29.96	0.231	1.034	52.91	0.042	0.266	0.497	1.77	1.36
<b>Average [wt.%]</b>	4.82	7.75	2.07	29.92	0.23	1.04	53.09	0.047	0.268	0.500	1.77	1.66
<b>Abs. Std. Dev. [wt.%]</b>	0.26	0.04	0.01	0.03	0.01	<0.01	0.12	0.002	0.003	0.002	0.01	<0.01
<b>Rel. Std. Dev. [%]</b>	5.4	0.5	0.6	0.1	2.1	0.4	0.2	5.3	1.0	0.4	0.3	0.3
<b>Certified</b>	4.66	7.76	2.01	30.32	0.240	1.03	53.06	0.053	0.260	0.55	1.75	1.64
<b>Difference</b>	0.16	0.01	0.06	0.40	0.011	0.00	0.03	0.006	0.008	0.05	0.02	0.02

Viscosity (V) Ratio: CaO / SiO<sub>2</sub>; Basicity (B3) Ratio = CaO / (SiO<sub>2</sub> + Al<sub>2</sub>O<sub>3</sub> + TiO<sub>2</sub>)

# Quick Results and Best Performance at Your Fingertips

## EDXRF Made Easy only with the S2 PUMA

In steel production process control every minute counts! Whenever you receive a sample, results are needed fast. The S2 PUMA Single is the perfect tool: Load the sample, touch the button and get results within minutes. Best quality meets easy-of-use, thanks to TouchControl, the S2 PUMA's intuitive user interface.

## S2 PUMA with TouchControl™ and SPECTRA.ELEMENTS

- Intuitive and failsafe operation
- One-button solutions
- Free language selection: English, Chinese, French, German, Indonesian, Italian, Japanese, Korean, Portuguese, Russian, Spanish
- Minimal training required – get results from day one
- Adjustable and glove-friendly touchscreen

The times of never-ending training and complex manuals belong to the past. With TouchControl and SPECTRA.ELEMENTS, any user can perform measurement jobs on the S2 PUMA. First, select the application and type in the sample ID. You can also add additional information, like preparation or sample weight. Then simply start the measurement and view the results on-screen. That's it!

Quick and easy sample loading



Simple and fast operation with TouchControl™



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# SampleCare™

## Unique multi-layer protection for vital system components

### S2 PUMA with HighSense - the Top-performing EDXRF for Slag Analysis

Instrument precision is the key for tight process control. The S2 PUMA delivers excellent precision with its HighSense™ technology, the 50-Watt power of the X-ray tube, the closely coupled beam path and the all-new HighSense detectors. This guarantees process control at its best with a very narrow range for the results, minimizing waste and maximizing yield of your production.

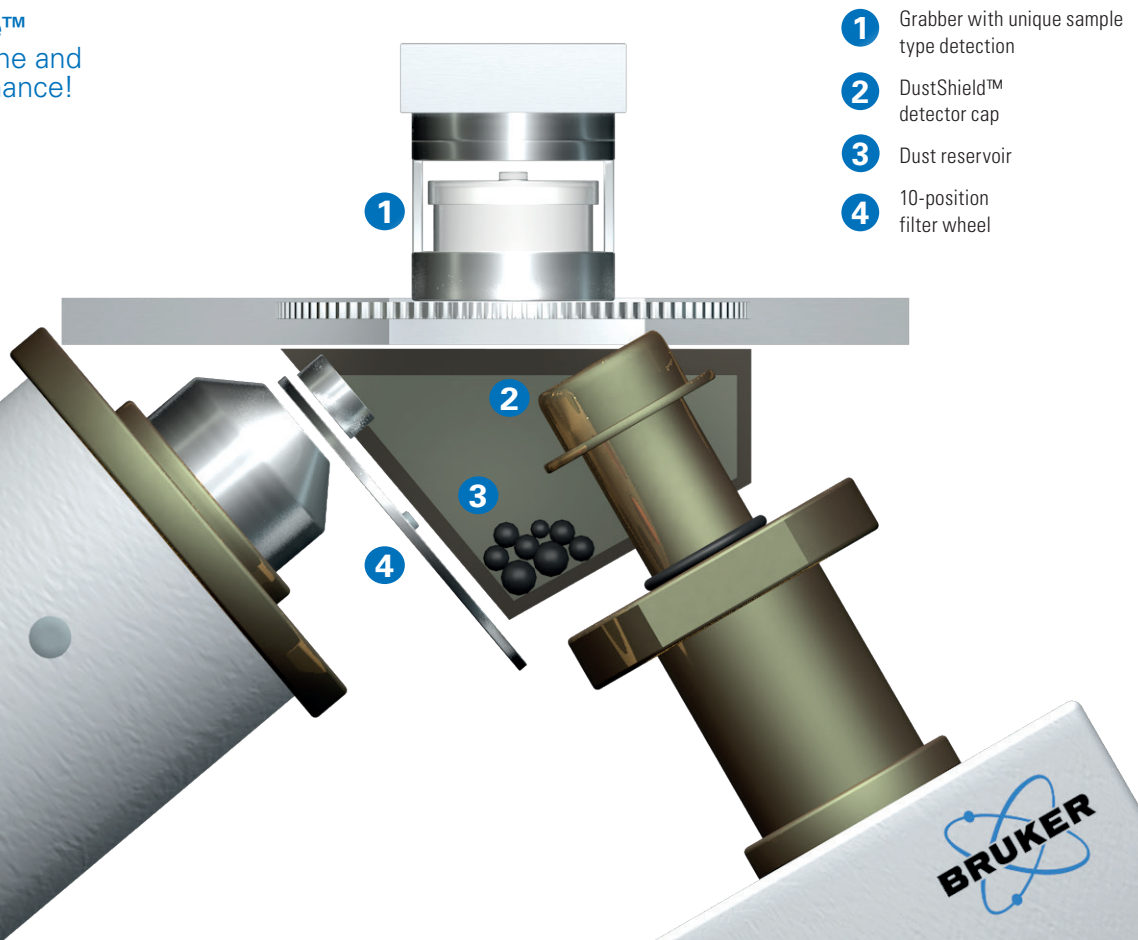
### Elemental Analysis Cannot be Easier!

Energy-dispersive X-ray fluorescence (EDXRF) with the S2 PUMA offers all you need to measure and monitor elements in your samples, independent of the industry or environment in which you are working. The outstanding strength of EDXRF is the wide range of elements covered by the technique, from very light elements like fluorine (F), to heavy elements such as uranium (U).

### S2 PUMA: Made for industrial Applications

The S2 PUMA is ready for challenging industrial environments. High system uptime is ensured by SampleCare™ technology, high-duty air filters, sturdy design, and overall high quality components. The integrated vacuum mode minimizes the operational costs when compared to XRF systems with helium mode only.

**SampleCare™**  
for high uptime and  
easy maintenance!



## Technical Data

<b>Element range</b>	F - U with HighSense XP detector		
<b>Concentration range</b>	From ppm to 100 %		
<b>X-ray tube</b>	10-position automatic filter changer for wide range elemental analysis		
<b>Detector</b>	Silicon Drift Detector: Peltier cooled (no need for liquid nitrogen) with DustShield™; Available as HighSense™ and HighSense™ XP version, both with super-high count rates and excellent energy resolution		
<b>Collimator Masks*</b>	For small spot analysis: 1, 3, 8, 12, 18, 23 and 28 mm		
<b>Sample Observation*</b>	Integrated HD video camera, for exact sample positioning and documenting the measurement position of a sample		
<b>Atmosphere Mode</b>	Air mode: For heavier elements in all sample types Helium mode*: Best performance for light elements in liquids and loose powders Nitrogen mode*: Cost-saving analysis of liquid samples Vacuum mode*: Enhanced light elements performance for stable samples and lowest cost of operation		
<b>TouchControl™</b>	Integrated 12.1" TFT touchscreen, adjustable, multilingual user interface, optional		
<b>Connectivity</b>	Built-in Ethernet port RJ45, 3x USB ports for mouse, keyboard, printer		
<b>Power Requirements</b>	100-240 V, 50/60 Hz, max. power consumption 600 VA		
<b>Sample Types</b>	Loose powders, granules, solids, pressed pellets, fused beads, and liquids		
<b>Sample Rotation*</b>	Spins all sample types and sizes for better measurement statistics with inhomogenous samples		
	<b>S2 PUMA Single</b>	<b>S2 PUMA XY Autochanger</b>	<b>S2 PUMA Automation</b>
<b>Sample Sizes</b>	Up to 51.5 mm (2.03") Ø; Liquids and powders in liquid cups up to 50 ml	Up to 40 mm (1.56") Ø and 38 mm (1.49") height in sample holders with max. 200 g sample weight, or 51.5 mm Ø as sample ring; Liquids and powders in liquid cups up to 20 ml	Up to 40 mm (1.56") Ø and 38 mm (1.49") height in sample holders with max. 200 g sample weight, or 51.5 mm Ø as sample ring; Liquids and powders in liquid cups up to 20 ml
<b>Sample Loader</b>	Single position, manual loading	EasyLoad™ XY sample tray with 20-positions, removable; 2 fixed positions for QC samples; Grabber with automatic liquid sample detection	EasyLoad™ XY sample tray with 20-positions, removable; Grabber with automatic liquid sample detection; 2 fixed positions for QC samples; Interface to conveyer belt or robot arm link-up to sample preparation, including sample flipper
<b>Dimensions</b> (width x depth x height); <b>Weight</b>	67 x 71 x 37 cm; 87 kg (26.2 x 27.8 x 14.6"; 192 lbs)	67 x 71 x 61 cm; 108 kg (26.2 x 27.8 x 23.8"; 238 lbs)	67 x 71 x 61 cm; 108 kg (26.2 x 27.8 x 23.8"; 238 lbs)

\* optional packages

TouchControl™, SampleCare™, EasyLoad™, HighSense™, and DustShield™ are trademarks of Bruker AXS Inc.

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**Bruker AXS**  
info.baxs@bruker.com

**Worldwide offices**  
bruker.com/offices

**Online information**  
bruker.com/s2puma

