G4 ICARUS C/S
Why We’re The Best Choice

July 30, 2020

Audience Poll

Did you know Bruker offers Carbon/Sulfur Analyzers?

- Yes
- No
- Somewhat

Webinar Schedule

C and S by Combustion Analysis

- Introduction of Speakers
- Why Analyze Carbon and Sulfur
- Typical Applications
- Sample Shapes
- The Principle of Combustion
- G4 ICARUS – Technical Overview
- Ease of Maintenance
- Instrument Specifications
- Benefits of the G4 ICARUS
- Question and Answer Session

Welcome!
Meet your speakers

Kristin Odegaard
Sr. Sales Engineer OES, CS/ONH
Bruker AXS LLC
Madison, WI

Christian Zühlke
Business Development Manager
Elemental Analysis CS/ONH
Bruker AXS GmbH
Karlsruhe, Germany

C & S by Combustion

Why Analyze Carbon and Sulfur – Steel Industry

Carbon

- Most alloying element in steel
- Influences hardness, wear resistance, workability, etc.
- Used in mineral processing
- Range: low ppm to high %

Sulfur

- Undesirable in steel
- Influences brittleness, conductivity, workability, formability, etc.
- Range: low ppm to high %

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Further examples

Material	C	S
Copper		x
Carbides	x	
Slag	x	x
Cement	x	x
Foundries	X	X
Automotive	X	X
Refractories	X	X
Welding	X	X
Minerals	X	X
Research Facilities	X	X

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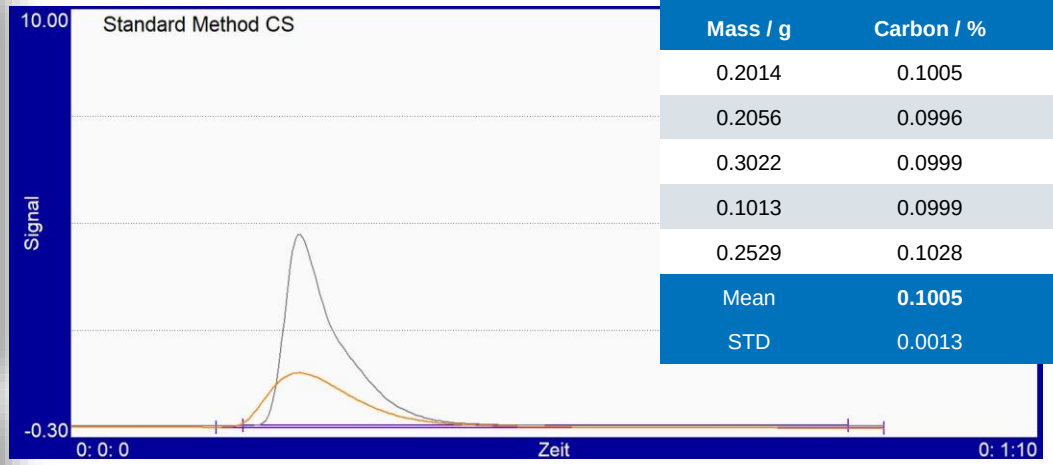
Steel

Concentration ranges

- C: 1 ppm to 1 %
- S: 1 ppm to 0.5 %



CRM 286-1	certified values:	C: 0.100 (±0.005) % S: 0.280 (±0.014) %
Mass / g	Carbon / %	Sulfur / %
0.2014	0.1005	0.2854
0.2056	0.0996	0.2732
0.3022	0.0999	0.2844
0.1013	0.0999	0.2820
0.2529	0.1028	0.2842
Mean	**0.1005**	**0.2819**
STD	0.0013	0.0050

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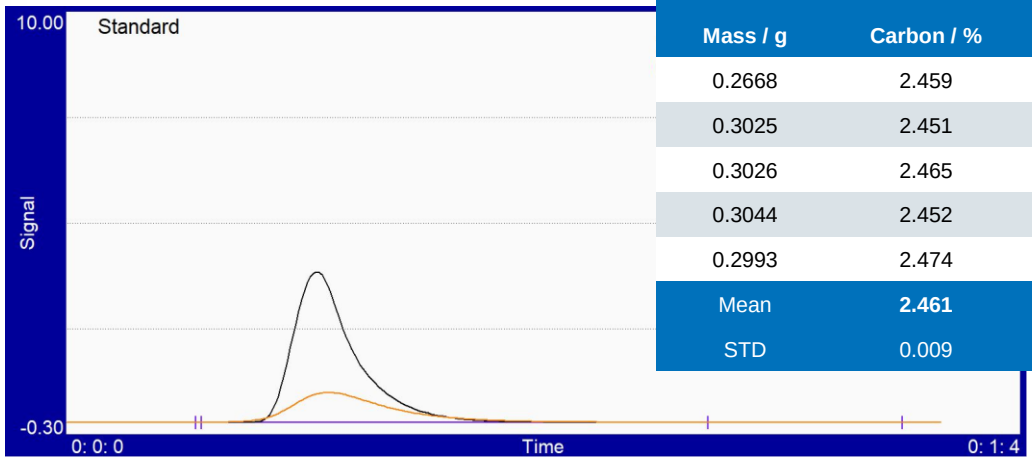
Cast iron

Concentration ranges

- **C: 0.1 to 5 %**
- **S: 10 ppm to 0.1 %**



CRM 483-1	certified values:	C: 2.463 (±0.012) % S: 0.103 (±0.002) %
Mass / g	**Carbon / %**	**Sulfur / %**
0.2668	2.459	0.1032
0.3025	2.451	0.1030
0.3026	2.465	0.1039
0.3044	2.452	0.1039
0.2993	2.474	0.1053
Mean	**2.461**	**0.104**
STD	0.009	0.001

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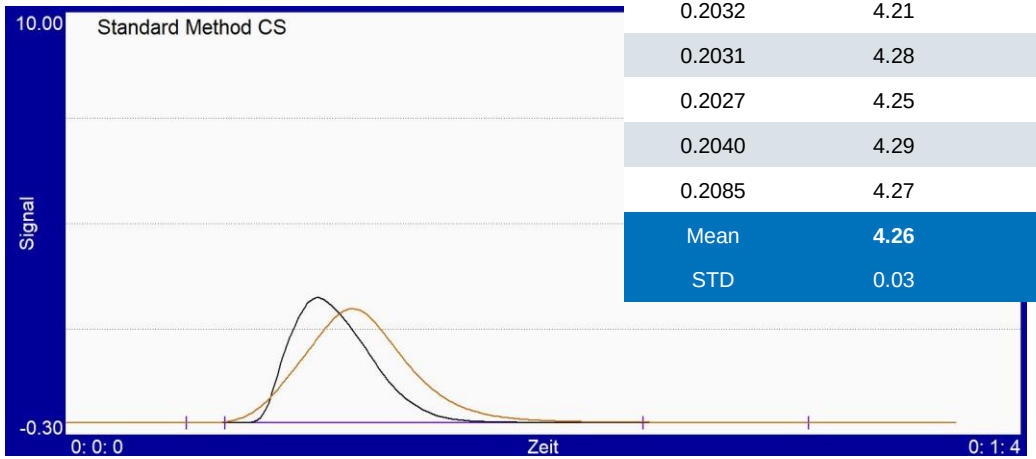
Ores & Minerals

Concentration ranges

- **C: up to 15 %**
- **S: up to 50%**



GS310-7	certified values:	C: 10.92 (±0.47) % S: 4.16 (±0.17) %
Mass / g	Carbon / %	Sulfur / %
0.2032	4.21	10.81
0.2031	4.28	10.60
0.2027	4.25	10.74
0.2040	4.29	10.59
0.2085	4.27	10.76
Mean	**4.26**	**10.71**
STD	0.03	0.09

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Typical samples

Inorganic solid samples

Examples: steel, copper, titanium, cast iron, refractories, carbides, minerals/mining, cement, metal powders (AM), ceramics

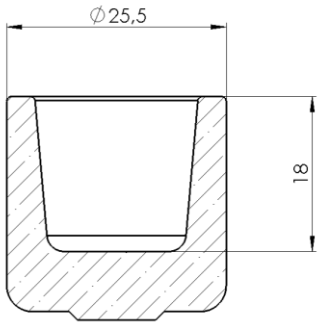

Pieces


Drillings/Chips


Coarse powders


Fine powders

Up to 1 g



Ceramic crucible G4 ICARUS

The Principle of Combustion

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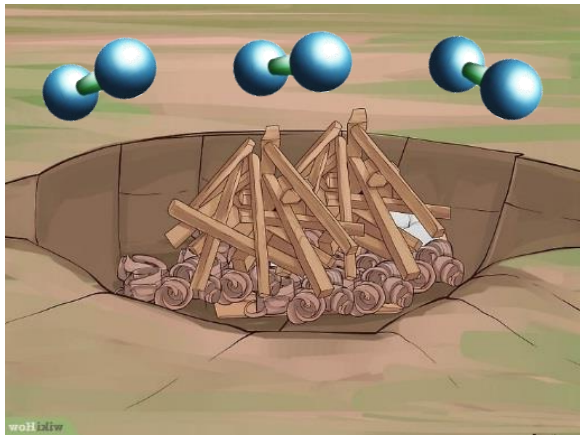
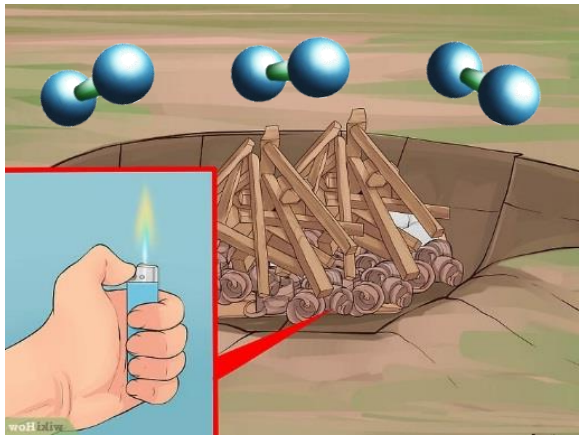
The principle of combustion

Combustion

[kuh m-buhs-chuh n]

the act or process of burning.





Combustion in chemistry:

- rapid oxidation accompanied by heat and, usually, light.

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The principle of combustion

combustion

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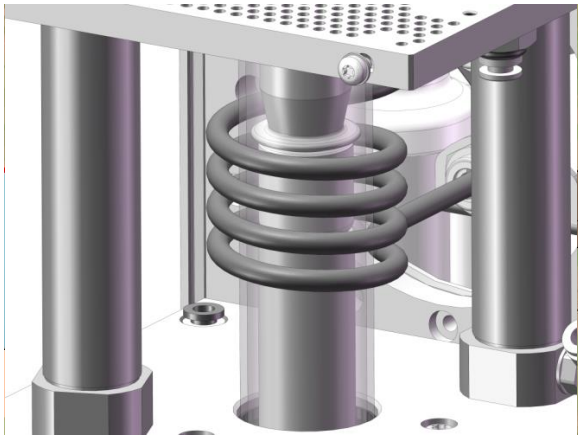

Combustion in chemistry:

- rapid oxidation accompanied by heat and, usually, light.

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Chemistry of combustion

Solid sample + accelerator
in ceramic crucible

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Chemistry of combustion

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Induction heating of the sample
Excess O_2 provided to sample

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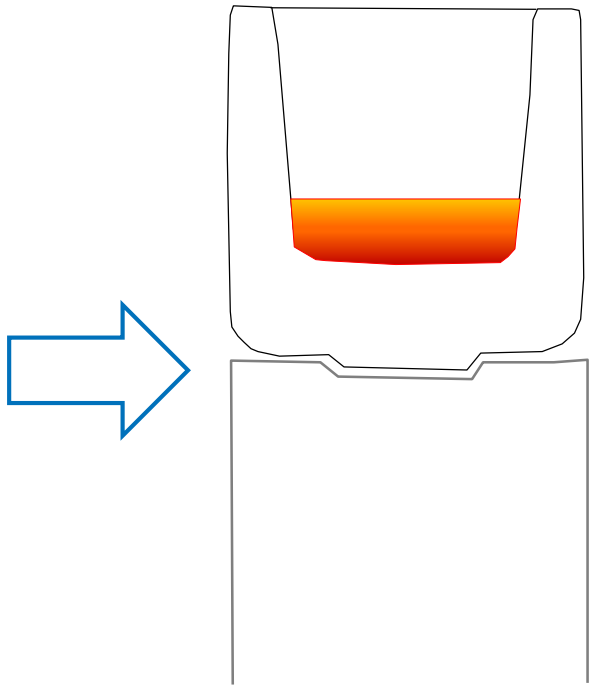

Sample melts

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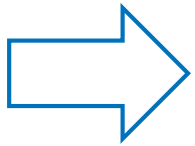
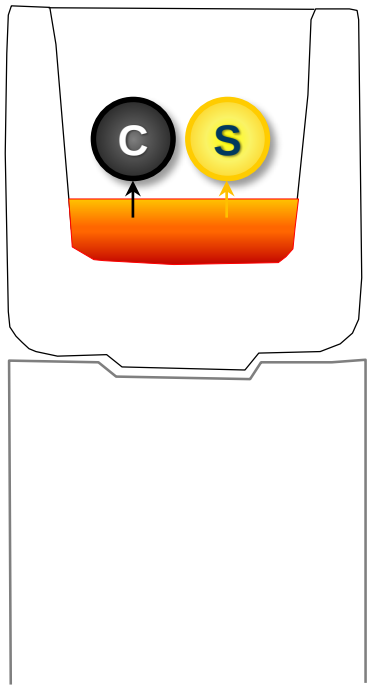
Chemistry of combustion

Solid sample + accelerator
in ceramic crucible

Induction heating of the sample
Excess O_2 provided to sample





Sample melts

C & S are released

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Chemistry of combustion

Solid sample + accelerator
in ceramic crucible

Induction heating of the sample
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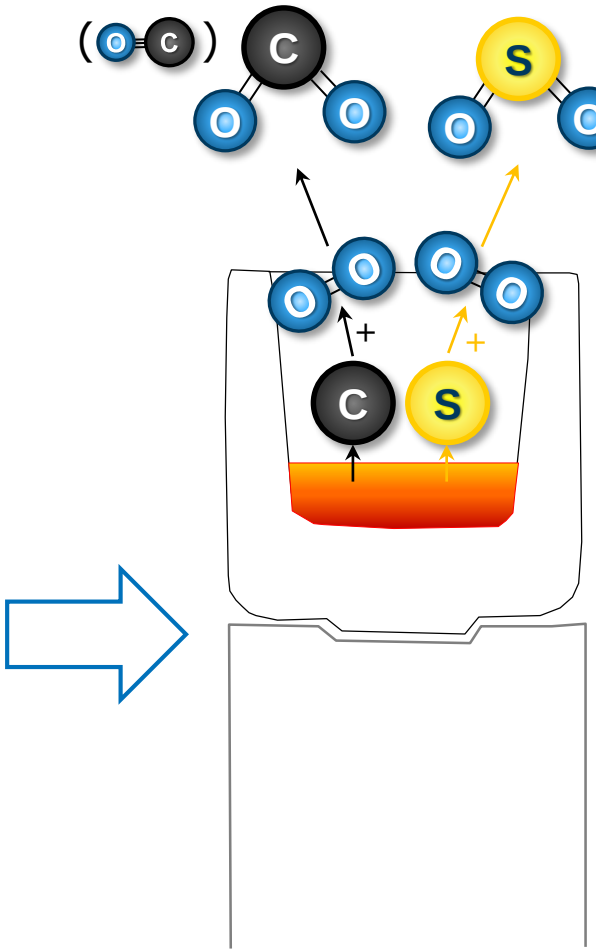

Sample melts

C & S are released

$C + O_2 \rightarrow CO_2$ (+CO)
$S + O_2 \rightarrow SO_2$

CO is later oxidized to CO_2 by oxidation furnace (platinized silica)

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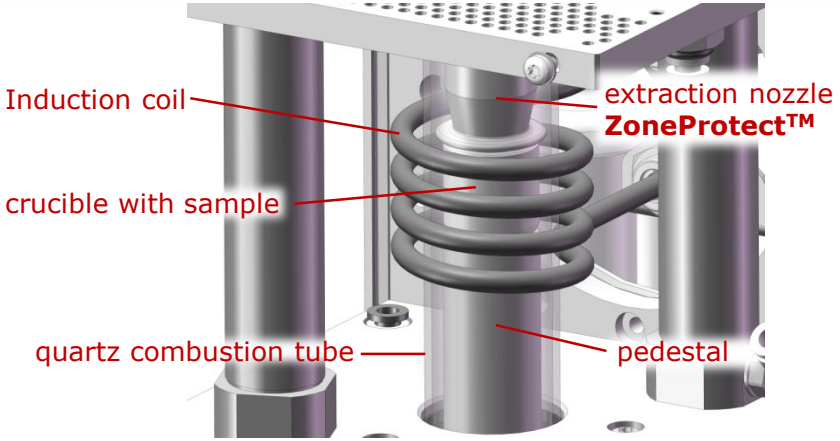
HF Induction Furnace

Induction Heating:

- Heating of an electrically conductive material (e.g. metal) by induction
- Application of AC power with high voltage & high frequency through induction coil
- Alternating EM-field induces eddy currents in the sample
- Electrical resistance leads to Joule-heating of the sample

⇒ Direct way of heating, short interaction time, T > 1600 dC possible



Accelerators

- conductive metal: coupling to the HF-field
- Ignite and "set-fire" to the sample; exothermic reaction, providing additional energy
- Act as flux to dissolve oxide layers and make melt thoroughly fluid (homogeneous melting)
- Different accelerators → different temperatures

Typical accelerators:
Tungsten, Tin, Iron, Copper

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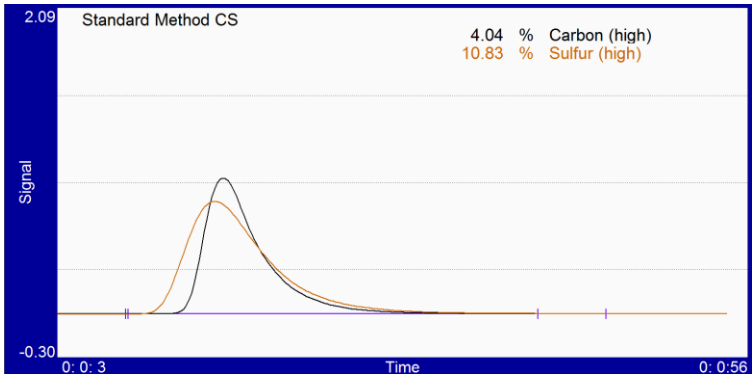
Method Benefits

Combustion Analysis by HF-induction is:

- Volumetric method: Entire sample mass is analyzed
  - Also applicable to difficult samples with uneven distribution of elements (e.g. C in grey cast iron)
- Provides high precision and accuracy
- Fast: Analysis in ~60s
- Applicable over the full concentration range (from sub-ppm to 100%, by varying sample mass)
- Flexible in sample type, mass and form (powder, pieces, chips, drillings, etc.)
- Easy to operate



...if everything is designed the right way

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A dirty affair…

The dark side of combustion

- Not only oxidation of C and S, but also of sample and accelerator

⇒ can create fine dust

- Fine dust can act as a column to retard or retain analyte delivery to the detectors dependent on amount and type of dust.
- Production of spraying particles and liquid metal splatters due to vigorous combustion

⇒ can damage quartz combustion tube

$$\{M\} + n\ O_2 \xrightarrow{\Delta} MO_{2n}$$

Metals/Minerals + O_2
= particulate oxides = DUST

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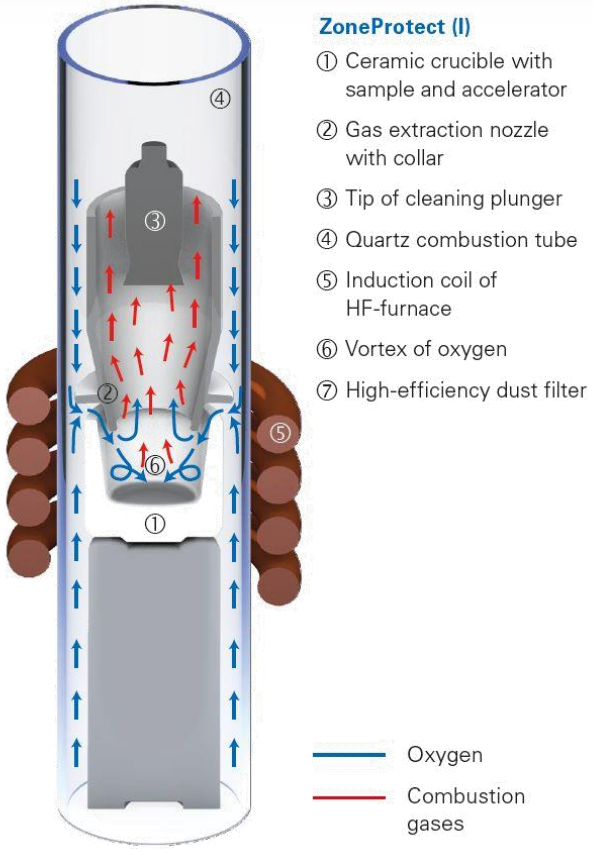
Intelligent Design: ZoneProtect™

ZoneProtect™

- More efficient combustion on a wider variety of samples
- Superior gas flow design for better analytical quality

  ⇒ Oxygen supply through annular flow gap & turbulences ensure perfect oxygen supply to the sample
- Combustion gases, dust & particles transported through the extraction nozzle upward
- Reduces splattering, maximizes component lifetime (combustion tube)
- Integrated auto cleaner



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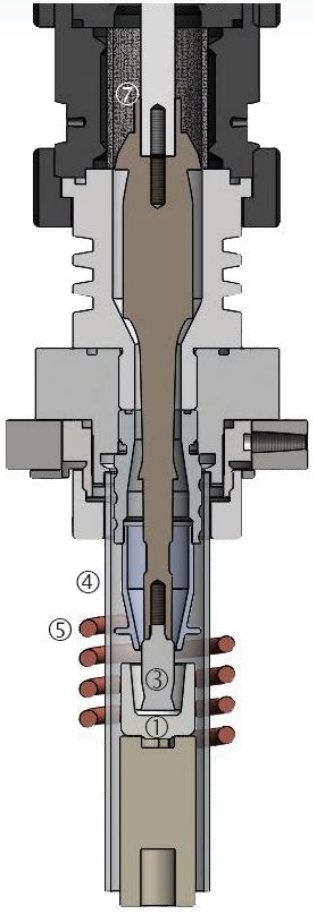
Easy Maintenance: ZoneProtect™

Integrated dust removal system:

- Vacuum & noise-free cleaning system
- Waste disposal into the used crucible
- Brush-free cleaning operated by solid plunger
- High efficiency, integrated dust filter (3µm pore size) for cleaner environment and improved analytical precision
- Tool-free & easy maintenance

Efficient dust removal into the crucible



Carbon and Sulfur Detection

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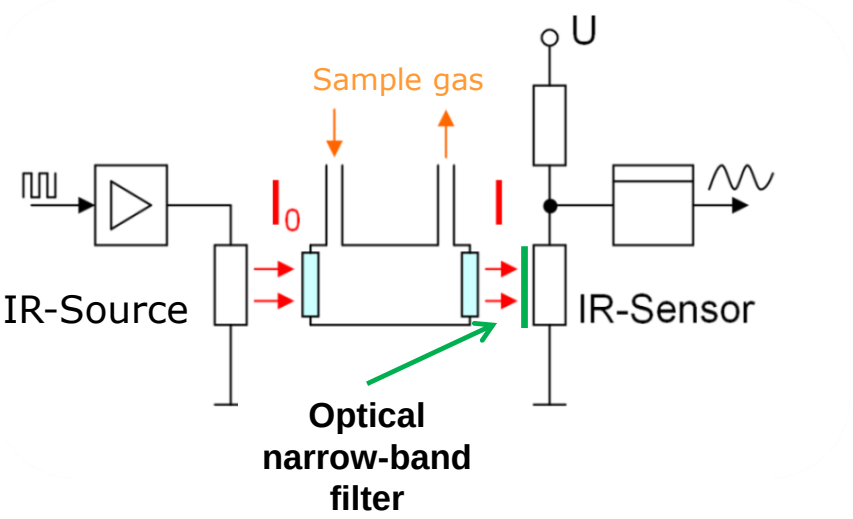
NDIR Detection (CO_2)

NDIR = **n**on-**d**ispersive **i**nfra**r**ed:

- Molecules absorb infrared radiation under excitation to specific levels of higher rotational and vibrational energy
- NDIR = non-dispersive IR wavelength is selected by narrow-band optical filters to the specific molecule, here to CO_2
- Due to the absorption by the particular molecule, the transmission of the IR light is attenuated, which is registered by the sensor
- IR sensors used (e.g. Pyroelectric) require choppering of the source

⇒ On-off mechanism

⇒ Not mechanical = no chopper



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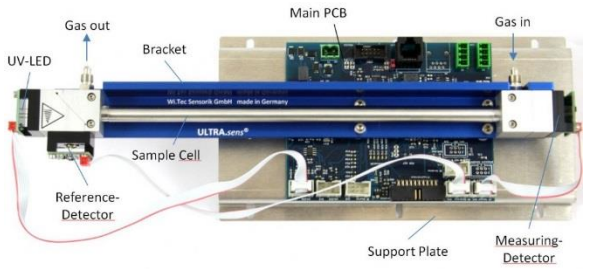
HighSense™ SO_2 Detection by UV-LED

HighSense™

- Electronic transitions (UV-energy) within the molecules are used
- UV-Transitions have much higher quantum efficiency than IR absorption (higher sensitivity, lower noise)
- No interferences for utmost stability and selectivity
- Unmatched lifetime and modulation speed of LED

Compared NDIR:

- 10 times better signal-to-noise
- Drift-free baseline, long-term stability
- Staggering selectivity (ppm traces in 100%)



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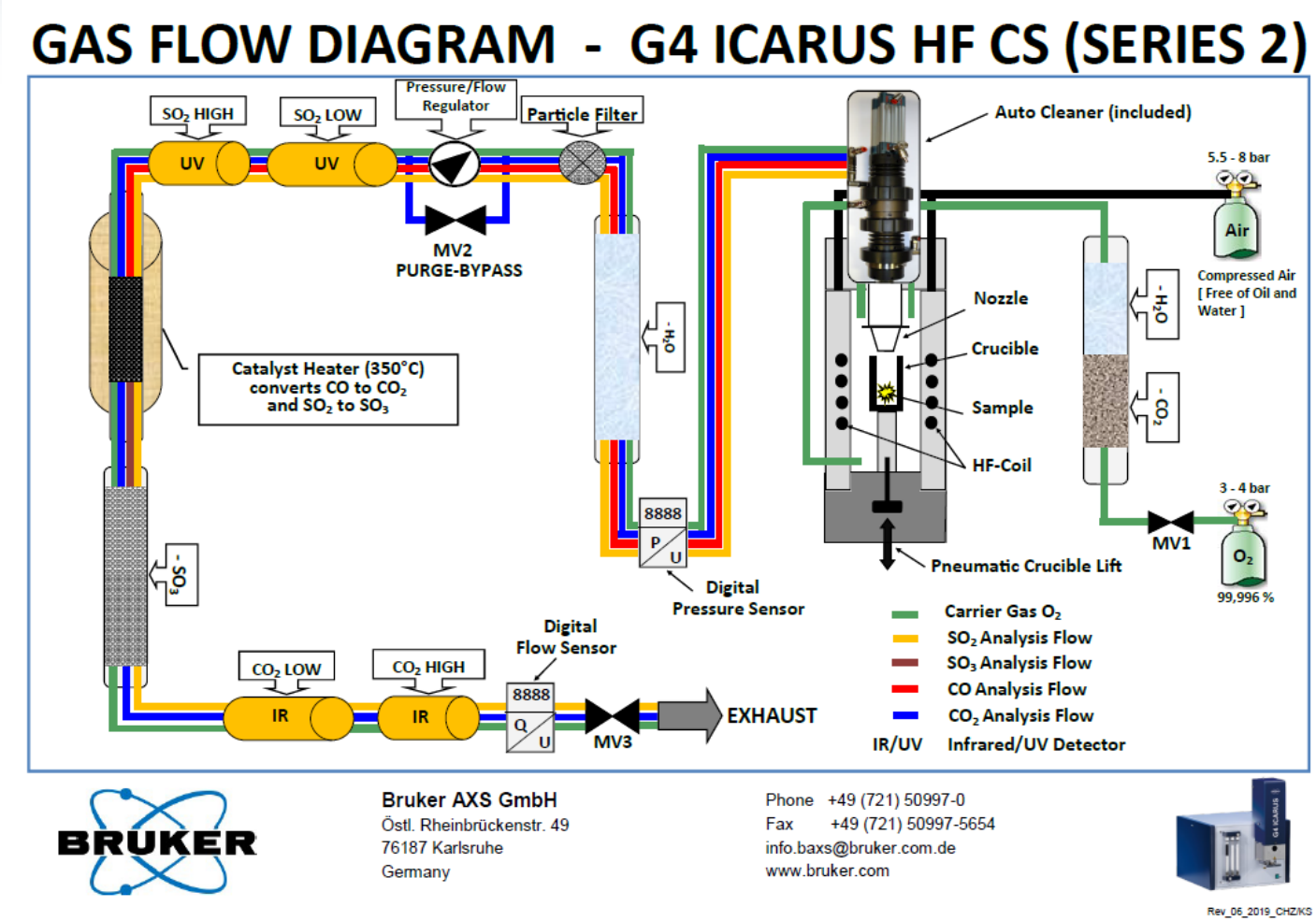
Gas Flow Diagram



Bruker AXS GmbH
Östl. Rheinbrückenstr. 49
76187 Karlsruhe
Germany

Phone +49 (721) 50997-0
Fax +49 (721) 50997-5654
info.baxs@bruker.com.de
www.bruker.com

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Maintenance

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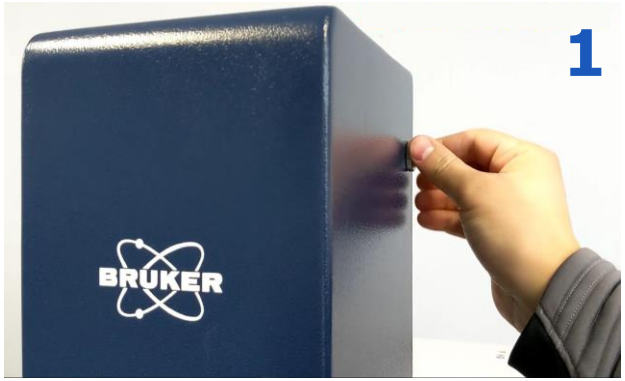
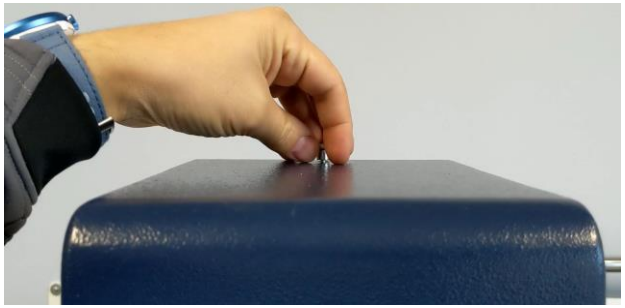
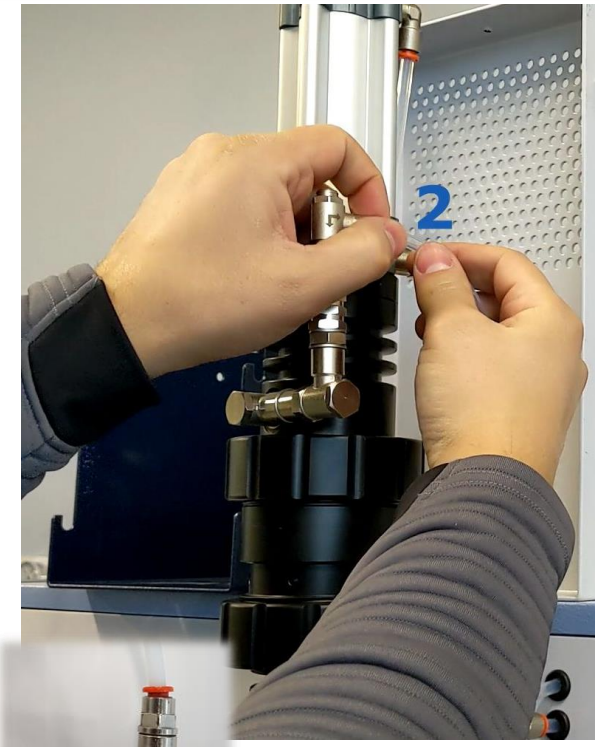
Tool-free & easy maintenance

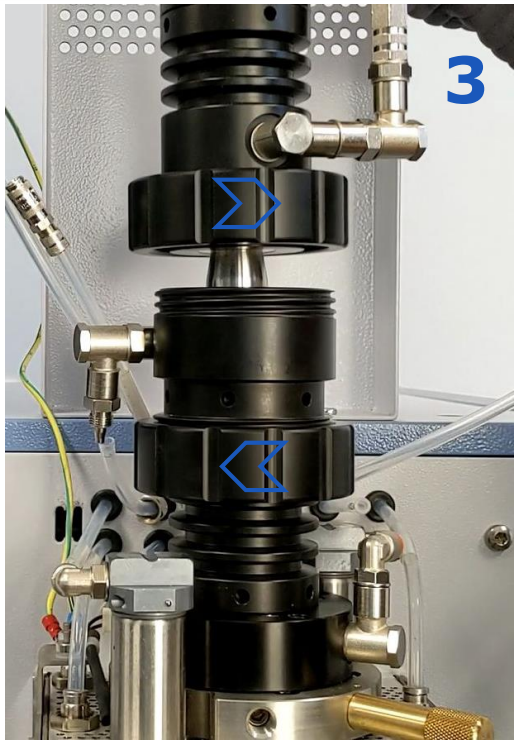




Loosening of the screws and
removal of the protective cover



Detaching of tubings
(Push-ins)



Removal of the autocleaner

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Tool-free & easy maintenance

Removal of the filter

Removal of ZoneProtect™

Cleaning of the components

Instrument specifications

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Instrument specifications

Analytical ranges

- Carbon: 0.0002 – 6 % (2 Ranges = Low/High)
- Sulfur: 0.0001 – 1 % (1 Range = Low)
- Sulfur: 0.0001 – 10 % (2 Ranges = Low/High) Optional

@ 1 g sample weight, extend ranges by reducing the sample weight

Analysis time

- Typically 40-60 s

Carrier gas & pneumatics

- Oxygen
- Purity: min. 99.95%
- Pressure: min. 3.5 bar
- Compressed air: min. 5 bar, free from oil, water and particles

Benefit of Bruker

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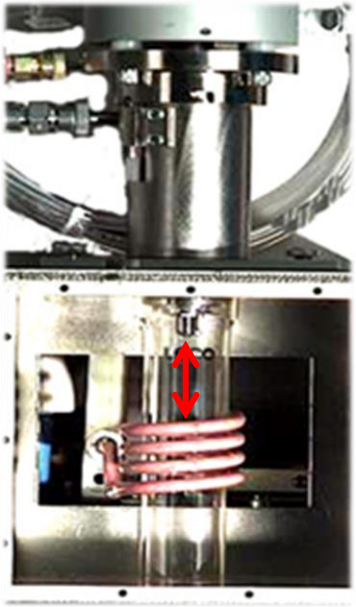
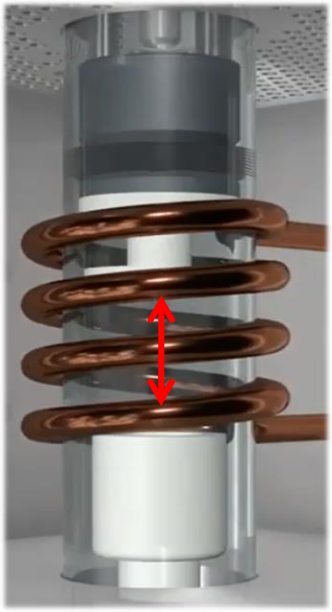
Comparison to competing manufacturers

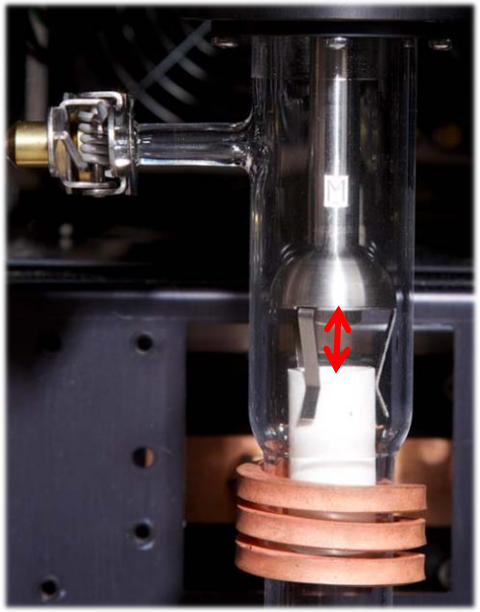
Manufacturer A



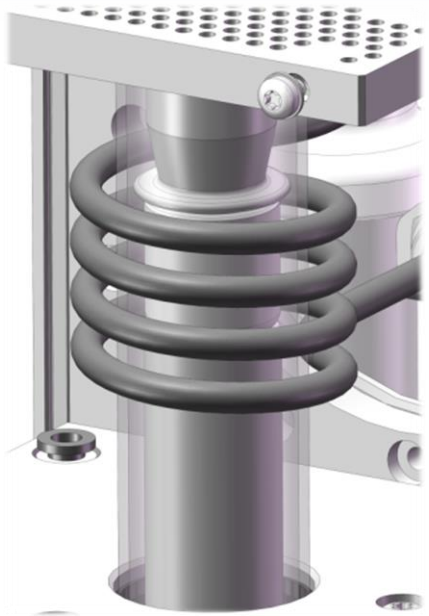
Manufacturer B



Manufacturer C



Bruker



What is the first thing you notice when comparing the other systems to the Bruker system?

Lance system vs. Bruker ZoneProtect™

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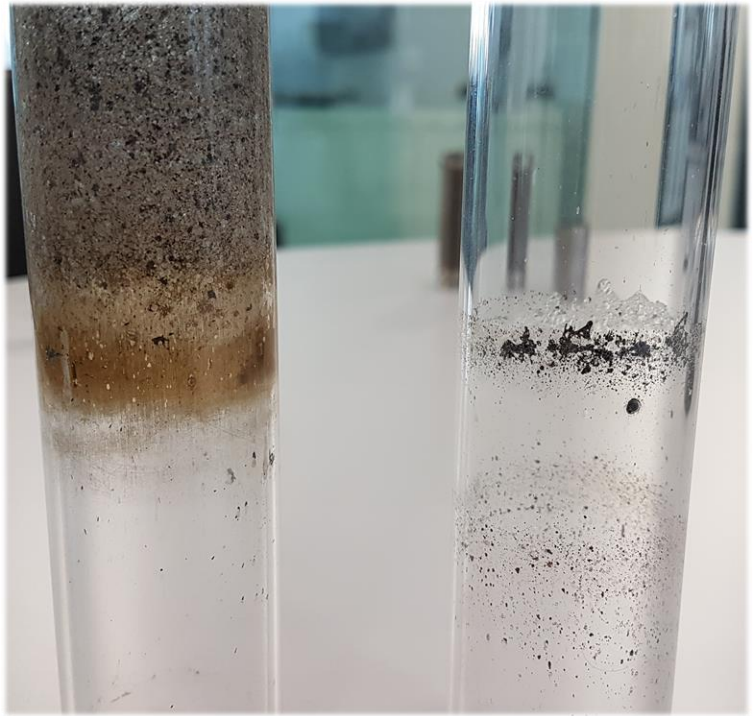
…different furnace design, different outcome

Metal samples, W+Fe accelerator

Competitor **Bruker**



Competitor **Bruker**

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Different dust filters

Competitor

Bruker

Support for Your Team
Applications and Service

Mark West: Service Supervisor
Time with Bruker: 22 years

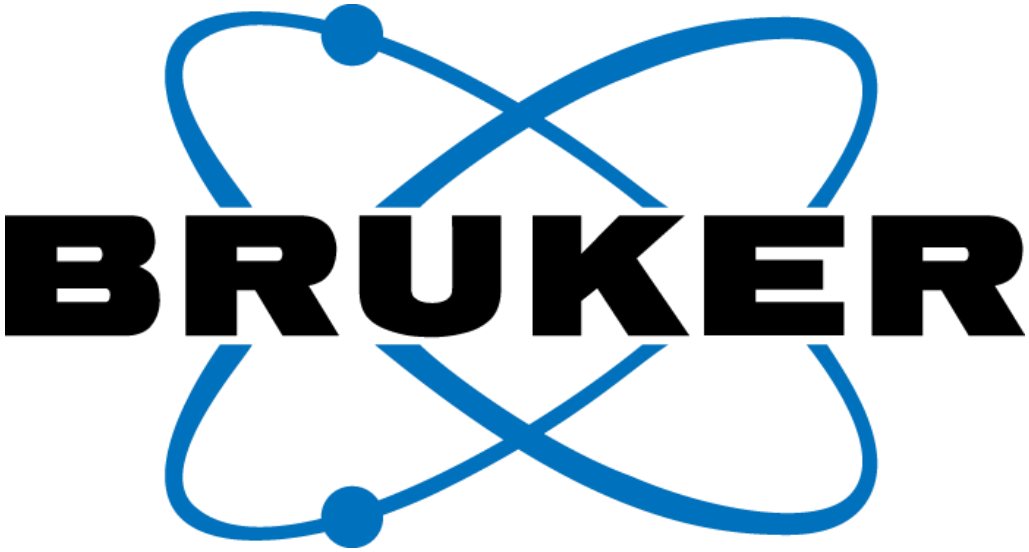
Okan Celik: Applications Scientist
Time with Bruker: 8 years

Kristin Odegaard: Sr Sales Engineer
Time with Bruker: 8 years

Mike Baal: Sr Sales Engineer
Time with Bruker: 8 years

Support for Your Team
Lab Reports

Q & A Session



Innovation with Integrity