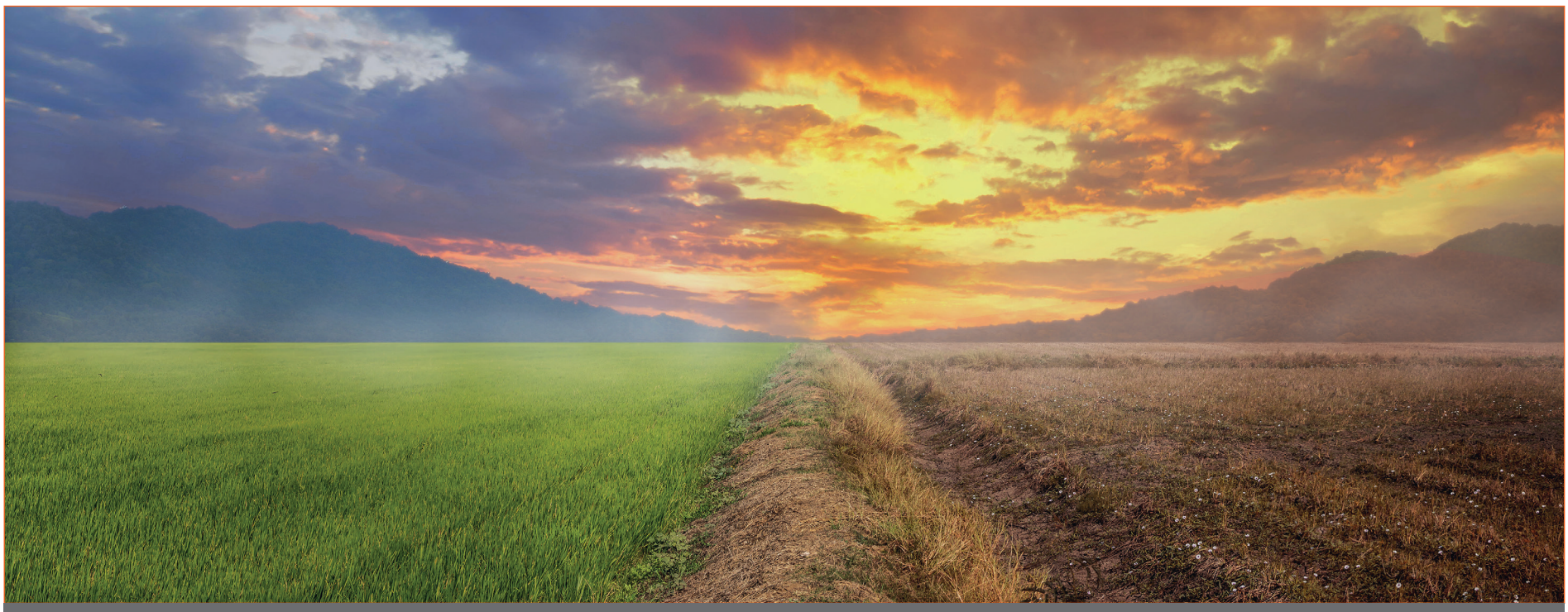

ENERGY-EFFICIENT AND SUSTAINABLE OVER THE ENTIRE LIFE CYCLE

Environmental measurement technology of increasing global importance!

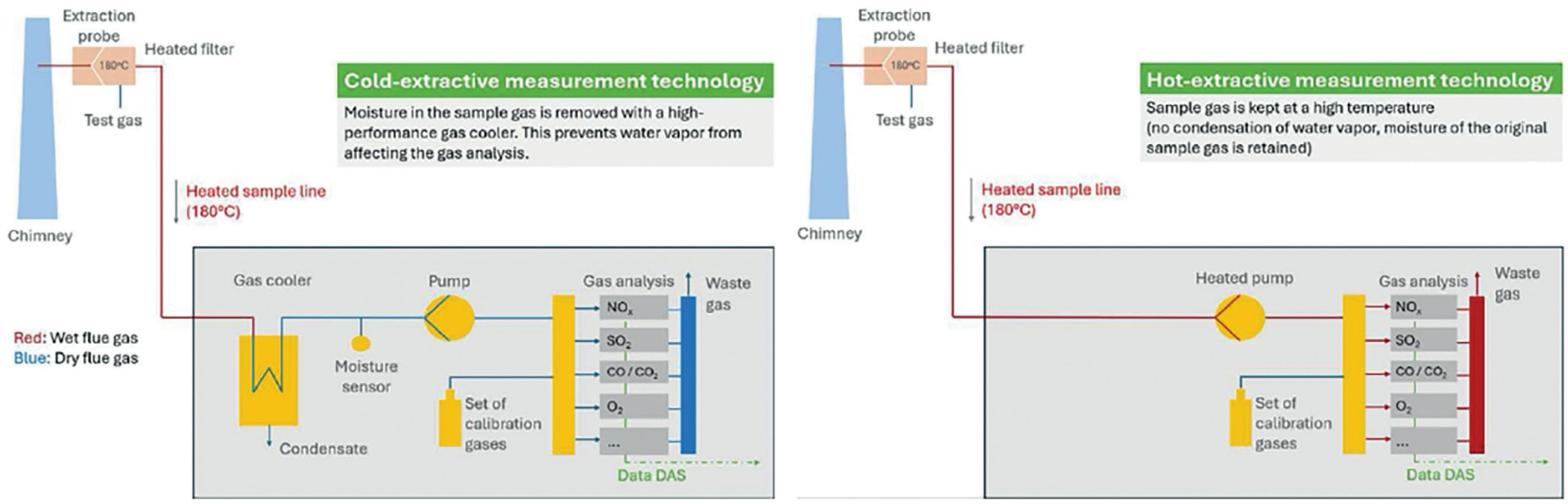

Figure 1: Variants in extractive gas analysis

Due to global warming and the resulting climate change, the monitoring of emissions from industrial processes or vehicle traffic is becoming increasingly important. Continuous emission monitoring systems (CEMS) are used worldwide to comply with environmental regulations. In addition to the analyzer itself, the heated sample gas line plays a central role in emission measurement technology. It maintains a constant temperature above the dew point of the sample gas during transport to the analyzer. This prevents condensation of water or other gaseous components, which can precipitate at low temperatures and distort the measurement results or even clog the line. The heated sample line also has a significant impact on the energy requirements of the overall system and the resulting operating costs.

Heated sample lines play a key role in the reliability of CEMS systems

Sample transport heating is particularly important for extractive emission measurement systems (see Figure 1). The usual holding temperature of heated sample lines for emission analysis in Europe is generally between 180 °C and 200 °C. The exact temperature may vary depending on standards, regulations and specific measurement requirements. In some regions of the world, holding temperatures as low as 120°C are common.

Wide range of design variants

There are a number of possible variations in the system design of the tube bundles, such as the number of sample lines (one or more inner lines, optionally also unheated calibration gas or pneumatic tubes), the material of the sample gas line (e.g. stainless steel, fluoropolymers, see Table 1), the control technology (regulated or self-regulating heating lines) or the material of the weatherproof outer jacket (e.g. stainless steel, polyamide, thermoplastic polyurethane) or the insulation material. The selection of the right sample line for use in sample transport systems of analytical instrumentation therefore requires critical consideration of the process and application conditions.

Precise and robust measurement

This is because improper tubing selection can lead to distorted measurement results or, in extreme cases, failure of the analyzer system due to adsorption, contaminants in the tubing, stress corrosion cracking, or gas permeation. Restricted sample flow, long delay times and kinking due to insufficient mechanical stability are also problems often associated with tubing selection. For applications in hazardous areas, care must also be taken to avoid electrostatic charging.

Simple and flexible installation

When installing the sample line, the installation route in the system and the resulting line lengths play a vital role. Bending radius, shortenability and the individual adaptability during installation on site or the maximum heating circuit length, but also the number of required heating circuits and the connected load must all be taken into account during project planning. The design of the sample lines therefore also has an impact on the energy requirement and therefore also on the profitability and sustainability of the overall system.

Challenges of sample transportation in practice

Innovations and advancements in the field of heated sample gas lines focus primarily on the materials used, heating technologies, and modularity. In addition to the predominantly handmade, traditional corrugated PA12 (Polyamide 12) hoses with fixed resistance heating, machine-made, extruded hoses with self-limiting heating tapes or parallel heating wires are increasingly entering the market.

Corrugated PA12 outer jacket - The flexible traditional model

Corrugated outer tubing offers a high degree of flexibility, especially for narrow installation paths. Another advantage is that these lines have a low permeation tendency of carbon monoxide (CO) into the sample path - the so-called CO baseline. This baseline can come from a variety of sources, including the pipeline environment, material emissions from the pipeline or the interaction of CO with other components in the gas stream. If the CO baseline is too high, the CO value must be corrected using a baseline correction, special filters, or absorbers prior to the actual measurement in order to obtain accurate emission values. With corrugated tubing, the flexibility of the sample line is achieved at the expense of a lower packing density of the insulation material. However, this makes the entire line less airtight, CO particles are lost to the outside and CO permeation is less of a concern. However, this type of pipe also requires up to 120 W/m of energy to maintain normal operating temperatures of 180°C.

Table 1: Types of sample lines (sample gas carrying inner lines)

Material of sample lines (Sample gas carrying inner lines)	Benefits	Limitations
Stainless steel (e.g. 304L oder 316L, welded and seamless)	cost-effective durable suitable for high and low temperatures	reactiv limited corrosion resistance
Fluoropolymers (e.g. PTFE, PFA, PFE)	corrosion-resistant inert cost-effective	permeable to gases when T or p is extreme easy to damage low melting point
Superalloys (e.g. Hastelloy, Monel, Inconnel, Incoloy)	corrosion-resistant	expensive limited availability reactive surface
Surface treatment (e.g. Electro polishing, chemical passivation)	corrosion-resistant inert temperature-resistant	expensive vulnerable to mechanical damage sensitive to abrasion, used mainly for metal lines

Table 2: Corrugated PA12 hose vs. extruded analysis line

Parameter	Heated sample line with corrugated outer jacket	Extruded, heated sample line (Example: PSG Emi, PSG Plus)
Outer jacket	Polyamid (PA12, jacket thickness 0,5 mm)	Polyvinylchhloride (PVC, jacket thickness 2 mm), thermoplastic Polyurethane (TPU), Polyethylene (PE)
Resistance	Robust	Extremely resistant (PVC suitable esp. for chlorine containing environment)
	Medium-range UV resistance	High UV resistance
Installation	Flexible routing due to small bend radius (4-6 x AD)	Versions for flexible installation due to small bend radius available (Extruded Flex, 4-6 x AD, Standard 7-8 x AD)
	Mounting restrictions for vertical routes	Can be laid over long, vertical distances (e.g. flue gas ducts or columns) due to fixed connections
	Limited maximum heating circuit lengths (e.g. 60 m at 230V)	Extended max. heating circuit lengths (e.g.100m at 230 V)
Lengths	Pre-assembled up to 80 meters	Can be produced in sections of up to 300 meters
	Can be shortened depending on the heating tape technology, not for fixed resistance heating conductors	Can be cut to size flexibly on site Cut-to-length every 50-60 cm
Zones	Atex-Zone 1+2, 21+22, T2, T3, T4, T6	Atex-Zone 1+2, 21+22, T2, T3, T4, T6
Isolation / Energy efficiency	Silicon foam / limited (90-120 Watt /m at 180°C)	Thermal fleece (approx.25% less energy) / high (60 Watt /m at 180°C)
Carbonmonoxid baseline	usually negligible	Restrictions are eliminated in PSG Emi/PSG Plus lines by additional design measures.

1x 8x1mm PTFE	PSG Extruded	Flex, corrugated outer jacket, Standard, 90 W
Manufacturing	Machine-made	Mainly handmade
Isolation	Thermal fleece	Silicon foam
Insulation thickness	10mm	7mm
Outer jacket	2mm PVC	0,5mm PA12
Heating cable	60W/m, parallel	90W/m, fixed resistance
Holding temperature	180°C / 120°C	180°C / 120°C
Heat loss at 120°C per m*	220 kWh per year	320 kWh per year
Heat loss at 180°C per m*	382 kWh per year	510 kWh per year

PSG Extruded

Flex corrugated

Figure 3: Energy-relevant parameters and energy consumption of a heated sample line

** The calculation is based on the following assumptions: Pipes laid 10% inside and 90% outside, Japan (Tokyo) average temperature 2022, 1 process pipe made of PTFE, OD 8mm and ID 6 mm, air flow medium, continuous operation, CO_2 emissions of 220g per kWh*

Extruded sample line - The economical innovative solution

Extruded heated sample gas lines, on the other hand, have significantly minimized heat transfer. The excellent insulation properties are achieved by their smooth and even surfaces,

the jacket materials used (TPU, PVC, PE) and the airtight seal. This significantly reduces the energy requirements. The temperature of 180°C can be maintained with only 60 W/m. This results in savings of 25% and more compared to corrugated pipes. Another advantage of the good insulation properties is that cables with a heating circuit, a 32 A fuse and a conventional 230 V connection can be used, even if they are 100 m long. This saves cables, connection work and the need for three-phase current in the analysis system. In addition to the complete assembly of a heated sample line in the factory, the cable can also be shortened on one side in the field thanks to the heating used (parallel heating tapes). This ensures efficient installation without unnecessary additional routes, saves costs during installation due to reduced safety surcharges for cable lengths and saves energy during operation over the entire life cycle.

However, the higher rigidity during installation compared to corrugated ring cables and the sometimes-higher CO baseline due to their high insulation properties pose a challenge.

New innovations in the design of heated sample lines

Product solutions are now available that combine the advantages of both technologies (corrugated outer jackets and extruded sample lines).

The innovative sample line type of the "PSG Emi Line" offers technical superiority

- Flexibility like corrugated PA12 lines: The optional flex mechanism (PSG Emi Flex) is perfect for angled plant environments and difficult installation routes.
- Robustness of extruded sample lines with thermoplastic outer jacket: Resistant to mechanical stress and weathering.
- Excellent insulation properties: Reduces energy loss and improves lifecycle efficiency
- Low energy requirements: Only 60 W/m is required to heat the pipe to 180°C.
- No carbon monoxide permeation: Specific measures are taken to ensure the safe transport of the sample gas without influencing the measured values through "outgassing".
- Maximum heating circuit length of 100 m: Long distances can be realized without additional power supply with minimized installation effort.
- Can be individually shortened using "cut-to-length" technology: saves material, reduces installation and repair costs and avoids heat build-up.
- Patented tube bundles (PSG Ex[2] and PSG Ex[3]) provide effective protection against hazardous electrostatic charges and are supplied with an ATEX certification for the entire assembly.

Figure 2: Typical installation of an extruded heated Emi pipe (also for long vertical sections, can belaid up to 300 m in one piece, length can be adjusted on site using cut-to-length technology)

Energy-efficient and sustainable over the entire life cycle

The PSG Emi Line is also sustainable. Its energy efficiency not only saves operating costs, but also significantly reduces the carbon footprint. Figure 3 shows an example compared to a corrugated PA 12 lines.

In the case of corrugated pipes, this is comparable to the annual energy requirement of ten modern single-family homes for a 50-meter pipe in continuous operation. At holding temperatures of 120°C or 180°C, this means an energy saving of at least 25% for extruded pipes compared to commercially available corrugated PA 12 hoses. Over the entire life cycle, the savings in kWh and the CO_2 balance add up significantly (see Figure 4)

Length	10m	25m	50m
Δ kWh	19.093	47.736	31.188
Δ t CO2	4,2	10,5	21,0

Figure 4: Savings potential with extruded sample gas lines (PSG Extruded) over 15 years

These benefits pay for themselves in a very short time - a real benefit for the environment and your budget.

Conclusion - A new era for using heated sample lines

Overall, innovations have significantly improved the performance, flexibility, and ease of use of heated sample lines. The extruded, heated line makes an important contribution to this trend.

The mechanical manufacturing process ensures high precision and consistency, but also scalability to higher production volumes and speed of delivery. Technical solutions with a high degree of installation flexibility and a negligible CO baseline are now available. New standards are also being set in terms of energy efficiency and sustainability. This means that extruded heated sample lines can be used for a wider range of applications in industry, research and especially environmental monitoring.

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