AUM$_{URJA}$ *vs* CV Analyzer – A Techno-Commercial Evaluation

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ABSTRACT

With the indigenous development of the novel, cost effective, photonic system AUM$_{URJA}$ for various real time applications across many fields, a detailed scientific study was taken up by an interdisciplinary group of scientists and industry experts across the world, to compare AUM$_{URJA}$ with conventional systems available for the steel and petrochemical industry.

The following note elucidates a technical intercomparison of the AUM$_{URJA}$ with typical Calorific Value (CV) Analyzer for use in the steel and petrochemical industries and makes a techno-commercial evaluation of AUM$_{URJA}$ and CV Analyzers based on a critical review of published and patented information, to help decision makers in the industry.

The study showcases the many technical and commercial advantages of the AUM$_{URJA}$ for various applications in the steel and petrochemical industry, when compared with the typical Calorific Value (CV) Analyzer.

1. Introduction

The novel AUM$_{URJA}$ (Air Unique Monitoring $_{\text{Upstream Remote-sensing Joule Analyzer}}$) and the Calorific Value (CV) Analyzer serve different but complementary roles in gas monitoring, with distinct technologies, applications, and features.

1.1 AUM$_{URJA}$ System

- Uses advanced principles of physics, photonics, laser backscattering, optoelectronics, statistical mechanics, AI, and machine learning for direct, real-time, in-situ, remote monitoring of a wide range of gases and air quality parameters.

- Monitors (remote sensing) multiple gases simultaneously (flammable, non-flammable, VOCs), particulate matter ($PM_{2.5}$, PM_{10}, dust, aerosols) and environmental / meteorological parameters with high precision and sensitivity, from ppm concentrations, down to ppb (parts per billion) concentrations, in industrial process pipelines directly.

- Supports spatial profiling for gas distribution over distances from 1 mm to 5 km, with very high sampling rates (from 200Hz - up to 25 kHz – wireless mode).

- The system estimates in-situ CV (Calorific Value), Wobbe Index, and density of the gases, and, or, mixtures in the industrial process pipelines, without the requirement for any additional sampling, filtering, and heating - thus ensuring realistic, real time, in-situ CV values of an undisturbed gas/mixture in the industrial process pipelines.

- Portable, compact, low power, and designed for remote, non-intrusive deployment with cloud data streaming and visual/thermal camera integration for safety.

- Developed specifically to withstand complex and severe environments present in steel, oil and gas, and chemical industries, where in-situ industrial fluid (gas/liquid) analysis, on a continuous basis, with spatial-temporal insights are critical, and are to be supported by high-resolution data.

- Designed and developed to focus on showcasing comprehensive pipeline gas (including hazardous gases and VOCs) quality, with real time analysis showcasing automated anomaly detection, even during extreme weather conditions and environmentally affected corroding pipelines.

1.2 **CV Analyzer** (Calorimeter)

- Primarily designed to provide indirect, deducted measurements of representative average gas quality parameters such as calorific value, Wobbe index, and specific gravity, based on the thermal (heat) and specific gravity measurements, *of a disturbed sample collected in a separate chamber, away from the in-situ process flow conditions.*

- The gas sample is collected in a separate chamber, subjected to combustion under control conditions, and then the thermal (heat) and specific gravity properties of the disturbed sample are measured using a thermocouple and an acoustic sensor. To facilitate the same, special additional infrastructure needs to be integrated with the process flow pipelines, in the industry.

- In conventional calorimetric systems, gas samples are extracted from the main process line through a sampling pipeline of smaller diameter (typically,0.25"), fabricated in SS316 for corrosion resistance. As, the gas stream—especially in coke oven pipelines—carries significant quantities of tar, naphtha, and other impurities, the gas is subjected to *preheating and filtering* by passing through fine filters (2 µm or 10 µm pore size) before reaching the calorimetric bomb or online calorimeter where the Calorific Value (CV) is estimated. The changes brought about in the fluid pressure and flow velocity characteristics (due to changed diameter and geometry of the sampling pipeline), thermal conditions (due to heating), and the physical and compositional characteristics (due to filtering) destroys the actual character of the gas in the process pipeline, which is supposed to be monitored for its properties (like the calorific value and Wobbe index).

- The measured sample's physical and chemical characteristics are therefore disturbed (altered / tampered) under controlled conditions in a separate chamber, apparently as part of sample preparation. The sample preparation therefore involves physically altering the original sample in the process pipeline, due to which the chemical characteristics of the sample would also be affected. Therefore, the process is destructive to the original gas sample in the process pipeline, and the sample tested is not representative of the gas in the process flow pipeline.

- Measures the temperature increase due to combustion using thermocouples or heat sensors. Determines calorific value (energy content), Wobbe index, and similar parameters based on heat released per volume of burned gas (tampered) sample.

- The estimated Calorific Value and Wobbe Index, which are the result of the combustion of the disturbed gas sample in a controlled environment, are therefore unrealistic of real world in-situ conditions.

- Suited specifically for non-rigorous industrial process control, fuel quality assurance, and energy management, not for open-air ambient monitoring.

- Known for industrial applications like monitoring syngas, natural gas, biomethane, and other process gases with not so quick response times.

- More focused on industrial process control with less emphasis on more realistic in-situ undisturbed samples, and on spatial or multi-parameter air quality assessment.

In summary, the novel AUM_{URJA} Photonic system is an advanced, in-situ, highly sensitive, versatile multi-parameter remote gas analyzer, with multifarious and broad range of environmental / industrial applications utilizing high resolution data, thus not restricting to the typical CV analyzer applications.

The CV analyzer is an industrial calorimetric instrument, based on in-vitro combustion and empirical determination of the energy content of altered gases (altered after filtering, heating and combustion) in the industrial process. Despite these limitations, CV analyzers have been in use in the industry for control and energy efficiency applications [1] – [20].

Table 1: Comparison Summary of Features of AUM Photonic System and CV Analyzer

Feature	AUM$_{URJA}$	CV Analyzer (Calorimeter)
Technology	Principles of photonics, Laser backscattering, opto-electronics, statistical mechanics, AI, big data analytics, cloud based remote data streaming to command control center.	Combustion calorimetry of disturbed samples.
Primary Measurement	In-situ measurement of multi-gas pollutants / mixtures (*high specificity and sensitivity of all gases with varying concentrations from ppb to ppm*), environment (meteorological) parameters, calorific values, Wobbe index and corrosion parameters.	Post combustion Calorific Value, Wobbe index, specific gravity of a disturbed (tampered by controlled combustion in a special chamber) mixture using thermocouples and acoustic sensors. Assuming no role of moisture, internal gas dynamics, and corrosion.
Application Focus	*In-situ*, direct, remote sensing of air (gas) quality, spatio-temporal gas profiling, safety, Quality Control, in the open as well as closed spaces, even in severe and harsh environments.	Industrial gas energy content and process gas monitoring of disturbed samples, indirectly in *invitro,* controlled conditions after the sample's physical and chemical characteristics are modified during sampling, filtering and combustion.
Sampling Requirements	Sampling in the process pipeline, ensuring in-situ measurements. No additional infrastructure is required. Cloud-enabled remote streaming data.	Special sampling and combustion infrastructure required. Sample characteristics are tampered due to changes in pipeline, heating and filtering.
Sensitivity and Sampling Frequency of Monitoring	Very high specificity and sensitivity (ppb), with very high sampling rates (up to 25kHz), of individual gases as well as multi-gas mixtures.	Slow response, with no scope for individual or multi-gas measurement scope.
Additional Requirements For Monitoring	Suitable for any industry, with as is where is industrial process pipelines. As per existing pipeline specifications (remote sensing).	Separate sample gas combustion chamber (industrial scale), needs to be designed and developed for integrating the measurement system.
Portability	Portable, compact, low-powered.	Not portable. Special fixed infrastructure to be integrated, Industrial stationary device, higher power. Separate line for sample collection, temperature compensation via software.
Use Cases	Real time, in-situ monitoring of pipeline gases/ mixtures, gas analysis, hazardous gas detection, anomaly detection, quality control, assessment of combustion dynamics of individual gases as well as gas mixtures efficiency, for better energy management.	Waste pyrolysis, gas quality control, combustion efficiency of disturbed samples.

2. AUM$_{URJA}$ vs CV Analyzer (Calorimeter)

The AUM photonic system and CV Analyzer (calorimeter) methodology differ fundamentally in both principle and application for gas monitoring.

2.1 **AUM$_{URJA}$**

- Utilizes continuous wave laser light for *non-intrusive remote sensing* of gas molecules and particulates in air.[17], ,21]
- Detects backscattered laser light with a position-sensing detector, supported by optical filters for selective molecule discrimination.[17], [21]
- Achieves *high sensitivity (to ppb levels)*, high temporal resolution (up to 25 kHz sampling), and *spatial profiling* (1 mm–5 km range).[17], [21],[22]
- Outputs *real-time data* on various in-situ gas concentrations (e.g., VOCs, CH_4, CO_2, H_2, H_2S) without altering or consuming the sample.[21][22]
- Data processed using AI and machine learning algorithms for automated anomaly detection, pattern recognition, and predictive insights.[22]

2.2 **CV Analyzer (Calorimeter)**

- Relies on *combustion of a disturbed and defined gas sample* in a controlled environment.[23]
- Measures the *temperature increase* due to combustion using thermocouples or heat sensors.[26][28]
- Determines *calorific value (energy content)*, Wobbe index, and similar parameters based on heat released per volume of burned gas.[26][28]
- Involves physical alteration and chemical reaction of the gas, meaning the process is destructive to the gas sample.[26]
- Suited specifically for industrial process control, fuel quality assurance, and energy management, not for open-air ambience monitoring.[26][28]

Table 2: Key Differences AUM$_{URJA}$ vs Calorific Value (CV) Analyzer

Aspect	AUM$_{URJA}$ [15],[17],[21],[22],[26],[27],[29]	Calorimeter [23],[24],[25],[28],[30],[31],[32],[33]
Principle	Direct, Laser backscatter detection, opto-electronics, photonics.	Indirect, Combustion with heat and specific gravity measurement using thermocouples and acoustic sensors.
Sample Handling	Non-intrusive, remote sensing, in-situ monitoring.	Intrusive consumes the disturbed sampled gas in a separate chamber.
Measurement Focus	Gas Concentrations, Calorific value, Wobbe index, air parameters.	Calorific value, Wobbe index.
Sensitivity	Gas / mixture composition (with concentrations from ppm to ppb levels) with high temporal/spatial resolution.	Variable, focused on energy not composition.
Output	Real-time multi-gas composition and energy metrics of individual gases as well as the mixture, cloud-enabled data streaming.	Single-value energy metric per sample.
Applications	Fuel/ gas quality, quality control, process safety, energy management based on direct, in-situ untampered samples.	Fuel/gas quality control, energy management based on indirect and invitro measurements of disturbed samples[28].
Industrial Safety	No issues, as sampling is in-situ, real time, and measurement is by remotely sensing, with a 1mW light beam.	Special industrial safety considerations are to be followed, as samples are drawn from in-line into separate chambers.
Known Problems	None	Frequent clogging of sampling pipelines disable CV and Wobbe Index measurements for extended intervals.

3. Methodologies of AUM$_{URJA}$ vs Calorific Value (CV) Analyzer

- AUM photonic systems are optimal for instantaneous, simultaneous, high-resolution detection and quantification of multiple gas mixtures in in-situ ambient, in-process settings, quality control, and energy management, based on real world process conditions, without any sample tampering and destruction.[15],[17],[21],[22],[26],[27],[29]

- Calorimeter methodologies are ideal for determining the energy content of process gases in settings, which do not require in-situ sampling, and which are satisfied with measurements based on tampered samples (burning under controlled conditions and measuring resultant heat).[23],[24], [25],[28],[30],[31],[32],[33]

Therefore, each methodology is suited for different monitoring goals:

- AUM for comprehensive direct, in-situ, highly sensitive gas analysis, quality control, energy metrics of individual gases as well as the mixture of gases, providing better energy management applications in the open (ambient air quality, air pollution, etc.) or closed spaces (pipelines, combustion chambers, etc.).
- Calorimeters for indirect, non-in-situ, industrial energy metrics.

4. Cost and Deployment Differences for AUM_{URJA} versus Industrial Gas Calorimeters

AUM photonic systems are typically cheaper, easier, and more flexible to deploy than traditional industrial gas calorimeters, which require more costly installation, rigorous calibration, and ongoing maintenance.

4.1 **Cost Differences**

4.1.1 AUM_{URJA}

- Designed for portability and remote deployment, the AUM system requires less infrastructural investment, minimal sample handling hardware, and lower power consumption. Its operational costs are also reduced due to non-intrusive measurement and cloud-based data management. Purchase and operating costs are significantly lower than those of industrial calorimeters because AUM does not require sample combustion, consumables, or frequent calibration cycles.[21], [22], [27] 4.1.2 Industrial Gas Calorimeters

- These systems demand substantial initial investment for installation, calibration, and integration into industrial process flows. Continuous Emission Monitoring (CEM), including calorimetry, requires rigorous calibration/verifications and periodic maintenance, raising both upfront and ongoing costs. Consumables (like calibration gases), high-quality heat sensors, and technical support further drive up the costs. For many basic monitoring tasks, the extra cost of direct calorimeter-based monitoring is difficult to justify solely for fuel quality unless regulatory mandates apply.[23], [24], [25],[30]

4.2 **Deployment Differences**

4.2.1 AUM$_{URJA}$

- **Portable and compact**, can be quickly set up in remote or mobile locations without special infrastructure.[22]
- Offers **cloud-based remote access** to real-time data, which simplifies scaling across many sites and locations.
- **Suitable for fast deployment even in severe and complex environments l**ike petrol pumps, industries, outdoor air quality stations, or on mobile vehicles.[27]
- **No sample collection, no combustion, or no hazardous handling needed.**
- **No additional safety and infrastructural compliances required.**

4.2.2 Industrial Calorimeters

- Require **fixed installation in process areas** (e.g., factories, processing plants) with sample gas lines feeding into the instrument.[23], [24], [25],[30]
- **Deployment needs support for sample extraction, conditioning, and return, including regulatory compliance for monitoring and reporting**.[30]
- Often located indoors or in controlled environments; not well-suited for rapid, ad-hoc deployments or open-air usage.
- Typically, part of stationary, integrated process control systems rather than mobile or distributed sensor networks.

Table 3: Costs and Deployment Comparison Summary

Feature	AUM_{URJA} [15],[17],[21],[22],[26],[27],[29]	Calorimeters [23],[24],[25],[28],[30],[31],[32],[33]
Capitol Cost	Lower (portable, minimal setup)	Higher (infrastructure, calibration)
Operating Cost	Lower (minimal maintenance)	Higher (consumables, calibration)
Deployment	Portable, rapid, cloud-ready	Fixed, Needs process-integration
Suitability	Versatile across Industry (outdoors, indoors, remote, mobile)	Specific Industry
Regulatory Use	No special compliances required	Requires additional stringent compliances

5. Summary and Conclusion

AUM_{URJA} photonic systems are more versatile, enabling in-situ, accurate and sensitive measurements of gases/mixtures, energy metrics (CV, Wobbe Index etc.) of individual gases, as well as gas mixtures, are less expensive and much easier to deploy.

In contrast the conventional calorimeters, which provide energy metrics pertaining to the tampered sample under control conditions and are better suited for less rigorous energy monitoring requirements of industries, which can afford a high level of technical infrastructure and support involving higher costs.

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