# Raman technology in the chemical industry

## Reliable composition measurement of chemical process streams

KAISER OPTICAL SYSTEMS, INC.
An Endress+Hauser Company

# Your challenges, our mission

## Boost your plant safety & performance

**Current challenges in chemical manufacturing**
The chemical industry is experiencing dramatic change driven by increasing market globalization, tightening industry regulations, and growing competition. Process safety in chemical operations is also always a concern, particularly when working with materials that are hazardous to people, the environment, and infrastructure. Maintaining safety compliance and ensuring product consistency while trying to reach or exceed nameplate capacity is a tough juggling act.

Adding to these strains, many chemical facilities are plagued by aging measurement equipment and workplace demographics. Mechanical issues, along with a vacuum of employee process and equipment knowledge, can result in costly plant downtime. Faced with all of these pressures, many chemical companies are adopting innovative strategies and embracing new technologies just to stay in the game.

**We can help** Our industry-proven Raman instrumentation, powered by Kaiser Raman technology, helps you to overcome these challenges. It empowers you to "see" directly into your chemical processes in real-time, so you can precisely and accurately:

- Measure the purity of the feed streams
- Monitor the reaction progress in continuous / batch reactors
- Detect the end-point of the reaction
- Determine the quality of the end products

With such tight process monitoring and control, Raman measurement helps you boost your plant safety and performance, while saving time and money across your entire organization.

Relying on our industry knowledge and skills, we work together with our customers to find the best solution for every application

# Value of Raman technology

## Fast, proven, & reliable chemical process measurement

**Risks of outdated systems** Throughout the chemical industry, many companies are realizing that investing today to replace old mechanical systems will pay dividends in the long run—in productivity gains, maintenance cost savings, product quality, and safety peace-of-mind. Older measurement technologies are less accurate and require higher levels of maintenance than modern equivalents. Outdated technology can also compromise production efficiency, availability, and plant safety. Since the late 1990's, laser-based, in-process measurement technologies like Raman spectroscopy have continued to gain traction in the chemical industry over alternative methods such as gas chromatography (GC) or mass spectrometry.

24/7 process visibility and control with our Raman systems

**Raman technology's time to shine** For many chemical manufacturers, the benefits of Raman technology are simply too compelling to ignore. Raman-based instrumentation is easy and economical to install, operate, and maintain. Up to four Raman probes can be inserted directly into multiple process streams, each one remotely connected to a single analyzer that can be located hundreds of meters away from a potentially hazardous process. As a result, one compact Raman analyzer can effectively replace four GCs, along with their sample handling systems. Companies can dramatically reduce CAPEX by saving shelter space and lower OPEX by eliminating the maintenance typically required on a GC and sample handling system with wearing parts. Raman-based analyzers truly shine in their ability to provide real-time, *in situ* measurement at the speed of light—far faster than other off-line techniques—with far greater accuracy and reproducibility.

### Challenges of traditional measurement technologies

- Often extensive sample preparation required via sample handling system
- Long measurement cycle resulting in significant sample lag times
- Ongoing cost of consumables and utilities
- Increased safety risks associated with manual extractive sampling and laboratory analysis
- Less adaptability for process changes
- Complex installation and utilities
- Large, expensive physical footprint

### Benefits of Raman technology systems

- Up to four streams measured from a single base analyzer
- Simplified installation, no consumables, and minimal maintenance requirements
- Highly reliable measurement in near real-time
- Improved plant safety
- Increased process efficiency and production rate
- Better product quality and reduced product giveaway

# Our Raman measurement system

## The most trusted Raman analyzer and probe technology

**Why companies trust our Raman products** For over 30 years, we have harnessed the powerful analytical information of Raman spectroscopy to help companies attain operational excellence. Our Raman analyzer systems, powered by Kaiser Raman technology, are proven and reliable process measurement tools for a wide range of upstream and downstream chemical applications. We offer real-world expertise that comes from having Raman analyzers successfully installed at multiple chemical plants around the globe.

Our Raman product suite is prized for its ability to perform chemical compositional analyses on gas, liquid, and solid samples with unparalleled accuracy and precision. Featuring highly intuitive Raman RunTime control software, our Raman analyzers work in conjunction with our wide range of versatile Raman sampling probes optimized for the chemical industry.

### Unique features of our Raman products

- Measurement of multiple components in up to four process streams per analyzer
- Inline, at-line, or online real-time process measurement
- User-friendly embedded control software for reliable 24/7 data analysis and recording
- Hardware format customizable to your installation environment
- Simplified process analyzer hardware with minimal or no sample handling system
- Easily adaptable to future process changes using the same hardware and software
- ISO 9001:2015 and hazardous area certification

**30+**

years of Raman spectroscopy expertise

**>2000**

process Raman analyzers installed around the world

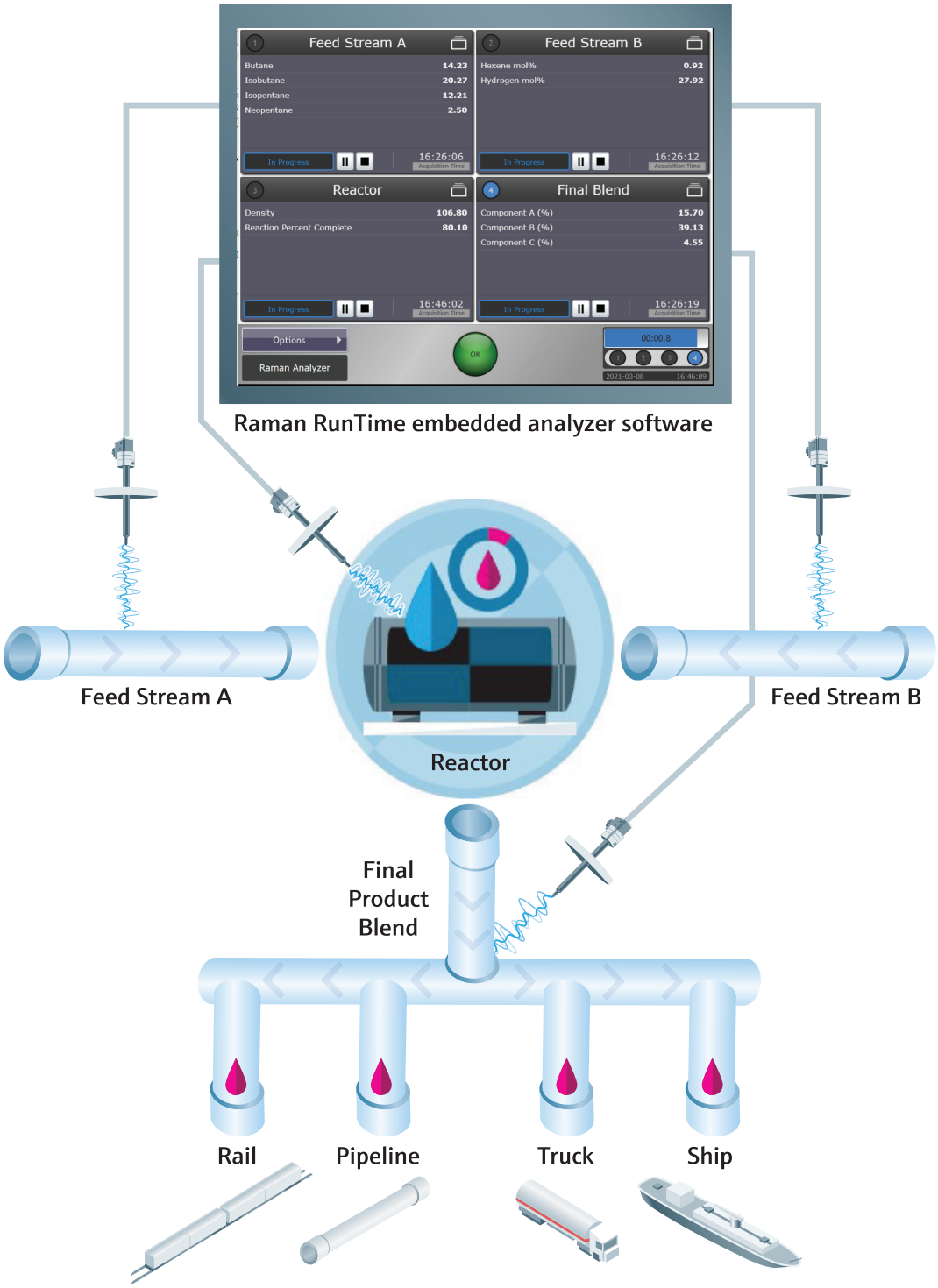
**75+**

U.S. patents in Raman and holographic technology

# Raman RunTime analyzer control software

## 24/7 inline, real-time process measurement

The “brain” of every Raman Rxn analyzer is its powerful, intuitive, and fully embedded Raman RunTime software control platform. Accessed via a user-friendly touchscreen or remote interface, Raman RunTime integrates the spectrometer functions into the analyzer electronics, avoiding the need to run proprietary software using an external computer. Designed to be inherently secure and support Industry 4.0, Raman RunTime is intended for easy integration with industry standard multivariate analysis, communication protocols, and automation platforms to deliver real-time, *in situ* monitoring and control of your chemical processes.



# We can support you

By measuring everything from hydrocarbons, specialty chemicals, diatomic molecules, catalysts, and gases...

...to solvents, paints, coatings, polymers, inorganics, agrochemicals, hazardous materials and more...


## Ensure plant safety

Raise the bar on safety across your plant by improving your ability to monitor and control your processes. With 24/7 unattended process monitoring, you gain the real-time knowledge that you need to better predict and avoid safety incidents, as well as minimize personnel and environmental risk exposure.

## Optimize efficiencies

Our Raman analyzers directly measure up to four process streams in real-time, delivering fast, reliable results in seconds. Our instruments also require minimal maintenance and drive lab-to-process scalability. These capabilities help you to de-bottleneck your processes for greater operational throughput and cost savings.

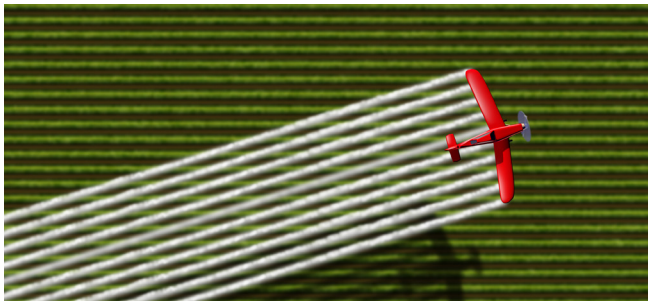
## Boost product quality

Precise, reliable measurement of your chemistries opens the door to full process transparency — allowing you to dramatically boost product quality, increase yields, and minimize product giveaway. Better product quality effectively means higher profit margins with fewer regulatory obstacles.

# Ensuring plant safety in agrochemical production

**Increasing safety with precise measurement of agrochemicals** The handling of highly toxic chemicals reinforces the demand for Raman-based measurement technologies that offer reliable, reproducible results without lag time. Many agrochemicals are dangerous due to their explosive capabilities. Process safety concerns arise because agrochemicals in bulk storage pose significant environmental and health risks, particularly in the event of accidental overflow or explosion. Fortunately, agrochemicals are strongly Raman active which makes them well-suited for automated, unattended Raman composition analysis.

**Our expertise in the field** Raman technology is highly effective at accurately measuring and continuously monitoring agrochemicals. Continuous, real-time, and reliable unattended measurement techniques with less system maintenance allow for much greater control over a process while achieving high safety standards in agrochemical production.



**Key benefits**

- Increases the capability to safely control complex chemical processes
- Eliminates lag times associated with manual sampling and lab analysis, avoiding potentially unsafe operating conditions
- Minimizes risk of chemical exposure to personnel and the environment
- Improves compliance with industry safety regulations

# Optimizing blended gasoline

**Efficiently controlling benzene and octane in gasoline** As fuel blend components, both benzene and alkylate increase the octane rating of gasoline, resulting in improved motor performance and reduced engine knock. However, concern over the negative health effects of benzene as a carcinogen and the high likelihood of benzene entering the groundwater supply has led many countries to set upper limits on the amount of benzene allowed in the final product. Alkylate is a high-value blend component that significantly increases the octane rating of gasoline. The octane rating must always meet a minimum spec such as 87 or 93 octane numbers (the numbers you see at the pump). Adding more than the minimum amount of alkylate necessary to meet spec is a waste of valuable feedstock. Benzene is used to increase octane rating, but adding too much puts human health and our environment at risk. Raman technology can easily measure the octane number of the alkylate component stream, as well as the octane number of the final blended gasoline, to ensure it meets the minimum octane rating. It can also measure benzene in the gasoline to maximize benzene content without exceeding the current upper limit of 0.62% in the USA.

**Our expertise in the field** Our Raman technology can be used to measure dozens of physical and chemical properties in the hydrocarbon processing industry, including benzene, aromatics, olefins, oxygenates, distillation points, RON, MON, and even RVP in gasoline. With 24/7 process monitoring and the ability to tightly control process parameters like these, companies can achieve desired blend recipes far more precisely. In doing so, hydrocarbon processors have the potential to save millions of dollars from reduced off-spec product, fines, and re-blending while minimizing product giveaway.

**Key benefits**

- Strict regulatory compliance
- Maximum use of benzene to increase octane number without exceeding regulatory limit
- Optimal use of high-value alkylate to ensure minimum spec is reached while eliminating high-value product giveaway
- Ability to easily accommodate crude slate variations and blend recipe changes over time, such as summer and winter blends

# Maximizing polymer product quality

**Maximizing product quality in polyethylene production** The global output of e.g. ethylene is an estimated 150 million metric tons annually and growing substantially. More than half of the total production of ethylene is used for the production of polyethylene, which is produced under extreme conditions like high temperature or with use of corrosive and hazardous substances. Developing a safe and efficient way to continuously produce top-quality polyethylene is challenging, and interruptions in the olefin process can cost companies hundreds of thousands of dollars in lost production.

**Our expertise in the field** Many unplanned shutdowns are caused by outdated mechanical measurement technologies that require manual sampling with aging equipment that needs frequent maintenance. Petrochemical companies count on the robust, reliable design of our Raman instruments to more accurately measure and control critical product quality parameters, while minimizing off-spec product and energy consumption.

**Key benefits**

- Better control of product quality parameters due to more accurate and precise real-time, in-line composition measurement
- Significantly enhanced productivity and reduced operational costs
- Adherence to safety standards under extreme process conditions

# Accurately measuring high pressure reactions

**Delivering real-time data for better control of your ammonia converter** Ammonia synthesis is a high-pressure reaction requiring careful monitoring. Maintaining a 3:1 stoichiometric ratio of $H_2$ to $N_2$ in the feed stream to an ammonia converter is critical for control and optimization of the synthesis process.

**Our expertise in the field** Our unique Raman analyzer and seamless sampling probe design helps you to precisely monitor the feed stream composition. The analyzer provides unique spectroscopic capability to measure the ratio of H2 and N2 diatomic gases in ammonia synthesis reactor feed streams. Our Raman system allows measurements to be taken directly at sample tap with no sample transport to the analyzer.

**Key benefits**

- Highly accurate and precise, real-time measurements of the $H_2$ to $N_2$ ratio
- Increased process control capability, resulting in improved plant performance
- Increased safety

To learn more about our expertise in the chemical industry, please view our chemical application notes at www.kosi.com.

# Raman Rxn2 analyzer

## Liquids or solids / laboratory R&D analysis

The Raman Rxn2 analyzer adeptly harnesses the power of Raman spectroscopy while serving as an ideal bridge from lab-to-process. Designed for use in analytical laboratories with model transfer capabilities, the Raman Rxn2 is heavily relied on for routine sample identification, support of R&D projects, early process development, and scale-up settings for *in situ* analysis. Available for a benchtop or on a wheeled mobile cart, the Raman Rxn2 offers location convenience and portability for process development laboratories. With single channel (standard) or optional four channel configuration, measurement from different reactors or sampling points is possible with one base analyzer. Control methods can be quickly achieved with successful transfer to pilot and manufacturing environments. Equipped with a unique self-monitoring, self-calibration, and self-diagnostic system, the Raman Rxn2 ensures the validity of each measurement. Like the rest of the Raman Rxn analyzer family, the Raman Rxn2 offers the benefit of having fully embedded, highly intuitive Raman RunTime software as its control platform. The Raman Rxn2 is available with 532 nm, 785 nm, or 1000 nm excitation laser wavelengths.

**Benefits at a glance**

- Reliable real-time, *in situ* measurements
- Intuitive, embedded control software via touchscreen or remote interface
- Configurable with one channel as standard, with optional four channel capability
- Sequential operation for fast analysis per channel and programmable channel interrogation
- Conversion of acquired Raman spectra into process knowledge using built-in multivariate predictors
- Hazardous area certification: ATEX, North American, IECEx
- Flexible installation options: benchtop or mobile wheeled cart

**Field of application**

- Raw material identification
- Reaction monitoring and optimization
- Catalyst investigation
- Final product blending
- Polymerization monitoring and blending

A Raman Rxn2 Hybrid variant of this analyzer is available for traditional small spot or wide area Raman sampling that is particularly well-suited for polymer applications (see PhAT-based wide-area sampling on page 15). In addition, an introductory analyzer is available for applications requiring lower spectral resolutions.

# Raman Rxn4 analyzer

## Liquids, solids, or gases / process analysis

Designed for use in process and manufacturing settings, the rugged Raman Rxn4 analyzer is the optimal choice for manufacturing or process environments. Many companies move to the Raman Rxn4 after their processes have been successfully tested and proven in the laboratory and process development stages. Stackable in a standard 19" rack, the Raman Rxn4 saves valuable space on the production floor. It comes with fully embedded, user-friendly Raman RunTime control software, enabling real-time, *in situ* process monitoring and control. The Raman Rxn4 analyzer can be configured with up to four channels with a 532 nm, 785 nm, or 1000 nm excitation wavelength, depending on your process needs. It also features unique self-monitoring, self-diagnostics and self-calibration capabilities to ensure the validity of each measurement. The Raman Rxn4 analyzer is certified for output into hazardous areas, and it is offered with an optional stainless steel NEMA 4X enclosure.

**Benefits at a glance**

- Configurable with one channel as standard, with optional four channel capability
- Robust, reliable, and highly accurate
- Easy installation and minimal maintenance/ downtime
- 24/7 inline, online, or at-line process measurement
- Intuitive, fully embedded Raman RunTime control software via touchscreen or remote interface
- Scale-up, scale-out, and pilot-plant compatible
- Hazardous area certification: ATEX, North American, IECEx
- Designed for 19" rack, NEMA 4X enclosure on trolley or stand also available

**Field of application**

- Online reaction monitoring
- Final product blending
- Real-time catalyst monitoring
- Reaction endpoint determination
- Extrusion monitoring
- Polymerization monitoring


A Raman Rxn4 Hybrid variant of this analyzer is also available for traditional small spot or wide area Raman sampling that is particularly well-suited for polymer applications (see P$^{h}$AT-based wide-area sampling on page 15).

# Optograf analyzer

## Gas-phase / process analysis

The Optograf analyzer is a turn-key, laser-based analyzer that uses Raman spectroscopy to provide quick and accurate quantitative chemical composition measurements of gas-phase processes. The design of the Optograf analyzer incorporates customer requirements for serviceability and hazard-area certification, provides a compact footprint, and minimizes utilities consumption. With a separate dedicated laser per probe, the Optograf analyzer can speed up chemical processes by measuring up to four streams simultaneously. The Optograf analyzer is designed to be located outdoors and does not require an analyzer shelter. It is environmentally robust and able to be placed in a three-sided shelter or under a sun shield for convenient user access.

### Benefits at a glance

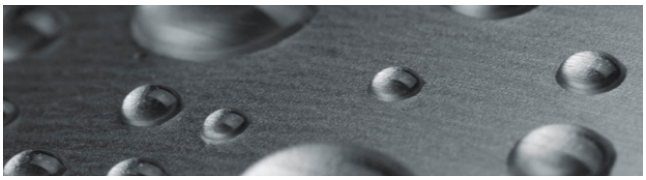
- Non-destructive analysis of gases, including homonuclear diatomics ($H_2$, $N_2$, $O_2$)
- Compact, smaller than most wall-mount GCs
- Simultaneous measurement of up to four streams for faster results
- No sample transport, no consumables, and minimal utility requirements
- Minimal analyzer technician time with maximum technician safety
- Hazardous area certification: ATEX, North American, IECEx
- Flexible installation options: IP56 wall- or rack-mounted, sealed/purged enclosure

### Field of application

- Hydrogen production/purity
- HyCO production
- Methanol production
- Ammonia production
- Hydrogen recycle
- Gas turbine fuel feed
- Synthetic natural gas/IGCC power plants

# RamanRxn probehead

## Liquids & solids / lab analysis



Designed for product and process development, the RamanRxn probehead is the workhorse of our Raman laboratory probe portfolio. It is trusted to deliver high performance Raman measurements across a wide spectral range to prove out chemical applications in the lab before scaling out to the pilot plant environment.

The RamanRxn probehead is compact, lightweight, and flexible - offering multi-purpose convenience for both solids and liquids laboratory analysis. The RamanRxn probehead accepts a variety of interchangeable optics which make it a highly versatile and easily adaptable instrument in your laboratory toolbox.


**Field of application**

- Reaction monitoring
- Final product blending
- Catalyst monitoring
- Hydrocarbon speciation
- Process unit optimization
- Polymerization reaction monitoring
- Extrusion monitoring
- Polymer blending

**Benefits at a glance**

- Multipurpose use for solids and liquids measurement
- Lightweight and compact
- Integrated laser safety interlock, including "laser on" indication and remote shut-off
- Easy switching of non-contact and immersion optics to suit a variety of applications
- Wide spectral range, including access to a critical low-wavenumber region

# PhAT probe

## Solids / laboratory & process analysis

For solids and semi-solids analysis, the PhAT probe reigns supreme. Its state-of-the-art, stainless-steel probe design produces representative, focus-free, quantitative Raman measurements. The PhAT probe illuminates a large surface area and eliminates the need to align the probe for surface roughness. A large excitation spot (6 mm) and multiple collection fibers in the PhAT probe achieves heterogenous solids sampling in both the axial and lateral dimensions. In doing so, it provides information on deeper layers in addition to the surface, which is highly useful for measuring heterogenous solids such as polymer beads. To enhance sampling flexibility, insertion and non-contact sampling optics are available for the PhAT probe.

**Field of application**

- Final product quality
- Blend impurities
- Crystallinity
- Raw materials
- Extruded pellet quality
- Crystallinity
- Density

**Benefits at a glance**

- Non-contact measurement of heterogeneous solids for better representation
- Non-destructive measurements from a distance
- Reproducible sampling
- "Focus free" alignment
- No need to align probe for surface roughness
- Surface and deep layer analysis
- Hazardous area certification

# WetHead probe

## Liquids / laboratory & process analysis

Designed to promote versatility and materials compatibility, the WetHead probe is a compact, sealed immersion probe for *in situ* Raman spectroscopy of liquid-phase samples in a laboratory or process plant setting. The WetHead probe provides inline, real-time chemical measurements without needing to send a technician to the field and collect a sample from the stream. The process connection for the WetHead probe can be swaged, compression-mounted, flange-mounted, or installed in a flow cell, and can be NeSSI compatible. These options allow for direct insertion in slip-streams, drain-valves, reactors, circulation loops, blend headers, and inlet or outlet pipework. The WetHead probe is highly customizable and offers a great deal of sampling flexibility. In addition, the WetHead probe is compatible with installations in hazardous areas/classified environments.

**Benefits at a glance**

- Customizable to your process
- Robust design with a range of process connections
- *In situ* /no transfer lines or fast-loops required
- Faster, simpler installation
- Support for a range of chemical processes and corrosivity requirements
- Ensures safety and meets regulatory requirements
- Suitable for hazardous /classified environments
- Hazardous area certified: ATEX, North American, IECEx

**Field of application**

- Reaction monitoring
- Blending
- Catalysis
- Feed
- Final product monitoring
- Polymerization reaction monitoring
- Extrusion monitoring
- Polymer blending

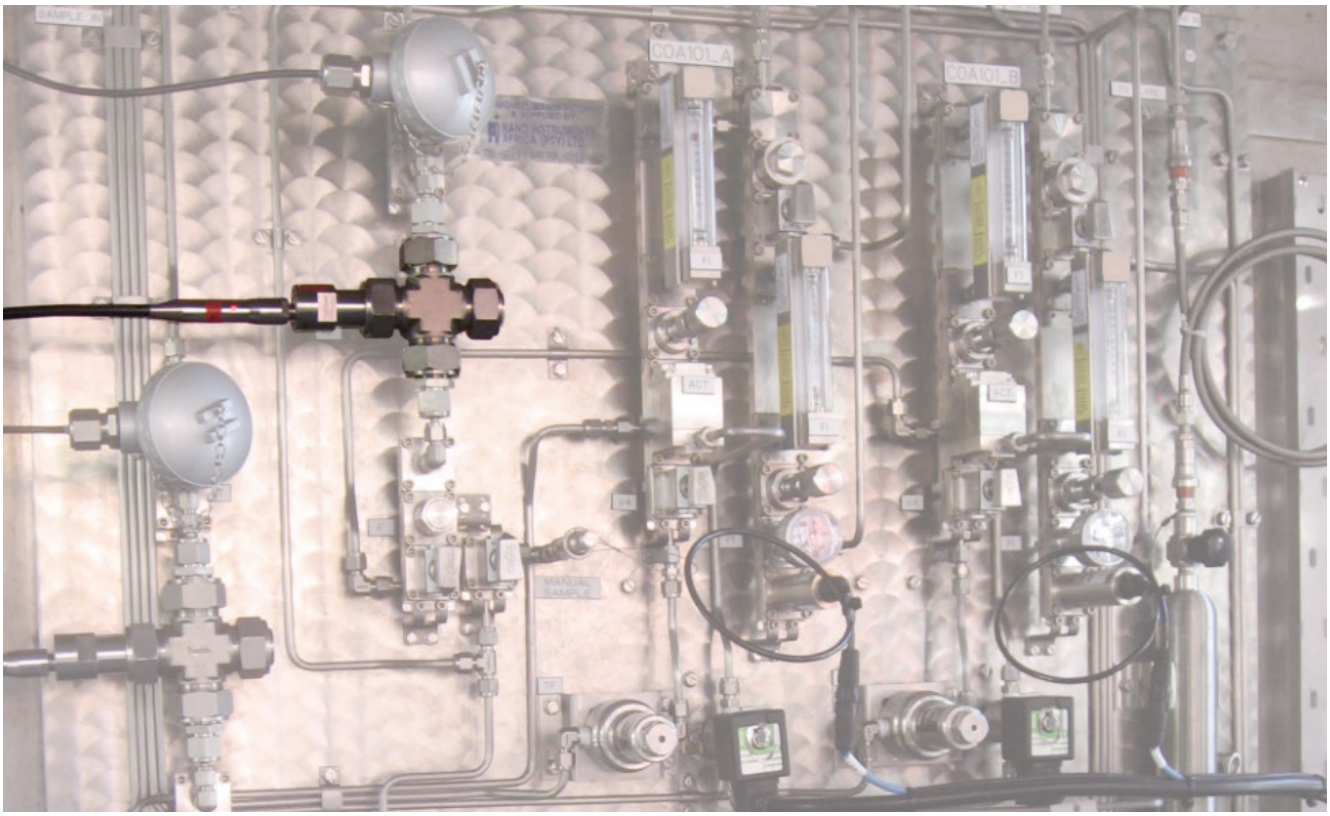
# Pilot-E probe

## Liquids / process analysis

The Pilot-E probe is a rugged, process insertion probe with no sample handling system. Its single cable design streamlines installation, eliminates risk scenarios, and minimizes installation cost for long fiber runs in the process environment. Like other probes in our Raman probe portfolio, the Pilot-E probe utilizes a hybrid electro/optical fiber cable assembly to carry the analytical signal and the safety interlock in a single easy-to-install cable. As such, it is ideally suited for use in chemical plants and refineries to measure batch or continuous flow production. The modular design of the Pilot-E probe enables the sampling point to be customized for each customer's facility, allowing for flexible integration via direct flange mounting onto transfer pipes or integration into a slip-stream or fast loop for easier maintenance. The Pilot-E probe is manufactured to meet Category 1 pressure equipment safety standards, and offers ATEX, North American, and IECEx hazardous area certification.

**Benefits at a glance**
- Constructed to individual site requirements
- Sealed probe design
- Integrated "laser on" indicator
- One in/one out fiber optics
- Direct insertion compatibility
- Meets Category 1 pressure equipment safety standards
- Suitable for use in classified / hazardous area environments
- Hazardous area certification: ATEX, North American, IECEx

**Field of application**
- Reaction monitoring
- Blending
- Feed
- Final product monitoring
- Polymerization reaction monitoring
- Polymer blending



# AirHead probe

## Gas-phase / process analysis

The AirHead probe has cross-industry appeal for its robust gas-phase headspace monitoring, *in situ* measurements, and material compatibility. In chemical processes, it successfully addresses common gas/vapor phase process application challenges such as corrosivity, wetness of the sample environment, and low sensitivity of analyzer technology. Certified for use in hazardous area environments, the AirHead probe can be inserted directly into processes with temperatures up to 150 °C degrees and pressures up to 1,000 psi, and it is available with a variety of mounting options for maximum installation and sampling flexibility.

**Benefits at a glance**

- Reliable, quantitative gas-phase measurements
- *In situ* measurement / no transfer lines or fast-loops required
- Can be directly inserted into processes with temperatures up to 150 °C and 1,000 psi
- Industry standard installation options
- Direct insertion, side insertion, or sample loop
- Designed to complement the Optograf analyzer
- Hazardous area certified: ATEX, North American, IECEx

**Field of application**

- Ammonia
- Methanol
- HyCO
- Reaction monitoring
- Blending
- Catalysis
- Polymerization reaction monitoring
- IGCC power plants, gas turbines

# The Endress+Hauser advantage

## Providing you with global service & support

**Global service & support** When it comes to critical control points, properly installed measurement instrumentation ensures safe and reliable operation. Our service experts, who are available around the world, have the expertise and experience needed to safely integrate your instruments into your processes. Our service teams offer comprehensive maintenance contracts, Instrument Management Solutions (IMS), workshop repairs, spares management, on-site commissioning, troubleshooting, installations and technical service advice and support over the phone.

Customer service at a glance:

- Commissioning and installation
- Project management
- Preventive maintenance
- Spare parts express service
- Training
- Help desk
- Online documentation
- Asset management services
- Calibration services

**Kaiser Optical Systems, Inc.**

371 Parkland Plaza
Ann Arbor, MI 48103
USA

Tel 734 665 8083
Fax 734 665 8199
www.kosi.com

IN/K-00003/N/61/EN/01.21

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An Endress+Hauser Company