Process Insights™
Premium Insights Into Process

HIGH-PERFORMANCE GAS ANALYZERS

PRODUCT BROCHURE

Advanced Spectroscopic Solutions for Fuel Cell Hydrogen Analysis

The combined portfolio of CRDS-based analyzers and Extrel's mass spectrometers for analysis of fuel-cell-grade hydrogen offers:

- Combination of two powerful analytical technologies: Cavity Ring-Down Spectroscopy (CRDS) and Mass Spectrometry (MS)
- Analysis of multiple critical contaminants listed in hydrogen purity standards SAE J2719 and ISO 14687: He, N_2, Ar, CH_4, H_2O, O_2, CO, CO_2, CH_2O, CH_2O_2 and NH_3
- Ideal detection limits from part-per-million (ppm) down to sub-part-per-billion (ppb) in line with requirements outlined in ISO 21087
- CRDS: freedom from the need for span calibrations, no periodic sensor replacement/ maintenance, and designed to comply with ASTM Standard Test Method D7941 for fuel-cell hydrogen analysis
- MS: brings an unmatched combination of speed, sensitivity, and precision to continuous, quantitative gas analysis. Has a dynamic range to measure component concentrations from 100% down to the low parts per trillion (ppt). Provides a full composition update every few seconds to measure changes in dynamic chemical processes.

The Easy Way to Ensure Hydrogen Quality

Hydrogen quality is vital for the performance and lifetime of hydrogen fuel cells. There are many critical contaminants for this application, causing many potential issues, including performance reduction, degradation of the proton exchange membrane, or damage to the catalyst. We offer powerful analytical tools for the measurement of trace amounts of these molecules. The instruments' ppm- and ppb-level detection limits help ensure compliance with SAE J2719, ISO 14687 and similar purity standards designed to protect fuel cell electric vehicles (FCEVs).

Based on powerful Cavity Ring-Down Spectroscopy (CRDS), all analyzers are free of drift, guaranteeing consistent and reliable trace detection for fuel-cell-grade hydrogen in the lab and in the field. Highly specific to the target molecule, CRDS also eliminates cross-interferences. Plus, there is no need to perform costly and time-consuming zero and span calibrations, saving both time and money with continuous, online service.

The high-performance CRDS analyzers are used in many demanding measurement applications from ultra-high purity electronic gases for semiconductor manufacturing to industrial and medical gases. We has also been working for many years with regulators, researchers, and gas manufacturers to develop measurement solutions for fuel-cell hydrogen analysis. CRDS's versatility makes it possible to use the instruments both in the lab and directly at fueling station, and anywhere along the supply chain, from manufacturing to transportation.

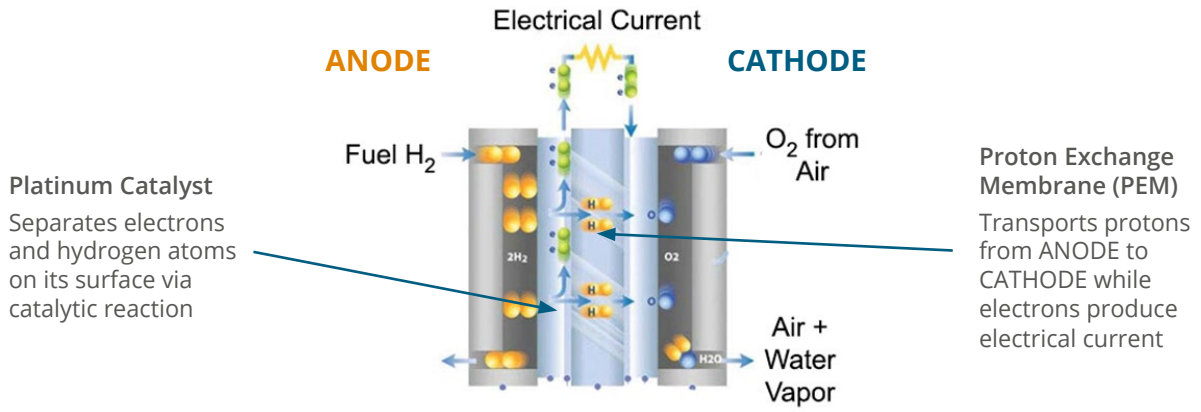
Extrel's quadrupole mass spectrometers are geared for ultimate performance and allow the detection of multiple contaminants within seconds. With decades of excellence in industrial automation and thousands of installations worldwide, our process mass spectrometers provide the rugged stability and ease-of-use necessary for continuous operation in demanding, mission-critical environments. Offering complete quantitative stream composition measurement, total application coverage, and low cost of ownership, we deliver performance specifications superior to other mass spectrometers and commercial process technologies.

Based on cutting-edge quadrupole mass spectrometer technology, the MAX300-LG™ has the dynamic range to measure component concentrations from 100% down to the low parts per trillion (ppt). It provides a full composition update every few seconds to measure changes in dynamic chemical processes. The MAX300-LG has the flexibility and rugged stability necessary for real-time quantitative gas analysis in applications as diverse as catalysis R&D, ambient air monitoring, and bioreactor process control.

Fuel Cells and Hydrogen Purity

High-purity hydrogen is crucial to the performance and lifetime of fuel cells. The critical components of the fuel cell are the platinum catalyst and the proton exchange membrane (PEM). Both can experience significant loss in performance or even irreversible damage in the presence of contaminants on the anode side (hydrogen side) of the fuel cell.

Principle of a PEM Hydrogen Fuel Cell used in FCEVs



Effects of contaminants in Hydrogen on the Fuel Cell Anode

Helium (He), Nitrogen (N_2), Argon (Ar)	Dilute hydrogen fuel, compromise performance
Methane (CH_4)	Degrades performance of catalyst
Moisture (H_2O), Oxygen (O_2)	Cathode-side molecule, impedes efficiency of fuel-cell reaction ($2H_2 + O_2 \rightarrow H_2O$)
Carbon Dioxide (CO_2)	Reduces to CO and adsorbs to catalyst
Carbon Monoxide (CO)	Adsorbs onto catalyst and severely degrades performance, difficult to recover
Formaldehyde (CH_2O), Formic Acid (CH_2O_2)	Reacts with catalysts, degrades performance
Ammonia (NH_3)	Impedes conductivity of membrane, significantly affects performance, recoverable

Hydrogen Purity and Measurement Standards

Most countries have adopted the fuel cell hydrogen purity standard SAE J2719, developed by the Society of Automotive Engineers, which sets limits for the species listed above, as well as several other critical contaminants. The purity specifications were also adopted by international standard ISO 14687.

We have worked with ASTM International to create a standard test method for the analysis of fuel-cell hydrogen using CRDS to allow users to take advantage of this powerful analytical method for this application. The standard was finalized in 2014 and is designated as ASTM D7941/D7941M.

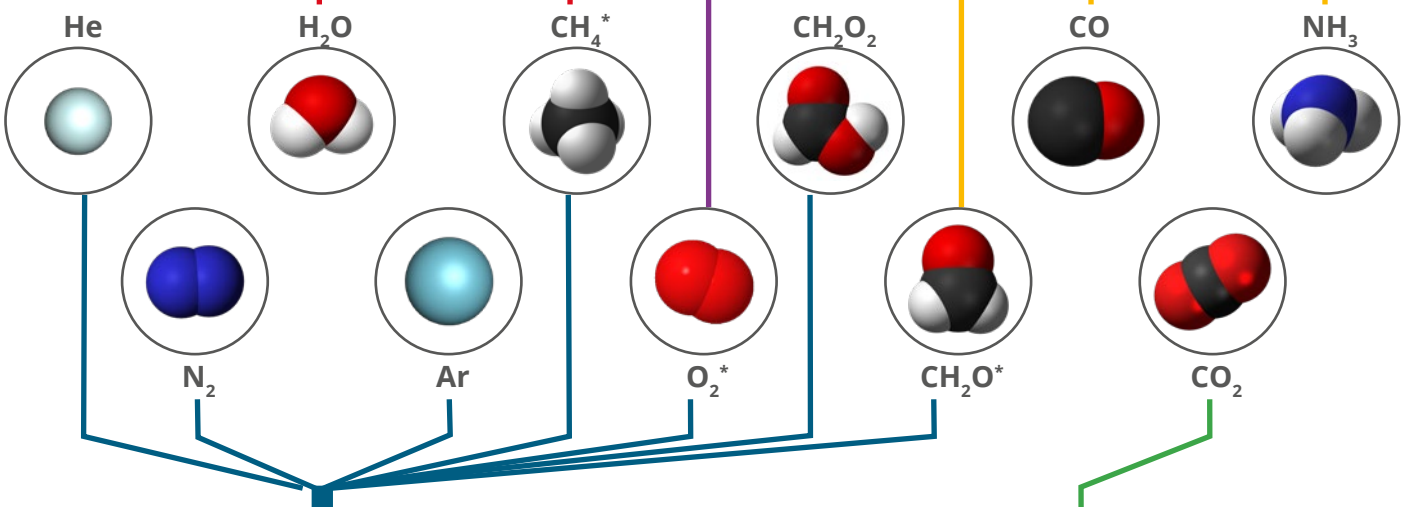
Products for H_2 Purity Analysis

We offer five different versatile CRDS and MS platforms for single-species or multi-species detection of critical impurities in fuel-cell-grade hydrogen to assure SAE J2719/ISO 14687 compliance.

Spark H_2O™ • Spark CH_4™
Cost-efficient, single-species

HALO OK™
Trace level oxygen

HALO 3 NH_3™ • HALO 3 CH_2O™
HALO 3 CO™
Sensitive, single-species



MAX300-LG
Mass spectrometer

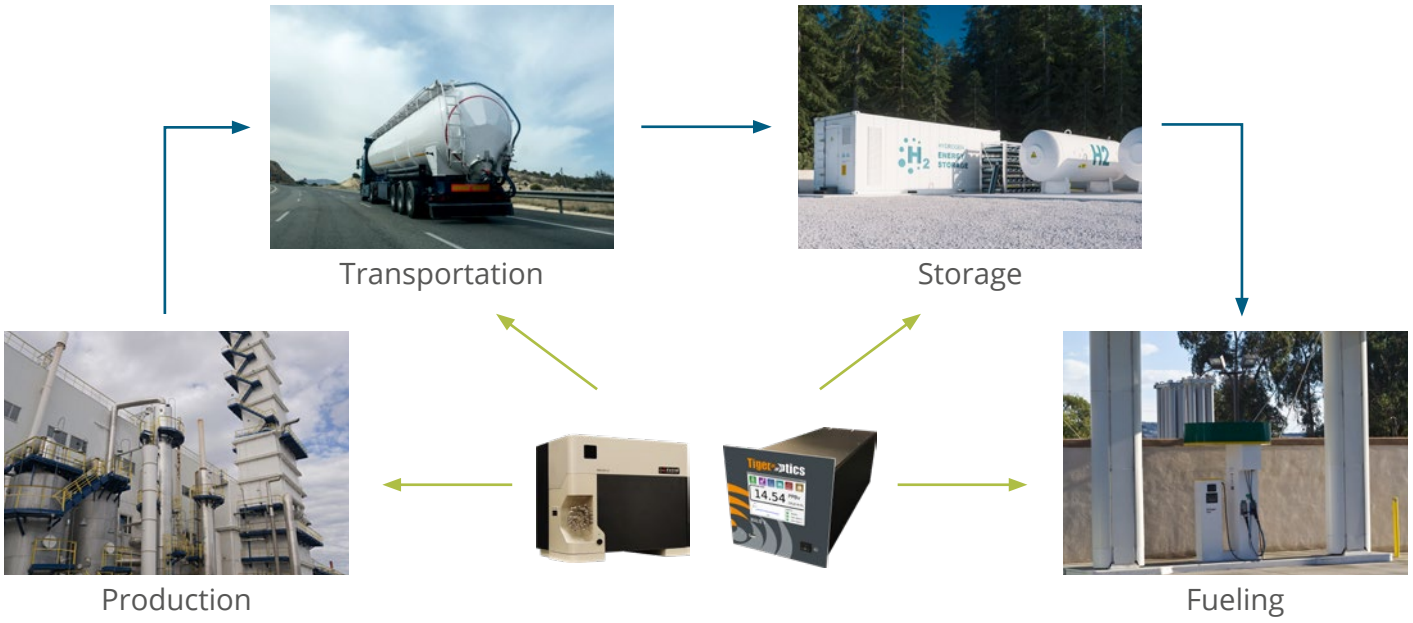
Spark Max CO_2™
Cost-efficient, single-species

*For CH_4, CH_2O, and O_2 detection, you can choose between dedicated single-species CRDS analyzers (Spark, HALO 3 and HALO OK) or the multi-species MAX300-LG mass spectrometer. The recommended analyzer combination depends on your specific requirements. Please contact us to discuss your optimum solution.

Products for H_2 Purity Analysis

Our analyzers offer detection limits that are ideally suited for the contaminant limits set by SAE and ISO hydrogen purity standards and fulfill the requirements for analytical techniques outlined in ISO 21087. All systems are also optimized for H_2 analysis according to ASTM Standard Test Method D7941.

Ensuring Contamination Control Throughout the Hydrogen Supply Chain



Summary of SAE/ISO Requirements and Analyzer Detection Limits

Impurity	SAE J2719/ ISO 14687 Limit	LDL (3σ)	Analyzer	LDL (3σ)	Analyzer
Helium (He)	300 ppm			0.5 ppm	MAX300-LG
Nitrogen (N_2)	300 ppm			5 ppm	MAX300-LG
Argon (Ar)	300 ppm			0.02 ppm	MAX300-LG
Methane (CH_4)	100 ppm	0.2 ppm	Spark CH_4	1.0 ppm	MAX300-LG
Moisture (H_2O)	5 ppm	0.0075 ppm	Spark H_2O		
Oxygen (O_2)	5 ppm	0.003 ppm	HALO OK	1.0 ppm	MAX300-LG
Carbon Dioxide (CO_2)	2 ppm	0.08 ppm	Spark Max CO_2		
Carbon Monoxide (CO)	0.2 ppm	0.05 ppm	HALO 3 CO		
Formaldehyde (CH_2O)	0.2 ppm	0.006 ppm	HALO 3 CH_2O	0.02 ppm	MAX300-LG
Formic Acid (CH_2O_2)	0.2 ppm			0.02 ppm	MAX300-LG
Ammonia (NH_3)	0.1 ppm	0.0003 ppm	HALO 3 NH_3		

Spark H_2O • Spark CH_4

CRDS Analyzers for Moisture and Methane

Performance

Operating range:	See table below
Detection limit (LDL, 3σ/24h):	See table below
SAE J2719/ISO 14687 Limit	See table below
Precision (1σ, greater of):	± 0.75% or 1/3 of LDL
Accuracy (greater of):	± 4% or LDL
Speed of response:	< 3 minutes to 90%
Environmental conditions:	10°C to 40°C 30% to 80% RH (non-condensing)
Storage temperature:	–10°C to 50°C

Gas Handling System and Conditions

Wetted materials:	316L stainless steel, 10 Ra surface finish
Gas connections:	1/4" male VCR
Inlet pressure:	10 − 125 psig (1.7 − 9.6 bara)
Flow rate:	~0.7 slpm (gas dependent)
Sample gases:	Most inert, toxic, passive and corrosive matrices
Gas temperature:	Up to 60°C

Dimensions & Weight

Standard sensor:	H × W × D 8.73 × 8.57 × 23.6 in (222 × 218 × 599 mm)
Sensor rack (fits up to two sensors)**:**	H × W × D 8.73 × 19.0 × 23.6 in (222 × 483 × 599 mm)
Standard sensor weight:	32 lbs (14.5 kg)

Electrical & Interfaces

Platform	Max Series analyzer
Alarm indicators:	2 user programmable, 1 system fault, Form C relays
Power requirements:	90 − 240 VAC, 50/60 Hz
Power consumption:	40 Watts max. per sensor
Signal output:	Isolated 4−20 mA per sensor
User interfaces:	5.7" LCD touchscreen. 10/100 Base-T Ethernet. USB, RS-232, RS-485. Modbus TCP (optional)
Data storage:	Internal or external flash drive
Certification:	CE Mark
Part Number:	F8100

Performance, H_2	Part Number	Range	LDL (3σ)	SAE/ISO Limit
Spark H_2O	F7700	0 − 1750 ppm	7.5 ppb	5 ppm
Spark CH_4 (standard range)	F7701	0 − 80 ppm	7.5 ppb	100 ppm
Spark CH_4 (high range)	F7701-H	0 − 1000 ppm	200 ppb	100 ppm

U.S. Patent # 7,277,177

Spark Max CO_2

CRDS Analyzer for Carbon Dioxide

Performance in H_2

Operating range:	0 – 800 ppm
Detection limit (LDL, 3σ/24h):	80 ppb
SAE J2719/ISO 14687 Limit	2 ppm
Precision (1σ, greater of):	± 0.75% or 1/3 of LDL
Accuracy (greater of):	± 4% or LDL
Speed of response:	< 3 minutes to 90%
Environmental conditions:	10°C to 40°C 30% to 80% RH (non-condensing)
Storage temperature:	–10°C to 50°C

Gas Handling System and Conditions

Wetted materials:	316L stainless steel, 10 Ra surface finish
Gas connections:	1/4” male VCR
Leak tested to:	1 x 10^{-9} mbar l / sec
Inlet pressure:	10 – 125 psig (1.7 – 9.6 bara)
Flow rate:	~0.7 slpm (gas dependent)
Gas temperature:	Up to 60°C

Dimensions & Weight

Standard sensor:	H × W × D 8.73 × 8.57 × 23.6 in (222 × 218 × 599 mm)
Sensor rack (fits up to two sensors)**:**	H × W × D 8.73 × 19.0 × 23.6 in (222 × 483 × 599 mm)
Standard sensor weight:	32 lbs (14.5 kg)

Electrical & Interfaces

Platform	Max Series analyzer
Alarm indicators:	2 user programmable, 1 system fault, Form C relays
Power requirements:	90 – 240 VAC, 50/60 Hz
Power consumption:	40 Watts max. per sensor
Signal output:	Isolated 4–20 mA per sensor
User interfaces:	5.7” LCD touchscreen. 10/100 Base-T Ethernet. USB, RS-232, RS-485. Modbus TCP (optional)
Data storage:	Internal or external flash drive
Certification:	CE Mark

Part Number: F8100

U.S. Patent # 7,277,177

HALO 3 NH_3 • HALO 3 CH_2O • HALO 3 CO

CRDS Analyzers for Ammonia, Formaldehyde and Carbon Monoxide

Performance

Operating range:	See table below
Detection limit (LDL, 3σ/24h):	See table below
SAE J2719/ISO 14687 Limit	See table below
Precision (1σ, greater of):	± 0.75% or 1/3 of LDL
Accuracy (greater of):	± 4% or LDL
Speed of response:	< 3 minutes to 90%
Environmental conditions:	10°C to 40°C 30% to 80% RH (non-condensing)
Storage temperature:	–10°C to 50°C

Gas Handling System and Conditions

Wetted materials:	316L stainless steel, 10 Ra surface finish
Gas connections:	1/4" male VCR
Leak tested to:	1 x 10^{-9} mbar l / sec
Inlet pressure:	10 − 125 psig (1.7 − 9.6 bara)
Flow rate:	~1 slpm
Gas temperature:	Up to 60°C

Dimensions & Weight

Standard sensor:	H × W × D 8.73 × 8.57 × 23.6 in (222 × 218 × 599 mm)
Sensor rack (fits up to two sensors)**:**	H × W × D 8.73 × 19.0 × 23.6 in (222 × 483 × 599 mm)
Standard sensor weight:	33 lbs (15 kg) for NH_3 and CH_2O, 28 lbs (12.7 kg) for CO

Electrical & Interfaces

Platform:	Max Series analyzer
Alarm indicators:	2 user programmable, 1 system fault, Form C relays
Power requirements:	90 − 240 VAC, 50/60 Hz
Power consumption:	40 Watts max.
Signal output:	Isolated 4−20 mA per sensor
User interfaces:	5.7" LCD touchscreen. 10/100 Base-T Ethernet. USB, RS-232, RS-485. Modbus TCP (optional)
Data storage:	Internal or external flash drive
Certification:	CE Mark

Performance in H_2

	Part Number	Range	LDL (3σ)	SAE/ISO Limit
HALO 3 NH_3:	F7617	0 − 6 ppm	0.3 ppb	0.1 ppm
HALO 3 CH_2O:	F7618	0 − 40 ppm	6 ppb	0.2 ppm
HALO 3 CO:	F7602	0 − 2500 ppm	50 ppb	0.2 ppm

U.S. Patent # 7,277,177

MAX300-LG

Mass Spectrometer for He, N_2, Ar, CH_4, O_2, CH_2O & CH_2O_2

Performance

Operating range:	See table below
Detection limit (LDL, 3σ/24h):	See table below
SAE J2719/ISO 14687 Limit	See table below
Precision (1σ):	± 0.05% relative over 24 hours
Stability (1σ):	± 0.5% relative over 30 days
Analysis rate:	0.005–16 sec per component (user selectable)
Environmental conditions:	13°C to 27°C 0% to 90% RH (non-condensing)

Maintenance and Calibration

Analyzer:	1-3 year*
Roughing pump:	6-12 months*
Calibration interval:	3-12 months (manual or fully automated)
Filaments:	Two—one active, one spare with automated switchover

Dimensions & Weight

Instrument:	H × W × D 23.0 × 26.25 × 19.0 in (584 x 667 x 483 mm)
with optional cart:	H × W × D 53.75 x 38.25 x 24.0 in (1365 x 972 x 610 mm)
Instrument weight (approx.):	165 lbs (75 kg)
Optional cart weight:	40 lbs (18 kg)

Electrical & Interfaces

Power requirements:	110 VAC ±10% 60Hz, 10A circuit or 230 VAC ±10% 60Hz, 10A circuit
Power consumption:	700 Watts nominal
System control interfaces:	Ethernet, USB
External communication:	Ethernet, Modbus serial, Digital I/O, analog I/O, OPC
Software:	Questor5 Quantitation Software

Performance in H_2

	Range	LDL (3σ)	SAE/ISO Limit
Helium (He):	0 – 100%	0.5 ppm	300 ppm
Nitrogen (N_2):	0 – 100%	5 ppm	300 ppm
Argon (Ar):	0 – 100%	0.02 ppm	300 ppm
Methane (CH_4):	0 – 100%	1.0 ppm	100 ppm
Oxygen (O_2):	0 – 100%	1.0 ppm	5 ppm
Formaldehyde (CH_2O):	0 – 100%	0.02 ppm	0.2 ppm
Formic Acid (CH_2O_2):	0 – 100%	0.02 ppm	0.2 ppm

*Application dependent

HALO OK

CRDS Analyzer

Performance in H_2

Operating range:	0 − 10 ppm
Detection limit (LDL, 3σ/24h):	3 ppb
SAE J2719/ISO 14687 Limit	5 ppm
Precision (1σ, greater of):	± 0.75% or 1/3 of LDL
Accuracy (greater of):	± 4% or LDL
Speed of response:	< 3 minutes to 95%
Environmental conditions:	10°C to 40°C 30% to 80% RH (non-condensing)
Storage temperature:	–10°C to 50°C

Gas Handling System and Conditions

Wetted materials:	316L stainless steel, 10 Ra surface finish
Gas connections:	1/4” male VCR
Leak tested to:	1 x 10^{-9} mbar l / sec
Sample inlet pressure:	10 − 125 psig (1.7 − 9.6 bara)
Sample flow rate:	0.5 to 1.8 slpm (gas dependent)
Gas temperature:	Up to 60°C

Dimensions & Weight

Standard sensor:	H × W × D 8.73 × 19.0 × 23.6 in (222 × 483 × 599 mm)
Standard sensor weight:	45 lbs (20.4 kg)

Electrical & Interfaces

Platform	Max Series analyzer
Alarm indicators:	2 user programmable, 1 system fault, Form C relays
Power requirements:	90 − 240 VAC, 50/60 Hz
Power consumption:	200 Watts max.
Signal output:	Isolated 4−20 mA
User interfaces:	5.7” LCD touchscreen. 10/100 Base-T Ethernet. USB, RS-232, RS-485. Modbus TCP (optional)
Data storage:	Internal or external flash drive
Certification:	CE Mark
Part Number:	F7502-H

U.S. Patent # 7,277,177 • U.S. Patent # 7,255,836

Advanced Spectroscopic Solutions for Fuel Cell Hydrogen Analysis

Spark

Spark Max

HALO 3

MAX300-LG

HALO OK

References

ASTM Standard D7941 / D7941M-14, "Standard Test Method for Hydrogen Purity Analysis Using a Continuous Wave Cavity Ring-Down Spectroscopy Analyzer," available from ASTM International, http://www.astm.org/Standards/D7941.htm

SAE J2719, "Hydrogen Fuel Quality for Fuel Cell Vehicles," available from the Society of Automotive Engineers, https://www.sae.org/standards/content/j2719_202003/

ISO 14687-2019, "Hydrogen fuel – Product specification," available from the International Organization for Standardization," https://www.iso.org/standard/69539.html

ISO 21087-2019, "Gas analysis – Analytical methods for hydrogen fuel – Proton exchange membrane (PEM) fuel cell applications for road vehicles," https://www.iso.org/standard/69909.html

Process Insights™
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HIGH-PERFORMANCE GAS ANALYZERS

GAIN REAL-TIME INSIGHT INTO YOUR PROCESS

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