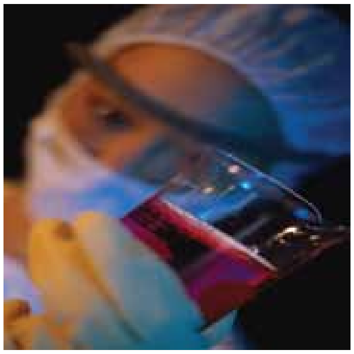
aerospace
climate control
electromechanical
filtration
fluid & gas handling
hydraulics
pneumatics
process control
sealing & shielding



Analytical Gas Systems Product Catalog

Bulletin AGS-J

Parker Balston

ENGINEERING YOUR SUCCESS.

Parker Hannifin Corporation

The Global Leader in Motion and Control Technologies

We engineer success of our customers around the world, drawing upon nine core motion and control technologies. These technolgies enable virtually every machine and process to operate accurately, efficiently and dependably.

As the global leader in motion and control, we partner with our distributors to increase our customers' productivity and profitability by delivering an unmatchable breadth of engineered components and value-added services.

We continue to grow with our customers by creating application-focused products and system solutions. A key to our global expansion has been to follow our customers and establish operations, sales and service wherever they are needed. No single competitor matches Parker's global presence.

Corporate Headquarters in Cleveland, Ohio.

Parker's Motion and Control Technologies

Aerospace	Hydraulics
Climate Control	Pneumatics
Electromechanical	Process Control
Filtration	Sealing & Shielding
Fluid & Gas Handling	

Parker Balston

ENGINEERING YOUR SUCCESS.

Parker Balston

Parker Hannifin Corporation
Filtration and Separation Division
Haverhill, MA • 1-800-343-4048
www.labgasgenerators.com

FID Gas Stations

- Ideal for up to 10-11 FIDs
- Produces UHP zero air from house compressed air (<0.1 ppm THC) and 99.9995% pure hydrogen in one enclosure
- Eliminates inconvenient and dangerous zero air and hydrogen cylinders from the laboratory
- Increases the accuracy of analysis and reduces the cleaning requirement of the detector
- Recommended and used by many GC and column manufacturers
- Payback period of typically less than one year
- Automatic water fill
- Silent operation and minimal operator attention required

FID Gas Station, Models FID-1000NA, FID-2500NA, and FID-3500NA

Parker Balston's FID-1000NA, FID-2500NA, and FID-3500NA Gas Stations can provide both hydrogen gas and zero grade air to FID detectors on Gas Chromatographs. These systems are specifically designed to provide fuel gas and support air to 10-11 Flame Ionization Detectors, Flame Photometric Detectors or Total Hydrocarbon Analyzers.

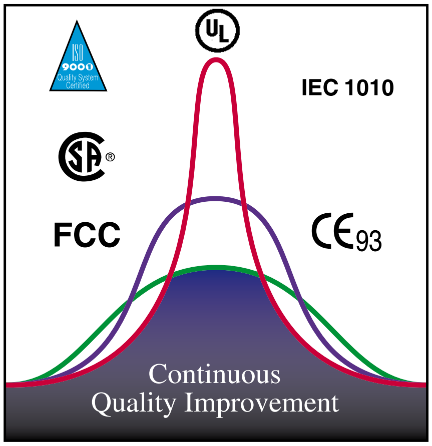
Hydrogen gas is produced from deionized water using a Proton Exchange Membrane Cell. The hydrogen generator compartment utilizes the principle of electrolytic dissociation of water and hydrogen proton conduction through the membrane. The hydrogen supply produces up to 500 cc/min of 99.9995% pure hydrogen with pressures to 60 psig.

Zero air is produced by purifying on-site compressed air to a total hydrocarbon concentration of < 0.1 ppm (measured as methane). The zero air compartment produces up to 3500 cc/min of Zero Grade Air.

The FID Gas Stations are complete systems with state-of-the-art, highly reliable components engineered for easy installation, operation, and long term performance. The Parker Balston® FID-1000NA, FID-2500NA, FID-3500NA eliminate all the inconveniences and cost of zero air and hydrogen cylinder gas supplies and dependence on outside vendors. Uncontrollable price increases, contract negotiations, long term commitments, and tank rentals are no longer a concern. With an FID Gas Station, you control your gas supply.

All Parker Balston gas generators exceed NFPA 50A and OSHA 1910.103 regulations which outline the storage of hydrogen.

Produced and supported by an ISO 9001 registered organization, Parker Balston's hydrogen generators are the first built to meet the toughest laboratory standards in the world: CSA, UL, CE and IEC 1010.



FID Gas Stations

Principal Specifications

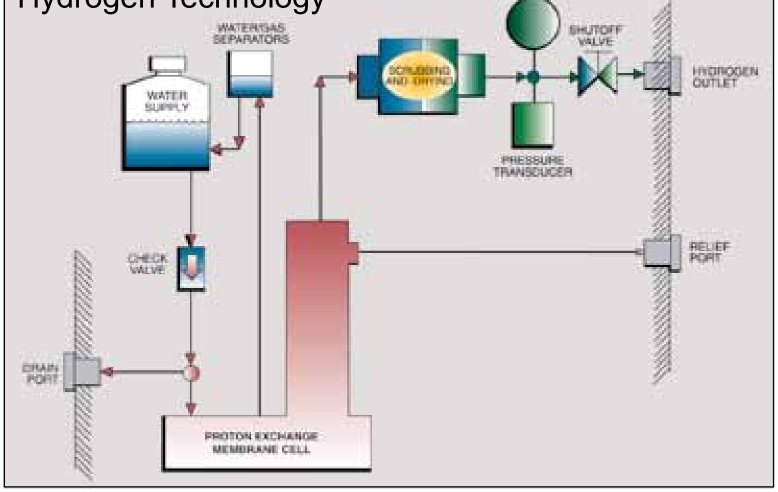
FID Gas Stations	
Hydrogen Purity	99.9995%
Zero Air Purity	<0.1 ppm (total hydrocarbon as methane)
Maximum Hydrogen Flow Rate	FID-1000NA: 90 cc/min FID-2500NA: 250 cc/min FID-3500NA: 500 cc/min
Maximum Zero Air Flow Rate	FID-1000NA: 1000 cc/min FID-2500NA: 2500 cc/min FID-3500NA: 3500 cc/min
Electrical Requirements (1)	FID-1000NA: 120VAC, 60Hz, 480 Watts FID-2500NA: 120VAC, 60Hz, 480 Watts FID-3500NA: 120VAC, 60Hz, 5.3 Amps
Hydrogen Outlet Pressure	60 psig
Zero Air Outlet Pressure	40-125 psig
Certifications	IEC 1010-1; CSA 1010; UL 3101; CE Mark
Dimensions	10.5"w x 17"d x 16.5"h (27cm x 43cm x 42cm)
Inlet Port	1/4" NPT (female) compressed air supply
Outlet Ports	1/8" Compression
Shipping Weight	FID-1000NA: 53 lbs / 24 kg FID-2500NA: 53 lbs / 24 kg FID-3500NA: 60 lbs / 27 kg

(1) Refer to voltage appendix to select correct part number and plug for Japan and 220VAC/50hz configurations.

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Time

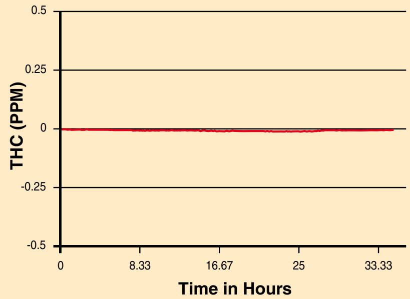
Model	**Description**
FID-1000NA, FID-2500NA, FID-3500NA	FID Gas Station
FID-1000-INST, FID-2500-INST FID-3500-INST	Installation Service
MKFID1000	Annual Maintenance Kit
MKFID3500	Annual Maintenance Kit
FID-1000-PM, FID-2500-PM, FID-3500-PM	Preventive Maintenance Plan
FID-1000-DN2, FID-2500-DN2, FID-3500-DN2	Extended Support with 24 Month Warranty

Hydrogen Technology

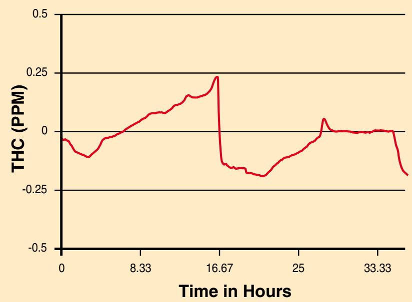


The Chromatograms (below) compare baselines produced by a Parker Balston Zero Air Generator and bottled fuel air. The baseline produced by the Parker Balston Generator is very flat, with no fluctuations or peaks, in comparison with the chromatogram of the bottled air fuel supply, which has many peaks ranging from .25 ppm to -.25 ppm.

Baseline FID-2500 Gas Station



Baseline Bottled Fuel Air



GC Gas Station

- Ideal for 1-3 FIDs and 1-3 capillary columns
- Produce UHP zero air from house compressed air (<0.05 ppm THC) and 99.99999+% pure hydrogen in one enclosure
- Eliminates costly and dangerous helium, zero air and hydrogen cylinders from the laboratory
- Speeds up separation, increases sample thru-put and extends column life
- Recommended and used by many GC and column manufacturers
- Payback period of less than one year

Model GCGS-7890NA GC Gas Station

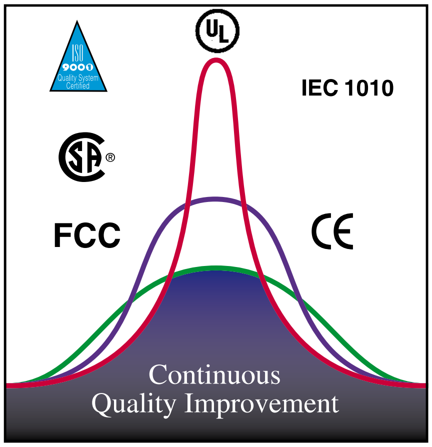
Parker Balston's GCGS-7890NA GC Gas Station can provide both hydrogen gas and zero grade air to FID detectors on gas chromatographs. These systems are specifically designed to provide carrier, fuel gas and support air for 1-3 Flame Ionization Detectors, and 1-3 capillary columns. Hydrogen gas is produced from deionized water using a proton exchange membrane cell. The hydrogen generator compartment utilizes the principle of electrolytic dissociation of water and hydrogen proton conduction through the membrane. The hydrogen cell produces up to 500 cc/min of 99.99999+% pure hydrogen gas after passing through an (NM) no maintenance palladium membrane with pressures to 100 psig.

Zero air is produced by purifying on-site compressed air to a total hydrocarbon concentration of < 0.05 ppm (measured as methane). The zero air compartment produces up to 3500 cc/min of zero grade air.

The GC Gas Station is a complete system with state-of-the-art, highly reliable components engineered for easy installation, operation, and long term performance. The Parker Balston® GCGS-7890NA will eliminate all the inconvenience and cost of helium, zero air, and hydrogen cylinder gas supplies and dependence on outside vendors. Uncontrollable price increases, contract negotiations, long term commitments, and tank rentals are no longer a concern. With a GC Gas Station, you control all your gas supplies.

All Parker Balston gas generators exceed NFPA 50A and OSHA 1910.103 regulations outlining the storage of hydrogen.

Produced and supported by an ISO 9001 registered organization, Parker Balston's gas generators are the first built to meet the toughest laboratory standards in the world: CSA, UL, CE and IEC 1010.



GC Gas Station

Principal Specifications

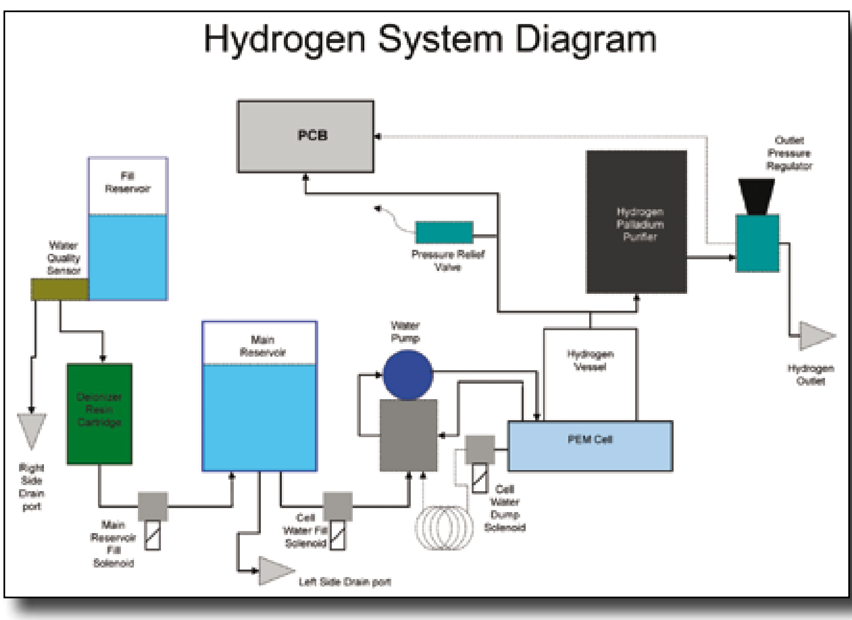
GCGS-7890 GC Gas Station

Hydrogen Purity	99.99999+%
Zero Air Purity	<0.05 ppm (total hydrocarbons as methane)
Maximum Hydrogen Flow Rate	500 cc/min
Maximum Zero Air Flow Rate	3500 cc/min
Electrical Requirements	120 VAC, 60 Hz, 5.3 Amps (1)
Hydrogen Outlet Pressure	100 psig
Zero Air Outlet Pressure	40-125 psig
Certifications	IEC 1010-1; CSA 1010; UL 3101; CE Mark
Dimensions	11"w x 27"d x 17"h (28cm x 69cm x 43cm)
Inlet Port	1/4" NPT (female tube) compressed air supply
Outlet Ports	1/8" Compression, Stainless
Shipping Weight	60 lbs/27 kg

(1) Refer to voltage appendix to select correct part number and plug for Japan and 220VAC/50hz configurations.

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern

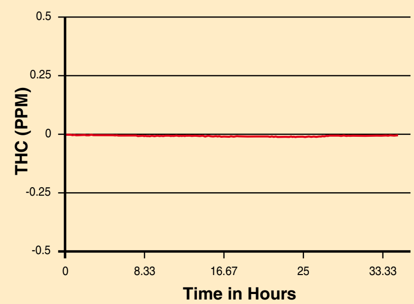
Model	Description
GCGS-7890NA	GC Gas Station
GCGS-7890-INST	Installation Service
GCGS-7890-PM	Preventive Maintenance Plan
GCGS-7890-DN2	Extended Support with 24 Month Warranty
MKGCGS-7890-12	Maintenance Kit @ 12 Months
MKGCGS-7890-36	Maintenance Kit @ 36 Months



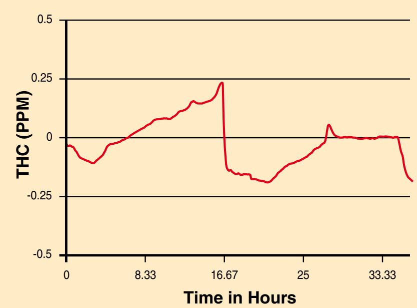
The Chromatograms (below) compare baselines produced by a Parker Balston GC Gas Station and bottled fuel air. The baseline produced by the Parker Balston Generator is very flat, with no fluctuations or peaks, in comparison with the chromatogram of the bottled air fuel supply, which has many peaks ranging from .25 ppm to -.25 ppm.

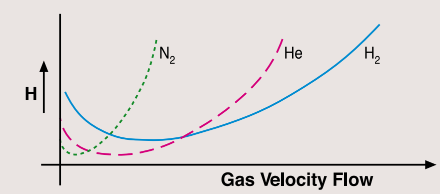
The Van Deemter Curves (below) show a comparison of nitrogen, helium and hydrogen carrier gases. A Parker Balston Gas Station will also allow the user to exploit the benefits of using hydrogen carrier gas instead of helium. Increased flow velocity can shorten analysis time by 50%.

Baseline GCGS-7890 Gas Station



Baseline Bottled Fuel Air





Hydrogen Generators for Fuel Gas

- Ideal for fuel gas, up to 14 FID's
- Eliminates dangerous and expensive hydrogen gas cylinders from the laboratory
- Exclusive water management system and control circuitry maximize uptime
- Unique display lighting changes color for easy status checks and water level indication
- Remote control and remote monitoring capable by adding USB options bay controller
- Compact and reliable - only one square foot of bench space required
- Includes 2 year cell warranty
- No liquid caustics

H2PEM Hydrogen Generator with Agilent 7890 GC-FID

Parker Balston's Proton Exchange Membrane (PEM) Cell eliminates the use of liquid electrolytes with hydrogen generators.

Proven in over 40,000 GC installations worldwide. Parker Balston's generators are the most reliable hydrogen generators on the market. Maintenance requires only a few moments per year - no inconvenient, extended downtime.

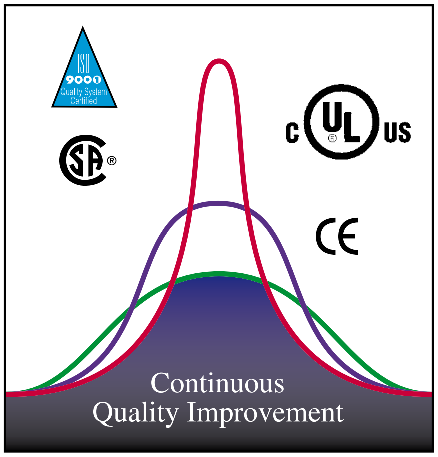
Simply change the filters every six months and the desiccant cartridge whenever it turns dark brown.

Deionized water is all that is required to generate hydrogen for weeks of continuous operation.

With an output capacity of up to 510 cc/minute, one generator can supply 99.9995% pure hydrogen for up to several FID's. Based on cylinder gas savings alone, a Parker Balston® hydrogen generator pays for itself in less than a year.

All Parker Balston hydrogen generators meet NFPA requirements and OSHA 1910.103 regulations governing the storage of hydrogen.

Produced and supported by an ISO 9001 registered organization, Parker Balston's hydrogen generators are the first built to meet the toughest laboratory standards in the world: CSA, UL, CE and IEC 1010.



Hydrogen Generators for Fuel Gas

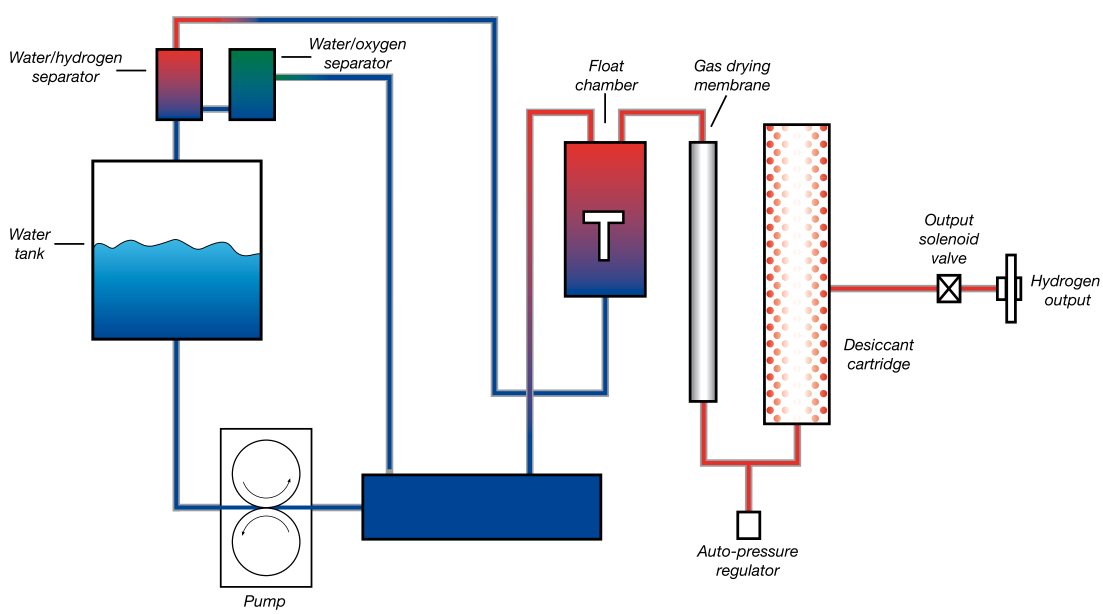
Principal Specifications

Model Number	H2PEM-100	H2PEM-165	H2PEM-260	H2PEM-510
Purity	99.9995%	99.9995%	99.9995%	99.9995%
Flow Rates	100 cc/min	165 cc/min	260 cc/min	510 cc/min
Outlet Port	1/8” compression	1/8” compression	1/8” compression	1/8” compression
Electrical	100 Vac/230 Vac	100 Vac/230 Vac	100 Vac/230 Vac	100 Vac/230 Vac
Delivery Pressure	5-100 psig ± 0.5 psig	5-100 psig ± 0.5 psig	5-100 psig ± 0.5 psig	5-100 psig ± 0.5 psig
Shipping Weight	59 lb (27 kg) dry	59 lb (27 kg) dry	59 lb (27 kg) dry	59 lb (27 kg) dry
Dimensions	17.12”H x 13.46”W x 17.95”D (43.48cm x 34.19cm x 45.6cm)	17.12”H x 13.46”W x 17.95”D (43.48cm x 34.19cm x 45.6cm)	17.12”H x 13.46”W x 17.95”D (43.48cm x 34.19cm x 45.6cm)	17.12”H x 13.46”W x 17.95”D (43.48cm x 34.19cm x 45.6cm)

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Time

Model	Description
MKH2PEM-D	Dessicant Cartridge (1 each)
MKH2PEM-6M	6 Month Service Kit
MKH2PEM-24M	24 Month Service Kit
H2PEM-100-PM, H2PEM-165-PM, H2PEM-510-PM	Preventive Maintenance Plan
H2PEM-100-INST, H2PEM-165-INST, H2PEM-260-INST, H2PEM-510-INST	Installation Service
604970894	USB Remote Control Accessory

How the generator works



Hydrogen Technology

Hydrogen Generators for Fuel and Carrier Gas

- Eliminates dangerous and expensive hydrogen gas cylinders from the laboratory
- Exceeds OSHA 1910.103 and NFPA 50A safety guidelines
- Safe - produces only as much gas as you need
- Produces a continuous supply of 99.99999+% pure hydrogen gas without snap on downstream purifiers
- Compact and reliable - only one square foot of bench space required and designed to run continuously 24 hours/day - includes automatic water fill
- Unique (NM) no maintenance palladium membrane prevents baseline drift unlike auto-drying technologies
- Certified for laboratory use by CSA, UL, IEC 1010, and CE Mark

Model H2PD-300 Hydrogen Generator

Parker Balston® Hydrogen Generators eliminate the need for expensive, dangerous, high pressure cylinders of hydrogen in the laboratory. It is no longer necessary to interrupt important analysis to change cylinders.

Generator flow capacities of up to 300 cc/min. of ultra high purity hydrogen are available.

Parker Balston Hydrogen Generators are compact benchtop units designed for use in the laboratory or in the field.

Hydrogen gas is produced by electrolytic dissociation of water. The resultant hydrogen stream then passes through a palladium membrane to assure carrier grade purity.

Only hydrogen and its isotopes can penetrate the palladium membrane; therefore, the purity of the output gas is guaranteed to be 99.99999+% consistently. This technology produces hydrogen at a guaranteed purity two orders of magnitude greater than desiccant or silica gel technologies.

Parker Balston Hydrogen Generators offer many special features to ensure safe and convenient operation. These features include smart-display technology system status at a glance and automatic water fill for endless operation.

Applications

Gas Chromatographs

Emmissions Test Equipment

Hydrogenation Reactors

ICP-MS Collision Gas

Fuel Cells

"Our H2 generator has saved us time, space, and money over a traditional tank configuration. We realized a return on our investment in less than one year and no longer have to manage bulky and unsightly tanks in the lab."

John Ross
Director Corporate Quality
Ungerer & Company

Hydrogen Generators for Fuel and Carrier Gas

Principal Specifications

Hydrogen Generators	Models	Specifications
Hydrogen Purity		99.99999+%
Oxygen Content		<.01 ppm
Moisture Content		<1.0 ppm
Max Hydrogen Flow Rate	H2PD-150 H2PD-300	150 cc/min 300 cc/min
Electrical Requirements		120 VAC/60 Hz, 3.15 Amps (1)
Hydrogen Outlet Pressure		Adjustable, 0 to 60 psig
Certifications		IEC 1010-1; CSA UL 3101; CE Mark
Dimensions		12”w x 12”d x 22”h (30cm x 33cm x 58cm)
Outlet Port		1/8” Compression
Shipping Weight		58 lbs (26 kg)

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Time

Description	Model Number
Hydrogen Gas Generator	H2PD-150, H2PD-300
Electrolyte Solution	920071
Pressure Regulator	W-425-4032-000
Installation Kit	IK7532
Preventive Maintenance plan	H2PD-150-PM, H2PD-300-PM
Extended Support with 24 Month Warranty	H2PD-150-DN2, H2PD-300-DN2

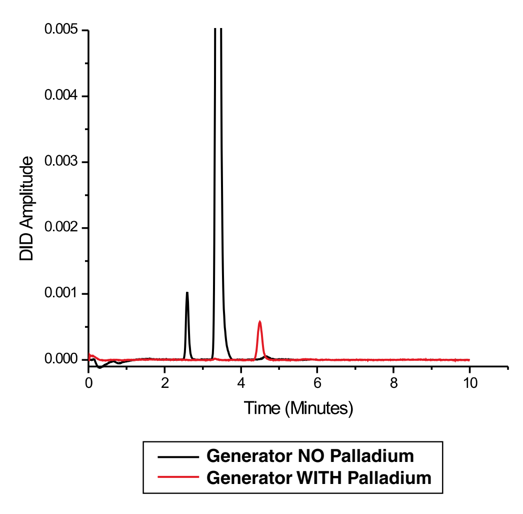
The Parker Balston® Hydrogen Generator is an excellent source of ultra pure, dry hydrogen for a wide range of laboratory uses. The generator is used extensively with Gas Chromatographs, as a fuel gas for Flame Ionization Detectors (FID), as a reaction gas for Hall Detectors, and as a carrier gas to ensure absolute repeatability of retention times. In high sensitivity Trace Hydrocarbon Analyzers and air pollution monitors, the hydrogen produced ensures the lowest possible background noise.

Other applications include using hydrogen for hydrogenation reactions and for FID’s used in the analysis of engine gas emissions in the automobile industry.

In all applications the Parker Balston Hydrogen Generator sets the standard for safety, operational performance, and dependability.

Simple Experimental: The two merged baselines in the right chromatogram were created using a Gow-Mac Gas Chromatograph Series 590 equipped with a (DID) discharge ionization detector with hydrogen separator. In creating both baselines (black and red) the gas sample is hydrogen from a hydrogen generator. Both generators are the same - as hydrogen gas is produced from water via electrolytic disassociation, but differ slightly as one generator incorporates a desiccant drying tube as a final purifier while the second generator has a palladium membrane as the final purifier.

The large black peak represents a combined 12 ppm concentration of oxygen and nitrogen, suitable for hydrogen fuel gas while the corresponding point in the red baseline represents a combined 12 ppb concentration of oxygen and nitrogen, suitable for either fuel or carrier gas.



(1) Refer to voltage appendix to select correct part number and plug for Japan and 220vac/50hz configurations.

Hydrogen Generators for Fuel and Carrier Gas

- Flow capacity to 1,200 cc/min
- Ideal for high speed and fast GC applications
- Eliminates dangerous and expensive helium and hydrogen gas cylinders from the laboratory
- Safe - produces only as much gas as you need
- Produces a continuous supply of 99.99999% pure hydrogen gas at 100 psig, palladium membrane prevents baseline drift unlike auto-drying technologies
- Compact and reliable - only one square foot of bench space required and designed to run continuously 24 hours/day
- Automatic water feed for continuous operation
- Simple maintenance, without Snap-on downstream purifiers
- Certified for laboratory use by CSA, IEC 1010, and CE Mark

Model H2-1200NA Hydrogen Generator

The Parker Balston® Hydrogen Generator is designed as a hazard-free alternative to high pressure gas cylinders. The generator can be used with any instrumentation requiring high purity hydrogen - anywhere a standard electrical supply is available. Deionized water is all that is required to generate hydrogen for weeks of continuous operation.

With an output capacity of up to 1,200 cc/minute, one generator can supply 99.99999% pure carrier gas, at 100 psig, to multiple GCs, and fuel gas up to 40 FIDs. Based on cylinder gas savings alone, a Parker Balston hydrogen generator pays for itself in less than one year.

The Parker Balston H2-500NA, H2-800NA and H2-1200NA Hydrogen generators use a Proton Exchange Membrane (PEM) to produce hydrogen on demand. Each generator incorporates a palladium purifier module to remove oxygen down to less than 0.01 ppm and moisture down to <1.0 ppm. Only 100 mL of hydrogen gas is stored in the system at any time and at a maximum of 140 psig. That's why the Parker Balston hydrogen generator meets the strict, safety guidelines of the National Fire Protection Agency (NFPA) and the regulations of the Occupational Safety and Health Association (OSHA). Most importantly, the Parker Balston hydrogen generator is certified for laboratory use by CSA, IEC 1010, and CE. Proven in over 40,000 GC installations worldwide, Parker Balston's generators are the most reliable hydrogen generators on the market. Maintenance requires only a few moments per year - no inconvenient, extended downtime. Simply change the deionizer bag every six months. If contaminated water or low water level is detected, the system activates a warning light and shuts off the generator - avoiding harm to the system.

"Our H2 generator has saved us time, space, and money over a traditional tank configuration. We realized a return on our investment in less than one year and no longer have to manage bulky and unsightly tanks in the lab."

John Ross
Director Corporate Quality
Ungerer & Company

Hydrogen Generators for Fuel and Carrier Gas

Principal Specifications

Hydrogen Generators	Specifications
Purity	99.99999+% pure H2 Oxygen < .01 ppm Moisture < 1 ppm
Max Hydrogen Flow Rate	H2-500NA 500 cc/min* H2-800NA 800 cc/min H2-1200NA 1200 cc/min
Delivery Pressure	0 to 100 psig
Electrical Requirement	60Hz, 100 - 130 VAC (1)
Power Consumption	5.3 Amp @ 120 VAC
Certifications	IEC 1010-1; CSA; UL 3101, CE Mark
Dimensions, H2-800NA and H2-1200NA	13"w x 17"d x 15.5"h
Dimensions, H2-500NA	15"w x 18"d x 13"h
Outlet Port	1/4" Compression
Shipping Weight	45 lbs (20.4 kg)

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Time

Description	Model Number
UHP Hydrogen Gas Generator	H2-500NA*
UHP Hydrogen Gas Generator	H2-800NA
UHP Hydrogen Gas Generator	H2-1200NA
Deionizer Bags (2 each)	7601132
Preventative Maintenance Plan	H2-500-PM, H2-800-PM
Extended Support with 24 Month Warranty	H2-500-DN2, H2-800-DN2, H2-1200-DN2

(1) Refer to voltage appendix for electrical and plug configurations for outside North America.

The Parker Balston® Hydrogen Generator is an excellent source of ultra pure, dry hydrogen for a wide range of laboratory uses. The generator is used extensively with Gas Chromatographs, as a fuel gas for Flame Ionization Detectors (FID), as a reaction gas for Hall Detectors, and as a carrier gas to ensure absolute repeatability of retention times. In high sensitivity Trace Hydrocarbon Analyzers and air pollution monitors, the hydrogen produced ensures the lowest possible background noise.

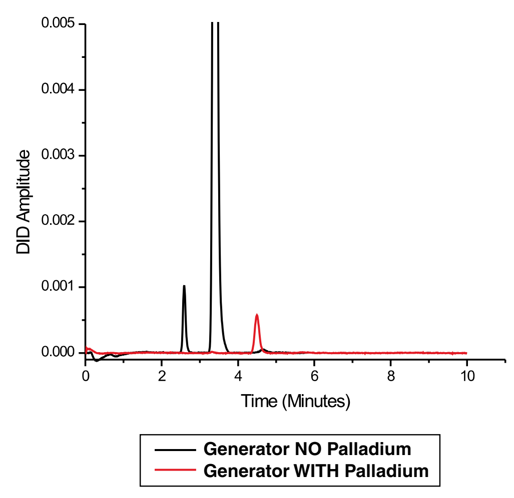
Other applications include using hydrogen for hydrogenation reactions and for FID's used in the analysis of engine gas emissions in the automobile industry.

In all applications the Parker Balston Hydrogen Generator sets the standard for safety, operational performance and dependability.

***Does not include automatic waterfeed feature and has maximum pressure output of 90 psig. Outlet port is 1/8" compression.**

Simple Experimental: The two merged baselines in the right chromatogram were created using a Gow-Mac Gas Chromatograph Series 590 equipped with a (DID) discharge ionization detector with hydrogen separator. In creating both baselines (black and red) the gas sample is hydrogen from a hydrogen generator. Both generators are the same - as hydrogen gas is produced from water via electrolytic disassociation, but differ slightly as one generator incorporates a desiccant drying tube as a final purifier while the second generator has a palladium membrane as the final purifier.

The large black peak represents a combined 12 ppm concentration of oxygen and nitrogen, suitable for hydrogen fuel gas while the corresponding point in the red baseline represents a combined 12 ppb concentration of oxygen and nitrogen, suitable for either fuel or carrier gas.



FID MakeupGas Generators

- Ideal for up to 5-6 FIDs
- Produces makeup grade nitrogen with less than 0.05 ppm THC (measured as methane)
- Eliminates dangerous and costly helium or nitrogen cylinders from the laboratory
- Improves flame shape within the FID detector and maximizes sensitivity
- Recommended and used by many GC and column manufacturers
- Payback period of typically less than one year
- Silent operation and minimal operator attention required

MGG-2500NA FID MakeupGas Generator

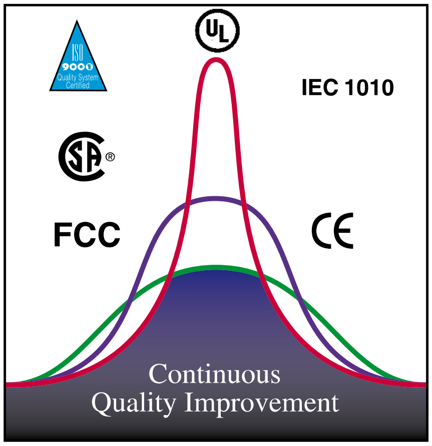
Parker Balston's MGG-400NA and MGG-2500NA, MakeupGas Generators can provide nitrogen gas and zero grade air to FID detectors on Gas Chromatographs. These systems are specifically designed to provide only nitrogen gas or both nitrogen and zero air to 5-6 Flame Ionization Detectors.

Zero grade nitrogen gas is produced by purifying on-site compressed air through the use of a heated catalyst technology mated with a hollow fiber membrane separator. The heated catalyst removes all heavy and light hydrocarbons while the hollow fiber membrane delivers nitrogen molecules to the generator's output. The nitrogen from the system is 99.9999+% pure in respect to hydrocarbons (suitable for FID Makeup Gas) and is 99+% pure in trace in respect to oxygen and water vapor.

Zero air is produced by purifying on-site compressed air to a total hydrocarbon concentration of < 0.05 ppm (measured as methane). The zero air compartment produces up to 2500 cc/min of zero grade air.

The MakeupGas Generators are complete systems with state-of-the-art, highly reliable components engineered for easy installation, operation and long term performance. The Parker Balston® MGG-400NA and MGG-2500NA eliminate all the inconveniences and of cylinder gas supplies and dependence on outside vendors. Uncontrollable price increases, contract negotiations, long term commitments, and tank rentals are no longer a concern. With a Parker Balston MakeupGas Generator, you control your gas supply.

Produced and supported by an ISO 9001 registered organization, Parker Balston's gas generators are the first built to meet the toughest laboratory standards in the world: CSA, UL, CE and IEC 1010.



FID MakeupGas Generators

Principal Specifications

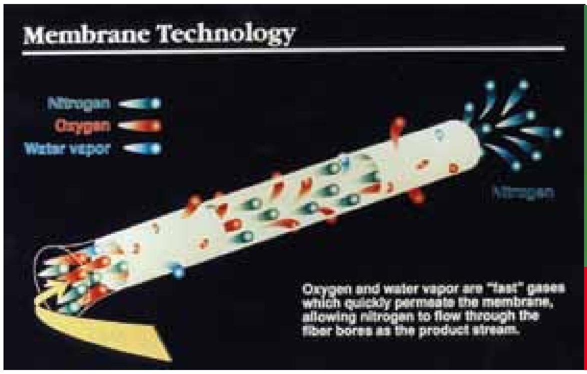
MakeupGas Generators	
Nitrogen Purity	99.9999+% (with respect to hydrocarbons)
Nitrogen Purity	99+% (with respect to oxygen)
Zero Air Purity	<0.05 ppm (total hydrocarbon as methane)
Maximum Nitrogen Flow Rate	MGG-400NA: 400 cc/min MGG-2500NA: 400 cc/min
Maximum Zero Air Flow Rate	MGG-2500NA: 2500 cc/min
Electrical Requirements (1)	MGG-400NA: 120VAC, 60Hz, 580 Watts MGG-2500NA: 120VAC, 60Hz, 580 Watts
Nitrogen Outlet Pressure	60 - 120 psig
Zero Air Outlet Pressure	60 - 120 psig
Certifications	IEC 1010-1; CSA 1010; UL 3101; CE Mark
Dimensions	7"w x 26"d x 16.5"h (18cm x 66cm x 42cm)
Inlet Port	1/4" NPT (female)
Outlet Ports	1/4" NPT (female)
Shipping Weight	MGG-400NA: 60 lbs / 27 kg MGG-2500NA: 60 lbs / 27 kg

(1) Refer to voltage appendix to select correct part number and plug for Japan and 220VAC/50hz configurations.

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Time

Model	Description
MGG-400NA, MGG-2500NA	MakeupGas Generator
MGGW-400NA, MGGW-2500NA	MakeupGas Generator (wall mount)
MGG-400-INST, MGG-2500-INST MGGW-400-INST, MGGW-2500-INST	Installation service
MKMGG2500-12	Annual Maintenance Kit
MGG-400-PM, MGG-2500-PM, MGGW-400-PM, MGGW-2500-PM	Preventive Maintenance Plan
MGG-400-DN2, MGG-2500-DN2, MGGW-400-DN2, MGGW-2500-DN2	Extended Support with 24 Month Warranty

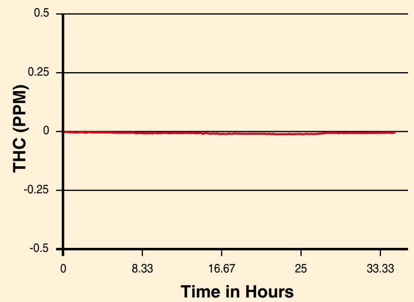
Nitrogen Technology



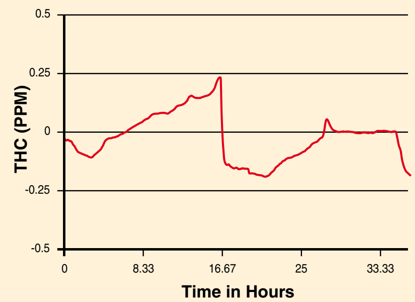
This technology features advanced HiFluxx Fiber

The Chromatograms (below) compare baselines produced by a Parker Balston MakeupGas Generator and bottled fuel air. The baseline produced by the Parker Balston Generator is very flat, with no fluctuations or peaks, in comparison with the chromatogram of the bottled air fuel supply, which has many peaks ranging from .25 ppm to -.25 ppm.

Baseline
MGG-2500NA MakeupGas Generator



Baseline Bottled Fuel Air



Zero Air Generators

- Produce UHP Zero Air from house compressed air (<0.05 ppm THC)
- Eliminate inconvenient and dangerous zero air cylinders from the laboratory
- Increase the accuracy of analysis and reduces the cleaning requirement of the detector
- Qualitative SMART-Display provides operational status at a glance
- Recommended and used by many GC and column manufacturers
- Payback period of typically less than 1 year
- Silent operation and minimal operator attention required
- Models available to service up to 66 FIDs

Model HPZA-7000

Parker Balston® Zero Air Generators are complete systems with state-of-the-art, highly reliable components engineered for easy installation, operation, and long term performance. Parker Balston Zero Air Generators are much easier to install than dangerous, high pressure gas cylinders, and only need to be installed once! All that is required is a standard compressed air line and an electrical outlet.

Parker Balston Zero Air Generators are easy to operate, there is no complicated operating procedure to learn or any labor intensive monitoring required.

Parker Balston Zero Air Generators eliminate all the inconveniences and costs of cylinder gas supplies and dependence on outside vendors. Uncontrollable vendor price increases, contract negotiations, long term commitments and tank rentals are no longer a concern; Parker Balston Zero Air Generators offer long term cost stability.

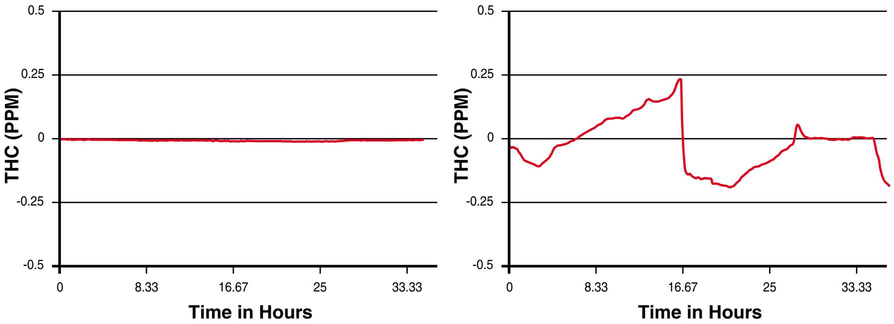
There is no need to use valuable laboratory floor space to store excessive reserves to protect yourself from late deliveries, transportation interruptions, or periods of tight supplies. With a Parker Balston Zero Air Generator, you control your supply.

Model Number	Number of FIDs*
75-83NA	Up to 2
HPZA-3500	Up to 8
HPZA-7000	Up to 16
HPZA-18000	Up to 40
HPZA-30000	Up to 66

*Based on a 450 ccm fuel air rate.

Zero Air Generators

Baseline Comparison



The Chromatograms (left) compare baselines produced by a Parker Balston® Zero Air Generator and bottled fuel air. The baseline produced by the Parker Balston Generator is very flat, with no fluctuations or peaks, in comparison with the chromatogram of the bottled air fuel supply, which has many peaks ranging from .25 ppm to -.25 ppm.

Principal Specifications

Parker Balston Models 75-83NA, HPZA-3500, HPZA-7000, HPZA-18000, HPZA-30000

Max Zero Air Flow Rate	75-83NA	1 lpm
	HPZA-3500	3.5 lpm
	HPZA-7000	7 lpm
	HPZA-18000	18 lpm
	HPZA-30000	30 lpm
Outlet Hydrocarbon Concentration (as methane)*		<0.05 ppm
Min/Max Inlet Air Pressure		40 psig/125 psig
Max Inlet Hydrocarbon Concentration (as methane)		100 ppm
Pressure Drop at Max Flow Rate		4 psig
Max Inlet Air Temperature		78°F (25°C)
Inlet/Outlet Ports		1/4" NPT (female)
Start-up Time for Specified Hydrocarbon Concentration (as methane)		45 minutes
Electrical Requirements (1)	75-83NA	120 VAC/60 Hz, 0.5 amps
	HPZA-3500, HPZA-7000	120 VAC/60 Hz, 2.0amps
	HPZA-18000, HPZA-30000	120 VAC/60 Hz, 4.0 amps
Dimensions	75-83NA	10"w x 3"d x 12"h
		(25cm x 8cm x 30cm)
	Other Models	11"w x 13"d x 16"h
		(27cm x 34cm x 42cm)
Shipping Weight	75-83NA	7 lbs.(3 kg)
	Other Models	41 lbs.(19 kg)

* Outlet hydrocarbon concentration (as methane) for models 75-83NA and HPZA-30000 is less than 0.1 ppm.
(1) Refer to voltage appendix for electrical and plug configurations for outside North America.

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Time

Description	Model Number
Zero Air Generator	75-83NA, HPZA-3500, HPZA-7000, HPZA-18000, HPZA-30000
Maintenance Kit for Model 75-83NA	MK7583
Maintenance Kit for All Other Models	MK7840
Installation Kit for All Models	IK76803
Preventive Maintenance Plan	75-83-PM, HPZA-3500-PM, HPZA-7000-PM, HPZA-18000-PM, HPZA-30000-PM
Extended Support with 24 Month Warranty	75-83-DN2, HPZA-3500-DN2, HPZA-7000-DN2, HPZA-18000-DN2, HPZA-30000-DN2

Nitrogen Generators with Research Grade Purity

- Produce a continuous supply of high purity nitrogen gas from existing compressed air
- Eliminate the need for costly, dangerous, inconvenient nitrogen cylinders in the laboratory
- Compact design frees up valuable laboratory floor space
- Offers long term cost stability - uncontrollable vendor price increases, contract negotiations, long term commitments and tank rentals are no longer a concern
- Ideal for carrier gas applications

Model UHPN2-1100

The Parker Balston® Models HPN2 and UHPN2 Series Nitrogen Generators are completely engineered to transform standard compressed air into 99.99% or 99.9999% nitrogen, exceeding the specification of UHP cylinder gas. These systems can produce up to 1.1 lpm of UHP nitrogen gas and up to 2.0 lpm of research grade purity nitrogen gas. Nitrogen is produced by utilizing a combination of state-of-the art purification technologies and high efficiency filtration.

Pressure swing adsorption removes O_2, CO_2, and water vapor. A catalyst module is incorporated in the UHPN2 Series to oxidize hydrocarbons from the inlet air supply. High efficiency coalescing prefilters and a 0.01 micron (absolute) membrane filter is also incorporated into the design of the generators.

The Parker Balston UHPN2 and HPN2 Series Nitrogen Generators are engineered and packaged in a small cabinet to fit on or under any bench-top. The systems eliminate the need for costly, inconvenient high pressure nitrogen cylinders.

Typical applications include GC carrier and make-up gas and low flow sample concentrators.

Flow Table

Inlet Air Pressure (psig)	Max Outlet Flow (cc/min.)	Max Outlet Pressure (psig)
Models HPN2-1100 and UHPN2-1100		
125	1100	85
110	1000	75
100	900	65
90	800	60
80	700	50
70	600	45
60	500	35
Model HPN2-2000		
75-120	2000	90

Nitrogen Generators with Research Grade Purity

Principal Specifications

Model	HPN2-1100, UHPN2-1100	HPN2-2000
Max Nitrogen flow rate	See Flow Table	2 lpm
Nitrogen Purity	99.9999%	99.99%
Max Nitrogen output pressure	See Table	90 psig
CO concentration	< 1 ppm	NA
CO_2 concentration	< 1 ppm	< 1 ppm
O_2 concentration	< 1 ppm	< 100 ppm
H_2O Concentration	< 1 ppm	< 2 ppm
Hydrocarbon concentration (1)	< 0.1 ppm	NA
Argon concentration (2)	0.9%	0.9%
Min/Max inlet pressure	60 psig/125 psig	75 psig/120 psig
Recommended inlet temperature	78°F (25°C)	78°F (25°C)
Ambient operating temperature	60°F-100°F (16°C-38°C)	60°F-100°F (16°C-38°C)
Max air consumption	42 lpm (1.5 scfm)	42 lpm (1.5 scfm)
Inlet connection	1/4" NPT (female)	1/4" NPT (female)
Outlet connection	1/8" compression	1/8" NPT compression
Electrical requirements (3, 4)	120 VAC/60 Hz	120 VAC/60 Hz
Dimensions	12" w x 16" d x 35" h (30cm x 41cm x 89cm)	12" w x 16" d x 35" h (30cm x 41cm x 89cm)
Shipping Weight	110 lbs. (50 kg)	110 lbs. (50 kg)

Notes:

1 Models HPN2-1100 and HPN2-2000 do not remove hydrocarbons and carbon monoxide.

2 Purity specification for Nitrogen does not include Argon concentration.

3 Power Consumption is as follows:
Model HPN2-1100 = 25 Watts
Model UHPN2-1100 = 700 Watts
Model HPN2-2000 = 25 Watts.

4 Refer to voltage appendixfor electrical and plug configurations for outside North America.

Ordering Information call 800-343-4048, 8 to 5 EST

Description	Model Numbers
High Purity Nitrogen Generator	HPN2-2000
Ultra High Purity Nitrogen Generator	HPN2-1100 and UHPN2-1100
Purity Indicator/Scrubber	72092
Optional Prefilter Scrubber Assembly	76080
Pressure Regulator	W-425-4032-000
Maintenance Kit	MK7692, MK7694, MKHPN22000
Installation Kit for All Models	IK7694
Preventive Maintenance Plan	HPN2-1000-PM, UHPN2-1100-PM, HPN2-2000-PM
Extended Support with 24 Month Warranty	HPN2-1100-DN2, UHPN2-1100-DN2, HPN2-2000-DN2

Explosion-Proof Zero Air Generator

- Eliminates dangerous, expensive, and inconvenient gas cylinders from the laboratory
- Safe, even in explosive environments
- Low maintenance
- Produces a continuous supply of ultra high purity zero grade air
- Compact and reliable
- Designed to mount on Unistrut® framing or directly on the wall
- Certified by CSA (CSA NRTL/C)

Model 75-82S

The Parker Balston® Model 75-82S Zero Air Generator produces up to 1,000 cc/min. of high purity zero grade air from a standard compressed air supply. The generator utilizes state-of-the-art catalytic technology to convert compressed air into zero-grade air, at safe regulated pressures, on a continuous basis without the need of operator attention.

The housing is a standard Crouse-Hinds® explosion-proof enclosure designed to operate in a class 1, division 1, groups B, C, D environments. The internals are all stainless steel. This generator completely eliminates the need for expensive, inconvenient and dangerous gas cylinders. It is a turnkey system, ready to install on Unistrut frames or directly to the wall.

The Parker Balston® Model 75-82S Zero Air Generator can be used as: a fuel air supply to process GC-FIDs, and zero grade gas supply/ zero reference for process analytical instruments.

Zero grade air is produced from compressed air by means of catalytic oxidation. The compressed air is channeled into a heated catalyst bed where the hydrocarbons are converted to carbon dioxide and water vapor, producing zero-grade air with less than 0.1 ppm hydrocarbon content (measured as methane). The use of a Parker Balston 75-82S Zero Air Generator has advantages over the conventional sources of fuel air for GC analysis. For example, a lower and more stable baseline signal can be obtained. Lower baseline noise means higher signal-to-noise ratio, giving rise to higher sensitivity or larger peak areas. The result is increased accuracy and reduced cleaning requirement of the detector.

Principal Specifications

Model 75-82S Zero Air Generator	
Explosion Proof Certification (CSA NRTL/C)	Class 1, Division1, Groups B, C, and D
Maximum Flow Rate	1000 cc/min.
Total Hydrocarbon Concentration	< 0.1 ppm (measured as methane)
Min./Max. Inlet Pressure	40 psig/125 psig
Maximum Inlet Hydrocarbon Content	100 ppm
Maximum Inlet Air Dewpoint	10°F (5°C) above ambient
Pressure Drop at Max. Flow Rate	< 8 psid
Outlet Air Temperature	Ambient +20°F (+11°C)
Start-up Time	45 min.
Electrical Requirements	120 VAC/60 Hz, 0.5 amps
Shipping Weight	28 lbs. (13 kg)
Dimensions	11”w X 7”h X 6”d (28 cm X 18 cm X 15 cm)

Ordering Information

Description	Model Number
Zero Air Generator	75-82S
Replacement Catalyst Module	75398
Final Filter Cartridge	75820
Optional Prefilter Assemblies	2002N-1B1-DX, 2002N-1B1-BX
Installation Kit	IK76803
Preventive Maintenance Plan	75-82S-PM
Extended Support with 24 Month Warranty	75-82S-DN2

Application Notes

FT-IR Purge Gas Generators

- Eliminates the need for costly, dangerous, inconvenient nitrogen cylinders in the laboratory
- Compact design frees up valuable laboratory floor space
- Improves signal-to-noise ratio even on non-purge systems
- Increases FT-IR sample thru-put and maximizes up-time
- Recommended and used by all major FT-IR manufacturers

Model 75-52NA, 75-62NA, and 75-45NA

The Parker Balston® FT-IR Purge Gas Generator is specifically designed for use with FT-IR Spectrometers to provide a purified purge and air bearing gas from compressed air. The generator supplies carbon dioxide-free air at less than -100°F (-73°C) dew point with no suspended impurities larger than 0.01 µm. The unit is designed to operate continuously 24 hours/day, 7 days/week. The Parker Balston Purge Gas Generator completely eliminates the inconvenience and the high costs of nitrogen cylinders and dewars, and significantly reduces the costs of operating FT-IR instrumentation. The Parker Balston unit offers cleaner background spectra in a shorter period of time and more accurate analysis by improving the signal-to-noise ratio. The typical payback period is less than one year. The generator is also ideally suited for use with CO_2 Analyzers and Matrix GC's in addition to supplying gas to other laboratory instruments.

The generators are quiet, reliable, and easy to install - simply attach the inlet and outlet air lines (at least 60 psig and 1/4 inch pipe), plug the power cord into a wall outlet, and enjoy trouble-free operation.

Here's what your colleagues say:

"A Parker Balston® FT-IR Purge Gas Generator and Self Contained Lab Gas Generator were used in conjunction with the Society for Applied Spectroscopy Fourier Transform Infrared Spectrometry Workshop at the University of Georgia, June 2000 (organized by Dr. James A de Haseth and Dr. Peter R. Griffiths). The Self-Contained Lab Gas Generator provided excellent purge for six spectrometers. The organizers were so pleased with the performance of the Parker Balston® systems, they have requested that Parker Hannifin Corporation, Inc. participate in future workshops."

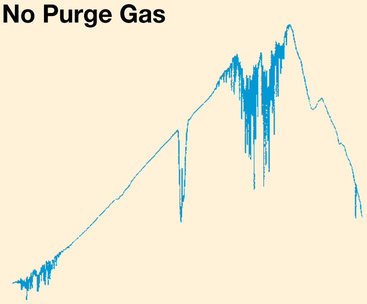
- Dr. James A. de Haseth and Dr. Peter R. Griffiths

FT-IR Purge Gas Generators

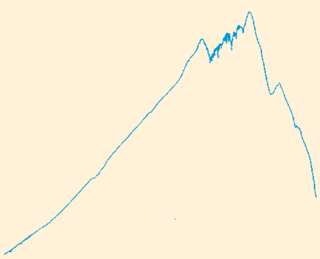
Products for Spectroscopy

Comparative Spectral Analysis in Purging an FT-IR Sample Chamber

No Purge Gas



2 Minutes Parker Balston®



The spectrum collected without purge gas is extremely noisy in several regions. When the sample is purged with nitrogen for two minutes, water vapor and CO_2 are removed and the noise in the spectrum is removed so that important features in the spectrum can be observed.

Principal Specifications

	Model	
Flow Rate for Specified Dew Point		
Inlet Pressure 125 psig	75-45NA	36 scfh (17 lpm)
Inlet Pressure 60 psig		18 scfh (9 lpm)
Inlet Pressure 125 psig	75-52NA	72 scfh (34 lpm)
Inlet Pressure 60 psig		36 scfh (17 lpm)
Inlet Pressure 125 psig	75-62NA	216 scfh (102 lpm)
Inlet Pressure 60 psig		120 scfh (57 lpm)
CO_2 Concentration		< 1 ppm
Dew Point		-100°F (-73°C)
Min/Max Inlet Air Pressure		60 psig/125 psig
Max Inlet Air Temperature (1)		78°F (25°C)
Air Consumption for regeneration (2)	75-45NA	30 scfh (14 lpm)
	75-52NA	60 scfh (28 lpm)
	75-62NA	120 scfh (57 lpm)
Inlet/Outlet Port Size		1/4" NPT (female)
Electrical Requirements (3)		120 VAC/60 Hz/10 watts
Dimensions	75-45NA	7"w x 13"h x 6"d (18cm x 33cm x 15cm)
	75-52NA	13"w x 28"h x 9"d (32cm x 71cm x 23cm)
	75-62NA	13"w x 42"h x 9"d (32cm x 102cm x 23cm)
Shipping Weight	75-45NA	26 lbs (12 kg)
	75-52NA	60 lbs (27 kg)
	75-62NA	88 lbs (40 kg)

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Time

Description	Model Number	
FT-IR Purge Gas Generator	75-45NA, 75-52NA, 75-62NA	
Annual Maintenance Kit	75-45NA	MK7505
	75-52NA	MK7552
	75-62NA	MK7520
Installation Kit for All Models	IK7572	
Preventive Maintenance Plan	75-45NA	75-45-PM
	75-52NA	75-52-PM
	75-62NA	75-62-PM
Extended Support with 24 Month Warranty	75-45-DN2, 75-52-DN2, 75-62-DN2	

Notes
1 Outlet dew point will increase at higher inlet compressed air temperatures.
2 Total air consumption = regeneration flow + flow demand.
3 Refer to voltage appendix for electrical and plug configurations for outside North America.

Self-Contained FT-IR Purge Gas Generator

- Less expensive and more convenient than nitrogen cylinders and dewars
- Includes state-of-the-art, oil-less compressor
- Compact, portable design is ideal for mobile labs
- Improves signal-to-noise ratio even on non-purge systems
- Increases FT-IR sample thru-put and maximizes up-time
- Special sound insulation design ensures quiet operation

Model 74-5041NA

The Parker Balston® Model 74-5041NA FT-IR Purge Gas Generator is specifically designed for use with FT-IR spectrometers to provide a purified purge and air bearing gas supply from compressed air. The Parker Balston model 74-5041NA provides instruments with CO_2-free compressed air at less than -100°F (-73°C) dew point with no suspended impurities larger than 0.01 micron 24 hours/day, 7 days/week. The Parker Balston Self-Contained FT-IR Purge Gas Generator completely eliminates the inconvenience and the high costs of nitrogen cylinders and Dewars, and significantly reduces the costs of operating FT-IR instruments.

The Parker Balston unit generates cleaner background spectra in a shorter period of time and more accurate analysis by improving the signal-to-noise ratio. The typical payback period is less than one year.

The generator is quiet, very reliable, and easy to install - simply attach the outlet air line, plug the electrical cord into a wall outlet, and the unit is ready for trouble-free operation.

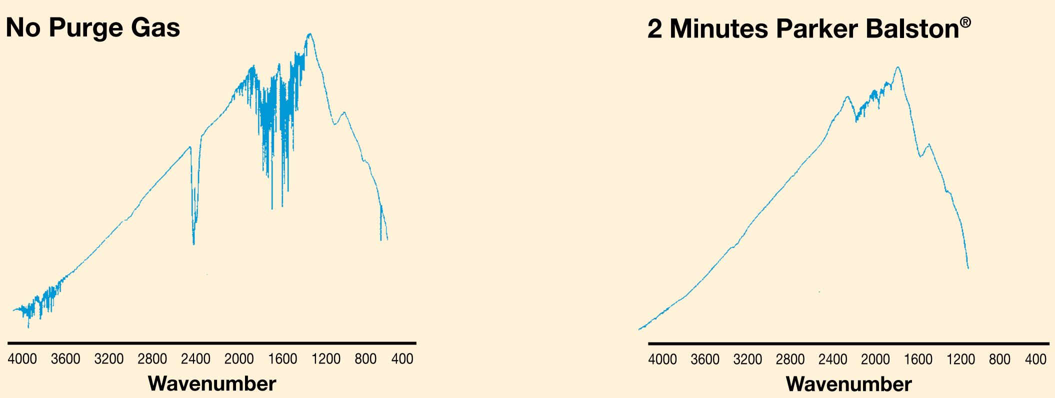
Here's what your colleagues say:

"A Parker Balston® FT-IR Purge Gas Generator and Self Contained Lab Gas Generator were used in conjunction with the Society for Applied Spectroscopy Fourier Transform Infrared Spectrometry Workshop at the University of Georgia, June 2000 (organized by Dr. James A de Haseth and Dr. Peter R. Griffiths). The Self-Contained Lab Gas Generator provided excellent purge for six spectrometers. The organizers were so pleased with the performance of the Parker Balston® systems, they have requested that Parker Hannifin Corporation, Inc. participate in future workshops."

- Dr. James A. de Haseth and Dr. Peter R. Griffiths

Self-Contained FT-IR Purge Gas Generator

Comparative Spectral Analysis in Purging an FT-IR Sample Chamber



This spectra comparison illustrates that a Parker Balston FT-IR Purge Gas Generator allows an FT-IR to be purged at a much higher flow rate than is practical with nitrogen. The sample chamber purged by the Parker Balston unit if free of CO_2 and water faster than the sample chamber purged by nitrogen.

Principal Specifications

Self-Contained FT-IR Purge Gas Generator	**74-5041NA**
Maximum Flow Rate (at 80 psig)	60 SCFH (28 lpm)
Maximum Output Pressure	80 psig
CO_2 Concentration	< 1 ppm
Dew Point	-100°F (-73°C)
Outlet Port Size	1/4" NPT (female)
Min/Max Ambient Temperature	30°F/90°F (-1°C/32°C)
Electrical Requirements (single phase)	120 VAC/60 Hz, 20 amps (1)
Compressor	3/4 hp
Dimensions	18"w x 31"h x 32"d (46 cm x 76 cm x 81 cm)
Shipping Weight	250 lbs. (114 kg)

(1) Refer to voltage appendix for electrical and plug configurations for outside North America.

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Time

Description	Model Number
FT-IR Purge Gas Generator	74-5041NA
Annual Maintenance Kit	74065
Replacement Compressor	74156
Preventive Maintenance Plan	74-5041-PM
Extended Support with 24 Month Warranty	74-5041-DN2

Ultra Dry Gas Generator

- Supplies ultra-dry, purified compressed air to NMR Spectrometers and other analytical instruments
- Ideal gas supply for spindle and automatic sample changer
- Completely eliminates costly, inconvenient nitrogen dewars - never pay for or change out another dewar
- Compact design frees up valuable laboratory floor space
- Completely automatic - plug it in and forget about it

Model UDA-300NA

The Parker Balston® Model UDA-300NA Compressed Air Dryer provides ultra-dry, purified compressed air to analytical instruments. The model UDA-300 reduces the dewpoint to -100°F (-73°C) without operator attention.

Each system is delivered complete, and ready for easy installation. A high efficiency prefiltration system, automatic drains, a 0.01μm final filter, a moisture indicator, and pretested controls are integral to the design of each dryer.

To install, simply connect your house compressed air supply (at least 60 psig and 1/4 inch pipe) to the dryer inlet port, and connect the dryer outlet port to your instruments. Plug the electrical cord into a wall outlet - no electrician required - and the unit is ready for trouble-free operation.

Designed specifically for NMR instrumentation, the generator is completely automatic, and virtually maintenance free. It is ideal for injecting, spinning, and lifting operations. It is recommended by major NMR instrument manufacturers and is currently installed in several thousand locations.

Principal Specifications

Model UDA-300NA Compressed Air Dryer	
Dew Point	-100°F (-73°C)
Flow Rate at 60 psig	390 scfh (184 lpm)
Flow Rate at 125 psig	720 scfh (340 lpm)
Min/Max Inlet Air Pressure	60 psig/125 psig
Max Inlet Air Temperature (1)	78°F (25°C)
Inlet/Outlet Port Size	1/4" NPT (female)
Electrical Requirements (2)	120 VAC/60 Hz, 10 Watts
Dimensions	41"h x 15"w x 8"d (104cm x 38cm x 20cm)
Shipping Weight	50 lbs (23 kg)

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Time

Description	Model Number
Compressed Air Dryer	UDA-300NA
Inlet Pressure Regulator	72-130-V883
Annual Maintenance Kit	MK7525
Preventive Maintenance Plan	UDA-300-PM
Extended Support with 24 Month Warranty	UDA-300-DN2

Notes:
1 Outlet dew point will increase at higher inlet compresses air temperatures
2 Refer to voltage appendix for electrical and plug configurations for outside North America.

ICP Spectrometer Nitrogen Generator

Products for Spectroscopy

- Produces a continuous supply of ultra high purity nitrogen gas from existing compressed air
- Eliminates the need for costly, dangerous, inconvenient nitrogen cylinders or dewars in the laboratory
- Extends ICP Analysis into far-UV range below 170 (nm)
- Compact design frees up valuable laboratory floor space
- Offers long term cost stability - uncontrollable vendor price increases, contract negotiations, long term commitments and tank rentals are no longer a concern

Model 76-98NA
Nitrogen Generator

The Parker Balston® 76-97NA and 76-98NA UHP Nitrogen Generators can produce 5-12 lpm of ultra high purity nitrogen gas. These systems are completely engineered to transform standard compressed air into 99.9999% of 99.995% pure nitrogen, exceeding the specification of UHP cylinder gas and dewars. Nitrogen is produced by utilizing a combination of state-of-the-art purification technologies and high efficiency filtration. Pressure swing absorption is utilized for the removal of 0_2, CO_2, and water vapor. A catalyst module is incorporated in the 76-98NA to oxidize hydrocarbons from the inlet air supply. The generators also have a combination of high efficiency prefilters and a 0.01 micron (absolute) membrane filter incorporated into their design. The Parker Balston UHP Nitrogen Generators are engineered and packaged in a laboratory cabinet to fit nearly any laboratory. The systems eliminate the needs for costly, inconvenient high pressure nitrogen cylinders or dewars. The 76-97NA and 76-98NA are ideal for ICP Purge gas applications.

Applications

Other applications include high flow GC carrier gas needs, DNA Synthesis and Sequencing Equipment, Mocon Moisture Analyzers, Circular Dichroism and Gel Permeation needs.

ICP Spectrometer Nitrogen Generator

Flow Table@ 99.9999% Purity

Inlet Air Pressure (psig) Models 76-97NA and 76-98NA	Max Outlet Flow (lpm)	Max Outlet Pressure (psig)
120	5	83
110	5	73
100	5	63
90	4	62
80	4	51
70	2	50
60	2	42

Flow Table@ 99.995% Purity

Inlet Air Pressure (psig) Models 76-97NA and 76-98NA	Max Outlet Flow (lpm)	Max Outlet Pressure (psig)
120	12	60
110	12	55
100	12	45
90	10	45
80	8	40
70	8	35
60	6	33

Principal Specifications

Model	**76-97NA/76-98NA**
Nitrogen Purity	99.995% and 99.9999%
Max Nitrogen Output Pressure	See Table (above)
CO Concentration	< 1 ppm
CO_2 Concentration	< 1 ppm
O_2 Concentration	< 1 ppm
H_2O Concentration	< 2 ppm
Hydrocarbon Concentration (1)	< 0.1 ppm
Argon Concentration (2)	0.9%
Min/Max Inlet Pressure	60 psig/120 psig
Recommended Inlet Temperature	78°F (25°C)
Ambient Operating Temperature	60°F-100°F (16°C-38°C)
Average Air Consumption	3.0 scfm
Inlet Connection	1/4" NPT
Outlet Connection	1/8" NPT, convertible to 1/4" NPT
Electrical Requirements (3, 4)	120 VAC/60 Hz
Dimensions	41"h x 25"w x 25"d (104cm x 64cm x 64cm)
Shipping Weight	500 lbs (227 kg)

Ordering Information

Model Numbers	Description
76-97NA and 76-98NA	Ultra High Purity Nitrogen Generator
76-97-PM, 76-98-PM	Preventive Maintenance Plan
76-97-DN2, 76-98-DN2	Extended Support with 24 Month Warranty

Notes:
1 Model 76-97NA does not remove hydrocarbons.
2 Purity specification for Nitrogen does not include Argon concentration.
3 Power Consumption is as follows:
Model 76-97NA = 10 Watts, Model 76-98NA = 1 KW
4 Refer to voltage appendix for electrical and plug configurations for outside North America.

NitroVap Gas Generators

- Ideal for any combination of sample evaporators up to 100 nozzle positions
- Produces clean, dry (to -20°F) dewpoint evaporator grade nitrogen from any standard laboratory compressed air source
- Accelerates evaporation by decreasing the partial vapor pressure above the solvent liquid
- Eliminates inconvenient and dangerous LN2 boil-off dewars and nitrogen gas cylinders from the laboratory
- Recommended and used by many sample concentrator and sample evaporator manufacturers
- Payback period of typically less than one year
- Sleep economy mode
- Silent operation and minimal operator attention required

NitroVap-1LV and NitroVap-2LV

Proven Technology

Parker Balston's NitroVap-1LV and NitroVap-2LV Nitrogen Generators can provide clean, ultra-dry nitrogen to sample evaporators. These systems offer high nitrogen output flows in a miniature cabinet. The user can activate the manual SLEEP economy mode to eliminate compressed air consumption when the sample concentrator is not in use.

Nitrogen Technology

Nitrogen is produced by utilizing a combination of filtration and membrane separation technologies. A high efficiency prefiltration system pretreats the compressed air to remove all contaminants down to 0.01 micron. Hollow fiber membranes subsequently separate the clean air into a concentrated nitrogen output stream and an oxygen enriched permeate stream, which is vented from the system. The combination of these technologies produces a continuous on demand supply of pure nitrogen.

Gas Generator Benefits

The NitroVap generators are complete systems with state-of-the-art, highly reliable components engineered for easy installation, operation, and long term performance. The Parker Balston NitroVap-1LV and NitroVap-2LV eliminate all the inconveniences and cost of LN2 dewar and nitrogen cylinder gas supplies and dependence on outside vendors. Uncontrollable price increases, dewar ice and condensation, contract negotiations, long term commitments, and tank rentals are no longer a concern. With a NitroVap generator, you control your gas supply.

Ease of Use

Since NitroVap generators incorporate unique membrane separation technology, nitrogen delivery is immediate to the sample concentrator. "Lock-it-and-leave-it" operation of the sample concentrator is maintained without downtime and without "running out of gas" mid blow-down.

This Technology Features Advanced HiFluxx Fiber!

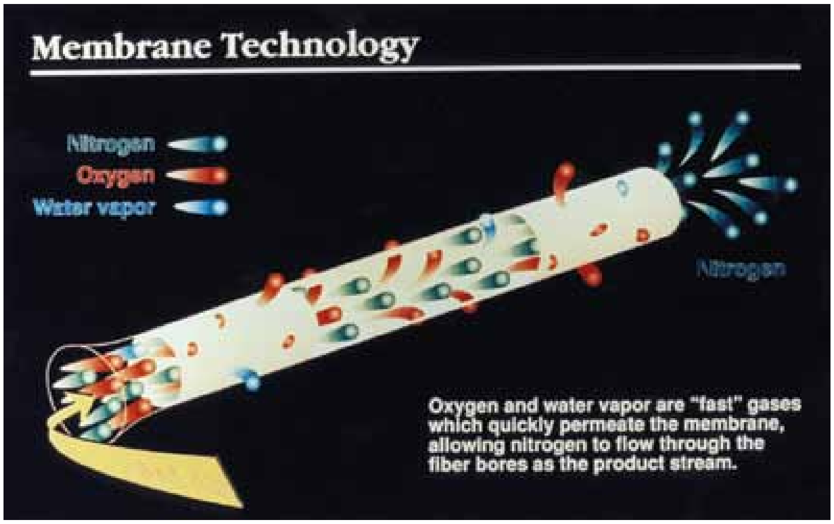
NitroVap Gas Generators

Principal Specifications - NitroVap Generators

Nitrogen Purity	Up to 90%
Nitrogen Dewpoint	Down to -20°F (-29°C) atmospheric
Maximum Nitrogen Flow Rate	NitroVap-1LV: up to 80 slpm @ 100 psig input up to 140 slpm @ 125 psig input NitroVap-2LV: up to 160 slpm @ 100 psig input up to 287 slpm @ 125 psig input
Electrical Requirements	None
Nitrogen Outlet Pressure	0-15 psig user controlled
Dimensions	10.63"w x 14.1"d x 16.5"h (26.92cm x 35.81cm x 41.91cm)
Inlet Port/Outlet Port	1/4" NPT (female)
Shipping Weight	53 lbs/24 kg

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Time

Model	Description
NitroVap-1LV and NitroVap-2LV	NitroVap Nitrogen Generators
MKNITROVAP	Maintenance Kit (Includes 1 each filter cartridge, and 1 each membrane cartridge)
NITROVAP-1LV-PM, NITROVAP-2LV-PM	Preventive Maintenance Plan
NITROVAP-DN2	Extended Support with 24 Month Warranty



Use with These and Other Blowdown Evaporators

TurboVap from Biotage

N-Evap from Organomation

RapidVap from LabConco

Reacti-Vap from Fisher Pierce

Duo-Vap from Jones Chromatography

DryVap from Horizon Technology

Evaporex from Apricot

NitroFlow Lab Self Contained LC/MS Membrane Nitrogen Generator

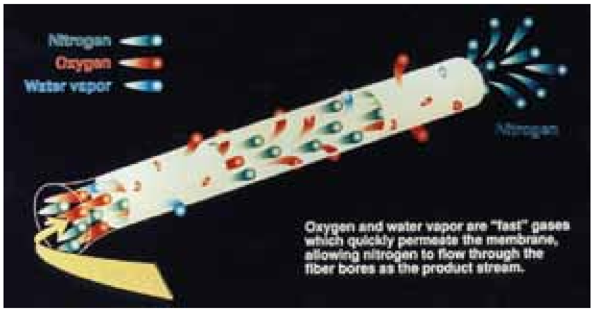
- Flow capacity to 30 LPM
- Includes 2 year compressor warranty
- Ideal for all derivatives of ESi and APCi modes
- Includes state-of-the-art, oil-less compressors
- Unlike PSA Hosmer technologies, membrane will not suppress corona needle discharge
- Special sound insulation design ensures quiet operation

NitroFlowLab

The Parker Balston® LC/MS Nitro-Flow Lab is a self-contained membrane nitrogen generator that produces LC/MS grade nitrogen with output pressure to 116 psig. Nitrogen is produced by utilizing a combination of compressors, carefully matched with filtration, and membrane separation technology components.

Intake ambient air from the laboratory is filtered using an inlet suction breather filter to remove airborne organic and particulate impurities. This purified air is delivered to a long life low pressure air compressor which provides an air stream to hollow fiber membranes which subsequently separate the clean air into a concentrated nitrogen retentate and oxygen enriched permeate, which is then cycled through the system. Prior to exiting the system pure nitrogen retentate is delivered to a nitrogen amplification compressor to assure proper pressure, flow and purity to the LC/MS.

The Parker Balston LC/MS NitroFlow Lab will deliver a continuous or on demand supply of pure nitrogen making it the smart alternative to cylinders. Superior engineering with carefully matched filtration, membrane separation and compression technolies have resulted in a system with the utmost reliability and longevity. Additional applications include: nebulizer gases, chemical and solvent evaporation, instrument supply and purge, evaporative light scattering equipment and sparging.



Principal Specifications

Model	NitroFlowLab
Nitrogen	Phthalate free with flow to 30 lpm @ sea level
Maximum Outlet Pressure	116 psig (8 barg)
Hydrocarbon Content	< 2ppm (excluding methane)
Atmospheric Dewpoint	-58°F (-50°C)
Outlet Port	Female 1/4" NPT
Min/Max Ambient Temperature	50°F/95°F (10°C/35°C)
Electrical Requirements	120Vac/60Hz/20Amp / NEMA 5 - 20 Straight Blade
Dimensions	27.6"h x 12.2"w x 35.4"d (70.1cm x 31cm x 90cm)
Shipping Weight	204 lbs. (92.5 kg)

"We've used the Parker Balston Nitroflow® (combined compressor and nitrogen generator) on our LCMS for 3 years. In just over two years, it more than paid for itself in nitrogen savings, but the real advantages of the nitrogen generator are the continuous supply of high quality nitrogen and the tremendous amount of time saved from not having to check, order and switch high pressure liquid nitrogen tanks."

Karl J. Dria, PhD.
Assistant Research Scientist
Department of Chemistry and Chemical Biology
Indiana University-Purdue University Indianapolis

SOURCE LC/MS TriGas Generator Series Model LCMS-5000NA

- Generates pure nitrogen, zero air and source exhaust air from compressed air
- Eliminates costly and inconvenient nitrogen gas and zero air gas cylinders
- Prevents running out of gases during LC/MS instrument operation
- Preserves valuable laboratory space and maximizes LC/MS instrument uptime
- Reliable scroll compressor, quiet 49 dB(A) operation at a safe, low pressure
- Gas purity to 99.999% and no phthalates
- Turnkey system that eliminates stainless steel regulators and gas distribution panels

Model LCMS-5000NA

The Parker Balston SOURCE LCMS-5000NA TriGas Generator is a completely engineered system designed to deliver pure nitrogen for curtain gas, pure zero grade air as gas-1/gas-2 source gases and dry -40°F dew point air as source exhaust. The system is designed to produce gases which meet and exceed the requirements of any LC/MS requiring three independent gases. The system consists of six functional technologies: Coalescing pre-filtration with timed solenoid drains, self regenerating compressed air dehydration membranes, a proprietary heated catalysis module, elegant self-regenerating nitrogen retentate membranes, high capacity - high sensitivity carbon absorption modules and carefully matched final filtration membrane media. These technologies are integrated to a reliable scroll compressor.

The Parker Balston SOURCE LCMS-5000NA TriGas Generator will provide enough gas for a single LC/MS instrument on a continual basis and will completely eliminate dependence, expense and hassle with using high pressure nitrogen and zero air cylinders.
The generator can be connected easily, be located in the lab, and features independent stainless steel output gas ports carefully matched to the instrument. Gas distribution, pressure and flow control are integral to each TriGas generator and therefore requirements for secondary gas pressure or gas management systems are eliminated.

There is no longer any need to use valuable laboratory floor space to store excess cylinder reserves to protect from running out of gas, late or missed cylinder deliveries, transportation interruptions or periods of tight supply. With a Parker Balston SOURCE LCMS-5000NA TriGas Generator, you control all your LC/MS gas supplies.

SOURCE LC/MS TriGas Generator Series Model LCMS-5000NA

- Supplies pure nitrogen, zero grade air and source exhaust air
- Produced and manufactured by an ISO 9001 registered organization
- Operates continuously 24 hours a day, 7 days a week
- Minimal annual maintenance
- Easy installation and whisper quiet operation
- Floor standing on movable casters
- Listed to U.S. & Canadian safety standards
- Carries CE Marking/Compliant to WEEE standard

Principal Specifications

Model	LCMS-5000NA
Curtain gas (nitrogen)	to 10 lpm and 80 psi
Source gas (uhp zero grade air)	to 23 lpm and 110 psi
Exhaust gas (dry air)	to 8 lpm and 60 psi
Compressor included	Yes - Scroll
Atmospheric dewpoint	-40°F
Hydrocarbons	<0.1 ppm measured as methane
Particles > 0.01 micron	None
Phthalates	None
Suspended liquids	None
Outlets	1/4" tube - stainless steel - 3 each
Dimensions	34"D x 41"W x 43"H
Pressure gauges	3 each
Electrical requirements (1)	120vac, 60Hz, 15 amp and 220vac, 60Hz, 30 amp
Noise level	< 49 dB(A)
Weight	611 lbs. (277 kgs)

(1) Refer to voltage appendix for electrical and plug configurations for outside North America.

Ordering Information

Model	Description
LCMS-5000NA	Source LC/MS Trigas Generator
LCMS-EZLINK	Backup Gas Cylinder Panel
IKLCMS-5000	Installation Kit
LCMS-5000NA-PM	Preventive Maintenance Plan
A03-0286	Voltage Reducing Transformer
11425-1 (specify length)	3/8" Clear PFA Tubing for Remote Compressor Use
11426-1 (specify length)	1/4" Clear PFA Tubing for Connections to LC/MS

"Using the Parker Balston Tri-Gas system with our new ABI 5500 assures maximum uptime of the instrument while offering us the lowest cost to supply gas...The more samples we run lowers our costs and shortens our overall return on the instrument."

Ed Dabrea
Laboratory Director
Jupiter Environmental Laboratories

SOURCE LC/MS TriGas Generator Series Model LCMS-5001NTNA

- Generates pure nitrogen, zero air and source exhaust air from compressed air
- Eliminates costly and inconvenient nitrogen gas and zero air gas cylinders
- Prevents running out of gases during LC/MS instrument operation
- Preserves valuable laboratory space and maximizes LC/MS instrument uptime
- Reliable, silent operation at a safe, low pressure
- Gas purity to 99.999% and no Phthalates
- Turnkey system that eliminates stainless steel regulators and gas distribution panels

Model LCMS-5001NTNA

The Parker Balston SOURCE LCMS TriGas Generator is a completely engineered system designed to transform ordinary compressed air into pure nitrogen for curtain gas, pure zero grade air as gas-1/gas-2 source gases and dry -40°F dew point air as source exhaust. The system is designed to produce gases which meet and exceed the requirements of any LC/MS requiring three independent gases. The system consists of six functional technologies: Coalescing pre-filtration with timed solenoid drains, self regenerating compressed air dehydration membranes, a proprietary heated catalysis module, elegant self-regenerating nitrogen retentate membranes, high capacity - high sensitivity carbon absorption modules and carefully matched final filtration membrane media.

The Parker Balston SOURCE LCMS TriGas Generator will provide enough gas for a single LC/MS instrument on a continual basis and will completely eliminate dependence, expense and hassle with using high pressure nitrogen and zero air cylinders.

The generator can connect easily to an existing compressed air supply line and features independent stainless steel output gas ports carefully matched to the instrument. Gas distribution, pressure and flow control are integral to each TriGas generator and therefore requirements for secondary gas pressure or gas management systems are eliminated.

There is no longer any need to use valuable laboratory floor space to store excess cylinder reserves to protect from running out of gas, late or missed cylinder deliveries, transportation interruptions or periods of tight supply. With a Parker Balston SOURCE LCMS TriGas Generator, you control all your LC/MS gas supplies.

SOURCE LC/MS TriGas Generator Series Model LCMS-5001NTNA

- Supplies pure nitrogen, zero grade air and source exhaust air
- Produced and manufactured by an ISO 9001 registered organization
- Operates continuously 24 hours a day, 7 days a week
- Minimal annual maintenance
- Easy installation and silent operation
- Floor standing
- Listed to U.S. & Canadian safety standards
- Carries CE Marking/Compliant to WEEE standard

Principal Specifications

Model	LCMS-5001NTNA
Curtain gas (nitrogen)	to 10 lpm and 80 psi
Source gas (uhp zero grade air)	to 23 lpm and 110 psi
Exhaust gas (dry air)	to 8 lpm and 60 psi
Air pressure required	85-145 psi (> 100 psi suggested)
Pressure dewpoint	-40°F
Hydrocarbons	<0.1 ppm measured as methane
Particles > 0.01 micron	None
Phthalates	None
Suspended Liquids	None
Inlet	3/8" tube (presto)
Outlets	1/4" tube - stainless steel - 3 each
Dimensions	21"D x 23"W x 41"H
Pressure gauges	3 each
Electrical requirements (1)	120vac, 60Hz, 3 amp
Noise	Silent operation
Weight	157 lbs. (71 kg)

(1) Refer to voltage appendix for electrical and plug configurations for outside North America.

Ordering Information

Model	Description
LCMS-5001NTNA	Source LC/MS Trigas Generator
LCMS-EZLINK	Backup Gas Cylinder Panel
IKLCMS-5000	Installation Kit
LCMS-5001NTNA-PM	Preventive Maintenance Plan
LCMS-5001NT-DN2	Extended Support with 24 Month Warranty
11426-1 (specify length)	1/4" Clear PFA Tubing for Connections to LC/MS

"Using the Parker Balston Tri-Gas system with our new ABI 5500 assures maximum uptime of the instrument while offering us the lowest cost to supply gas...The more samples we run lowers our costs and shortens our overall return on the instrument."

Ed Dabrea
Laboratory Director
Jupiter Environmental Laboratories

SOURCE LC/MS Super Flow TriGas Generator Series Model LCMS-SF5000NA

- Generates pure nitrogen, zero air and source exhaust air from compressed air
- 3 year compressor pump warranty
- Prevents running out of gases during LC/MS instrument operation
- Preserves valuable laboratory space and maximizes LC/MS instrument uptime
- Reliable scroll compressor, quiet 49 dB(A) operation at a safe, low pressure
- Gas purity to 99.999% and no phthalates
- Turnkey system that eliminates stainless steel regulators and gas distribution panels

Model LCMS-SF5000NA

The Parker Balston SOURCE LCMS-SF5000NA Super Flow TriGas Generator is a completely engineered system designed to deliver pure nitrogen for curtain gas, pure zero grade air as gas-1/gas-2 source gases and dry -40°F dew point air as source exhaust. The system is designed to produce gases which meet and exceed the requirements of any LC/MS requiring three independent gases. The system consists of six functional technologies: Coalescing pre-filtration with timed solenoid drains, self regenerating compressed air dehydration membranes, a proprietary heated catalysis module, elegant self-regenerating nitrogen retentate membranes, high capacity - high sensitivity carbon absorption modules and carefully matched final filtration membrane media. These technologies are integrated to a reliable scroll compressor.

The Parker Balston SOURCE LCMS-SF5000NA Super Flow TriGas Generator will provide enough gas for a single LC/MS instrument on a continual basis and will completely eliminate dependence, expense and hassle with using high pressure nitrogen and zero air cylinders.
The generator can be connected easily, be located in the lab, and features independent stainless steel output gas ports carefully matched to the instrument. Gas distribution, pressure and flow control are integral to each TriGas generator and therefore requirements for secondary gas pressure or gas management systems are eliminated.

There is no longer any need to use valuable laboratory floor space to store excess cylinder reserves to protect from running out of gas, late or missed cylinder deliveries, transportation interruptions or periods of tight supply. With a Parker Balston SOURCE LCMS-SF5000NA Super Flow TriGas Generator, you control all your LC/MS gas supplies.

SOURCE LC/MS Super Flow TriGas Generator Series Model LCMS-SF5000NA

- Supplies pure nitrogen, zero grade air and source exhaust air
- Produced and manufactured by an ISO 9001 registered organization
- Operates continuously 24 hours a day, 7 days a week
- Minimal annual maintenance
- Easy installation and whisper quiet operation
- Floor standing on movable casters
- Listed to U.S. & Canadian safety standards
- Carries CE Marking/Compliant to WEEE standard

Principal Specifications

Model	**LCMS-SF5000NA**
Curtain gas (nitrogen)	to 20 lpm and 80 psi
Source gas (uhp zero grade air)	to 46 lpm and 110 psi
Exhaust gas (dry air)	to 16 lpm and 60 psi
Compressor included	Yes - Scroll
Atmospheric dewpoint	-40°F
Hydrocarbons	<0.1 ppm measured as methane
Particles > 0.01 micron	None
Phthalates	None
Suspended liquids	None
Outlets	1/4” tube - stainless steel - 6 each
Dimensions	34”D x 61”W x 43”H
Pressure gauges	6 each
Electrical requirements (1)	120vac, 60Hz, 15 amp and 220vac, 60Hz, 30 amp
Noise level	< 49 dB(A)
Weight	788 lbs. (357 kg)

(1) Refer to voltage appendix for electrical and plug configurations for outside North America.

Ordering Information

Model	**Description**
LCMS-SF5000NA	Source LC/MS Trigas Generator
LCMS-SFEZLINK	Backup Gas Cylinder Panel
IKLCMS-5000	Installation Kit
LCMS-SF5000NA-PM	Preventive Maintenance Plan
A03-0286	Voltage Reducing Transformer
11425-1 (specify length)	3/8” Clear PFA for Remote Compressor Use
11426-1 (specify length)	1/4” Clear PFA Tubing for Connections to LC/MS

SOURCE LC/MS TriGas Generator Series Model LCMS-5001TNA

- Generates pure nitrogen, zero air and source exhaust air from compressed air
- Eliminates costly and inconvenient nitrogen gas and zero air gas cylinders
- Prevents running out of gases during LC/MS instrument operation
- Preserves valuable laboratory space and maximizes LC/MS instrument uptime
- Reliable, silent operation at a safe, low pressure
- Gas purity to 99.999% and no Phthalates
- Turnkey system that eliminates stainless steel regulators and gas distribution panels

Model LCMS-5001TNA

The Parker Balston SOURCE LCMS TriGas Generator is a completely engineered system designed to transform ordinary compressed air into pure nitrogen for curtain gas, pure zero grade air as gas-1/gas-2 source gases and dry -40°F dew point air as source exhaust. The system is designed to produce gases which meet and exceed the requirements of any LC/MS requiring three independent gases. The system consists of six functional technologies: Coalescing pre-filtration with timed solenoid drains, self regenerating compressed air dehydration membranes, a proprietary heated catalysis module, elegant self-regenerating nitrogen retentate membranes, high capacity - high sensitivity carbon absorption modules and carefully matched final filtration membrane media.

The Parker Balston SOURCE LCMS TriGas Generator will provide enough gas for a single LC/MS instrument on a continual basis and will completely eliminate dependence, expense and hassle with using high pressure nitrogen and zero air cylinders.

The generator can connect easily to an existing compressed air supply line and features independent stainless steel output gas ports carefully matched to the instrument. Gas distribution, pressure and flow control are integral to each TriGas generator and therefore requirements for secondary gas pressure or gas management systems are eliminated.

There is no longer any need to use valuable laboratory floor space to store excess cylinder reserves to protect from running out of gas, late or missed cylinder deliveries, transportation interruptions or periods of tight supply. With a Parker Balston SOURCE LCMS TriGas Generator, you control all your LC/MS gas supplies.

SOURCE LC/MS TriGas Generator Series Model LCMS-5001TNA

- Supplies pure nitrogen, zero grade air and source exhaust air
- Produced and manufactured by an ISO 9001 registered organization
- Operates continuously 24 hours a day, 7 days a week
- Minimal annual maintenance
- Easy installation and silent operation
- Floor standing, includes internal economizer air receiver system
- Listed to U.S. & Canadian safety standards
- Carries CE Marking/Compliant to WEEE standard

Principal Specifications

Model	LCMS-5001TNA
Curtain gas (nitrogen)	to 10 lpm and 80 psi
Source gas (uhp zero grade air)	to 23 lpm and 110 psi
Exhaust gas (dry air)	to 8 lpm and 60 psi
Air pressure required	85-145 psi (>100 psi suggested)
Pressure dewpoint	-40°F
Hydrocarbons	<0.1 ppm measured as methane
Particles > 0.01 micron	None
Phthalates	None
Suspended Liquids	None
Inlet	3/8" tubing (presto)
Outlets	1/4" tube - stainless steel - 3 each
Dimensions	25"D x 20"W x 43"H
Pressure gauges	3 each
Electrical requirements (1)	120vac, 60Hz, 3 amp
Noise	Silent operation
Weight	271 lbs (123 kgs)

(1) Refer to voltage appendix for electrical and plug configurations for outside North America.

Ordering Information

Model	Description
LCMS-5001TNA	Source Trigas Generator
LCMS-EZLINK	Backup Gas Cylinder Panel
IKLCMS-5000	Installation Kit
LCMS-5001TNA-PM	Preventive Maintenance Plan
LCMS-5001T-DN2	Extended Support with 24 Month Warranty
11426-1 (specify length)	1/4" Clear PFA Tubing for Connections to LC/MS

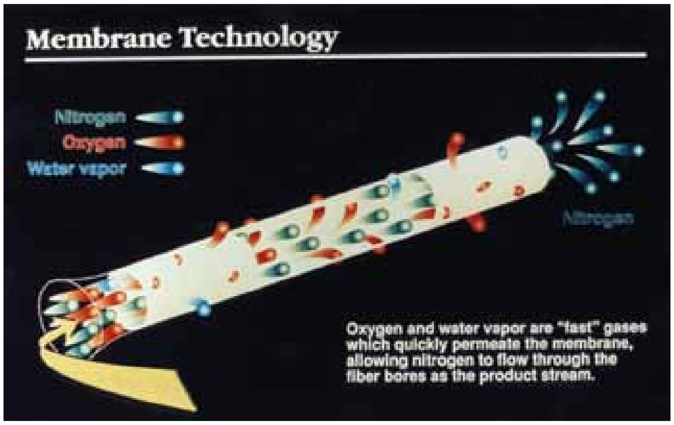
Low and Mid Flow Nitrogen Generators

- Recommended and used by all major LC/MS manufacturers
- Eliminates the need for costly, dangerous, inconvenient nitrogen cylinders in the laboratory
- Models N2-04, N2-14, N2-22, N2-35 require no electricity
- Compact design frees up valuable laboratory floor space
- Phthalate-free, no organic vapors
- Unlike PSA technology, membrane will not suppress corona needle discharge.

Model N2-22 Mid Flow Membrane Nitrogen Generator

Parker Balston® Low Flow Nitrogen Generators include models N2-04, N2-14, N2-14A that produce up to 61 SLPM of compressed nitrogen, on-site. The Parker Balston® Mid-Flow Nitrogen Generators include models N2-22, N2-22ANA, N2-35, and N2-35ANA that produce 132 SLPM of compressed nitrogen, on-site. The purity level of the nitrogen stream is defined by the user, for the application, and may range from 95% to 99.5%.

Low Flow Model N2-14ANA and Mid Flow Models N2-22ANA and N2-35ANA Nitrogen Generators include an oxygen analyzer which monitors the oxygen concentration of the nitrogen stream. An audible alarm signals high or low oxygen concentrations. Parker Balston Nitrogen Generators are complete systems engineered to transform standard compressed air into nitrogen at safe, regulated pressures, on demand, without the need for operator attention. The systems eliminate the need for costly, dangerous dewars and cylinders in the laboratory.



Nitrogen is produced by utilizing a combination of filtration and membrane separation technologies. A high efficiency prefiltration system pretreats the compressed air to remove all contaminants down to 0.01 micron. Hollow fiber membranes subsequently separate the clean air into a concentrated nitrogen output stream and an oxygen enriched permeate stream, which is vented from the system. The combination of these technologies produces a continuous on demand supply of pure nitrogen.

This Technology Features Advanced HiFluxx Fiber!

Typical applications include: LC/MS, nebulizer gas, chemical and solvent evaporation, instrument purge and supply, evaporative light scattering detector use (ELSD), and sparging.

Nitrogen Purity / Flow Chart

Flow measured in SLPM at indicated Operating Pressure, psig. Flows for Model N2-04 printed in black, flows for Models N2-14 and N2-14A in red.

	145		125		110		100		90		80		70		60	
99.5	–	11	–	10	–	9	–	8	–	7	–	6	–	5	–	4
99	6	18	5	16	5	15	4	13	4	11	3	10	3	8	2	7
98	11	29	10	25	9	25	8	20	7	18	6	16	5	13	4	11
97	15	40	13	34	13	33	10	27	9	25	8	21	7	18	6	15
96	20	50	17	43	16	42	13	34	12	31	10	26	9	22	7	19
95	24	60	21	52	20	51	17	42	15	37	13	32	11	28	9	24

Nitrogen Purity / Flow Chart

Flow measured in SLPM at indicated Operating Pressure, psig. Flows for Model N2-22, N2-22A printed in black, flows for Models N2-35, N2-35A in red.

	145		125		110		100		90		80		70		60	
99.5	19	29	16	25	14	22	13	20	12	18	10	16	9	13	17	11
99	29	44	25	37	22	33	20	30	18	27	15	23	13	20	11	17
98	44	66	38	57	34	51	30	46	27	41	24	36	20	30	17	26
97	59	83	50	74	45	65	40	57	36	52	31	46	26	40	23	35
96	73	109	63	94	56	84	50	75	45	67	39	59	32	50	27	42
95	88	131	177	114	69	102	61	90	55	81	48	71	41	60	35	52

Principal Specifications

Models		**N2-04, N2-14, N2-14ANA, N2-22, N2-22ANA, N2-35 and N2-35ANA**
Nitrogen Purity		95.0% - 99.5%
Atmospheric Dewpoint		-58°F (-50°C)
Suspended Liquids		None
Particles > 0.01µm		None
Commercially Sterile		Yes
Phthalate-free		Yes
Hydrocarbon-free		Yes
Min./Max. Operating Pressure		60/145 psig
Max. Press. Drop @ 99% N_2 Purity, 125 psig		10 psig
Recommended Ambient Operating Temperature		68°F (20°C)
Max. Inlet Air Temperature	110°F (43°C)	
Inlet/Outlet Ports		1/4" NPT
Electrical Requirements	N2-04, N2-14, N2-22, N2-35	None
	N2-14ANA, N2-22ANA, N2-35ANA	120 VAC/60 Hz/25 Watts
Shipping Weight	N2-04	42.5 lbs (19 kg)
	N2-14	75 lbs (34 kg)
	N2-14ANA, N2-22, N2-22ANA	80 lbs (36 kg)
	N2-35, N2-35ANA	90 lbs (41 kg)
Oxygen Analyzer		Included with Model N2-14ANA, N2-22ANA, N2-35ANA
Dimensions, N2-04		16.1"h x 10.7"w x 13.4"d (40.9cm x 27.2cm x 34cm)
Dimensions, N2-14, N2-14ANA, N2-22, N2-22ANA, N2-35, N2-35ANA		51.5"h x 18"w x 16.2"d (130.8cm x 45.7cm x 41.1cm)

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Standard Time

Description	Galvanic Cell	Annual Maintenance Kit	Installation Kit	Preventive Maintenance Plan	Extended Support with 24 Month Warranty
N2-04	N/A	MK7840	IK7572	N2-04 -PM	N2-04-DN2
N2-14	N/A	MK7572C	IK7572	N2-14-PM	N2-14-DN2
N2-14ANA	72695A	MK7572C	IK7572	N2-14A-PM	N2-14A-DN2
N2-22, N2-35	N/A	MK7572C	IK7572	N2-22-PM, N2-35-PM	N2-22-DN2, N2-35-DN2
N2-22ANA, N2-35ANA	72695A	MK7572C	IK7572	N2-22A-PM, N2-35A-PM	N2-22A-DN2, N2-35A-DN2

High Flow Nitrogen Generators

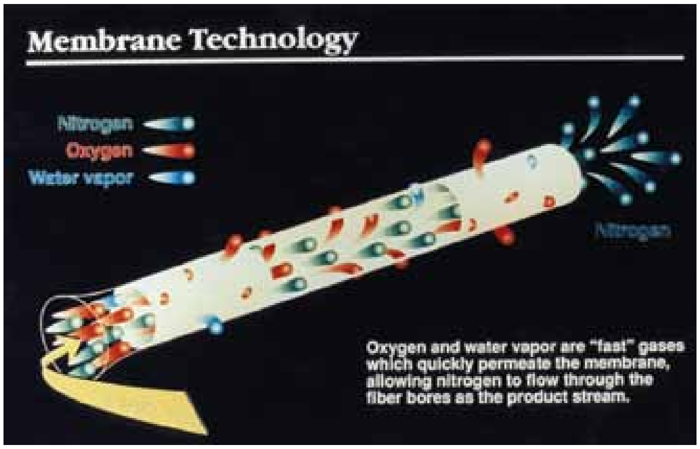
- Recommended and used by all major LC/MS manufacturers
- Eliminates the need for costly, dangerous, inconvenient nitrogen cylinders in the laboratory
- Models N2-45, N2-80, and N2-135 require no electricity
- Compact design frees up valuable laboratory floor space
- Phthalate-free, no organic vapors
- Unlike PSA technology, membrane will not suppress corona needle discharge.

Model N2-135 High Flow Membrane Nitrogen Generator

Parker Balston® High Flow Nitrogen Generators include models N2-45, N2-80, N2-135 that produce up to 467 SLPM of compressed nitrogen, on-site. The purity level of the nitrogen stream is defined by the user, for the application, and may range from 95% to 99.5%.

High Flow Model N2-45ANA, N2-80ANA, and N2 135ANA Nitrogen Generators include an oxygen analyzer which monitors the oxygen concentration of the nitrogen stream. An audible alarm signals high or low oxygen concentrations. Parker Balston Nitrogen Generators are complete systems engineered to transform standard compressed air into nitrogen at safe, regulated pressures, on demand, without the need for operator attention. The systems eliminate the need for costly, dangerous dewars and cylinders in the laboratory.

Nitrogen is produced by utilizing a combination of filtration and membrane separation technologies. A high efficiency prefiltration system pretreats the compressed air to remove all contaminants down to 0.01 micron. Hollow fiber membranes subsequently separate the clean air into a concentrated nitrogen



output stream and an oxygen enriched permeate stream, which is vented from the system. The combination of these technologies produces a continuous on demand supply of pure nitrogen.

Typical applications include: LC/MS, nebulizer gas, chemical and solvent evaporation, instrument purge and supply, evaporative light scattering detector use (ELSD), and sparging.

High Flow Nitrogen Generators

Nitrogen Purity / Flow Chart

Flow LPM (liters per minute), at 68°F (25°C) inlet air temperature and operating pressure, PSIG.
Flows printed in black are for Models N2-45 and N2-45A
Flows printed in red are for Models N2-80 and N2-80A
Flows printed in green are for Models N2-135 and N2-135A

	145			125			110			100			90			80		
99.5	67	100	133	55	83	110	47	71	94	39	59	78	33	50	66	27	41	54
99	92	138	183	74	112	149	63	95	127	53	79	106	44	66	89	35	53	71
98	129	194	258	106	159	212	89	134	179	73	110	147	62	93	124	50	75	101
97	163	244	325	132	198	264	113	169	226	94	141	187	79	119	159	65	97	130
96	200	300	400	160	240	320	137	205	274	114	171	228	97	145	194	80	119	159
95	233	350	467	187	281	374	160	241	321	134	201	268	111	167	222	90	135	180

Principal Specifications

Model		**N2-45, N2-80, N2-135, N2-45ANA, N2-80ANA, and N2-135ANA**
Nitrogen Purity		95.0% - 99.5%
Atmospheric Dewpoint		-58°F (-50°C)
Suspended Liquids		None
Particles > 0.01µm		None
Commercially Sterile		Yes
Phthalate-free		Yes
Hydrocarbon-free		Yes
Min./Max. Operating Pressure		60/145 psig
Max. Press. Drop @ 99% N_2 Purity, 125 psig		10 psig
Recommended Ambient Operating Temperature		72°F (22°C)
Max. Inlet Air Temperature	110°F (43°C)	
Inlet/Outlet Ports		1/2” NPT
Electrical Requirements	N2-45, N2-80, N2-135	None
	N2-45ANA, N2-80ANA, N2-135ANA	120 VAC/60 Hz/25 Watts
Shipping Weight	N2-45, N2-80, N2-135	250 lbs (114 kg)
	N2-45ANA, N2-80ANA, N2-135ANA	250 lbs (114 kg)
Oxygen Analyzer		Included with Model N2-45ANA, N2-80ANA, N2-135ANA
Dimensions		67”h x 24”w x 20”d (140cm x 61cm x 50cm)

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Time

Description	Galvanic Cell	Carbon Tower	Maintenance Kit	Installation Kit	Preventive Maintenance Plan	Extended Support with 24 Month Warranty
N2-45	N/A	75344	75478	IK75880	N2-45-PM	N2-45-DN2
N2-45ANA	72695A	75344	75478	IK75880	N2-45A-PM	N2-45A-DN2
N2-80	N/A	75344	75478	IK75880	N2-80-PM	N2-80-DN2
N2-80ANA	72695A	75344	75478	IK75880	N2-80A-PM	N2-80A-DN2
N2-135	N/A	75344	75478	IK75880	N2-135-PM	N2-135-DN2
N2-135ANA	72695A	75344	75478	IK75880	N2-135A-PM	N2-135A-DN2

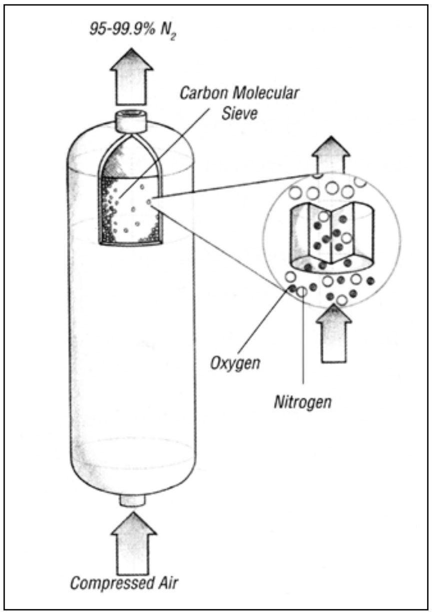
High Flow Nitrogen Generators

- Lower cost...eliminates the need for costly gas cylinders
- Complete package with prefilters, final filters, and receiving tank
- Compact - frees up valuable floor space
- Eliminates unexpected shutdowns due to a “bad” or empty cylinder
- Hassle-free, easy to install, easy to operate
- Safe and reliable

Parker Balston
Dual Bed Nitrogen Generators

Parker Balston® Monobed Nitrogen Generators produce up to 99.95% pure, compressed nitrogen at dewpoints to -70°F (-21°C) from nearly any compressed air supply. The generators are designed to continually transform standard compressed air into nitrogen at safe, regulated pressures without operator attention.

Parker Balston PSA Nitrogen Generators utilize a combination of filtration and pressure swing adsorption technologies. High efficiency prefiltration pretreats the compressed air to remove all contaminants down to 0.1 micron. Air entering the generator consists of 21% oxygen and 78% nitrogen. The gas separation process preferentially adsorbs oxygen over nitrogen using carbon molecular sieve (CMS). At high pressures the CMS has a greater affinity for oxygen, carbon dioxide, and water vapor than it does at low pressures. By raising and lowering the pressure within the CMS bed, all contaminants are captured and released, leaving the CMS unchanged. This process allows the nitrogen to pass through as a product gas at pressure. The depressurization phase of the CMS releases the absorbed oxygen and other contaminant gases to the atmosphere.



The Parker Balston PSA Nitrogen Generators completely eliminate the inconvenience and the high costs of nitrogen Dewars and cylinders. There is no need to depend on outside vendors for your nitrogen gas supplies. The hassles of changing dangerous, high pressure cylinders, and interruption of gas supplies are completely eliminated. The Balston PSA Nitrogen Generators offer long term cost stability eliminating uncontrollable vendor price increases, contract negotiations, long term commitments, and tank rentals. Once the generator is installed, a continuous nitrogen supply of consistent purity is available within minutes from start-up.

High Flow Nitrogen Generators

Installation consists of simply connecting a standard compressed air line to the inlet and connecting the outlet to a nitrogen line. Plug the electrical cord into a wall outlet, and the unit is ready for trouble-free operation. This system is designed to operate 24 hours per day, 7 days per week.

Once the system is operating, it requires little monitoring. The only maintenance involves changing the coalescing prefilter cartridges and final sterile air filter periodically. The PSA towers do not require any maintenance.

An oxygen monitor to measure the oxygen concentration of the nitrogen stream is available as an option. An audible alarm signals high or low oxygen concentrations (determined by the application). The oxygen analyzer is supplied with alarm relay outputs which may be used to signal a remote alarm, open a backup supply or the process stream, or close the process flow for protection of downstream equipment or processes.

Principal Specifications

Model		**AGS200, AGS400**
Nominal Conditions		
Feed Pressure		140 psig
Temperature		80°F
Ambient Pressure		1 Atm.
Compressed Air Specifications		
Maximum Pressure		140 psig
Temperature Range		60°F - 105°F
Dewpoint		40°F pressure dewpoint or better
Residual Oil Content		Trace
Particles		<.01 micron
Ambient Conditions		
Temperature		45°F-90°F
Ambient Pressure		Atmospheric
Air Quality		Clean air without contaminants
Dimensions		28.5"L x 32.25"D x 76.25"H
Weight	AGS200	520 lbs (236 kg)
	AGS400	738 lbs (335 kg)
Inlet		1/2" NPT
Outlet		1/2" NPT

Nitrogen Purity Flow Chart

	Models AGS200 and AGS400	
	Flow Rate (SCFH)	**Flow Rate (SCFH)**
Model	99.9%, 140 psig	99.99%, 140 psig
AGS200	235	47
AGS400	470	94

High Flow Nitrogen Generators

- Lower cost...eliminates the need for costly gas cylinders
- Complete package with prefilters, carbon filter, and membrane filter
- Compact - frees up valuable floor space
- Eliminates unexpected shutdowns due to a “bad” or empty cylinder
- Hassle-free, easy to install, easy to operate
- Safe and reliable
- Expandable modular design

**Parker Balston N2-300
Nitrosource Nitrogen Generator**

Parker Balston® High Flow Nitrosource Nitrogen Generators produce up to 99.5% pure, commercially sterile nitrogen at dewpoints to -58°F (-50°C) from a compressed air supply. All Membrane Nitrogen Generators include a 0.01 micron membrane filter which ensures the nitrogen is completely free of suspended impurities.

Parker Balston High Flow Nitrosource Nitrogen Generators are one of the most effecient membrane systems available with higher recovery rates and lower operating costs than many other membrane systems.

The generators utilize proprietary membrane separation technology. The membrane divides the air into two separate streams: one is 95%-99.5% pure nitrogen, and the other is oxygen rich with carbon dioxide and other trace gases.

The generator separates air into its component gases by passing inexpensive, conventional compressed air through bundles of individual hollow fiber, semi-permeable membranes. Each fiber has a perfectly circular cross section and a uniform bore through its center. Because the fibers are so small, a great many can be packed into a limited space, providing an extremely large membrane surface area that can produce a relatively high volume product stream.

Compressed air is introduced to the center of the fibers at one end of the module and contacts the membrane as it flows through the fiber bores. While oxygen, water vapor and other trace gases permeate the membrane fiber and are discharged through a permeate port, the nitrogen is contained within the hollow fiber membrane, and flows through the outlet port of the module.

Water vapor also permeates through the membrane; therefore, the nitrogen product gas is very dry.

Applications

High thru-put LC/MS contract labs

Sample concentrators

Nitrogen supply to analytical lab

Custom Systems Available

Flow rates to 2,265 lpm

Delivery presssures to customer’s specifications

Skid mounted systems with compressor, receiving tank and controls are available

High Flow Nitrogen Generators

The Parker Balston Nitrosource Nitrogen Generators completely eliminate and inconvenient and the high costs of nitrogen Dewars and cylinders. There is no need to depend on outside vendors for nitrogen gas supplies. The hassles of changing dangerous, high pressure cylinders and interruption of gas supplies are completely eliminated. The Balston Systems offer long term cost stability by eliminating uncontrollable vendor price increases, contract negotiation, long term commitments and tank rentals. Once the generator is installed, a continuous nitrogen supply of consistent purity is available within minutes from start-up.

The Parker Balston Nitrosource Nitrogen Generators are complete systems ready to operate as delivered with carefully matched components engineered for easy installation, operation and long term reliability.

The generators are free-standing and housed in an attractive cabinet. Standard features include: high efficiency coalescing prefilters with automatic drains, an activated carbon filter, and a 0.01 micron membrane final filter. Installation consists of simply connecting a standard compressed air line to the inlet and connecting the outlet to a nitrogen line.

There is no complicated operating procedure to learn or labor intensive monitoring involved. Simply select the purity your process requires, set the flow and pressure, and within minutes high purity, dry nitrogen is available
for use!

Once the system is operating, it requires little monitoring. The only maintenance involves changing the coalescing filter cartridges and activated carbon filter periodically. This is a simple ten minute procedure.

All models also include an oxygen monitor which offers LCD readouts and remote alarm or chart recorder capabilities. An audible alarm signals high or low oxygen concentrations (determined by the application). The oxygen monitor is supplies with alarm relay outputs which may be used to signal a remote alarm, open a backup supply or the process stream, or close the process flow.

Flow Rates (lpm) @ 100 psig, 68°F

Model	99.5%	99%	98%	97%	96%	95%
N2-300	200	311	538	736	935	1133
N2-460	297	467	807	1104	1402	1699
N2-600	396	623	1076	1473	1869	2266

Principal Specifications - Nitrosource Series

Model	N2-300	N2-460	N2-600
Atmospheric Dewpoint	-58°F (-50°C)	-58°F (-50°C)	-58°F (-50°C)
Commercially Sterile	Yes	Yes	Yes
Particles >0.01 micron	None	None	None
Suspended Liquids	None	None	None
Min/Max Operating Pressure	60 psig/145 psig	60 psig/145 psig	60 psig/145 psig
Max Pressure Drop (at 95% N2, 125 psig)	15 psig	15 psig	15 psig
Operating Temperature	70°F (21°C)	70°F (21°C)	70°F (21°C)
Min/Max Inlet Air Temp.	50°F /104°F (10°F /40°F)	50°F /104°F (10°F /40°F)	50°F /104°F (10°F /40°F)
Recommended Inlet Air Temp.	70°F (21°C)	70°F (21°C)	70°F (21°C)
Electrical Requirements	90-250 VAC 50-60 Hz	90-250 VAC 50-60 Hz	90-250 VAC 50-60 Hz
Dimensions	29"W x 31"D x 76"H (74cm x 51cm x 193cm)	29"W x 42"D x 76"H (74cm x 79cm x 193cm)	29"W x 53"D x 76"H (74cm x 107cm x 193cm)
Shipping Weight	660 lbs. (300 kg)	870 lbs. (395 kg)	1,290 lbs. (586 kg)

Laboratory Membrane Air Dryers

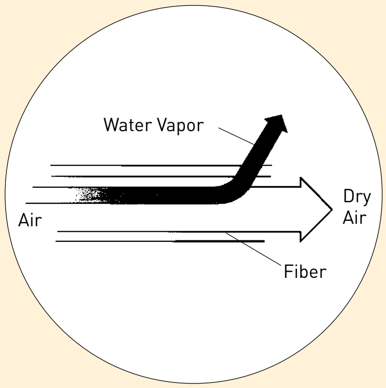
- Low dewpoint instrument air - prevents analytical instrument contamination
- Dry air for hazardous areas
- No electricity required - low operating costs
- No refrigerants or freons - environmentally sound
- Explosion proof
- No moving parts or motors - silent operation

Model 64-02

The Parker Balston® 64-01, 64-02 and 64-10 Membrane Air Dryers will supply oil and particulate free dry compressed air to atmospheric dewpoints as low as -40°F (-40°C), and at flow rates of up to 25 SCFM. Parker Balston Membrane Air Dryers are engineered for easy installation, operation, and long term reliability. The dryers incorporate the highest efficiency membrane available, offering low cost operation and minimal maintenance.

Parker Balston Membrane Air Dryers are designed to operate continuously, 24 hours per day, 7 days per week. The only maintenance required is changing the prefilter cartridge once each year. This annual maintenance takes approximately 5 minutes.

The dryers are lightweight, compact, and can be easily installed on an existing air line. In a vertical or horizontal orientation (depending upon model), a high efficiency coalescing prefilter is installed directly upstream from the dryer module to protect the membrane from potential contamination caused by pipe scale, liquids, or other solids. Parker Balston Membrane Air Dryers require no electrical connections, making them ideal for remote and point-of-use installations or for installation in hazardous areas.



Water vapor quickly permeates the membrane, and is released harmlessly to atmosphere. Air flows along the membrane fiber as a separate product stream.

Laboratory Membrane Air Dryers

Principal Specifications

Membrane Air Dryers	Model	At -40°F Dewpoint (-40°C)	At 32°F Dewpoint (0°C)
Max. Flow Rate (1)	64-01	28 LPM	71 LPM
	64-02	57 LPM	142 LPM
	64-10	283 LPM	708 LPM
Min/Max Inlet Air Temp. (2)		40°F/140°F (4°C/60°C)	
Recommended Operating Temp. Range		60°F-100°F (16°C-38°C)	
Min/Max Inlet Pressure		60 psig/150 psig	
Maximum Pressure Drop		<4 psig	
Wall Mountable		Yes	
Inlet/Outlet Port Size	64-01	1/4" NPT (female)	
	64-02	1/4" NPT (female)	
	64-10	1/2" NPT (female)	
Electrical Requirements	None		
Shipping Weight	64-01	9 lbs. (4 kg)	
	64-02	10 lbs. (5 kg)	
	64-10	18 lbs. (9 kg)	
Dimensions	64-01	6"w x 22"h x 5"d (15cm x 57cm x 13cm)	
	64-02	6"w x 23"h x 5"d (15cm x 112cm x 13cm)	
	64-10	6"w x 37"h x 5"d (15cm x 93cm x 13cm)	

Notes:
1 Dewpoint specified with inlet air at 100°F (38°C) saturated at 100 psig.
2 Inlet compressed air dewpoint must not exceed the ambient air temperature.

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Time

Description		Model Number
Parker Balston Membrane Dryer		64-01, 64-02, 64-10
Annual Maintenance Kit	64-01	MK7601
	64-02	MK7601
	64-10	MK7610
Installation Kit	64-01	IK7572
	64-02	IK7572
	64-10	IK75880
Pressure Regulator	All	72-130-V883
Preventive Maintenance Plan	64-01	64-01-PM
	64-02	64-02-PM
	64-10	64-10-PM
Extended Support with 24 Month Warranty	64-01	64-01-DN2
	64-02	64-02-DN2
	64-10	64-10-DN2

Products for Ultra Dry Air

Ultra Dry Gas Generator

- Supplies ultra-dry, purified compressed air to NMR Spectrometers and other analytical instruments
- Ideal gas supply for spindle and automatic sample changer
- Completely eliminates costly, inconvenient nitrogen dewars - never pay for or change out another dewar
- Compact design frees up valuable laboratory floor space
- Completely automatic - plug it in and forget about it

Model UDA-300NA

The Parker Balston® Model UDA-300NA Compressed Air Dryer provides ultra-dry, purified compressed air to analytical instruments. The model UDA-300 reduces the dewpoint to -100°F (-73°C) without operator attention.

Each system is delivered complete, and ready for easy installation. A high efficiency prefiltration system, automatic drains, a 0.01µm final filter, a moisture indicator, and pretested controls are integral to the design of each dryer.

To install, simply connect your house compressed air supply (at least 60 psig and 1/4 inch pipe) to the dryer inlet port, and connect the dryer outlet port to your instruments. Plug the electrical cord into a wall outlet - no electrician required - and the unit is ready for trouble-free operation.

Designed specifically for NMR instrumentation, the generator is completely automatic, and virtually maintenance free. It is ideal for injecting, spinning, and lifting operations. It is recommended by major NMR instrument manufacturers and is currently installed in several thousand locations.

Principal Specifications

Model UDA-300NA Compressed Air Dryer	
Dew Point	-100°F (-73°C)
Flow Rate at 60 psig	390 scfh (184 lpm)
Flow Rate at 125 psig	720 scfh (340 lpm)
Min/Max Inlet Air Pressure	60 psig/125 psig
Max Inlet Air Temperature (1)	78°F (25°C)
Inlet/Outlet Port Size	1/4" NPT (female)
Electrical Requirements (2)	120 VAC/60 Hz, 10 Watts
Dimensions	41"h x 15"w x 8"d (104cm x 38cm x 20cm)
Shipping Weight	50 lbs (23 kg)

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Time

Description	Model Number
Compressed Air Dryer	UDA-300NA
Inlet Pressure Regulator	72-130-V883
Annual Maintenance Kit	MK7525
Annual Preventive Maintenance Plan	UDA-300-PM
Extended Support with 24 Month Warranty	UDA-300-DN2

Notes:
1 Outlet dew point will increase at higher inlet compressed air temperatures

2 Refer to voltage appendix for electrical and plug configurations outside North America.

Application Notes

TOC Gas Generators

- **Replaces high pressure oxygen or nitrogen gas cylinders with hydrocarbon-free, CO_2-free compressed gas for TOC Analyzers**
- **Ensures consistent, reliable, TOC operation and reduces instrument service and maintenance costs**
- **Compact design frees up valuable laboratory floor space**
- **Purity meets or exceeds all TOC manufacturer's gas purity requirements**
- **Operational display shows system status at a glance**
- **Requires minimal annual maintenance**

Model TOC-625

Model TOC-1250

The Parker Balston® TOC Gas Generators produce carrier/combustion gas, from an existing compressed air supply for TOC instruments, eliminating the need to purchase expensive, inconvenient, high pressure cylinders of air, nitrogen, or oxygen.

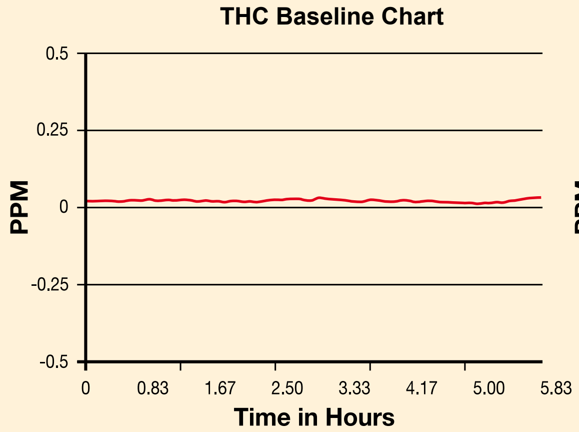
The generators utilize catalytic oxidation and pressure swing adsorption technologies to remove hydrocarbons to 0.05 ppm (measured as methane), CO_2 to 1 ppm, water vapor to 1 ppm, and CO to 1 ppm.

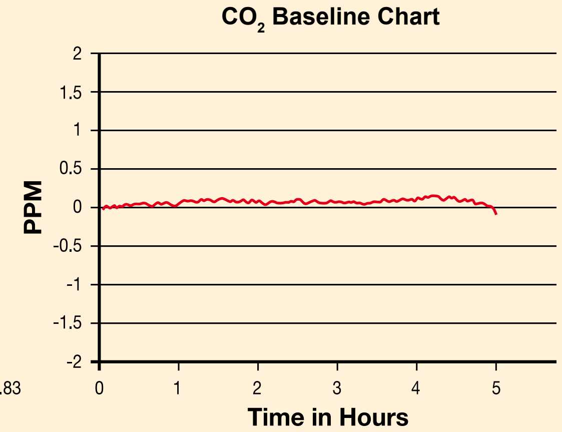
Parker Balston TOC Gas Generators eliminate all the inconveniences and costs of cylinder gas supplies and dependence on outside vendors. Uncontrollable vendor price increases, contract negotiations, long term commitments and tank rentals are no longer a concern. The Parker Balston TOC Gas Generator offers long-term cost stability.

Parker Balston TOC Gas Generators are complete systems with carefully matched components engineered for easy installation, operation, and long term reliability. Installation consists of connecting a standard compressed air line to the inlet and connecting the outlet to the TOC gas supply line. Plug the generator into a standard electrical wall outlet and within minutes high purity carrier/combustion gas is supplied!

TOC Gas Generator

Baseline Supplied by a Parker Balston TOC Gas Generator





Baselines of THC Analyzer (above) and CO_2 Content Analyzer (right) after 5 hours supplied by a Parker Balston® TOC Gas Generator.

Principal Specifications

TOC Gas Generator	Model TOC-625	Model TOC-1250
Max. TOC Gas Flow Rate (outlet) at 100 psig	0.625 lpm (650 cc/min)	1.25 lpm (1,250 cc/min)
Outlet Hydrocarbon Concentration (as methane)	< 0.05 ppm	0.1 ppm
Outlet CO_2 Concentration	< 1 ppm	< 1 ppm
Outlet CO Concentration	< 1 ppm	< 1 ppm
Dewpoint	< -100°F (-73°C)	< -100°F (-73°C)
Inlet and Outlet Port Connections	1/4" NPT (female)	1/4" NPT (female)
Min/Max Inlet Air Pressure	60 psig/125 psig	65 psig/125 psig
Max Inlet Air Temperature	78°F (25°C)	78°F (25°C)
Min Required Inlet Air Flow at 100 psig	2.0 lpm (2,000 cc/min)	2.5 lpm (2,500 cc/min)
Max Inlet Hydrocarbon Concentration (as methane)	100 ppm	100 ppm
Pressure Drop at Maximum Flow Rate	7 psig	7 psig
Warm-up Time	30 minutes	45 minutes
Electrical Requirements (1)	120VAC/60 Hz, 2.0 Amps.	120VAC/60 Hz, 2.0 Amps.
Dimensions	9"w x 12.5"h x 16"d (23 cm x 32 cm x 41 cm)	11"w x 17"h x 17"d (28 cm x 43 cm x 43 cm)
Shipping Weight	34 lbs. (15.42 kg)	48 lbs. (22 kg)

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Time

Description	Model Number	Model Number
TOC Gas Generator	TOC-625	TOC-1250
Maintenance Kit @ 12 months	MKTOC625-12	MK7840
Maintenance Kit @ 36 months	MKTOC625-36	Consult Factory
Installation Kit	IK76803	IK76803
Preventive Maintenance Plan	TOC-625-PM	TOC-1250-PM
Extended Support with 24 Month Warranty	TOC-625-DN2	TOC-1250-DN2

(1) Refer to voltage appendix for electrical and plug configurations for outside North America.

Nitrogen Generators for TOC

- Produces a continuous supply of high purity nitrogen gas from existing compressed air
- Eliminates the need for costly, dangerous, inconvenient nitrogen cylinders in the laboratory
- Ideal for all combustion, UV persulfate, and wet oxidation sampling techniques
- Compact design frees up valuable laboratory floor space
- Offers long term cost stability - uncontrollable vendor price increases, contract negotiations, long term commitments and tank rentals are no longer a concern

Model HPN2-1100

The Parker Balston® Models HPN2-1100 and UHPN2-1100 Nitrogen Generators can produce up to 1.1 lpm of ultra high purity nitrogen gas. These systems are completely engineered to transform standard compressed air into 99.9999% nitrogen, exceeding the specification of UHP cylinder gas.

Nitrogen is produced by utilizing a combination of state-of-the art purification technologies and high efficiency filtration. The Model HPN2-2000 can produce up to 2 lpm of 99.99% pure nitrogen gas from standard compressed air.

Pressure swing adsorption removes O_2, CO_2, and water vapor. A catalyst module is incorporated in the UHPN2-1100 to oxidize hydrocarbons from the inlet air supply. The generators also have high efficiency coalescing prefilters and a 0.01 micron (absolute) membrane filter incorporated into their design.

The Parker Balston UHP Nitrogen Generators are engineered and packaged in a small cabinet to fit nearly any benchtop. The systems eliminate the need for costly, inconvenient high pressure nitrogen cylinders. The HPN2-1100 and UHPN2-1100 are ideal for TOC carrier gas and purge applications.

Flow Chart

Inlet Air Pressure (psig)	**Max Outlet Flow** (cc/min.)	**Max Outlet Pressure** (psig)
Models HPN2-1100, UHPN2-1100		
125	1100	85
110	1000	75
100	900	65
90	800	60
80	700	50
70	600	45
60	500	35

Nitrogen Generators for TOC

Principal Specifications

Model	HPN2-1100, UHPN2-1100	HPN2-2000
Max Nitrogen flow rate	See Flow Table	2 lpm
Nitrogen Purity	99.9999%	99.99%
Max Nitrogen output pressure	See Table	90 psig
CO Concentration	< 1 ppm	NA
CO_2 Concentration	< 1 ppm	< 1 ppm
O_2 Concentration	< 1 ppm	< 100 ppm
H_2O Concentration	< 1 ppm	< 1 ppm
Hydrocarbon concentration (1)	< 0.1 ppm	NA
Argon Concentration (2)	0.9%	0.9%
Min/Max Inlet Pressure	60 psig/125 psig	75 psig/120 psig
Recommended Inlet Temperature	78°F (25°C)	78°F (25°C)
Ambient Operating Temperature	60°F-100°F (16°C-38°C)	60°F-100°F (16°C-38°C)
Max Air Consumption	42 lpm (1.5 scfm)	42 lpm (1.5 scfm)
Inlet Connection	1/4" NPT (female)	1/4" NPT (female)
Outlet Connection	1/8" NPT (female)	1/8" NPT (female)
Electrical Requirements (3,4)	120 VAC/60 Hz	120 VAC/60 Hz
Dimensions	12" w x 16" d x 35" h (31cm x 41cm x 89cm)	12" w x 16" d x 35" h (31cm x 41cm x 89cm)
Shipping Weight	110 lbs. (50 kg)	110 lbs. (50 kg)

Notes:
1 Model HPN2-1100 does not remove hydrocarbons and carbon monoxide

2 Purity specification for Nitrogen does not include Argon concentration.

3 Power Consumption is as follows:
Model HPN2-1100 = 25 Watts,
Model UHPN2-1100 = 700 Watts,
Model HPN2-2000 = 25 Watts.

4 Refer to voltage appendix for electrical and plug configurations for outside North America.

Ordering Information call 800-343-4048, 8 to 5 EST

Description	Model Numbers
High Purity Nitrogen Generator	HPN2-1100, HPN2-2000
Ultra High Purity Nitrogen Generator	UHPN2-1100
Purity Indicator/Scrubber	72092
Optional Prefilter System	2002N-1B1-DX
Maintenance Kit	MK7692*, MK7694
Installation Kit for all Models	IK7694
Preventive Maintenance Plan	HPN2-1100-PM, UHPN2-1100-PM, HPN2-2000-PM
Extended Support with 24 Month Warranty	HPN2-1100-DN2, UHPN2-1100-DN2, HPN2-2000-DN2

*For Model HPN2-1100

Atomic Absorption Gas Purifier

- Designed specifically for AA Instrumentation
- Protects microcomputer gas controls and burner system
- Ensures a clean, contaminant-free flame
- Ensures consistent quality of compressed air oxidant and fuel gas
- Convenient, turnkey system
- Services a single AA

Model 73-100 AA Gas Purifier

The Parker Balston® AA Gas Purifier is a completely engineered, wall mountable system designed to purify gases commonly used with Atomic Absorption Spectrophotometers. The Purifier consists of two independent filtration systems. The first system is designed to purify the compressed air (oxidant) with two stages of high efficiency coalescing filtration. These filters will remove all oil, water, and particulate matter down to 0.01 micron.

The second filtration system is designed to purify the acetylene gas. This system removes liquid acetone and solid particulate from the gas. The 73-100 protects the microcomputer gas controls and AA burner assembly from contamination and corrosion. In addition, the acetylene filter has an integral flashback arrestor, meeting all OSHA requirements, to enhance the safe operation of the spectrophotometer.

Principal Specifications

Model 73-100 Atomic Absorption Gas Purifier	
Compressed Air Inlet/Outlet	1/4" NPT (female)
Recommended Inlet Air Temperature	< 78°F (26°C)
Min/Max Inlet Pressure (compressed air)	15 psig/125 psig
Acetylene Inlet/Outlet	9/16 - 18 LH ("B" size)
Max Inlet Pressure (acetylene)	15 psig max. working pressure
Ambient Operating Temperature	40°F - 100°F (4°C - 38°C)
Dimensions	11" w x 8" d x 10" h (28cm x20cm x 25cm)
Shipping Weight	10 lbs (4.5 kg)

Ordering Information for assistance, call 800-343-4048, 8 to 5 Eastern Time

Description	Model Number
Atomic Absorption Gas Purifier	73-100
73-100 Service Kit (contains one year supply of all replacement filter cartridges)	73065
Acetylene Hose Assembly (6 feet in length)	19257

Application Notes

Recommended Gas Generators for Analytical Instruments

Instrument	Gas Requirements	Gas Purity Requirements	Flow Rates	Generator Recommendation/ Model
Atomic Absorption (AA) with Flame	Air for Oxidant Gas	Clean, Dry	1-7 SCFM	**AA Gas Purifier** (Model 73-100)
Atomic Thermal Desorber	Zero Air	Clean, Dry, Hydrocarbon-free	Up to 1600 ml/min.	**Zero Air or TOC Gas Generator** (HPZA-3500 or TOC-1250)
	Hydrogen for FID Fuel	Clean, Dry,High Purity	Up to 40 ml/min. per FID	**Hydrogen Generator** (H2PEM-100, H2PEM-165) (H2PEM-260, H2PEM-510)
Atmospheric Pressure Ionization (API-MS)	Air for Nebulizer Gas	Clean, Dry, Hydrocarbon-free	< 30 LPM	**Zero Air Generator** (HPZA-30000)
	Nitrogen for Curtain, Sheath, and Shield gas	99% or higher	< 20 LPM	**Nitrogen Generator** (N2-14, N2-22, N2-35, NitroFlowLab)
Autosamplers for Various Instruments	Air for Pneumatic Controls	Clean, Dry	< 1 SCFM	**Membrane Air Dryer** (64-02)
	Nitrogen for Sample Injector	Ultra High Purity	< 550 cc/min	**UHP Nitrogen Generator** (HPN2-1100) (UHPN2-1100)
CO_2 Analyzers	Calibration Air	CO_2-free	0.5-1.0 SLPM	**FT-IR Purge Gas Generator** (75-45NA, 75-52NA)
Continuous Emissions Monitoring (CEM)	Calibration Air Dilution Air	Dry, CO_2, SO_2, NO_x, Hydrocarbon-free	10-15 SLPM	**CEM Zero Air Generator** (75-45-M744)
Emissions Analyzers	Zero Air	Hydrocarbon-free	2-15 SLPM	**Zero Air Generator** (HPZA-18000)
Fourier Transform Infrared Spectrometer (FT-IR)	Air for Sample Compartment, Optics, and/or Air-Bearing Components	Clean, Dry, CO_2-free	0.3-3 SCFM	**FT-IR Purge Gas Generator** (75-62NA, 75-52NA, 75-45NA) **Lab Gas Generator** (74-5041NA)
Gas Chromatograph (GC) GC-FID	Zero Air as Flame Support Air	Clean, Hydrocarbon-free	150-600 cc/min.	**Zero Air Generator** (HPZA-3500)
	Hydrogen as Flame Fuel Gas	Ultra High Purity	30-40 cc/min.	**Hydrogen Generator** (H2PEM-260)
	Hydrogen as Capillary Carrier Gas	Ultra High Purity	Varies	**Hydrogen Generator** (H2PD-300)
	Nitrogen as Packed Carrier Gas	Ultra High Purity, Zero Grade	Varies	**UHP Nitrogen Generator** (UHPN2-1100)
	Nitrogen as Make up Gas	Ultra High Purity, Zero Grade	<100 cc/min	**UHP Nitrogen Generator** (UHPN2-1100)
GC-FPD	Zero Air as Flame Support Air	Clean, Hydrocarbon-free	<200 cc/min	**Zero Air Generator** (HPZA-3500)
	Hydrogen as Flame Fuel Gas	Ultra High Purity	50-70 cc/min	**Hydrogen Generator** (H2PEM-260)
	Hydrogen as Capillary Carrier Gas	Ultra High Purity	Varies	**Hydrogen Generator** (H2-1200)
	Nitrogen as Packed Carrier Gas	Ultra High Purity	Varies	**UHP Nitrogen Generator** (UHPN2-1100)
GC-NPD	Zero Air to Rubidium/Thermonic Bead	Dry, Clean, Hydrocarbon-Free	60-200 cc/min.	**Zero Air Generator** (HPZA-3500)
	Hydrogen as Detector Support Gas	Ultra High Purity	<10 cc/min	**Hydrogen Generator** (H2PEM-100)
	Hydrogen as Capillary Carrier Gas	Ultra High Purity	Varies	**Hydrogen Generator (Palladium)** (H2PD-300)
	Nitrogen as Packed Carrier Gas	Ultra High Purity	Varies	**UHP Nitrogen Generator** (UHPN2-1100)

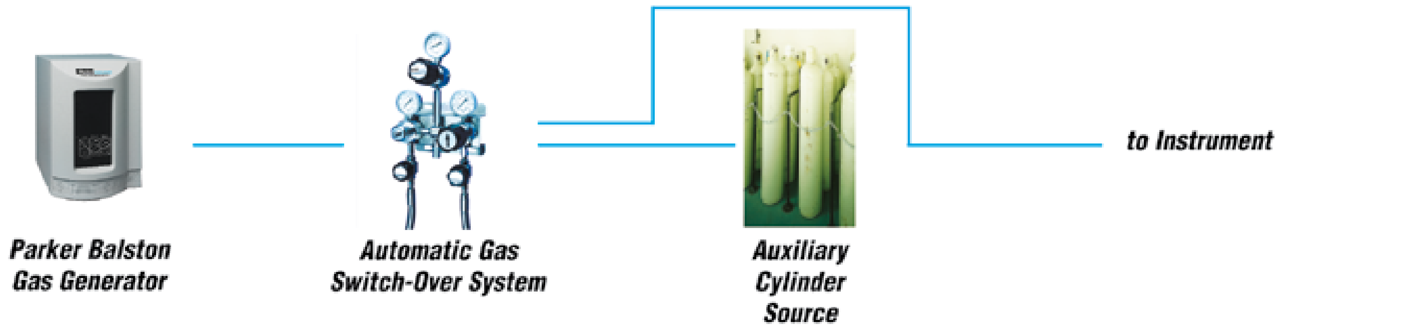
Recommended Gas Generators for Analytical Instruments

Instrument	Gas Requirements	Gas Purity Requirements	Flow Rates	Generator Recommendation/ Model
GC-ECD	Nitrogen as Carrier Gas	Ultra High Purity, Zero Grade	Varies	**UHP Nitrogen Generator** (UHPN2-1100)
	Nitrogen as Make up Gas	Ultra High Purity, Zero Grade	<100 cc/min	**UHP Nitrogen Generator** (UHPN2-1100)
GC-ELCD, HALL	Hydrogen as Reaction Gas	Ultra High Purity	70-200 cc/min	**Hydrogen Generator** (H2PD-300)
GC-TCD	Hydrogen as Carrier & Reference Gas	Ultra High Purity	Varies	**Hydrogen Generator** (H2PD-300)
LC/MS	Nitrogen as a Curtain Gas	LC/MS Grade	3-30 lpm	**Nitrogen Generator** (N2-14, N2-14ANA, NitroFlowLab) (N2-35, N2-35ANA)
ICP Spectrometer	Nitrogen as Optic/Camera Purge	Ultra High Purity	<1-5 lpm	**Nitrogen Generator** (76-97NA, 76-98NA)
Nuclear Magnetic Resonance (NMR)	Air for Lifting, Spinning	Clean, Dry	<10 SCFM	**Air Dryer** (UDA-300NA) **Lab Gas Generator** (74-5041NA)
Ozone Generator	Supply Air	Clean, Dry	.3-20 SCFM	**Air Dryer** (64-01, 64-02, 64-10, UDA-300NA)
Protein Analyzer	Dry Air, Nitrogen	Clean, Dry	40 psig	**Nitrogen Generator** (N2-14, N2-22, NitroFlowLab, N2-35)
Solvent Evaporators (Sample Concentrators)	Nitrogen	Clean, Dry Nitrogen	Up to 5 SCFM	**Nitrogen Generator** (Nitrovap-1LV, Nitrovap-2LV)
Stack Gas Sampler	Dilution Air	Clean, Dry	<1.0 SCFM	**CEM Zero Air Generator** (75-45-M744)
Total Oxygen Demand (TOD)	Nitrogen Carrier Gas	Ultra High Purity	300 cc/min	**Nitrogen Generator** (UHPN2-1100)
Thermal Gravametric Analyzer (TGA)	Nitrogen as Furnace Purge	Clean, Dry, Inert	<100 cc/min	**Nitrogen Generator** (UHPN2-1100)
Differential Scanning Calorimeter (DSC)	Air for Air Shield	Clean, Dry	<100 cc/min	**Dry Air Generator** (64-01, UDA-300)
Total Hydrocarbon Analyzer (THA)	Zero Air for FID	Clean, Hydrocarbon-Free	50-500 cc/min	**Zero Air Generator** (75-82S, 75-83NA)
	Hydrogen as Flame Fuel Gas	Ultra High Purity	5-50 cc/min	**Hydrogen Generator** (H2PEM-100)
Total Organic Carbon Analyzer (TOC)	Dry Air or Nitrogen for Carrier Gas or Combustion Gas	Clean, Dry, Hydrocarbon-Free CO2-Free	100-500 SLPM	**TOC Gas Generator** (TOC-625, TOC-1250)
		Ultra High Purity	50-700 cc/min	**UHP Nitrogen Generator** (UHPN2-1100)

Installation Schematic

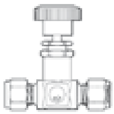
TOC Gas Generator

Automatic Gas Switch-Over System



Zero Air Generator

Ultra High Purity Nitrogen Generator



Needle Valve

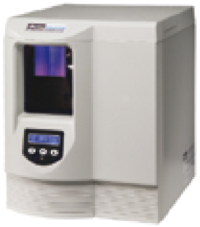
WFM Series Flowmeter

Gas Receiving Tank Model 72-007

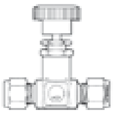
to Instrument

Hydrogen Generator

72-230 DI Water Purifier

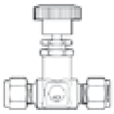


Parker Balston Hydrogen Generator

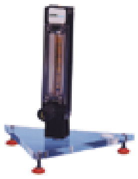


Needle Valve

to Instrument

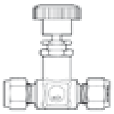


Needle Valve

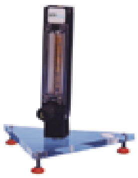


WFM Series Flowmeter

to Instrument



Needle Valve



WFM Series Flowmeter

to Instrument

Basic Lab Compressor

- Ideal for Parker Balston® Gas Generators
- Pressure Switch
- Manual Drain
- Pressure Safety Valve (ASME)
- Pressure Gauge
- Unloading Capability
- Globe Valve
- 100% Oil-less Operation
- Only Minutes to Install

Gast® Model 2HAH-92T-M200X Compressor

The Gast® Compressor is for locations without a compressed air supply or low pressure supply. This quality product is in stock and available for immediate delivery along with your Parker Balston Gas Generator. This product is fully supported and serviced exclusively by Gast® Manufacturing Corporation. It is ideal for use with smaller Parker Balston Gas Generators only.

Principal Specifications

Model 2HAH-92T-M200X	
Tank Size	2 Gallons (7.5 liters)
Output Pressure	Output Flow
@ 0 psig	1.65 CFM
@ 10 psig	1.55 CFM
@ 30 psig	1.30 CFM
@ 50 psig	1.15 CFM
@ 70 psig	1.00 CFM
@ 90 psig	.90 CFM
Noise Level @ Full Flow	65 dBa @ 3 ft.
Standard Pressure Settings - ON/OFF	70 psig / 90 psig
Pressurization Time (0 psig to set pressure)	1min. 30 sec.
Recovery Time (to set pressure)	24 sec.
Motor Specifications	115 VAC/60 Hz, 1/4 hp
Dimensions	18"w x 18"h x 5"d (46 cm x 46 cm x 13 cm)
Shipping Weight	56 lbs. (25 kg)

Ordering Information

Description	Model Number
Gast Compressor	2HAH-92T-M200X
Automatic Drain Valve	20-440

High Output Oil-Free Piston Compressor

- 100% Oil-Free Air
- Air to Air Heat Exchanger
- Integral 50 Liter Receiver Tank & Electronic Tank Drain
- Single Stage Motor
- Power Cord Included
- Quiet Operation
- 24-hour Continuous Duty Applications
- Approved for smaller Parker Balston Gas Generators

Model 8115410931 Compressor

Parker has teamed with Atlas Copco to offer the latest innovation in high output piston compression technology. The **8115 Series** compressor offers a quiet, compact, high quality source of oil-free compressed air. Each **8115 Series** compressor is totally pre-piped and wired for easy and economical installation. Along with quiet operation, each compressor is simple to use, low-vibration and requires virtually no preventative maintenance. **Full service and warranty are provided exclusively from Atlas Copco. Each compressor includes Atlas Copco "Certified Start-up Assistance Service" as standard.**

Principal Specifications

Model 8115410931	
Motor HP (3)	1.5
Flow and Pressure (1)	up to 5.06 CFM and to 116 psig
Sound Level (dBA) (2)	62
Standard Voltage (4)	115VAC, 60Hz, 20 Amp
Dimensions	33"w x 36"h x 14"d (84 cm x 91 cm x 36 cm)
Net Weight	143 lbs. (65 kg)

1 Unit performance measured according to Pneurop/CAGIPN2CPTC2
2 Maximum noise level measured at a distance of 3 ft. according to Pneurop/CAGIPN8NTC2 test code
3 Unit includes 3' power cord with NEMA class plug
4 Use Model 8115410196 for 230 VAC 50 Hz locations

Ordering Information

Model/Series	Use on Gas Generators
8115410931	64-01, 75-45, 75-52, N2-04, HPN2-1100, UHPN2-1100, HPN2-2000, TOC-625, TOC-1250, HPZA-3500, HPZA-7000, HPZA-18000, HPZA-30000, MGG-400, MGG-2500

Rotary Scroll Compressors

- 100% Oil Free Air
- 35-39°F External Refrigerant Air Dryer
- Air Cooled, Fully Packaged
- Single Stage Motor
- High Efficiency
- Whisper Quiet Operation
- 24-hour Continuous Duty Applications
- Approved for all Parker Balston Gas Generators

SE Series

Parker's Balston operation has teamed with Powerex to offer the latest innovation in scroll compressor technology. The SE Series compressors offer a lubrication free compression chamber that eliminates the possibility of oil carryover into the compressed air. Each compressor configuration is carefully matched for easy installation. Simply select your desired compressor from the side table and order from Parker. **Full service and warranty are provided exclusively from Powerex. Each compressor includes Powerex "Certified Start-up Assistance Service*" as standard.**

Principal Specifications

	SES03 [3]	SES05 [4]	SED10 [4]	SET15 [5]	SEQ20 [5]
Motor HP	3	5	10	15	20
Capacity CFM [1] @ 145 psig	7.1	12.5	24.2	36.3	48.4
Sound Level (dBA) [2]	49	51	53	53	53
Net Weight (lbs.)	309	359	582	970	1,213

1 Unit performance measured according to Pneurop/CAGIPN2CPTC2
2 Maximum noise level measured at a distance of 3 ft. according to Pneurop/CAGIPN8NTC2 test code
3 Unit includes comprehensive full-featured phenol coated external 30-gallon receiver tank
4 Unit includes comprehensive full-featured phenol coated external 60-gallon receiver tank
5 Unit includes comprehensive full-featured phenol coated external 80-gallon receiver tank

Ordering Information

Model/ Series	Dimensions	Specify Desired Voltage**	Use on Gas Generator
SES03	25"W x 24"D x 39"H	200VAC, 230VAC or 460VAC	76-97, 76-98, 75-62, N2-14, N2-14ANA
SES05	25"W x 24"D x 39"H	200VAC, 230VAC or 460VAC	N2-22, N2-22ANA
SED10	26"W x 38"D x 47"H	200VAC, 230VAC or 460VAC	N2-35, N2-35ANA, N2-45, N2-45ANA
SET15	26"W x 38"D x 47"H	200VAC, 230VAC or 460VAC	N2-80, N2-80ANA
SEQ20	26"W x 38"D x 61"H	200VAC, 230VAC or 460VAC	N2-135, N2-135ANA

* "Certified Start-up Assistance" excludes electrical supply work, due to local code restrictions. Electrician may be required.
** Contact Parker Technical Services or your local representative for exact part number suffix prior to ordering. 800-343-4048.

HydroGen Mate™ DI Water System

- Economical means of providing deionized water to hydrogen generators
- Minimal maintenance
- Visual indication for cartridge changes
- Easy fill dispensing gun
- Removal of organics, phosphates, chlorine, and all ionizable constituents from water supply
- No electrical requirements

Parker Balston® Model 72-230
HydroGen Mate™ DI Water System

Analytical Gas Supplies

The Parker Balston® HydroGen Mate™ DI Water System is specifically designed to provide high purity deionized water to all models of Parker Balston hydrogen generators. The system is ready to install and is shipped complete with prefiltration, two DI resin exchange cartridges, dispensing gun, and a final filter.

The only required maintenance on the system is to change out the resin exchange cartridges and to replace the filter cartridges as needed.

Principal Specifications

Model 72-230 and 72-231 DI Water Systems**	
Maximum Flow Rate	1 lpm
Water Inlet	1/4" "Push to connect"
Maximum Water Supply Pressure	50 psig
Maximum Water Supply Temperature	80°F (27°C)
Physical Dimensions	12"w x 18"h x 3"d (30 cm x 46 cm x 8 cm)
Shipping Weight	12 lbs. (5.5 kg)

Ordering Information

Description	**Model Number**
Complete DI Water System	72-230, 72-231
Cartridge Kit*	72236

* Includes 2 each resin exchange cartridges, 1 each prefilter and 1 each final filter.

**Model 72-231 does not include dispensing gun and connects directly to generator automatic water feed port.

Gas Receiving Tanks

- External powder-coat finish eliminates rust and contamination
- Internal primer eliminates particle shedding and vapor out-gassing
- Convenient mounting brackets for floor or wall placement
- Smoothes out gas pressure fluctuations
- Reduces duty cycle on compressors

Parker Balston® Models 72-007 and 72-012 Receiving Tanks

The Parker Balston® Gas Receiving tanks are highly recommended for supplying gas to pressure sensitive instrumentation, for the storage of compressed nitrogen from nitrogen generators, and for other instruments requiring an occasional high flow burst of compressed gas in excess of the normal capacity of a Parker Balston Gas Generator.

Three models of gas receivers are available. The Model 72-007 has a maximum pressure rating of 240 psig. At 240 psig, the 72-007 will hold approximately 1.7 scf (50 liters) of compressed gas. The model 72-012 has a maximum pressure rating of 125 psig. At 125 psig, the 72-012 will hold approximately 15 SCF (430 liters) of compressed gas. The IK7698C model will hold over (1,075 liters) of compressed gas.

Principal Specifications

	Model 72-007	Model 72-012	Model IK7698C*
Material of Construction	3003 Aluminum	Carbon steel	Carbon steel
Capacity at Atmospheric Pressure	0.75 gallons (2.8 liters)	12 gallons (45 liters)	30 gallons (136 liters)
Max. Temperature	130°F (54°C)	130°F (54°C)	130°F (54°C)
Max. Pressure at Max. Temperature	240 psig	125 psig	125 psig
Inlet/Outlet Ports	1/8” NPT (female)	1/4” NPT (female)	3/8” Tubing Included
Dimensions	18” w x 5” h (45 cm x 12 cm)	26”w X 13”h (66 cm x 33 cm)	16”w X 40”h (41 cm x 102 cm)
Shipping Weight	4 lbs (1.8 kg)	42 lbs (19 kg)	109 lbs (49.4 kg)

Ordering Information

Description	Model Number		
Gas Receiving Tank	72-007	72-012	IK7698C*

* Includes 30 gallon receiver, pressure regulator, gauge, and fittings.

Gas Cylinder Regulators

- Unique patented compression member loads the seal to the body without requiring a threaded nozzle or additional seals to atmosphere
- Internally threadless seat design to promote long seat life
- Positive upward and downward diaphragm stops increasing cycle life by preventing over stroking of the diaphragm
- Captured bonnet allows for safety venting
- Unique carrier design disperses gas uniformly through the regulator to improve purging

Parker Balston® Models 402 and 422 Gas Cylinder Regulators

Analytical Gas Supplies

Parker Balston® offers a range of pressure control accessories to include high-pressure cylinder gas regulators. Use stainless steel for critical detection limits and brass for less demanding applications. These regulators provide stable flow over wide temperature ranges and are suited as primary pressure control. Select the 402 series for noncorrosive, less demanding applications or the 422 series for ultra high purity (UHP) requirements.

Principal Specifications

	Model 402	**Model 422**
Maximum Inlet Pressure	3000 psig (210 bar)	3000 psig (210 bar)
Temperature Range	-40°F to 140°F (-40°C to 60°C)	-40°F to 140°F (-40°C to 60°C)
Pressure Control Range	0-250 psig (0-17bar)	0-250 psig (0-17bar)
Material of Construction		
Body	Brass barstock	316L SS barstock
Bonnet	Brass barstock	Chromplated brass barstock
Seat	PTFE	PTFE
Filter	10 µm sintered bronze	10 µm sintered SS
Diaphragm	316L SS	316L SS
Internal Seals	PTFE	PTFE
Gages	2” dia. brass	2” dia. SS
Ports	1/8” Tube fitting	1/8” Tube fitting
Helium Leak Integrity	$1*10^{-9}$ scc/sec	$1*10^{-9}$ scc/sec
CV	0.1 (50 psig)	0.1 (50 psig)

Ordering Information

Less Demanding Applications

W-402-4332-350 Hydrogen Cylinders
W-402-4332-580 Argon, Helium, Nitrogen Cylinders
W-402-4332-590 All Air Cylinders

Critical Applications (UHP)

W-422-4332-350 Hydrogen Cylinders
W-422-4332-580 Argon, Helium, Nitrogen Cylinders
W-422-4332-590 All Air Cylinders

In-Line Gas Regulators

- Unique patented compression member loads the seal to the body without requiring a threaded nozzle or additional seals to atmosphere
- Internally threadless seat design to promote long seat life
- Positive upward and downward diaphragm stops increases cycle life by preventing over stroking of the diaphragm
- Captured bonnet allows for safety venting
- Unique carrier design disperses gas uniformly through the regulator to improve purging

Parker Balston® Models 405 and 425 In-Line Gas Regulators

Parker Balston® In-Line Gas Regulators are suitable for pressure control with all Parker Balston gas generators and as secondary control for high-pressure gas cylinders and bulk gas systems. Use stainless steel for critical detection limits and brass for less demanding applications. Parker Balston regulators provide stable flow over wide temperature ranges. Select the 405 series for noncorrosive, less demanding applications and the 425 series for ultra high purity (UHP) requirements.

Principal Specifications

	Model 405	Model 425
Maximum Inlet Pressure	3000 psig (210 bar)	3000 psig (210 bar)
Temperature Range	-40°F to 140°F (-40°C to 60°C)	-40°F to 140°F (-40°C to 60°C)
Pressure Control Range	0-250 psig (0-17 bar)	0-250 psig (0-17 bar)
Material of Construction		
Body	Brass barstock	316 SS barstock
Bonnet	Brass barstock	Chromplated brass barstock
Seat	PTFE	PTFE
Filter	10 µm sintered bronze	10 µm sintered SS
Diaphragm	316L SS	316SS
Internal Seals	PTFE	PTFE
Gages	2” dia. brass	2” dia. SS
Ports	1/4” FNPT to 1/8” Tube fitting	1/4” FNPT to 1/8” Tube fitting
Helium Leak Integrity	$1*10^{-9}$ scc/sec	$1*10^{-9}$ scc/sec
CV	0.1 (50 psig)	0.1 (50 psig)
Shipping Weight	2.25 lbs. (1.05 kg)	2.25 lbs. (1.05 kg)

Ordering Information

Less Demanding Applications

W-405-4032-000 Air, Argon, Helium, Hydrogen, Nitrogen

Critical Applications (UHP)

W-425-4032-000 Air, Argon, Helium, Hydrogen, Nitrogen

In-Line Gas Regulators

- Oversized connection ports minimize pressure settings
- Convenient user-friendly pressure control range from 10 to 130 psig
- Bolt down regulator adjustment handle locks pressure settings, maximizes tampering
- Ideal for regulating inlet compressed air pressure to Parker Balston Gas Generators

Parker Balston® Model 72-130-V883 In-Line Regulator

Parker Balston® High Flow Rate In-Line Gas Regulators are suitable as primary inlet pressure control to all compressed air supplied gas generators. They are ideal for use with high-output nitrogen generators as models N2-45, N2-45ANA, N2-80, N2-80ANA, N2-135 and N2-135ANA. Parker Balston High Flow Rate In-Line Gas Regulators are not suitable for use with hydrogen generators, cylinder gases, corrosive gases, or gases that are flammable. Minimal assembly required.

Principal Specifications

Model 72-130-V883	
Maximum Inlet Pressure	150 psig
Maximum Temperature	220°F (104°F)
Pressure Control Range	10-130 psig
Material of Construction	Aluminum, Brass, Buna
Ports (Inlet/Outlet)	1/2” FNPT
Flow Rate Limitation	65 SCFM

Oxygen Analyzer

- Protects instruments against undesirable oxygen concentrations
- Low maintenance
- LED display
- One year warranty
- Shipped ready to install from local stock

A Parker Balston Model 72-O2730NA Oxygen Analyzer

The Parker Balston 72-O2730NA Oxygen Analyzer is a self-contained wall-mountable or benchtop unit designed to monitor the oxygen concentration in a process stream, display the concentration in digital form, and provide appropriate alarms and controls for protecting a process against undesirable oxygen concentrations. The Parker Balston 72-O2730NA Oxygen Analyzer is offered as an integral accessory to Balston Nitrogen Generation Systems. The Analyzer is also designed to be used on existing house nitrogen systems. The Analyzer has all the controls necessary to assure safe and accurate monitoring of oxygen concentration in a nitrogen process stream.

Features include:

Alarm Set Points: The high and low limits of the integral alarm may each be set anywhere between .1% and 23% oxygen, depending on the process limitations and requirements.

Alarm Output: The oxygen analyzer, through the use of the alarm relay outputs, may be used to control the process stream. For example, a high or low oxygen concentration could signal a remote alarm, open a backup supply for the process stream, or close the process down for protection of downstream equipment or processes.

Easy Installation and Maintenance: A convenient power selection switch affords quick adaptation to available power supplies of 120 VAC/60 Hz or 240 VAC/50 Hz. The Analyzer requires very little maintenance other than timely calibration and sensor replacement.

Principal Specifications

	72-O2730NA Oxygen Analyzer
Accuracy	± 1% full scale calibrated span, after 30 min. stabilization
Sensitivity range	0 to 100% oxygen
Digital display limits	00.0 to 99.9% oxygen
Span concentration	0 to 23% oxygen
Response time	12 seconds
Min/Max Sample inlet pressure	2 psig/145 psig (0.1 barg/10 barg)
Min/Max sample flow rate range	25/850 ccm
Min/Max operating temperatures	59°F/95°F (15°C/35°C)
Alarm outputs	DPDT relay contacts 5 amp, 250 VAC rating, 1/8 HP resistive
Power requirement	120 VAC/60 Hz., 240 VAC/50 Hz.
Dimensions	11"w x 5"h x 5"d (28 cm x 13 cm x 13 cm)
Shipping Weight	6 lbs (3 kg)

Ordering Information

Description	Model Number
Oxygen Analyzer	72-O2730NA
Galvanic Cell (sensor)	72695A

Automatic Gas Switch-Over Systems

- Metal to metal diaphragm seal assures gas purity integrity
- Capsule® seat mechanism promotes increased serviceability and long life
- One knob switches gas generator or cylinder priority
- Total user control
- Check valves at inlet gland prevent contamination and backflow

Parker Balston Model 527 Automatic Gas Switch-Over System

Parker Balston Automatic Gas Switch-over Systems provide primary control to switch from gas generator to cylinder or from cylinder to cylinder. Uninterrupted gas is provided regardless of source. Use stainless steel for critical applications and brass for less demanding applications. Switch-over systems provide stable flow over wide temperature ranges and are suited as a primary gas control. Select the 526 series for noncorrosive, less demanding applications, and the 527 series for ultra high purity (UHP) requirements.

Principal Specifications

	Model 526	**Model 527**
Maximum Inlet Pressure	3000 psig (210 bar)	3000 psig (210 bar)
Switchover Pressure	50 or 70 psig	50 or 70 psig
Temperature Range	-40°F to 140°F (-40°C to 60°C)	-40°F to 140°F (-40°C to 60°C)
Material of Construction		
Body	Brass barstock	316 SS barstock
Bonnet	Brass barstock	Chromplated brass barstock
Seat	PTFE	PTFE
Filter	10 µm sintered bronze	10 µm sintered SS
Diaphragm	316L SS	316L SS
Internal Seals	PTFE	PTFE
Gages	2” dia. brass	2” dia. SS
Ports	1/4” to CGA Pigtails	1/4” to CGA Pigtails
Helium Leak Integrity	$1*10^{-8}$ scc/sec	$1*10^{-8}$ scc/sec
CV	0.1 (50 psig)	0.1 (50 psig)
Shipping Weight	8.25 lbs. (3.71 kg)	8.25 lbs. (3.71 kg)

Ordering Information

Less Demanding Applications

W-526-2532-350 Hydrogen
W-526-2532-580 Argon, Helium, Nitrogen
W-526-2532-590 Air, Dry Air, Hydrocarbon-Free Air, Zero Air

Critical Applications (UHP)

W-527-2532-350 Hydrogen
W-527-2532-580 Argon, Helium, Nitrogen
W-527-2532-590 Air, Dry Air, Hydrocarbon-Free Air, Zero Air

Flow Controllers

- Conveniently regulates and distributes clean air output and pressure
- Easy installation and operation
- Manifold and single flow versions available
- Immediate delivery from stock

Parker Balston Manifold Flow Controller

Parker Balston Flow Controllers provide a convenient means for regulating and distributing the clean air output from a Parker Balston compressed Air Dryer, FT-IR Purge Gas Generator, or Self-Contained Lab Gas Generator. Two styles of flow Controllers are available: manifolded flow controllers or single flow controllers.

Manifold models 72-398, 72-400, 72-401, and 72-402 accept clean gas, at the regulated pressure, into the manifold where independently adjustable flow controls may be set to serve three separate instruments. Single Flow Models 72-428, 72-430, 72-431, and 72-432 include a pressure regulator and a single flow controller.

Each flow controller is equipped with a triple scale pressure gauge (psig, bar, kg/cm^2), a pressure regulator, and a flow meter mounted on a convenient bracket for wall or panel mount installations.

Principal Specifications

	Manifold Flow Models 72-398, 400, 401, 402	**Single Flow Models 72-428, 430, 431, 432**
Inlet Ports	1/4” NPT (female)	1/8” NPT (female)
Max. Pressure	125 psig	125 psig
Pressure Gauge Range	0-60 psig	0-100 psig
Outlet Ports	1/8” tube fitting	1/8” tube fitting
Dimensions	8”w x 7”h x 6”d (20cm x 18cm x 15cm)	4”w x 7”h x 2”h (10cm x 18cm x 5 cm)
Shipping Weight	5 lbs (2 kg)	5 lbs (2 kg)

Ordering Information

Description	**Flow Range**
Manifold Models	
72-398	1-5 scfh (.5-2.5 lpm)
72-400	10-100 scfh (5-50 lpm)
72-401	5-50 scfh (2.5-25 lpm)
72-402	20-200 scfh (10-100 lpm)
Single Flow Models	
72-428	1-5 scfh (.5-2.5 lpm)
72-430	10-100 scfh (5-50 lpm)
72-431	5-50 scfh (2.5-25 lpm)
72-432	20-200 scfh (10-100 lpm)

Precision Control Flow Meters

- Rib-guided metering tubes assure accurate stable readings
- Magnifier lens in front shield enhances reading resolution
- Non-rotating feature prevents turning of flow tube
- Interchangeable flow tubes provide simple upgrade for use with other applications as required
- Difficult flow calculations and conversions eliminated by matching the bottom table – select flow meter by generator model

Parker Balston WFM Series Flowmeters

Parker Balston Precision Control Flow Meters are suitable with all Parker Balston Gas Generators. These flowmeters incorporate traditional variable area flow technology and are ideal for trace low flow and high flow control requirements. Leak integrity is tested using a state-of-the-art mass spectrometer and helium. The flowmeters are constructed of rugged, inert materials. Low flow series meters include a flat surface tripod.

Principal Specifications

Maximum Inlet Pressure	200 psig (13.8 bar)
Maximum Temperature	250°F (121°C)
Material of Construction	
Float (gas specific)	Glass, Sapphire, or 316 SS
Flow Tube	Heavy walled Borosilicate glass
Side Panels	Aluminum, black anodized
Front Shields	Lexan® with magnifier lens
Back Plates	1/8” White acrylic
Calibrated Accuracy	±1% FS
Ports	1/8” convertible to 1/4” compression
Helium Leak Integrity	$1*10^{-7}$ scc/sec
Repeatability	± 0.25% FS
Flat Surface Tripod	Acrylic with level adjust
Shipping Weight	5 lbs. (2kg)

Ordering Information

FT-IR Purge Gas Generators	
75-45NA	W-FM76807
75-52NA	W-FM76830
75-62NA	W-FM7562
Membrane Air Dryers @ min. flow rate	
64-01	W-FM76830
64-02	W-FM7562
64-10	W-FM6410
Membrane Air Dryers @ max. flow rate	
64-01	W-FM7562
64-02	W-FM7562
64-10	W-FM6410HF
NMR Gas Generator	
UDA-300NA	W-FM6410

TOC Gas Generator	
TOC-625, TOC-1250	W-FM7583
UHP Nitrogen Gas Generators	
HPN2-1100	W-FM7694
UHPN2-1100	W-FM7694
HPN2-2000	W-FM7696
76-97, 76-98	W-FM7698
Zero Air Gas Generators	W-FM76807
75-83	W-FM7583
HPZA-3500	W-FM76807
HPZA-7000	W-FM76807
HPZA-18000	W-FM76830
HPZA-30000	W-FM76830

Halogenated Hydrocarbon Scrubber

- Ideal for removing halogenated hydrocarbons from compessed air
- Extended-life adsorbent requiring minimal maintenance
- Protects equipment from chlorinated solvent vapors
- Purifies bulk inert non-corrosive gases

Parker Balston Model 76080 Halogenated Hydrocarbon Scrubber

Parker Balston Halogenated Hydrocarbon Scrubbers effectively remove halogenated hydrocarbons from an existing compressed air supply. The scrubber can be used with any Parker Balston Zero Air Generator or UHP Nitrogen Generator if the compressed air supply contains halogenated hydrocarbons. Halogenated hydrocarbons can corrode piping, filters, valves, and other components.

Principal Specifications

Model 76080 Halogenated Hydrocarbon Scrubber	
Min/Max Pressure Rating	60 psig to 125 psig (4 barg - 8.6 barg)
Inlet/Outlet Ports	1/4” NPT (female)
Change Frequency @ 17 LPM	18 Months
Dimensions	41”h x 15”w x 8”d (104 cm x 38 cm x 20 cm)
Shipping Weight	29 lbs. (13 kg)

Ordering Information

Description	Model Number
Halogenated Hydrocarbon Scrubber (New)	76080

Installation Kits

- Provides clean tubing for commissioning of new gas generators
- Eliminates the wait for materials to install new gas generators
- Logical complement to gas generator purchases

Installation Kit Contents

Each Installation Kit combines all of the basic fittings and tubing required to connect your Parker Balston gas generator to a compressed air source (where applicable) and up to two instruments. Parker Balston Installation Kits are designed specifically for each model of gas generator. All Installation Kits use Parker fittings and refrigerant grade copper tubing. Parker fittings provide a leakproof, torque-free seal at all tubing connections, and eliminate leaks in instrumentation tubing. Additional valves, pressure regulators, scrubbers, and other vital components are available for each gas generator.

Principal Specifications

Installation Kit Part Number	Used On
IK75880	N2-45, N2-45ANA, N2-80, N2-80ANA, N2-135, N2-135ANA (50 ft. 1/8" copper tubing, union tees, tubing connectors)
IK76803	75-83NA, HPZA-3500, HPZA-7000, HPZA-18000 HPZA-30000, TOC-625, TOC-1250, N2-04, NitroVap (50 ft. 1/8" Copper tubing, 50 ft. 1/4" copper tubing, union tees, tubing connectors)
IK7694	HPN2-1100, UHPN2-1100, HPN2-2000 (50 ft. 1/8" Copper tubing, 50 ft. 1/4" copper tubing, union tees, tubing connectors)
IK7532	H2PEM-100, H2PEM-100AWF, H2PEM-165, H2PEM-165AWF, H2PEM-260, H2PEM-260AWF, H2PEM-510, H2PEM-510AWF, H2PD-150, H2PD-300, H2-500NA, H2-800NA, H2-1200NA (50 ft. 1/8" copper tubing, union tees, tubing connectors)
IK7572	N2-14, N2-14ANA, N2-22, N2-22ANA, NitroFlow Lab, N2-35, N2-35ANA (50 ft. 1/8" copper tubing, union tees, tubing connectors)
IK7698	76-97NA, 76-98NA (50 ft. 1/4" copper tubing, connectors, nut and sleeve assembly)

Extended Support Programs

UHP Nitrogen Generators produce 99.9999% pure N_2 for GC's or ICP Spectrometers

Hydrogen Generators produce 99.99999% pure hydrogen for GC's

FT-IR Gas Generators produce dry, CO_2-free purge gas for FT-IR Spectrometers

Zero Air Generators produce zero grade air for GC's

Pure Air and Nitrogen Generators produce dry, ultra pure compressed gas for laboratory instruments including LC/MS

Accessories for Gas Generators

Parker Balston Analytical Gas Generators, Filtration and Separation equipment are world renowned for their reliability, dependability, and long life. Since commercializing our first laboratory scale analytical gas generator in the 1980s, we now serve an installed customer base of over 40,000 gas generator users globally.

Our experience shows that with regularly scheduled maintenance, generators and analytical instruments continue to consistently produce precise results, and precise purity for decades.

Parker Balston is pleased to offer a variety of Extended Support Plans to assure this standard of performance is possible with your new gas generator purchase. At the fraction of the cost of a new gas generator, Parker Balston Extended Support Plans are truly affordable to purchase.

Our plans range from the standard Depot class of support to our exclusive Express class of support. Both types of plans are convenient and are designed to match your needs and budget.

Parker Balston Extended Support Plans are smart to select when you depend upon high performance analytical equipment. Our exclusive Express support program offers the piece-of-mind of a new or like new replacement generator arriving at your door the very next business morning.

Included with Extended Support Program	Express (EN2)	Depot (DN2)
Next Day Delivery of New or Like New Temporary Replacement Unit	X	NA
Extends Warranty Coverage to 30 Months	X	X
Covers Replacement Parts for Repair	X	X
Covers Labor Charges for Repair	X	X
Covers Packaging Materials for Repair	X	X
Covers Freight Charges for Repair	X	X

Benefits Summary/Overview:

- Next business morning delivery of a replacement gas generator
- Extension of standard gas generator warranty to 30 months
- Responsive turn-around time for service center repairs
- Complete coverage of freight charges, to and from service center
- Complete expense coverage regarding labor, parts, and packaging materials
- Dedicated technical support hot-line

Application Notes

The Effect of Fuel Air Purity on FID Sensitivity

*Dorothea J. Jeffery, Gregory C. Slack and Harold M. McNair, Dept. of Chemistry,
Virginia Polytechnic Institute and State University, Blacksburg, VA 24061*

Poster Session Report

*Presented by Virginia Polytechnic Institute and State University
and Parker Hannifin Corporation*

Abstract

In the field of capillary gas chromatography, the presence of sensitive detectors and trace analyte samples increases the need for dry, clean fuel gases. Laboratories in an industrial setting often maintain several gas chromatographs in continuous operation. Since large volumes of fuel gases are consumed daily, gas cylinders are changed almost as frequently. Usually the fuel air is of breathing quality and is introduced either directly or after drying via a molecular sieve trap. The objective of this study is to compare flame ionization detector sensitivity vs. air purity under isothermal conditions. This study included air sources as follows: the Parker Balston® Type HPZA-3500 Zero Air Generator, breathing air (cylinder without scrubbers), ultra zero air (cylinder), and filtered house air.

The study proceeded as follows:

1. compared baseline runs taken at 10 minutes, 60 minutes, and 12 hours
2. compared runs of a 50 ppm trace alkane sample, and
3. compared runs of a 1 ppm trace alkane sample for the air sources with the exception of the house air. Finally, both breathing and generated air studies were repeated under optimized conditions and without air scrubbers. This final study also included the filtered house air.

A comparison of the chromatograms for the baseline and the trace component runs showed that both the Parker Balston® Type HPZA-3500 Zero Air Generator and the ultra pure air produced lower signals and better sensitivity: as shown by increased peak area counts. These baseline were also more stable than either the breathing air or the house air. In addition to the lower and stable baseline, the air generator had the advantage of providing a continuous source of air.

Table 1: Chromatographic Conditions

Column	HP-1, 12 m x 0.2 mm, 0.33 µm df
Oven Temperature	110°C
Inlet Temperature	250°C
Detector Temperature	300°C
Split Ratio	28:1
Carrier Gas	0.8 ml/min He
Fuel Gases	30 ml/min H and 300 ml/min Air
Samples	50 ppm and 1 ppm decane, undecane

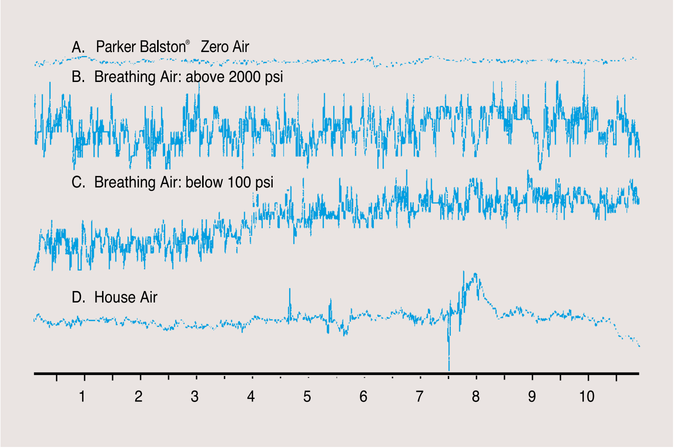


Figure 1: *Baseline Signals – Random spike at 6 min. for Zero Air (A). Baselines are raw data (mA) on equivalent scales*

Introduction

In a previous study, baseline and trace alkane sample data was obtained utilizing a HP 5890 gas chromatograph (GC) equipped with a flame ionization detector (FID) and a 12 meter methyl silicone column (Hewlett-Packard, Avondale, PA). The air sources in that study were the Parker Balston® Type HPZA-3500 Zero Air Generator, an ultra pure air cylinder, and a breathing air cylinder. An improvement in both the baseline and the peak areas was noted for the Parker Balston® zero air, in comparison with the breathing air. In this study, the Zero Air was compared with breathing air at the two specified cylinder pressures of above 2000 psi and below 100 psi and with filtered house air.

For each air source, this study proceeded from a 30 minute baseline run to triplicate runs of each standard: 1 ppm and 50 ppm decane, undecane, and dodecane in iso-octane. Between each air supply, the system was allowed to equilibrate several hours before the baselines were run. Chromatograms showing area counts were generated by a HP 3396A integrator for each run. This peak area data was statistically compared using Statview, a Macintosh statistics software package.

Experimental

A 30 minute baseline and triplicate runs of the 1 ppm and the 50 ppm alkane standard of the air supply were obtained under the conditions listed in *Table 1* for the following air sources:

1. Parker Balston® Type HPZA-3500 Zero Air Generator
2. Breathing Air Cylinder (at pressures above 2000 psi and below 100 psi)
3. House Air via Parker Balston® DXE and BXE filters

The house air was filtered before introduction to the GC due to its potential to damage or contaminate the system by introducing particulate.

Results

Optimized carrier gas flow rate and split ratio were used in order to produce better quantitation. Similar to previous baseline runs, the zero air signal (average signal during blank runs) was lower than either of the other air sources (*Figure 1 and Table 2*). In addition, the zero air undecane peak area counts for both the 50 ppm and 1 ppm standards were significantly larger than those of either the breathing or house air (*Table 2*). Tables 3 and 4 contain the statistical comparisons of the average peak area counts for both the 50 ppm and 1 ppm standards respectively.

Parker Balston® zero air was used as the reference in the paired t value and 2-tail probability determinations. The paired t value critical values at the 97.5 confidence level were 3.18 for 3 degrees of freedom and 4.30 for 2 degrees of freedom. The calculated values in both the 50 ppm and the 1 ppm runs were larger than the respective critical values; therefore, the differences in area counts were not due to random fluctuations. In addition, the 2-tail probabilities were below the absolute critical value of 0.05. This occupance supports the theory of non random differences in area counts as determined by the paired t test. Since both the paired t values and 2-tail probability values were outside their respective critical ranges, the differences in peak areas were not due to random fluctuations[1]. These differences were due to the flame purity.

Table 2: Baseline Data

Air Source	Parker Balston®	Breathing Air > 2000 psi	Breathing Air < 100 psi	House Air
Signal	12	22	18	22

Table 3: Undecane Peak Area Data 50 ppm Standard Data

Mean Area Counts	10878	9784	9181	8206
Standard Deviation	426	194	179	89
Paired t Values	–	3.8	8.75	14.82
Probability (2-Tailed)	–	0.032	0.003	0.001
Degrees of Freedom	3	3	3	3

[1] *Abacus Concepts, Statview II, Abacus Concepts, Inc.: California 1987*

Table 4: Undecane Peak Area Data 1 ppm Standard Data

Mean Area Counts	1744	1629	1531	1404
Standard Deviation	2.1	35.2	20.8	21.1
Paired t Values	–	4.77	19.57	27.06
Probability (2-Tailed)	–	0.041	0.003	0.001
Degrees of Freedom	2	2	2	2

Conclusion

The Parker Balston® Type HPZA-3500 Zero Air Generator has advantages over the conventional sources of air for GC analysis. A lower and more stable baseline signal can be obtained. Due to lower baseline noise, the signal-to-noise ratio is larger, giving rise to higher sensitivity or larger peak areas. A comparison of peak areas for the alkane standards gave similar results. The air generator produced peak areas which were more than 12% of the breathing air peak areas. Not only does the air generator give better baselines. In addition, the air generator also removes the need for frequent cylinder changes, thus saving time.

[1] Abacus Concepts, Statview II, Abacus Concepts, Inc.: California 1987.

Dr. Harold M. McNair is Chairperson of the Chemistry Department at Virginia Polytechnic Institute and State University. Dorothea J. Jeffery and Gregory C. Slack are currently undergraduate students at VPI & SU.

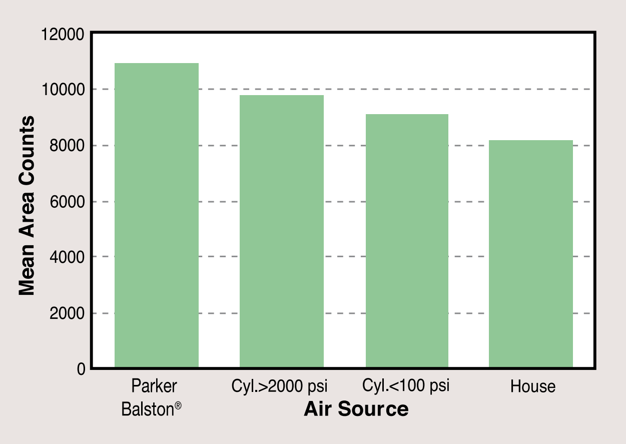


***Figure 2:** Average Area Counts – 50 ppm Undecane.*

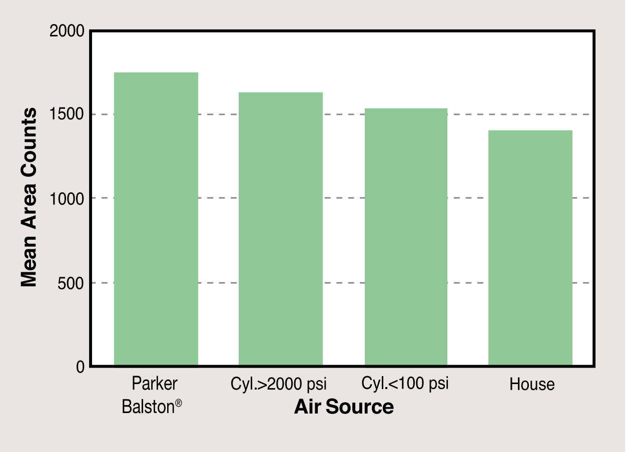


***Figure 3:** Average Area Counts – 1 ppm Undecane.*

The Effect of Detector Gas Purity on FID Baseline Stability By Eugene Barry

American Laboratory
Reprinted from American Laboratory April 1993

It is well accepted in the field of gas chromatography that the purity of gases utilized for the operation of the gas chromatograph will affect the accuracy of analyses, consistency of results, detector sensitivity, and column life as well as column performance. As a result, it is important that sources of gas used by the chromatographer meet the highest possible purity standards affordable in order to meet the demand to achieve higher sensitivities required for environmental analysis, quality control procedures, government regulations, as so forth. Traditionally, this source has been a high-pressure gas cylinder specified to a wide range of purities (99.99% to 99.9999%). More recently, gas generators have become available as a source of high-purity hydrogen (for carrier and fuel gas) and high-purity nitrogen (for make-up gas).

This paper describes the results of a performance study using the Parker Balston® Model H2PD-300 Hydrogen Gas Generator (*Fig. 1*) and the Parker Balston® Model UHPN2-1100 Ultra High Purity Nitrogen Generator (*Fig. 2*) (Parker Hannifin Corporation, Haverhill, MA) to provide make-up gas and detector fuel for a GC flame ionization detector. The objective of the study was to demonstrate any effect of using hydrogen and nitrogen from the generators on the performance of the gas chromatograph. The results of the instrument operation using the generators as a source were compared to the results using the highest purity grade of cylinder gas (research grade) available. Baseline stability was the primary basis for comparison of the gases in the study.

Dr. Barry is a Professor of Chemistry and Graduate Coordinate at the University of Massachusetts at Lowell, Dept of Chemistry,
One University Ave., Lowell, MA 01854, U.S.A.

Figure 1: *Model H2PD-300 hydrogen gas generator*

Table 1

Gases used to establish baselines shown in Figure 3

Gas function	Gas source	Specified purity	Flow rate (cm³/min)	Pressure (psig)
Fuel air	Parker Balston® Zero Air Generator	< 0.05 ppm total hydrocarbons	300	35
Fuel Gas (H_2)	Parker Balston® H2PD-300 H_2 generator	99.99999%	40	22
	Research-grade cylinder	99.9995%		
Carrier gas (He)	Research-grade helium cylinder	99.9999%	0.7 23 cm/sec linear velocity	40
Make-up gas (N_2)	Research-grade N_2 cylinder	99.9995%	30	28

Table 2

Gases used to establish baselines shown in Figure 4

Gas function	Gas source	Specified purity	Flow rate (cm³/min)	Pressure (psig)
Fuel air	Parker Balston® Zero Air Generator	< 0.05 ppm total hydrocarbons	300	35
Fuel Gas (H_2)	Research-grade H_2 cylinder	99.9999%	40	22
Carrier gas (He)	Research-grade helium cylinder	99.9999%	0.7 23 cm/sec linear velocity	40
Make-up gas (N_2)	Parker Balston® UHPN2-1100 N_2 generator research-grade N_2 cylinder	99.9999%	30	28

The Effect of Detector Gas Purity on FID Baseline Stability By Eugene Barry

Ultra Pure Hydrogen as a Carrier Gas for Capillary Chromatography

Traditionally, chromatographers have used helium and nitrogen as the carrier gases of choice in gas chromatography. Now, with the availability of a reliable, safe, ultra pure Parker Balston® Hydrogen Generator from Parker Hannifin Corporation (Haverhill, MA) for the laboratory, the use of hydrogen as a carrier gas for capillary G.C. has advantages worth considering.

A comparison of the Van Deemter curves for nitrogen, helium and hydrogen is illustrated in *Figure 1*.

The small slope after the optimum flow velocity would mean that flow velocities could be increased without too much loss in efficiency (increase in H). Increased flow velocities will shorten analysis time (often cutting analysis time in half), resulting in lower elution temperature requirements, lower cost per analysis, and extended column life. From a theoretical yet practical viewpoint, the use of Hydrogen as a carrier gas allows the generation of nearly four times as many effective theoretical plates per second as Nitrogen. From a practical chromatographer's view, the chance of picking a good flow rate with the first experiment is increased.

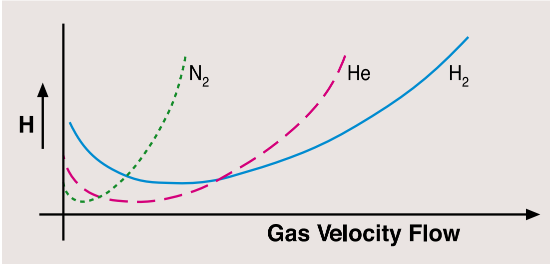


Figure 1: *A Comparison of the Van Deemter Curves for Nitrogen, Helium, and Hydrogen.*

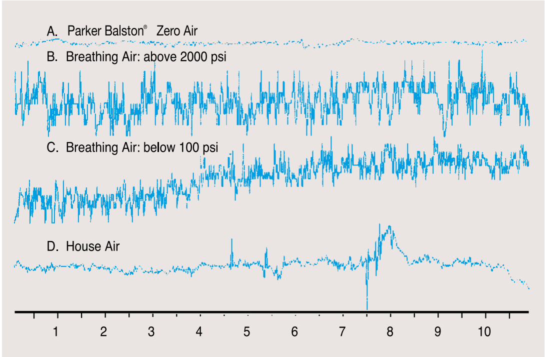


Figure1: *Baseline Signals – Random spike at 6min. for Aero Air (A). Baselines are raw data (mA) on equivalent scales.*

Summary

Very acceptable separations and increased sensitivity for trace analyses can be obtained by using hydrogen generated by the Parker Balston® Hydrogen Generator as a carrier gas. This unit provides a safe, reliable, economical source of very pure hydrogen. Cost figures show that the 300 ml/min Parker Balston generator pays for itself in 1 to 2 years. The hydrogen is produced by electrolysis through palladium, which produces ultra-dry hydrogen with less than 10 ppb impurities. Only 50 ml of hydrogen are stored at any time in the unit, ensuring complete safety and compliance with OSHA and NFDA regulations.

With this new, safe source of ultra pure hydrogen available, chromatographers are experiencing some additional benefits with the use of hydrogen as a carrier gas. These benefits would include the subjected to shorter runs of cooler temperatures, typically increasing their useful life by 33%.

"The predominant opinion... that the gas with the lower viscosity, that is, hydrogen, is the best carrier gas... " for capillary G.C. has been expressed by Rohrschneider and Pelster. The Parker Balston® Ultra High Purity Hydrogen Generators are the only Generators available that enable Chromatographers to use hydrogen for both carrier gas and fuel gas applications. Hydrogen is being put into use in more laboratories with the availability of a safe, economical, ultra pure Parker Balston® hydrogen generator.

Exhibit A: *A Parker Balston® Zero Air Generator*

Exhibit B: *A Parker Balston® Hydrogen Generator*

The Effect of Detector Gas Purity on FID Baseline Stability *(Continued)*

The chromatographer's concerns with the quality of the gases used in the analysis focus on impurities. Impurities in a chromatographer's gas supply can result in excessive noise, baseline drift, ghost peaks, column bleed, and reduced column life.[1-3] The specified purity of the gases supplied by the generators is 99.9999% for the nitrogen and 99.99999% for the hydrogen. These stated purities are sufficiently high that the gases should yield a baseline stability comparable to that achieved with the highest purity cylinder gases available, namely research grade.

Experimental

This gas chromatography performance study was conducted at the University of Massachusetts, Lowell, using a 5890A GC (Hewlett-Packard Co., Palo Alto, CA) with flame ionization detector. The column used during the study was a HP-1 fused silica capillary column, 30 m in length, 0.07-mm i.d., with a film thickness of 0.25 um, and the column was operated under isothermal conditions at 100½C at a linear velocity of 23 cm^3/sec. The split ratio used in the performance testing was 100:1. The instrument used two sets of conditions in order to obtain a set of baselines to show the effect of the hydrogen generator as a source of fuel gas (Figure 3) and a set of baselines to show the effect of the UHP nitrogen generator as a source of make-up gas (Figure 4). The operation of the instrument to obtain the baselines shown in Figure 3 used the gases as described in Table 1. The operation of the instrument to obtain the baselines shown in Figure 2 used the gases as described in Table 2.

Results

Figure 3 shows the effect of using fuel hydrogen supplied by a H2PD-300 hydrogen generator on baseline stability. The baseline generated is compared to that generated while using a research-grade cylinder of hydrogen as the fuel gas source. Figure 3 shows that there is not a distinguishable difference between the two baselines.
Figure 4 shows the effect of using make-up nitrogen gas supplied by a UHPN2-1100 UHP nitrogen generator on baseline stability. The comparison of the baseline generated while using make-up gas from a research-grade cylinder shows that the two gas sources are indistinguishable.

Figure 2: *Model UHPN2-1100 UHP Nitrogen Gas Generator*

Conclusion

A GC was used to compare the baseline stability of a flame ionization detector while using a gas generator as the source of detector fuel and make-up gas with the baseline stability obtained while using corresponding research-grade cylinder gases. The results demonstrate that the H2PD-300 hydrogen generator (used as a source of detector fuel) and the UHPN2-1100 UHP nitrogen generator (used as a source of make-up gas) will provide the chromatographer with GC baseline stability equivalent to that achieved with the highest purity grade of gas cylinder available, while offering the inherent advantages of eliminating high pressure gas cylinders (such as safety, convenience, and cost).

References

1. Hinshaw JV. LC•GC 1988; 6(9):794-8.
2. Hinshaw JV. LC•GC 1990; 8(2):104-14.
3. Hinshaw JV. LC•GC 1991; 10(5):368-76.

For additional Information

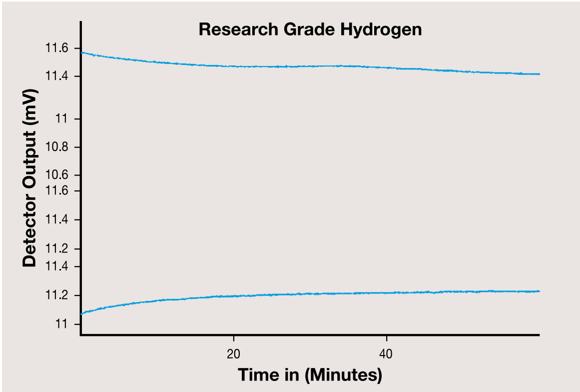


Figure 3: *Gas chromatograph baselines using a H2PD-300 hydrogen generator and a research-grade cylinder as fuel sources.*

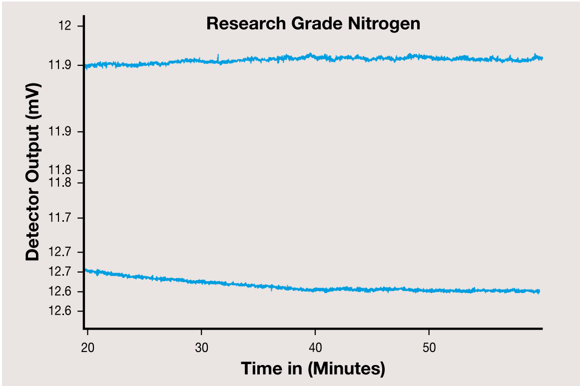


Figure 4: *Gas chromatograph baselines using a UHPN2-1100 UHP nitrogen generator and a research-grade cylinder as make-up gas sources.*

Loctite Saves Almost $20,000 Per Year By Generating Its Own Hydrogen for GC/FIDs

Loctite is saving almost $20,000 per year in cylinder costs alone by generating its own hydrogen for use as carrier gas and fuel in gas chromatographs with flame ionization detectors (GC/FIDs). Helium and hydrogen gas cylinders used in the past were expensive to purchase and required a considerable amount of time on the part of the laboratory staff to order, transfer to the lab and install them while maintaining safety regulations. As a result, a few years ago the company's Rocky Hill Analytical laboratory purchased an on-site hydrogen generator to produce hydrogen from water on demand which results in virtually no operating costs. "We save a considerable amount of money every year, avoid the time and difficulties involved in dealing with gas cylinders and produce purer gas more reliably with our on-site generator," said Robert Trottier, Manager, Analytical Services for Loctite.

Loctite manufactures and markets a broad range of high-technology sealants, adhesives and coatings that are used in computers, automobiles, airplanes, vacuum cleaners, speakers, syringes, cosmetics, compact disk players and many other products. The company often develops the complex equipment used for application and assembly as well. Loctite is in the business of solving problems. When a customer buys a Loctite product it also gets a partner that will work side-by-side with them to find innovative solutions to their design and manufacturing problems. Loctite is a subsidiary of Henkel, KgaA, an international manufacturer of chemicals, detergents, industrial adhesives and cosmetics.

Analytical Services group

Loctite's Analytical Services group supports the company's research activities by providing chemical testing of incoming raw materials, intermediates, new compounds and formulations developed to meet customer needs. The vast majority of materials involved in the company's research are organic based. Liquid chromatography (LC) and gas chromatography (GC) are two of the best tools for characterizing these types of materials. Several years ago, the Analytical Services group converted several of their GCs to capillary column systems. Capillary GC systems typically produce sharper analyte peaks and deliver higher resolution in separating these organic materials.

About the same time, Analytical Services management began considering converting the carrier gas for its Perkin Elmer Autosystem and Autosystem XL GC/FIDs over to hydrogen from helium. "Helium tends to be relatively expensive, it's a nonrenewable resource," Trottier said. Another problem is that the purity of commercial-grade helium can be less than ideal for some of the more sensitive analytical methods. We occasionally experienced problems with contaminants that generate background noise in our chromatograms, sometimes causing us to expend time trying to identify the source."

Cost of gas cylinders

In addition, Trottier said, he was not happy with the cost or the time involved in dealing with gas cylinders. "Each instrument used approximately one cylinder of helium per week at a cost of $167 per cylinder or $8,684 per year. In addition, our laboratory staff had to spend time checking on the supplies of gas for each of our instruments and ordering new tanks when required. Our new Analytical labs are located at the opposite end of the R&D building and are somewhat distant from the shipping & receiving docks. So we would either have to transport the tanks across the building or alternatively, pay to have a gas line run from the receiving area to the lab. It typically took about an hour of staff time to haul the cylinders from the loading dock and install in the laboratory. The cylinders also took up a lot of valuable space. Each instrument required a cylinder to run, a spare cylinder supply and often an additional one in transit or storage."

"When it was time for us to move to our new facility in Rocky Hill, we decided to take a close look at whether it made sense to switch to hydrogen as carrier gas and fuel for the GC/FIDs," Trottier said. "The primary motivation was cost – hydrogen is less expensive than helium. But what intrigued us even more was the availability of a new generation of hydrogen generators that are capable of producing hydrogen on an as needed basis with virtually no operating costs. This eliminates the need to purchase, transport and install cylinders. The generator services each instrument and automatically produces what is required on demand."

Eliminating need to purchase cylinders

Trottier spoke to Phil Allison, at that time a Sales Representative and now Product Manager for Parker Balston® Branded Products at Parker Hannifin Corporation in Haverhill, Massachusetts, the leading producer of hydrogen generators. Based on usage, Allison demonstrated that nearly $20,000 per year could be saved by equipping the 2 Perkin Elmer GC-FIDs in the new laboratory with a hydrogen generator. In addition to these hard savings by eliminating the need to purchase gas cylinders, Trottier felt that the lab could achieve a significant productivity increase by avoiding the need for lab personnel to spend time dealing with cylinders. The gas generator could simply be set up and (almost) forgotten.

Trottier also considered the safety issues involved in the switch from cylinders to on-site generation. Loctite expended considerable effort in ensuring safe handling of gas cylinders and never experienced a gas cylinder accident. Yet Trottier was aware of potential dangers, as highlighted by the

Loctite Saves Almost $20,000 Per Year By Generating Its Own Hydrogen for GC/FIDs
(Continued)

American Chemical Society's training film that is shown to laboratory personnel. The film depicts a cylinder valve being suddenly broken off and the resulting rush of pressurized gas which propels the cylinder through a concrete wall. Gas cylinders also present far more prosaic dangers to extremities such as rolling onto a person's toe.

On-site generation is safe

On-site generators, on the other hand, eliminate many of these concerns. The gas is produced under very low pressures and is consumed nearly as soon as it is produced, eliminating most of the safety issues involved with cylinders

Parker Balston H2PD-300 generators produce dry hydrogen gas to a purity level in excess of 99.99999% from deionized water and electricity. The hydrogen generator utilizes the principle of electrolytic disassociation of water and subsequent diffusion through a palladium membrane. The outlet pressure of the hydrogen generator is adjustable and the generator can deliver hydrogen at pressures up to 60 psi. The H2PD-300 has a hydrogen delivery capacity of 300 cc/minute. The high purity of the gas produced by this generator makes it ideal for use with FIDs, TCDs, trace hydrocarbon analyzers and air pollution monitors.

How on-site generators work

The electrolytic disassociation of water takes place in the electrolytic cell as electricity passes through deionized water. During electrolysis, oxygen and other impurities collect at the nickel anode and are vented from the generator. Hydrogen ions collect at and pass through the tubular palladium cathode driven by the applied electric potential. Inside the tubes, the hydrogen recombines to form purified molecular hydrogen. The newly formed hydrogen is under pressure and ready to be delivered to the usage point. The purity of the hydrogen is ensured by the fact that the palladium membrane allows only hydrogen and its isotopes to pass.

The hydrogen pressure at the outlet is regulated by an electronic pressure control circuit. A pressure transducer monitors the hydrogen pressure at a point between the cell and the outlet of the hydrogen generator. The control circuit adjusts the electrical current to maintain the set hydrogen pressure. Key safety features include minimal hydrogen storage capacity, a production control switch, an electrolytic leak detector, an over-temperature switch, a pressure sensor and a low water shutoff control. The generators also have built-in system diagnostics to monitor the performance and operation of the generator.

Annual maintenance and electricity costs are only $248 per year. The primary maintenance activities are filling the feed water bottle and changing the electrolyte solution. If the generator is operated 24 hours per day at the rated maximum flow, the water in the feed bottle lasts for 8 to 10 days. At this point, the water reservoir is refilled using deionized water with a rating of 5 Megaohm-cm or better. The electrolyte solution must be changed once each year to maintain efficient operation of the hydrogen generator. The electrolyte is a specially prepared solution of sodium hydroxide.

The net result was a substantial and easily measured cost savings as well as significant intangible benefits. "The hydrogen generator more than paid for itself in the first year of operation and has generated savings of approximately $10,000 per machine or $20,000 total each year since,"
Trottier said. "In addition, we have eliminated the time and aggravations that were previously involved in purchasing, installing and monitoring the gas cylinders. In my opinion, on-site generation is the wave of the future in gas chromatography."

Industrial Process Products and Technology

Reprinted from Industrial Process Products and Technology October 1993

BASF Corporation is the North American member of the BASF Group. The corporation employs about 19,000 people at 41 major production facilities in North America. BASF Corporation's highly diversified product mix includes printing links and plates, anti-freeze, audio, video and computer recording media, automotive coatings, basic colorants, crop protection products, pharmaceuticals and plastics.

Ernie Bedard, a Senior Chemist at the company's Greenville, Ohio resin plant, was using cylinders of hydrogen and zero air to supply fuel and air to the Flame Ionization Detectors of his two gas chromatographs which are used to follow the course of reactions, check for residual monomers in certain products, check compositions on solvent blends, and analyze waste water. Although the cylinders provided adequate gas purity, he had some concerns about the handling of the cylinders. "We weren't experiencing any problems with gas purity, but it was an unwieldy situation handling the cylinders, and I wasn't happy with it." Another problem occurred when the cylinders were not monitored carefully. "We would know that a cylinder needed to be changed when the Flame Ionization Detector went out. No damage would occur, but we would have to change the cylinder, start-up, and repeat the run which was an inconvenience." To change a cylinder, a person had to remove the regulator, replace the cylinder and re-attach the regulator. If the regulator was not seated properly, the cylinder would leak, resulting in gas loss. Since a move to a new laboratory was planned, Ernie thought that it would be ideal, at this time, to eliminate the inconveniences associated with handling gas cylinders. The generator was reviewed and approved by the site safety committee prior to its installation in the new laboratory.

When contacted by BASF, Parker Hannifin Corporation, Haverhill, MA recommended the Parker Balston® Zero Air Generator. The Generator reduces the total hydrocarbon content of compressed air to less than 0.05 ppm, measured as methane, by using catalytic oxidation to convert hydrocarbons to carbon dioxide and water. The Generator is a complete system with carefully matched components engineered for easy installation, operation and long term reliability. Standard features include coalescing prefilters with automatic drains, state-of-the-art heater module and a membrane final filter.

A Parker Balston® Zero Air Generator

"Installation was easy. All we had to do was just hook the Zero Air Generator up to the plant air line and then get it up and running."

Ernie is pleased to report that the Generator "has been running trouble-free" since it was installed. "The GC baselines have been nice and stable with no fluctuations." The unit has completely eliminated the problems associated with handling gas cylinders. Ernie also reports that prior to installation, "BASF was using approximately 2-3 cylinders of zero air a week at an annual cost of $5,054, not including demurrage and shipping fees." The Generator paid for itself in six months.

Effect of Purging a Sealed and Desiccated FTIR Spectrometer Sample Compartment

By R. Daly and D. Connaughton

American Laboratory
Reprinted from American Laboratory News Edition February 1994

The purpose of providing a dry, CO_2-free purge to an FTIR spectrometer is twofold. The purge prevents deterioration of the beamsplitter by moisture and also eliminates undesired absorbance by water and carbon dioxide in the background. Consequently, the purge enhances the instrument's reliability by the reduction of the potential need for service and increases the accuracy of analysis by the elimination of inconsistencies in the background levels of water and carbon dioxide.

A study was undertaken to demonstrate the inconsistency in background levels of water and carbon dioxide for an unpurged, sealed, and desiccated FTIR spectrometer as compared to a sealed and desiccated FTIR spectrometer with the sample compartment purged.

All of the testing discussed in this application note was conducted by an independent consultant with extensive experience in the field of FTIR spectroscopy who is unbiased toward the instrument and the purge gas generator. The tests were performed on an FTIR spectrometer that was designed as a sealed and desiccated instrument to be operated without purged gas. All data were collected in scan sets of four scans and each scan took approximately 15 sec. One scan was recorded for the background spectrum and a second was collected to produce the 100% transmittance line. For some spectra, scan sets were collected consecutively; for others, there was a time lag between the collection of the scans. The specific conditions are noted in the discussion of results. All spectra were apodized with the Norton-Beer strong function. The detector was a deuterated triglycine sulfate (DTGS) detector.

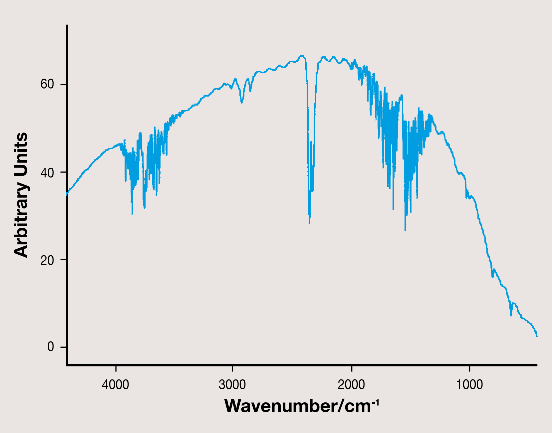


Figure 1: Single-beam spectrum from unpurged, sealed, and desiccated FTIR spectrometer.

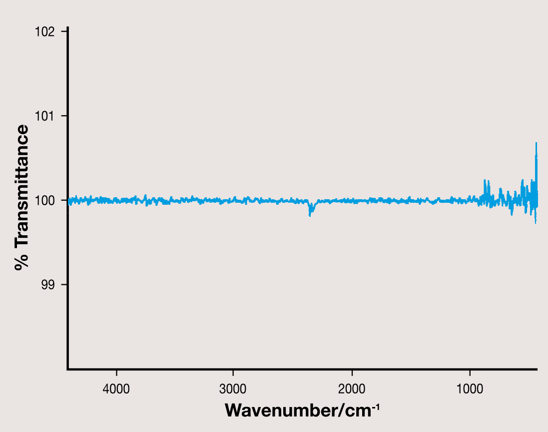


Figure 2: 100% Transmittance from unpurged, sealed, and desiccated FTIR spectrometer.

Mr. Daly is Marketing and Sales Manager and
Mr. Connaughton is Product Sales Manager,
Parker Hannifin Corporation, 242 Neck Rd., Haverhill, MA 01835; Tel: 800-343-4048 or 978-858-0505;
Fax: 978-556-7501

Experimental

Two sets of tests were conducted in order to demonstrate the effect of purging an FTIR spectrometer sample compartment. The first set of tests consists of various scans without the instrument sample compartment being purged. The second set of tests demonstrates the effect of purging the spectrometer sample compartment.

A model 75-45NA FTIR purge gas generator (Parker Hannifin Corporation, Haverhill, MA) was used as the source of purge gas in the experiments. The generator was connected directly to an air line and operated at 80 psig. The air was treated prior to entering the generator by a condensing unit in order to remove gross quantities of water, and by filtration to remove oil droplets. During experiments with the use of a purge gas, the gas entered the sample compartment at a flow rate of 0.4 scfm.

Results

Performance without sample compartment purge *Figure 1* shows a single-beam spectrum of an unpurged, sealed, and desiccated FTIR spectrometer. Figure 2 shows the 100% transmittance line for the same, unpurged spectrometer. This line was produced from two consecutive scan sets. The spectrometer sample compartment had not been opened for at least 8 hr. The time between the two scan sets was less than 1 min. Despite the fact that there was a sealed atmosphere in the system, it can clearly be seen that there is a change in the carbon dioxide concentration.The problem is that the interferometer compartment is sealed, but the sample compartment is not. The carbon dioxide and water levels in the atmosphere change because the operator is in the vicinity of the spectrometer. If the operator were to cease breathing, there would be no recorded change in the carbon dioxide or water levels. If the time between scans increases, the situation becomes worse. This is illustrated in *Figure 3*. The time between scans was 40 min. The spectrometer was not opened in this time, but the operator was in the laboratory during that period. The operator was in the laboratory during that period. The operator was across the room for most of the time, and was alone.

Effect of Purging a Sealed and Desiccated FTIR Spectrometer Sample Compartment
(Continued)

Figure 3 indicates that the carbon dioxide and water content of the air change as a result of one person being in a room of approximately 7200 ft^3. In this case, the water level actually decreased, but there was a marked increase in the amount of CO_2 in the air. In an actual experiment, scan sets should never be collected 40 min apart. This figure simply illustrates how severe the lack of purge can be even for a sealed system.

A new background scan set was collected, and the sample cell was opened for 15 sec; then another scan set was collected immediately after the sample compartment was closed. The resulting 100% transmittance line is shown in *Figure 4*. As can be seen from this spectrum, the level of atmospheric water has decreased and the level of carbon dioxide has increased. Without purge, it is virtually impossible to maintain the atmospheric absorption bands as constant while a sample is changed. The levels of these vapors and gases are constantly changing, and the spectrometer is a very good detector for the change. Even if the operator were to hold his or her breath while opening the sample compartment, the ambient level of water and CO_2 in the atmosphere has enough fluctuation that it is impossible to maintain a constant level of water and CO_2.

Performance with the sample compartment purged

The sealed and desiccated spectrometer used in this study has a purge port with a line that leads directly to the sample compartment. This is provided so that the atmosphere within the sample compartment can be purged and maintained in a water-free and carbon dioxide-free state. *Figure 5* is a single-beam spectrum of the spectrometer once the sample compartment had been totally purged by the purge gas generator. When this is compared with *Figure 1*, it is evident that the water and the CO_2 bands have reduced in intensity, but there is still plenty of water in the desiccated compartment. It should be mentioned, however, that the desiccant was at the end of its cycle; consequently, there is more water than there would be if the desiccant were fresh. Herein lies another problem with sealed and desiccated systems: The dryness of the sealed interferometer compartment changes as the desiccant becomes saturated. The corresponding 100% line from the purged sample compartment is shown in *Figure 6*. The sample compartment door had not been opened between the two consecutive scan sets, so the 100% line is again very good.

If the sample compartment is open for 15 sec, then closed, and a new 100% line is measured with the background spectra from before the door had been opened, the resulting 100% line is shown in *Figure 7.* Clearly, there is a great deal of water vapor in the spectra. If the system were allowed to purge for 3 min, the water vapor and CO_2 that were in the sample compartment

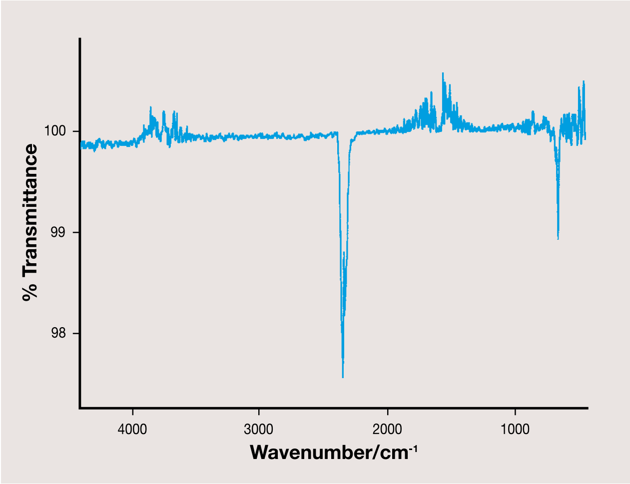


Figure 3:*100% Transmittance from unpurged, sealed, and desiccated FTIR spectrometer: 40 min between scans.*

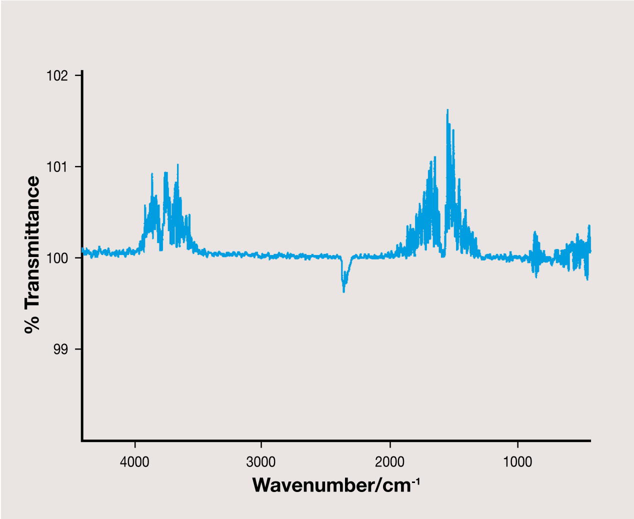


Figure 4: *100% Transmittance from unpurged, sealed, and desiccated FTIR spectrometer: 15 sec between scans.*

Effect of Purging a Sealed and Desiccated FTIR Spectrometer Sample Compartment
(Continued)

are completely removed. This can be seen in Figure 8 where a 100% line is obtained from the background spectra before the door was opened, and a new scan was collected 3 min after the door was closed. Figure 6, 7, and 8 illustrate that simple purging the sample compartment will provide good results. This, of course, does not remove all of the water and CO_2, and the water vapor and the CO_2 gas are still present in the desiccated chamber. Nonetheless, if a system is purged only in the sample compartment, it is far better than not purging at all.

Conclusion

Changing levels of CO_2 and water vapor in a laboratory atmosphere can result in interference from these contaminants for unpurged FTIR spectrometers. The changing levels of CO_2 and water are primarily a result of operator breathing, and the extent of interference to the FTIR spectra is dependent on the amount of time elapsed between the background spectra and the sample spectra.

Purging of the sample compartment increases the reliability and consistency of FTIR spectra. The experiments described above clearly identified the need for purge, even for the purgeless sealed and desiccated FTIR spectrometer sample compartment. The purge gas generator proved to be a suitable source of purge gas for such FTIR spectrometers.

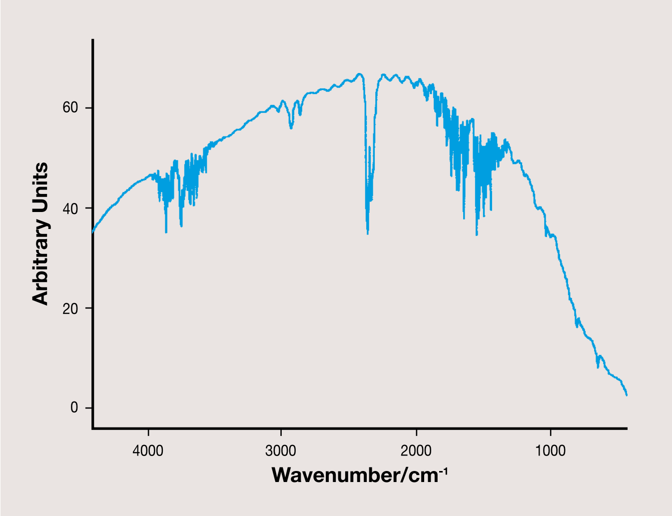


Figure 5: *Single-beam spectrum from sealed and desiccated FTIR spectrometer with purged sample compartment.*

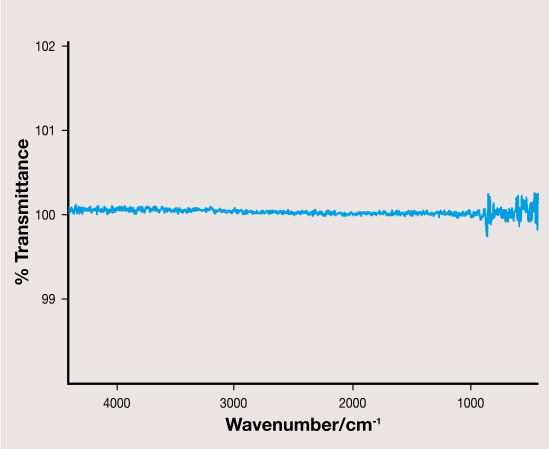


Figure 6: *100% Transmittance from sealed and desiccated FTIR spectrometer with purged sample compartment.*

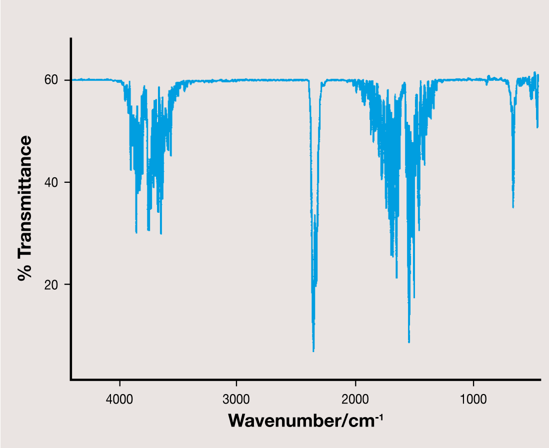


Figure 7: *100% Transmittance from sealed and desiccated FTIR spectrometer with purged sample compartment. Sample compartment opened for 15 sec between scans.*

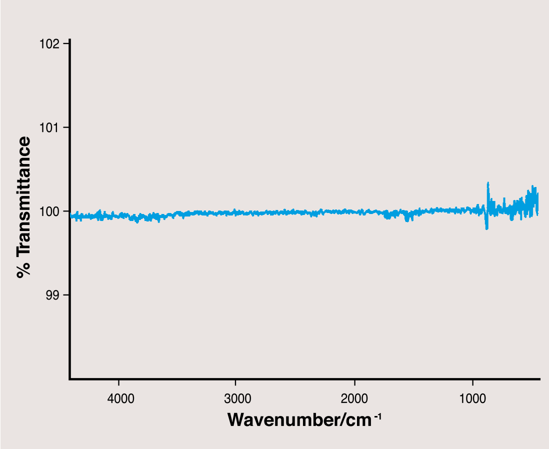


Figure 8: *100% Transmittance from sealed and desiccated FTIR spectrometer with purged sample chamber. Second scan collected 3 min after sample compartment was opened.*

Nitrogen Generation in a Drug Metabolism Laboratory *by Eldridge Luther*

American Laboratory
Reprinted from American Laboratory March 1999

A drug metabolism laboratory is now saving $750,000 per year in cylinder costs alone by generating its own nitrogen. Pfizer, Inc. (Groton, CT) has also saved the time required to change 30 gas cylinders per day, which would keep one person busy for the entire day. The laboratory uses nitrogen as curtain gas and shield gas in mass spectrometers used in high-throughput screening applications. The on-site nitrogen generation system uses a membrane separation technique to produce nitrogen from air on demand with virtually no operating costs.

An important portion of drug development is determining the pharmacokinetics—the impact of the body on the drug. An aspect of the study of pharmacokinetics is concerned with measuring the rate and extent with which the drug is absorbed into the systemic circulation and the manner through which the body disposes of the drug. One goal is to determine a dosing regimen that will maintain the drug in the body at a level at which it is therapeutically effective without any undesirable toxic or side effects.

Rise of mass spectrometry

To measure how rapidly the body disposes of drugs, the drug metabolism group must perform a huge number of analytical measurements of drugs in tissue slices and animal and human blood samples. Over the last several years, atmospheric pressure ionization (API) mass spectrometry has become the primary tool for making these measurements. Before a sample is introduced into the mass spectrometer, LC mobile phase solution containing the sample is nebulized using nitrogen gas. As the aerosol spray droplets evaporate, the molecules are charged. These charged gas phase ions are then drawn from the atmosphere into the vacuum of the mass spectrometer passing through a curtain of nitrogen gas to decluster from polar neutrals (solvents). Parent ions are very readily formed and can be fragmented into daughter ions by up-front collision induced dissociation (CID) or between the first and second quadrupole with LC-MS-MS by introducing a collision gas such as nitrogen. All the ions are accelerated, separated, and focused onto an ion detector by means of a quadrupole mass analyzer. The fragmentation pattern usually provides a unique fingerprint of a molecule, allowing positive identification.

Nitrogen is a critical requirement for nearly all state-of-the-art mass spectrometers. First of all, it is used to form a curtain of gas behind the inlet of the instrument that prevents air from entering along with the sample. Curtain gas must be maintained at higher than atmospheric pressure so that it continually seeps out of the inlet and requires continual replenishment. Secondly, after they enter the instrument, sample molecules are accelerated and made to collide with a second reservoir of nitrogen, known as collision gas. The purpose of the collision gas is to knock molecular clusters apart into individual ions that are far simpler to analyze.

Cost of nitrogen

The drug metabolism laboratory at Pfizer was the first in the pharmaceutical industry to use API mass spectrometry to evaluate drug pharmacokinetics. The company purchased one of the first laboratory-scale API mass spectrometers offered for sale on a commercial basis from Sciex, formerly a division of Perkin-Elmer (Norwalk, CT) (*Figure 1*). This instrument provided substantially more utility and greater sensitivity than the earlier analytical methods; therefore the drug metabolism laboratory soon purchased two more. This was the point at which management noticed that it was using a lot of nitrogen. The three instruments required an average of three nitrogen cylinders per day at a total cost of $300. In addition, about an hour of a technician's time had to be devoted to hauling the cylinders from the loading dock and installing them in the laboratory.

The expense and inconvenience associated with the use of nitrogen cylinders were high enough that management was motivated to investigate the recent development of inexpensive methods for on-site nitrogen generation. Joint ventures between industrial gas companies and chemical companies have resulted in successful R&D programs to improve gas generation technology. The most influential of these developments is the use of membranes and specialized adsorbents for the production of nitrogen gas.

Membrane filtration methods

The laboratory initially purchased a model N2-14 nitrogen generator (*Figure 2*). The system utilizes proprietary membrane separation technology. The generator separates air into its component gases by passing inexpensive, conventional compressed air through bundles of individual hollow-fiber, semipermeable membranes. Each fiber has a perfectly circular cross-section and a uniform bore through its center. Because the fibers are so small, a great many can be packed into a limited space, providing an extremely large membrane surface area.

Two stages of coalescing prefiltration are incorporated into the generator to protect the membrane module from contamination. These filters are located behind the filtration access panel, and they remove liquids and particulate matter from the incoming air supply. The filters are equipped with float drains that automatically open to empty any accumulated liquid inside the filter housing. The drains are connected to 1/4" o.d. plastic tubing, which discharges to atmosphere at the back of the nitrogen generator.

Nitrogen Generation in a Drug Metabolism Laboratory *(Continued)*

High-purity source

Air separation takes place in the membrane module. The module consists of bundles of hollow-fiber membranes. The inlet air enters the center bore of these fibers and travels the length of the fibers.

As the air passes through these hollow fibers, oxygen and water molecules pass through the membrane at a higher rate than nitrogen molecules. This results in a high-purity, dry LC-MS grade nitrogen gas exiting the membrane module. The oxygen-enriched permeate stream exits the membrane module through ports on the side of the module at very low pressure.

The final filter, a 0.01-µm absolute membrane filter, provides a clean, commercially sterile supply of high-purity nitrogen. The controls on the nitrogen generator consist of an operating pressure gauge, flowmeter and flow control valve, outlet pressure regulator, and final gauge. Proper use of these controls ensures the user of a 99–99.5% LC-MS grade nitrogen outlet stream, depending on operating pressure and flow rate. The pressure gauges, which are mounted on the front panel, measure operating pressure and outlet pressure. The flowmeter measures the flow rate of nitrogen exiting the membrane module.

Cost savings

This initial nitrogen generator installation saved $300 per day or about $75,000 per year. This paid for the approx. $8,000 cost of the nitrogen generator within a few months and generated substantial savings from that point on. However, these savings were soon to greatly increase because the use of mass spectrometry at the drug metabolism laboratory was just beginning to take off. Today, the laboratory has 30 of these instruments, including Sciex model 150 single quadrupoles and 300 and 365 triple quadrupoles and Finnigan (San Jose, CA) TSQ and LCQ instruments (*Figure 3*). Researchers estimate that if the laboratory were still using nitrogen cylinders, the annual cost would be in the area of $750,000, and one full-time employee would be required to install the 30 cylinders per day needed to keep the instruments running.

Instead, the laboratory has purchased several model N2-14 nitrogen generators and a compressor that provides 125 psig air. The total cost of this equipment was about $34,000. As a result, instead of paying $750,000 for nitrogen, the cost is nearly zero. The only recurring expense is the electricity required to operate the compressor. Operating costs of the nitrogen generators are limited to changing the filter on each unit every six months or so, which costs about $300. In addition, the generator has saved one full-time position by eliminating the need to handle nitrogen cylinders and eliminating the danger of downtime caused by running out of nitrogen.

Zero environmental impact

The generator requires virtually no attention because it uses simple electromechanical components such as pressure vessels, and valves with a history of reliability in laboratory applications. A key factor in the increased reliability provided by the generator is its elimination of the logistics of the gas supply chain. Since the nitrogen generator simply separates air into its constituent parts, it has no adverse environmental effects. Both the nitrogen produced by the unit and the oxygen mixture generated as a by-product can be released into the atmosphere. Gas generators are also much safer than high-pressure cylinders. The generator typically operates at a low pressure of around 100 psig and stores small volumes of compressed gas. The stored volume is much less than 1 ft3, compared to about 200 ft3 stored in a typical high-pressure gas dewar. Gas generators also eliminate the need to handle cylinders, which presents a risk of injury caused by dropping, lifting, or asphyxiation.

The development of on-site gas generators is very good news for drug development laboratories and diverse users of mass spectrometers and other instruments that require a regular supply of nitrogen. In addition to saving money, nitrogen generators provide long-term cost stability by eliminating the risk of gas shortages or uncontrollable vendor price increases.

Model N2-14 **Figure 2**

The Shift to On-Site Gas Generation *By Robert Daly*

American Environmental Laboratory

Reprinted from American Environmental Laboratory March 1995

Over the past three decades we have experienced many changes in our culture: in our homes, governments, institutions and occupations. Technological advancement has resulted in the elimination of time-honored traditions and behaviors. In many instances, we have forever changed the way we do things. This phenomena is often described as a paradigm shift. The word paradigm is derived from the Greek word paradeigma, which means pattern, example, or model. A paradigm shift is the change from a traditional way of acting, thinking, or doing, to newer, more effective ways.

Paradigm shifts are often motivated by the availability of new technologies and typically result in obvious benefits such as increased efficiency and convenience, improved performance, reduced cost and an ability to solve difficult problems. Two examples of a paradigm shift are elimination of the home delivery of ice by the invention and commercialization of the refrigerator/ freezer and replacement of the home delivery of milk in resuable glass bottles by disposable packaging. More recently, the delivery of water deionization tanks to laboratories has been replaced by the availability of point-of-use water purification systems; personal computers have resulted in internal corporate desktop publishing, and a paradigm shift in Japanese manufacturing has resulted in the changed perception of Japanese products from poor quality during the 1960s and 1970s to among the highest quality in the world during the 1980s and 1990s. It is easy to imagine the future obsolescence of video rental stores resulting in the availability of movies through a fiber optic superhighway and replacement of the current internal combustion engine by one that is powered by alternative fuels such as natural gas, electricity, or hydrogen.

Many such paradigm shifts have occurred in the laboratory, including the use of autosamplers, computer-controlled instrumentation, automated titration, fused-silica capillary columns and the use of supercritical fluids for extraction.[1] This article describes the paradigm shift occurring within the laboratory related to the method for supplying compressed gases used for a variety of purposes.

Applications for compressed gases

Many applications exist for compressed gases in the laboratory. These include purge gas, carrier gas, and fuel gas for instruments such as fourier transform infrared spectrometers, gas chromatographs, total organic carbon analyzers, nuclear magnetic resonance spectrometers and thermal analyzers. Noninstrument applications include solvent evaporation, purging of laser gas chambers, use with autosamplers, and blanketing of solvents and samples. The gases typically used for these applications include air, nitrogen, hydrogen, helium, argon and various mixtures. The required gas purity depends on the application and can range from filtered air to research-grade nitrogen with less than 1ppm contaminant concentration.[2]

For these applications, compressed gases are an important utility. Much like electricity, water, natural gas, heat and telephones, compressed gases are essential to the operation of the laboratory. Consequently, the source of this utility should be convenient, reliable, safe, and cost effective. As with many other utilities, the supply of compressed gases should be simple and taken for granted. Currently, the availibility of on-site, point-of-use gas generators is allowing scientists and managers to treat the supply of compressed gases as a utility as opposed to a contracted service.

Traditional source of compressed gases

Ever since compressed gases have been used in the laboratory, the accepted source has been the high-pressure gas cylinder. These cylinders are filled to a high pressure, typically 2200 psig, with the required gas by a supplier operating a gas production facility. The cylinders are delivered to customers upon purchase and picked up when empty. The empty cylinders are then refilled and delivered to another customer.

The primary disadvantages of gas supply in the form of high-pressure cylinders are delivery and service inconveniences, safety, purity and cost (including hidden cost). The advantage of high-pressure cylinders is the availability of a wide range of gases for applications in a laboratory.

Several types of inconvenience are frequently experienced in the use of delivered high-pressure gas cylinders. Every user of gas cylinders will eventually experience unplanned downtime as a result of an empty cylinder. This may occur in the midst of an analysis, overnight, or during a weekend. Other inconveniences include delayed delivery, inflexible delivery schedules, price increases, and
long-term contracts. The procurement procedure within the customer's company may also result in unwanted delays.

The use of high-pressure compressed gas cylinders must be accompanied by a concern for safety. The primary safety issues are transportation, handling, storage, use, asphyxiation, toxicity and flammability.[3] Special precautions must be taken while handling high-pressure cylinders.[4,5]

A dangerous situation can be created if a cylinder is dropped and a valve is broken off, potentially causing the cylinder to become a projectile.[6] Other potential hazards that are inherent in the storage of compressed gases include asphyxiation, combustion, and explosion.[7] Various regulations by the Department of Transportation (DOT) and the Occupational Safety and Health Administration (OSHA) address the hazardous aspects of high-pressure gas cylinders.[8,9] Potential hazards in the use of high-pressure gas cylinders are serious enough to warrant the use of warnings indicating that improper use can result in serious injury or death.

Mr. Daly is Marketing and Sales Manager,
Parker Hannifin Corporation, 242 Neck Road
Haverhill, MA 01835; Tel: 800-343-4048 or 978-858-0505;
Fax: 978-556-7501

The Shift to On-Site Gas Generation *(Continued)*

There are disadvantages to the use of compressed gas cylinders based on gas purity considerations. The gas purity will vary from one cylinder to another and it will also vary as the gas within the cylinder becomes used.[10] Cylinders may be dirty, rusted, and contaminated, resulting in outgassing of contaminants from the cylinder walls. Compressed gas supplied in high-pressure cylinders can be tested and certified upon request, for an additional charge. If a cylinder is not certified, the customer has no confirmation that the actual purity meets the stated specification.[11] The result of
using a gas that has a purity below specification can be the costs associated with inaccurate analysis.

Many indirect or hidden costs in the use of high-pressure gas cylinders include the time and effort to change cylinders; generation and expedition of a purchase order; receipt of full cylinders and shipment of empty cylinders; payment of monthly invoices; and maintenance of a gas inventory for reordering purposes. Consider the departments involved in this process; R&D, purchasing, shipping, accounts payable, and central supplies. These hidden overhead costs are generally accepted as part of the cost of operating a laboratory and should be taken into consideration during the process: of choosing a supply of compressed gases. Laboratory managers might be surprised if the full cost of compressed gas delivery was plainly visible.

All the costs listed (direct and indirect) can be obtained either from the compressed gas supplier or through an activity-based costing approach to the purchasing company's overhead costs. This type of cost analysis is shown in Table 1 for the purchase of a single cylinder of ultrazero-grade air used for one month, before replacement. This analysis shows that the hidden costs amount to an additional 47% of the actual purchase price of the gas delivered in the high-pressure cylinders.

On-site generation of compressed gases

In the past five years, the availability and use of on-site compressed gas generators has increased significantly.[12] This increase can be attributed primarily to the improvement of technologies used in the generation and purification of gases, the recent commercialization of many on-site generators and the ever-increasing prices for compressed gases delivered in high-pressure cylinders.

The technologies contributing to the increased availability of point-of-use gas generators include membranes, specialized adsorbents and catalysts, improved air compressor designs, and enhanced electronic controls. These technologies will continue to improve the availability, performance and value of laboratory gas generators. The most influential of these technological developments is the use of membranes and specialized adsorbents for the production of nitrogen gas. Joint ventures between industrial gas companies and chemical companies have resulted in successful R&D programs to improve the technology for on-site generation of nitrogen. On-site generation of nitrogen is available for purities ranging from 95% to 99.9999%. Other gases that can be reliably produced on site include hydrogen and various purities of air.

Table 1

Cost analysis for compressed gas supplied in a high-pressure cylinder *

Cost component		Typical cost
Cylinder gas price		$100
Cylinder demurrage (one month)		$5.25
Labor cost to change cylinder		$8.33
Order processing cost		$10
Shipping cost		$10
Invoice payment cost		$10
Inventory control cost (monthly		$3.33
Total	US	$146.91

* Gas cylinder price is based on typical ultra zero-grade air.
All indirect costs are typical for gas cylinder suppliers or calculated through activity-based costing of a manufacturing company.

The effectiveness of on-site generation should be analyzed based on convenience, reliability, safety, and cost. The attractiveness of on-site gas generation depends greatly on the specific gas being used, the required purity, required flow rate, hours of operation per day, and local gas prices. For instance, on-site generation may not be an attractive alternative for an application requiring sporadic usage of research-grade nitrogen based on cost alone, whereas it will be attractive for purging an FTIR spectrometer or providing hydrogen fuel to a flame ionization detector (FID) that operates 24 hr/day (based solely on cost).

Gas generators provide convenience through the elimination of reliance on an external delivery service. Once the on-site gas generator has been purchased and installed, delivery of the desired gas is automatic, reliable and relatively inexpensive. Typical preventative maintenance is performed on an annual basis and requires little or no downtime.

Reliability of on-site generators is based on the operation of simple electromechanical components involved in gas purification. These components, such as pressure vessels, valves, timers and heaters, have a history of reliability in industrial applications. The logistics of a delivery system have been eliminated so that reliability is based only upon the performance of the gas generator.

The purity of gas delivered by quality on-site generators is typically very consistent and dependent upon adherence to maintenance schedules. On-site generators deliver gases through the same flow system from the day they are installed until they are decommissioned. Thus, the gas purity is not influenced by a change in the materials of contact, as it is with high-pressure cylinders.

Gas generators provide increased safety in comparison to high-pressure cylinders. The generators typically operate at low pressures (such as 100 psig) and store small volumes of pressurized gas. This stored volume may vary from less than 50 cm^3 to several gallons as compared to over 200 ft^3 of gas stored in high-pressure gas cylinders. Gas generators eliminate the need to handle heavy gas cylinders, which is a risk of injury or damage caused by lifting, dropping, asphyxiation, and potential explosion. Safety issues with gas generators concern the use of electrical and mechanical components. These types of concerns should be relieved if the generators are designed and tested to Underwriters Laboratories (UL), Canadian Standard Association (CSA) and International Electrotechnical Commission (IEC) specifications.

The cost of purchasing and operating a gas generator is attractive as compared to the use or high-pressure cylinders. Paybacks are typically calculated at less than one year depending on the specific usage and required purity. Perhaps most importantly, the cost to operate and maintain a gas generator is very low, especially relative to the cost of ordering, storing and changing high-pressure gas cylinders. Table 2 shows a cost analysis for a typical installation of a gas generator to replace the use of high-pressure gas cylinders. This cost analysis of a hypothetical laboratory replacing high-pressure gas cylinders with an on-site gas generator shows a payback of about six months.

Disadvantages to on-site generation should be mentioned. Generation equipment may need to be budgeted for purchase as opposed to paying for delivered gas through an expense account. Users of gas generators should plan for present and future gas requirements in order to properly size a system.

American Environmental Laboratory

Reprinted from American Environmental Laboratory March 1995

Table 2

Ultrazero-grade air cost comparison:
On-site generator versus high-pressure cylinders *

Cost component	Gas generator	High-pressure cylinder
Gas generator price	$3,500	NA
Annual power cost	$15	NA
Annual maintenance cost	$411	NA
Annual cylinder gas price	NA	$5,700
Annual cylinder demurrage	NA	$126
Annual labor cost to change cylinders	NA	$475
Annual order processing cost	$30	$360
Annual shipping cost	$10	$570
Invoice payment cost	$10	$120
Inventory control cost	NA	$40
Total	$3,961	$7,391

* Gas generator cost is based on a model HPZA-3500 (Parker Hannifin Corporation, Haverhill, MA), which requires 120 VAC power.

Cylinder gas cost is based on 3 slpm flow rate of ultra zero-grade air for 8 hr day, 260 days/yr, at a price of $100/cylinder.

Other cylinder costs include demurrage at $5.25/cylinder per month, cylinder change labor at 10 min/cylinder and $50 hr, order processing cost at $10 order, shipping cost of $10/cylinder, invoice payment of $10/monthly invoice, and an inventory control cost of $40/yr.

Test laboratory example

Minnesota Valley Testing Laboratories (MVTL, New Ulm, MN) represents an example of the benefits of on-site gas generation. The laboratory provides environmental, agricultural, and energy testing services to industry. The laboratory was purchasing ultrahigh-purity hydrogen cylinders to supply fuel gas for FIDs and nitrogen phosphorous detectors (NPDs), make-up gas for electrolytic conductivity detectors (ELCDs), and carrier gas for GC columns. Safety was a concern and monitoring of the cylinders was an inconvenience. Technicians had to continually watch the cylinders. Hydrogen was used as a carrier gas for GC columns, and if it were to run out, the column would be damaged.[13] Also, MVTL would occasionally get a contaminated cylinder, resulting in skewed analysis and delayed work.

The laboratory has purchased on-site generators to replace zero air cylinders for fuel air to FIDs, flame photometric detectors (FPDs), and NPDs; to replace ultrahigh-purity nitrogen cylinders for make-up gas for electron capture detectors (ECDs), NPDs, ELCDs, and FIDs; and to replace hydrogen cylinders for fuel gas applications. An MVTL chemist indicated that the unit will have paid for itself in less than two years, after which the laboratory will be producing its own hydrogen at a fraction of the cylinder cost. Other benefits cited by MVTL include no longer having to handle and monitor cylinders. Low maintenance is also an advantage. Installation was easy: the generator was plugged in, water was added, and the instruments connected. The hydrogen generator also takes up less space.

Conclusion

Change is never easy and it is seldom comfortable, but change allows us to learn and improve, increase efficiencies and convenience, achieve better performance, reduce costs and solve difficult problems. In this day of corporate reengineering and global competition, laboratories are experiencing a paradigm shift related to the use of compressed gases. This shift from high-pressure gas cylinders to on-site gas generators will result in reduced operating and overhead costs, positioning laboratories to be more competitive and successful.

The Shift to On-Site Gas Generation *(Continued)*

users should use convenience, reliability, safety and cost as primary criteria. The convenience, reliability and safety of gas generators compare favorably to high-pressure gas cylinders. A simple cost analysis utilizing activity-based costing techniques will show pay-backs of less than one year for the change to on-site gas generation for many typical applications. Over the next decade, as this paradigm shift matures, laboratory managers and scientists will view the last few cylinders in their laboratory similar to the way we all view the glass milk bottle.

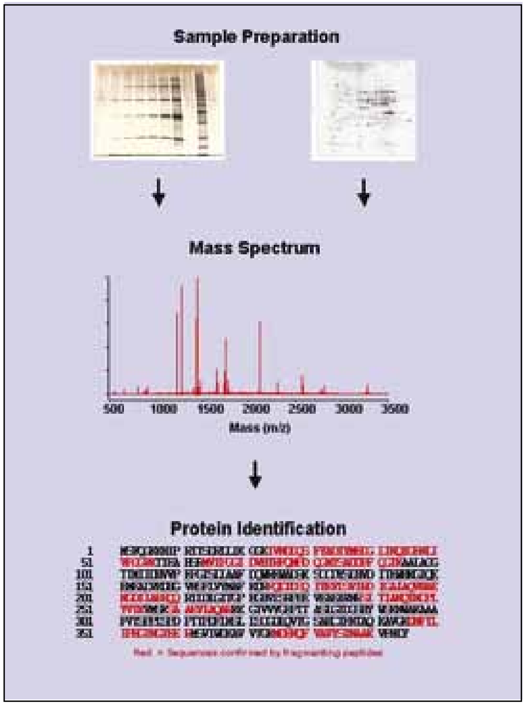
References

1. Halloran K. Laboratory automation: The professional's role. Today's Chemist Oct 1993:48.
2. Hinshaw JV. Carrier and detector gases. LC.GC Sept 1988:794-8.
3. Compressed Gas Association, Inc. Handbook of compressed gases. New York: Van Nostrand Reinhold Co., 1981.
4. Air Products and Chemicals, Inc. Safety-gram-10. Handling, storage and use of compressed gas cylinders; 1988.
5. Air Products and Chemicals, Inc. Safety-gram-11. Emergency action in handling leaking compressed gas cylinders; 1993.
6. Air Products and Chemicals, Inc. Safety-gram-14. Don't turn a cylinder into a rocket; 1988.
7. Air Products and Chemicals, Inc. Safety-gram-17. Dangers of oxygen deficient atmospheres; 1992.
8. United States Code of Federal Regulations. Title 49, Parts 170 to 179.
9. United States Government. Department of Labor, Occupational Safety and Health Act of Congress. December 29, 1970, Public Law 91-596.
10. Albert A, et al. What happens to gas cylinder purity as content is consumed? IEEE/SEMI Advanced Semiconductor Manufacturing Conference, 1993, Boston, MA.
11. Krippene DT, Kurek WT, Samuels SL. The nines mirage. A question of purity. Pittsburg Conference and Exhibition. 1989, Atlanta, GA.
12. Hardenburger T. Producing nitrogen at the point of use. Chem Eng News. 1992; 99(10): 136-46.
13. Balston, Inc. Technical tips from Balston, Minnesota Valley Testing Laboratories eliminates the danger and inconvenience of hydrogen cylinders, winter 1993.

Proteomics Mass Spectrometry Facility Saves Time, Money and Space By Using a Nitrogen Generator

The Johns Hopkins School of Medicine Mass Spectrometry Facility is saving time, money and space by generating its own nitrogen gas, according to Robert N. Cole, Ph.D., facility director. "When we first opened this facility, we obtained nitrogen gas from cylinders and discovered that we were changing tanks daily to prevent interruption in the nitrogen supply" Cole said. "So we invested in a nitrogen generator and compressor that produces all of our nitrogen requirements. It takes up less space than a single cylinder and, best of all, almost never needs any attention. Based on cylinder costs alone the gas generator and compressor will pay for itself in less than two years. In addition, it saves me from spending time checking gas levels and setting up tanks. The unit provides very high purity gas and has run reliably since we put it into operation."

Of all the medical schools in this country with associated basic science research, Hopkins has perhaps the longest-standing reputation. It was the first institution, in the late 1890s, to separate teacher-researchers from clinicians and offer them a salary for their work. Many of this country's first true basic scientists gathered at Hopkins then, eager to set up laboratories. William Henry Howell, for example, sparked physiology research and first laid down a clear explanation of blood clotting. Today, researchers in the School of Medicine bring to Hopkins more National Institutes of Health research funding than to any other medical school. For the 11th consecutive year, The Johns Hopkins University School of Medicine was one of the top two medical schools in the nation, according to U.S. News & World Report's annual ranking. Hopkins was a close second to Harvard with a score of 94, up dramatically from 73 points last year.



Sciex QStar

New mass spectrometry facility

Johns Hopkins recently opened a new mass spectrometry facility designed to service the entire university. Most of their work involves the identification of proteins or peptides that researchers have isolated and are trying to identify. The facility has two mass spectrometers, the most advanced is the QSTAR hybrid liquid chromatograph/mass spectrometry system from Applied Biosystems, Inc. For scientists engaged in identifying metabolites or potential-lead compounds, the QSTAR system offers high mass accuracy to determine the compound's elemental composition and fragmentation analysis to obtain structural information for compound identification. Parent molecules or fragment ions from the quadrupole section enter the ion accelerator and are pulsed into the flight tube. The ion mirror reverses the direction of the ions and corrects for small energy differences in ions. The detector records the precise arrival time of each ion and generates the signal to form the mass spectrum.

Nitrogen is a critical requirement for the QSTAR as well as nearly all state-of-the-art mass spectrometers. It is used to form a curtain of gas behind the inlet of the instrument that prevents air from entering along with the sample. Curtain gas must be maintained at higher than atmospheric pressure so it continually seeps out of the inlet and requires continual replenishment. Nitrogen is also used as a collision gas. After ions enter the instrument, they are accelerated and made to collide with a second reservoir of nitrogen. The purpose of the collision gas is to break up sample molecules to determine their composition.

Proteomics Mass Spectrometry Facility Saves Time, Money and Space By Using a Nitrogen Generator *(Continued)*

Solving the nitrogen supply problem

When Johns Hopkins first purchased the QSTAR, they were faced with the issue of how to provide nitrogen gas to their new instrument. Cole decided to try purchasing nitrogen cylinders from a local gas supplier. He soon discovered that the cylinders needed to be changed at least once and sometimes twice a day. This meant that he had to pay close attention to the amount of gas in the cylinder and, when it was nearly empty, take the time to change the cylinder and order a replacement. The time spent dealing nitrogen supply subtracted from the amount time that he had to set up analysis runs and manage the facility. In addition, he had to keep two or three cylinders on hand at all time to avoid a supply disruption that could shut down the laboratory. The problem was that the cylinders are quite bulky and the laboratory is small, creating a substantial space problem.

Cole investigated the new breed of nitrogen generators that eliminate the inconvenience and cost of cylinder gas supplies. He made the decision to purchase the Balston N2-22 membrane nitrogen generator and AGS-L189 compressor from Parker Hannifin Corporation, Filtration and Separation Division, Haverhill, MA. The system utilizes proprietary membrane separation technology. The generator separates air into its component gases by passing inexpensive, conventional compressed air through bundles of individual hollow fiber, semi-permeable membranes. Each fiber has a perfectly circular cross-section and a uniform bore through its center. Because the fibers are so small, a great many can be packed into a limited space, providing an extremely large membrane surface area.

Three stages of pre-filtration

Three stages of coalescing pre-filtration are incorporated into the Parker Balston N2-22 nitrogen generator to protect the "The nitrogen generator now supplies all curtain and collision gas required by the QSTAR mass spectrometer," Cole said. " It basically runs by itself without requiring any attention from me. It eliminates the need to keep track and change gas cylinders. Most important, it eliminates having to worry about whether we have enough gas to continue in operation until new cylinders are delivered. It saves a considerable amount of space. The gas generator is less than the size of a single cylinder. The gas generator also saves about $1,000 per month in cylinder costs. Including the compressor and storage tank, it cost about $20,000, so it will pay for itself in cylinder costs alone in less than two years. The unit has provided trouble-free operation since it was installed. The only interruption of supply that I have had was when someone accidentally turned off the compressor, which is located in a different room. All in all, it has met all my requirements, providing high quality gas without disrupting
my work."

For additional information on Parker Balston® products, contact Parker Hannifin Corporation, Filtration and Separation Division, 242 Neck Road, Haverhill, MA 01835
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Web site: www.labgasgenerators.com

Model AGS-L189 Series Compressor

Hydrogen/Zero Air Gas System Saves Money in GC/FID Operation at Crime Lab

A new system specifically designed to support gas chromatography/flame ionization detector (GC/FID) operation has generated cost savings at the Texas Department of Public Safety's Crime Laboratory Service. The gas cylinders used in the past for the FID were expensive and costly, building modifications would have been needed to meet new regulatory requirements if they had continued to be used. Crime Lab staff were aware that gas generators were available but found it difficult to justify the cost and space required by two separate units. Then they discovered the Parker-Balston Model FID-1000 gas station, which is specially designed for FIDs and provides both pure hydrogen and zero grade air. The new gas station has eliminated the expense of purchased gas as well as the labor involved in handling gas bottles and has also eliminated the need for what would have been expensive building modifications.

From a one-chemist operation established in 1937 at Camp Mabry in Austin, the Crime Laboratory Service has developed into a staff of more than 160 in 13 locations today. The major function of the Toxicology Section is body fluid analyses in cases of driving while intoxicated (DWI) and drug overdose. The analyses require specialized instrumentation and procedures such as automated gas chromatography (GC), automated gas chromatograph/mass spectrometry (GCMS), solid phase extraction preps, and Enzyme Multiplied Immunoassay Technique (EMIT) screening techniques, which is a drug screen of blood and urine. Targeted drug classes include amphetamines, barbiturates, benzodiazepines, cocaine, opiates, and phencyclidine. Additional drugs are detected with GCMS screening.

FID used for blood alcohol analyses

The Crime Lab in Austin analyzes approximately 250 samples per month for blood alcohol using a PerkinElmer Autosystem XL GC with a HS40-XL Headspace autosampler. Blood alcohol analysis is typically performed in DWI investigations and in traffic accidents where people have been critically injured or killed. Alcohol analysis is used to determine the concentration of ethanol and to determine if methanol, acetone, 2-propanol, or toluene is present in blood or urine. The procedure used by the Toxicology Section employs automated headspace GC with quantitation by internal standard integration. According to Henry's Law, at equilibrium, in a sealed vessel, volatile compounds in the liquid state will be present in the vapor state at a concentration proportional to the concentration in liquid. By sampling this vapor, the headspace, through a gas chromatograph, the volatile compound may be qualitatively identified and quantitatively measured. A single headspace injection is split into two capillary columns, each exiting to an FID. The columns have different polarity for unique separations of the volatiles of interest. An FID consists of a hydrogen/air flame and a collector plate. Organic compounds eluting from the chromatographic column are swept into a flame that burns in a mixture of hydrogen and air within what is called the detector jet. During this process the organic compounds are broken down into carbon fragments and acquire a positive charge (i.e., become ionized) from the surface of the jet, which serves as an electrode. These ionized carbon fragments are detected by a second electrode slightly down-stream in the detector cell. This signal is amplified and sent to the data processing system. Because of its relatively high sensitivity to most organic compounds, the FID is very powerful tool for GC. The response of the detector does not change markedly with variations in changes in the flowrate, pressure or temperature of the mobile phase gas and thus, provides a very robust, stable detector. It also has a linear response over a wide mass range, generally encompassing several orders of magnitude.

Critical requirements for FID gas supply

"Purity of the hydrogen gas and air supplied to the FID is very critical to the accuracy of the measurements," said Glenn Harrison, Supervisor of Toxicology for the Texas Department of Public Safety Austin Laboratory. "Any extra hydrocarbons that enter the detector through either the hydrogen or air supply generate extra signal that raises the baseline of the measurements. In the past, we purchased hydrogen and zero air gas bottles to supply our FID detector used in blood alcohol analysis. This was pretty expensive, although we didn't track the costs with any level of precision. What brought the issue to a head was when we discovered that some new safety regulations would have required that we vent the special room to store the gas bottles outside the building."

"The costs of this construction project would have been high and it highlighted the general safety issues involved in storing pressurized hydrogen gas," Harrison continued. "Every time you have a cylinder of compressed hydrogen there are issues that you need to be concerned with. We have never had a problem handling hydrogen but the potential always exists for a person to make a mistake. I decided to take a look at gas generator technology to see if it could eliminate these concerns. At first, I expected that I was going to have to purchase two separate units to supply the needs of the FID, pure hydrogen and zero grade air," Harrison continued. "That would have substantially stretched out the payback and two units also would have required more space, more maintenance, and involved more potential things that could go wrong. That's why I was very happy to hear that Parker had developed a gas system that meets all the requirements of an FID."

Hydrogen/Zero Air Gas System Saves Money in GC/FID Operation at Crime Lab *(Continued)*

Parker Balston unit meets all FID requirements

The Parker Balston FID-1000 gas station provides both pure hydrogen gas at 99.9995% purity from deionized water and zero grade air from compressed air. Hydrogen is produced through electrolytic dissociation of water and hydrogen proton conduction. Positively charged hydrogen ions are transported across a solid polymer electrolyte where molecular hydrogen is formed. The hydrogen stream is further purified to scavenge oxygen and is delivered at an outlet of the device. Zero air is produced by purifying on-site compressed air to a total hydrocarbon concentration of less than 0.1 parts per million (100 ppb), measured as methane. The FID-1000 gas station produces up to 90 cc/min of hydrogen and 1000 cc/min of zero grade air. The system is designed to provide fuel and air to support two FIDs. It takes up a space of 16.5 inches high, 10.5 inches wide and 17 inches deep and weighs only 46 pounds.

The unit offers automatic water fill capability, silent operation and requires minimal operator attention. The generator requires virtually no attention because it uses simple electromechanical components such as pressure vessels, and valves with a history of reliability in laboratory applications. Routine maintenance is limited to periodic replacement of filter cartridges, requires no factory servicing and can easily be performed by the user. A key factor in the increased reliability provided by the generator is its elimination of the logistics of the gas supply chain. Since the gas station simply separates water into its constituent parts, it has no adverse environmental effects. Both the hydrogen produced by the unit and the oxygen mixture generated as a byproduct can be released harmlessly to atmosphere. Gas generators are also much safer than high-pressure cylinders. The generator typically operates at a low pressure in the neighborhood of 100 psig and stores small volumes of compressed gas. The stored volume is significantly less than 1 cubic foot, compared to about 300 cubic feet stored in a typical high-pressure gas cylinder. Gas generators also eliminate the need to handle cylinders, which presents a risk of injury caused by dropping, lifting, or asphyxiation.

"Our decision to purchase the gas station has eliminated the need to purchase gas bottles on a regular basis," Harrison said. "We have also eliminated the need to upgrade our facility because the gas station eliminates the need to store hydrogen and operates at such a low pressure that special venting is not needed. We haven't seen any change in the performance of the FID, which indicates that the gas we are producing is just as pure as what we were purchasing in the past. In the several months that we have operated the gas station, it has delivered trouble-free performance. We are also using a second gas station to support a GC/FID in the controlled substances section. This is clearly a concept that should be explored by other crime labs that are concerned about the high cost and safety issues involved in handling bottled hydrogen."

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Nitrogen-Generator Helps NMR Uncover New Methods of Targeting Anthrax

A nitrogen generator is playing a key role by improving the resolution of nuclear magnetic resonance (NMR) spectrometers in studies aimed at finding biological targets with which to attack anthrax bacteria. One of the things that makes anthrax so dangerous is its ability to form spores that are so tough you can put them in boiling water without killing the bacteria. John Cavanagh, Professor of Biochemistry at North Carolina State University, Raleigh, North Carolina, is studying signal transduction pathways that allow bacteria such as anthrax to respond to environmental stress with the goal of eventually developing new therapeutic targets. A critical part of this work involves the use of NMR to determine the three-dimensional structures and interactions of biological molecules in solution. Cavanagh has long used nitrogen to maintain the physiological temperature of the sample undergoing NMR spectroscopy. In the past, his laboratory spent about $400 per month purchasing liquid nitrogen dewars and nitrogen gas cylinders. Recently he invested in a gaseous nitrogen generator that can continually produce nitrogen direct from his building's compressed air at minimal cost and requires practically no maintenance. "The NMR machine we are using cost exactly one million dollars but we were able to substantially improve its performance with a simple device that cost under $11,000," Cavanagh said.

The Parker Balston Nitrogen Generator installed at NCSU

Bacteria are highly adaptable organisms occupying an inexhaustible variety of ecological niches. They possess exceptional protective and responsive capabilities by encoding, at the correct times, a repertoire of genes normally unexpressed unless called upon. The key to bacterial adaptability lies in their capacity to invoke the necessary signal transduction pathways needed for protection and maximal growth in the specific situation in which they find themselves. They accomplish this by sensing signals emanating from their environment, recognizing its composition and subsequently initiating the correct response to ensure survival. Bacteria are extraordinarily accomplished at all these tasks and rapidly establish complex communication networks to cope with a myriad of stressful circumstances. The commitment for self-protection requires an enormous investment of energy, and there would be little advantage in such an undertaking if the environmental hostility was fleeting. Consequently the cell first enters a transition-state. During this time the cell decides which particular protective strategy is the most appropriate in light of the stress it faces. The transition-state is under the control of so-called transition-state regulators. These communication modules are very important targets for antimicrobial therapeutic agents.

Transition-state regulators

Transition-state regulators provide the cell with some well-needed breathing room as it contemplates its future. Not surprisingly they play essential roles in inducing synthesis of virulence factors in many pathogens in response to nutrient and metabolite deprivation. Studies to this point have centered on broad genetic characterization of transition-state regulators and little is known about their detailed mechanism of action. Cavanagh's laboratory was responsible for the first detailed structural characterization of any transition state regulatory protein, AbrB (antibiotic resistance protein B) from Bacillus subtilis bacteria. AbrB from B. subtilis shares 100% identity in the DNA-binding domain and 85% identity overall with AbrB from anthrax, lending his studies extra significance. The AbrB protein from anthrax is known to be a negative regulator of the three anthrax toxins, lethal factor, edema factor and protective antigen. Anthrax secretes the three subunits of its toxin into the bloodstream of its host. Seven protective-antigen molecules then assemble into a pre-pore. The pre-spore undergoes a change in shape, forming a mature spore that allows lethal factor and edema factor to enter cells. Once inside, these toxin subunits destroy the cell, paving the way to disease.

NMR spectroscopy is the most powerful analytical technique available for determining the three-dimensional solution structure of proteins that form the molecular basis for these and many other biological processes. NMR is a phenomenon that occurs when the nuclei of certain atoms are immersed in a static magnetic field and exposed to a second oscillating magnetic field. Some nuclei experience this phenomenon, and others do not, depending upon whether or not they possess a property called spin. Under proper conditions, such nuclei absorb electromagnetic radiation in the radio-frequency region at frequencies governed by their chemical environment. This environment is influenced by chemical bonds, molecular conformations, and dynamic processes, for example. By measuring the frequencies at which

Nitrogen-Generator Helps NMR Uncover New Methods of Targeting Anthrax *(Continued)*

these absorptions occur and their strengths, it is usually possible to deduce facts about the structure of the molecule being examined. NMR spectroscopy is routinely used by chemists to study chemical structure using simple one-dimensional techniques. Two, three- and four--dimensional techniques are used by structural biologists to determine the structure of more complicated molecules. Time domain NMR spectroscopic techniques are used to probe molecular dynamics in solutions. These techniques are challenging and complementing x-ray crystallography for the determination of protein structure.

Challenge of distinguishing spectral lines

"For the most part the results of NMR spectroscopy – the resonances - are displayed as a two-dimensional map with the axes representing two different, identifying nuclear frequencies in the protein." Cavanagh said. "As the size of the molecule being studied increases, the resonance lines generated by its various atomic components broaden and can begin to overlap which makes it difficult or impossible to determine its structure. Keeping resonances as narrow as possible to alleviate any overlap is a huge part of performing high-resolution NMR on complex biomolecules. At the same time, the protein sample we study must typically be maintained around room temperature and this is generally accomplished by blowing air over it. The problem with air is that it partly consists of oxygen atoms with one unpaired electron. That single electron often couples to the nuclei which greatly broadens the lines on the spectrum, increasing their tendency to overlap and making them that much more difficult to interpret. We overcome this problem by delivering temperature-controlled nitrogen instead because it doesn't interfere with the sample. We have found that nitrogen can dramatically improve the quality of the results that we are able to obtain with NMR."

When Cavanagh's laboratory first began using nitrogen, he purchased nitrogen tanks from a local gas supplier. The tanks cost in the neighborhood of $100 each and lasted about one week. This represented a significant expense and also meant that he and other laboratory personnel had to pay close attention to the amount of gas left and, when it was nearly empty, take the time to change the tank and order replacements. Moving the tanks was a particularly delicate operation because the magnets in the NMR spectrometer are so powerful that if you drop a flashlight near them it will never hit the floor. The time spent dealing with nitrogen supply subtracted from the amount time that was available to set up analysis runs and manage the facility.

Nitrogen generator provides continuous supply

In an effort to eliminate these problems, Cavanagh investigated the new breed of gas generators that produce nitrogen to a high level of purity by separating it from air. The basic advantage of this approach is that the laboratory eliminates the need to purchase and handle gas tanks. Cavanagh selected a Balston® N2-45 nitrogen generator from Parker Hannifin Corporation, Filtration and Separation Division, Haverhill, Massachusetts that produces up to 124 standard liters per minute at a purity level ranging from 95% to 99.5% without using any electricity. The generator requires virtually no attention because it uses simple electromechanical components such as pressure vessels, and valves with a history of reliability in laboratory applications. Since the nitrogen generator simply separates air into its constituent parts, it has no adverse environmental effects. Gas generators are also much safer than high-pressure tanks as the generator typically operates at a low pressure in the neighborhood of 100 psig and stores small volumes of compressed gas.

The N2-45 produces nitrogen by utilizing a combination of filtration and membrane separation technologies. A high efficiency pre-filtration system pre-treats the compressed air to remove all contaminants down to 0.01 micron. Hollow fibers separate the clean air into concentrated nitrogen output stream and oxygen enriched permeate stream that is vented form the system. The combination of technologies produces a continuous on demand supply of pure nitrogen. Routine maintenance is limited to periodic replacement of filter cartridges, requires no factory servicing and can easily be performed by the user.

"This machine paid for itself very quickly by eliminating the need to purchase gas dewars and cylinders," Cavanagh concluded. "It is very robust. We couldn't break it even if we tried. While I am continually working with a million-dollar NMR machine, I have to admit that I get an enormous kick out of this one, which cost only a few thousand dollars. It's a very simple but elegant device. If we didn't have it our lives would be much more complicated."

For additional information on Parker Balston® products, contact Parker Hannifin Corporation, Filtration and Separation Division, 242 Neck Road, Haverhill, MA 01835.
Tel: 800-343-4048 Fax: 978-556-7501
Web site: www.labgasgenerators.com

A shot of the Varian Inova 600MHz NMR spectrometer with the N2 generator in the background

Providing Gases for LC-MS Systems in a Safe, Convenient, and Cost-Effective Manner

By Peter Froehlich

American Laboratory
Reprinted from American Laboratory August 2007

A liquid chromatographic system with a mass spectrometric detector (LCMS) requires a supply of nitrogen as the curtain gas, pure zero grade air as the source gas, and dry (–40 °F dewpoint) air as the source exhaust gas. In many facilities, these gases are provided by a series of compressed gas tanks; while the use of gas tanks can meet the overall requirements of the system, this approach imposes a number of serious operational, safety, and economic disadvantages. From an operational standpoint, the tanks must be replaced periodically, requiring operator involvement and reducing the overall uptime of the system. In addition, the handling of compressed gas tanks introduces a significant safety risk and is an expensive way to supply the necessary gases.

A considerably safer, more convenient, and cost-effective method of providing the necessary gases is via in-house gas generation. An in-house gas generator is a compact system that can be located in the facility directly alongside the LC-MS system and operate on a continuous basis with a minimal amount of operator interaction. This paper describes how gas generation systems can provide the various gases from laboratory air, discusses the benefits that arise from their use, and portrays a number of cases in which significant benefits have been achieved from self generation of the gases.

In-house generation of gases for LC-MS

In-house generation of gases such as nitrogen, zero air, and source exhaust air from laboratory air involves a number of discrete processes to separate the various components of air into a series of gas streams of the desired purity that can be directly ported into the LC-MS. A variety of gas generation systems are available that can provide a single component (e.g., nitrogen), and many facilities acquire a generator for a single gas since the other gases (e.g., dry air) may already be available in the facility.

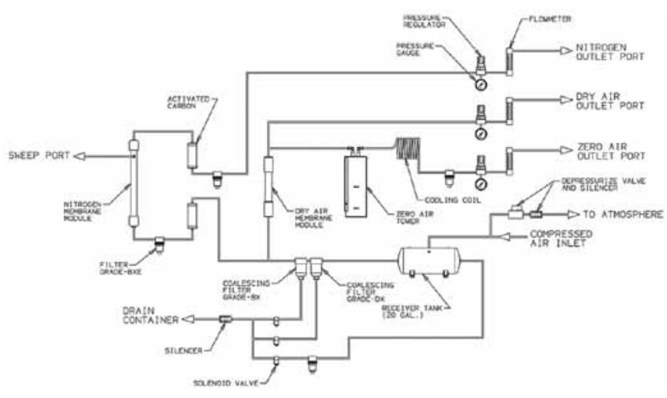

Figure 1 *Schematic representation of Parker Balston model LCMS-5000 tri-gas generator. (Reprinted with permission from Parker Balston Source LC/MS TriGas Generator Series Model LC-MS 5000 Technical Bulletin, 2006.)*

In recent years, the various components of gas generation systems have been integrated into a single system to generate the assorted gases that provide all of the gases required for LC-MS. This offers a significantly greater degree of convenience, system control, and cost savings for the chromatographer. The general design of an integrated system (Parker Balston model LCMS-5000 tri-gas generator [Parker-Hannifin Corp., Filtration and Separation Div., Haverhill, MA]) is presented in Figure 1 (gas generation systems that are designed to provide only one of the gases [e.g., nitrogen contain only those components relevant for generation of the desired gas). The input for the generator is laboratory air, which is divided into three streams to generate the desired gases. The generator includes the following major components to produce the various gases:

- Compressor—pressurizes ambient laboratory air to 110–140 psi (7.5–9.6 bar). An oil-less rotary scroll compressor is employed, which consists of two identical spirals offset 180° with respect to the other so that the scroll mesh is used to compress the air. An after-cooler cools the temperature of the discharged air. The cooling serves to extend the system life and condenses much of the water in the compressed air, which is sent to an electric drain trap and is automatically discarded.
- Coalescing filters—remove additional water and particulate matter (as small as 0.01 μm) from the compressed laboratory air. Drains collect the liquid that is accumulated and automated valves allow the liquid to be sent to waste. This filter protects the hollow fiber membrane that generates nitrogen (see below) and associated components from contamination that may foul the operation.
- Activated carbon module—removes hydrocarbon contaminants that may be present in the air. One module is located before the hollow fiber membrane, and a second carbon module is located after the hollow fi ber membrane to ensure that research-grade purity gas is supplied to the instrument.A filter is placed after the carbon module to trap any carbon particles.
- Hollow fiber membrane bundle (for nitrogen)—consists of a series of hollow fiber membranes that permit oxygen and water vapor to permeate it and escape through the sweep port while the nitrogen flows through the tube, as shown in Figure 2. While each individual fiber membrane has a small internal diameter, a number of fibers are bundled together to provide an extremely large surface area for permeation of oxygen and water. After the membrane bundle, the nitrogen passes through another carbon filter and is allowed to fl ow directly to the outlet port at a flow rate of up to 10 L/min at a pressure of 80 psi.

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(Continued)

- Dryer membrane (for dried air)—permits water vapor to permeate the hollow fi bers of the membrane, resulting in dry air. A small portion of the dry air is redirected along the fibers to sweep out additional water vapor. Dried air from the dryer membrane is allowed to flow directly to the outlet port. Air with a dewpoint of –40 °F is delivered at a flow rate of 28 slpm at a pressure of 100 psig.
- Catalyst module (for zero air)—oxidizes hydrocarbons into CO_2 and H_2O. A coiled copper after-cooler and fan are employed to cool the hot outlet air. The cooled zero air passes to the zero air outlet port at a flow rate of up to 23 L/min at a pressure of 110 psig.

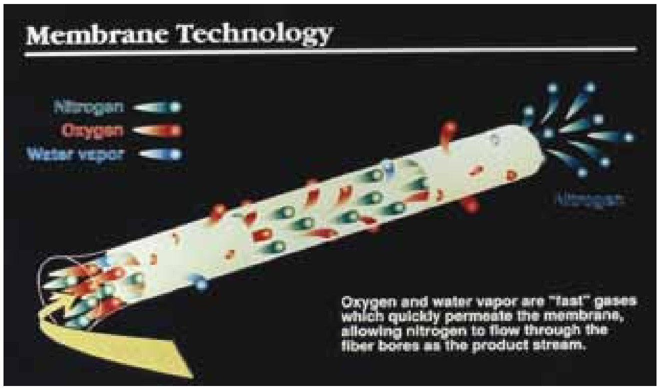

Figure 2 *The hollow fi ber membrane bundle separates nitrogen from air. Oxygen and water vapor permeate the membrane, allowing nitrogen to flow through the tubes. (Reprinted with permission from Parker Balston Analytical Gas Systems Bulletin AGSB, 2006, p. 32.)*

The detailed specifications of the various gases provided are summarized in Table 1. The in-house gas generator can supply a continuous stream of the requisite gas(es) for the LC-MS system at the flow rate and pressure necessary to maintain operation of an LC-MS system, and systems are available to provide the necessary gases for a single or two LC-MS systems.

Operation of an in-house gas generator is straightforward. Once the system is installed, no day-to-day maintenance or user interaction is required. The system contains no moving parts, except for the compressor. On a periodic basis, the filters should be replaced; typically they are replaced after approx. 5000 hr of operation or on a yearly basis to ensure optimum performance.

Comparing in-house generation of gases with the use of tank gases for LC-MS

An in-house gas generator offers a number of significant benefits to the operator of an LC-MS system relative to the use of tank gas. These include a dramatic improvement in safety, a reduction in the inconvenience of changing and handling tanks, and a significant lowering of the cost of supplying the gases.

Minimizing safety hazards

When a gas generator is used, only a small amount of the gas is present at a low pressure, and the gas can be ported directly to the LC-MS. Typically, a gas generator produces 10 L/min of nitrogen gas at a maximum pressure of 80 psig of nitrogen. If a nitrogen leak were to occur, there is relatively little danger of asphyxiation with an in-house gas generator. In contrast, a number of significant hazards are present when tank gas is employed to supply the necessary gases to the LC-MS. For example, if the contents of a full tank of nitrogen were suddenly vented into the laboratory, up to 9000 L of nitrogen gas would be released. This volume would displace the laboratory air, thereby reducing the breathable oxygen content of the atmosphere and potentially creating an asphyxiation hazard to the laboratory occupants.
In addition, the use of tank gas requires that the analyst transport each replacement tank from a secure storage area to the laboratory. A standard tank is quite heavy and can become a guided missile if the valve on a full tank is compromised during transport.

Table 1 Principal specifications of gases generated by Parker Balston model LCMS-5000NA

Curtain gas (nitrogen)	To 10 L/min at 80 psi
Source gas	To 23 L/min at 110 psi
Exhaust gas	To 8 L/min at 60 psi
Pressure dewpoint	–40 °F
Hydrocarbons	<0.05 ppm (measured as methane)
Particles	>0.01 μm None
Phthalates	None
Suspended liquids	None

Convenience issues

When an in-house gas generator is utilized, the gases are supplied on a continuous basis and can be provided 24 hr/7 days a week without any user interaction or routine maintenance. In contrast, when tank gas is employed, the user must pay close attention to the level of gas in the tank and replace the tank periodically. If the need for replacement occurs during a series of analyses, the analyst must interrupt the analytical work to restart the system, wait for a stable baseline, and may have to recalibrate the system.
In addition, if a series of automated analyses is desired (i.e.,on an overnight basis), the analyst must check that sufficient volume of each gas is on hand before starting the sequence.

The frequency of tank replacement clearly depends on the usage of the LC-MS system. For example, the central mass spectrometry facility at the Johns Hopkins University School of Medicine (Baltimore, MD) recently reported that the volume of samples to be analyzed required changing the

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(Continued)

tanks at least once and sometimes twice a day.1 This is clearly an inconvenience and leads to a reduction in the useful operating time of the LC-MS facility. In addition to the actual time required for changing the tank, the laboratory staff must verify that there are sufficient tanks in storage and order replacement tanks as appropriate. The use of a nitrogen generator eliminates the need to keep track of and change gas cylinders.

A further issue is that in many facilities, spare gas tanks are stored outside in a remote area (for safety reasons), and it may be time consuming to get a replacement cylinder. When it is necessary to obtain a tank, the operator may need to find an individual who is qualified to handle the tanks. Many users have indicated that replacing used tanks can be a significant inconvenience, especially in inclement weather if the tanks are stored outside.

The Parker Balston model LCMS-5000NA tri-gas generator is a flexible system that can be readily adapted to a broad range of LC-MS systems. For example, a system is employed at mSpec (Concord, Ontario, Canada), an instrument service group that supports, maintains, and services LC-MS systems. This group has found the generator to be an extremely reliable system that provides the necessary gases with little effort and superb results. Scientists at mSpec have
found that no condensable residues were observed when a cryogenic pump was used in the LC-MS system.

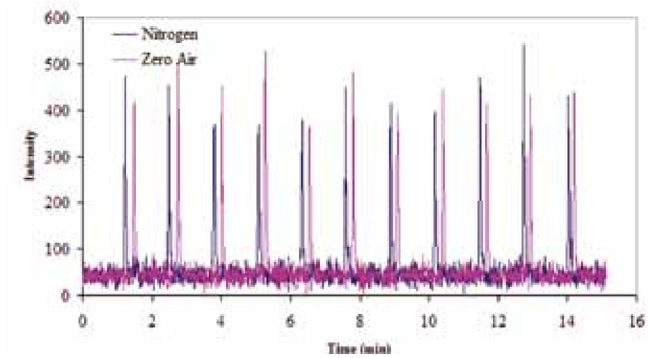

Figure 3 *Comparison of sensitivity (S/N) between nitrogen and zero air for HBCD. (Figures 3–5 reprinted with permission from Ref. 2.) Courtesy of Environment Canada, Burlington, Ontario, Canada.*

Comparing the use of zero air and nitrogen in MS detection

A recent study indicated that the LC-MS data of small molecules of environmental interest collected using zero air produced by a Parker Balston model 64-02 membrane dryer and Parker Balston model HPZA-18000 zero air generator were equivalent to data collected using nitrogen generated via a Parker Balston 75-880 nitrogen generator.[2] This study compared the LC-MS of HBCD (hexabromocyclodecane), PFOS (perfl uorooctanoic sulfonic acid), PFOA (perfluorooctanoic acid), imidacloprid, and linuron using a Sciex API 2000 mass spectrometer (Toronto, Ontario, Canada). For HBCD analysis, the mass spectrometer was operated in electrospray ionization (ESI) negative ion mode. MS-MS detection used multiple reaction monitoring (MRM) conditions for the m/z [M-H] 640.6 to Br [79, 81] transition utilizing unit resolution on the first and third quadrupole with a 100-msec dwell time. For linuron, the transitions from m/z 249 to m/z 160 and m/z 247 to m/z 160 were measured in both positive ion and negative ion mode. For imidacloprid, the transitions from m/z 256 to m/z 209 and m/z 254 to m/z 153 were measured in both positive ion and negative ion mode. Typical data are shown in Figures 3–5, where it can be seen that no significant changes in sensitivity were observed when either gas was employed.

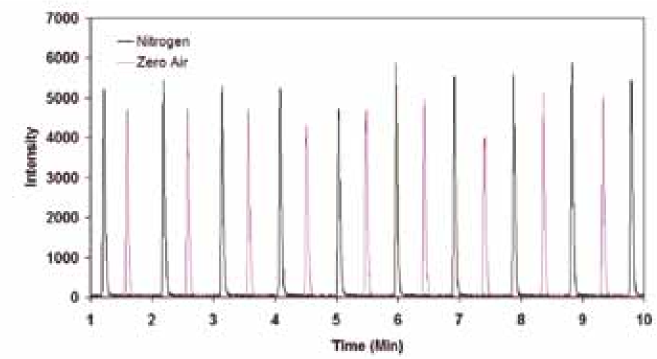

Figure 4 *Comparison of sensitivity (S/N) between nitrogen and zero air for linuron. Courtesy of Environment Canada, Burlington, Ontario, Canada.*

Cost issues

In addition to the signifi cant safety and convenience benefits, an extremely important benefit of a gas generator is that it provides a powerful economic benefit compared to the use of gas tanks. The running cost to operate a tri-gas generator is extremely low, since the raw materials used to prepare the required gases are air and electricity. The running costs and maintenance for a tri-gas generator are a few hundred dollars per year. The cost for gas tanks includes their actual cost, and the time involved to change tanks, order new tanks, and maintain inventory, etc. While the calculation of the precise cost of the use of gas tanks for a given user is dependent on a broad range of local parameters and the amount of gas that is used, some reports are presented below to give the reader an understanding of the potential savings that arise from the use of an inhouse gas generator:

- The laboratory at Pfizer (Groton, CT) used 2–3 tanks of nitrogen gas per day to support three LC-MS systems. A nitrogen generator was purchased and saved approximately $300/day (in 1999), or about $75,000/yr. The laboratory grew to about 30 LC-MS systems and is estimating a savings of approximately $750,000/year.[3]

Providing Gases for LC-MS Systems in a Safe, Convenient, and Cost-Effective Manner
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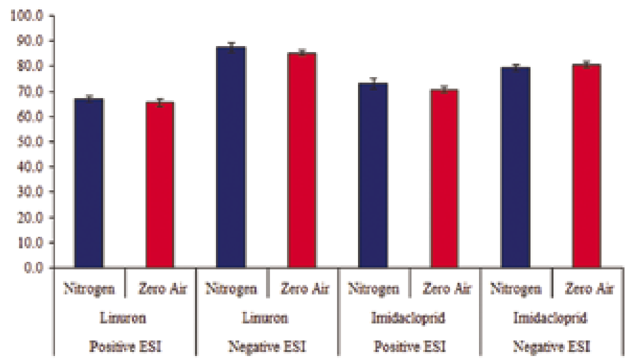


***Figure 5** Comparison of sensitivity (S/N) between nitrogen and zero air for linuron and imidacloprid. Courtesy of Environment Canada, Burlington, Ontario, Canada.*

- The laboratory at Johns Hopkins calculated that the nitrogen generator requires less space than a tank of gas. It saved over $1000/month (in 2002) and will pay for itself in cylinder costs alone in less than two years.[1]
- A laboratory at Applied Biosystems (Framingham, MA) employs nitrogen generators and zero air generators for a bank of eight LC-MS systems. It is estimated that the use of nitrogen tanks would require four tanks per week. The nitrogen generator has been in operation for approximately five years without any problems, except for routine maintenance.

It should be noted that there are many hidden costs, including transportation costs, demurrage costs, and paperwork (e.g., a purchase order, inventory control, and invoice payment) when tank gas is employed. In addition, the value of the time required to get the tank from the storage area, install the tank, replace the used tank in storage, and wait for the system to reequilibrate after the tank has been replaced costs money as well.

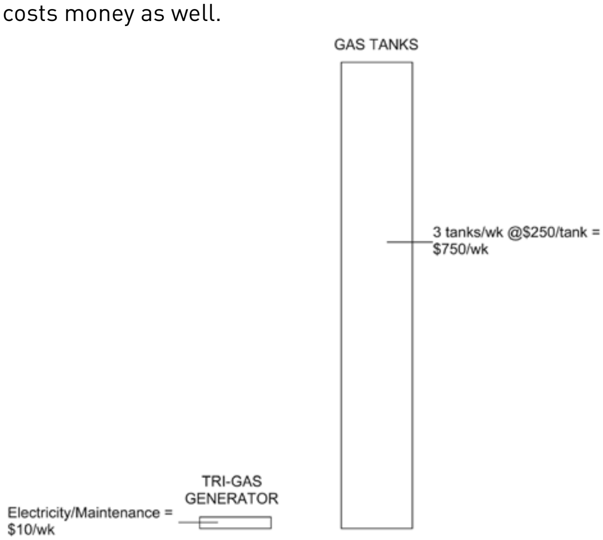


***Figure 6** Cost comparison between tank gas and tri-gas generation (assuming gas consumption of one tank of each gas per week).*

A comparison of the cost to supply gases via tanks versus the cost to use the trigas generator is presented in Figure 6. In this analysis, it was assumed that a single tank of each gas is consumed per week at a cost of $250 per tank (this approximation does not take into account the incidental cost of handling the gas tank, downtime, ordering tanks, etc.), for a total of $750. In comparison, the cost of using the tri-gas generator is perhaps $10 per week.

Conclusion

The use of an in-house generator for the gases (nitrogen, dry air, and zero air) required for an LC-MS system provides a significant number of benefits to the chromatographer compared to the use of tank gas. A gas generator system eliminates the safety issues inherent in the use of tank gas and the transportation of gas tanks. In addition, the generator can supply the necessary gases with a high degree of purity on a 24-hr/7-day basis. The gas generator can operate 24 hr/7 days a week with essentially no operator involvement, removing the inconvenience of replacing tanks. Signifi cant economic benefi ts can be attained with the gas generator, since the requisite gases are obtained from laboratory air, and it is no longer necessary to purchase and maintain an inventory of gas tanks. Integrated systems, which generate the three gases, provide a total solution and can simplify use of the LC-MS system. The employment of nitrogen and zero gas leads to equivalent data in LC-MS analysis.

References

1. Cole, R.N.; Hart, G.W. Am. Biotechnol. Lab. 2002, 20 (9), 32.
2. Alaee, M.; Kriwoy, P.; Spencer, C.; Scott, B.; Ueno, D.; McInnis, G.; Marvin, C.; Hewitt, M.; Batchelor, S.; Sverko, E. 54th American Society for Mass Spectrometry, San Antonio, TX, May 2005, Session MP05, Slot 68.
3. Luther, E. Am. Lab. 1999, 31(6), 62.

Dr. Froehlich is President, Peak Media, 10 Danforth Way, Franklin, MA 02038, U.S.A.; tel.: 508-528-6145; e-mail: pfpeakmedia@msn.com.

Reprinted from *American Laboratory News* March 2008

by Peter Froehlich and Rich Cardarople

Is Bottled Nitrogen a Greenhouse Gas?

The level of greenhouse gases such as CO_2 is believed by scientists to have a dramatic, unfavorable impact on worldwide climate change. In recent years, many individuals and organizations have analyzed how the overall use of energy and its by-products contribute to the generation of greenhouse gases. Subsequently, new approaches have been developed to reduce the contribution of these gases to the atmosphere. While the long-range reduction of greenhouse gases will likely be achieved by the development of new approaches to power generation and broad changes in energy consumption (e.g., transportation), in the short term, significant reductions in the generation of greenhouse gases can be obtained by analyzing energy consumption patterns and implementing alternative techniques that reduce the amount of energy consumed by various processes.

The generation of nitrogen gas for the laboratory is an excellent example of how a significant reduction in the generation of greenhouse gases can be brought about by selecting an alternative process that performs the desired operation while consuming less energy. Nitrogen gas is commonly used in a broad range of applications in the laboratory; typical applications include gas chromatography, liquid chromatography with mass spectroscopy detection, Fourier transform infrared spectroscopy, inductively coupled plasma spectroscopy, glove boxes, and blanketing of reactions that require an inert atmosphere.

High-purity nitrogen gas for laboratory applications is normally obtained by the fractional distillation of air. This process requires a considerable amount of energy since the air must be compressed and chilled to below the vaporization point of nitrogen (–195.8 °C at 1 atm) to liquefy it. The liquid nitrogen is then vaporized to produce nitrogen gas. Since the gas is usually generated at a facility that is somewhat distant from the site at which it will be used, it is then stored in bottles or tanks and transported to the end user's facility. Once the gas has been consumed, the empty bottle must eventually be transported back to the distillation site to be refilled. The overall energy that is required to operate the fractional distillation facility and to transport the tank to and from the end user's site is a significant contributor of greenhouse gases such as CO_2 in the atmosphere.

An alternative approach to the generation of nitrogen gas in the laboratory uses a hollow fiber membrane to separate the desired gas from air with a high degree of purity. The only power that is required by a system that uses a hollow fiber membrane is the electrical power needed to operate a compressor to deliver the air to the membrane.

This paper compares the various approaches for the generation and delivery of nitrogen gas to the laboratory; discusses the energy considerations that are required for each operation in the two processes; compares the greenhouse gas emissions; and shows how the use of a membrane-based system to supply nitrogen gas provides a safer, lower-cost, and more convenient, effective approach to providing nitrogen in the laboratory.

Nitrogen generation by fractional distillation of air

Commercially, the fractional distillation of air producing nitrogen and oxygen is an energy-intensive process that is normally performed on a continuous basis on a large scale. Typically, commercial facilities are designed to generate hundreds or thousands of tons of the gases per day. While each fractional distillation facility is specifically designed to meet the needs of the customer base and the nature of the available energy input, the following is a general description of the various operations required to obtain nitrogen from air:

Table 1 Composition and boiling points of the components of dry air

Component	Volume	Boiling point (1 atm)
Nitrogen	78.04%	–195.8 °C
Oxygen	20.95%	–183.0 °C
CO_2	0.03%	–78.5 °C
Ar	0.93%	–189.2 °C
Ne	18 ppm	–246.0 °C
He	5 ppm	–268.9 °C
Kr	1 ppm	–152.3 °C
Xe	0.08 ppm	–107.1 °C
H_2	0.5 ppm	–257.9 °C
CH_4	2 ppm	–164.0 °C
N_2O	0.5 ppm	–88.5 °C

- Air is withdrawn from the atmosphere using a compressor
- The compressed air is chilled to approximately 10 °C and passed through a moisture separator; an oil absorber; and molecular sieves to remove water vapor, oil, particulate matter, and other contaminants
- The dried, purified air enters a multipass heat exchanger and then a Joule-Thompson type expansion engine to cool and liquefy the air
- The liquefied gas is vaporized and purified (if necessary); nitrogen boils and vaporizes before oxygen (see *Table 1*)
- The purified nitrogen gas is pressurized and stored in bottles or tanks
- The nitrogen bottles are transported from the distillation site to the end user.

A number of small-scale liquid nitrogen generators based on the fractional distillation approach for operation in the laboratory are available. These systems operate in a similar manner as the large-scale commercial systems, or use a pressure swing absorption technology, employing carbon molecular sieves. These smaller systems can generate on the order of 50–100 L of liquid nitrogen per day. Once the liquid has been generated, it is allowed to evaporate, producing gaseous nitrogen. While these systems eliminate the transportation issues, they still require significant energy input. Because the volume from such a system is smaller than the large "industrial-scale systems," economies of scale suggest that these are even more energy-intensive than the large systems normally used. In addition to the significant energy input required to liquefy the gas, the user should consider the possibility of personal injury from contact with the liquid.

Nitrogen generation using an in-house hollow fiber membrane system

Pure nitrogen for laboratory use can be readily obtained from air using an in-house hollow fiber membrane system. The membrane module, which is the heart of the system, is designed to preferentially allow oxygen and water vapor in the air to quickly permeate the membrane wall (*Figure 1*) while nitrogen travels through the hollow fiber out the end.

The processes involved in the in-house generation of nitrogen using a hollow fiber membrane system include:

- Air is withdrawn from the atmosphere using a compressor
- The compressed air passes through a high-efficiency coalescing filter to remove water vapor and particulate matter
- The clean, dried air passes through an activated carbon filter, removing hydrocarbons before entering the separation module

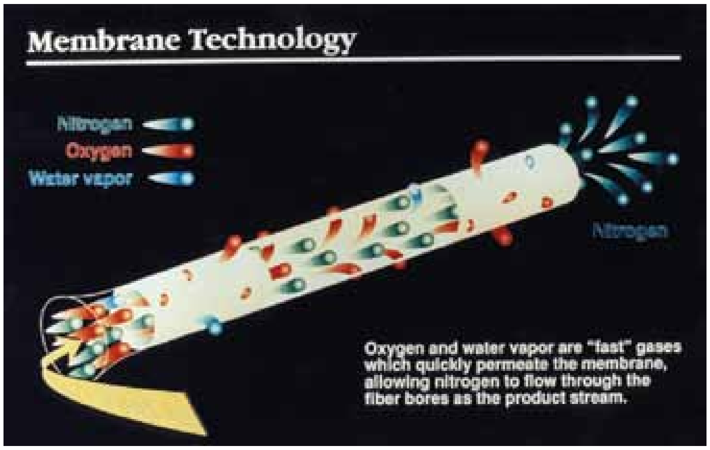


Figure 1 *Hollow fiber membrane bundle separates nitrogen from air. Oxygen and water vapor permeate the membrane, allowing nitrogen to flow through the tubes (reproduced with permission from* ***Parker Hannifin Corp.****).*

- The stream passes through hollow fiber membranes to separate the oxygen and any remaining water vapor from the nitrogen-enriched gas stream (see Figure 1)
- The nitrogen passes through a final filter, which contains coalescing or activated carbon, if required, based on the application to ensure a clean, commercially sterile supply of high-purity nitrogen
- The nitrogen supply passes directly to an outlet port of the system that is directly connected to the device in which the gas is required.

The hollow fiber has a small internal diameter, and thousands of fibers are bundled together to provide a large surface area to provide the desired flow of nitrogen. In a typical system, a high-purity gas greater than 99.5% N_2 at a flow rate up to 467 L/min at an outlet pressure of 100 psig can be obtained. A schematic diagram of a typical system for the generation of nitrogen is shown in *Figure 2*.

Additionally, the hollow fiber membrane technology can be used to dry air. If desired, a nitrogen-generating system can be combined with a dryer membrane module to supply individual streams of dry air, source exhaust, air, and nitrogen (e.g., for an LC-MS system).

Energy considerations for obtaining nitrogen using the fractional distillation of air

Obtaining nitrogen using the fractional distillation of air is a very energy-intensive process because it is necessary to condense the ambient air into the liquid form by cooling it and compressing it. While the amount of energy that is required clearly depends on the dynamics of the system used, it is apparent that a considerable amount of energy

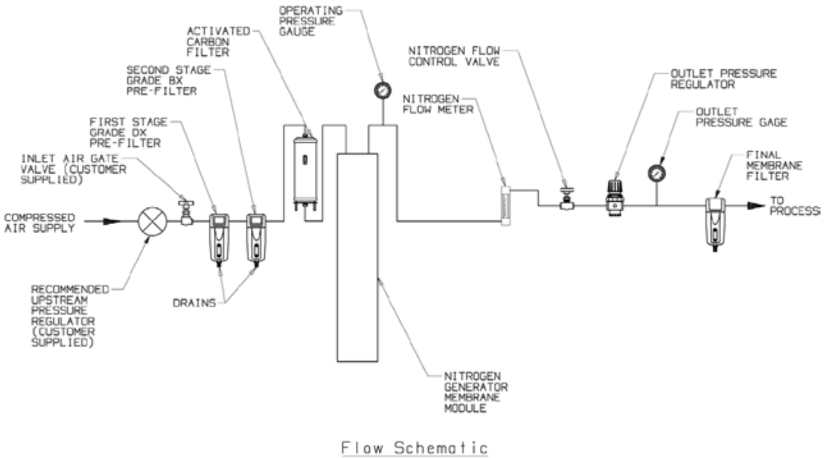


Figure 2 *Schematic representation of Parker Balston N2-14 nitrogen generator (***Parker Hannifin Corp.,** *Haverhill, MA) (reproduced with permission from* **Parker Hannifin Corp.***).*

Table 2 Annual costs; in-house generation versus high-pressure tanks (in $U.S.)*

	In-house generator	Tanks
Electrical power	$380	$0
Maintenance (compressor)	$1500	$0
Maintenance (generator)	$800	
Cylinders	$0	$11,160[a]
Demurrage	$0	$840[b]
Labor (changing cylinders)	$0	$5580[c]
Order processing	$30	$360[d]
Shipping	$100	$3720[e]
Invoice processing	$10	$120
Inventory control	$0	$72
Total	$2820	$21,852

*Assumptions:
[a]186 cylinders at $60/cylinder.
[b]10 cylinders in use (5 in use; 5 filled) at $7/month.
[c]$30 labor/cylinder.
[d]1 order/month at $30 processing costs.
[e]$20/cylinder.

must be expended. Once the nitrogen has been separated from the air, it is necessary to employ additional energy to purify it to the desired level and fill the bottle.

In addition to the energy required for the fractional distillation process, a significant amount of energy is required to transport a bottle of gas from the distillation site to the end user. The amount of energy required to transport the bottle is dependent on the distance from the plant to the end facility. If, for example, the gas bottles are delivered by a truck that travels 10 miles/gal and must travel 50 miles to deliver 100 bottles to the end user's facility, an energy consumption of 0.05 gal of fuel per bottle is required to deliver the bottle, and 0.05 gal of fuel to return the bottle to the distillation site, for a total energy consumption of 0.1 gal of fuel per bottle (this can be significantly higher if the tank is delivered to a severely congested area).

Energy considerations for obtaining nitrogen using a hollow fiber membrane system

When a hollow fiber membrane system is used for the generation of nitrogen, the only energy that is required is the energy used to power the compressor that supplies air to the system. Assuming a 3-hp compressor is used with a 50% duty cycle, the equivalent of five 9000-L tanks of nitrogen can be generated per day at an approximate power expenditure of 25 kWh (kilowatt-hour). Since the nitrogen system is normally directly connected to the instrument, no energy is required for transporting the gas.

Comparing the greenhouse gas contribution for the generation of nitrogen by fractional distillation and a hollow fiber membrane

Clearly, the amount of greenhouse gas that is generated by providing nitrogen gas to the laboratory is dependent on the mode of generation as well as the manner of delivering the gas to the end user. In addition, the manner in which the expended energy is created is a critical issue. The energy employed for fractional distillation and operation of the compressor is very dependent on local considerations (fossil fuels, nuclear, wind, biomass, etc.), while the energy required for transport of the gas to the end user is clearly derived from fossil fuels. The use of a hollow fiber membrane for the generation of nitrogen utilizes significantly less energy and hence generates less greenhouse gas than fractional distillation. Additionally, less energy is required for the isolation of the gas, and no transportation of heavy bottles is required.

Comparing the cost of bottled nitrogen and nitrogen obtained via a hollow fiber membrane system

An in-house hollow fiber membrane system can provide a significant economic benefit compared to the use of bottled nitrogen, in addition to the environmental benefits. As a conservative example, the cost of the two approaches is compared for a facility that has an LC-MS system that uses a flow of 20 L/min (slpm) of N_2 for 4 hr per day. Over the period of one year (250 days), 1,200,000 L of N_2 will be consumed, equivalent to 186 standard 9 × 56 in. cylinders. An estimate of the various costs for the use of the gas generator versus the use of tanks to deliver the gas is presented in *Table 2*. It can be seen that considerable savings can be obtained using a nitrogen generator. Since the capital expenditure for the compressor and gas generator is approximately $18,000, and the annual cost savings is $19,032, the payback period is slightly more than one year. The payback period will vary depending on the local situation. Some LC-MS systems use in excess of 50 slpm of nitrogen and operate 24 hours per day, 7 days per week. In these situations, a quicker payback will be realized. In addition, the price of electrical power, labor, and gas tanks will vary for each facility.

Conclusion

The in-house generation of nitrogen gas using a system that employs hollow fiber bundles is environmentally friendly and an effective, energy-efficient approach to providing pure, clean, dry nitrogen gas to laboratory instrumentation. Since considerably less energy is expended to generate the gas, less greenhouse gas is created.

In addition, using in-house generation of nitrogen in the laboratory is a convenient, safe, and cost-effective approach to the problem of supplying the gas. The gas can be readily generated on an as-needed basis at pressures and volumes that meet the needs of typical instrumentation. A significant benefit of the membrane approach is that considerably less energy is required, thereby reducing the generation of greenhouse gases and helping to protect the environment.

Dr. Froehlich is President, ***Peak Media****, 10 Danforth Way, Franklin, MA 02038, U.S.A.; tel./fax: 508-528-6145; e-mail: pfpeakmedia@msn.com. Mr. Cardarople is a Product/Regulatory Manager,* ***Parker Hannifin Corp.****, Filtration and Separation Division, Haverhill, MA, U.S.A.* *The authors would like to thank Pat Kriwoy, District Manager, Canada,* ***Parker Hannifin Balston Operation****, for support in the preparation of this paper.*

Hydrogen vs. Helium

Which carrier gas is best for GC-FID?

Richard Cardarople and Peter Froehlich

Gas chromatography with flame ionization detection (GC-FID) is used in the detection of trace levels of a broad range of compounds in complex mixtures such as the analysis of pharmaceuticals and hydrocarbons. A GC system with an FID uses a carrier gas to separate the mixture through a stationary phase. Helium (He) is commonly used as the carrier gas, as it is inert, provides a high degree of safety and facilitates an efficient separation in a short period of time.

Helium is typically provided to the GC system from a pressurized cylinder that is acquired from a commercial source, and is obtained from the fractional purification of natural gas (natural gas contains 4 to 7% He). In recent years, the use of He has been greater than the production of the gas, and subsequently, supplies in storage have been used and supplies are diminishing.[1] As a result, the availability and price of He has become a significant issue and various reports indicate the situation will likely be exacerbated over time, i.e., supplies in the world's largest reserve, near Amarillo, TX, are expected to be depleted in 2016.[2] This impending shortage suggests that chromatographers should begin to find alternatives to its use and be prepared when He is no longer economically reasonable to use.

As an example of the significance of this problem, the U.S. Pharmacopeia alone contains over 200 GC methods that employ He as a carrier gas and thus development time will be required to develop new methods using hydrogen gas.[3]

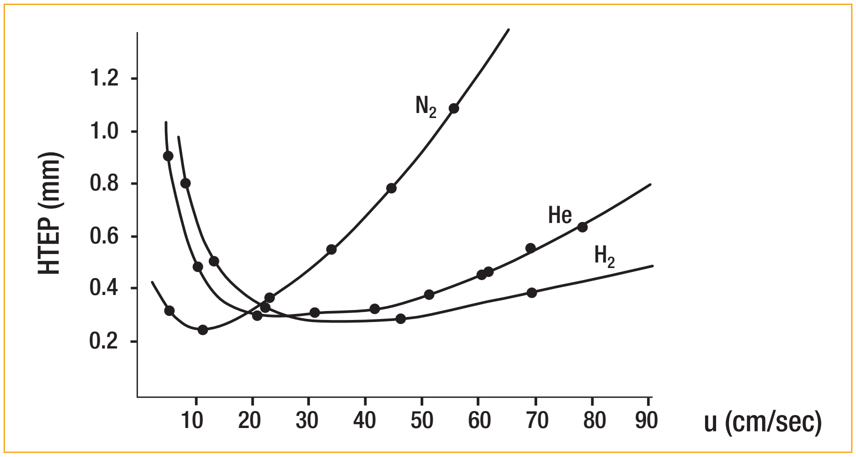


Figure 1: Van Deemter Plot for N, He and H_2. While N_2 provides the highest chromatographic efficiency, the optimum velocity for H_2 is considerably greater, so the use of H_2 as the carrier gas leads to analysis times that are four times faster than when N_2 is used.

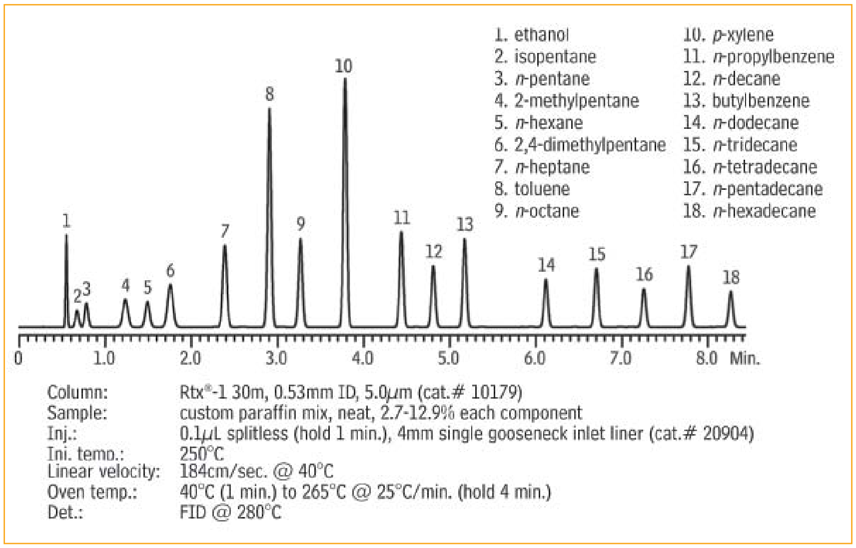


Figure 2: Separation of simulated distillation reference mix. *Courtesy of Restek, Inc.*

Hydrogen, an alternate carrier gas for GC

Hydrogen (H_2) and nitrogen (N_2) are two satisfactory alternative carrier gases to He in GC-FID. Figure 1 presents the van Deemter plot of HETP (efficiency) versus velocity for H_2, N_2 and He. It should be noted that while N_2 produces the highest chromatographic efficiency of the three gases (the height of a theoretical plate is 0.22 mm when N_2 is used, while the height using H_2 is 0.28), the maximum efficiency for N_2 is obtained at a linear velocity of 8 to 10 cm/sec, while the optimum linear velocity for H_2 is approximately 40 cm/sec. H_2 provides a four-fold decrease in the average analysis time relative to N_2 and results in a significant increase in laboratory throughput. In addition, the use of H_2 frequently allows for a lower temperature than He for the separation, thereby increasing column life and system longevity, and reducing the possibility that the analyte will undergo thermal decomposition.

A chromatogram showing the separation of a standard reference mix using H_2 as the carrier gas is presented in Figure 2. This separation was performed in less than 9 minutes using an Rtx -1 column (0.53 mm id, 5 µm). The same separation took more than four times as long with N_2. It is clear that a very satisfactory separation can be obtained with H_2, and

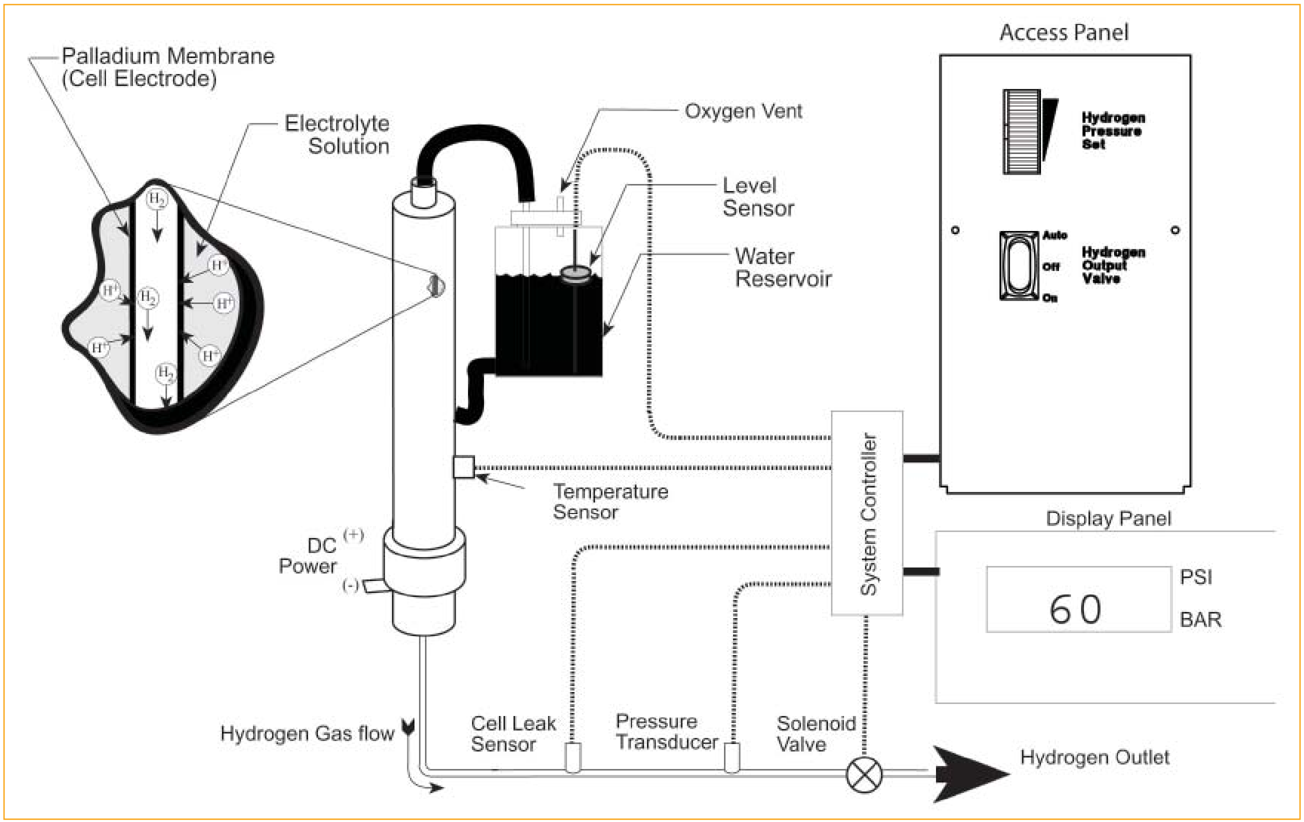


Figure 3: Overall design of a system for the generation of hydrogen via the electrolysis of water using a metal catalyst. *Courtesy of Parker Hannifin Corp., Haverhill, MA.*

additional studies indicate that the retention times are extremely repeatable.[4]

In the same vein, a recent study by scientists at Schering-Plough demonstrates the utility of H_2 as the carrier gas. In this study, calibration curves (five standards for each of 13 common solvents) were generated using H_2 or He as the carrier gas with headspace sampling using a gas-tight headspace injection system. The linearity data for the calibration curves indicates that the use of the two gases was equivalent, and the area for a given standard and the y-intercept were very similar.[5] In addition, the recovery data, when He was used for the carrier and auxiliary, was equivalent to the case where H_2 was used as the carrier and N_2 was used as the auxiliary gas.

In many laboratories, H_2 is imported to the gas chromatograph from a pressurized cylinder obtained from a commercial source. While this is an acceptable way of supplying the gas, this approach has a number of disadvantages including safety, convenience and cost issues that will be discussed in detail below. As an alternative, high purity H_2 can be readily obtained by the electrolysis of water on an in-house basis. An in-house, benchtop H_2 generator with palladium can provide the gas at a purity, pressure and flow rate that meets the needs of the gas chromatography laboratory, and is considerably safer, more convenient and less expensive than the use of cylinder H_2 (or He) gas.

Generation of hydrogen via the electrolysis of water

In-house generation of hydrogen gas is based on the electrolysis of water as shown in the equation below. A metallic electrode or an ionomeric proton exchange membrane can be employed in this reaction.

$$2H_2O + 2e^- \longrightarrow 2H_2 + O_2 \qquad 1$$

a) Electrolysis of Water using a Metal Electrode

The traditional method of generating hydrogen via the electrolysis of water involves a metal anode (i.e., Pd) and a metal cathode. Since water does not conduct an electric current very effectively, a strong, water-soluble electrolyte, such as 20% NaOH, is added to the water.

To provide high-purity H_2, a cathode in the form of a bundle of palladium tubes can be employed. Since only hydrogen and its isotopes are capable of passing through the cathode (oxygen and other impurities collect at the anode), hydrogen gas of an ultra-high purity can be obtained.

Figure 3 presents the design of a typical system (Parker Balston Model H2PD-300 hydrogen generator) for the generation of H_2 via the electrolysis of water using a metal electrode. This system generates H_2 with a purity of 99.99999+%, an oxygen content of <0.01 ppm and a moisture content of 0.01 ppm at a maximum flow rate of 300 cc/min with a maximum outlet pressure of 60 psig. Once the hydrogen is generated, it can be directly ported to the instrument.

Some systems that generate hydrogen via the electrolysis of water using a metal electrode use a desiccant as the final drying agent, instead of palladium tubes as the final purifier. Figure 4 presents gas chromatograms that were collected via a discharge ionization detector for hydrogen gas prepared by the two techniques. The large black peaks indicate the presence of a combined concentration of 12 ppm of O_2 and N_2 in the hydrogen that was dried with the desiccant. These peaks are not present in the hydrogen that was dried with the Pd tubes. It is clear that the palladium tube cathode provides a very considerable improvement in purity.

b) Electrolysis of Water using a Proton Exchange Membrane

A proton exchange membrane (PEM) is an ionomeric (ionic polymer) membrane such as Nafion (a sulfonated tetrafluoroethylene polymer) or polybenzimidzole (PBI) that is designed to conduct protons while being impermeable to gases such as hydrogen and oxygen. PEMs are commonly used in fuel cells to create an electric current (and form water) from hydrogen gas and oxygen gas. When an appropriate potential is applied to a PEM in the presence of water, the reverse process occurs and the water is dissociated to form oxygen and hydrogen. A significant benefit of this approach for the generation of H_2 is that DI water can be employed instead of the caustic 20% solution of sodium hydroxide to promote the electrolysis. A palladium membrane is included to further purify the hydrogen by removing oxygen to less than 0.01 ppm and moisture down to <1.0 ppm.

The general design of a hydrogen generator based on PEM membrane technology (Parker Model H2PEM-510 hydrogen gas generator) is shown in Figure 5. This system is capable of generating 99.9995% pure H_2 (non-carrier grade) at a flow rate of 510 mL/min at pressures up to 100 psi.

Benefits of in-house generation of hydrogen

Safety

In-house generation of hydrogen is considerably safer than employing cylinder gas, as in-house generation allows for the generation of the required volume of gas on demand at a low pressure. In contrast, when cylinder gas is used, a cylinder may contain a considerable amount of hydrogen gas at high pressure. If a leak were to occur (i.e., the valve was compromised), the gas in the tank would be released into the laboratory and would displace the air, leading to the potential of asphyxiation and/or explosion. Since in-house hydrogen generators typically have a maximum output of 1,200 mL/min at a pressure of 100 psig, the volume of gas that could escape in the laboratory due to a leak in the system is very small and presents minimal hazard.

An additional safety concern with the use of cylinder gas is the requirement to transport the cylinders from the storage location. If the individual moving the cylinder loses control during transport and the valve is damaged, the tank can become a guided missile.

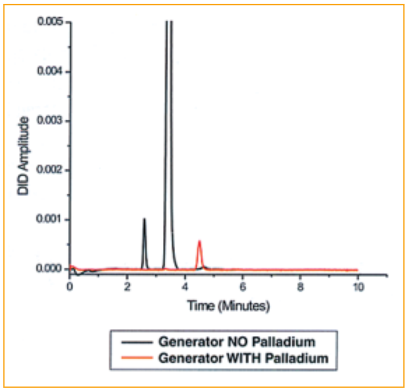


Figure 4: GC-FID chromatogram. Black line: generation of hydrogen with a system using palladium membrane as the final purifier. Red line: generation of hydrogen with a generator using a desiccant as the final purifier.

The in-house hydrogen generators described above include a variety of safety features to minimize the possibility of hazardous situations. As an example, if an overpressure or a pressure loss of the system is observed, hydrogen production will be immediately terminated and a diagnostic message will be generated. In addition, the message can trigger an audible alarm and/or send a signal to an external controller or operator.

In-house hydrogen generating systems are designed to meet the standards of a broad range of safety requirements including NFPA, OSHA 1910.103, as well as other regulatory agencies, such as IEC, CSA, UL and cUL. In addition, the systems are CE compliant.

Convenience

When an in-house hydrogen generator is employed, the gas is readily available on a continuous or on-demand basis. The operator simply needs to add DI water manually. Full flow operation on a 24/7 basis requires approximately 4 L of water a week, which can be automatically filled by installing a continuous source of DI water to ensure nonstop operation. The conductivity of the water used for PEM-based systems is continuously monitored; ionic materials in the water could foul the electrode, causing the system to shut down if the conductivity reaches a preset level. If a PEM-based system is employed, the user replaces the deionizer and filter every six months. On a periodic basis, the desiccant and the deionizer (on the non-palladium, non-carrier-grade system) should be replaced. These activities depend on the level of use of the system, but are typically in the order of twice a year.

Michael DiMarco, a research scientist at Ariad Pharmaceuticals (Cambridge MA), is a typical user of such an in-house hydrogen generator. Dr. DiMarco uses the system to provide hydrogen for the synthesis of pharmaceutical intermediates, reporting that "hydrogen gas for hydrogenation is always available on an on-demand basis. Generation of the gas is convenient and the Parker system is extremely easy to operate. It requires a minimum amount of maintenance and has had no downtime in over five years of operation."

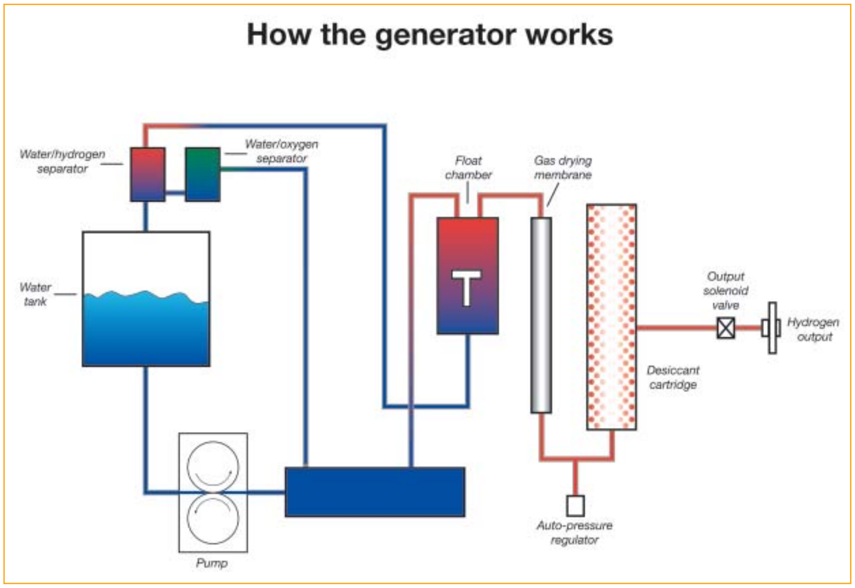


Figure 5: Overall design of a hydrogen generator based on PEM technology and a palladium membrane. *Courtesy of Parker Hannifin Corp., Haverhill, MA.*

In contrast, when a hydrogen cylinder is employed, the operator must make certain that it contains a sufficient amount of gas for the desired operation. In many facilities, replacement cylinders are frequently stored in a remote (outdoor) location for safety reasons and specially qualified personnel may be required to perform cylinder replacement. In addition, this certainly would be an inconvenience in inclement weather, and could lead to hazard in earthquake-prone zones of the world. When bottled gas is employed, it is necessary to maintain a supply of spare cylinders and order/return cylinders on a periodic basis.

Contamination Elimination

When a bottle is used to deliver H_2, the connection between the source of the gas and the chromatograph must be broken when the cylinder is replaced. This can lead to the introduction of contaminants into the system, such as moisture, oxygen and any other materials that may be present in the laboratory atmosphere. This may have a deleterious effect on the column and/or the separation. In contrast, when an in-house hydrogen generator is employed, a direct connection is made between the generator and the chromatograph that need not be broken, thereby practically eliminating the possibility of contamination.

Cost

The overall cost of operation of an in-house hydrogen generator is considerably lower than the use of hydrogen cylinders. The operating costs for an in-house generator are for electricity and DI water. For example, the power consumption for the 500 mL/min system is 235 W. If the generator is used for a 40-hour cycle on a 52-week basis, approximately 5000 Kwh would be used. At 10 c/kwh, the annual operating cost would be $500. The cost of maintenance and replacement of the deionizer and desiccant in the in-house H_2 generator is about $500/year. While the payback period of the hydrogen generator clearly depends on the amount of gas that is consumed and the local cost of the gas cylinders, the hydrogen generator pays for itself in a year in many facilities.

When cylinders are used to supply the gas, the time cost of ordering the gas and bottle demurrage should be included; these costs are not present with an in-house hydrogen generator. Recently, Loctite reported that they saved over $10,000 in the first year and $20,000 in later years by replacing a tank hydrogen system with an in-house hydrogen generator to service two GC-FID systems.[6]

Conclusion

The use of helium in GC-FID analyses is dependent on the availability of the gas, which is in short supply and becoming considerably more expensive. As an alternative, H_2 provides rapid separations with a minimum loss in chromatographic efficiency. While H_2 is typically provided to the GC from a high-pressure cylinder, the use of an in-house system to supply the gas via the electrolysis of water provides a number of safety, convenience and cost benefits. A hydrogen generator creates a steady stream of gas at a low pressure and stores a very small quantity, so that safety issues, due to the potential of an explosion, are dramatically minimized. In addition, the hydrogen generator is more convenient than tank gas, requires essentially no maintenance and dramatically reduces the cost of hydrogen relative to the use of tank gas. Since the connection between the in-house generator and the GC is permanent, the possibility of system contamination (i.e., by breaking the connection when a new tank is installed) is eliminated A single hydrogen generator can provide the carrier gas for several GC systems, as well as the gas needed for detectors. ■

References

1. N. Pacheco, United States Geological Survey, 2006 Minerals Yearbook, p 35.1 (Washington DC).
2. *Science Daily*, January 5, 2008.
3. Pappa, H.N. United States Pharmacopeia, Bethesda, MD, personal communication.
4. Restek Corp., Bellefonte, PA
5. A. Durand-Capece, A., Richardson, D.D., Smith, R., Pittsburgh Conference, New Orleans, LA, March 2008, paper 430-13P.
6. R. Trottier, *American Laboratory*, xx (2001), 10.

Richard Cardarople is the Reliability/Regulatory Manager at Parker-Hannifin Corp. Peter Froehlich is the President of Peak Media. They may be contacted at ChromatographyTechniques@advantagemedia.com.

In-House Generation of Hydrogen Carrier Gas for Gas Chromatography

Phillip L. Allison, Parker Hannifin Corporation

The use of hydrogen as a carrier gas for gas chromatography shortens the time required for a separation. In addition, an in-house gas generator is considerably safer, more convenient and less expensive than the use of tank gas.

Hydrogen is commonly used instead of nitrogen as the carrier gas for gas chromatography as it has a considerably greater optimum linear velocity; this can dramatically reduce the time required for a given separation. Typically, the time for the separation can be reduced by 50% or greater. An additional benefit of hydrogen is that allows a lower the temperature to be used for the separation, thereby increasing column longevity.

Hydrogen gas can be readily prepared in the laboratory via the electrolytic dissociation of water using the Parker Balston Model H2-1200 Hydrogen Generator. The system includes an electrochemical cell which contains a solid polymer membrane to support electrolysis and a palladium cell to optimize the purity of hydrogen as indicated in the schematic diagram shown in Figure 1. The palladium membrane is heated to $>$ 600 °C so that only hydrogen and its isotopes can pass through the pores; this provides carrier gas with a purity of $>$ 99.99999+ %, with $<$ 0.01 ppm oxygen and a moisture content that is less than 1.0 ppm at flow rates up to 1200 mL/min at a pressure of 100 psi. The Parker Balston Hydrogen Generator produces a steady, dependable and precise flow of gas to provide superb baseline stability. Extremely reproducible retention times can be obtained; when a simulated distillation mix was separated, extremely small standard deviations for the retention time was observed (typical % RSD's -ethanol [R_t = 0.55 min] = 0.176, toluene [R_t = 2.90 min] = 0.035, n-hexadecane [R_t = 8.26 min] = 0.007).

There are number of important advantages to the use of in-house generated hydrogen compared to the common approach of using a gas cylinder:

- Safety: Only a small amount of gas is generated at low pressure using an electrolytic system and the gas is ported directly to the GC. In contrast, a full gas tank contains ca 9000 L of the gas at high pressure. If the contents of a full tank of hydrogen were suddenly vented into the laboratory, the possibility of an explosion or a reduction of the breathable air could be a significant hazard. An additional concern is the possibility that the tank could become a hazard if the valve was compromised during transportation.
- Convenience: The hydrogen generator supplies the carrier gas on a 24 hour/7 day a week basis. In contrast, when tank gas is employed the tank must be replaced on a periodic basis. If the need for replacement occurs during a series of analyses, the analyst must interrupt the analytical work to restart the system, wait for a stable baseline and may have to recalibrate the system. The only user interaction with the hydrogen generator is to add water every week or so. This can be done during operation, so there is no down time.
- Cost: The hydrogen generator uses deionized water and electricity; and the cost of operation is the order of $200-300/year. A recent cost estimate for a laboratory that uses two-three cylinders of hydrogen per week is in the range of $15,000–25,000/year. While the exact cost of using tank gas depends on a number of factors, a dramatic cost saving can be obtained by the use of in-house generation of hydrogen.

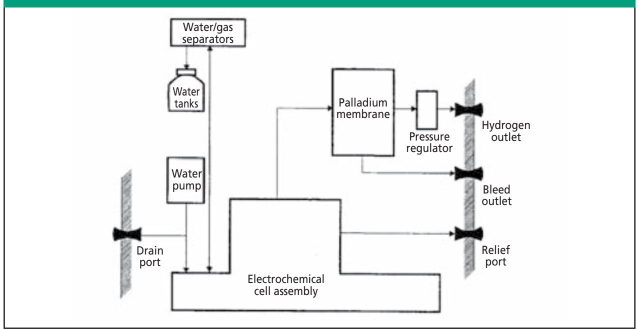


Figure 1: Legend: Schematic Design of Parker Balston H2-1200NA Hydrogen Generator.

Figure 2: Legend: Parker Balston H2-1200NA Hydrogen Generator

Parker Hannifin Corporation
Filtration and Separation Division
242 Neck Rd., Haverhill MA 01835
tel. (800) 343-0051, fax (978) 556-7510

CT10 Chromatography Techniques June 2005

DEALING with GAS

An analysis of providing nitrogen for LC-MS.

Phillip Allison, Parker-Hannifin, and Peter Froehlich, Peak Media

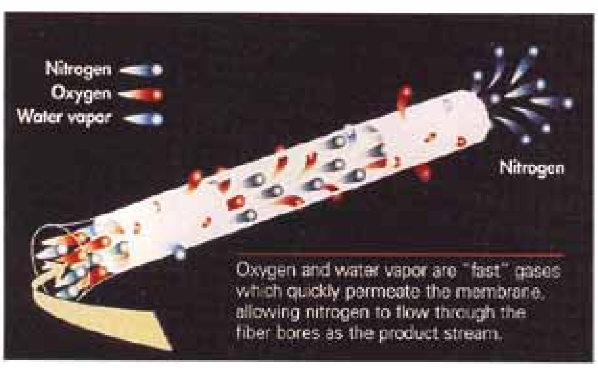
Nitrogen is used to nebulize the mobile phase when liquid chromatography is coupled with mass spectrometric detection (LC-MS). In addition, it's employed as an inert gas when the multiple reaction mode (MRM) is used to generate fragment ions from the molecular ion in the MS. LC-MS and MRM are used in a broad range of applications in pharmaceutical, environmental and quality control labs. Typical applications include the qualitative and quantitative analysis of drugs and drug metabolites in drug development and diagnostic studies. The source and rate of consumption of nitrogen are important issues facing the chromatographer when optimizing the performance of an LC-MS.

Nitrogen can be provided to the LC-MS in various ways—cylinders, a Dewar containing liquid nitrogen, or an in-house generator. In this paper we compare these delivery methods and discuss the benefits of in-house generation for the chromatographer.

In-house generation

Consumption of nitrogen for LC-MS depends on various factors such as the flow rate for the chromatograph, the mobile phase composition and the nature of the detection technique. Various in-house generators are available with flow capacities ranging from 30 L/min to >200 L/min.

In-house generation of nitrogen from ambient air involves separating the gas from oxygen, water vapor and particulate matter and porting it into the LC-MS. The heart of an in-house nitrogen generator is a hollow fiber membrane which permits oxygen and water vapor to permeate the membrane and escape through the sweep port while the nitrogen flows through the tube. While each individual fiber membrane has a small internal diameter, a large number of fibers are bundled together to provide a large surface area for the permeation of oxygen and water.



Oxygen and water vapor are "fast" gases which quickly permeate the membrane, allowing nitrogen to flow through the fiber bores as the product stream.

Compressed air is filtered using a high efficiency activated carbon filter to remove hydrocarbons while a pre-filtration system removes particulates down to 0.1 micron and delivers the gas to the membrane bundle. Oxygen and water that permeate the membrane are vented and purified nitrogen is passed through another membrane filter and delivered to the LC-MS.

Parker-Hannifin's N2-45 nitrogen generator can continuously produce pure nitrogen. The purity of this nitrogen depends on the operating pressure and the desired flow rate; for example, 67 L/min of 99.5% nitrogen gas can be generated at an operating pressure of 145 psi and 68 F, which is sufficient to supply several LC-MS systems.

The gas delivered to the LC-MS by the N2-45 has an atmospheric dew point of -50 C, contains no particulate matter >0.01 µm, and is hydrocarbon- and phthalate-free and commercially sterile.

Benefits of a gas generator

The in-house nitrogen generator provides a number of significant benefits to LC-MS operators including improvements in safety, increased convenience, the possibility of improving the sensitivity of the assay and reduced cost of supplying the gas.

SAFETY – When in-house nitrogen generators are used, only a small amount of the gas is present at a low pressure at any given time. The N2-45 generates a maximum of 133 L/min of nitrogen at a maximum pressure of 140 psig. If a generator leak occurred, there would be a small change in the composition of the lab air with only trace nitrogen dissipating harmlessly.

In contrast, serious hazards exist when nitrogen is supplied in tanks. For example, if the contents of a full tank are suddenly vented into the lab, up to 9,000 L of nitrogen can be released. This volume could displace the air, reduce the breathable oxygen content and create an asphyxiation hazard. Another hazard that's eliminated by in-house generators is the possibility of injury or damage during transport and installation of the tanks. A standard tank is heavy and can become a guided missile if the valve is compromised during transport.

When a Dewar is used to supply nitrogen, the possibility of user contact with the cryogenic liquid (with a b.p. of -196 C) must be considered. As with tank nitrogen, a leak in the delivery system could create a significant volume of gas in the lab.

CONVENIENCE – With in-house generators, the nitrogen can be supplied continuously and provided 24/7 without any user interaction other than routine maintenance. In contrast, when tank gas is employed, the user must monitor the tank level and periodically replace it. An in-house system obviates the need for replacements.

In many labs, spare tanks are stored outside for safety reasons, making it time consuming to get a replacement. When a replacement tank is needed, the chromatographer may have to get someone who's qualified to handle them. Many users have indicated that replacing used tanks is a significant inconvenience, especially in inclement weather if they're stored outside or not secured properly.

If tanks are used and replacement is required during an analysis, the analyst must interrupt his work to restart the system, wait for a stable baseline and possibly even recalibrate the system. In addition, if a series of automated analyses is desired, the analyst must ensure that a sufficient volume of gas is on hand before starting the sequence.

Using a gas generator saves a considerable amount of time and increases efficiency since it's not necessary to re-calibrate the system. A standard sample is analyzed on a periodic basis which takes just a few minutes. An additional benefit is that it's unnecessary to train each technician in the calibration process.

A large number of labs have converted to in-house nitrogen generation. Chris Beecher, a professor of pathology at the Univ. of Michigan, recently obtained an in-house system for his LC-MS because of the convenience and stability it provides. Similarly, A. Daniel Jones, director of the Mass Spec Lab at Michigan State Univ. has been using in-house generators for several years and reports that "no maintenance is required with the three systems we use. One system has been operating for more than 26,000 hr and the only maintenance has been annual filter replacement, which takes just a few minutes."

The frequency of tank replacement clearly depends on system usage. Changing tanks is clearly an inconvenience and leads to reduced operating efficiencies. In addition to the actual time required to change tanks, staff must verify there are replacement tanks in storage and order them as needed. The use of an in-house generator eliminates the need to keep track of and change gas cylinders. Similarly, if Dewars are used, the lab must rely on the secure delivery of the LN2, which is questionable in inclement weather or during holidays.

COSTS – In addition to the safety and convenience benefits, another benefit of in-house generators are the cost savings compared to using gas tanks or LN2. The cost of operating an in-house generator is extremely low since the raw materials are air and electricity (if an optional oxygen analyzer is used, the electrical requirement is 25 W or 0.6 kW/day). The running costs and maintenance for an in-house generator is a few hundred dollars/year.

In contrast, the cost for using nitrogen gas from tanks includes the actual cost of obtaining the gas tank as well as the time involved in changing tanks, ordering new tanks, maintaining inventory, and support. The calculation of the precise cost of nitrogen from tanks for a given user depends on a broad range of parameters and the amount used.

It should be noted that there are hidden costs, including transportation costs, demurrage costs and paperwork when tanks are used. In addition, the value of the time required to transport the tank from the storage area, install the tank, replace the used tank in storage and wait for the system to re-equilibrate after replacement also involves costs.

A comparison of the costs of supplying tank gas versus in-house generators is presented in Table 3. In this analysis, we assumed that a single tank of gas is consumed each week and that the cost of each tank is $60 (this approximation ignores the incidental cost of handling the gas tank, down time and ordering tanks). In comparison, the cost of using the in-house generator is approximately $20/wk.

SENSITIVITY – When an atmospheric pressure chemical ionization interface is employed, it's been found that raising the oxygen content can increase the sensitivity of the detector. If tank gas is used, that gas is normally extremely high purity, and the oxygen content is fixed—changing it may require considerable plumbing. For example, Dr. Jones routinely uses 99% nitrogen for his LC-MS systems. If he wanted a different concentration for enhanced sensitivity or to eliminate the oxygen, he could simply change the pressure of the input gas.

In conclusion, in-house generation of nitrogen can provide the necessary gas for LC-MS systems with significant improvements in safety and convenience compared to tank nitrogen or LN2 from a Dewar. The overall cost is also lower and the operator can rapidly change the composition of the gas by simply varying the input pressure to optimize sensitivity of the procedure. CT

Mode	LC Flow Rate (µp/min)	Gas Consumption (L/min)
Electrospray	50 to 400	7.7 to 13.7
Electrospray	400 to 1,000	13.7 to 14.1
APCI	100 to 1,500	6.0 to 6.5
MRM-ES	100 to 1,500	6.0 to 6.5
MRM-APCI	100 to 1,500	6.0 to 6.5
MM-ES+APCI	100 to 1,500	6.0 to 6.5
Standby	—	3.7 to 4.2

Source: Parker-Hannifin

TABLE 1. Typical Nitrogen Consumption for LC-MS Systems with Various Detectors

Desired Purity	Input	Input	Input	Input	Input	Input
	145 psi	125 psi	110 psi	110 psi	90 psi	80 psi
99.5%	67 L/min	55 L/min	47 L/min	39 L/min	33 L/min	27 L/min
99.0%	92 L/min	74 L/min	63 L/min	53 L/min	44 L/min	35 L/min
98.0%	129 L/min	106 L/min	89 L/min	73 L/min	62 L/min	50 L/min
97.0%	163 L/min	132 L/min	113 L/min	94 L/min	79 L/min	65 L/min
96.0%	200 L/min	160 L/min	137 L/min	114 L/min	97 L/min	80 L/min
95.0%	233 L/min	187 L/min	160 L/min	134 L/min	111 L/min	90 L/min

Source: Parker-Hannifin

TABLE 2. Flow Rates for Various N_2 Purity Levels (N2-45 Nitrogen Generator, 35 C)

	In-House Generator	Tanks
Electrical Power	$100	$0
Maintenance	$800	$0
Cylinders	$0	$3,120
Demurrage	$0	$840
Labor (changing cylinders)	$0	$1,040
Order Processing	$30	$360
Shipping	$50	$3,720
Invoice Processing	$10	$120
Inventory Control	$0	$72
Total	$890	$9,272

Assumptions:
52 cylinders at $60/cylinder
10 cylinders in use (5 in use, 5 filled) at $7/mo
$30 labor/cylinder
1 order/mo @ $30 processing costs
Labor $20/cylinder change

Source: Parker-Hannifin

TABLE 3. Annual Costs, In-House Generation versus High-Pressure Tanks (in U.S.$)

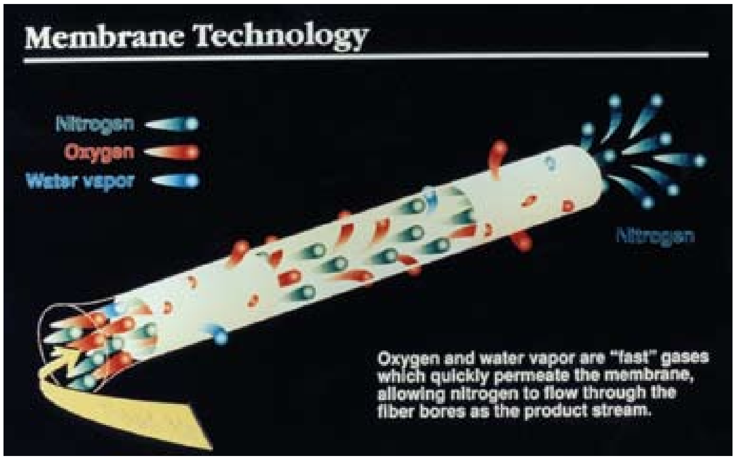
Selecting Makeup Gas for GC with FID

IN-HOUSE GENERATION PROMISES IMPROVED SAFETY, INCREASED CONVENIENCE AND REDUCED GAS COSTS ***by Phillip Allison and Peter Froehlich***

> **"The optimum flow rate for detection of the compounds of interest is typically significantly larger than the flow rate for the carrier gas."**

When gas chromatography is employed for the detection of trace compounds, the characteristics of the carrier gas used for the actual separation and the gas used for detection may be significantly different. As an example, the carrier gas flow rate is selected to provide optimum resolution of the compounds of interest and is determined by the van Deempter relationship. The optimum carrier gas flow rate is a function of the compounds to be separated, the nature of the column, the temperature and a number of other considerations. Typically, the on-column carrier gas flow rate is in the order of a few mL/min. In contrast, the optimum flow rate for detection of the compounds of interest is typically significantly larger As an example, when a flame ionization detector (FID) is employed, the detector gas flow has to maintain a sufficiently high concentration of electrons for ionization of the compounds of interest and must be capable of sweeping the solute through the detector so that sharp peaks can be obtained for highly retained peaks. The flow rate for optimizing the detection is frequently as high as 500-2000 mL/min.

Figure 1: Separation of nitrogen from oxygen and water vapor via a hollow fiber membrane.



In addition to flow rate differences, the chromatographer may be concerned with the composition of the carrier gas and the detector gas. While low levels of impurities such as hydrocarbons will likely have little effect on the actual separation, they could dramatically increase the background and/or the noise from the detector, thereby reducing the sensitivity of the analysis, and a higher level of purity may be required for the detector gas than for the carrier gas.

To increase the gas flow to what is required for the detection step, a "makeup" gas such as helium or nitrogen is delivered to the chromatographic system between the column and the detector. The makeup gas should be selected so that it does not affect the fuel and oxidant balance, and it must be fairly inert to the detector so that it does not affect the report of the concentration of the compound(s) of interest. In many facilities, the makeup gas is provided from a cylinder or tank. While this approach works, an in-house makeup gas generator can provide a higher level of purity than bottled helium or bottled nitrogen. In addition, an in-house makeup gas generator can provide a considerably safer, more convenient and less expensive approach to supply the required gas.

Generation of zero-grade nitrogen and zero-grade air using an in-house generator

Zero-grade nitrogen for makeup gas can be readily obtained from laboratory compressed air using an in-house generator (model MGG-400NA or MGG-2500NA FID MakeupGas generator, Parker Filtration and Separation Division, Haverhill, Massachusetts) that includes a heated catalytic converter that is similar to an automobile exhaust system. The converter includes a proprietary catalyst blend that is combined with platinum and a hollow fiber membrane separator.

The heated catalyst is used to remove all hydrocarbons by converting them to CO2 and water vapor, while the hollow fiber membrane allows the separation of nitrogen from oxygen and water vapor. The hollow fiber membrane module (Figure 1), which is the heart of the system, is designed to preferentially allow oxygen and water vapor in the air to quickly permeate the membrane wall while nitrogen travels through the hollow fiber out the end. A schematic diagram of a typical system for the generation of nitrogen is shown in Figure 2.

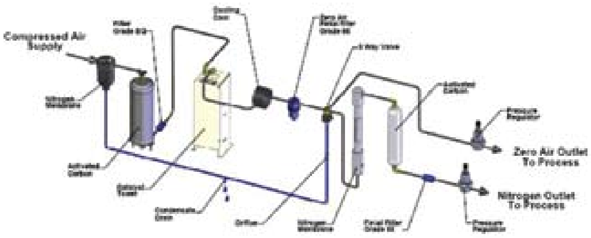


Figure 2 : Schematic diagram of FID makeup gas generator.

The hollow fiber used to separate the nitrogen has a small internal diameter, and thousands of fibers are bundled together to provide a large surface area for the desired flow of nitrogen, as shown in Figure 3. The makeup gas generator can produce makeup nitrogen with purity of better than 99.9999 percent with respect to hydrocarbons (< 1 ppm) at a maximum flow rate of 400 mL/min. In addition, the purity of the nitrogen is greater than 99 percent with respect to oxygen. In addition, the in-house generator can produce zero-grade air with a hydrocarbon concentration that is less than 0.05 ppm at flow rates up to 2500 mL/min. Figure 4 shows a comparison of zero-grade air that was produced by the MakeupGas generator and zero-grade air that was obtained from bottled fuel air from a commercial supplier. It shows that the gas generated by the generator is purer than that from bottled fuel air, as it provides an extremely flat baseline with essentially no signal due to hydrocarbons, while the zero-grade bottled air provided an irregular baseline with a significant level of hydrocarbons, which could impact analysis. Dr. Nithy Govindarajah, a scientist at Symrise Laboratories in Branchburg, New Jersey, reports that he has used the MakeupGas generator with three GCs and analyzed over 1000 samples of essential oils a month, and always obtained a flat baseline.

Figure 3: A bundle of hollow fibers provides a high flow of zero-grade nitrogen.

Minimizing safety hazards

When a makeup gas generator is employed, only a small amount of the gas is present at a low pressure at a given time and the gas is ported directly to the GC. The system generates a maximum of 2.5 L/min of air or 400 mL of nitrogen at a maximum pressure of 120 psig of nitrogen. If a nitrogen leak were to occur with the generator, there would be a negligible change in the composition of the laboratory air, with only trace nitrogen dissipating harmlessly.

In contrast, a number of serious hazards exist when makeup gas is supplied to the GC via a tank. As an example, if the contents of a full tank of helium or nitrogen were suddenly vented into the laboratory, up to 9000 L of gas would be released. This volume would displace the laboratory air, reducing the breathable oxygen content and potentially creating an asphyxiation hazard for the laboratory occupants. Another potential hazard that is eliminated by use of a makeup gas generator is injury or damage while transporting and installing a gas tank. A standard tank is quite heavy and can become a guided missile if the valve on a full tank is compromised during transport (in many facilities, specially trained technicians are used to replace gas tanks).

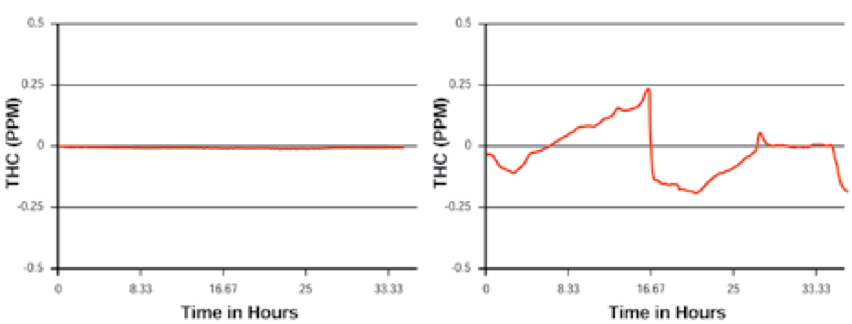


Figure 4: FID baseline from Makeup Gas generator (top) and from bottled fuel air (bottom). Flow rate = 450 mL/min.

Convenience

When an in-house generator is employed, the gas is supplied on a continuous basis and can be provided on a 24-hour, 7-day-a-week basis without any user interaction other than a minimum of routine annual maintenance. In contrast, when tank gas is employed, the user must pay close attention to the level of gas in the tank and replace the tank on a periodic basis. The in-house system obviates the need to obtain a replacement tank. In many facilities, spare gas tanks are stored outside in a remote area for safety reasons, and it is time-consuming to get a replacement cylinder. When it is necessary to get a replacement makeup gas tank, the chromatographer may require an individual who is qualified to handle the tanks. Many users have indicated that replacing used tanks can be a significant inconvenience, especially in inclement weather if the tanks are stored outside or if not properly secured when the laboratory is located in a seismic zone.

If the need for replacement occurs during a series of analyses, the analyst must interrupt the analytical work to restart the system and wait for a stable baseline, and may have to recalibrate the system. In addition, if a series of automated analyses is desired (e.g., overnight or over a weekend), the analyst must ensure that a sufficient volume of each gas is on hand before starting the sequence.

The frequency of tank replacement depends on the usage of the system. Changing the tank is clearly an inconvenience and leads to a reduction in the useful operating efficiency of the facility. In addition to the actual time required for changing the tank, the laboratory staff must verify that there are sufficient replacement tanks in storage and order replacement tanks as appropriate. The use of a makeup gas generator eliminates the need to keep track of and change gas cylinders. Dr. Govindarajah indicated that he previously had to replace the gas tank approximately three times a month when tank gas was used for makeup gas, and now simply turns on the generator, saving time and eliminating inconvenience. Similarly, Dr. Mike Jordan of Agriculture Canada (Kentville, Nova Scotia, Canada), who analyzes volatile anaerobic compounds in fruits, indicated that the generator allows him to leave the FID detectors on the gas chromatographs powered up on a 24/7 basis. This saves considerable time and increases laboratory efficiency, as it is not necessary to calibrate the detector every time it is turned on. Dr. Jordan simply runs a standard sample on a periodic basis, which takes only a few minutes, to ensure that the system is operating properly. An additional benefit is that it is no longer necessary to train each technician in the calibration process.

Cost

In addition to safety and convenience, another benefit of a makeup gas generator is the cost compared to the use of gas tanks. The cost of operation of the generator is extremely low, as the raw materials to prepare the required gas are air and electricity. Running costs and maintenance for the generator add up to a few hundred dollars a year.

In contrast, the cost for using makeup gas from tanks includes the actual cost of obtaining the gas tank as well as the time involved in changing tanks, ordering new tanks, maintaining inventory and related activities. While calculating the precise cost of using makeup gas from tanks for a given user is dependent on a broad range of local parameters and the amount of gas that is used, we present below an overview of the potential savings from the use of an in-house makeup gas generator.

It should be noted that there are many hidden costs, including transportation costs, demurrage costs and the required paperwork (e.g., a purchase order, inventory control and invoice payment) when tank gas is employed. In addition, the time that is required to transport the tank from the storage area, install the tank, replace the used tank in storage and wait for the system to re-equilibrate represents money as well.

A comparison of the cost of supplying gases via tanks versus a makeup gas generator is presented in Table 1. For this analysis, we assumed that a single tank of makeup gas is consumed each week by each chromatograph and that the cost of each tank is $60 (this approximation ignores the incidental costs of handling the gas tank, downtime, ordering tanks, etc.). In comparison, the cost of using the generator is approximately $50 per week. Since the cost of supplying makeup gas is significantly lower with the generator than with tank gas, it is now possible to leave the FID detector on continuously.

Table 1.	In-House Generator	
Electrical Power	$380	$0
Maintenance (compressor)	$1,500	$0
Maintenance (generator)	$800	$0
Cylinders	$0	$3,120
Demurrage	$0	$840
Labor (changing cylinders)	$0	$1560
Order Processing	$30	$360
Shipping	$100	$3,720
Invoice Processing	$10	$120
Inventory Control	$0	$72
Other	$2,820	$9792

Assumptions:
52 cylinders at $60/cylinder
10 cylinders in use (5 in use, 5 filled) at $7/mo
$30 labor/cylinder
1 order/month @ $30 processing costs
$20/cylinder

Table 1 Annual costs, in-house generation versus high pressure tanks (in U.S. $)

Conclusions

An in-house makeup gas generator can provide high-purity nitrogen and zero-grade air at the flow rates required for the use of flame ionization detectors in gas chromatography. The hydrocarbon content of the makeup gas generated is considerably lower than that in bottled gas from external sources. In addition to the higher purity of the makeup gas, an in-house generator is safer, more convenient and less costly than bottled gas. These benefits allow the chromatographer to maintain power to the detector on a continuous basis, obviating the need for frequent, time-consuming recalibration.

Phillip Allison *global product manager of Parker Hannifin Corporation, Haverhill, Massachusetts.*
Peter Froehlich *is president of Peak Media, Franklin, Massachusetts.*

SUPPLYING HIGH-PURITY GASES

MAKING A CASE FOR IN-HOUSE GAS GENERATORS

By Kim Myers and Peter Froehlich

Selecting the most effective source for high-purity gases is a critical issue for laboratory managers. Zero air and hydrogen are used for gas chromatography with flame ionization detection (GC-FID), and nitrogen is used for high-performance liquid chromatography or gas chromatography with mass spectrometric detection (LC-MS or GC-MS). High-purity gases are used with other instruments: CO_2 free purge gas for Fourier transform infrared spectroscopy (FT-IR), highly purified nitrogen for inductively coupled plasma (ICP) systems, dry air for nuclear resonance spectroscopy (NMR) and hydrocarbon-free combustion gas for TOC analyzers.

Many laboratories employ in-house high-purity gas generators to supply the necessary gases, as they provide significant safety, convenience and cost advantages when compared to the use of tank gas.

In-house gas generators

Nitrogen, purge gas, ultra dry gas, source exhaust air and zero air can be obtained from compressed air, and hydrogen can be obtained by the electrolysis of water, using in-house generators. An in-house gas generator can be dedicated to a single instrument or used to supply multiple instruments (e.g., a hydrogen generator can provide fuel gas for 14 FIDs).

a) Generation of nitrogen

Nitrogen is generated from compressed air by the removal of oxygen, water vapor and particulate matter. The heart of an in-house nitrogen generator is a hollow fiber membrane through which oxygen and water vapor permeate and escape through the sweep port while the nitrogen flows through the tube (Figure 1). A large number of fibers are bundled together (Figure 2) to provide an extremely large surface area.

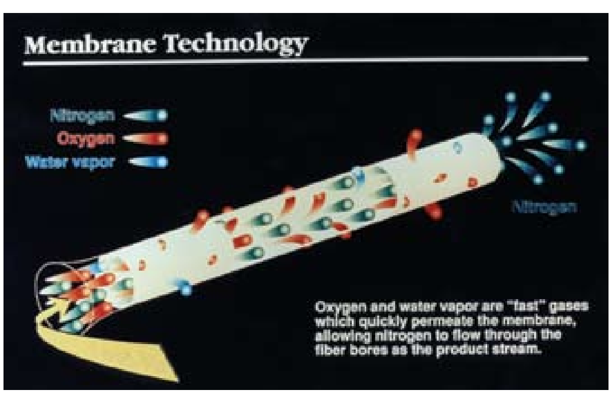


Figure 1. Operation of a Hollow Fiber Membrane

Figure 2. A Hollow Fiber Membrane Bundle

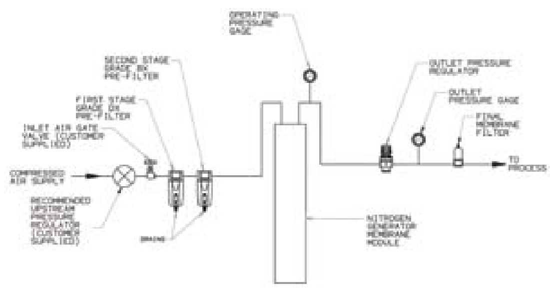


Figure 3. Schematic Diagram of N2-04 Nitrogen Generator (courtesy of Parker Hannifin Corp.)

The schematic of a typical nitrogen generator (Model N2-04, Parker Hannifin Corp., Haverhill, MA) is shown in Figure 3. Compressed air is filtered using a high-efficiency activated carbon filter to remove organic impurities, and a pre-filtration system is used to remove particulate matter >0.01µm. Air passes through a fiber membrane bundle to remove the oxygen and water, while the purified nitrogen is passed through another absolute membrane filter and delivered to the instrument.

The N2-04 nitrogen generator produces 99.5 percent pure nitrogen on a continuous basis (the purity of the nitrogen depends on the operating pressure and the desired flow rate, e.g., 3 L/min of nitrogen at 80 psi). The gas has an atmospheric dew point of -58°F (-50°C), contains no particulate matter >0.01 µm and no suspended liquids, and is hydrocarbon and phthalate free.

b) Generation of hydrogen by electrolysis of water

i)Using metallic electrodes

An inert anode and a cathode such as a bundle of palladium tubes are used to dissociate water (20 percent NaOH is added to enhance electrolysis). Hydrogen passes through the cathode while oxygen and other impurities collect at the anode, and hydrogen gas with purity in excess of 99.99999+ percent can be obtained.

ii)Using a proton exchange membrane

A proton exchange membrane (PEM) is an ionomeric (ionic polymer) membrane that conducts protons and is impermeable to hydrogen and oxygen. PEMs are used in fuel cells to create an electric current (and form water) from hydrogen and oxygen. When an appropriate potential is applied to a PEM in the presence of pure water (caustic NaOH is not required), water is dissociated to provide hydrogen and oxygen.

c) Generation of ultra dry air, purge gas, zero air and source exhaust air

Several techniques are employed to remove moisture, particulate matter and hydrocarbons from air to provide air with the desired purity. A coalescing compressed air filter, which consists of a matrix of borosilicate glass hollow fibers in a fluorocarbon resin binder, removes water, hydrocarbon lubricants and synthetic lubricants from compressed air. For instrument-grade air, two-stage filtration removes 99.99 percent of 0.01 µm particles and droplets and a three-stage filter system is used to remove compressor oil vapor. A heated catalysis module and high-capacity carbon absorption modules and coalescing filters remove very light methane-based hydrocarbons.

d) In-house multi-gas generating systems

In-house generation of nitrogen and purified air from compressed air is performed with the Source LC/MS Tri Gas Generator (Figure 4), which includes coalescing pre-filtration with timed solenoid drains, self-regenerating compressed air dehydration membranes, a proprietary heated catalysis module, self-regenerating nitrogen retentate membranes, high-capacity high-sensitivity carbon absorption modules and matched final filtration membrane media.

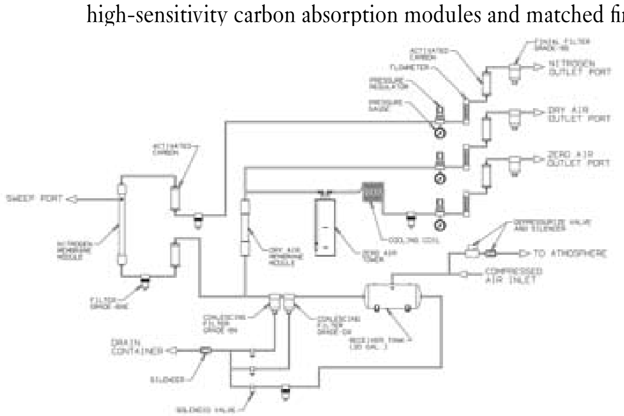


Figure 4. Schematic Diagram of Tri-Gas Generator (courtesy of Parker Hannifin Corp.)

Benefits of in-house gas generators

In-house gas generators provide significant benefits to the laboratory, including a dramatic improvement in safety, an increase in convenience and a lower cost.

Minimizing safety hazards

An in-house generator is considerably safer than tank gas; only a small amount of gas is stored at low pressure at a given time and it is ported directly to the instrument. As an example, the TriGas Generator generates 10L/min of nitrogen at a maximum pressure of 80 psig, 23 L/min of source air at a maximum pressure of 110 psi and 8L/min of exhaust gas at a maximum pressure of 60 psi. If a leak occurred, only a small quantity of nitrogen gas would be dissipated into the laboratory.

In contrast, serious hazards exist if nitrogen is supplied using a high-pressure gas tank or a liquid tank. If a full tank of nitrogen were suddenly vented into the laboratory, up to 9000 L of gas would be released, displacing laboratory air and reducing the breathable oxygen content.

"IN-HOUSE GAS GENERATION ALLOWS FOR CONTINUOUS OPERATION."

An in-house gas generator also eliminates the possibility of injury or damage from the transportation and installation of a gas tank. A heavy gas tank can be a hazard to staff and facilities if the valve is compromised during transport (in many facilities, specially trained technicians replace gas tanks). A leaking hydrogen tank could lead to an explosion. When a Dewar flask or a high-pressure liquid tank is used to supply nitrogen, a leak or spill could lead to frost burns.

New construction or laboratory expansion

An important factor when considering new construction or expanding an existing laboratory is the gas requirements for the instruments being used. It is important to select a supply, manifold and purification system to ensure that the gases supplied will meet your requirements for pressure, volume and purity. Architects and designers will typically allocate space for cylinders or other gas storage options (i.e., Dewars or bulk systems). For many installations, a gas generator will provide a superior gas supply with higher purity for a lower operating cost and will require less floor space. In addition to the need for less lab space, less space for storage of back-up and empty cylinders is required.

Maximizing convenience

An in-house gas generator can supply gas on a 24-hour, seven-days-a-week basis with no user interaction (other than routine annual maintenance). Dr. Chris Ransom, a chemist at MedTox Scientific, a toxicology company in St. Paul, MN, reports that they have used in-house nitrogen and zero-air generators with GC systems and HPLC with MS for over ten years, with little or no maintenance, except for periodic changing of filters.

In contrast, when tank gas is employed, the user must monitor the level of gas in the tank and ensure that there is sufficient gas available for the desired analyses. The in-house system eliminates the need to retain extra tanks; when it is necessary to get a replacement gas tank, the chromatographer may need to find an individual who is qualified to handle the tanks. Tanks are typically stored outside in a remote area for safety reasons, and replacing tanks can be a significant inconvenience, especially in inclement weather. In addition, a pressurized tank could be a significant hazard if the laboratory is located in a seismic zone.

If a gas tank must be replaced during a series of analyses, the analyst must interrupt the work, restart the system, and wait for a stable baseline and perhaps recalibrate. Since in-house gas generation allows for continuous operation, calibration of the detector simply requires the measurement of a standard sample at a user-specified interval to ensure that the system is operating properly.

A major benefit of in-house gas generators is that "once they are installed, you don't have to worry about the gas supply," according to Fran Diamond, a chromatographer at NMSLabs, a clinical and toxicology lab in Willow Grove, PA. This lab has used several Parker Hannifin hydrogen and nitrogen generators since 1996 and presently has ten units, installed into appropriate manifolds. Mr. Diamond reports that the maintenance requirements are minimal. They replace the filters and perform routine maintenance on the compressor for the nitrogen generators on a periodic basis and monitor the water in the hydrogen generators. John Kucowski, facilities manager at NMSLabs, reports that their four Tri-Gas generators have been operating very reliably and preventive maintenance is done about once a year. This maintenance can be conveniently performed on-site using Parker's national third-party service provider, Mettler Toledo.

Minimizing the cost

An important advantage of an in-house generator is the economic benefit compared to the use of gas tanks or liquid nitrogen. The running cost of an in-house generator is extremely low, since the gas is obtained from compressed air or water and maintenance is a few hundred dollars per year for periodic filter replacement.

In contrast, when a gas tank is used, the actual cost is significantly greater than the cost of the tank. Dr. Ransom indicated that zero-air tanks are very expensive and the time and hidden costs including transportation, demurrage and paperwork when tank gas is employed impose a significant cost on the user. In addition, the time required transporting the tank, installing it, returning the used tank to storage and waiting for the system to re-equilibrate must be considered. While the calculation of the precise cost of the use of gas from tanks for a given user is dependent on a broad range of local parameters and the amount of gas that is used, significant potential savings can be obtained by the in-house generation of gas. A comparison of the cost of supplying gas via tanks versus the cost for use of an in-house gas generator is presented in Table 1. In this analysis, a tank of gas costing $60 is consumed per week, and four are in-house (i.e., tanks are replaced monthly). In comparison, the maintenance cost of the in-house generator is for replacement of filters at perhaps $1,000 per year, or approximately $20 per week.

	IN-HOUSE GENERATOR	TANKS
Maintenance	$800	$0
Cylinders	$0	$3120
Demurrage	$0	$336
Labor (changing cylinders)	$0	$1040
Order processing	$30	$360
Shipping	$50	$3720
Invoice processing	$10	$120
Inventory control	$0	$72
Total	$890	$8768

Table 1. Annual costs: in-house generation vs. high-pressure tanks (in U.S. $)

Conclusion

In-house generation of gases provides a safe, convenient and less costly method of providing the required gases. The gases are continually provided, and it is not necessary to replace tanks on a periodic basis. In addition to the cost reduction, less energy is required to supply gas, since tank gas or liquid nitrogen requires distillation of air (an energy-intensive process) and transportation of tanks to the final point of use.

Kim Myers, *Business Development Manager, Parker Hannifin Corporation, can be reached at kmyers@parker.com or by phone at 978-858-0505.*

Peter Froehlich, *president, Peak Media, can be reached at pfpeakmedia@msn.com or by phone at 508-528-6145.*

Technical Article

by Peter Froehlich and Corky Belobraydich

Advantages of In-House Generation of Nitrogen for HPLC With Evaporative Light Scattering Detection

Evaporative light scattering detection (ELSD) is a universal detection technique for HPLC that provides a number of distinct advantages over other commonly employed detection methods such as UV-VIS absorbance, fluorescence, and electrochemical measurements. The technique allows for the trace-level detection of essentially all compounds in the sample and does not require the presence of a chromophoric group for detection (required for UV-VIS absorption or fluorescence detection) or an electroactive group (required for electrochemical methods such as coulometry). While other universal techniques for HPLC exist (e.g., refractive index measurements), they provide poor sensitivity and are generally restricted to isocratic elution.

Detection of the components of a sample via an ELSD includes three distinct stages (*Figure 1*): a) nebulization of the effluent, in which the mobile phase is transformed into a stream of small droplets by the addition of a pressurized stream of nitrogen gas through a narrow orifice such as a needle; b) evaporation of the mobile phase, where the droplets are passed through a drift tube in which the mobile phase is evaporated; and c) measurement of the scattered light, in which the particles resulting from the evaporation of the mobile phase pass through a light scattering detector.

The nebulization step requires a supply of clean dry nitrogen from 98 to 99% purity that is regulated from 65 to 80 psig. In many laboratories, the nitrogen is provided by the evaporation of liquid nitrogen from a high-pressure liquid nitrogen tank, a Dewar flask, or a high-pressure gas cylinder. While these methods are satisfactory, the use of an in-house generator to provide the nitrogen for ELSD offers a number of significant benefits. This paper describes how an in-house nitrogen generator operates, and discusses the safety, convenience, and cost benefits of this approach.

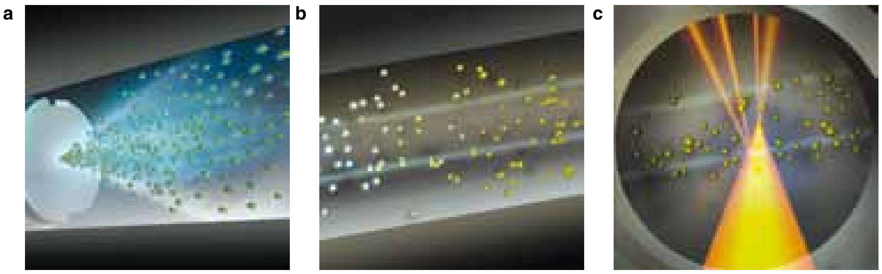


Figure 1 Steps in ELSD (courtesy of ***Grace Davison Discovery Sciences****). a) Nebulization: The column effluent passes through a needle and is mixed with high-pressure nitrogen to form a dispersion of droplets. b) Evaporation: The droplets pass through a heated drift tube to evaporate the mobile phase and form a fine mist of dried sample particles in solvent vapor. c) Detection: The sample particles pass through a cell and scatter light from a laser beam. The scattered light generates a signal that is monitored to provide the chromatogram.*

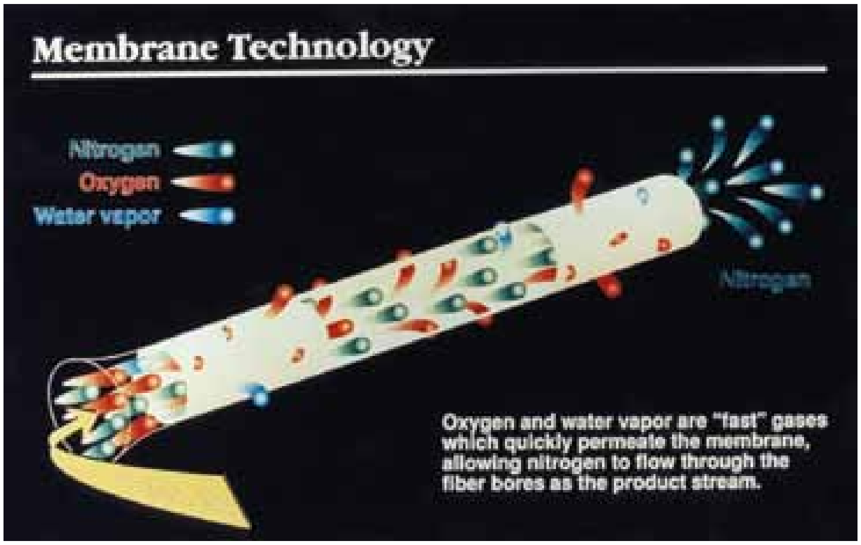


Figure 2 Operation of hollow fiber membrane (courtesy of ***Parker Hannifin Corp.****).*

Generation of nitrogen for ELSD using an in-house generator

Nitrogen for ELSD nebulization can be generated from ambient air by removal of oxygen, water vapor, and particulate matter. The heart of an in-house nitrogen generator is a hollow-fiber membrane that permits oxygen and water vapor to permeate the membrane and escape through the sweep port while the nitrogen flows through the tube (*Figure 2*). While each individual fiber membrane has a small internal diameter, a large number of fibers are bundled together (*Figure 3*) to provide an extremely large surface area for the permeation of oxygen and water.

The schematic of a typical nitrogen generator (model N2-04, **Parker Hannifin Corp.**, Haverhill, MA) is shown in *Figure 4*. Compressed air is filtered using a high-efficiency activated carbon filter to remove hydrocarbons, and a prefiltration system is used to remove particulate matter (all particles >0.01 µm are removed). The air is then delivered to the fiber membrane bundle, where the oxygen and water permeate the membrane, and is vented while the purified nitrogen is passed through another membrane filter and then delivered to the ELSD.

Figure 3 *Hollow-fiber membrane bundle (courtesy of* ***Parker Hannifin Corp.****)*.

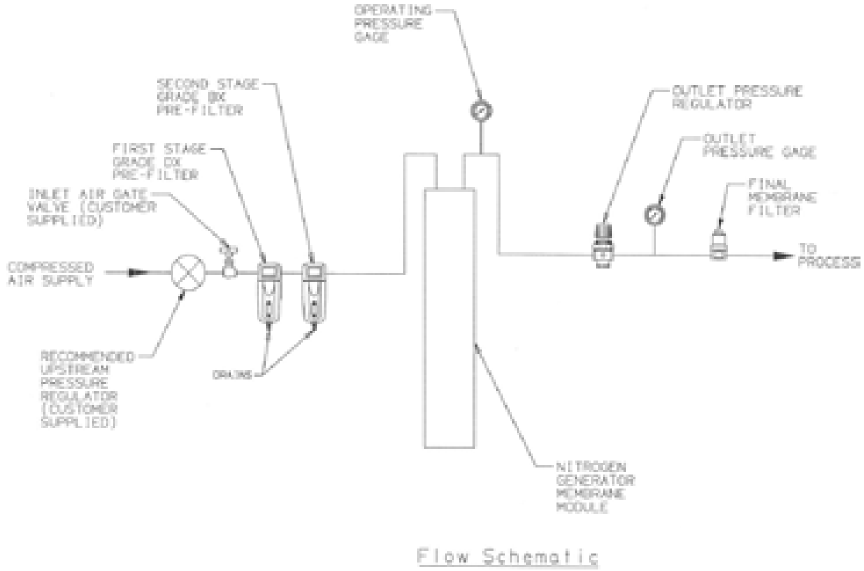


Figure 4 *Schematic diagram of N2-04 nitrogen generator (courtesy of* ***Parker Hannifin Corp.****)*.

The N2-04 nitrogen generator can produce up to 99.5% pure nitrogen on a continuous basis, which is more than satisfactory for ELSD measurements. The purity of the nitrogen is dependent on the operating pressure and the desired flow rate; as an example, 3 L/min of nitrogen gas can be generated using an operating pressure of 80 psi at room temperature, sufficient to supply the gas that is required for an ELSD system. The gas that is delivered to the LC-MS by the N2-04 has an atmospheric dewpoint of –58 °F (–50 °C) and contains no particulate matter greater than 0.01 µm and no suspended liquids. In addition, the nitrogen gas is hydrocarbon-free and phthalate-free, and is commercially sterile.

Benefits of an in-house makeup gas generator

An in-house nitrogen generator provides a number of significant benefits to the operator of an HPLC with an ELSD, including a dramatic improvement in safety, a significant increase in convenience, and a lowering of the cost of supplying the gas.

Minimizing safety hazards

Perhaps the most important benefits of an in-house nitrogen generator are the safety considerations that the generator provides. For example, when an in-house nitrogen generator is employed, only a small amount of the gas is present at a low pressure at a given time, and the gas is ported directly to the detector. The N2-04 generates a maximum of 11 L/min of nitrogen at a maximum pressure of 145 psig. If a nitrogen leak were to occur with the generator, there would be a small change in the composition of the laboratory air, and a small quantity of nitrogen gas would be harmlessly dissipated.

In contrast, a number of serious hazards exist when nitrogen gas is supplied to the detector using a high-pressure gas tank or a liquid tank. For instance, if the contents of a full tank of nitrogen were suddenly vented into the laboratory, up to 9000 L of gas would be released. This volume would displace the laboratory air, reducing the breathable oxygen content of the atmosphere and potentially creating an asphyxiation hazard to the laboratory occupants.

The use of an in-house nitrogen generator also eliminates the possibility of injury or damage inherent in the transportation and installation of a gas tank. A standard gas tank is quite heavy and can be a significant hazard to staff and facilities if the valve on a full tank is compromised during transport (in many facilities, specially trained technicians are used to replace gas tanks).

When a Dewar flask or a high-pressure liquid tank is used to supply nitrogen, the possibility of user contact with the liquid (which has a boiling point of –196 °C) must be considered. As with tank nitrogen, a leak in the delivery system could create a significant increase in the amount of nitrogen gas in the laboratory.

Maximizing the convenience

When an in-house nitrogen generator is employed, the gas can be provided on a 24 hr/day, 7 days/week basis. No user interaction is required, other than a minimum of routine annual maintenance. In contrast, when tank gas is employed, the user must pay close attention to the level of gas in the tank and replace the tank on a periodic basis to ensure that the gas does not run out in the middle of a long series of analyses. The in-house system obviates the need to obtain a replacement tank, which is typically stored outside in a remote area for safety reasons. It can be time-consuming to get a replacement cylinder; when it is necessary to get a replacement nitrogen gas tank, the chromatographer may need to get an individual who is qualified to handle the tanks. Replacing used tanks can be a significant inconvenience, especially in inclement weather if the tanks are stored outside. In addition, it should be noted that a pressurized tank could be a significant hazard if the laboratory is located in a seismic zone.

If a gas or liquid nitrogen tank is used and the need for replacement occurs during a series of analyses, the analyst must interrupt the analytical work to restart the

Table 1 Annual costs: In-house generation vs high-pressure tanks (in U.S. dollars)*

	In-house generator	Tanks
Maintenance	$800	$0
Cylinders	$0	$3120
Demurrage	$0	$336
Labor (changing cylinders)	$0	$1040
Order processing	$30	$360
Shipping	$50	$3720
Invoice processing	$10	$120
Inventory control	$0	$72
Total	$890	$8768

*Assumptions: 52 cylinders at $60/cylinder, four cylinders in-house (one in use, three in storage) at $7/month, $30 labor/cylinder, one order/month at $30 processing costs, labor $20/cylinder change.

system and wait for a stable baseline. In addition, if a series of automated analyses is desired (i.e., on an overnight or weekend basis), the analyst must ensure that sufficient volume of gas is on hand before starting the sequence. A typical user, Lakshmy Nair at **Baxter Healthcare** in Deerfield, IL, reports that "the use of an in-house nitrogen generator for her **Alltech** ELSD systems [**Grace Davison Discovery Sciences**, Deerfield, IL] provides an uninterrupted supply of nitrogen, which is especially useful for long runs of [a] large number of samples."

Since the in-house nitrogen generator allows for continuous operation, calibration of the detector simply requires the measurement of a standard sample at a user-specified interval to ensure that the system is operating properly. In contrast, when the supply of nitrogen is changed, it may be necessary to recalibrate the system to ensure accurate results. This can be a time-consuming procedure that decreases laboratory efficiency. An additional benefit is that it is no longer necessary to train each technician in the calibration process and maintain detailed calibration records that may be required for validation.

The maintenance requirements for the in-house nitrogen generator are minimal since the filters must be replaced on a periodic basis. Dr. Nair indicated that she has used her generator on a continuous basis since 2000 with maintenance on an annual basis.

Minimizing the cost

In addition to the significant safety and convenience benefits, an extremely important advantage of an in-house generator is the dramatic economic benefit compared to the use of gas tanks or liquid nitrogen. The running cost of operation of an in-house generator is extremely low since the gas is obtained from laboratory air (no electricity is required). The running costs and maintenance for an in-house generator are a few hundred dollars a year for periodic filter replacement.

In contrast, when a liquid or gas nitrogen tank is used, the actual cost for using nitrogen gas from tanks is usually significantly greater than the actual cost of obtaining the gas tank. The time involved in changing tanks, ordering new tanks, maintaining inventory, and related activities imposes an additional cost to the user. These hidden costs also include the transportation costs, demurrage costs, and paperwork (e.g., a purchase order, inventory control, and invoice payment) when tank gas is employed. In addition, the value of the time that is required to transport the tank from the storage area, install the tank, replace the used tank in storage, and wait for the system to reequilibrate after the tank has been replaced must be considered as well. While the calculation of the precise cost of the use of nitrogen gas from tanks for a given user is dependent on a broad range of local parameters and the amount of gas that is used, it is clear that significant potential savings can be obtained by the in-house generation of nitrogen for ELSD. Dr. Dae-Kyun Ro of the Bioscience Department at the University of Calgary (Canada) indicates that the in-house nitrogen system in his laboratory provides a very considerable economic benefit compared to the use of liquid nitrogen or high-pressure nitrogen tanks.

A comparison of the cost of supplying gases via tanks versus the cost for use of an in-house gas generator is presented in *Table 1*. In this analysis, it is assumed that a single tank of gas is consumed each week and that the cost of each tank is $60 (this approximation ignores the incidental cost of handling the gas tank, downtime, ordering tanks, etc.) and four are in-house (i.e., tanks are replaced once a month). In comparison, the cost of using the in-house generator is solely for maintenance (replacement of filters) at an overall expense of perhaps $1000 per year or approximately $20 per week.

Environmental considerations

Generation of nitrogen gas via an in-house generator requires essentially no environmental resources except for a compressor to deliver the air to the systems. In contrast, when tank gas is employed, considerable energy is expended to fractionally distill air. Once the nitrogen has been generated, the tank must be transported to the location at which it will be used, and the empty tank must be returned for refilling.

Conclusion

In-house generation of nitrogen for ELSD provides the analyst with a safe, convenient, and less costly method of providing the required gas to the detector. Nitrogen is isolated from laboratory air using a bundle of membranes through which oxygen and water vapor can permeate, thereby allowing the nitrogen to be directed to the nebulizer of the detector. Nitrogen is provided on a continuous basis and does not require the replacement of tanks on a periodic basis. In addition to the reduction in cost, the use of the in-house generator reduces the energy requirement to supply nitrogen gas, since tank gas or liquid nitrogen requires distillation of air (an energy-intensive process) and transportation of tanks to the final point of use.

*Dr. Froehlich is President, **Peak Media**, 10 Danforth Way, Franklin, MA 02038, U.S.A.; tel./fax: 508-528-6145; e-mail: pfpeakmedia@msn.com. Mr. Belobraydich is Senior National Account Manager, **Parker Hannifin Corp.**, Haverhill, MA.*

General Reference: Articles

Considerations on Switching from Helium to Hydrogen

The operational considerations for switching from helium to hydrogen are explained and options discussed. Analysts need to make decisions about their approach to switching the carrier gas to hydrogen. Are they looking for analysis time reductions or would they like to quickly switch their analysis without having to optimize or change their run conditions? The source of the hydrogen and purity levels needed for its use as a carrier gas are discussed along with the advantages or disadvantages of using hydrogen generators versus gas cylinders.

Reginald J. Bartram* and Peter Froehlich†

*****GC Consultant, State College, Pennsylvania

†Peak Media, Franklin, Massachusetts

Direct correspondence to: regbart@comcast.net

Gas chromatography (GC) uses a wide range of gases including helium, hydrogen, and nitrogen as the carrier gas. In the U.S., the most common carrier gas is helium, as it provides good separations, is inert, is readily available, and it is safe to use. In many other countries, helium is less available or is very expensive, and hydrogen is commonly employed. In recent years, the availability of helium has decreased and its cost has increased significantly, so many chromatographers have considered switching to the use of hydrogen (1). In this article, we compare the use of helium and hydrogen in GC and discuss the advantages of hydrogen. In addition, we will discuss how a chromatographer can obtain hydrogen in a convenient, safe, and economical manner to meet the needs of the laboratory.

The Availability of Helium

Helium is a minor component of natural gas formed by the natural breakdown of uranium. Fractional distillation of natural gas allows for the purification of helium from the natural gas. The largest helium concentrations found in natural gas are in Texas, Oklahoma, and Kansas. Sites outside the U.S. with high concentrations of helium are in Algeria and Qatar.

Helium has many uses and applications. These include (by order of size) cryogenic cooling (28%), tank purging (26%), welding cover gas (20%), as a controlled atmosphere (13%), leak detection (4%), and for breathing mixtures (2%) (2). The use of the gas as a carrier gas for GC falls under a miscellaneous category and is a relatively small fraction of the available supply. Many larger users of helium are seeing considerable growth in their use of the gas and will need even larger quantities in the future.

Helium is a critical and national resource for the U.S. During World War II, huge caverns were sealed and used to store the helium, creating the USA Helium National Reserves. In 1995, the government decided to allow the sale of 600 million ft^3 of helium between January 1, 2005 and January 1, 2015 (The Helium Privatization Act of 1996- Public Law 104-273) (3). Sales are ongoing and continue in the U.S. and to foreign countries, leading to reduced supplies and much higher prices for helium. In addition, breakdowns in manufacturing

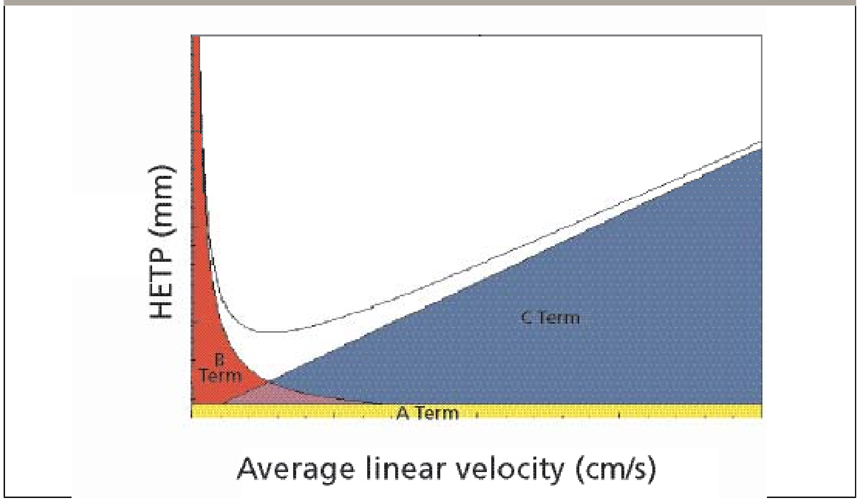


Figure 1: Plot of HETP versus linear velocity (5).

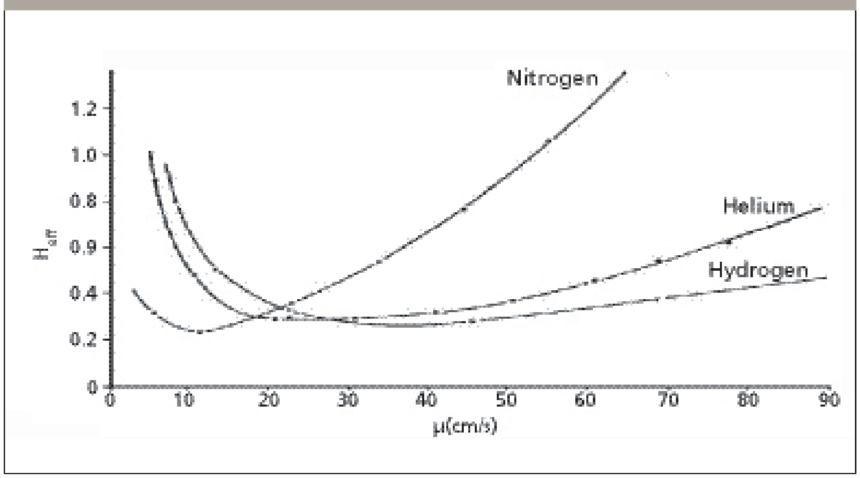


Figure 2: Typical plot for various carrier gases with capillary columns (6).

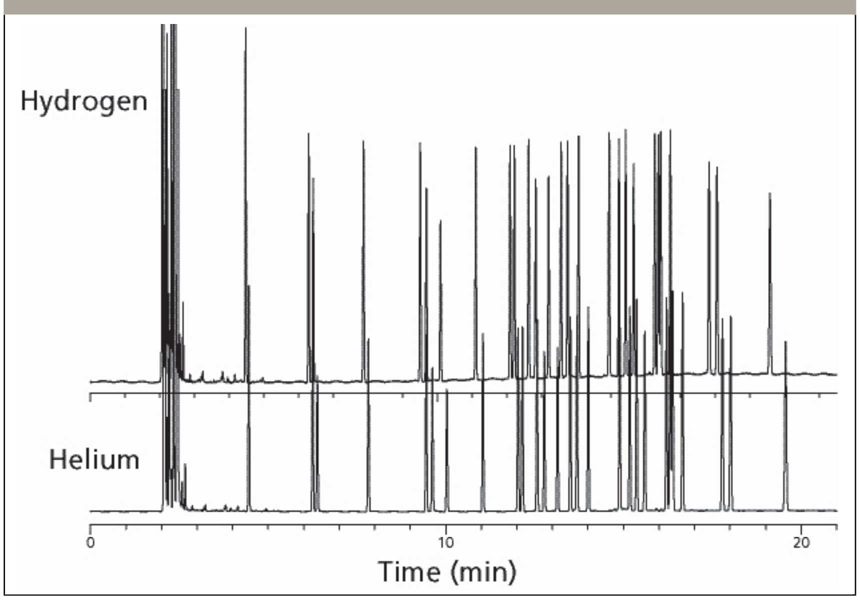


Figure 3: Separation of bacterial acid methyl esters (7).

facilities have also reduced available supplies (4). The end result of the increase in demand and the decrease in supply has required the withdrawal of the gas from the national reserves and there are significant concerns about the ability to obtain helium on a reliable basis. Many users worry more about the ability to obtain helium when they need it than the increased price.

Why Use Hydrogen for Gas Chromatography

Hydrogen and helium are both very efficient gases to use for GC and chromatographers can switch from one to the other with little to no difficulty. While the nature of the separation is the same with the two gases, the differences in the properties of the two gases will lead to differences in the efficiency of the separation. A plot of the efficiency of a column is a van Deemter (4) (packed column) or Golay (5) (capillary column) plot that depicts the efficiency of a column versus different operating velocities of various carrier gases. The van Deemter equation (equation 1) is used to calculate the height equivalent to a theoretical plate (HETP). It describes the column efficiency or a measure of its ability to separate peaks. The desired HETP value would be the smallest value obtainable.

$$\mathrm{HETP} = A + B/\mu + C\mu \qquad [1]$$

where

μ = linear velocity of carrier gas (mobile phase)

A = A constant that accounts for the effects of "eddy" diffusion in the column. (The *A* term is not used with capillary columns because there is only one flow path and no packing material in a capillary column)

B = A constant that accounts for the effect of molecular diffusion of the vapor in the direction of the column axis

C = A constant proportional to the resistance of the column to mass transfer of solute through it.

Figure 1 shows a plot of HETP versus linear velocity and depicts the areas of the plot that represent the *A*, *B*, and *C* terms

$$\mu = L/t_M \qquad [2]$$

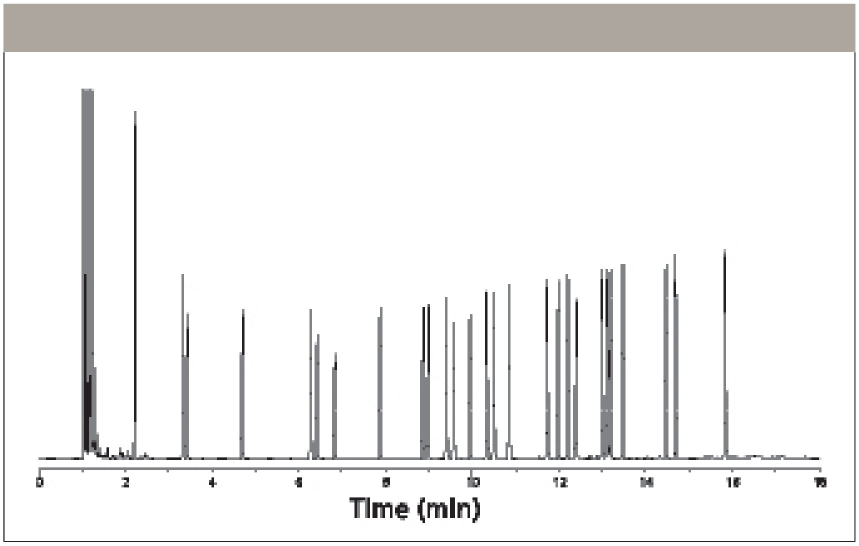


Figure 4: Separation of bacterial acid methyl esters using hydrogen (50 cm/s) (8).

where

L = Length of the column in centimeters

t_M = Retention time in seconds of a nonretained compound (typically methane).

The B term in the van Deemter expression defines the slope of the curve after the minimum (or bottom) or lowest HETP value. It is this slope and the minimum that displays the difference between the use of hydrogen and helium.

From an operational perspective, the HETP values are determined experimentally at various carrier gas velocities. A plot of HETP versus the linear velocity is generated using equation 3 and equation 4.

$$\text{HETP} = L/N_{eff} \quad [3]$$

where

L = Length of the column in centimeters

N_{eff} = Theoretical plate number

and

$$N_{eff} = 16\,(t_R/w)^2 \quad [4]$$

where

t_R = Retention time of the peak being measured

w = Width of the peak.

Measure the peak width for packed columns at the base line and for capillary columns at the half height of the peak.

Determination of HETP

The chromatographer would desire conditions that provide the smallest value for HETP, as this would provide the accumulation of the most plates or separation power within a column). When looking at the typical plot of HETP versus the linear gas rate (LGR), there is not much difference between the minimum value for the HETP for helium and hydrogen, but there is a large difference for the average linear velocity or linear gas rate values obtained for the HETP minimum for each gas. When using helium with typical capillary columns, the usable range of LGR is 20–30 cm/s, while for hydrogen, we see a much wider range of LGR of 25–65 cm/s. The slope of the HETP versus LGR curve for hydrogen (C term) is smaller than that for helium and shows only a 25% reduction in the optimum HETP value over the 25–65 cm/s range.

Switching from Helium to Hydrogen:

When you switch from helium to hydrogen, there are two options:

• Choose to duplicate your analysis using hydrogen with little to no loss of efficiency.

• Choose to take advantage of the higher LGR available with hydrogen to speed up your analysis as the higher linear velocity used for hydrogen leads to shorter retention times and a shorter analysis.

Comparing the Use of Hydrogen and Helium at the Same LGR: The chromatograms in Figure 3 compare the separation of a complex sample of bacterial acid methyl esters on an Equity-1 column with a linear velocity of 25 cm/s for both helium and hydrogen. Notice that at the same LGRs that even with this complex sample the retention times for these components are about the same.

Comparing Chromatograms at Optimum LGR: The chromatograms shown in Figure 3 shows the bacterial acid methyl esters for helium and hydrogen with the helium being at the optimum LGR for helium and the run for hydrogen also being at 25 cm/s but not at its optimum (hydrogen is the top chromatogram and helium is the bottom chromatogram.) The run shown for hydrogen shows a total run time of 19.5 min. What would this run look like at the optimum of 50 cm/s with hydrogen?

The chromatogram in Figure 4 is the same column run at 50 cm/s using hydrogen at the same program rate as used in Figure 3. The total run time is at 16 min. Though there is an improvement in the reduction of the run time, you do not see a great reduction. This is because this separation is very temperature sensitive and needs a higher temperature program rate to speed it up. To obtain a faster separation you would increase your temperature program rate by close to twice that used for the run in Figure 3. (See later in this article for temperature program concerns.)

Major Benefits of Hydrogen: The use of hydrogen provides the chromatographer with a number of benefits:

• Increased speed: Increasing the linear flow rate allows for shorter run times, thereby increasing the throughput of a laboratory.

• Achieve lower temperature separations: At the faster elution times, it might not be necessary to increase the column temperature run rate. You might be able to lower the maximum temperature needed for the analysis or remain at those temperatures for shorter periods.

• Longer column life: Lower temperatures lead to less column bleed and can provide to longer column life. In addition, hydrogen is a reducing gas and can remove out potential acidic sites inside of the column. The removal of these sites leads to less sample absorption and less generation of phase breakdown (column bleed). The result is a longer usable life for the column.

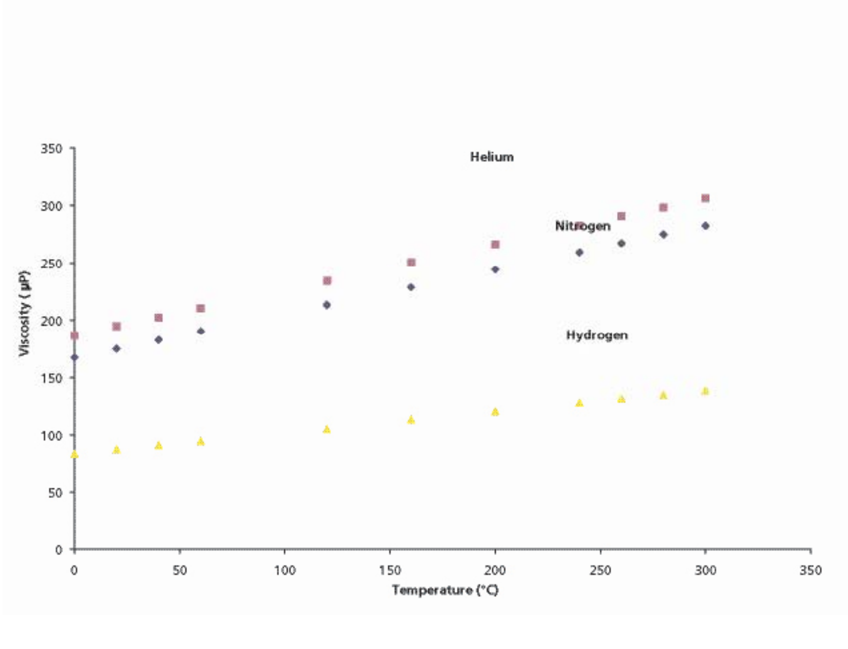


Figure 5: Plot of gas viscosity versus pressure (9).

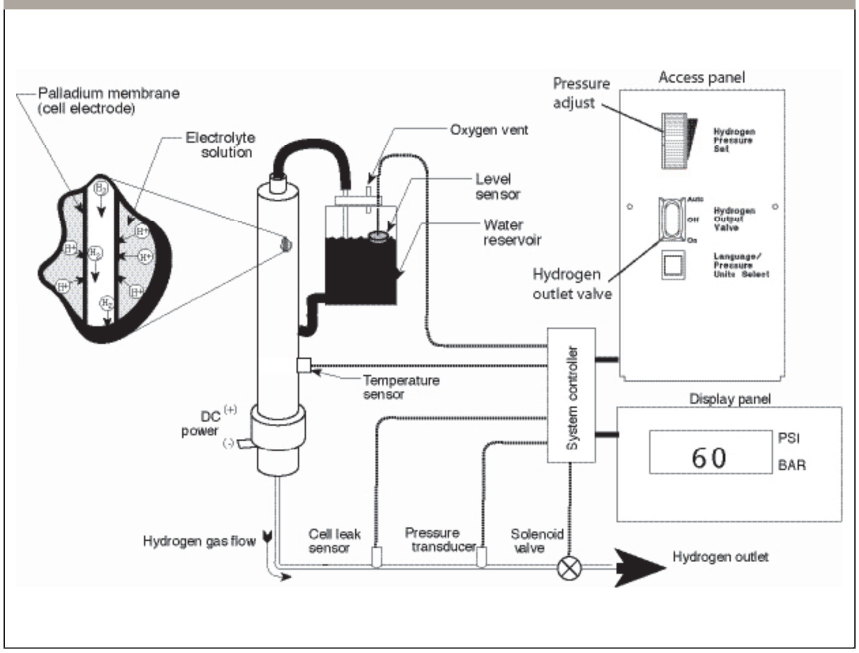


Figure 6: Flow schematic of a hydrogen generator with a palladium membrane.

• Environmental concerns: Hydrogen is available readily via the electrolysis of water and is not a critical national resource. In contrast, helium is a by-product of natural gas or petroleum production and there are environmental concerns with the production and purification of the gas. Hydrogen is a green gas in that its production does not contribute to environmental pollution.

• Cost savings: The cost of hydrogen is significantly lower than that of helium. (Comparisons of cost are best made in-house due to differing cost structures from site to site.)

• Availability: Because the generation of hydrogen is from water, the chromatographer need not be concerned about availability issues.

Switching to Hydrogen: Chromatographers can switch to hydrogen readily if flame ionization detection (FID) or other flame-based detection methods such as phosphorus, nitrogen, electron-capture, or Hall detection are employed for the separation. If the separation requires a helium detector, it will be necessary to maintain the use of helium. The use of mass spectrometry (MS) might allow or not allow the use of hydrogen and it is best to check with the manufacturer of your unit about its capability. Thermal conductivity detection (TCD) typically uses helium for the best thermal differences between the carrier gas and other compounds to be detected. Some analyses do use hydrogen as a carrier such as with oxygen, helium, and other very light gases. Therefore, the use of hydrogen for TCD is application dependent.

Delivering Hydrogen to the Chromatograph: When switching the carrier gas from helium to hydrogen, it might be necessary to change the external tubing connections to the GC system. If the GC system employs a flame-ionization detector, a hydrogen line is already in place. First, vent the line and then cut it and install a tee. Connect the other side of the tee to the supply carrier gas.

If you are using copper tubing for delivery of the carrier gas (as is common in many facilities), replace it with stainless steel tubing as copper tubing will oxidize and harden with time. Hardened copper tubing is quite brittle and may break if it is bumped while stainless steel tubing is much more robust. To avoid contamination to the GC system be sure to use clean, preferably GC-quality tubing.

The purity of the fuel gas also should be a consideration. If fuel-grade hydrogen is used, it will be necessary to include a purifier in the system to reduce moisture and oxygen levels so that the gas is 99.9999% pure. The other choice is to switch to carrier-gas grade as the carrier gas. Several inline purifiers are available that will reduce the impurities to the desired levels and include indicators to notify the user when the purifier is expended and needs to be changed.

If the GC system automatically adjusts for LGR: Many modern GC systems include electronic pneumatics and it simply necessary to indicate the gas used so that automatic adjustments based on

Table I: Typical detector fuel gas flow rates*

Detector	Flow rate
Flame ionization	30–40 cm^3/min
Flame photometric	60–75 cm^3/min (sulfur mode); 100–175cc/min (phosphorus mode)
Nitrogen–phosphorus	2–3 cm^3/min (nitrogen compounds only) 300 cm^3/min for both nitrogen and phosphorus compounds

*Consult your GC manufacturer for your specific unit flow requirements.

the density differences of the gases are considered. Indicate that hydrogen is the carrier gas in the control program of the GC system and the unit will make the necessary density adjustments in controlling the carrier gas. Typically, the system will control the LGR in the column, the split ratio, and the amount of flow of fuel gas to the FID system.

If you are using a short column and a flow controller: Some units use flow controllers in combination with pressure controllers to control the LGR. If you are using a short column or wide bore column, the LGR for hydrogen might lead to a column head pressure that is below 10 psig. In this case, it might be necessary to change the flow controller to allow flow control below 10 psig.

If the operation of the GC system is pressure: The operation of simple GC systems and some older GC systems is related to the pressure of the carrier gas (that is, do not automatically adjust for LGR); in this case, it will be necessary to make adjustments to the head pressure. To achieve the same LGR for hydrogen as you used for helium, it will be necessary to set the head pressure to approximately 45% of the pressure used for helium.

Changes needed for various injection techniques: Adjusting the split ratio: If you desire to shorten your analysis time by increasing your LGR, then you will need to reestablish your vent flow to maintain your desired split ratio. This adjustment to the split ratio is necessary to allow for only the correct amount of sample to enter the column; the rest of the sample goes to a vent. The ratio of sample entering the column versus that going to the vent is the split ratio. The typical injection size of 1 μL of sample saturates most columns and leads to broad peaks. splitting the sample reduces the amount of sample entering the column to an acceptable level. When switching the carrier gas to hydrogen, it may be necessary to adjust the split ratio (which is the ratio of sample and carrier gas that enters the column versus how much is vented) and increase the LGR to obtain the best possible analysis and the shortest possible run time.

Split ratios: To calculate the split ratio you most know the flow of the column and the split vent flow. With this technique, it is desired to reduce the amount of sample down to a level where the on-column concentration of the individual components due not saturate and cause wide and often tailing peaks.

$$\text{split ratio} = \text{split vent flow/column flow} \quad [5]$$

To calculate the column flow use equation 5.

$$\text{Flow} = \pi r^2 L/t_M \quad [6]$$

where

$\pi = 3.1416$

r = Radius of the column (in centimeters converted)

L = Length of the column (in centimeters)

t_M = Retention time of a non retained peak typically methane

$$\text{Where } L/t_M = \text{LGR} = \mu \quad [7]$$

Simplified:

$$\text{Flow} = \pi r^2 \mu \text{ (Remember to use centimeters as units)} \quad [8]$$

With a column that has an internal diameter of 0.25 mm, the split ratio is typically 100/1 (that is, only 1 part in 100 of the sample enters the column and the rest of the sample and carrier gas flow is vented).

Always measure the column flow and vented carrier gas before changing the gas to make sure you know the split ratio you were using. After changing the gas, it will be necessary to measure and adjust your split vent flow to allow for the same split ratio you previously used.

Note: The split flow does not always need to be on. With splitless injection techniques, the flow is off for a short period after injection. Use this same technique with a split injection technique. After about 2 min, the entire sample that is going into the column is in the column, and the split flow can be turned off at this time. Turn it back on as you prepare for the next injection. This can provide huge savings in gas usage.

Note: If you are doing splitless injections you will still need to know the amount of gas exiting the vent port when the port is open (typically 20–60 s after an injection). Make adjustments to duplicate the split flow after the switch to hydrogen.

Splitless injection techniques: Hydrogen is preferred over helium for splitless injection techniques as it carries the solute from the inlet into the column faster than helium. This results in sharper peaks (higher efficiencies) and reduces band broadening with the resulting wide and shorter peaks, which allows for lower detection limits.

Direct injection: There is no concern on the conversion when using direct injection.

Temperature Programming Concerns

Many analyses use temperature programming to allow the later eluted compounds to be eluted at a reasonable temperature to obtain sharp symmetric peaks. The changeover from helium to hydrogen has significant implications with temperature programming runs. There is a significant difference in the viscosity of helium and hydrogen and this difference is temperature dependent as indicated in Figure 5. Both gases increase in viscosity as temperature increases, but hydrogen has a much lower viscosity than helium throughout the temperatures shown. The lower viscosity of hydrogen means that lower pressures are required for hydrogen. Because the viscosity of hydrogen is approximately 45% lower than helium, the pressure needed to run the analysis is about 45% lower when hydrogen is used.

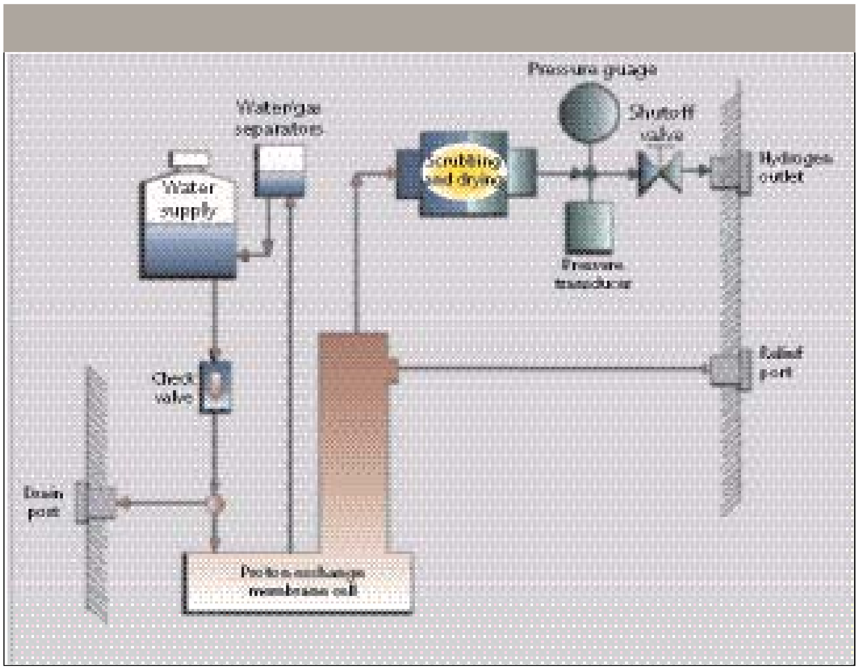


Figure 7: Hydrogen generator with a proton exchange membrane.

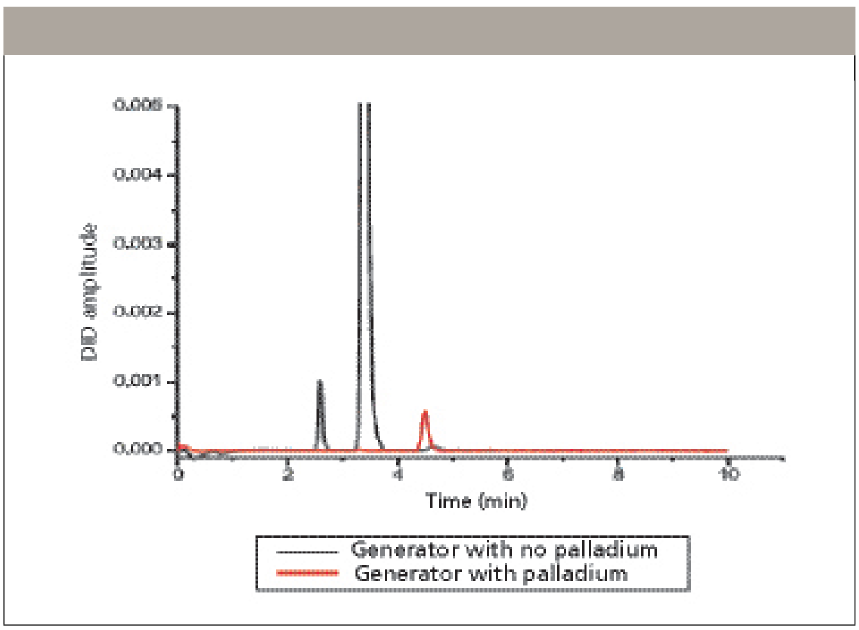


Figure 8: Hydrogen collected via a GC system equipped with a discharge ionization detector.

When running capillary columns with a system using LGR, you can use the same LGR but the resulting head pressure for the hydrogen is 45% lower.

If you choose to use higher flow rates for hydrogen, it might be necessary to make corrections to the temperature program when desiring a rapid analysis time. Some compounds might be eluted faster but provide broader peaks than desired if the temperature program rates are not increased to match the higher flows. If, for example, when doubling the LGR and using a 5 °C/min temperature program rate, it might be desirable to increase the program to 10 °C/min. If the peaks are coming out rapidly and are sharp, you can take advantage of the lower column temperatures and stop the temperature programming just before or after the last peak is eluted. This might mean a lower final run temperature and will often extend column life.

Elution Order of Peaks: With most analyses, the change of linear gas rate and temperature might not change the order of elution of compounds. If you choose to use the same LGR and temperature as used with helium, typically, you should not see any problems. However, with polar columns, such as Carbowax or the highly polar Cyano phase columns it may be necessary to check the elution order as some column phases, at differing temperature, exhibit different polarities or orders of peak elution.

Detector Optimization Concerns: Flame detectors need an optimum flow of hydrogen to optimize the flame sensitivity and other detectors can have similar requirements on how much hydrogen can be used. With the flame ionization detector, the flow optimum is 30–40 cm^3/min of hydrogen. When you switch to hydrogen as a carrier gas, you will have to take the flow from the column into consideration so that you do not exceed the optimum flow range of hydrogen for the detector. With packed columns or large-bore capillary columns, this might mean reducing the fuel gas flow so that the combination of carrier and fuel gas is at that rate previously used for the separation. For typical detector fuel flow ranges see Table I.

Make-Up Gas for Detectors: If you do use hydrogen as the make-up gas, it will be necessary to consider this flow with the carrier gas and fuel gas to optimize the detector sensitivity. Take care not to saturate the detector with too much hydrogen, as this will affect both base line noise and sensitivity.

Hydrogen is not the best choice for make-up gas; the best gas for a make-up gas with flame detectors is 99.9999% pure nitrogen. Its use leads to lower baseline noise and better flame performance.

Safety Concerns When Using Hydrogen

General Considerations: Hydrogen gas is used commonly in the laboratory for a variety of purposes and is the carrier gas of choice for gas chromatography in countries other than the U.S. It is the fuel used in the most commonly used detectors (flame ionization, nitrogen, and phosphorus detectors) and therefore, already in the laboratory and in use with most gas chromatographs.

If the analyst changes from helium to hydrogen, the safety issues should be well understood to ensure safe operation. The flammability of the gas ranges from 4 to 74% in air, with an explosion limit of 18.3–59%, so there are real hazards if a build-up of hydrogen were to occur. Similarly, if a large buildup of hydrogen or helium were to occur in the laboratory, the oxygen concentration for breathing might be compromised. As we describe in the following, the use of a hydrogen generator obviates many of the safety concerns, as only a small quantity of gas is present at a given time, in contrast a significant amount of hydrogen is present when a tank is used.

Although hydrogen can form an explosive mixture with air, it diffuses rapidly. It dilutes quickly by combining with air into a nonflammable concentration. Hydrogen rises two times faster than helium at a speed of almost 45 mph (20 m/s). In a laboratory with good air turnover, it would be very difficult to achieve flammable limits. In addition, most modern GC systems incorporate a turn-off system when flows or pressures suddenly increase or decrease (as in the case of a column breakage in the GC oven) and help to reduce the possibility of a problem.

In the case of a column or line break when using a gas generator, the available volume of gas is low, and also the generation of gas will be terminated. Generators only store about 60 cm^3 of gas.

Proper Venting: It is best to consider special venting systems to remove the chance of any build up of hydrogen. When using hydrogen as a carrier gas you need to consider all of the flows exiting the unit. In many detectors, the carrier gas burns in the flame and is not a problem, but you should consider the venting of the gas from detectors that do not burn the hydrogen.

A source of venting is the septum vent port. The typical septum purge is 1–5 cm^3/min. It is easy to vent this flow with the split vent exhaust. The split exhaust port will have the highest vented flow. split vent ports can have flows of 50–500 cm^3/min. This can mean a lot of vented hydrogen and will need special venting.

Many laboratories already have special fume hood vents over the split vent to allow for the venting of hazardous sample components. If you do not have such vents in place, you should consider them for both the sample and the venting of hydrogen.

Safety Concerns: Gas Generators Versus Cylinders: The concern with flammable gases is with the build up of these gases to flammable or explosive limits. Consider as one of the primary concerns the total volume of hydrogen in your lines. If a break in the line occurs, an explosive level of the gas in the lab could be present. Gas generators with their safety shutoffs and monitoring safety features only allow for small volumes of gas in their lines and units. If there is a sudden release of pressure or flows, the gas generators will turn off (some modern GC systems also incorporate this feature).

Cylinders often involve long lines leading to GC systems and the hook-ups are often at the end of benches or in other rooms. With a long run of tubing, you will have large volumes of gas in the lines, under pressure, and the possibility of venting of these lines with a line break. This could allow for the entire venting of the volume of one or more cylinders into the lab. With the proper installation of cylinders, it is unlikely that you will see cylinders taking off like rockets and shooting across laboratories. Be sure to review your operating procedures and safety concerns before switching to hydrogen. There are codes and standards for safe building and installation practices. Any new hydrogen component installations should follow strict guidelines and undergo third-party testing for safety and structural integrity. To make sure you have the latest guidelines you can check your standards against the following sources on the Internet.

Internet sources of safety information include www.hydrogenSafety.info; www.fuelcellstandards.com; and www.eere.energy.gov/hydrogenandfuelcells/codes.

Ways of Supplying Hydrogen Gas via an In-house System: To obtain hydrogen gas for GC, use high-pressure cylinders or an in-house generator. The in-house generation of hydrogen is based upon the electrolysis of water, as shown in equation 9.

$$2H_2O + 2e^- \rightarrow 2H_2 + O_2 \qquad [9]$$

Connecting a power source to two electrodes placed in water performs the electrolysis of water. The cathode, where hydrogen gas collects can be a metal electrode or a polymeric membrane, while the anode, where oxygen is collected, is a metal electrode.

Electrolysis of water using two metal electrodes: The electrolysis of water can be performed readily using a metallic cathode and metallic anode immersed in a strong, water-soluble electrolyte such as 20% sodium hydroxide. The base is an electrolyte, as pure water does not conduct a current very effectively, and the quantity of hydrogen generated is very low. To provide hydrogen of high purity, the cathode consists of a bundle of palladium tubes. The cathodes are palladium tubes because only hydrogen (and its isotopes) is capable of passing through it and ultra-high-purity hydrogen gas is obtained.

As an alternative to the use of a palladium cathode, some systems that generate hydrogen via the electrolysis of water via a metal electrode use a stainless-steel cathode and employ a desiccant as the final drying agent. While the initial cost of such approach is lower, the hydrogen gas collected in this manner is less pure as it contains significantly more oxygen and nitrogen than hydrogen gas generated via a palladium electrode (see Figure 6). In addition, systems that employ a desiccant, require regeneration on a periodic basis.

Presented in Figure 6 is a typical hydrogen generator (Parker Balston Model H2PD-30, Parker Hannifin Corporation, Haverhill, Massachusetts). It generates hydrogen via the electrolysis of water using a metal electrode. This system generates hydrogen with a purity of 99.99999+%, oxygen content of <0.01 ppm, and moisture content of 0.01 ppm at a maximum flow rate of 300 mL/min with a maximum outlet pressure of 60 psig.

Electrolysis of water using a proton exchange membrane: In recent years, ionic polymeric materials such as Nafion (a sulfonated tetrafluoroethylene polymer) or polybenzimidzole (PBI) have been found to conduct protons while being impermeable to gases such as hydrogen and oxygen. Proton exchange membranes (PEMs) made from such polymers are used in fuel cells to generate electricity from oxygen and hydrogen. If a potential is applied to a system containing a PEM in the presence of water and a counterelectrode, the water will be dissociated to form hydrogen ions, which are then converted into hydrogen gas. The primary benefit of using a PEM is that deionized water can be used instead of the 20% sodium hydroxide used when two metallic electrodes are used and sodium hydroxide, which is caustic, is not required. When a PEM is used to generate hydrogen, a palladium membrane can be used to purify the hydrogen further by reducing the oxygen concentration to less than 0.01 ppm and moisture down to <1.0ppm.

Shown in Figure 7 is the general design of a hydrogen generator based upon PEM membrane technology (Parker Model H2PEM-510). This system is capable of generating 99.9995% pure hydrogen (noncarrier grade) at a flow rate of 510 mL/min at pressures up to 100 psi.

Figure 8 shows the chromatograms of hydrogen gas collected via a gas chromatograph equipped with a discharge ionization detector. The red trace is from gas generated via a palladium cathode ,while the black trace is from gas collected using a stainless-steel electrode and a desiccant drying tube.

The large black peaks indicate the presence of a combined concentration of 12 ppm of O_2 and N_2 in the hydrogen, which is not present in the hydrogen that was dried with the Pd tubes. It is clear that the palladium tube cathode provides a very considerable improvement in purity.

Conclusion

The process of switching from helium to hydrogen involves many issues but with attention to detail, one can switch successfully and duplicate previous analysis with little to no problems. If desired, the analysis can be run at higher LGRs and greatly reduce the analysis time. The switch from helium to hydrogen will allow reduced cost of analysis due to the lower cost of hydrogen and allow for longer column lifetimes. For most chromatographers, hydrogen is a gas already in the lab and is not an increased safety issue. Consider venting hydrogen, along with any sample vapor, to provide the safest, cleanest environment for the analyst to work within. To avoid the problems with cylinders in the laboratory and to obtain the best, most convenient source of hydrogen, consider the use of a hydrogen gas generators.

References

(1) N. Pacheco, U.S. Bureau of Mines, U.S Geological Survey Minerals Yearbook, 1 –2, (2007).

(2) The Helium Privatization Act of 1996, Public Law 104-273.

(3) M Rose, *Photonics* 1–12, 2008.

(4) J.J. van Deemter, F.J. Zuiderweg, and A. Klinkenberg, *Chem. Eng. Sci.* **5**, 271 (1956).

(5) E. Glueckauf, M.J.E. Goley, and J. H. Purnell, *Ann NY Acad. Sci.* **72**, 612 (1956).

(6) L. Sidisky, "Carrier Gas Selection: Helium vs. Hydrogen," Pittcon 2008, Orlando, Florida.

Reginald Bartram is presently a consultant for gas chromatography and is semiretired. He is a past president of the Chromatography Forum of Delaware Valley and the recipient of the 1999 Chromatography Forum of Delaware Valley Award for Contribution to Theory, Instrumenation, and Application of Chromatography. He has been widely published on the subject of gas handling and gas purification. In his 35 years of service to GC, he has worked at Supelco and Alltech as a scientist and marketing manager.

Peter Froehlich is President of Peak Media, Franklin, Massachusetts. He received the Ph.D. in chemistry from Purdue University, West Lafayette, indiana, and has over 30 years of marketing and technical support experience in the scientific instrument industry, with an emphasis on a broad range of chromatographic techniques including GC and LC. ■

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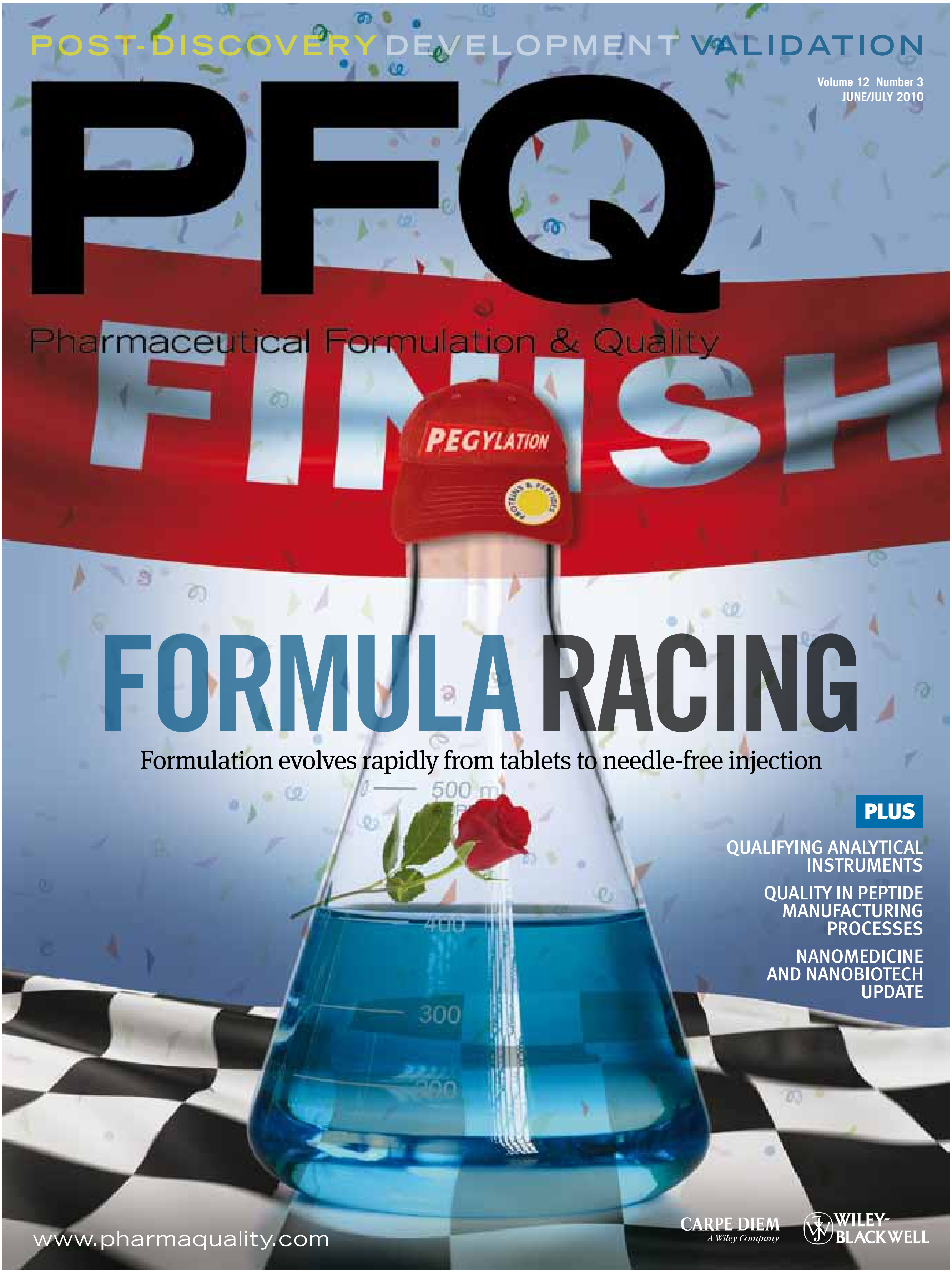
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THERMAL ANALYSIS

In-House Generation of Nitrogen for Thermal Analysis

In addition to saving money, method is safe, convenient

BY **PETER FROEHLICH** AND **PAT KRIWOY**

A broad range of thermal analysis (TA) techniques measure the effects of temperature on stability and other physical properties of polymers that are used in pharmaceuticals and pharmaceutical packaging. When TA measurements are taken, the chemical nature of the polymer should not change because of a reaction with oxygen or water vapor in the sample chamber.

To minimize the possibility of oxidation or other reactions, a high-purity inert gas such as nitrogen is passed through the sample chamber to displace the air. The DSC-1 Differential Scanning Calorimeter (Mettler-Toledo, Columbus, Ohio), for example, uses a flow of nitrogen on the order of 200 mL/minute at a pressure of two to five pounds per square inch (psi) to maintain optimum analytical conditions.

A high-pressure tank, a dewar, or an in-house nitrogen generator can supply nitrogen for thermal analysis. An in-house generator provides significant benefits compared with other approaches, including increased safety and convenience, lower cost, and diminished use of energy.

Figure 1.

Nitrogen is generated from air using a hollow-fiber membrane bundle. It has a small diameter, so many fibers are bundled together to provide a large surface area for the permeation of oxygen and water.

Generation of Nitrogen for Analysis

In-house generation of nitrogen from ambient air requires the removal of oxygen, water vapor, and particulate matter. Nitrogen can be generated from air using a hollow-fiber membrane that permits oxygen and water vapor to permeate the membrane while the nitrogen flows through the tube. A fiber membrane has a small internal diameter, so a large number of fibers are bundled together to provide a large surface area for the permeation of oxygen and water (see Figure 1, left).

The Model N2-04 Nitrogen Generator (Parker Hannifin Corporation, Haverhill, Mass.) can provide six standard liters per minute (SLPM) of 99% nitrogen at 145 psi. Compressed air is first filtered to remove liquids and particulate matter; the filters are equipped with float drains to empty liquids that accumulate inside the filter housing. Separation of the nitrogen takes place inside the membrane bundle. The nitrogen is then directed downstream while oxygen and water molecules are ported to the atmosphere at a low pressure. A 0.01 µm membrane performs the final filtration, and the gas is delivered to the analyzer (see Figure 2, p. 27). The nitrogen has an atmospheric dew point of -58°F (-50°C), contains no particulate matter greater than 0.01 µm and no suspended liquids, is hydrocarbon- and phthalate-free, and is commercially sterile.

In-house generator s can provide nitrogen with a purity as high as 99.9999%, with CO, CO_2, H_2O, and O_2 levels at less than one parts per million, and at a flow rate and pressure compatible with thermal analysis.

Benefits of In-House Generator

An in-house nitrogen generator is safer, significantly more convenient, and less expensive than other methods. In addition, use of an in-house generator dramatically reduces environmental impact.

Because an in-house nitrogen generator will not alter the atmospheric composition of the air in the lab, it is considerably safer than a tank or a dewar. The generator separates the O_2 from the N_2 and vents it to the atmosphere; the 200 ml/min of N_2 that is used by the TA instrument is then vented back to the room as well. The net change to the room atmosphere is zero.

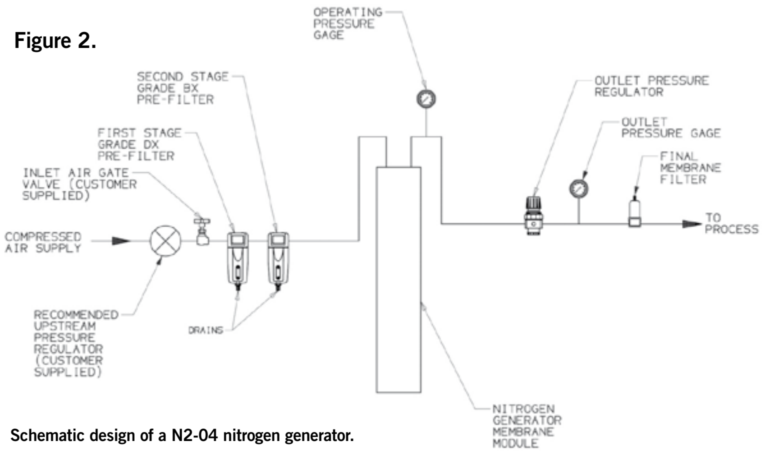
In contrast, serious hazards are present when nitrogen gas is supplied to a thermal analyzer using a high-pressure gas tank or a liquid tank. If the contents of a full tank were suddenly vented into the laboratory, up to 9,000 L of gas would be released into the atmosphere. This volume would displace the equivalent amount of laboratory air, thereby reducing the breathable oxygen and potentially creating an asphyxiation hazard for laboratory occupants.

Use of an in-house generator eliminates the possibility of injury or damage that can occur when a gas tank is transported and installed. A standard gas tank is quite heavy and can pose a significant hazard to staff and facilities if the valve on a full tank is compromised during transport. In many facilities, trained technicians are used to replace gas tanks.

When a dewar flask or a high-pressure liquid tank is used, the possibility of user contact with liquid nitrogen, which has a boiling point of -196°C, must be considered. As with a high-pressure tank, a leak in the delivery system could release a significant amount of gas into the laboratory.

Roland Brunell, special projects manager at Danafilms Inc., of Marlborough, Mass., a manufacturer of films for packaging, said that safety was "the primary reason that an in-house generator was selected for the DSC used for analyzing polyethylene films."

Figure 2.



Schematic design of a N2-04 nitrogen generator.

More Convenient

When an in-house generator is used, the gas can be supplied continually for 24 hours, seven days a week, with no user interaction other than routine annual maintenance. With tank gas or a dewar, on the other hand, the user must pay close attention to the level of gas in the tank and replace it periodically to ensure that the gas will not be depleted in the middle of a long series of analyses. For safety reasons, tanks are typically stored outside in a remote area, so replacing a cylinder can be time-consuming as well as inconvenient in inclement weather. Also, the analyst may need to get a qualified handler to move the tanks. A pressurized tank can be a significant hazard if the laboratory is located in a seismic zone.

If a nitrogen tank must be replaced during a series of analyses, analytical work will be interrupted to restart the system and wait for a stable baseline. In addition, if a series of automated analyses is desired, perhaps overnight, the analyst must ensure that a sufficient volume of gas is available before starting the sequence.

An in-house nitrogen generator allows for continuous operation of the thermal analyzer, and calibration only requires the measurement of a standard sample at a user-specified interval to ensure proper operation of the system. When a new tank is installed, however, the system may need recalibration to ensure accuracy, a time-consuming procedure that decreases laboratory efficiency and throughput.

The maintenance requirements for the in-house nitrogen generator are minimal. The readily accessible filters are typically replaced once year, a process that takes about 10 minutes for all three filters.

Table 1.
Annual Costs of In-House Generation vs. High-Pressure Tanks (U.S. $)

	IN-HOUSE GENERATOR	TANKS
Maintenance	$800	$0
Cylinders	$0	$3,120
Demurrage	$0	$336
Labor (changing cylinders)	$0	$1040
Order Processing	$30	$360
Shipping	$50	$3,720
Invoice Processing	$10	$120
Inventory Control	$0	$72
TOTAL	**$890**	**$8,768**

ASSUMPTIONS

- 52 cylinders at $60/cylinder
- Four cylinders in house (one in use, three in storage) at $7/month
- $30 labor/cylinder
- One order/month, $30 processing costs each order
- Labor, $20/cylinder change

Lower Costs

In addition to significant improvements in safety and convenience, use of an in-house generator provides economic benefits in comparison with a gas tank or liquid nitrogen. The running cost of operating an in-house generator is extremely low, because the gas is obtained from laboratory air, with no electricity required. The running costs and maintenance for an in-house generator add up to a few hundred dollars a year for periodic filter replacement.

In contrast, the expense associated with a liquid or gas nitrogen tank is higher. The actual cost for using nitrogen gas from tanks is usually significantly greater than just the cost of obtaining the gas tank. The time involved in changing tanks, ordering tanks, maintaining inventory, and conducting related activities adds to the cost.

Hidden costs of tank gas can include the transportation demurrage and paperwork—purchase orders, inventory control and invoice payment. Additional costs are associated with the time required to transport the tank from the storage area, install the tank, replace the used tank in storage, and wait for the system to re-equilibrate after the tank has been replaced.

While the calculation of the precise cost of nitrogen gas from tanks is dependent on a broad range of local parameters as well as amount of gas used, significant savings are probable with in-house generation of nitrogen. According to Brunell of Danafilms, the payback period of the in-house nitrogen generator is about two years.

Table 1 (see left) shows a cost comparison between supplying gas with a tank vs. generating gas in house. For the analysis, we assumed that a single tank of gas is consumed weekly, that the tanks cost $60 each, and that four tanks are in house, with each tank replaced once each month. The analysis does not include incidental expenses, such as the costs associated with handling the gas tank, down time, ordering tanks, and other related activities. As this comparison shows, the cost of using an in-house generator is solely tied to maintenance (filter replacement) and is estimated to be about $1000 per year or approximately $20 per week. ■

Froehlich is with Peak Media and **Kriwoy** is an employee of Parker Hannifin Corporation. Reach them at pfpeakmedia@msn.com or (508) 528-6145.

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Lab Manager MAGAZINE®
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December 2010 Volume 5 • Number 10

TECHNOLOGY & OPERATIONS

GAS ON DEMAND

MAKING A CASE FOR IN-HOUSE GENERATION OF CARRIER GAS FOR TOC ANALYSES by Jack Mahan and Peter Froehlich

Total organic carbon (TOC) analyzers are commonly used in applications including the determination of organic matter in water in municipal water supplies and sewage facilities, the monitoring of water used in semiconductor manufacturing and nuclear power plants, and the clean-in-place procedures used in pharmaceutical manufacturing.

TOC analysis includes three discrete steps:

1. Acidification of the sample to remove inorganic carbonaceous material and purgeable organic carbon (e.g., methane)
2. Oxidation of the organic matter in the sample (typically via persulfate in a heated quartz tube) into CO_2
3. Detection of the CO_2 (typically by non-dispersive IR)

> "A TOC analyzer can be coupled with a nitrogen analyzer... so that the level of both elements can be determined."

High-purity air or N_2 is used to drive the CO_2 from the oxidation process to the detector, and its purity is a critical issue in the optimization of the sensitivity and operating range of the system. The gas must be free of CO, CO_2 and hydrocarbons (e.g., compressor oils), and is typically supplied to the analyzer at a pressure of 80 to 100 psig and at a flow rate of 400 to 800 mL/min to provide a broad operating range; as an example, organic carbon can be detected over the range from 4 to 25,000 mg/L using the Shimadzu TOC-V_{CSH} Analyzer (Shimadzu Corporation, Tokyo, Japan) shown in Figure 1. In addition to analysis of organic carbon in water, a TOC analyzer can be coupled with a nitrogen analyzer (which converts organic nitrogenous compounds to NO followed by measurement of the chemiluminescence of the NO) so that the level of both elements can be determined.

Figure 1. Shimadzu TOC-V_{CSH} TOC analyzer

Although carrier gas for TOC analysis can be provided by a cylinder obtained from an external source, many laboratories employ an in-house generator to supply the gas. In this article, we will describe how carrier gas

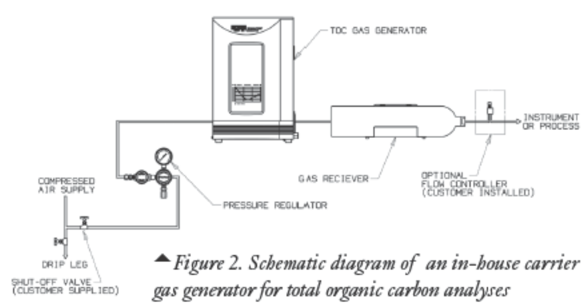


Figure 2. Schematic diagram of an in-house carrier gas generator for total organic carbon analyses

for TOC analysis can be generated in-house from laboratory air and show that this is a safer, more convenient and less expensive approach than the use of a cylinder.

Design of an in-house gas generator for TOC analysis

The initial steps in generating TOC carrier gas involve filtration of the compressed air and oxidization of hydrocarbons. The compressed air is then passed into a pressure swing adsorption (PSA) system to remove water vapor and CO_2, and a final filtration step is employed to remove all particulate matter >0.01 micron. An overall schematic diagram of a typical in-house generator designed to generate high-purity gas for TOC is shown in Figure 2.

The heart of an in-house gas generator for TOC analyses is the PSA system. This system involves pressurizing air and passing it into a chamber that contains molecular sieves that are specially designed to retain the gases that are not desired while allowing the product air to be passed into a storage tank for use with the TOC analyzer. The undesired gases are purged from the molecular sieves on a periodic basis by heating the sieves and reducing the pressure.

A molecular sieve such as activated carbon (charcoal) is used in the PSA system because it has a very large surface area available for adsorption, is extremely porous and can retain a significant amount of the undesired gases before it must be purged. Due to its high degree of micro porosity, 1 g of activated carbon may have a surface area in excess of 500 m_2 (which is equivalent to the area of about two tennis courts), as determined by nitrogen gas adsorption experiments.

The carrier gas supplied by an in-house generator contains extremely low levels of CO_2 and provides superb sensitivity with a TOC analyzer. As an example, the composition of the gas generated by the Parker TOC-1250 TOC gas generator (Figure 3) is presented in Table 1. Although the gas contains approximately 1 percent Ar (Ar is not retained by the molecular sieve), this is not a problem for TOC analysis since Ar is

Gas	Composition
Nitrogen	99.9999%
CO	<1 ppm
CO2	<1 ppm
O2	<1 ppm
H2O	<1 ppm (Dew Point <-100oF [-73oC])
Hydrocarbon (as methane)	<0.1 ppm
Argon	0.9%

Table 1. Composition of nitrogen provided by a typical in-house generator

Figure 3. Parker Balston TOC-1250 TOC gas generator

not detected at the wavelength used to monitor the CO_2 that is generated by the oxidization of the organic compounds. If the compressed air supply contains halogenated hydrocarbons, a scrubber should be installed upstream from the generator, as halogenated hydrocarbons will render the molecular sieves inactive.

The TOC-1250 TOC gas generator shown in Figure 3 can generate gas at flow rates as high as 1,200 mL/min (at an inlet pressure of 150 psig). The total hydrocarbon and CO_2 concentration of the gas from this generator is extremely low and provides an extremely stable baseline for extended periods of time (Figure 4).

Benefits of in-house generation of TOC-grade gas

Safety considerations

In-house generation of TOC-grade gas readily provides the required volume of sufficiently pure gas for superb sensitivity with a TOC analyzer. The gas is available on demand and is present at a lower pressure than the gas from a cylinder, increasing laboratory safety.

A cylinder contains a considerable amount of gas at high pressure; if a leak occurs (e.g., if the valve is compromised), a large quantity of N_2 would be released into the laboratory and would displace the air, leading to the potential of asphyxiation. Since an in-house gas generator typically has a maximum output of 600 to 1,200 mL/min at a pressure of approximately 100 psig, the volume of gas that could escape in the laboratory due to a leak in the system is very small and presents a minimal hazard.

An additional safety concern with the use of cylinder gas involves potential hazards inherent in transporting it from the storage location to the instrument. As an example, if the individual moving the cylinder loses control of it during transport and the valve is damaged, the cylinder can become a guided missile. A typical user, Dr. Michael Lockney, a chemist at Momentive Performance Materials (Sistersville, WV) who uses a TOC analyzer to monitor plant waste water, indicated that they obtained an in-house TOC gas generator to minimize the safety issues and eliminate the concerns involving the handling of gas tanks.

In-house generators include a variety of safety features to minimize the possibility of injury to personnel and facility damage. As an example, if an overpressure or a pressure loss is observed, gas production is immediately terminated and a diagnostic message is generated. If desired, an audible alarm and/or a signal can be sent to an external controller or to the operator. In addition, these systems meet the requirements of a broad range of safety standards, including NFPA and OSHA

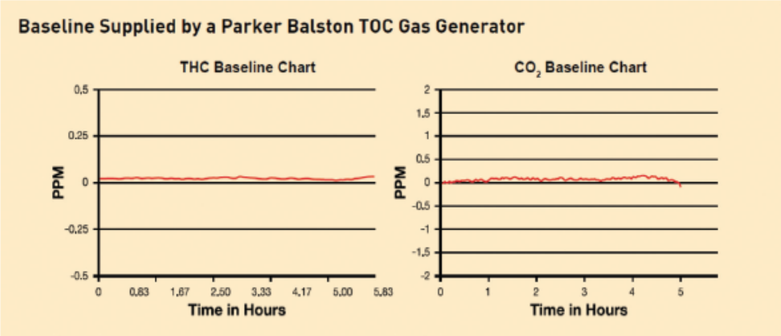


Figure 4. Baselines observed on a TOC analyzer from carrier gas from a Parker Balston generator. Left: total hydrocarbons; right: CO_2

(1910.103), and of regulatory agencies such as the IEC, CSA, UL, cUL and CE.

"The heart of an in-house gas generator for TOC analyses is a pressure swing adsorption (PSA) system."

Convenience

When an in-house gas generator is employed, the TOC-grade gas is readily available on a continuous (24/7) basis or can be generated as required with a short system warm-up. In contrast, when a cylinder is employed, the operator must make certain that the cylinder contains a sufficient amount of gas for the desired operation. In many facilities, replacement cylinders are frequently stored in a remote (outdoor) location for safety reasons, and specially qualified personnel may be required to perform cylinder replacement (replacing a tank is inconvenient in inclement weather). When bottled gas is employed, it is necessary to maintain a supply of spare cylinders and order/return cylinders on a periodic basis.

In contrast, when an in-house generator is employed, very little maintenance is required. Once the system is set up, gas is readily available for an extended period of time with no effort on the part of the analyst. As an example of this point, Dr. Charles Weatherford, the QA supervisor at Metrex Research (Romulus, MI), a division of Sybron Dental Specialties, Inc., reports that their TOC air system has been in use for over eight years with only a minimum of annual maintenance. Similarly, Dr. Lockney indicates that the system at Momentive Performance Materials has been in use for three years with no service issues, and it is not necessary for them to monitor the usage of the generator.

Elimination of contamination

When a cylinder is used to deliver TOC gas, the connection between the source of the gas and the TOC analyzer must be broken when a cylinder is replaced. This can lead to the introduction of contaminants such as water vapor, O_2, CO_2 and other materials that may be present in the laboratory atmosphere into the system. These may have a deleterious effect on the TOC measurement. In contrast, when an in-house generator is employed, a permanent direct connection is made between the generator and the TOC system, thereby practically eliminating the possibility of contamination.

Cost

The overall cost of operation of an in-house generator is considerably lower than the cost of cylinders to provide gas. The only costs for an in-house generator are for electricity and periodic service. The power consumption of the TOC-1250 system is 2 A, so if the generator is used for a 40-hour cycle on a 52-week basis, approximately 500 kWh would be used. At 10c/kWh, the annual operating cost would be approximately $50 and the cost of maintenance and replacement of an in-house generator would be about $500/yr. While the payback period of the generator clearly depends on the amount of gas that is consumed and the local cost of the gas cylinders, the generator can pay for itself in a year in many facilities. When cylinders are used to supply the gas, many other expenses must be considered, including the time cost of ordering the gas and bottle demurrage. These costs are not relevant when an in-house generator is used.

"In-house generators include a variety of safety features to minimize the possibility of injury to personnel and facility damage."

Conclusion

In-house generation of carrier gas for total organic carbon analyses provides the lab with a number of significant benefits compared to the use of cylinders. An in-house generator is safer, as it produces the necessary gas on demand and eliminates the need to handle high-pressure tanks. An in-house generator can provide gas on a 24/7 basis with essentially no maintenance and has an operating cost that is significantly less than the cost of obtaining pressurized cylinders. Since an in-house generator eliminates the requirement for transporting heavy cylinders from the production facility to the point of use, significant environmental benefits are obtained.

Jack Mahan*, national sales manager, Parker Hannifin Corporation, can be reached by email at jmahan@parker.com or by phone at 978-556-2728.*

Peter Froehlich*, Peak Media, can be reached by email at pfpeakmedia@msn.com or by phone at 508-528-6145.*

220vac / 50hz configuration for locations where final plug configuration is unknown	Order Part Number
	FID-1000-220, FID-2500-220, FID-3500-220, GCGS-7890-220, H2PD-150-220, H2PD-300-220, 75-83-220, HPZA-3500-220, HPZA-7000-220, HPZA18000-220, HPZA30000-220, HPN2-1100-220, HPN2-2000-220, UHPN2-1100-220, 76-97-220, 76-98-220, 74-5041-220, UDA-300-220, LCMS-5000-220, LCMS-5001T-220, LCMS-5001NT-220, N2-14A, N2-22A, N2-35A, N2-45A, N2-80A, N2-135A, MGG-400-220, MGG-2500-220, TOC-625-220, TOC-1250-220

* Units will be supplied only with IEC connector as depicted, power cord to be customer supplied

220vac / 50hz plug configuration for Australia	Order Part Number
 	FID-1000AU, FID-2500AU, FID-3500AU, GCGS-7890AU, H2PD-150AU, H2PD-300AU, 75-83AU, HPZA-3500AU, HPZA-7000AU, HPZA-18000AU, HPZA-30000AU, HPN2-1100AU, HPN2-2000AU, UHPN2-1100AU, 76-97AU, 76-98AU, 74-5041AU, UDA-300AU, LCMS-5000AU, LCMS-5001TAU, LCMS-5001NTAU, N2-14AAU, N2-22AAU, N2-35AAU, N2-45AAU, N2-80AAU, N2-135AAU, MGG-400AU, MGG-2500AU,TOC-625AU, TOC-1250AU

* Models 75-45AU, 75-52AU and 75-62AU will include universal fit plug and transformer kit.

220vac / 50hz plug configuration for Europe	Order Part Number
 	FID-1000EU, FID-2500EU, FID-3500EU, GCGS-7890EU, H2PD-150EU, H2PD-300EU, 75-83EU, HPZA-3500EU, HPZA-7000EU, HPZA-18000EU, HPZA-30000EU, HPN2-1100EU, HPN2-2000EU, UHPN2-1100EU, 76-97EU, 76-98EU, 74-5041EU, UDA-300EU, LCMS-5000EU, LCMS-5001TEU, LCMS-5001NTEU, N2-14AEU, N2-22AEU, N2-35AEU, N2-45AEU, N2-80AEU, N2-135AEU, MGG-400EU, MGG-2500EU, TOC-625EU, TOC-1250EU

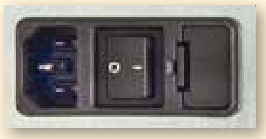
* Models 75-45EU, 75-52EU and 75-62EU will include universal fit plug and transformer kit.

100vac / 60hz plug configuration for Japan	Order Part Number
 	FID-1000JA-100, FID-2500JA-100, FID-3500JA-100, GCGS-7890JA-100, H2PD-150JA-100, H2PD-300JA-100, 75-83JA-100, HPZA-3500JA-100, HPZA-7000JA-100, HPZA-18000JA-100, HPZA-30000JA-100, HPN2-1100JA-100, HPN2-2000JA-100, UHPN2-1100JA-100, 76-97JA-100, 76-98JA-100, 74-5041JA-100, UDA-300JA-100, LCMS-5000JA-100, LCMS-5001TJA-100, LCMS-5001NTJA-100, N2-14AJA-100, N2-22AJA-100, N2-35AJA-100, N2-45AJA-100, N2-80AJA-100, N2-135AJA-100, MGG-400JA-100, MGG-2500JA-100, TOC-625JA-100, TOC-1250JA-100

* Models 75-45JA-100, 75-52JA-100 and 75-62JA-100 will include universal fit plug and transformer kit.

220vac / 50hz plug configuration for United Kingdom (some Asia)	Order Part Number
 	FID-1000UK, FID-2500UK, FID-3500UK, GCGS-7890UK, H2PD-150UK, H2PD-300UK, 75-83UK, HPZA-3500UK, HPZA-7000UK, HPZA-18000UK, HPZA-30000UK, HPN2-1100UK, HPN2-2000UK, UHPN2-1100UK, 76-97UK, 76-98UK, 74-5041UK, UDA-300UK, LCMS-5000UK, LCMS-5001TUK, LCMS-5001NTUK, N2-14AUK, N2-22AUK, N2-35AUK, N2-45AUK, N2-80AUK, N2-135AUK, MGG-400UK, MGG-2500UK, TOC-625UK, TOC-1250UK

* Models 75-45UK, 75-52UK and 75-62UK will include universal fit plug and transformer kit.

220vac / 50hz configuration for locations where final plug configuration is unknown	Order Part Number
	FID-1000-220, FID-2500-220, FID-3500-220, GCGS-7890-220, H2PD-150-220, H2PD-300-220, 75-83-220, HPZA-3500-220, HPZA-7000-220, HPZA18000-220, HPZA30000-220, HPN2-1100-220, HPN2-2000-220, UHPN2-1100-220, 76-97-220, 76-98-220, 74-5041-220, UDA-300-220, LCMS-5000-220, LCMS-5001T-220, LCMS-5001NT-220, N2-14A, N2-22A, N2-35A, N2-45A, N2-80A, N2-135A, MGG-400-220, MGG-2500-220, TOC-625-220, TOC-1250-220

* Units will be supplied only with IEC connector as depicted, power cord to be customer supplied

220vac / 50hz plug configuration for Australia	Order Part Number
 	FID-1000AU, FID-2500AU, FID-3500AU, GCGS-7890AU, H2PD-150AU, H2PD-300AU, 75-83AU, HPZA-3500AU, HPZA-7000AU, HPZA-18000AU, HPZA-30000AU, HPN2-1100AU, HPN2-2000AU, UHPN2-1100AU, 76-97AU, 76-98AU, 74-5041AU, UDA-300AU, LCMS-5000AU, LCMS-5001TAU, LCMS-5001NTAU, N2-14AAU, N2-22AAU, N2-35AAU, N2-45AAU, N2-80AAU, N2-135AAU, MGG-400AU, MGG-2500AU,TOC-625AU, TOC-1250AU

* Models 75-45AU, 75-52AU and 75-62AU will include universal fit plug and transformer kit.

220vac / 50hz plug configuration for Europe	Order Part Number
 	FID-1000EU, FID-2500EU, FID-3500EU, GCGS-7890EU, H2PD-150EU, H2PD-300EU, 75-83EU, HPZA-3500EU, HPZA-7000EU, HPZA-18000EU, HPZA-30000EU, HPN2-1100EU, HPN2-2000EU, UHPN2-1100EU, 76-97EU, 76-98EU, 74-5041EU, UDA-300EU, LCMS-5000EU, LCMS-5001TEU, LCMS-5001NTEU, N2-14AEU, N2-22AEU, N2-35AEU, N2-45AEU, N2-80AEU, N2-135AEU, MGG-400EU, MGG-2500EU, TOC-625EU, TOC-1250EU

* Models 75-45EU, 75-52EU and 75-62EU will include universal fit plug and transformer kit.

100vac / 60hz plug configuration for Japan	Order Part Number
 	FID-1000JA-100, FID-2500JA-100, FID-3500JA-100, GCGS-7890JA-100, H2PD-150JA-100, H2PD-300JA-100, 75-83JA-100, HPZA-3500JA-100, HPZA-7000JA-100, HPZA-18000JA-100, HPZA-30000JA-100, HPN2-1100JA-100, HPN2-2000JA-100, UHPN2-1100JA-100, 76-97JA-100, 76-98JA-100, 74-5041JA-100, UDA-300JA-100, LCMS-5000JA-100, LCMS-5001TJA-100, LCMS-5001NTJA-100, N2-14AJA-100, N2-22AJA-100, N2-35AJA-100, N2-45AJA-100, N2-80AJA-100, N2-135AJA-100, MGG-400JA-100, MGG-2500JA-100, TOC-625JA-100, TOC-1250JA-100

* Models 75-45JA-100, 75-52JA-100 and 75-62JA-100 will include universal fit plug and transformer kit.

220vac / 50hz plug configuration for United Kingdom (some Asia)	Order Part Number
 	FID-1000UK, FID-2500UK, FID-3500UK, GCGS-7890UK, H2PD-150UK, H2PD-300UK, 75-83UK, HPZA-3500UK, HPZA-7000UK, HPZA-18000UK, HPZA-30000UK, HPN2-1100UK, HPN2-2000UK, UHPN2-1100UK, 76-97UK, 76-98UK, 74-5041UK, UDA-300UK, LCMS-5000UK, LCMS-5001TUK, LCMS-5001NTUK, N2-14AUK, N2-22AUK, N2-35AUK, N2-45AUK, N2-80AUK, N2-135AUK, MGG-400UK, MGG-2500UK, TOC-625UK, TOC-1250UK

* Models 75-45UK, 75-52UK and 75-62UK will include universal fit plug and transformer kit.

Offer of Sale

The items described in this document and other documents and descriptions provided by Parker Hannifin Corporation, its subsidiaries and its authorized distributors ("Seller") are hereby offered for sale at prices to be established by Seller. This offer and its acceptance by any customer ("Buyer") shall be governed by all of the following Terms and Conditions. Buyer's order for any item described in its document, when communicated to Seller verbally, or in writing, shall constitute acceptance of this offer. All goods or work described will be referred to as "Products".

1. Terms and Conditions. Seller's willingness to offer Products, or accept an order for Products, to or from Buyer is expressly conditioned on Buyer's assent to these Terms and Conditions. Seller objects to any contrary or additional term or condition of Buyer's order or any other document issued by Buyer.

2. Price Adjustments; Payments. Prices stated on the reverse side or preceding pages of this document are valid for 30 days. After 30 days, Seller may change prices to reflect any increase in its costs resulting from state, federal or local legislation, price increases from its suppliers, or any change in the rate, charge, or classification of any carrier. The prices stated on the reverse or preceding pages of this document do not include any sales, use, or other taxes unless so stated specifically. Unless otherwise specified by Seller, all prices are F.O.B. Seller's facility, and payment is due 30 days from the date of invoice. After 30 days, Buyer shall pay interest on any unpaid invoices at the rate of 1.5% per month or the maximum allowable rate under applicable law.

3. Delivery Dates; Title and Risk; Shipment. All delivery dates are approximate and Seller shall not be responsible for any damages resulting from any delay. Regardless of the manner of shipment, title to any products and risk of loss or damage shall pass to Buyer upon tender to the carrier at Seller's facility (i.e., when it's on the truck, it's yours). Unless otherwise stated, Seller may exercise its judgment in choosing the carrier and means of delivery. No deferment of shipment at Buyers' request beyond the respective dates indicated will be made except on terms that will indemnify, defend and hold Seller harmless against all loss and additional expense. Buyer shall be responsible for any additional shipping charges incurred by Seller due to Buyer's changes in shipping, product specifications or in accordance with Section 13, herein.

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5. **Claims; Commencement of Actions.** Buyer shall promptly inspect all Products upon delivery. No claims for shortages will be allowed unless reported to the Seller within 10 days of delivery. No other claims against Seller will be allowed unless asserted in writing within 60 days after delivery or, in the case of an alleged breach of warranty, within 30 days after the date within the warranty period on which the defect is or should have been discovered by Buyer. Any action based upon breach of this agreement or upon any other claim arising out of this sale (other than an action by Seller for any amount due to Seller from Buyer) must be commenced within thirteen months from the date of tender of delivery by Seller or, for a cause of action based upon an alleged breach of warranty, within 13 months from the date within the warranty period on which the defect is or should have been discovered by Buyer.

6. LIMITATION OF LIABILITY. UPON NOTIFICATION, SELLER WILL, AT ITS OPTION, REPAIR OR REPLACE A DEFECTIVE PRODUCT, OR REFUND THE PURCHASE PRICE. IN NO EVENT SHALL SELLER BE LIABLE TO BUYER FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF, OR AS THE RESULT OF, THE SALE, DELIVERY, NON-DELIVERY, SERVICING, USE OR LOSS OF USE OF THE PRODUCTS OR ANY PART THEREOF, OR FOR ANY CHARGES OR EXPENSES OF ANY NATURE INCURRED WITHOUT SELLER'S WRITTEN CONSENT, EVEN IF SELLER HAS BEEN NEGLIGENT, WHETHER IN CONTRACT, TORT OR OTHER LEGAL THEORY. IN NO EVENT SHALL SELLER'S LIABILITY UNDER ANY CLAIM MADE BY BUYER EXCEED THE PURCHASE PRICE OF THE PRODUCTS.

7. Contingencies. Seller shall not be liable for any default or delay in performance if caused by circumstances beyond the reasonable control of Seller.

8. User Responsibility. The user, through its own analysis and testing, is solely responsible for making the final selection of the system and Product and assuring that all performance, endurance, maintenance, safety and warning requirements of the application are met. The user must analyze all aspects of the application and follow applicable industry standards and Product information. If Seller provides Product or system options, the user is responsible for determining that such data and specifications are suitable and sufficient for all applications and reasonably foreseeable uses of the Products or systems.

9. Loss to Buyer's Property. Any designs, tools, patterns, materials, drawings, confidential information or equipment furnished by Buyer or any other items which become Buyer's property, may be considered obsolete and may be destroyed by Seller after two consecutive years have elapsed without Buyer placing an order for the items which are manufactured using such property. Seller shall not be responsible for any loss or damage to such property while it is in Seller's possession or control.

10. Special Tooling. A tooling charge may be imposed for any special tooling, including without limitation, dies, fixtures, molds and patterns, acquired to manufacture Products. Such special tooling shall be and remain Seller's property notwithstanding payment of any charges by Buyer. In no event will Buyer acquire any interest in apparatus belonging to Seller which is utilized in the manufacture of the Products, even if such apparatus has been specially converted or adapted for such manufacture and notwithstanding any charges paid by Buyer. Unless otherwise agreed, Seller shall have the right to alter, discard or otherwise dispose of any special tooling or other property in its sole discretion at any time.

11. Buyer's Obligation; Rights of Seller. To secure payment of all sums due or otherwise, Seller shall retain a security interest in the goods delivered and this agreement shall be deemed a Security Agreement under the Uniform Commercial Code. Buyer authorizes Seller as its attorney to execute and file on Buyer's behalf all documents Seller deems necessary to perfect its security interest. Seller shall have a security interest in, and lien upon, any property of Buyer in Seller's possession as security for the payment of any amounts owed to Seller by Buyer.

12. Improper use and Indemnity. Buyer shall indemnify, defend, and hold Seller harmless from any claim, liability, damages, lawsuits, and costs (including attorney fees), whether for personal injury, property damage, patent, trademark or copyright infringement or any other claim, brought by or incurred by Buyer, Buyer's employees, or any other person, arising out of: (a) improper selection, improper application or other misuse of Products purchased by Buyer from Seller; (b) any act or omission, negligent or otherwise, of Buyer; (c) Seller's use of patterns, plans, drawings, or specifications furnished by Buyer to manufacture Product; or (d) Buyer's failure to comply with these terms and conditions. Seller shall not indemnify Buyer under any circumstance except as otherwise provided.

13. Cancellations and Changes. Orders shall not be subject to cancellation or change by Buyer for any reason, except with Seller's written consent and upon terms that will indemnify, defend and hold Seller harmless against all direct, incidental and consequential loss or damage. Seller may change product features, specifications, designs and availability with notice to Buyer.

14. Limitation on Assignment. Buyer may not assign its rights or obligations under this agreement without the prior written consent of Seller.

15. Entire Agreement. This agreement contains the entire agreement between the Buyer and Seller and constitutes the final, complete and exclusive expression of the terms of the agreement. All prior or contemporaneous written or oral agreements or negotiations with respect to the subject matter are herein merged.

16. Waiver and Severability. Failure to enforce any provision of this agreement will not waive that provision nor will any such failure prejudice Seller's right to enforce that provision in the future. Invalidation of any provision of this agreement by legislation or other rule of law shall not invalidate any other provision herein. The remaining provisions of this agreement will remain in full force and effect.

17. Termination. This agreement may be terminated by Seller for any reason and at any time by giving Buyer thirty (30) days written notice of termination. In addition, Seller may by written notice immediately terminate this agreement for the following: (a) Buyer commits a breach of any provision of this agreement (b) the appointment of a trustee, receiver or custodian for all or any part of Buyer's property (c) the filing of a petition for relief in bankruptcy of the other Party on its own behalf, or by a third party (d) an assignment for the benefit of creditors, or (e) the dissolution or liquidation of the Buyer.

18. Governing Law. This agreement and the sale and delivery of all Products hereunder shall be deemed to have taken place in and shall be governed and construed in accordance with the laws of the State of Ohio, as applicable to contracts executed and wholly performed therein and without regard to conflicts of laws principles. Buyer irrevocably agrees and consents to the exclusive jurisdiction and venue of the courts of Cuyahoga County, Ohio with respect to any dispute, controversy or claim arising out of or relating to this agreement. Disputes between the parties shall not be settled by arbitration unless, after a dispute has arisen, both parties expressly agree in writing to arbitrate the dispute.

19. Indemnity for Infringement of Intellectual Property Rights. Seller shall have no liability for infringement of any patents, trademarks, copyrights, trade dress, trade secrets or similar rights except as provided in this Section. Seller will defend and indemnify Buyer against allegations of infringement of U.S. patents, U.S. trademarks, copyrights, trade dress and trade secrets ("Intellectual Property Rights"). Seller will defend at its expense and will pay the cost of any settlement or damages awarded in an action brought against Buyer based on an allegation that a Product sold pursuant to this Agreement infringes the Intellectual Property Rights of a third party. Seller's obligation to defend and indemnify Buyer is contingent on Buyer notifying Seller within ten (10) days after Buyer becomes aware of such allegations of infringement, and Seller having sole control over the defense of any allegations or actions including all negotiations for settlement or compromise. If a Product is subject to a claim that it infringes the Intellectual Property Rights of a third party, Seller may, at its sole expense and option, procure for Buyer the right to continue using the Product, replace or modify the Product so as to make it noninfringing, or offer to accept return of the Product and return the purchase price less a reasonable allowance for depreciation. Notwithstanding the foregoing, Seller shall have no liability for claims of infringement based on information provided by Buyer, or directed to Products delivered hereunder for which the designs are specified in whole or part by Buyer, or infringements resulting from the modification, combination or use in a system of any Product sold hereunder. The foregoing provisions of this Section shall constitute Seller's sole and exclusive liability and Buyer's sole and exclusive remedy for infringement of Intellectual Property Rights.

20. Taxes. Unless otherwise indicated, all prices and charges are exclusive of excise, sales, use, property, occupational or like taxes which may be imposed by any taxing authority upon the manufacture, sale or delivery of Products.

21. Equal Opportunity Clause. For the performance of government contracts and where dollar value of the Products exceed $10,000, the equal employment opportunity clauses in Executive Order 11246, VEVRAA, and 41 C.F.R. §§ 60-1.4(a), 60-741.5(a), and 60-250.4, are hereby incorporated.

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Europe

Compressed Air Treatment

domnick hunter Industrial
England NE
+44 (0) 191 402 9000,
www.domnickhunter.com

Hiross Zander
Padova Business Unit
Angelo di Piove Padova, Italy
+39 049 9712 111
www.parker.com/hzd

Hiross Zander
Essen Business Unit
Essen, Germany
T +49 2054 9340, F +49 2054 934164
www.parker.com/hzd

Parker Gas Separations
Etten- Leur, Netherlands
+31 76 508 5300

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Racor
England
+44 (0) 1924 487000,
www.parker.com/rfde

Racor Research & Development
Stuttgart Germany
+49 (0)711 7071 290-0
www.parker.com/racor

Hydraulic Filtration

Hydraulic Filter
Arnhem, Holland
+31 26 3760376
www.parker.com/eurofilt

Urjala Operation
Urjala as Finland
+358 20 753 2500
www.parker.com/fi

Condition Monitoring Center
Norfolk IP 24 1HP England
+44 1842 763299
www.parker.com/cmc

Process Filtration

domnick hunter Process
DH3 2SF England
T +44 (0) 191 410 5121
www.domnickhunter.com

Asia Pacific

Australia
NSW 2154, Australia
+61 2 9634 777
www.parker.com/australia

China
Shanghai 101206 China
+86 21 5031 2525
www.parker.com/china

India
Mahape, Navi Mumbai 400 709 India
T +91 22 5613 7081, 82, 83, 84, 85
www. parker.com/india

Japan
Yokohama-shi, 244-0003 Japan
T +81 45 870 1522
www.parker.com/japan

Korea
Hwaseong-City Gyeonggi-Do, Korea
T +82 31 359 0771
www.parker.com/korea

Singapore
Singapore 619 702
T +65 6887 6300
www.parker.com/singapore

Thailand
Bangkok 10250 Thailand
T +66 2717 8140
www.parker.com/thailand

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Parker Comercio Ltda. Filtration Division
Sao Jose dos Campos
CEP 12225-390 SP Brazil
+55 12 4009 3500
www.parker.com/br

Pan American Division - Miami
Miami, FL
305 470 8800
www.parker.com/panam

Africa

Aeroport Kempton Park,
1620 South Africa
+27 11 9610700
www.parker.com/eu

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Parker Balston

Parker Hannifin Corporation
Filtration and Separation Division
242 Neck Road
Haverhill, MA 01835
T 978 858 0505, F 978 556 7501
1 800 343 4048 (US & Canada)
www.labgasgenerators.com