

# Liquid Vaporizer Systems

Systems and Solutions



DLI Plate Mount System

## Breakthrough Vaporization Solutions for All Liquid-to-Vapor Applications

### Overview

The Brooks family of extremely high-performing direct liquid injection (DLI) vaporizer solutions is designed for customers who require reliable liquid vaporization. Featuring unique atomization and heat exchanger technologies, Brooks direct liquid injection vaporizers deliver pure vapor for every application. Applications include:

- Water vaporization for fuel cell stack humidification and many other water addition applications
- Liquid precursor vaporization for chemical vapor deposition (CVD), metal oxide chemical vapor deposition (MOCVD), and atomic layer deposition (ALD)
- Depositing thin films for enhanced thermal, optical, or hardness characteristics such as diamond-like carbon coating and glass coating
- Vaporizing monomers for vacuum polymer film deposition
- Generating calibration vapor
- Vaporizing liquid hydrocarbons
- Many more.

Brooks' direct liquid injection vaporizer technology overcomes the many limitations of conventional vaporizing technologies. Bubblers, or vapor draw systems, are difficult to start and stop, require very close control of temperature and pressure, and are inefficient at generating well controlled vapor mass flow. Vaporizing valves, hot frit, heat tracing, and other "flash vaporizers" that apply heat to the liquid using a hot metal surface are also inefficient at generating vapor mass and frequently can cause thermal decomposition of the liquid precursor. None of these conventional technologies can eliminate the potential for liquid carry-over and its attendant problems. Figure 1 on page 2 illustrates CVD deposition chamber pressure fluctuations caused by incomplete vaporization and precursor carry-over from a conventional vaporizer.

Furthermore, it is very challenging to determine precisely how much vapor mass is actually being delivered from a conventional vaporizer. In applications that require precise vapor mass addition, users must turn to secondary measurement/control devices such as vapor mass flow controllers, increasing the cost and complexity of the vapor module.

## Product Description

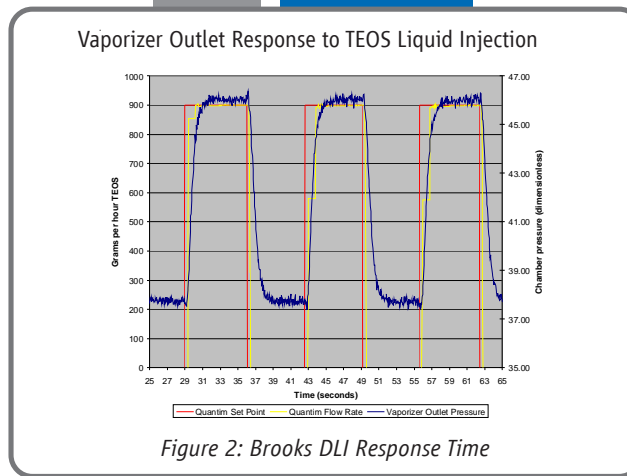
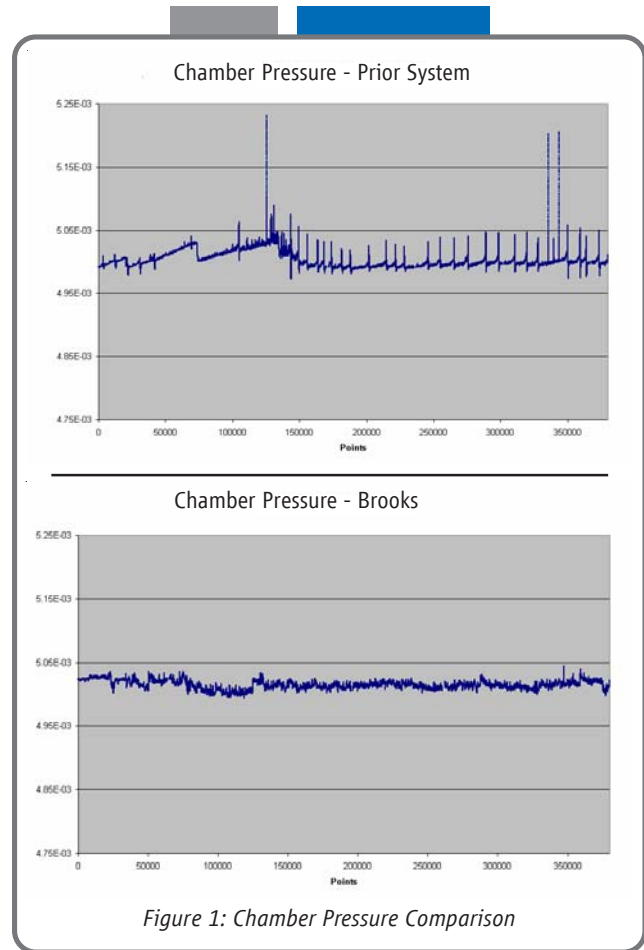
A Brooks direct liquid injection vaporizer employs hot gas, rather than a hot metal surface, to accomplish liquid vaporization. As liquid enters the hot gas chamber, it is atomized by a carrier gas stream. Once the atomized liquid contacts the hot gas, it immediately changes to vapor. The result is chemically pure vapor, free of decomposition byproducts or liquid carry-over. Moreover, a Brooks direct liquid injection vaporizer can accept multiple liquid inlets and will generate perfectly mixed vapors. Brooks offers several heat exchanger designs to accommodate an extraordinarily wide range of liquid properties: extremely low vapor pressures (sub 1 torr), very low flow rates (sub 5 grams per hour), and very high flow rates (more than 15 kg/hr). Unlike bubblers and hot-surface vaporizers, Brooks direct liquid injection vaporizers are extremely efficient at producing vapor from liquid.

The Brooks direct liquid injection vaporizer is close to being a true "vapor-on-demand" system because increasing, decreasing, or stopping the incompressible liquid flow quickly results in the desired change in vapor flow. Figure 2 demonstrates the Brooks direct liquid injection vaporizer's extremely fast response to 900 g/hr tetraethyl orthosilicate (TEOS) step challenges. By comparison, for example, the large bubblers commonly used for MTS (methyltrichlorosilane), BCl<sub>3</sub>, TiCl<sub>4</sub> and similar liquids are difficult to start, run, and stop effectively.

Many Brooks vaporizer solutions prominently feature the Brooks Quantim Coriolis liquid flow controller. Because it uses the Coriolis measurement principle, the Quantim is able to provide ultra-precise liquid mass delivery to the hot gas chamber without regard to chemical composition or flow rate. By definition, the vapor mass that exits the chamber is the same as the liquid mass that entered it, eliminating the need for additional vapor measurement/control devices and greatly simplifying system complexity.

The Brooks direct liquid injection vaporizers are uniquely designed to operate in a wide range of process pressure regimes, from sub-atmospheric to many atmospheres. Convenient, modular construction makes it easy to adapt Brooks direct liquid injection vaporizers to alternate process conditions. Both ultrahigh purity (UHP) and standard service designs are available.

In CVD and ALD applications, Brooks direct liquid injection vaporizer users report excellent layer morphology, significantly increased deposition rates, reduced precursor consumption, and less waste gas than with conventional vaporization technologies. For these applications, the return on investment in a Brooks direct liquid injection vaporizer is exceedingly fast. Figure 3 demonstrates the remarkable improvement in layer to layer reproducibility reported by one plasma assisted CVD (PACVD) customer.



In $\mu\text{m}$	Prior System	Brooks
wafer #1	2.64	2.54
wafer #1	2.86	2.48
wafer #1	2.69	2.54
std. dev.	0.12	0.03

Figure 3: Layer to Layer Reproducibility

## Product Description

Brooks direct liquid injection vaporizers can be delivered as fully integrated systems, including gas and liquid flow control, chamber temperature control, setpoint control, hazardous gas detection, safety interlocks, and more. Figures 4 and 5 show a Brooks direct liquid injection vaporizer that features gas and liquid flow controllers, and setpoint and temperature control in a NEMA-4X enclosure. For Class I, Division 2 requirements, optional positive purge, safety interlock, and hazardous gas detectors are also available.

Figure 6 shows another integrated system design for generating calibration vapor. In this example, the Brooks direct liquid injection vaporizer, gas and liquid flow controllers, and setpoint and temperature controllers are packaged in a 19" rack-mount enclosure.

In many applications, a plate-mounted direct liquid injection vaporizer is entirely adequate. Figure 7 shows a Brooks direct liquid injection vaporizer, gas flow controller, and liquid flow controller mounted on a plate.

Furthermore, Brooks direct liquid injection vaporizer system components can be provided as discrete elements - vaporizer module, temperature controller, gas flow controller, liquid flow controller, setpoint controller, and so on - for customers who elect to do their own system integration.

Contact Brooks today to discuss your liquid-to-vapor application. Coming from the leader in liquid flow control, Brooks direct liquid injection technology is quite simply the best vaporizer solution available today.



Figure 4: DLI NEMA 4X Configuration



Figure 5: NEMA 4X Configuration



Figure 6: DLI 19" Rack Mount Configuration



Figure 7: DLI Plate Mounted Configuration

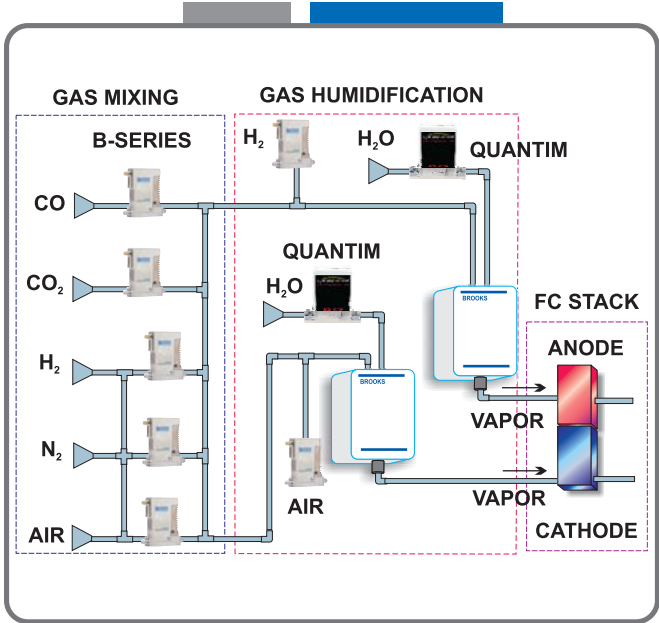
## Features and Benefits

Features	Benefits
Liquid atomization	Generates superfine aerosol mist for instantaneous vaporization
Heated gas for complete vaporization	Efficiently vaporizes even ultralow vapor pressure liquids Extremely compact and simple physical package compared to bubbler/vapor draw systems of comparable vapor capacity Eliminates thermal decomposition Eliminates liquid carry-over mass in = mass out means no clogging or "routine" maintenance
Chemically pure vapor	Virtual "vapor-on-demand" response to changing vapor setpoints In deposition applications, improved deposition rate, minimized precursor consumption, and reduced waste
Accepts multiple liquid inlets	Provides perfectly mixed vapor Capable of vaporizing liquids with different vapor pressures
Multiple vaporizer designs	Accommodates a wide range of liquid properties Modular design permits rapid changeover from application to application Ultra high purity (UHP) and standard service constructions available
Start-up service	Brooks will set up, test and make sure your DLI vaporizer is operating perfectly in your application

# Representative Applications

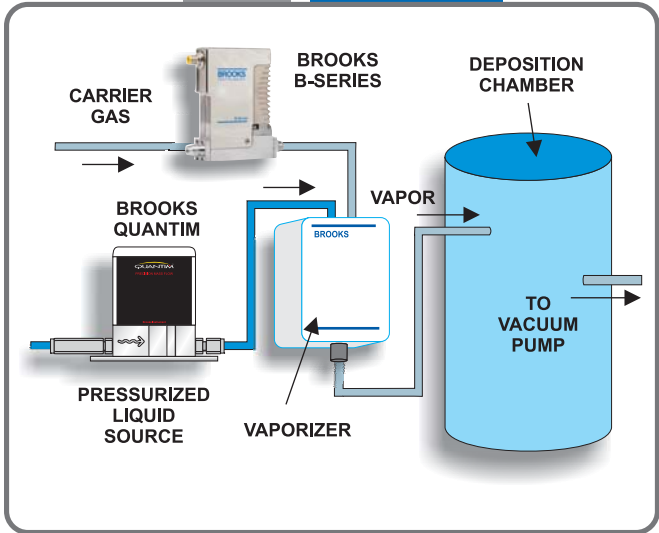
## Fuel Cell Humidification

Maintaining fuel cell membrane hydration is one of the most difficult challenges in fuel cell testing. Excess humidification and water in droplet form can flood the catalytic reaction sites of the electrodes; too little humidification will dry the membrane impeding proton passage or damaging the membrane. Bubblers, steam injection, flash evaporation, and other conventional humidification technologies are challenging to operate for fuel cells tested over a range of gas flow rates, desired humidity levels, operating temperatures, and loads. Mitigating liquid water carryover can be a concern with some technologies especially at high gas flow rates. The Brooks DLI vaporizer system overcomes these issues by precisely controlling incoming gas and water mass flows, atomizing the water, and vaporizing it instantaneously. Increasing or decreasing humidity is simply a matter of adjusting the mass flow ratio of water to gas, with the desired humidity level achieved at the vaporizer outlet in a few seconds. Liquid carryover is prevented by limiting water flow to less than saturation for a given gas flow rate and chamber temperature.



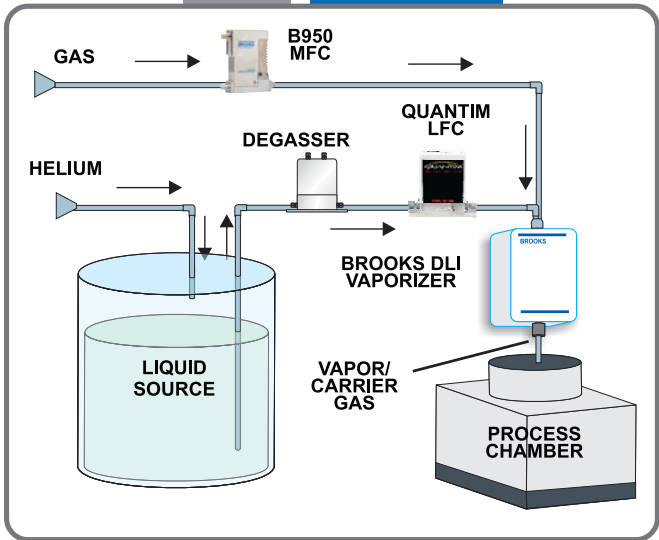
## Industrial Deposition

The versatile Brooks DLI vaporizer is ideal for industrial CVD applications such as depositing silicon carbide, tin oxide, titanium nitride, boron nitride, zinc oxide, diamond-like carbon, and other materials – whether as layers, infused into a matrix, or as bulk material. Unlike a large, complex, and difficult to control bubbler system or vapor draw system that employs a temperature controlled vessel, Brooks' DLI vaporizer responds almost instantaneously to start, stop, and change in vapor demand commands and is physically much smaller and simpler for a given vapor mass flow capacity. In vacuum polymer deposition applications, the Brooks DLI vaporizer's capability to accept more than one liquid feed greatly facilitates vaporizing monomers with dissimilar vapor pressures. A complete Brooks industrial deposition solution frequently comprises a DLI vaporizer, Quantim Coriolis liquid mass flow controller, gas thermal mass flow controller, and temperature and setpoint controllers.



## Semiconductor Thin Films

Brooks vaporizers are ideal for vaporizing semiconductor precursors, including advanced, thermally sensitive precursors containing lanthanum, zirconium, strontium, or hafnium. The diagram illustrates a common semiconductor application - depositing silicon oxide films from TEOS. Unlike flash vaporizers, bubblers, and vapor draw systems, fast and repeatable silicon oxide films are now possible at flow rates in excess of 15 grams per minute. Figure 2 shows a Brooks DLI vaporizer outlet vapor concentration response time to 15 grams per minute TEOS step changes. TEOS vapor reaches full concentration in less than 3 seconds. This extremely fast response time, together with Brooks Quantim's 0.2% of flow rate accuracy and wafer to wafer repeatability of better than 0.2 grams per hour, can produce high quality repeatable films at very high deposition rates while eliminating the time wasting vapor divert steps for liquid and vapor flow stabilization.



## Product Specifications

The Brooks direct liquid injection vaporizer family of products is highly customizable. The specifications given below are intended to provide guidelines about the scope of product family.

### Direct Liquid Injection Vaporizer

- Allowable process pressure: vacuum to many atmospheres
- Vapor capacity: less than 5 grams per hour to greater than 15 kg per hour. (In calibration vapor applications, the target analyte concentrations may be achieved proportioning the liquid and carrier gas flows.)
- Accepts multiple liquid feeds
- Sample wetted materials: 316L stainless steel with elastomer seals; all welded 316L; or electropolished 316L with nickel seals
- Vaporizer chamber heating: electric band heater
- Heater power: less than 100W to greater than 5000W, application dependent; 100, 115, or 230 VAC
- Temperature sensors: 2 K-type thermocouples, 1 for chamber temperature and 1 for over-temperature alarm
- Process connections: 1/8" to 1" compression, face-seal, or NPT typical
- Leak integrity:  $1 \times 10^{-9}$  cc/sec helium
- Dimensions: vary by application. A 400W DLI vaporizer is approximately (HWD) 7.5" x 5" x 5" (200mm x 125mm x 125mm)

### Liquid Flow Controller

Brooks' Quantim Coriolis liquid flow controller is recommended in most applications. Unlike conventional thermal liquid flow controllers, the Quantim is insensitive to liquid properties. Quantim also measures liquid density which can provide important diagnostic confirmation about the liquid being controlled.



### Gas Flow Controller

A Brooks thermal mass flow controller is recommended in most applications. Brooks offers a variety of digital, analog, elastomer sealed, and all-metal UHP designs depending on the application requirements.



## How to Order

Every Brooks direct liquid injection vaporizer system is customized to your specific requirements. Contact any of the Brooks offices listed or find your local Brooks expert by visiting [BrooksInstrument.com/RepLocate](http://BrooksInstrument.com/RepLocate) and they will provide you with a comprehensive proposal.

## Brooks Service and Support

Brooks is committed to assuring all of our customers receive the ideal flow solution for their application, along with outstanding service and support to back it up. We operate first class repair facilities located around the world to provide rapid response and support. Each location utilizes primary standard calibration equipment to ensure accuracy and reliability for repairs and recalibration and is certified by our local weights and measures authorities and traceable to the relevant international standards.

Visit [www.BrooksInstrument.com](http://www.BrooksInstrument.com) to locate the service location nearest to you.

### START-UP SERVICE AND IN-SITU CALIBRATION

Brooks Instrument can provide start-up service prior to operation when required. For some process applications, where ISO-9001 quality certification is important, it is mandatory to verify and/or (re)calibrate the products periodically. In many cases this service can be provided under in-situ conditions, and the results will be traceable to the relevant international quality standards.

### CUSTOMER SEMINARS AND TRAINING

Brooks Instrument can provide customer seminars and dedicated training to engineers, end users and maintenance persons.

Please contact your nearest sales representative for more details.

### HELP DESK

In case you need technical assistance:

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Due to Brooks Instrument's commitment to continuous improvement of our products, all specifications are subject to change without notice.

#### TRADEMARKS

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