



VAPORIZERS AND GAS FILTERS

DEVELOP THE NEXT
BREAKTHROUGH



MSP

TURBO-VAPORIZERS™

PRECISION, CONTROL, STABILITY, UNIFORMITY

Vapor Solutions by MSP

MSP, a division of TSI, offers a complete line of vaporization products for liquid source vaporization in gas-phase processing like Chemical Vapor Deposition (CVD) and Atomic Layer Deposition (ALD) used in semiconductor device fabrication and industrial coating applications. MSP's line of Turbo-Vaporizers use a droplet vaporization, direct liquid injection (DLI) technique designed to meet modern demanding vaporization needs.

The Turbo-Vaporizer Difference

MSP's exclusive technology offers a broad range of advantages over older, more conventional techniques. The Turbo-Vaporizer applies advanced technology from aerosol science and thermo-dynamics to create a more refined solution to vaporization. In thin film applications, the stable and uniform vapor leads to a higher quality thin film and higher wafer yields. The precision and control of the vaporizer makes it possible to vaporize difficult precursors, which were not usable before, opening up new areas for process development. The unique design provides longer, stable operation resulting in less down time and more money saved for users.

This market-proven technology provides faster response time, precision flow control, and options for high temperature operation.

Other benefits include:

- + Extremely stable concentration output
- + Active heat exchanger for complete vaporization
- + Low temperature vaporization/reduced risk of thermal decomposition
- + Longer Mean Time Between Repair (MTBR)
- + Ability to vaporize difficult precursors
- + Direct liquid injection (DLI) - liquid on demand
- + Higher vapor concentration potential



Applications

The complete line of Turbo-Vaporizers are used in a variety of applications including most types of CVD and ALD processes and some types of etch/ashing processes. For the complete model line, please refer to the table on page 8.

The vaporizers are ideal for applications that require a high quality, stable vapor, some of which include:

- | | | |
|----------------------------------|-----------------------------|----------------------|
| + Semiconductor Microelectronics | + Nanoparticle Synthesis | + Solar Photovoltaic |
| + LEDs Optoelectronics | + Energy Production/Storage | + Medical Device |
| + Protective Coatings | + Powder/Fiber Processing | + Bio Assays |

BETTER VAPORIZATION MORE PROCESS OPTIONS

Industry Leading Technology

State-of-the-art vaporization from MSP stands apart from other techniques. These older technologies, including valve/injection, bubbler, and flash vaporization, are commonly used today, however they provide moderate or poor performance. See below how MSP's vaporization technique stands up to the other vaporization techniques.

	MSP Turbo-Vaporizer	Valve/ Injection	Bubbler	Flash Vaporization
Stability	H	M	L	M
Precision Flow Control	H	H	L	M
Complete Vaporization	H	L	H	L
No Thermal Decomposition	H	L	M	L
Low Liquid Flow Rates	H	H	M	M
High Vapor Concentrations	H	L	L	L
Longer MTBR	H	L	M	L
Carrier Gas	M	H	M	M
Fast Response Time	H	M	L	M

H = Superior; M = Moderate; L = Poor

Full Range of Precursors

A wide array of liquids can be vaporized with the Turbo-Vaporizer, including new precursors for high dielectric (K), low dielectric, and gap-fill processes. The flexibility and precision of the vaporizer enables the vaporization of difficult precursors which may have a tight window between thermal decomposition and vaporization or have low vapor pressures. A partial list of liquid precursors which have been used in the Turbo-Vaporizer is listed below:

- | | | | | |
|----------------------|---------------------|----------------------|---------------------|---------------------------------|
| + TEOS | + TMA | + GeCl ₄ | + HCD | + Acetic Acid |
| + TEMA _{Hf} | + TMB | + TIPCL _a | + HDFDA | + H ₂ O ₂ |
| + TEMA _{Zr} | + TMOS | + TCA | + HDSO | + Water |
| + THF | + TMCTS | + TCS | + HMDS | + Alcohol |
| + TDEAT | + TMOGe | + DEZ | + TaEO _t | + Benzene |
| + TDMAT | + MTS | + DMS | + GafMD | + Octane |
| + TTIP | + TDMAS | + DMZ | + OMCTS | + Cyclo-Hexane |
| + TPT | + TPMS | + DPMS | + PMCH | + Toluene |
| + TEB | + SiCl ₄ | + BDEAS | + PFOSF | + ACL |
| + TEPO | + TiCl ₄ | + BTBAS | + SAM ₂₄ | |



THE DIFFERENCE IS IN THE DESIGN

Precision flow control directly upstream of the vaporization zone results in extremely fast response times. Annular gas entry creates axially homogenous vapor concentrations. Pair these features with active heating downstream of the liquid breakup zone and the result is the most stable and uniform vapor delivery system available. Carrier gas type, carrier gas flow rate, liquid flow rate, and temperature can all be easily adjusted providing more process flexibility.

Operating Principle

- + Carrier gas at a high pressure passes through a small orifice to produce a high velocity gas jet
- + Liquid is introduced into this high velocity gas jet to form extremely small droplets
- + Generally, the higher the gas velocity, the smaller the droplet diameter
- + Carrier gas to liquid mass flow rates, and orifice sizes can be optimized to ensure 100% vaporization

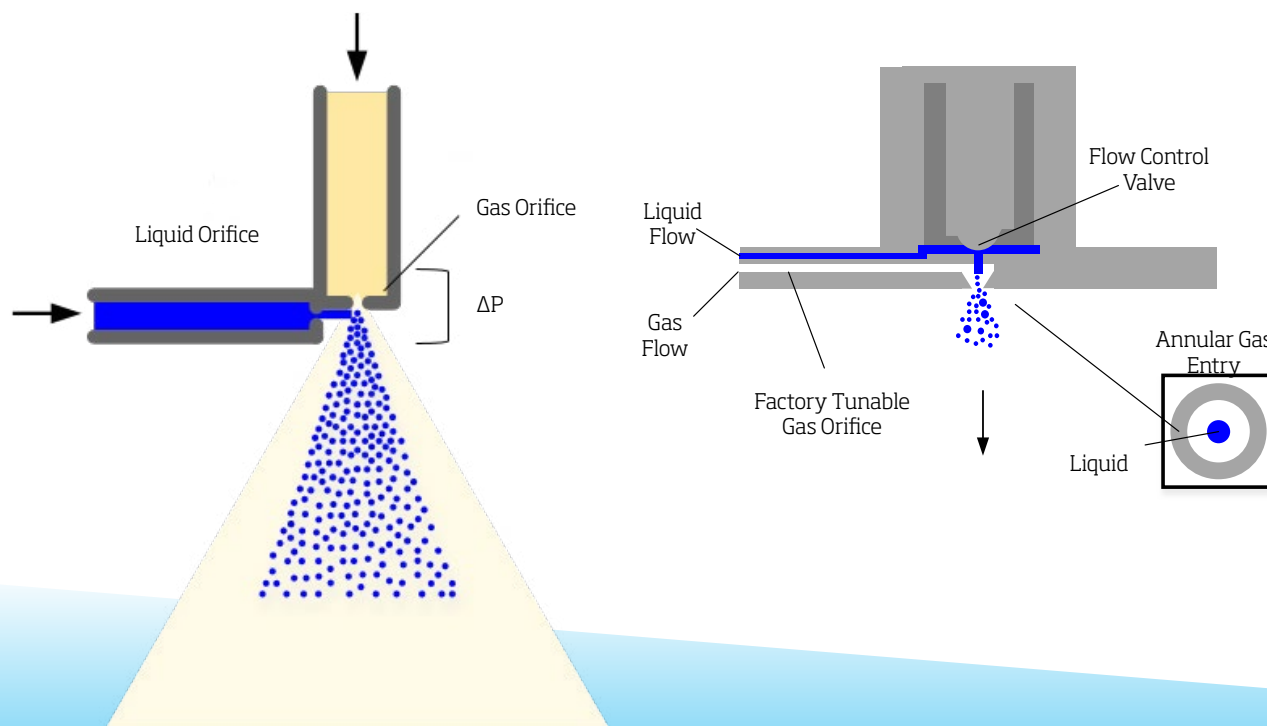
Ultra-fast, Low Heat

By breaking the liquid flow into ultra-fine droplets, the surface area of the liquid is increased $>10^4$, creating almost instantaneous vaporization at the lowest possible heat load.

Performance Enhanced Turbo-Vaporizer™

The Performance Enhanced (PE) Turbo-Vaporizers are designed to handle demanding applications in ALD and CVD. These vaporizers include on-board precision liquid flow control, and are designed to generate extremely small droplets and to minimize dead volume. These features result in superior concentration stability, the ability to eliminate thermal decomposition, and extremely fast response times. Benefits include:

- + Precision liquid control /vapor concentration
- + Fast response time/minimal dead volume
- + Smaller droplet diameters
- + No contamination particles generated due to thermal decomposition elimination
- + Uniform axial droplet/vapor concentration
- + Liquid bubble elimination /suppression
- + Factory adjustable gas orifice

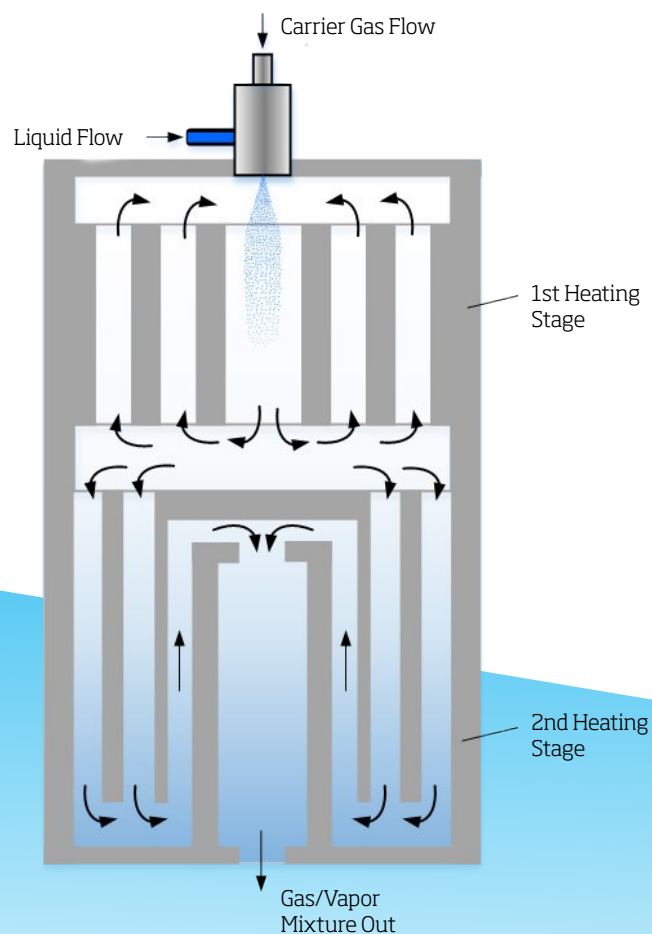


Heat Exchanger Design

- + 2-stage heating process ensures complete droplet vaporization
- + The high velocity atomizing gas jet establishes a recirculating gas flow in the first stage to heat the gas uniformly to the vaporizer temperature
- + Vaporization then occurs by mixing the droplet aerosol with the recirculating hot gas flow
- + Low maintenance: clean carrier gas sheathes the liquid droplets preventing deposition inside the vaporizer which can lead to clogging.

Excellent for Thermally Sensitive Liquids

- + Heat transfer occurs indirectly through the gas to the suspended droplets
- + Carrier gas flow surrounds droplets, largely eliminating direct liquid-to-hot metal contact
- + Droplet temperature remains low due to evaporative cooling
- + Thermal decomposition is largely eliminated or greatly reduced



MEETS YOUR APPLICATION NEEDS

ONE SIZE DOESN'T FIT ALL...

Model	Description	Flow Rate	Features
Model 2840PE	Extremely stable output, perfect for ALD	Low Flow	+ Compact design + Excellent for low flow applications + Ultra-fast response time
Model 2820	Classic system, great for easy to vaporize precursors	Medium Flow	+ Wide internal orifices for minimized clogging + Compact design + Great for high vapor pressure precursors
Model 2820D	Dual liquid inlet	Medium Flow	+ Wide internal orifices for minimized clogging + Compact design + Great for R&D applications
Model 2800PE	Ultra-fast vaporization, good for thermolabile liquids	Medium Flow	+ Fast vaporization + Excellent for thermally sensitive liquids + Dual pass heat exchanger
Model 2800	High temperature vaporization	Medium Flow	+ <300°C operating temperature + Ultra-fast vaporization + Excellent for thermally sensitive liquids
Model 2801PE	High flow, good for expansive vapors	High Flow	+ Long heat exchanger residence time + Dual vaporization mode + Wide internal pathways allow room for expansion
Model 2841PE	High flow, perfect for water vapor	High Flow	+ Dual heaters + 500W heater power + Generates up to 5000 sccm of water vapor
Model 2821	Stable vaporization at very high flow	Very High Flow	+ 3600W heater + Up to 6000g/hr (TEOS equivalent) + Three controlled heated zones
Model 2860PE	Drop-in replacement for direct injection valve	Medium Flow	+ Compact design + Air cool option + Extremely stable output

* Since absolute flow ranges are dependent on liquid and carrier gas types, flow ranges are meant to be comparative across models



SOLUTIONS FOR ADVANCED PROCESSING

Model	Flow Rate	Description	ALD	CVD	Etch/ Water Vapor	R&D	Industrial	Thermo- labile Liquids	High Temp	Liquid Injection Valve Replacement
2840PE	Very Low	Extremely Stable Output	Best	Good	Good	Good	Good	Good	Good	Good
2820	Medium	Easy to Use Precursors	Good	Good	Good	Good	Best	Good	Good	Good
2820D	Medium	Dual Liquid Inlet	Good	Good	Good	Best	Good	Good	Good	Good
2800PE	Medium	Thermolabile Liquids	Best	Best	Good	Good	Good	Best	Good	Good
2800	Medium	High Temperature	Good	Good	Good	Good	Good	Good	Best	Good
2841PE	High	High Heat	Good	Good	Best	Good	Good	Good	Good	Good
2801PE	High	Expansive Vapors	Good	Best	Good	Good	Good	Good	Good	Good
2821	Very High	High Output	Good	Good	Good	Good	Best	Good	Good	Good
2860PE	Medium	Injection Valve Replacement	Best	Good	Good	Good	Good	Good	Good	Best

■ Best
 ■ Better
 ■ Good

Specifications	2840PE	2820	2820D	2800PE	2800	2801PE	2841PE	2821	2860PE
Perform Enhanced (PE) Design	Y	N	N	Y	N	Y	Y	N	Y
Max. Liquid Flow* DI Water (g/hr)	60	90	90	90	90	120	300	600	60
Max. Flow Flow* TEOS equivalent (g/hr)	720	900	900	900	900	1200	3000	6000	720
Gas Flow Range* N ₂ (SLPM)	0.25-15	0.5-20	0.5-20	0.25-15	0.5-15	0.25-15	0.25-15	1-100	0.25-15
Temperature Range* (°C)	40-200				40-300	40-200			
Typical Power (W)	300					300	500	3600	300
Dimensions HxWxD (cm)	29x8x11	22x18x14	22x14x18	29x17x12		31x12x17	30x12x12	42x14x18	24x8x9
Dimensions HxWxD (in)	11.4x3.3x4.3	8.8x7.2x5.5	8.6x5.5x7.2	11.6x6.8x4.8		12.2x4.7x6.8	11.7x4.7x4.8	16.4x5.5x7.2	9.3x3.2x3.5
Line Voltage, Frequency	120VAC, 60Hz							220VAC, 60Hz	120VAC, 60Hz

* Liquid and gas flow ranges are effected by liquid and gas type; assuming medium vacuum or lower downstream of the vaporizer

INNOVATION IN FILTER DESIGN

Extremely Low Pressure Drop

MSP's chemically and thermally resistant vapor/gas filters are specifically designed for low pressure and high temperature applications, providing reliable filtration even for chemically aggressive vapors/gases. The filters are designed to have extremely low pressure drops, making it easier to work in an ultra-low pressure environment. Pump down is faster, and lower pressures are possible.

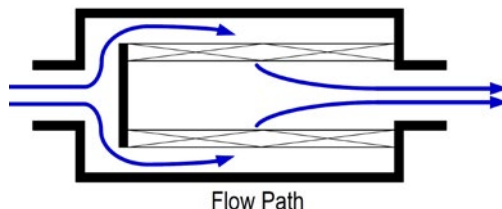
Nano-Filtration Media

The Nano-Filtration Media used in the VPG-A6 is comprised of sintered stainless steel fibers of a homogenous construction with efficiency and pressure drop capabilities not previously attainable by a conventional sintered metal filter media construction.

Cross Flow Filter Design

The cross flow filter design provides high efficiency, low pressure drop filtration with an easy to install form factor.

- + The flow is diverted to pass through the filter media perpendicular to the gas entry
- + As face velocity decreases, pressure drop across the filter decreases and efficiency increases
- + The cross flow design reduces the face velocity in a tube type filter, which leads to decreased pressure drop and increased filtration efficiency



VAPOR PROCESS GAS (VPG™) FILTERS – 316SS



Model	VPG-A3	VPG-A6	VPG-C1
Description	Ultra-low pressure drop, high filtration efficiency	Ultra low pressure drop, ultra high efficiency	Large surface area, long life
Flow Range (SLM)	0-100	0-30	0-100
2.5nm Filter Efficiency @1 SLPM (%)	99.9999999 (nine 9s)	99.999999999 (twelve 9s)	99.999999999 (twelve 9s)
10nm Filter Efficiency @1 SLPM (%)	99.9999 (six 9s)	99.9999999 (ten 9s)	99.999999999 (nine 9s)
50nm Filter Efficiency @1 SLPM (%)	99.99 (four 9s)	99.99997 (five 9s)	99.9999 (six 9s)
Pressure drop	<0.04 kPa@ 1 SLPM; kPa = 0.0439*Q(SLPM)-0.0516	<0.04 kPa@1 SLPM; kPa = 0.0477Q(SLPM)-0.066	
Filter Media	Sintered 316SS powder	Sintered 316SS fiber	Sintered 316SS powder
Fittings	1/2" VCR		
Wetted Materials	316 Stainless Steel		
Temperature Range (°C)	<300		
Length (")	5	5	8
Weight (lb)	1	1	3

CONTROL SOLUTIONS

Flexible Solutions

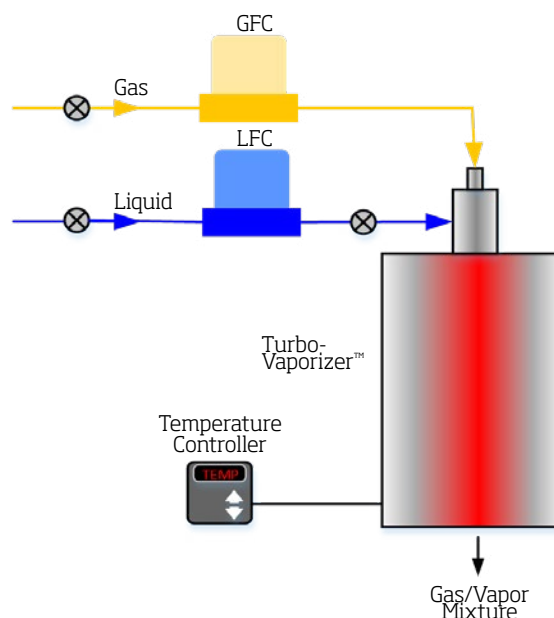
Turbo-Vaporizer can be used with many commercially available control solutions, allowing you to standardize flow controllers, temperature controllers, and voltage controllers across your system.

2910 Multi-function Controller

This versatile precision controller can be used to control the on-board liquid controller in PE vaporizers, when paired with almost any commercially available liquid flow meter (LFM). It can be used to maintain a steady liquid flow, or to generate repeatable short duration vapor pulses for ALD applications.

2940 Liquid Flow Controller

This thermal LFC can be used to control the on-board Piezo valve in our PE Vaporizers. The 2940 features an all digital control system resulting in response times of <200ms making the 2940 a great choice for ALD applications. The 2940 supports zoned PID settings, and has a self-learning function to optimize control.



Model	2940 Liquid Flow Controller		
Model Number	FC1 2940-01-1004	FC2 2940-01-1001	FC3 2940-01-1005
Full Scale DI Water (g/min)	0.08	1.0	5.0
Full Scale TEOS Equiv (g/min)	0.58	6.4	32
Overpressure Resistance (bar)	5	2	1
Max Pressure Drop (mbar)	5	2	1
Capillary Inner Diameter (mm)	0.48	1.0	1.8
Port Connectors	1/8" Male VCR Fitting		
Operating Temp (°C)	0-50		
Operating Humidity	20-80 non-condensing		
Dimensions (")	5x6x1		
Weight (lb)	1.0		

2910 Multi-Function Controller	
Model Number	2940-01-5008
Power @ 24V (W)	48
Cycle Time (ms)	100
Input Signal (V)	0-5
Input Impedance (kΩ)	10
Output Signal @ 0-24V (mA)	<100
Operating Temperature	10-50
Operating Humidity (%)	20-80 non-condensing
Dimensions (")	8x6x1
Weight (lb)	1.0

VAPORIZATION EXPERTS

Custom Solutions

Processes which require vapor created from a liquid cover an extremely wide spectrum of process conditions. Several important process parameters that affect vaporization include:

- + Liquid type and flow rate
- + Carrier gas type and flow rate
- + Process pressure and temperature
- + Ambient pressure and temperature
- + Distance between vaporizer and process zone

Designed for Your Application

MSP offers the widest range of standard vaporizer solutions commercially available. However, for many applications - particularly processes that will be rolled out to a large number of systems; a vaporizer solution specifically designed for your operating parameters may result in the highest quality, most stable and reliable vapor delivery solution. MSP routinely partners with industry leaders to co-develop and supply unique vaporization solutions for their leading edge technology process equipment.

The MSP Difference

MSP's foundation was born out of academia, and the company is dedicated to partnering with leading technology research groups across the globe to bring cutting edge design to commercial applications.

Vaporization Experts

For over 30 years MSP has embraced and researched the science of vaporization becoming the foremost experts in this specialized field.

Commitment to Innovation

Every year our MSP vaporization experts continue to innovate and drive vaporization technology to new heights to meet the demands of progressively challenging process requirements. With 40+ active designs patents, MSP continues to lead the way in vapor delivery solutions.



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5910 Rice Creek Parkway, Suite 300
Shoreview, Minnesota
55126, U.S.A.
Tel: 651.287.8100