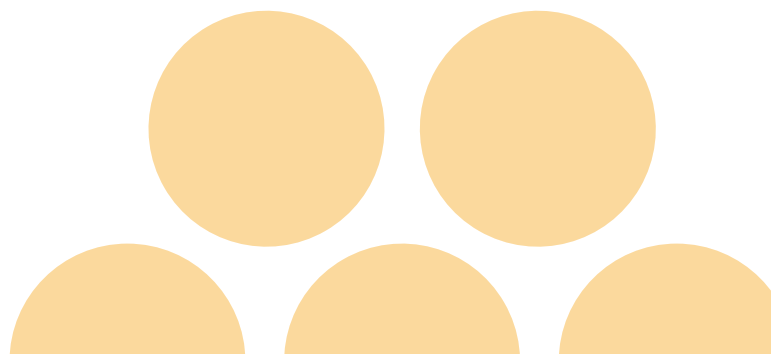




Twice the Output, Half the Size

MSP Turbo II™ Vaporizer
Next Generation of Vapor Delivery Solutions



Better Vaporization, More Process Options

MSP Turbo II™ (T2) Vaporizer – Next Generation

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 Turbo II™ Vaporizers use a droplet vaporization, direct liquid injection (DLI) technique designed to meet modern demanding vaporization needs.

The Turbo II™ Vaporizer Difference

MSP's patented technology offers a broad range of advantages over older, more conventional techniques. The T2 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 highly reliable, stable operation resulting in less downtime and more money saved for users.



Applications

The complete line of MSP Turbo II™ Vaporizers are used in a variety of applications including most types of CVD and ALD processes and some types of etch/ashing processes. The vaporizers are ideal for applications that require a high quality, stable vapor, some of which include:

- Semiconductor Microelectronics
- Functional Coatings
- Powder/Fiber Processing
- Nanoparticle Synthesis
- Energy Production/Storage
- Medical Device Manufacturing

MSP Turbo II™ Vaporizer - Next Generation

- 2x vapor output, 1/2 the size*
- High-flow and low-flow models
- With and without on-board liquid control valve
- Modular solution
- Small internal volume -> shorter time constant (fast response to concentration step changes)
- Tight temperature control – excellent for thermally sensitive liquids
- Direct liquid injection
- No need to pre-heat the liquid or to use expensive Helium as carrier gas

*compared to previous MSP Vaporizers



Lower Cost of Ownership

Low Maintenance – Component not Consumable

MSP Vaporizers are designed to last the lifetime of the tool or system they are installed in. They are a component versus a consumable - unlike some other vaporization solutions which require periodic replacement (from 6 months to 3 years). This long lifetime can result in substantial cost savings over the lifetime of the tool. MSP Vaporizers also frequently require much less routine maintenance than competitive solutions. Our applications team works with you to ensure the vaporizer is sized correctly for the process, and will provide the performance you need.

Higher Throughput & Less Liquid Waste

MSP Vaporizers can deliver higher concentrations versus conventional vapor delivery solutions. For most vapor-phase processes, higher vapor concentrations translate to higher deposition rates or faster etch rates; leading to more throughput. Additionally, the MSP Turbo II™ Vapor Delivery System (VDS) features a high-speed liquid flow controller which provides extremely fast stabilization rates/response times. That combined with the short time constant (time to respond to a step change in concentration) of the vaporizers leads to less time waiting for vapor concentration stability, and more time processing wafers.

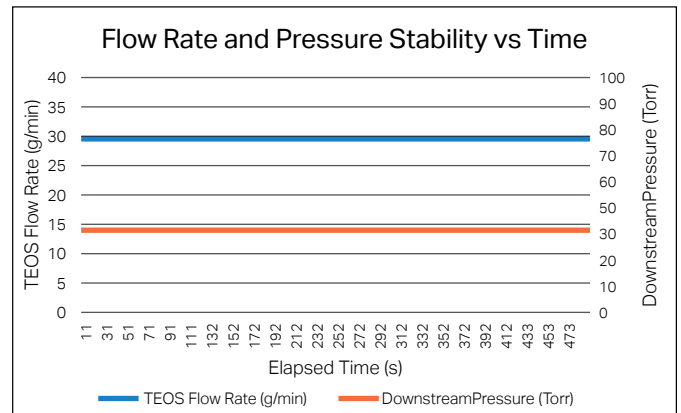
Works Well for Difficult (and Easy) to Vaporize Liquids

A wide array of liquids can be vaporized with the MSP Turbo II™ VDS, including new precursors for high k dielectrics, low k dielectrics, barriers, interconnects, and gap-fill deposition processes. The flexibility and precision of the vaporizer enables vaporization of difficult precursors, like low vapor pressure liquids, which may have a tight window between thermal decomposition and vaporization at concentrations necessary for processing. A partial list of liquid precursors which have been used in the MSP Vaporizers is below:

- Acetic Acid
- Alcohol
- BDEAS / SAM24
- Benzene
- BTBAS
- Cyclo-Hexane
- DEZ
- DIPAS
- DMAT
- DMCS
- DMDS
- DMMP
- DMZ
- GafMD
- GeCl₄
- H₂O₂
- HCDS
- HDSO
- HMDS
- LaCp₃
- MTS
- Octane
- OMCTS
- PMCH
- SiCl₄
- SnCl₄
- TaEOt
- TCA
- TCS
- TDEAT
- TDMAS
- TDMASb
- TDMAT
- TDMATe
- TEB
- TEOS
- TEMAHf/CpHf
- TEMAZr/CpZr
- TEPO
- THF
- TiCl₄
- TIPCLa
- TMA
- TMB
- TMCTS
- TMOGe
- TMOS
- Toluene
- TTIP/TPT
- Water

Highly Stable Concentration Overtime

Stable vapor concentration output is critical for many gas-phase processes and is also a key criteria for long-term reliable field performance. The MSP Turbo II™ Vaporizer delivers extremely stable concentration over-time, making it suitable even for highly sensitive processes like PECVD.



TEOS flow rate and pressure stability downstream of a Model 2855PE Turbo II™ Vaporizer.

Droplet Size Matters

MSP Turbo II™ (T2) Vaporizer – Next Generation

Two Major Unique Elements

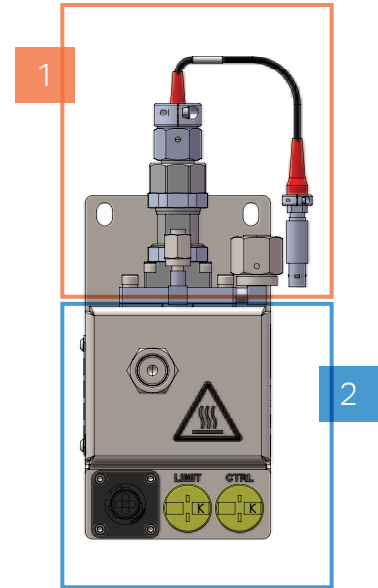
The MSP Turbo II™ Vaporizer has two major components that enable it to vaporize high efficiently with excellent reliability:

- 1 Atomizer
- 2 Heat exchanger

Nano Droplets -> More Efficient Vaporization

The MSP T2 Vaporizer uses a patent-protected technique to generate extremely small droplets. The atomizer creates a spray of micro-sized droplets to drastically increase the heat transfer into the liquid, resulting in more effective vaporization and a more efficient use of heat.

- Increases the amount of liquid that can be vaporized
- Minimizes heat applied to the liquid
- Minimizes chance of particulate generation



Breaking the liquid into micro-sized droplets increases the surface area of the liquid by $>10^5$, which is directly proportional to convective heat rate.

Convective Heat Rate

$$\frac{Q}{\Delta t} = hA (\Delta T)$$

▲
Directly proportional to Surface Area

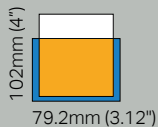
$Q/\Delta t$ = Amount of heat transferred per unit time

h = Heat transfer co-efficient

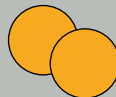
A = Cross-sectional surface area

ΔT = Temperature difference between fluid temperature and surface temperature

Small Ampule



1 mm Droplets



0.5 μm Droplets



Liquid Volume	# Droplets	Total Surface Area cm ²
0.5 liter	N/A	3.02×10^2

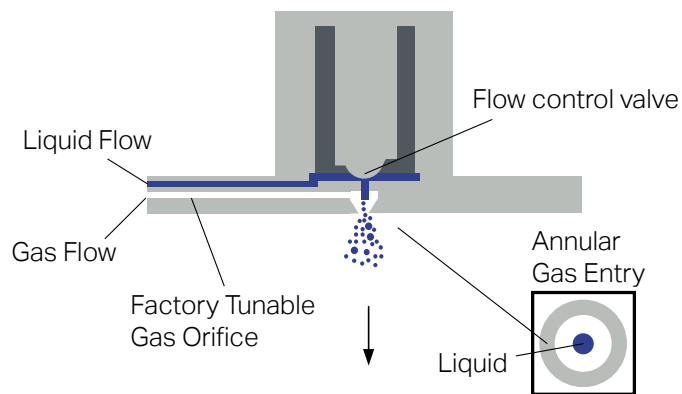
Liquid Volume	# Droplets	Total Surface Area cm ²
0.5 liter	9.54×10^5	3.01×10^4

Liquid Volume	# Droplets	Total Surface Area cm ²
0.5 liter	7.66×10^{15}	6.01×10^7



Built-in Atomizer

The atomizer in the T2 Vaporizer creates the micro-droplet spray. Carrier gas is used to create a high velocity gas jet which is used to shear the liquid into droplets. Precision flow control directly upstream of the vaporization zone results in extremely fast response times. Annular gas entry creates an axially homogeneous vapor concentration, and ensures the liquid droplets are surrounded by clean sheath gas to prevent vaporizer clogging.



Feature	Result	Benefit
Patented atomizer design	Micro-sized droplets	Faster evaporation -> Higher vapor output
On-board liquid flow control	Flow control at the point of vaporization – minimized dead volume	Faster response times
Factory tunable gas orifice	Droplet size can be optimized for a variety of applications	Maximized vapor output
Annular gas entry	Uniform axial droplet spray	More efficient evaporation
Carrier gas	Carrier gas surround liquid droplets	Reduce clogging risk, reduced risk of thermal decomposition and condensation, faster delivery to chamber
Liquid on-demand	Liquid is not heated prior to use	Lower risk of thermal decomposition or liquid degradation



Heat Exchanger

2x Capacity: 1/2 Size

Heat Exchanger

The heat exchanger on the MSP Turbo II™ Vaporizer was the result of focused research on optimizing heat transfer efficiency to micro-droplets, using MSP's foundational expertise in aerosol science, fluid mechanics and vaporization specifically for the semiconductor industry. For almost two years extensive droplet atomization and evaporation models were studied; a variety of designs were evaluated, developed and extensively tested.

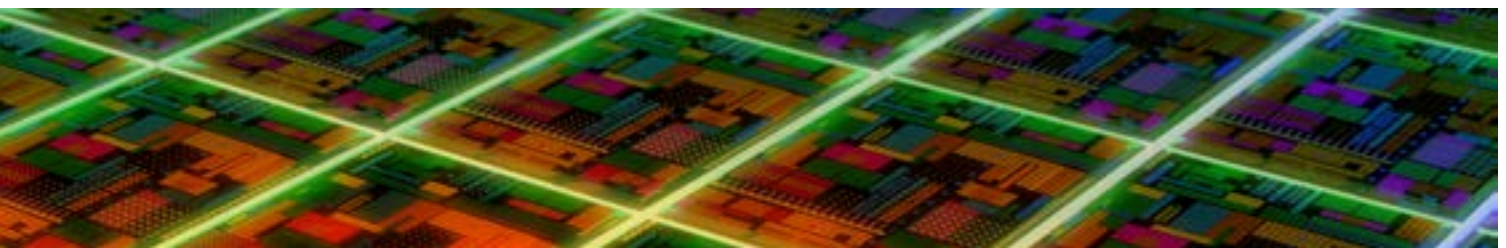
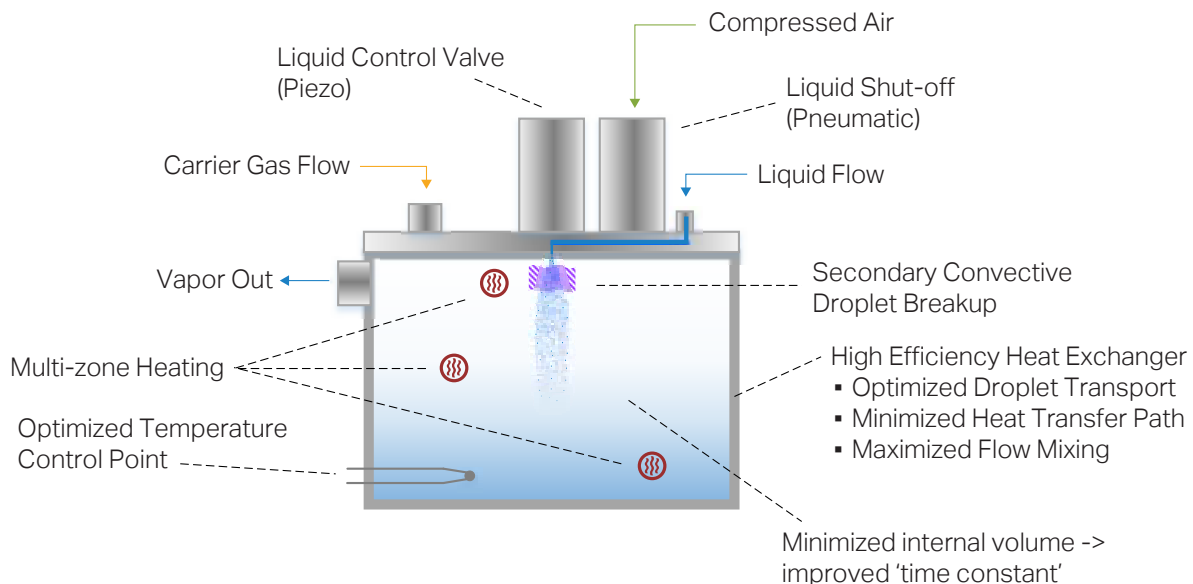
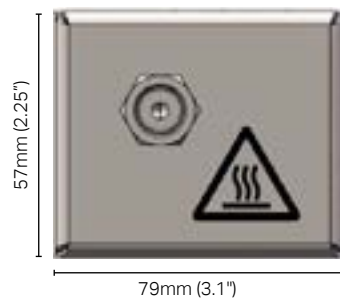
2x Capacity; 1/2 Size

The result of these efforts was the ability to increase vapor out by 200%, while reducing the size of the heat exchanger by 50%; Moore's law in vaporization technology.

**Model 2855
Heat Exchanger**



**Model 2852
Heat Exchanger**



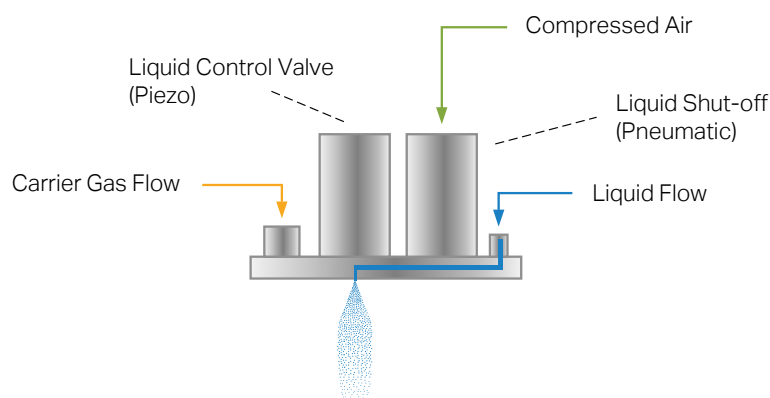
Choose the Features You Need

PE or NP – That's the Question

On-board Liquid Control Valve

The T2 Vaporizer can either have an on-board liquid flow control valve (piezo valve), or a pneumatic shut-off valve. Both atomizers feature a small droplet size and uniform droplet distribution, however the on-board flow control valve provides extremely fast response time, precise liquid control and liquid bubble suppression. The pneumatic shut-off valve only option can be used with any Liquid Flow Controller and also works well for very high temperature applications.

PE = Piezo Valve on Atomizer

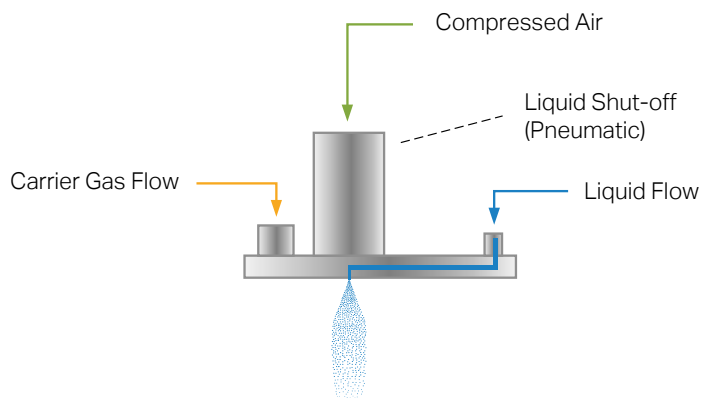


PE Atomizer Turbo II

Piezo Valve on Atomizer for Liquid Control (used with LFC w/o control valve: 2950 series MSP Turbo™ LFC)

- Smaller droplet diameters/shorter vaporization time*
- Uniform axial droplet/vapor concentration*
- Fast response time/reduced dead space
- Precise liquid control
- Liquid bubble suppression
- In combination with high-speed Turbo LFC minimizes stabilization time and reduces waste of precious precursors

NP = No Piezo Valve on Atomizer



NP Atomizer Turbo II

No Liquid Control on Atomizer (used with LFC with control valve - 2950-V series MSP Turbo™ LFC)

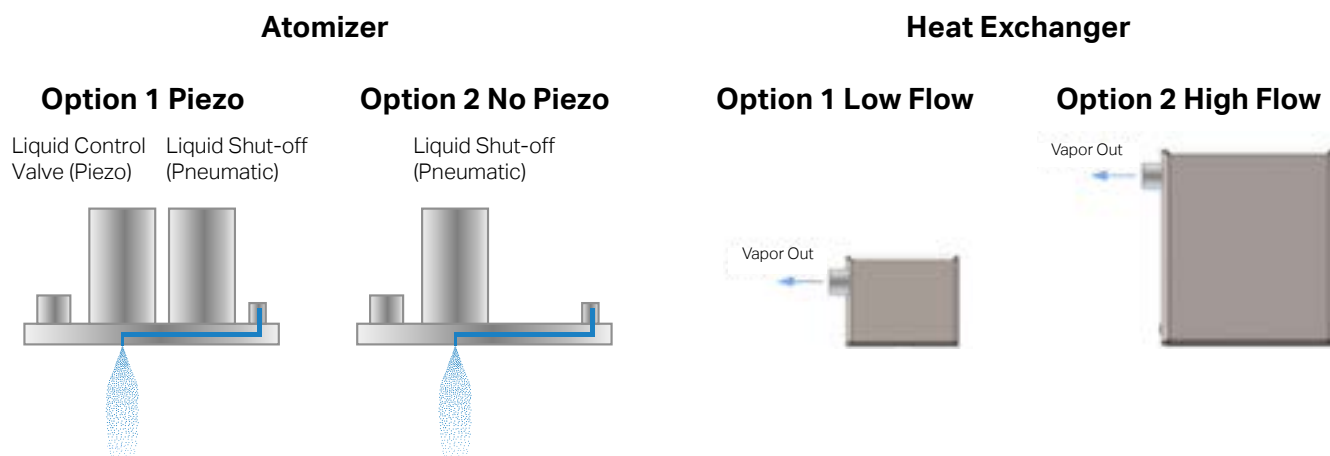
- Smaller droplet diameters/shorter vaporization time*
- Uniform axial droplet/vapor concentration*
- Fast vapor shut-off
- Simple liquid control scheme; can be use with many different flow control methods
- Works well for high temp applications

*Applies to both atomizer versions

Modular Solution

Choose the Option that Works for Your Application

The MSP Turbo II™ Vaporizer is a modular solution, meaning that heat exchangers and atomizers can be mixed and matched. There is a high-flow and a low-flow heat exchanger option. Additionally, the atomizer can have an on-board liquid control valve or just a pneumatic shut-off valve. High-flow heat exchangers with piezo valve comes with an in-line liquid shut-off valve. The low-flow piezo valve does not come with an inline pneumatic valve, and must be used with a shut-off valve immediately upstream of the atomizer.



MSP Turbo II™ (T2) Vaporizer Specifications

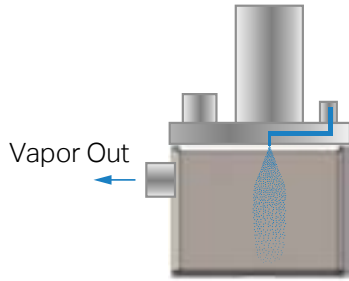
	2852NP	2852PE	2855NP	2855PE
On-board piezo liquid control valve	No	Yes	No	Yes
On-board pneumatic liquid shut off valve	Yes	No	Yes	No
Max Carrier Flow - N ₂ (SLPM) at 50 psig ¹	2		10	
Max. Liquid Flow - TEOS equivalent (g/min) ²	7		40	
Max Temperature (°C) ³	180		200	
Typical Power (W) ¹	450		900	
Dimensions HxWxD (mm/in)	198 x 79 x 114 (7.8 x 3.1 x 4.5)		249 x 79 x 142 (9.8 x 3.1 x 5.6)	
Line Voltage	208			

¹ Max Carrier Flow, Power (W) and Line Voltage are factory adjustable, visit www.tsi.com/contact to request more information.

² Max. liquid flow is process dependent. The spec assumes a max. vaporizer temperature, max. carrier gas flow and pressure <50 Torr immediately downstream of the vaporizer.

³ Appropriate venting is required.

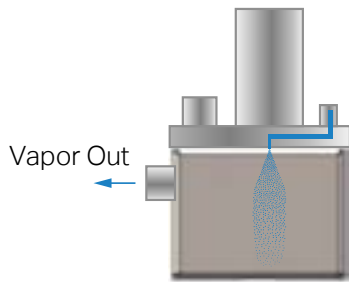
Liquid Shut-off
(Pneumatic)



**No Piezo + Low Flow
Model 2852NP**

- Low precision, low flow
- High temp, low flow
- Alternate flow control, low flow

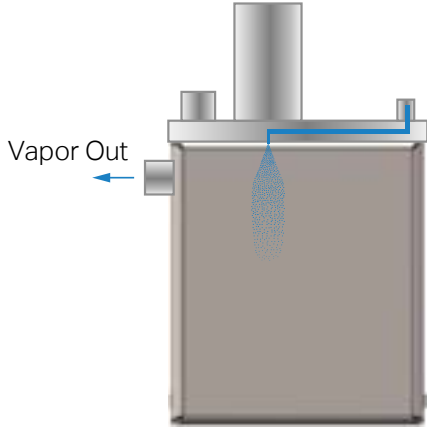
Liquid Control
Valve (Piezo)



**Piezo + Low Flow
Model 2852PE**

- ALD or short pulse CVD
- Low flow PECVD
- Mid/high precision, low flow
- Need liquid bubble suppression, low flow

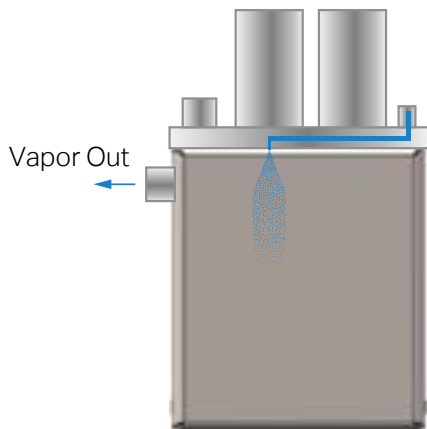
Liquid Shut-off
(Pneumatic)



**No Piezo + High Flow
Model 2855NP**

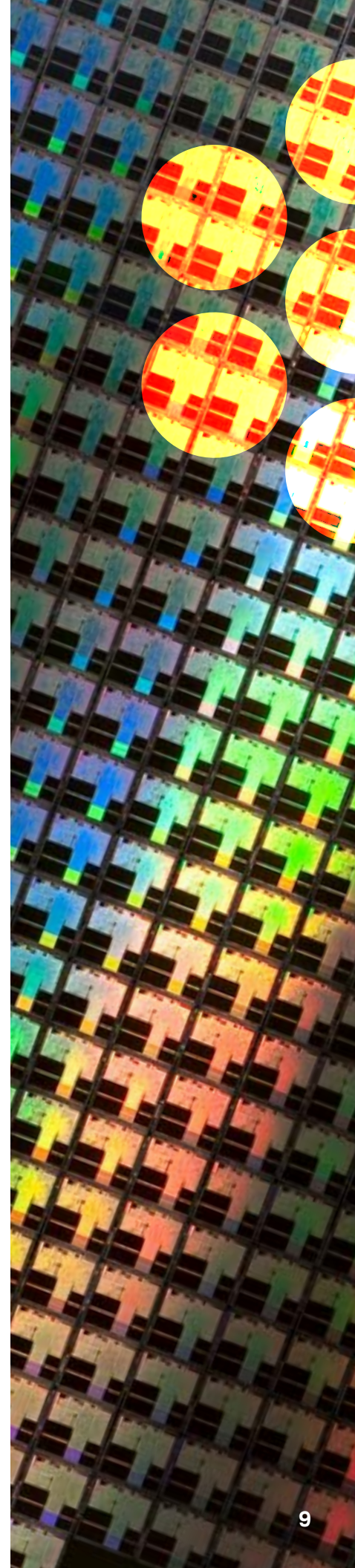
- SIC parts coating
- Fiber optic ingot
- Formic acid strip
- High temp applications
- Low precision, mid/high flow
- Alternate flow control, high flow

Liquid Control Valve (Piezo) Liquid Shut-off (Pneumatic)



**Piezo + High Flow
Model 2852PE**

- Mid/high flow PECVD
- Mid/high precision mid/high flow
- Short mid/high flow process
- Need liquid bubble suppression, high flow



Save Time, Money and Reduce Waste

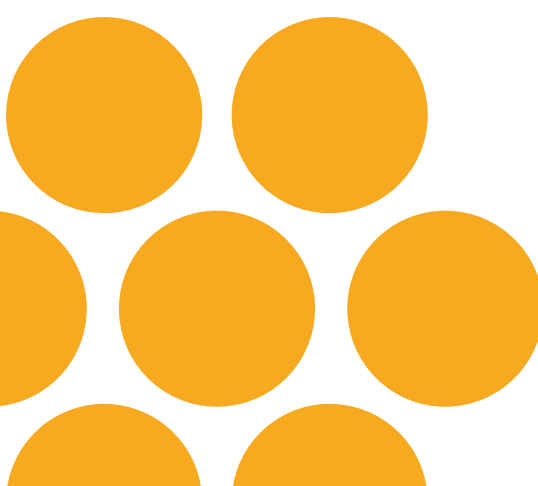
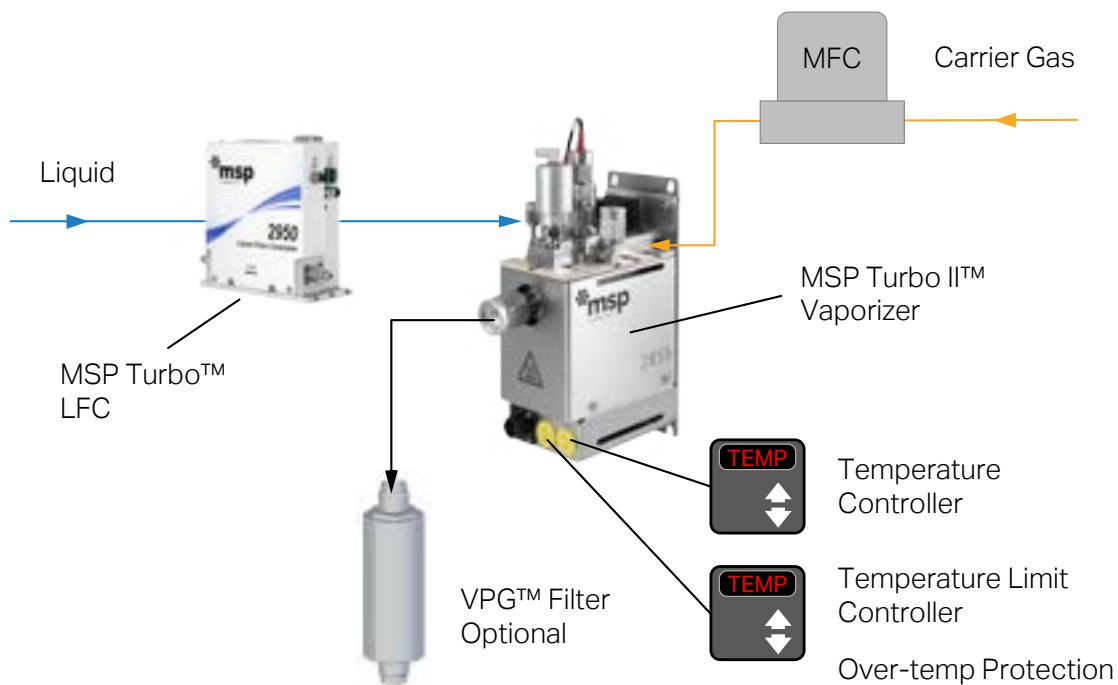
MSP Turbo™ Liquid Flow Controller (LFC) 2950

Designed for Microelectronic Applications

Built upon field-proven technology and designed specifically for leading edge microelectronic applications; this highly accurate, high-speed liquid flow controller contains a custom engineered high-precision flow sensor and meticulously designed flow control electronics to provide the world-class performance necessary for advanced semiconductor processing.

MSP Turbo II™ Vapor Delivery System (VDS)

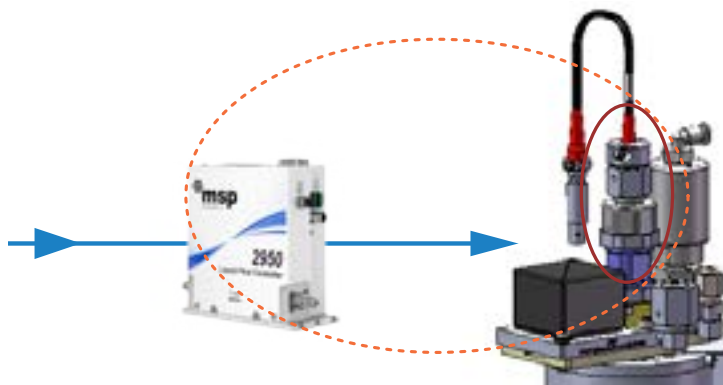
The 2950 was engineered to pair with MSP Turbo II™ Vaporizers to provide a reliable, high-performance liquid vapor delivery solution. Now you can procure a vaporizer and a high-end liquid flow controller from a single, trusted manufacturer, ensuring your process system has unmatched liquid source vapor delivery performance, versatility and longevity.





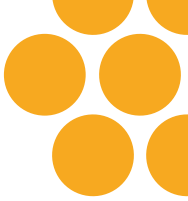
MSP Turbo™ LFC Key Features

- Exceptional accuracy
- Ultra-fast response time
- Superior repeatability
- Stable, tightly controlled flowrate
- PID tuning made easy
- Change liquids WITHOUT factory calibration
- EtherCAT, RS485 or analogue communications



Precision Flow Control

The MSP 2950 series Turbo™ LFC is designed to control the piezo liquid control valve on MSP Turbo II™ Vaporizers. For MSP Vaporizers without an on-board liquid control valve the 2950-V series LFC can be used.



'High-Speed' Liquid Flow Controller

Impact of a Fast Flow Sensor

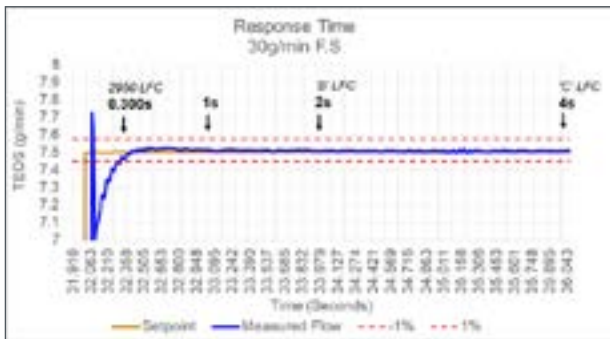
A fast sensor in a Liquid Flow Controller results in 1) faster stabilization/response time and 2) a shorter scan interval.

Fast Response Time -> Shorter Processes & Less Waste

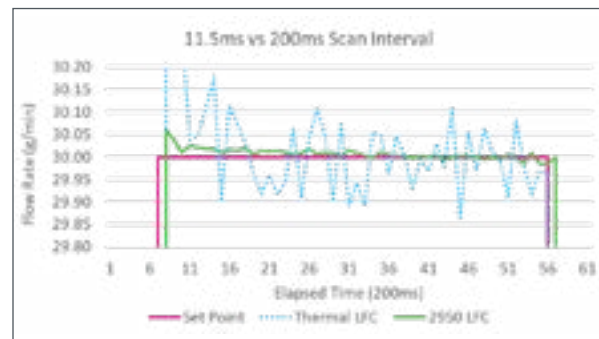
The MSP response time is defined as the time it takes the LFC to reach within +/-1% of set-point. The Turbo™ Liquid Flow Controller has stabilization/response times up to 12x faster than other semi LFC solutions. This industry leading response time can save time and money by increasing throughput and reducing waste. Shortened stabilization times results in shorter processes and less time diverting process flows.

Shorter Scan Interval -> Tighter Flow Control

A faster sensor also means a shorter scan interval. The scan interval is the time it takes a controller to sense flow, evaluate the flow versus the set-point and adjust the signal sent to the flow control valve based on the PID settings. The MSP Turbo™ LFC has a scan interval of 11.5 ms, meaning it can sense flow, and adjust the flow quickly, enabling it to more tightly control liquid flow rates.



Response time of 2950 Turbo™ LFC compared to published specification of publicly available manufacturers specification sheets.



Flow rate versus time for 2950 LFC with 11.4ms scan interval vs thermal LFC with 200ms scan interval.

Why is Response/Stabilization Time Important?

Process Example 7g/min liquid flow, 30s process time, 26s wafer transport time

4s response time	Value
Stabilization Time	4s
Process Time	30s
Wafer Transport	26s
Total	60s
% Stabilization Time	6.7%

0.3s response time	Value
Stabilization Time	0.3s
Process Time	30s
Wafer Transport	26s
Total	56.3s
% Stabilization Time	0.5%

Impact of Slow Response Time -> Long Liquid Divert

	In 24 hours	1 Month	1 Year
Divert Time	96 min	48 hours	24.3 days
Throughput Loss	-103 wafers	-3,090 wafers	-37,500 wafers
Liquid Waste	672 g	20.2 kg	245 kg

Impact of Fast Response Time -> Short Liquid Divert

	In 24 hours	1 Month	1 Year
Divert Time	7.7 min	3.8 hours	1.9 days
Throughput Loss	-8.2 wafers	-246 wafers	-3,000 wafers
Liquid Waste	54 g	1.6 kg	19.6 kg

← 13x less pump divert
← 12.5x fewer wafers lost
← 13x less liquid waste

Defect-Free Processing

Filters for Process Vapors

Designed for Vapor Delivery Solutions

MSP's patent-protected Vapor Process Gas (VPG) Filters were specifically engineered for the unique environment downstream of a vapor delivery solution.

Extremely Low Pressure Drop

The filters are designed to have extremely low pressure drops, minimizing risk of condensation and gas-conversions in the filter which are a unique concern in a vapor stream. The low pressure drop also makes it easier to work in an ultra-low pressure environment. Pump down is faster, and lower pressures are possible.

Increased Thermal Mass

MSP VPG Filters have increased thermal mass versus conventional filters so that, downstream of a vaporizer or liquid injector in a heated line, there is more thermal energy available to prevent cool spots and condensation (which can result in particle issues).

High Efficiency Filtration <2nm

With the nanometer sized structures used in today's microelectronic circuits, there is no room for particulate contamination. Ensure your vapor is particle free by using MSP's ultra-high efficiency VPG filters which filter particulates down to 2nm and below. The unique 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.

Thermal/Chemical Resistance

Made entirely out of 100% 316SS, MSP's filters are chemically and thermally resistant, providing reliable filtration even for chemically aggressive vapors/gases.

Vapor Process Gas VPG Filters – 316ss



Model	VPG-A3	VPG-A6	VPG-A15
Part number	2920-01-5001	2920-01-1000	2715
Description	Ultra-low pressure drop, high flow rates, small footprint	Ultra-low pressure drop, high filtration efficiencies	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)	99.9999999 (ten 9s)
50nm Filter Efficiency @1 SLPM (%)	99.99 (four 9s)	99.9997 (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	<0.02 kPa@1 SLPM; kPa = 0.0151Q(SLPM)-0.0424
Filter Media	Sintered 316SS powder	Sintered 316SS fiber	Sintered 316SS fiber
Fittings	1/2" VCR		
Wetted Materials	316 Stainless Steel		
Temperature Range (°C)	<300		
Length/Diameter (")	5/1.5	5/1.5	15.6/2.0
Weight (lb)	1	1	3

MSP Turbo™ Vaporizer 2821

Ultra-high Flow Solution

MSP's Turbo™ Vaporizer 2821 is the solution for ultra-high flow applications. It provides the highest liquid flow rate of the standard MSP Vaporizers. It features 3600W of heater power and can be used to deliver flow rates up to 100 g/min (TEOS or equivalent).



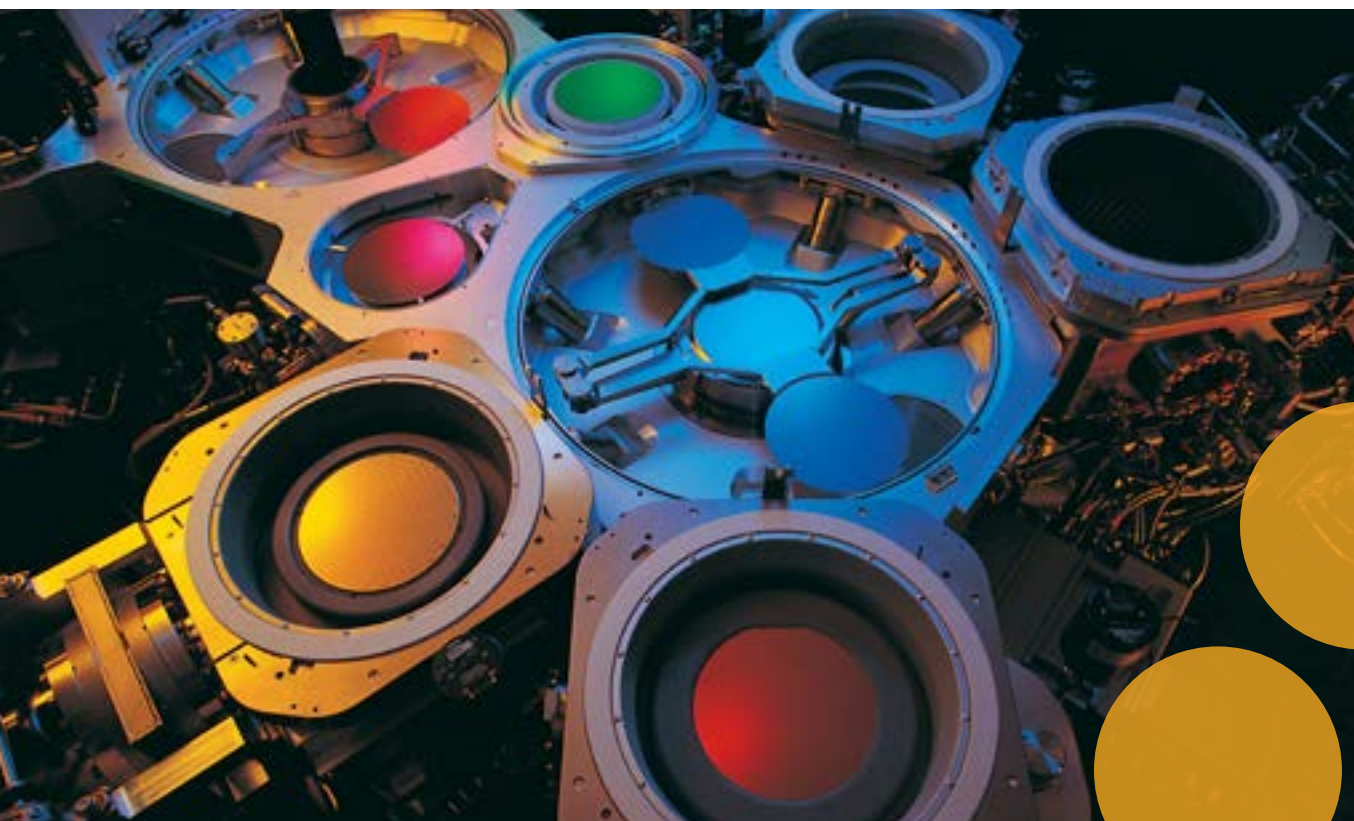
MSP Turbo™ Vaporizer 2821 Specifications

On-board piezo liquid control valve	No
On-board pneumatic liquid shut off valve	Yes
Max. Liquid Flow: TEOS equivalent (g/min) ¹	100
Max Carrier flow: N ₂ (SLPM) at 50 psig ²	20
Max Temp (°C) ³	40-200
Typical Power (W)	3600W
Dimensions HxWxL (mm/in)	417 x 140 x 183 (16.4 x 5.5 x 7.2)
Line Voltage	220V

¹ Carrier gas flow range is factory adjustable; visit www.tsi.com/contact to request more information.

² Max. liquid flow is process dependent. The spec assumes a vaporizer temperature of 200C, max. carrier flow rate, and pressure <50 Torr immediately downstream of the vaporizer.

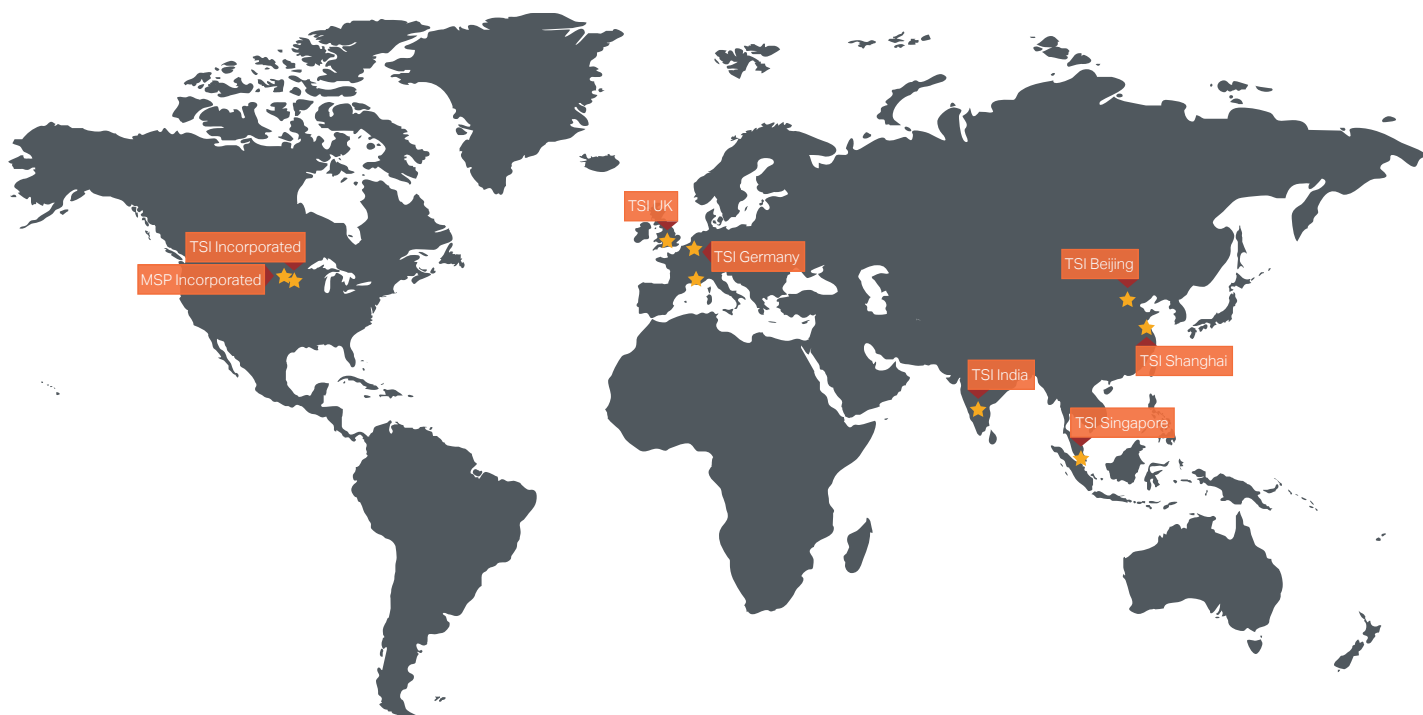
³ Appropriate venting is required.





Global Footprint

MSP, a Division of TSI®, has 11 offices worldwide including a dedicated facility in South Korea for sales, field service, inventory, and support of vaporizers in the semiconductor industry.



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, routinely partnering with industry leaders to co-develop and supply unique vaporization solutions for their leading edge technology process equipment.

The MSP Difference

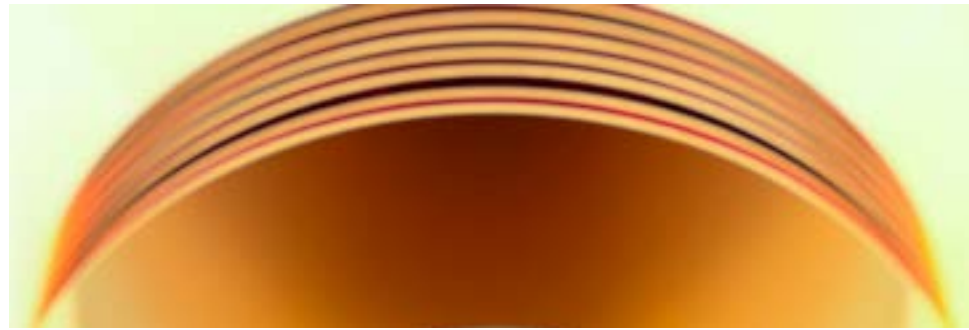
MSP's foundation was born out of academia, and the company is dedicated to partnering with leading technology research groups across the globe to bring cutting edge design to commercial applications.

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.



To learn more, please visit
[tsi.com/MSP-Turbo-II](https://www.tsi.com/MSP-Turbo-II)

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MSP - Visit our website www.tsi.com/msp for more information.

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