

# Model 3450 Vibrating Orifice Aerosol Generator

*Creates monodisperse particles from 1 to 200 micrometers in diameter*



Uniform particle creation is critical for successful aerosol research. Controlled experiments and proper instrument calibration require a generation source that guarantees production of uniform, monodisperse particles.

The Model 3450 Vibrating Orifice Aerosol Generator (VOAG) produces solid or liquid aerosols from a wide variety of solutions. It creates aerosol particles that are uniform in size, density, shape, and surface characteristics.

The VOAG's integrated design makes it easy to start up and adjust. Liquid flow, dispersion air, dilution air, and oscillation frequency can be conveniently monitored and controlled from the front panel. Because the generation head, syringe pump, and signal generator are contained in one package, the VOAG provides all the data necessary to calculate final particle diameter.

## Applications

The VOAG's consistency and accuracy make it an effective aerosol generation standard for a variety of applications. It is especially suited to controlled experiments where airborne particle size must be known and within a narrow range. Typical applications include:

- Generation of micrometer particles of known size from any material that can be put into solution with a volatile solvent
- Transport, deposition, collection, charging, and dispersion of aerosols related to aerosol research and health-effects studies
- Evaporation studies
- Pharmaceutical formulation testing
- Calibration of optical particle counters, particle sizers, cascade impactors, cyclones, and impingers
- Development and testing of equipment such as baghouse filters, cyclones, scrubbers, and electrostatic precipitators
- Instrument performance studies involving the measurement of design parameter effectiveness as a function of particle characteristics



## Features

**Acrylic Drying Column.** Made of clear acrylic so you can view particles as they are generated, the drying column facilitates the evaporation of solvent. It may be removed for special experimental needs, or it can hold an optional TSI Model 3054 Aerosol Neutralizer\* to remove charge from the generated aerosol.

**Jet-Viewing Light.** A built-in halogen lamp produces a highly focused light beam, allowing easy visual verification of droplet monodispersity. (See photographs on opposite page.)

**Removable Generation Head.** The generation head can be removed and inverted to accommodate the generation of large particles. This flexibility also makes it easy to deliver aerosol to the desired location.

**Interchangeable Orifices.** Two orifice sizes (10- and 20-micrometer diameter) come with the VOAG for varying particle size. Orifices of 35, 50, and 100 micrometers are also available.

**Constant-Speed Syringe Pump.** A powerful stepper motor drives the built-in syringe pump to maintain constant volumetric flow. This constant flow, rather than constant pressure, ensures uniform particle size. An error detection system and warning light alert the operator to any operational problem.

**Corrosion-Resistant Liquid Path.** The use of corrosion-resistant materials, such as stainless steel and Teflon<sup>®</sup>, make the VOAG appropriate for applications that use caustic solutions to generate particles.

**Digitally Displayed Signal Generator.** The front panel of the VOAG displays a digital readout of the signal generator's frequency output, and includes convenient controls for frequency and amplitude.

**Easily Accessible Controls.** The front panel also contains controls and indicators for the filtered air supply (both dispersion and dilution air), syringe pump, and halogen lamp. You can even monitor liquid pressure and operate the liquid drain from the front panel.

\*Instrument shown with optional Model 3054 Aerosol Neutralizer installed in the drying column. The neutralizer must be ordered separately.



The Model 3450 produces highly uniform, monodisperse particles, in solid or liquid form. (Photo courtesy of Prof. Richard K. Chang, Center for Laser Diagnostics and Department of Applied Physics, Yale University)

## Operation

Left uncontrolled, a liquid jet is unstable and breaks into nonuniform droplets. Applying a periodic disturbance of an appropriate frequency can regulate this process. The VOAG uses a vibrating orifice to control the breakup of a liquid jet. This technique enables the VOAG to produce highly uniform droplets with a typical standard deviation of less than one percent of the mean droplet size.

A syringe pump feeds a liquid solution through a small orifice at a predetermined rate. The volumetric flow remains constant. A piezoelectric ceramic driven by an oscillating voltage potential causes the orifice to vibrate at a constant frequency, producing a uniform droplet stream.

The droplet stream is introduced into the center of a turbulent air jet, dispersing droplets and preventing coagulation. The dispersed droplets mix with a larger volume of clean, dry air, which evaporates any volatile portion of the droplets.

The VOAG generates primary droplets in the 21- to 48-micrometer range using a standard, interchangeable set of 10- and 20-micrometer nominal diameter orifices. Larger orifices are optionally available to generate larger primary droplets. The solution used to generate the droplets determines evaporation and ultimate particle size.

Because each disturbance cycle produces only one droplet, the precise size of the droplet can be calculated using operating parameters. The two key parameters are liquid flow rate ( $Q$ ) and oscillation frequency ( $f$ ). If a portion of the primary droplet is volatile, the final particle size depends on the volumetric concentration ( $C$ ) of the nonvolatile portion.

Using the  $Q$ ,  $f$ , and  $C$  parameters, the following equation calculates the final particle diameter:

$$D_p = \left( \frac{6QC}{\pi f} \right)^{1/3}$$

The operator can conveniently monitor liquid flow rate, dispersion air rate, and oscillation frequency from the VOAG's front panel.

The VOAG produces a charged aerosol. While this charge does not affect particle-size uniformity, it often causes considerable transport losses, especially with smaller-sized particles. TSI recommends using a radioactive neutralizer for applications involving particles smaller than 5.0 micrometer in diameter. The VOAG's acrylic drying column easily accommodates a TSI Model 3054 Aerosol Neutralizer.

### Precise View of Droplet Generation



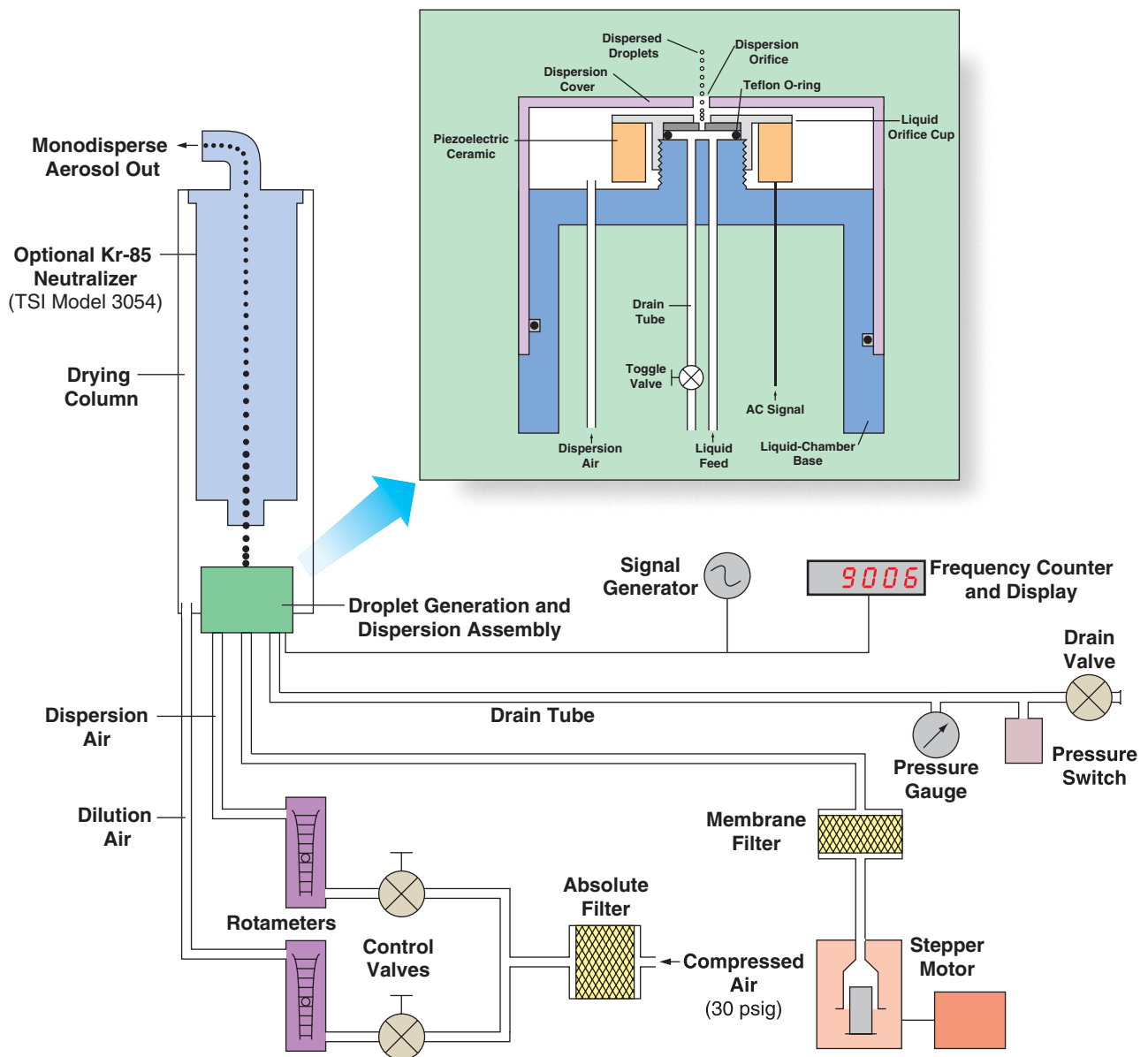
The VOAG generates identical droplets from a liquid stream as the stream passes through the vibrating orifice. The droplets form a thin, vertical jet when the VOAG is operating properly. The jet-viewing light allows easy monitoring of this operation.



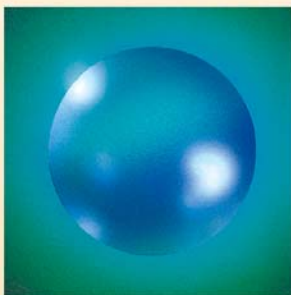
The operator checks droplet uniformity by using a gentle flow of air to deflect the droplet stream. A single, deflected jet indicates uniform droplet size.



Two or more deflected jets indicate generation of more than one droplet size, and therefore, the need for an adjustment by the operator. The "satellites" shown above can be eliminated simply by adjusting the vibration frequency or amplitude.



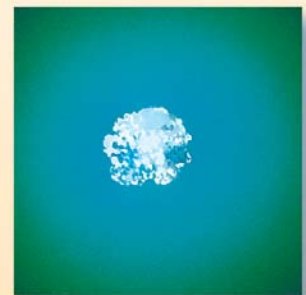
## From Droplet to Solid Particle



The VOAG generates identical primary droplets, one at a time. By varying the liquid flow rate and oscillation frequency, the operator can generate a specific range of primary droplet sizes.



Primary droplets composed of two liquids with different volatilities produce a less volatile droplet. For example, droplets containing both alcohol and oil lose the more-volatile alcohol in the drying column, leaving only the oil.



Primary droplets composed of a volatile liquid and a nonvolatile solute produce particles from the solute when the liquid evaporates. A saline solution produced the salt particle pictured above.

## Specifications

### Model 3450 Vibrating Orifice Aerosol Generator

Mode of Operation	Constant liquid feed rate through a vibrating orifice
Particle Size Range	1 to 200 $\mu\text{m}$
Initial Droplet Diameter	20 to 400 $\mu\text{m}$
Geometric Standard Deviation	<1.01
Particle Type	Oil and solids soluble in water or alcohol*
Particle Generation Rate	1,000 to 300,000 particles/sec (depends on particle size)
Syringe Pump	
Syringe Ram Speed	0.1 $\times 10^{-4}$ to 9.9 $\times 10^{-3}$ cm/sec
Flow Rate	Selectable, 0.001 cm <sup>3</sup> /min (10-cm <sup>3</sup> syringe) to 2.2 cm <sup>3</sup> /min (60-cm <sup>3</sup> syringe)
Syringe Holders	Hold 10-, 20-, or 60-cm <sup>3</sup> syringes
Signal Generator	
Frequency Range	1 kHz to 1 MHz
Accuracy	$\pm 1\%$ of full scale, $\pm 1$ digit
Amplitude of Square Wave	0 to 30 V, peak-to-peak
Physical Specifications	
Cabinet Size	44 cm $\times$ 37 cm $\times$ 20 cm (17.3 in. $\times$ 14.5 in. $\times$ 7.9 in.)
Weight	16 kg (35 lb)
Drying-Column Height	60 cm (23.6 in.)
Drying-Column Material	Acrylic
Orifice Material	Stainless steel
Electrical Requirements	100/115/230/240 VAC, 50-60 Hz, 100 W maximum
Compressed-Air Requirements	Up to 100 L/min at 207 kPa (30 psig)

\*The VOAG is not suitable for use with nonsoluble solids such as polystyrene latex (PSL). To generate PSL aerosol, use TSI's Model 3433 Small-Scale Powder Dispenser with a turntable loaded with PSL.

Specifications are subject to change without notice.

## Bibliography

Remiarz RJ, JK Agarwal, and EM Johnson, Improved Polystyrene Latex and Vibrating Orifice Monodisperse Aerosol Generators, *TSI Quarterly VIII*(3):3-12 (1982). (TSI paper Q20)

Vanderpool RW, AP Black-Hall, and KL Rubow, Generation of Large, Solid, Monodisperse Calibration Aerosols, *TSI Quarterly X*(1):3-6 (1984). (TSI paper Q26)

Berglund RN and BYH Liu, Generation of Monodisperse Aerosol Standards, *Environmental Science and Technology* 7(2):147-153 (1973). (TSI paper A13)

Keady PB and PA Nelson, Monodisperse Particle Generators for Calibrating Aerosol Instrumentation, *Proceedings, Institute of Environmental Sciences*, 94-100 (1984). (TSI paper A34)

## To Order

Specify	Description
3450	Vibrating Orifice Aerosol Generator

### Includes these standard accessories:

Accessory kit: 10-, 20-, and 60-cm<sup>3</sup> syringes; 12 filter holders; 100 Teflon<sup>®</sup> membrane filters (0.5- $\mu\text{m}$  pore size, 13-mm diameter); replacement O-rings; tubing; and air filters  
One 10- $\mu\text{m}$  orifice (nominal size)  
Two 20- $\mu\text{m}$  orifices (nominal size)  
Jet-deflection nozzle  
Small syringe holder (for 10- and 20-cm<sup>3</sup> syringes)  
Large syringe holder (for 60-cm<sup>3</sup> syringe)  
250-cm<sup>3</sup> beaker  
Light assembly  
Exhaust hose  
Drying column assembly  
Instruction manual

### Optional accessories (must be ordered separately):

Specify	Description
393520	10- $\mu\text{m}$ orifice (nominal size)
393530	20- $\mu\text{m}$ orifice (nominal size)
393540	35- $\mu\text{m}$ orifice (nominal size)
393550	50- $\mu\text{m}$ orifice (nominal size)
393560	100- $\mu\text{m}$ orifice (nominal size)
393590	0.5- $\mu\text{m}$ filters, 13-mm diameter (quantity of 100)
3054	Aerosol Neutralizer
3074B	Filtered Air Supply

## To Order a Complete System

Specify	Description
3941	Supermicrometer Monodisperse Aerosol Generation System

### Includes these system components:

3450	Vibrating Orifice Aerosol Generator with one 10- and two 20- $\mu\text{m}$ orifices and standard accessories
3054	Aerosol Neutralizer
3074B	Filtered Air Supply
393540	35- $\mu\text{m}$ orifice
393550	50- $\mu\text{m}$ orifice
393560	100- $\mu\text{m}$ orifice
—	Interconnecting hardware

This system is described on the back of this document.

# Model 3941 Supermicrometer Monodisperse Aerosol Generation System

*A complete system for generating monodisperse particles*

The Vibrating Orifice Aerosol Generator (VOAG) described in this product sheet is also available in a complete system. The Model 3941 Supermicrometer Monodisperse Aerosol Generation System provides all components needed to generate particles from 1 to 200 micrometers in diameter. The system includes a VOAG, a Model 3054 Aerosol Neutralizer, and a Model 3074B Filtered Air Supply. It also includes a complete set of orifices (10, 20, 35, 50, and 100 micrometers, nominal size). Ordering information is provided under "To Order a Complete System," found inside this product sheet.

## Specifications

### Model 3450 Vibrating Orifice Aerosol Generator

Specifications provided on inside page

### Model 3054 Aerosol Neutralizer

Source	Kr-85†
Emission	99+% beta
Radioactivity	10 millicurie
Half-Life	10.4 years
Flow Rate (Maximum)	150 L/min
Temperature (Maximum)	50°C (122°F)
Pressure (Maximum)	35 kPa (5 psig)
Dimensions	
Inlet Diameter	2.5 cm (1 in.)
Outlet Diameter	3.1 cm (1.2 in.)
Length	50 cm (20 in.)
Housing Diameter	8.9 cm (3.6 in.)
Weight	3.5 kg (7.7 lb)

### Model 3074B Filtered Air Supply

Inlet Connection	Parker H2C 1/4-in., male, quick-disconnect fitting
Outlet Connector	3/8-in. female Swagelok® fitting that connects to 3/8-in. tubing (1/4-in. fitting also included)

<b>Roughing Filter</b>	99.5% efficiency at 0.1 µm
<b>Intermediate Filter</b>	99.99995% efficiency at 0.1 µm
<b>Membrane Dryer</b>	Reduces wet, incoming air to a dew-point of 1.6°C (35°F) at 2 scfm (56 L/min) using the principle of selective permeation through a membrane
<b>Final Filter</b>	99.99995% efficiency at 0.1 µm, contains activated carbon
<b>Pressure Regulator</b>	0 to 4.0 kg/cm <sup>2</sup> (0 to 60 psig)
<b>Pressure Gauge</b>	0 to 4.0 kg/cm <sup>2</sup> (0 to 60 psig)
<b>Dimensions (LWH)</b>	81 cm ¥ 20 cm ¥ 37 cm (32 in. ¥ 8 in. ¥ 14.5 in.)
<b>Weight</b>	2.3 kg (5 lb)

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*The Model 3941 Supermicrometer Monodisperse Aerosol Generation System includes the VOAG and the accessories needed to generate particles from 1 to 200 micrometers in diameter.*



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