

Rotating Disk Thermodiluters and Thermal Conditioners

Dilute and condition particle emissions to preserve the original size distribution and concentration for accurate measurements.



Combustion sources are typically hot, highly concentrated, and are made up of volatile gaseous compounds. These compounds condense either homogeneously to create nucleation mode particles or heterogeneously onto solid particles as the exhaust gas cools. If exhaust emissions are not properly diluted and thermally conditioned, the particle size distribution and concentration will quickly undergo significant changes between the source and measurement instrument due to coagulation. To ensure proper sample conditioning, TSI offers a range of diluters and thermal conditioners to fulfill your emission measurement requirements.

Rotating Disk Thermodiluters

TSI Rotating Disk Thermodiluters are highly regarded in the field of particle emission measurement. They are especially suited for sampling, diluting, and conditioning exhaust particles from diesel and spark-ignition engines, as well as performing stack emission studies. The Model 379020 features a separate exhaust probe and control unit that effectively dilutes and thermally conditions the sample at the source (tailpipe, CVS tunnel, or stack) in order to preserve it for accurate measurement. The Model 379021 features the rotating disk diluter built into the control unit for convenience. Additional features of these two rotating disk diluters include:

- Adjustable dilution ratio with no tools or recalibration required
- Accurate dilution over two full decades
- Built-in heater with selectable temperatures to avoid measurement of condensed volatile materials
- Compatibility with a wide variety of TSI particle sizers and counters, including:
 - Scanning Mobility Particle Sizer™ (SMPS™) spectrometers
 - Engine Exhaust Particle Sizer™ (EEPS™) spectrometer
 - Condensation Particle Counters (CPC)
 - Electrical Aerosol Detector (EAD)
 - Nanoparticle Surface Area Monitor (NSAM)
- Model 379020 offers a small exhaust probe that is convenient for mounting in confined spaces
- Rotating disk that is easy to clean and maintain



Figure 1. Model 379020 exhaust probe (10-cavity disk shown)

Thermal Conditioners

Model 379030

Evaporation Tube	
Temperature Range	Ambient to 400°C (selectable)
Temperature Measurement	±2°C
Temperature Control	±3°C
Secondary Diluter	
Dilution Range	1:1 to 11:1
Air Supply Flow	0 to 15 L/min with accuracy of 3% of set value +0.1 L/min
Dilution Range Settings	Adjustable via front panel 10-turn potentiometer or via analog input (0 to 10 V)
Measurement Channel Flow	
Rate (to instrument)	Up to 16.5 L/min; Excess air leaves secondary diluter via dedicated excess air channel that includes filter and mass flow meter
Programming Interface	
	Functions can be controlled by digital (5 V) and analog (0 to 10 V) signals via 25-pin D-sub female connector on rear panel
Control Unit	
Dimensions (HWD)	146 mm × 485 mm × 530 mm (5.75 in. × 19 in. × 20.9 in.); control unit occupies ½ the case; when ordered with the 379020, the 379020 control unit occupies the other half
Weight	Approx. 13.5 kg (30 lbs) without 379020; 17.5 kg (38.5 lbs) when combined with 379020
Power Requirements	100 to 240 VAC, 50/60 Hz, 350W (without 379020; 460W when combined with 379020)

Model 379031

Evaporation Tube	
Temperature Range	Ambient to 400°C (selectable)
Temperature Measurement	±2°C
Temperature Control	±3°C
Measurement Channel Flow	
Rate (to instrument)	Up to 5.0 L/min
Programming Interface	
	Functions can be controlled by digital (5 V) and analog (0 to 10 V) signals via 25-pin D-sub female connector on rear panel
Control Unit	
Dimensions (HWD)	146 mm × 485 mm × 530 mm (5.75 in. × 19 in. × 20.9 in.); control unit occupies ½ the case; when ordered with the 379020, the 379020 control unit occupies the other half
Weight	Approx. 13 kg (29 lbs) without 379020; 17 kg (37 lbs) when combined with 379020
Power Requirements	100 to 240 VAC, 50/60 Hz, 260W (without 379020; 370W when combined with 379020)

To Order

Rotating Disk Thermodiluters

Specify	Description
379020	Rotating Disk Thermodiluter and carrying case
379021	Rotating Disk Thermodiluter and carrying case

Accessories

379030	Thermal Conditioner Air Supply
379031	Thermal Conditioner

Accessories must be ordered separately. See accessory specifications at left.

Specifications are subject to change without notice. TSI, the TSI logo, Engine Exhaust Particle Sizer, EEPS, Scanning Mobility Particle Sizer, and SMPS are trademarks of TSI Incorporated. Swagelok is a trademark of Swagelok Company.

Specifications

Rotating Disk Thermodiluters

	Model 379020	Model 379021
Sample Inlet Conditions		
Flow Rate	Approximately 1.0 L/min	Approximately 1.2 L/min
Differential Pressure ²	-100 to +150 mbar	-50 to +150 mbar
Diluter		
Separate Exhaust Probe with rotating disk diluter	Yes; heated diluter	No; heated diluter built into control unit
Temperature Settings	OFF, 80, 120, or 150°C	OFF, 40, or 80°C
Nominal Dilution Ranges³		
10-cavity Disk	15:1 to 300:1	12:1 to 240:
8-cavity Disk	150:1 to 3000:1	120:1 to 2400:1

Models 379020 and 379021 (common specifications)

Measurement Channel Flow	
Rate (to Instrument)	0.5 to 5.0 L/min
Dilution Range Settings	Adjustable via front panel 10-turn potentiometer or via analog input (0 to 10 V)
Dilution Accuracy	±10% within range specified in Figure 5 using the calibration factors supplied with each disk. Thermodiluter may operate correctly at lower measurement channel flow rate and ratio adjustments but without guarantee for compliance with the specifications
Permissible Gases	Thermodiluter is constructed of stainless steel, non-corroding Erta Peek plastic, brass fittings, PVC materials and/or silicon tubing; provisions for chemicals that attack these materials are available upon request
Raw Gas Temperature Range	0 to 200°C, noncondensing gas environment
Control Unit	
Power Requirements	100 to 240 VAC, 50/60 Hz, 140W maximum
Construction	Half 19-inch plug-in unit (3HU/42TE) in laboratory case with carry handle
Dimensions (HWD)	148 mm × 258 mm × 312 mm (5.8 in. × 10.2 in. × 12.3 in.)
Weight	Approx. 8 kg (17.6 lbs)
Inputs/Outputs	Functions can be controlled by analog (0 to 10 V) signals via 25-pin D-sub female connector on rear panel
Connections to Instrument	
Model 379020	Swagelok® fitting for 6mm OD tube
Model 379021	Swagelok fitting with nipple for 6mm OD tube

Exhaust Probe (Model 379020 only)

Sample Probe	Stainless steel tube connected to dilution block via Swagelok fitting (8mm OD); exhaust probe can be connected directly to the tail pipe, CVS tunnel, or stack
Connections to Control Unit	
Pneumatic	Flexible, metal protective tube containing two silicon and one conductive plastic tube (3m length)
Electrical	Multi-pole electrical cable housed in a flexible, metal protective tube (3m length)
Dimensions (HWD)	180 mm × 280mm × 90 mm (7 in. × 11 in. × 3.5 in.)
Weight	Approx. 2.5 kg (5.5 lb)

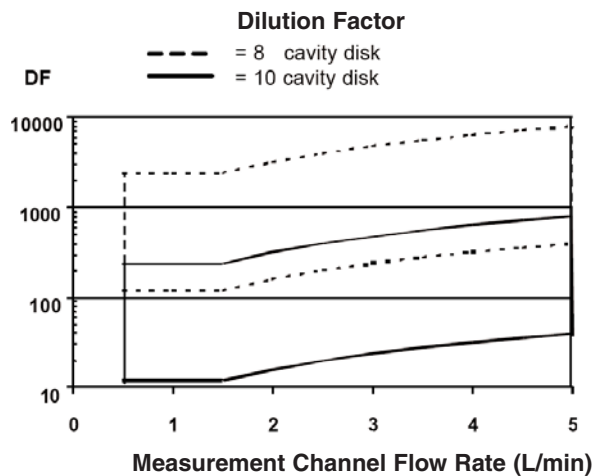


Figure 5. Dilution range as function of measurement channel, flow rate and number of cavities on the disk

²Between raw gas channel and ambient conditions

³Dilution ratios can be achieved with measurement channel flow rate of 0.5 to 1.5 L/min. For measurement channel flow rates >1.5 L/min, see figure for nominal dilution range.

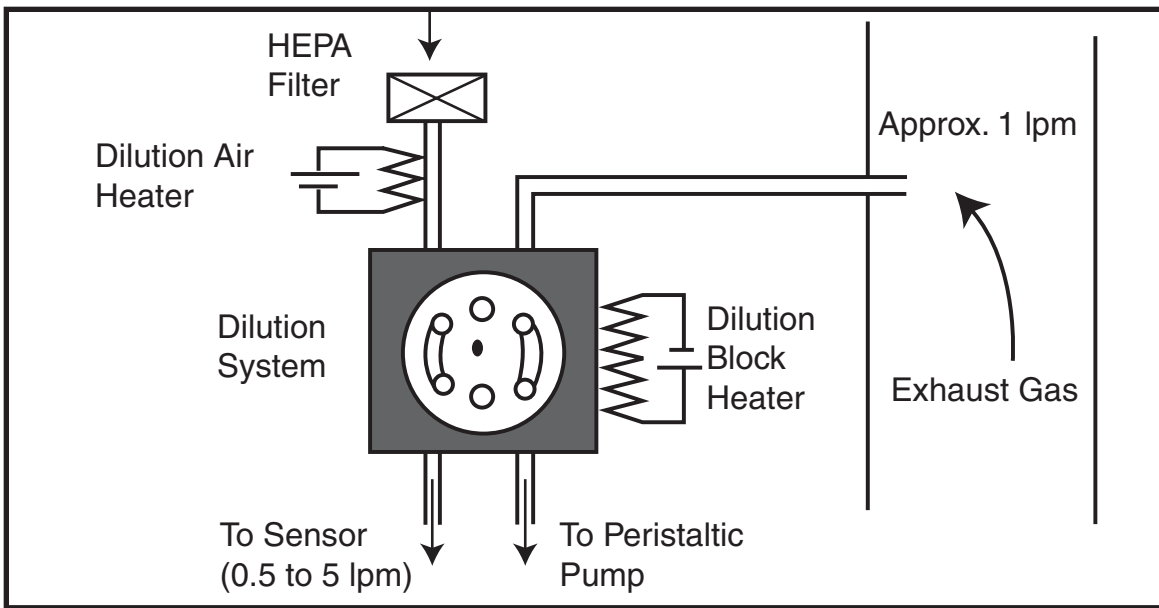


Figure 2. Principle of dilution method

Thermodiluter Operation

Models 379020 and 379021 use a unique, rotating disk method to dilute a sample for measurement. Each unit is supplied with two disks: one with eight cavities and the other with ten cavities. This allows you to select a dilution ratio from 15:1 to 3000:1 (Model 379020) and from 12:1 to 2400:1 (Model 379021). As shown in Figure 2, the raw, undiluted exhaust emissions are sampled at a rate of approximately 1.0 L/min (Model 379020) and 1.2 L/min (Model 379021). A portion of the raw exhaust is captured by each cavity of the rotating disk and transported to the measurement channel where it is mixed with HEPA-filtered, particle-free dilution air. The dilution ratio is a linear function of the disk calibration factor (corresponding cavity volume and number of cavities per disk), the rotation frequency and

$$\text{Dilution Ratio (DR)} = \frac{\text{Disk Calibration Factor} \times \text{Disk Rotation Frequency}}{\text{Dilution Air Flow Rate}}$$

the flow rate of the dilution air:

This method accomplishes dilution of emissions in a range of over two decades with high precision and stability. The diluters control and regulate flows, and indicate faulty conditions with alarm outputs.

To avoid measurement of condensed volatile materials, users may heat the make-up dilution air and the dilution block. Temperature settings are controlled via the control unit. Lower temperatures allow the study of volatile fractions



379020



379021

Thermal Conditioners

Hot vehicle exhaust contains both solid particles (carbonaceous soot and ash, for example) and vapors of volatile substances (such as water, sulfate, and hydrocarbons). When a standard dilution tunnel like a CVS tunnel is used for emissions testing, the volatile substances may condense into nanodroplets, which are detected as particles together with nonvolatile solid particles. In order to measure only the solid particle fraction, it is necessary to condition the sample thermally in order to eliminate the volatile fraction.

TSI offers two Thermal Conditioners for emission testing purposes – models 379030 and 379031. Both use a heated evaporation tube, which can be heated up to 400°C, to eliminate nanodroplets that may have formed during the dilution process. The evaporation tube temperature can be set to lower temperatures for studying the effects of the volatile fraction. Both thermal conditioners can be combined with either TSI Rotating Disk Diluter to lower the concentration range within acceptable limits of the measurement instrumentation and to thermally condition the sample thermally. The combination of the Model 379020 Rotating Disk Thermodiluter, the Model 379030 Thermal Conditioner Air Supply, and the Model 3790 EECPC creates the particle number (PN) concentration measurement proposed by the GRPE/PMP draft regulations R83 and R49. Additional Thermal Conditioner features include:

- Suppression of volatile particle formation in order to measure the solid particle fraction
- Adjustable heater temperature up to 400°C
- Local and remote controlled operation
- 19-inch stand-alone unit may be combined with a Rotating Disk Thermodiluter in the same cabinet

Thermal Conditioner Operation

The Figure 3 illustrates how volatile compounds form nanodroplets, depending upon the sampling and dilution method, and how they can be eliminated or suppressed using proper dilution and thermal conditioning. When measuring emissions from a CVS tunnel, both the concentration and the temperature of the volatile compounds are reduced (path A → B). During dilution, the volatile compound passes its dewpoint and nucleates into nanodroplets (curve N). Subsequent secondary dilution (path B → D) will reduce the number concentration of such nanodroplets, but is unable to evaporate them, because of the hysteresis effect between nucleation and evaporation.

One strategy to avoid the formation of nanodroplets is to sample directly from the hot exhaust using hot dilution (a rotating disk diluter along path A → C). Given a sufficient dilution factor, the volatile compounds will not nucleate during subsequent cooling (path C → D), even though the same final state is reached when sampling from a CVS tunnel using a secondary diluter along path A → B → D. However, some emission measurement applications require the use of a CVS tunnel, which makes direct sampling and dilution of the hot exhaust impossible. To eliminate or suppress nanodroplet formation when measuring emissions from a CVS tunnel, one must dilute and thermally condition the sample prior to measurement. Using a Rotating Disk Thermodiluter, the sample is first diluted along path A → B → D. Next, it is heated above the evaporation point of the volatile compound (path D → C, crossing curve E) using a Thermal Conditioner.

As with hot dilution, the volatile compound remains in vapor phase upon subsequent cooling (path C → D), but never crosses the nucleation curve to reform nanodroplets. Thus, when measuring emissions from a CVS tunnel, nanodroplets can be eliminated or suppressed using the combination of a Rotating Disk Thermodiluter and Thermal Conditioner as illustrated along the path A → B → D → C → D.

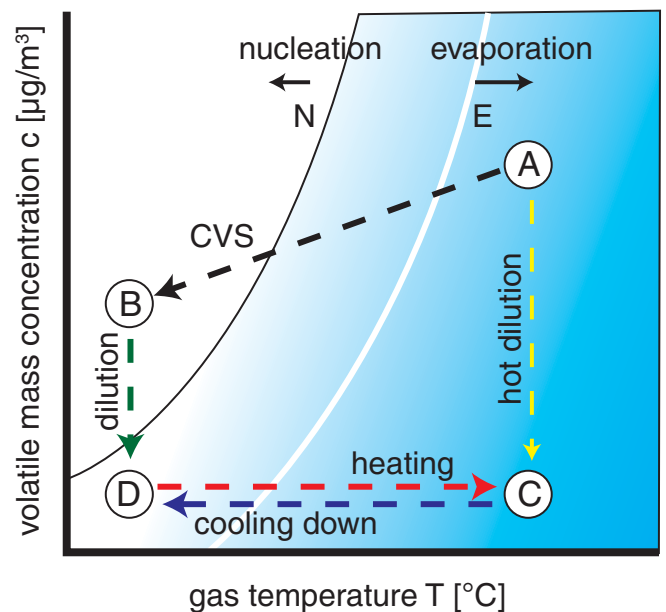


Figure 3. Schematic plot of mass concentration of a volatile compound vs. temperature of the surrounding gas

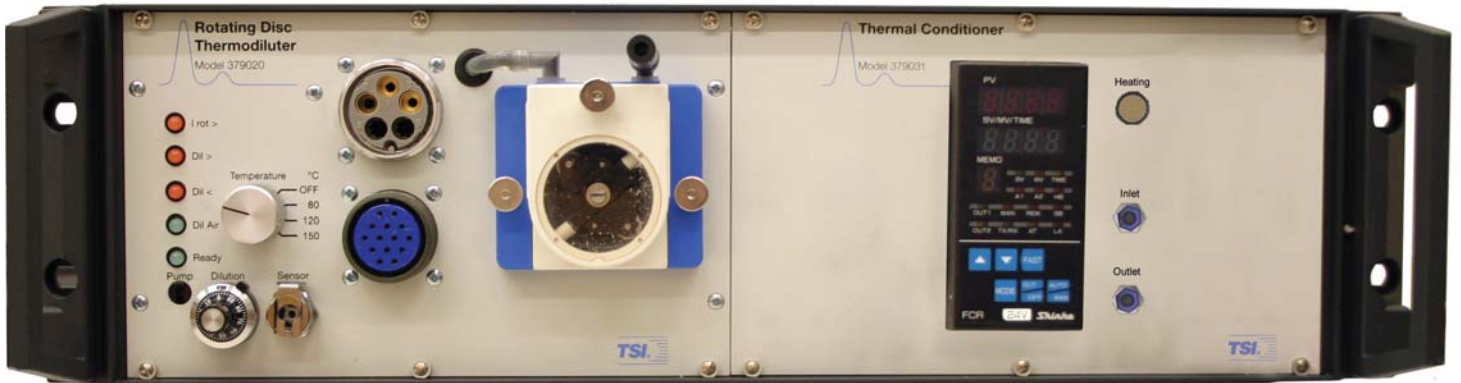
Dilution Unit

Conditioner Unit



379020

379030



379020

379031

Figure 4. Model 379020 shown with optional thermal conditioners (when ordered together, the control units are assembled and delivered in a 19-inch rack-mountable cabinet).

Choosing the Right Configuration

Applications

The Model 379020 and 379021 Rotating Disk Thermodiluters and Model 379030 and 379031 Thermal Conditioners can be used with a wide variety of TSI particle sizers and counters to characterize particle emissions. Typical emission measurement applications include:

- Diesel- and gasoline-engine emissions research
- Calibrating diesel and gasoline engines
- Characterizing steady-state and transient engine emissions
- DPF loading and particle slippage observations
- DPF regeneration studies and optimization
- Characterizing efficiency of particle traps and DPFs

- Studying emission-specific effects of different fuels, lubricants, and additives
- Measuring particle emissions of off-road diesel vehicles, ships, and locomotives
- Studying stack emissions of various fuels such as wood, oil, natural gas, propane, and coal
- Characterizing particle emissions from biomass combustion, garbage incinerators, agricultural burning, and stationary power generators
- Measuring particle number (PN) concentration as proposed by GRPE/PMP draft regulations R83 and R49¹

¹The GRPE/PMP draft regulations specify certain measurement criteria and procedures. Please refer to the draft regulations for details.



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