SAMPLING, DILUTING AND CONDITIONING FOR CHARACTERIZING PARTICLE EMISSIONS

THERMODILUTER AND THERMAL CONDITIONER

UNDERSTANDING, ACCELERATED

ROTATING DISK THERMODILUTERS

TSI Rotating Disk Thermodiluter is highly regarded in the field of particle emission measurement. It is especially suited for sampling, diluting, and conditioning exhaust particles from diesel- and spark-ignition engines, as well as performing stack emission studies. The Model 379020A features a separate diluter head and control unit that effectively dilutes the sample at the source (tailpipe, CVS tunnel, or stack) in order to preserve it for accurate measurement. Additional features of the rotating disk diluter include:

+ Adjustable dilution ratio with no tools or recalibration required
+ Accurate dilution over two full decades
+ Built-in heater with selectable temperatures to avoid condensation of water and volatile materials that can interfere with measurements
+ Rotating disk that is easy to clean and maintain
+ Robust disk coatings to reduce wear and improve lifetime
+ Rep e for added convenience and to reduced maintenance downtime
+ Improved design to simplify operation and to increase durability

Model 379020A Diluter Head

THERMODILUTER OPERATION

TSI's Model 379020A uses 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. As shown in Figure 1, the raw, undiluted exhaust emissions are sampled at a rate of approximately 2.0 L/min. 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 the flow rate of the dilution air:

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

This method accomplishes dilution of emissions in a range of over two decades with high precision and stability. The diluter controls and regulates flows, and indicates faulty conditions with alarm outputs.

To avoid condenstation of water and 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.

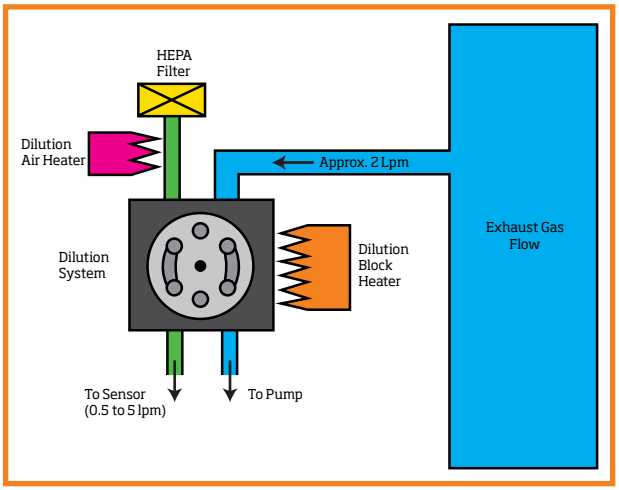

Figure 1. Diluter head block diagram


379020A

SOLUTIONS FOR ADVANCED ENGINE EMISSIONS MEASUREMENTS

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 a Thermal Conditioner for emission testing purposes Model 379030 uses a heated evaporation tube, which can be heated up to 400°C, to evaporate condensation particles 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. This thermal conditioner can be combined with the TSI Rotating Disk Diluter to lower the concentration range within acceptable limits of the measurement instrumentation and to thermally condition the sample. The combination of the Rotating Disk Thermodiluter Model 379020A, the Thermal Conditioner Air Supply Model 379030, (379020A-30) and the EECPC Model 3790 creates the particle number (PN) concentration measurement system compliant with GRPE/PMP 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

Figure 2 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.

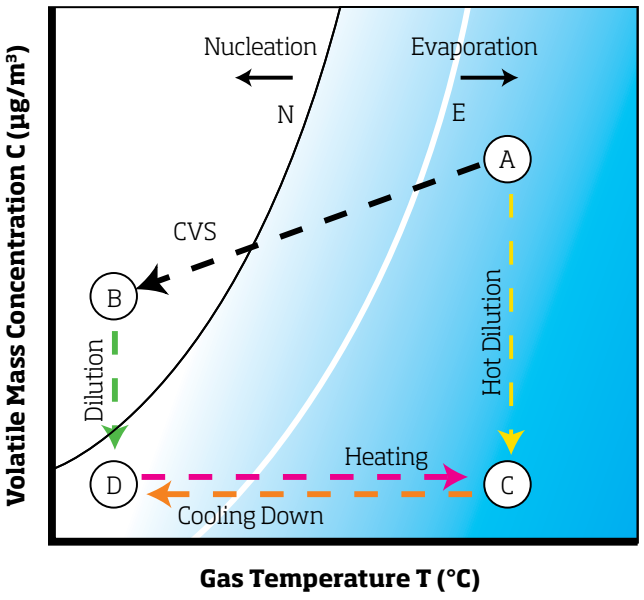

Figure 2. Principle of Thermaldilution

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. Combined unit 379020A-30

COMBINE MODEL 379020A WITH MODEL 379030 TO MEET GRPE/PMP REQUIREMENTS R83 AND R49

Applications

The Rotating Disk Thermodiluter Model 379020A and Thermal Conditioner Model 379030 (379020A-30) 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 defined by GRPE/PMP regulations R83 and R49[1]

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

SPECIFICATIONS

MODEL 379020A ROTATING DISK THERMODILUTER

Sample Inlet Conditions

Inlet Flow Rate	Approximately 2.0 L/min
Differential Pressure[2]	-100 to +100 mbar (with no effect on sample flows up to 5 L/min). Can be used with back pressure up to 300 mbar with reduced flows
Raw Gas Temp Range	0 to 200°C, noncondensing gas environment

Diluter

Separate Exhaust Probe with rotating disk diluter	Yes; heated diluter
Temperature Settings	OFF, 80, 120, or 150°C
Nominal Dilution Ranges[3]	
10-cavity Disk	15:1 to 300:1
8-cavity Disk	150:1 to 3,000:1

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 4 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.

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 (H x W x D)	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 379020A	Diluted gas outlet: 1/4" barb

DILUTER HEAD (COMES WITH 379020A)

Sample Inlet Tube

Stainless steel tube connected to dilution block via Swagelok® fitting (10 mm OD); exhaust probe can be connected directly to the tail pipe, CVS tunnel, or stack.

Raw gas outlet tube

6 mm stainless steel Swagelok® fitting

Connections to Control Unit

Pneumatic	Flexible, metal protective tube containing three silicon and one conductive plastic tube (3m length)
Electrical	Multi-pole electrical cable housed in a flexible, metal protective tube (3m length)

Dimensions (H x W x D)

180 mm × 280 mm × 90 mm (7 in. × 11 in. × 3.5 in.)

Weight

Approx. 2.5 kg (5.5 lb)

[2] Between raw gas channel and ambient conditions
[3] Dilution 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.

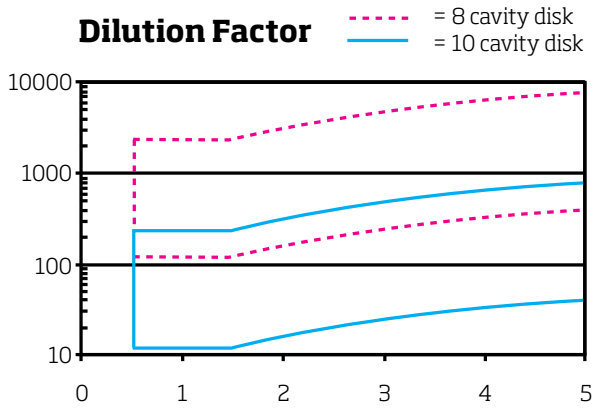

Figure 4. Dilution range as function of measurement channel, flow rate and number of cavities on the disk

MODEL 379030
THERMAL CONDITIONER

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 (H x W x D)	146 mm × 485 mm × 530 mm (5.75 in. × 19 in. × 20.9 in.); control unit occupies ½ the case; when ordered with the 379020A, the 379020A control unit occupies the other half
Weight	Approx. 13.5 kg (30 lbs) without 379020A; 17.5 kg (38.5 lbs) when combined with 379020A
Power Requirements	100 to 240 VAC, 50/60 Hz, 350W (without 379020; 460W when combined with 379020)

Specifications are subject to change without notice.

379020A-30

COMPATIBILITY

WITH A WIDE VARIETY OF
TSI PARTICLE SIZERS AND COUNTERS

EEPS™ Spectrometer (left) and CPC (right)

Compatible With:

+ 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)

TO ORDER

Rotating Disk Thermodiluters and Conditioners

Specify	Description
379020A	Rotating Disk Thermodiluter
379030	Thermal Conditioner Air Supply
379020A-30	Rotating Disk Thermodiluter with thermal conditioner air supply

Accessories

Specify	Description
379032A	Digital Control Unit
379027	Cyclone for 379020A
1137009	8 cavity disk - not calibrated (379020A)
1137008	10 cavity disk - not calibrated (379020A)
1137014	Dilution block - not calibrated (379020A)
1137015	Yearly Service Pack 379020A (Cal., pump, heat elements, filters, o-ring) disk sold separately
1137016	Yearly Service Pack 379020A and 379030 (Cal., pump, heat elements, filters, o-ring) disk sold separately

Upgrade

Specify	Description
399020-U05	Upgrade to 379020A Head (block, both disks, coupling and calibration) (2005 - 2006)
379020-U	Upgrade to 379020A Head (block both disks, coupling and calibration) (2007 - 2008)

Service and Calibration

Specify	Description
CL-379020A	Standard calibration 379020A (or disk)
CL-379030	Standard calibration 379030
RP-379020A	Repair and calibration 379020A
RP-379030	Repair and calibration 379030
PMP-379020A	PMP calibration 379020A

UNDERSTANDING, ACCELERATED

TSI Incorporated - Visit our website **www.tsi.com** for more information.

USA	**Tel:** +1 800 874 2811	**India**	**Tel:** +91 80 67877200
UK	**Tel:** +44 149 4 459200	**China**	**Tel:** +86 10 8219 7688
France	**Tel:** +33 1 41 19 21 99	**Singapore**	**Tel:** +65 6595 6388
Germany	**Tel:** +49 241 523030		

P/N 2980487 RevD

Printed in U.S.A.