ROTATING DISK THERMODILUTER MODEL 379020A

THERMAL CONDITIONER AIR SUPPLY MODEL 379030

OPERATION AND SERVICE MANUAL

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Manual History

The following is a history of the Model 379020A Rotating Disk Thermodiluter and Model 379030 Thermal Conditioner Air Supply Operation and Service Manual, P/N 6002726.

Revision	Date
A	Preliminary
B	October 2012

Warranty

Part Number 6002726 / Revision B / October 2012

Address TSI Incorporated / 500 Cardigan Road / Shoreview, MN 55126 / USA

Fax No. (651) 490-3824

E-mail Address particle@tsi.com

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(effective June 2011)

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Trademarks

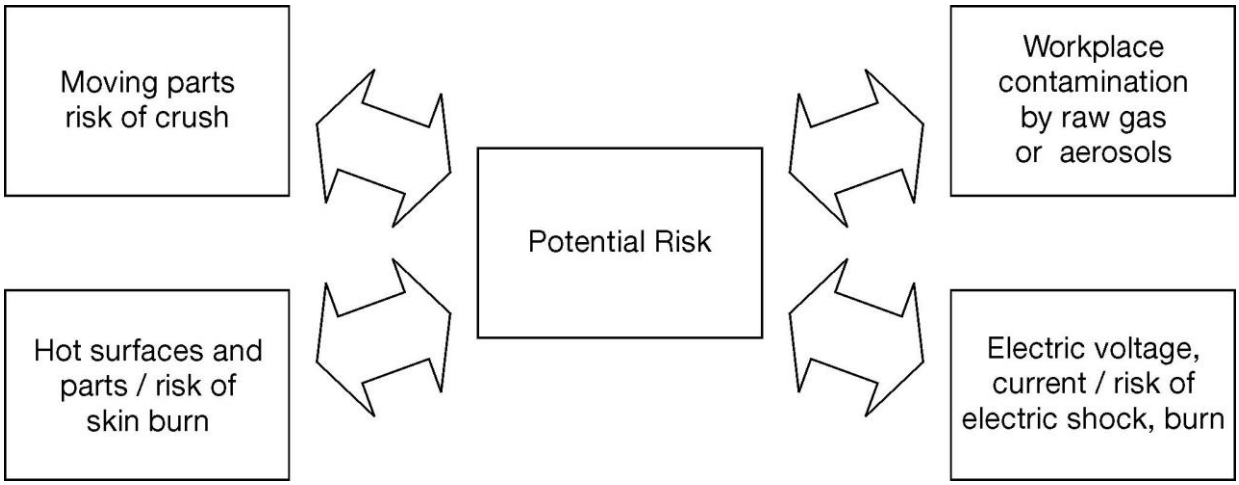
Safety

This section gives instructions to promote safe and proper operation of the Model 379020A Rotating Disk Thermodiluter and the Model 379030 Thermal Conditioner Air Supply. Samples of warnings and information on labels attached to the instrument chassis are also presented.

- Make sure that the raw aerosol pressure ***never*** exceeds 500 mbar (relative).
- Make sure that the pressures at the dilution air inlet and diluted measuring gas outlet always are within the limits of ±50 mbar (relative)
- Always use genuine replacement parts supplied by TSI (see Chapter 6, "Replacement Parts, Optional Accessories, and Service.").
- Always use heat protection gloves or allow the diluter block to cool down before any maintenance at the rotating disk or stator block unit.

Risk Types

The following diagram shows typical risks that could cause damage or injury while handling the Model 379020A Rotating Disk Thermodiluter or Model 379030 Thermal Conditioner Air Supply.



Labels and Explanations

When operating the Model 379020A with or without the Model 379030, you are always operating under certain risk factors as electricity, hot surfaces, moving parts and the aerosols which are processed by the Thermodiluter. Therefore, the Model 379020A includes several safety features. Nevertheless, some precautions still need to be taken to ensure safe and reliable operation. Listed labels, Cautions, and Warnings are explained in general, and the further specific labels refer to type of hazard and danger.

Note

N o t e
Note means this content describes important, useful, and/or necessary information to help guide you through the manual.

Caution

C a u t i o n
Caution means ***be careful***. If you ***do not*** follow the manual instructions you might result an instrument or accessories damage, but no human injury. Also Caution refers to important information about installation, operation, and maintenance.

Warning

W A R N I N G
Warning means that improper operation could cause a serious human or instrument damage or injury with consequence of irrevocable instrument damage.

Warnings for Model 379020A-30

Electric shock

Hazardous voltage. Contact may cause electric shock or burn. Turn off and lock out system power before servicing

Mechanical shock

Parts of the Model 379030 are thermally insulated by a quartz glass tube that may be damaged by intense mechanical shock. Handle the device with care.

	**Skin burn** Hot surface. Do ***not*** touch. To avoid possible skin burns, wear heat protection gloves or turn heating off and allow surfaces to cool down before servicing. The gloves enclosed with Model 379020A provide specified heat protection up to 150°C. Always use these gloves when handling the hot Thermodiluter head with removed heat protection hood, especially when exchanging rotating Thermodiluter disk or cleaning Thermodiluter block or disk surfaces. The Thermal Conditioner pipe of the Model 379030 is heated up to 400°C/752°F. Pipes and other parts on the back side of the device may be hot and must not be touched.

	**Crush** Crush hazard. Keep hands clear of moving parts. Lockout/tagout before servicing.

	**Aerosol** Aerosols containing invisible nanoparticles and toxic exhaust gases are handled. Diluted or undiluted aerosol may escape from the Model 379020A if the gas return ports are not properly connected. ***Never*** operate the system without having either the waste gas outlet connected to an offtake or to the waste gas inlet for returning the aerosol to the exhaust pipe.

Caution for Model 379020A-30

	Ensure that the specified raw gas pressure range of -30 mbar to 500 mbar is ***not*** exceeded. Too much negative pressure can lift the disk from the block leading to uncontrolled dilution conditions, while too high positive pressure may damage disk surface and enhance the drive torque over the motor torque maximum.

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About This Manual

This manual guides you through the unpacking, installation, start-up, operation, and maintenance procedures of the Model 379020A and the Model 379030 Thermal Conditioner Air Supply, which is a common accessory to the Model 379020A. In detail you will find information about the system as:

- Safety
- System Overview
- Unpacking
- Installation and Setup
- Operating Instructions
- Electrical Connections
- Maintenance
- Specifications
- Technical Data

The Model 379020A Rotating Disk Thermodiluter can be used without the Model 379030 Thermal Conditioner Air Supply. The Model 379030 Thermal Conditioner Air Supply has limited use unless it is paired with the Model 379020A.

Follow the instructions provided by this manual for safe and proper operation of the Model 379020A Rotating Disk Thermodiluter and the Model 379030 Thermal Conditioner Air Supply.

N o t e
Read this manual carefully before installing and operating the Model 379020A(-30). TSI accepts no liabilities if improper functioning, damages, or injuries are caused by ignoring the instructions in this manual.

Related Product Literature

- **Model 3936 SMPS™ Scanning Mobility Particle Sizer™ Instruction Manual** (part number 1933796) TSI Incorporated
- **Model 379032A Digital Control Unit User's Manual** (part number 6004321) TSI Incorporated
- **Model 3091 Fast Mobility Particle Sizer™ Spectrometer Operation and Service Manua**l (part number 1980520) TSI Incorporated
- **Model 3790 Engine Exhaust Condensation Particle Counter Operation and Service Manual** (part number 1933802) TSI Incorporated

Submitting Comments

TSI values your comments and suggestions on this manual. Please use the comment sheet on the last page of this manual to send us your opinion on the manual's usability, to suggest specific improvements, or to report any technical errors.

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CHAPTER 1

System Overview

Dilution Principle of the Model 379020A-30 Rotating Disk Thermodiluter with Conditioning Air Supply

This section details:

Principle

The Model 379020A Rotating Disk Thermodiluter is especially suited for sampling, diluting, and conditioning exhaust particles from diesel and spark-ignition engines, light oil burners, or wood or coal combustion, as well as performing stack emission studies. It may also be used for gases or aerosols emerging from other processes. The Model 379020A features a separate exhaust probe and control unit that effectively dilutes the sample at the source (tailpipe, CVS tunnel, or stack) in order to preserve it for accurate measurement.

Model 379020A

The Model 379020A Rotating Disk Thermodiluter features a separate diluter head and control unit, which allows the sample to be diluted and thermally conditioned at the point of measurement (i.e. tailpipe, CVS tunnel, or stack). It also features a variable dilution ratio that is adjustable from 15:1 to 3000:1 and selectable heated diluter temperatures up to 150°C to avoid measurement of condensed volatile materials. Both dilution air and Thermodiluter block can be heated to evaporate liquid particles before and during dilution to a concentration which is as low as the former liquid particle matter does not condense out anymore.

The raw, undiluted exhaust emissions are sampled at a rate of approximately 1.0 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. This method provides dilution of emissions in a range of over two decades with high precision and stability. The instrument controls and regulates flows, and indicates faulty conditions with alarm

outputs. To avoid measuring condensed volatile materials, the make-up dilution air and the dilution block can be heated. Temperature settings are controlled via the control unit. Lower temperatures allow the study of volatile fractions.

The diluting parts, i.e., heated Thermodiluter block and rotating disk are placed in the Thermodiluter head which is an external part of the device. The Thermodiluter head can be connected as close as possible to the source of the aerosol. It is connected to the control unit by one electrical and one pneumatic 3-meter long connection.

The power supply, all controls and signal LEDs, and the control electronics are located in the control unit. Filtered dilution air is sent to the Thermodiluter head, and a membrane pump sucks the raw aerosol through the Thermodiluter block. The rotational speed of the Thermodiluter disk depends on the dilution air flow, which also is determined in the control unit.

The complete system containing control unit (left), pneumatic and electrical connections, and Thermodiluter head (right) are shown in Figure 1-1.

Figure 1-1
Model 379020A Thermodiluter Control Unit, Connections and Diluter Head

Model 379030

The Model 379030 Thermal Conditioner Air Supply can be combined with the Model 379020A to thermally condition the sample in order to eliminate the semi-volatile and volatile fractions in order to measure only the solid particle emissions. The Model 379030 uses an evaporation tube to heat the sample up to 400ºC, which effectively eliminates volatile compounds that may have formed in the exhaust as it cools or becomes diluted.

Both the Model 379020A and Model 379030 can be controlled using the Model 379032A Digital Control Unit, which provides remote control of the system and software for handling data.

All of these components can be integrated into a 19 inch test bench equipped with Ethernet connections.

Model 379020A-30

The combination of a Model 379020A Rotating Disk Thermodiluter, a Model 379030 Thermal Conditioner Air Supply, and a Model 3790 EECPC creates the particle number (PN) concentration measurement according to the GRPE/PMP regulations R83 and R49, and is fully compliant with the EURO 5 specifications.

Thermo dilution using both the Model 379020A and Model 379030 separates sampling, dilution, and conditioning of the aerosol into the following steps:

- Primary dilution of combustion engine emissions from a tail pipe or CVS with the Model 379020A. The Model 379030 generates the primary dilution air for the diluter with a calibrated and controlled flow of 1.5 L/min.
- Removal of volatile particles in the evaporation tube of the Model 379030 thermal conditioner where the evaporation temperature can be adjusted up to 400°C, which is the recommended heating temperature according to GRPE-regulation = 300 °C. No re-condensation takes place in the cooling down zone, assuming the sampled aerosol is below the dew point after primary dilution.
- Secondary dilution from 1 to 11 in a mixing chamber that minimizes thermophoretic losses. The primary diluted measuring gas from the Model 379020A is diluted with secondary dilution air generated in the Model 379030. Flow is adjustable from 0 to 15 L/min corresponding to a dilution factor range of 1 to 11. The total measuring gas flow, up to 16.5 L/min, enables the user to connect instrumentation, which use higher gas flow. The Model 379020A (without the 379030) diluted gas flow is limited to 5 L/min.

The Model 379020A Rotating Disk Thermodiluter is compatible with a wide range 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)

Figure 1-2
Model 379020A-30 Thermodiluter Control Unit, Connections, and Thermodiluter Head and Thermal Conditioner Air Supply

Applications

Model 379020A

Usually instruments which determine nanoparticle number concentrations have specific measuring ranges, wherein measurements are possible or best accuracy of the determined values is reached. With the continuously variable Rotating Disk Thermodiluter, it is possible to adapt particle number concentrations to the measuring range of the applied particle sensor.

Particles in the nanometer range strongly tend to coagulate which means smaller primary particles meet together and build larger secondary particles, especially if the particle concentrations are high. This leads to smaller particle numbers and a displacement of the particle size distributions. In the Thermodiluter head of the Model 379020A the particle concentrations are reduced as close to their emission source as possible before being transported to the measuring sensor and the coagulation effects are reduced significantly.

Depending on fuel and combustion parameters, such as air humidity, temperatures, and residual times, combustion generated aerosols mostly not only contain CO_2 and solid particles, but also water vapor and other volatile components which may condense out if the temperatures drop to ambient conditions, resulting in liquid particles which may damage or pollute the measuring sensors. In the Model 379020A Thermodiluter head these components are at first evaporated and then diluted. At low concentrations, they remain dissolved in the surrounding gas and will; therefore, not affect solid particle measurements anymore.

Model 379030

The Model 379030 Thermal Conditioner Air Supply is combined with the Model 379020A Rotating Disk Thermodiluter (379020A-30) to lower the concentration range within acceptable limits of the measurement instrumentation and to thermally condition the sample.

Hot vehicle exhaust contains both solid particles (such as carbonaceous soot and ash) and vapors of volatile substances (such as water, sulfate, and hydrocarbons). When a standard dilution tunnel (like a constant volume sample (CVS) tunnel) is used for emissions testing, the volatile substances may condense into nanodroplets, which are detected as particles together with nonvolatile solid particles. To measure only the solid particle fraction, it is necessary to condition the sample thermally to eliminate the volatile fraction. The Model 379030 Thermal Conditioner Air Supply uses 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 volatile fractions.

Model 379020A-30

The Model 379020A Rotating Disk Thermodiluter and Model 379030 Thermal Conditioner (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 proposed by GRPE/PMP draft regulations R83 and R49[1].

Functionality

The Model 379020A Rotating Disk Thermodiluter can be combined with the 379030 secondary dilution system (379020A-30) and the 379032A digital control unit. All these components are mounted in standard 19" cases and can easily be integrated in a test bench equipped with 19" racks and Ethernet connections.

Benefits

Model 379020A

- Continuously variable aerosol dilution
- 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
- Rotating disk that is easy to clean and maintain
- Robust disk coatings to reduce wear and improve lifetime
- Replaceable disks are available for added convenience and to reduced maintenance downtime
- Improved design to simplify operation and to increase durability
- Dilution takes place close to the aerosol source
- Flexible and simple operation
- Simple integration into standard 19" racks
- Low maintenance, 1000 operation hours between recommended service
- Raw aerosol pressure up to 400 mbar (relative)
- Deviation of non-calibrated disks max. (4% lower / 8% upper dilution range)
- Raw gas return to the exhaust or any offtake
- Full remote control available with the Model 379032A Digital Control Unit (optional)

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

Model 379030

- 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

System

The Model 379020A is power supplied by one phase electricity. It can be operated with measuring sensors sucking their needed amount of dilution air to which the suitable quantum of raw gas is added to reach the desired dilution. In combination with the 379030 secondary dilution and condition unit, dilution air is fed to the Model 379020A Rotating Disk Thermodiluter, resulting in a certain diluted aerosol flow available for any measurements.

This external dilution air supply can also be done using compressed air and a simple mass flow controller, if no secondary dilution is needed but the pressure drop over the Model 379020A Rotating Disk Thermodiluter system is too high for the diluted aerosol to be drawn by the measuring sensor(s) downstream.

Both 379020A and 379030 (or together as the 379020A-30) can be operated manually or by a 379032A digital control unit which can be remote controlled via Ethernet.

An electrical block diagram is sketched in Figure 1-6. All signals entering and leaving control unit and Thermodiluter head are shown. Figure 1-7 shows all pneumatic components of the Model 379020A system. The pathways of dilution air, raw gas and diluted measuring gas are visible. The numbers and letters in small circles refer to the description in Figure 1-7 where all controls, ports, and removable Thermodiluter components are described.

Definitions

Air Supply	Part of 379030, supply of primary and secondary dilution air.
Evaporation Tube	Stainless steel tube with heater on the back side of 379030, for heating up primary diluted measuring gas.
Measuring gas	Primary or secondary diluted aerosol from the emission source (combustion engine or CVS).
Primary dilution	Takes place in 379020A or other separate diluter before the measuring gas enters into the evaporation tube.
Secondary dilution	Dilution of the primary diluted and thermally conditioned measuring gas on the outlet of the evaporation tube.
Thermal conditioner	Part of 379030, evaporation tube with electronic temperature control in the measuring gas.

Abbreviations

CVS	Constant Volume Sample, full stream dilution tunnel in vehicle test benches.
DF	Dilution Factor in secondary dilution: DF = $(Q_{AS} + Q_{MD})/ Q_{MD}$
LED	Light Emitting Diode.
Lpm *or* L/min	Liters Per Minute. Volume gas flow at normal conditions 1013 mbr/0°C.
Q_{MD}	Flow of the primary diluted measuring gas from the evaporation tube.
Q_{AS}	Flow of the secondary dilution air from the air supply part of 379030.
Q_{MG}	Flow of the secondary diluted measuring gas to the connected instrumentation.
Q_{EX}	Flow of the secondary diluted measuring gas which is not consumed by the instrumentation.
ThC	Thermal Conditioner.

Flow Schematics

The Model 379020A has multiple flow paths. Figure 1-3 is the raw gas path for the 379020A (applies also for 379020A-30). Figure 1-4 is the path of the diluted sample. Figure 1-5 shows the sample air path (diluted) for the combined 379020A-30 system.

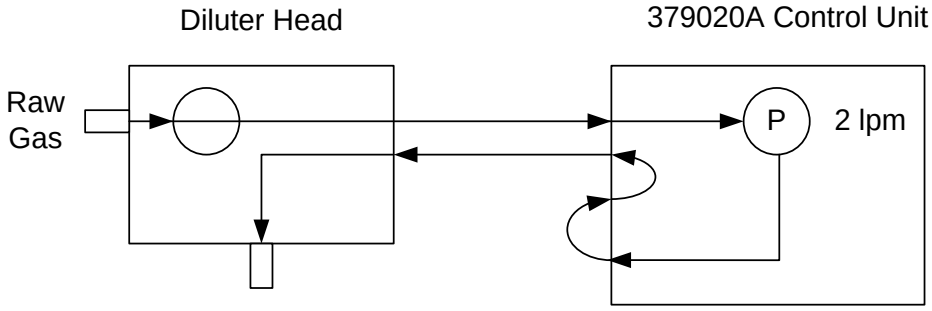


Figure 1-3
Raw Gas Path for 379020A

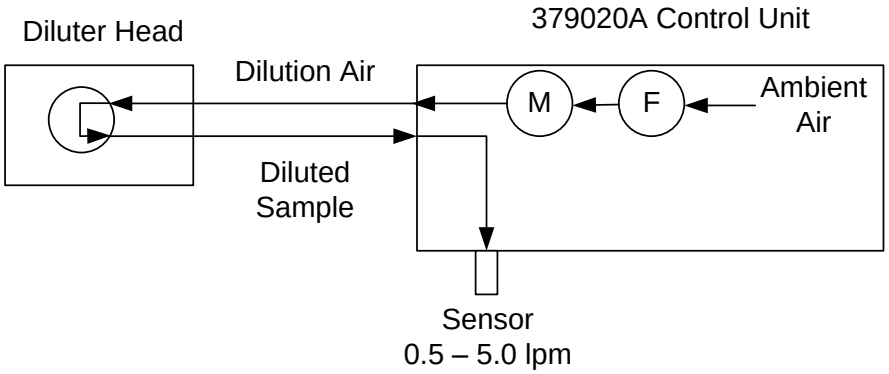


Figure 1-4
Diluted Sample (379020A in standalone mode)

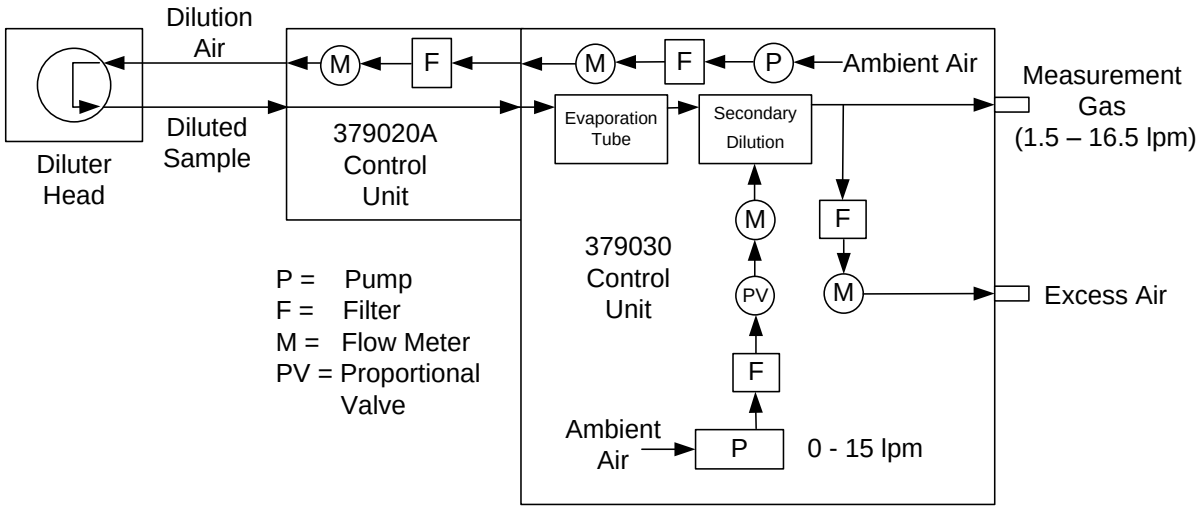


Figure 1-5
Sample Air Path (diluted) for the Combined 379020A-30 System

Block Diagrams

Electrical Diagram

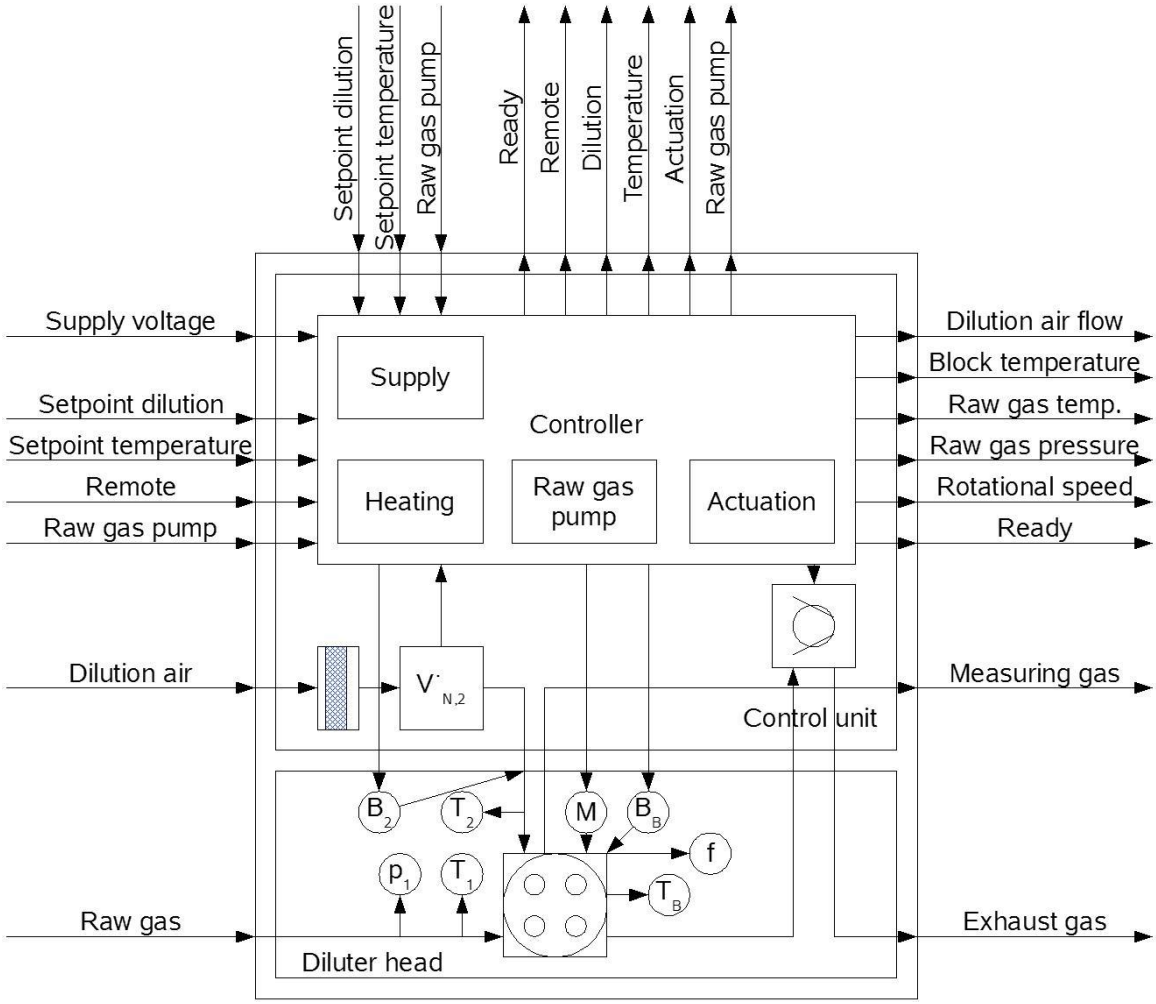
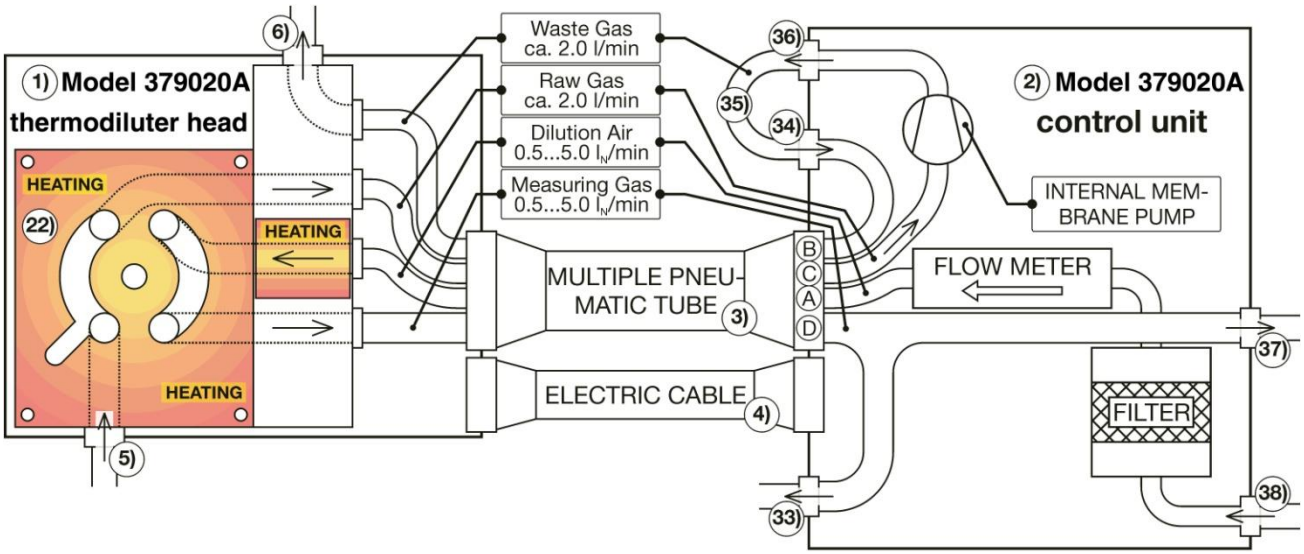


Figure 1-6
Function Principle—Electrical Block Diagram 379020A

Pneumatic Diagram



1) 379020A Thermodiluter head
2) 379020A control unit
3) Multiple pneumatic tube between Thermodiluter head and control unit
tube A) Particle free dilution air duct to the Thermodiluter head
tube B) Waste gas return to the Thermodiluter head
tube C) Raw gas duct from the Thermodiluter head to the membrane pump inside the control unit
tube D) Diluted measuring gas return to the Thermodiluter head
4) Electrical cable between Thermodiluter head and control unit
5) Raw gas inlet
6) Waste gas outlet from Thermodiluter head to the exhaust pipe
22) Thermodiluter Block
33) Self-sealing quick coupling for measuring gas output to sensor(s)
34) Quick coupling for waste gas inlet for return to the Thermodiluter head
35) Waste gas return bridge
36) Undiluted waste gas outlet to exhaust
37) Self-sealing quick coupling for measuring gas outlet to sensor(s) or secondary dilution
38) Quick coupling for dilution air input

Figure 1-7
Function Principle—Pneumatic Block Diagram

Thermodiluter Elements

Components

The Model 379020A consists of two main parts, the Model 379020A Thermodiluter head 1) and the Model 379020A control unit, which are connected by a multiple pneumatic tube 3) and an electrical cable 4). These parts are shown in Figure 1-8.

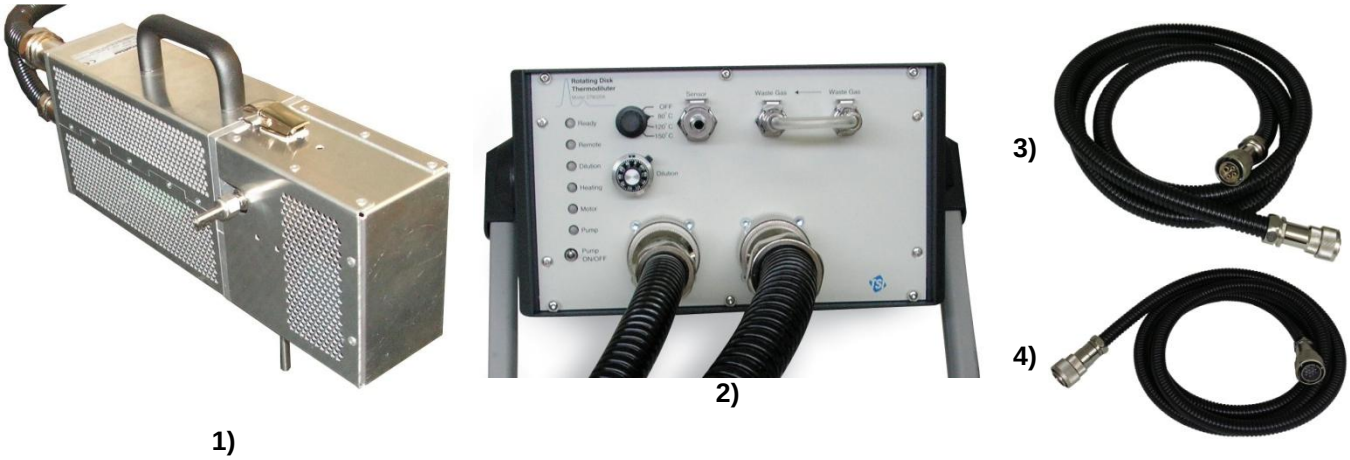


Figure 1-8
379020A Thermodiluter Head 1), Control Unit 2), Pneumatic 3) and Electric Connection 4)

Operating Elements of Model 379020A Thermodiluter Head

Figure 1-9 shows all ports and functional elements which are visible when the hot parts protection hood 8) is mounted and the device is ready for dilution.

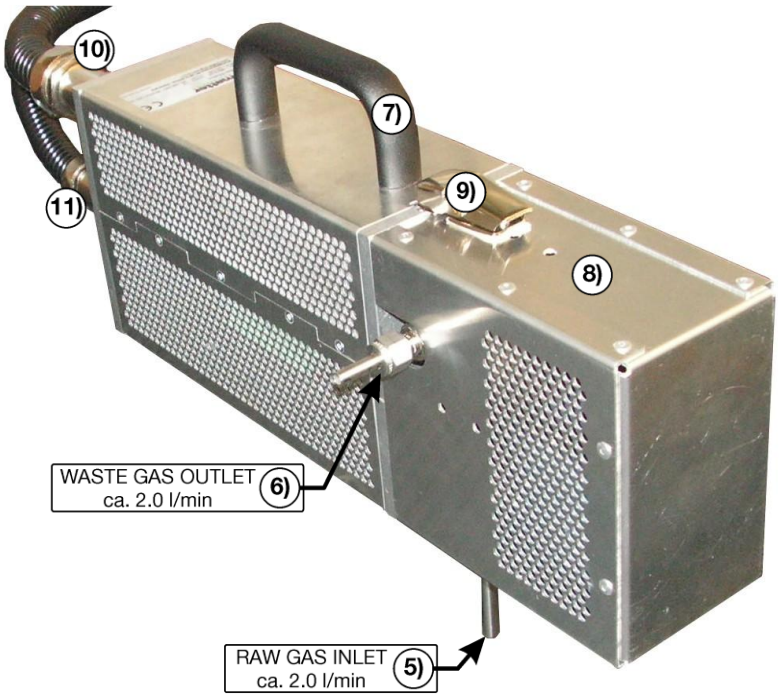


Figure 1-9
Thermodiluter Head Overview

5) Raw gas inlet into Thermodiluter head:10 mm Swagelok® fitting

6) Undiluted waste gas outlet from Thermodiluter head to the exhaust pipe: 6 mm Swagelok® fitting

7) Handle

8) Hot parts protection hood

9) Protection hood latch

10) Connector to multiple pneumatic tube 3)

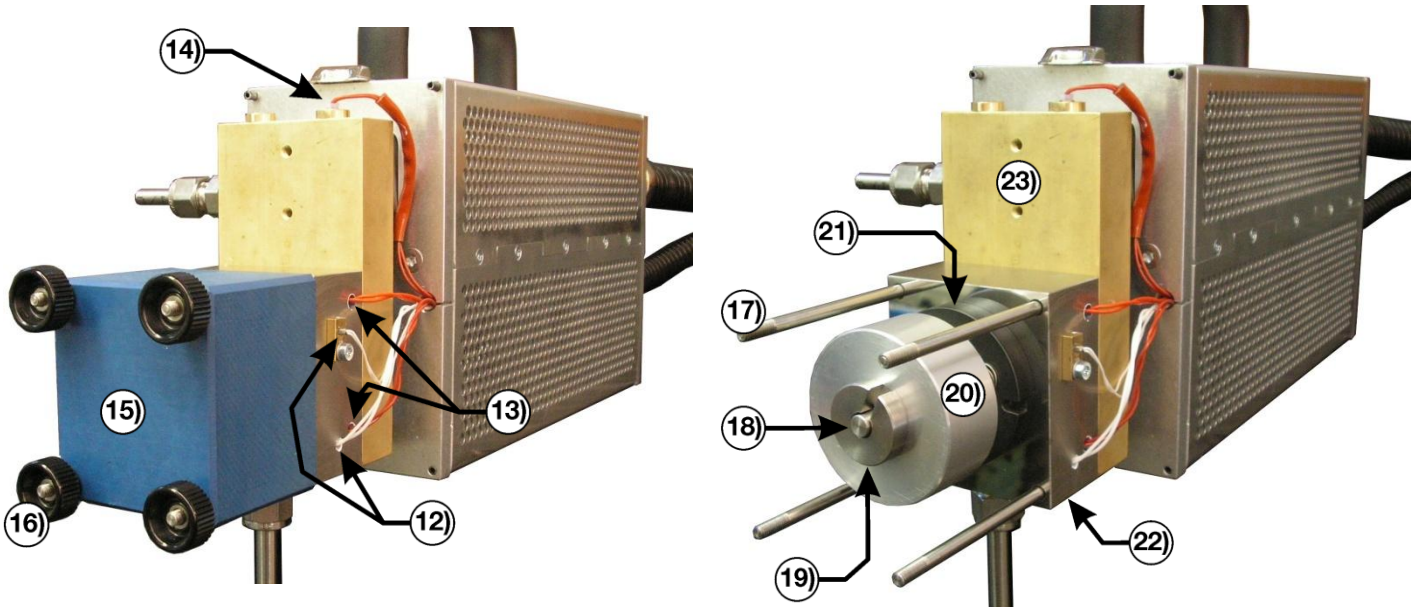
11) Connector to electrical cable 4)

Protection Hood Removed

Figure 1-10 explains the diluting components which are accessible with the hot parts protection hood 8) removed.

W A R N I N G

Skin Burn
Dilution block and other parts of the Thermodiluter head are heated up to 150°C/302°F. The gloves enclosed with Model 379020A provide specified heat protection up to 150°C. ***Always*** use these gloves when handling the hot Thermodiluter head with removed heat protection hood, especially when exchanging rotating Thermodiluter disk or cleaning Thermodiluter block or disk surfaces.



12) Temperature sensors
13) Thermodiluter block heating cartridges
14) Dilution air heating cartridge
15) Pressure compensation cap
16) Cap holder nuts
17) Cap holder bolts
18) Thermodiluter disk drive shaft
19) Fast lock ring
20) Thermodiluter disk fixation cap
21) Rotating Thermodiluter disk
22) Thermodiluter block
23) Aerosol/air duct block

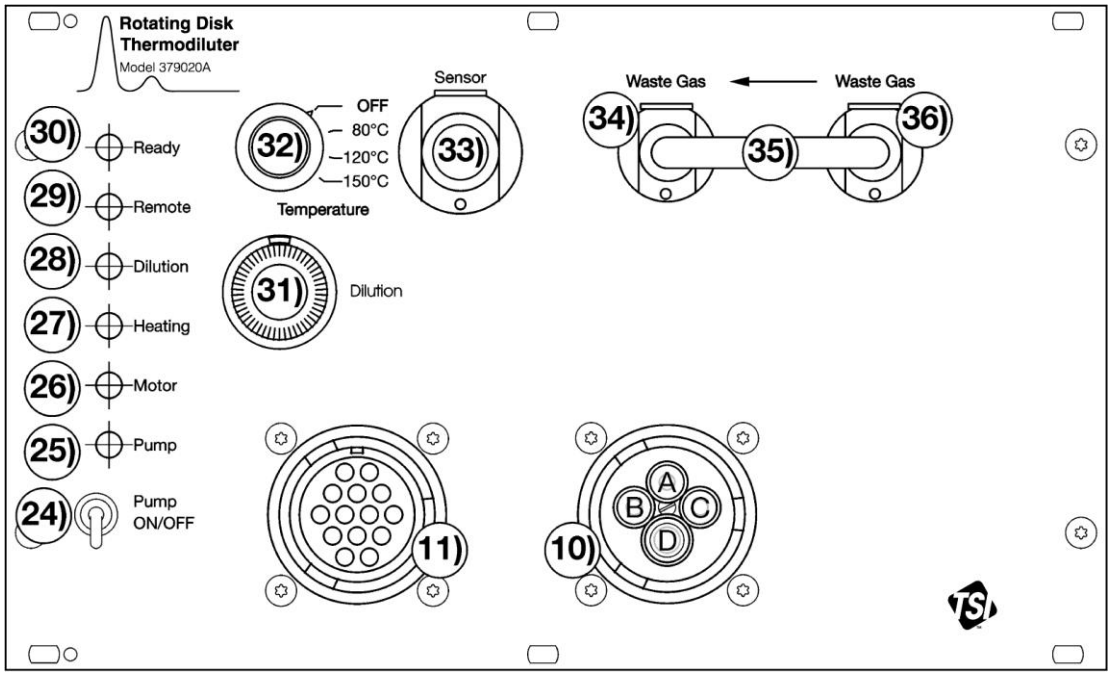
Figure 1-10
Thermodiluter Head with Removed Heat Protection Hood

Operating Elements of Model 379020A Control Unit

In Figure 1-11 all ports and operating elements situated at the front side of the control unit are shown. The waste gas return bridge 35) is not exactly a part of the control unit but is always set between the two waste gas ports in normal use except the control unit is connected to another offtake than the exhaust pipe where the undiluted waste gas usually is fed back.

Figure 1-12 and Figure 1-13 show the connections at the back side of the control unit. The control unit is built into a 3U/42HP plug-in case which can be integrated into the 19" case of the secondary dilution unit ASET15 or into a laboratory case as a stand-alone unit.

Front Side



10) Multiple pneumatic tube connection

11) Electrical cable connection

24) Raw gas pump switch: up: ON down: OFF

25) Raw gas pump LED: green: running red: error dark: OFF

26) Actuation motor LED: green: rotating red: error dark: motor stopped

27) Block and dil. air heating LED: green: OK red: error dark: OFF orange: heating up

28) Dilution factor LED: green: OK red: dilution factor out of specified range

29) Remote LED: green: device is remote controlled

30) All signals ready LED: green: OK dark: at least one signal not OK

31) 10 turn potentiometer for dilution setting

32) Dial for temperature setting of block and dilution air heating

33) Self-sealing quick coupling for measuring gas output to sensor(s)

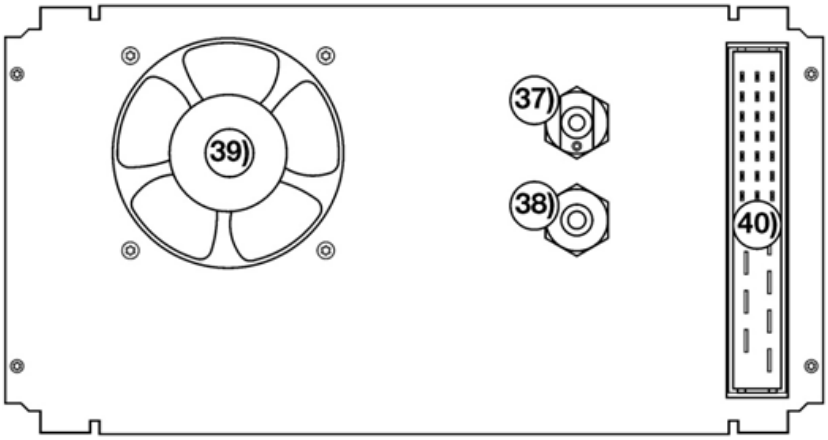
34) Quick coupling waste gas inlet for return to the Thermodiluter head

35) Waste gas return bridge for connection to another offtake than the exhaust pipe

36) Quick coupling for waste gas outlet

Figure 1-11
Front View 379020A

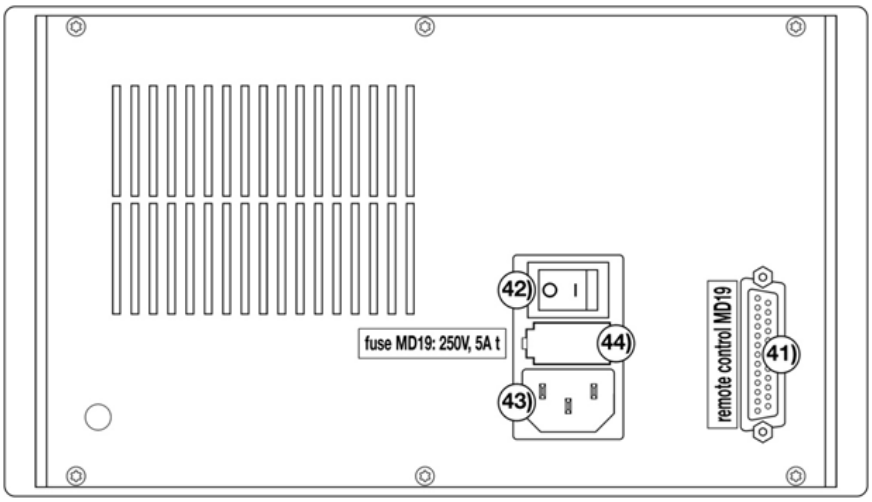
3U / 42HP Plug-In Back Side



37) Self-sealing quick coupling for measuring gas output to sensor(s) or secondary dilution
38) Quick coupling for dilution air input to 379020A Rotating Disk Thermodiluter
39) Ventilator
40) Connector to electronic circuit

Figure 1-12
Back View 379020A Plug-in Unit

Laboratory Case Back Side



41) Remote control interface connector: 25 pin D-Sub female
42) Mains switch
43) Mains connector
44) Fuse MD19. 250 V, 5.0 A, t

Figure 1-13
Back View 379020A Laboratory Case

Important Remarks

The Model 379020A Rotating Disk Thermodiluter is constructed to dilute exhaust or flue gas from combustion processes in diesel engines, light oil burners, or wood or coal combustion. It may also be used for gases or aerosols emerging from other processes. The dilution ratio is specified for gases and aerosols containing particles in the size range 10...1000 nm.

W A R N I N G

Electric Shock
When in operation, any electrical equipment can produce dangerous voltages. Ignoring these warnings may result in serious injury or damage of the equipment. It is mandatory that only suitably qualified personnel are allowed to work on this instrument. Satisfactory and safe operation of this instrument necessitates proper handling in transportation, storage, and installation as well as careful control and maintenance.

W A R N I N G

Skin burn
Dilution block and other parts of the Thermodiluter head are heated up to 150°C/302°F. The gloves enclosed with Model 379020A provide specified heat protection up to 150°C. Always use these gloves when handling the hot Thermodiluter head with removed heat protection hood, especially when exchanging rotating Thermodiluter disk or cleaning Thermodiluter block or disk surfaces.

W A R N I N G

Aerosol
Diluted or undiluted aerosol may escape from the Model 379020A if the gas return ports are not thoroughly connected to an offtake. ***Never*** operate the system without having either the waste gas outlet connected to an offtake or to the waste gas inlet for returning the aerosol to the exhaust pipe.

C a u t i o n

Ensure that the specified raw gas pressure range of -30 mbar to 500 mbar is ***not*** exceeded. Too much negative pressure can lift the disk from the block leading to uncontrolled dilution conditions, while too high positive pressure may damage disk surface and enhance the drive torque over the motor torque maximum.

CHAPTER 2

Unpacking

Use the information in this chapter to unpack the Model 379020A Rotating Disk Thermodiluter.

Packing List

Table 2-1 shows the components shipped with the Model 379020A Rotating Disk Thermodiluter. Contact TSI immediately if any components are missing.

Table 2-1
Model 379020A Rotating Disk Thermodiluter Packing List

Qty.	Description	
1	Model 379020A control unit	
1	Waste gas return bridge, mounted on control unit	
1	Model 379020A Thermodiluter head	
1	10 cavities Thermodiluter disk for lower dilution range, mounted on Thermodiluter head	
1	Model 379020A multiple pneumatic tube between head and control unit, length 3 m	
1	Model 379020A electrical cable between Thermodiluter head and control unit, length 3 m	
1	Model 379020A accessories box, containing:	
1	8 cavities Thermodiluter disk for upper dilution range	
1	Operating manual Model 379020A-30	
2	Set of 2 calibration certificates for both Thermodiluter disks (not if Model 379020A is integrated into a ViPR system calibrated according PMP standards)	
1	IEC power cord	for Switzerland for Germany, France, Italy, Korea, etc. for USA, Canada, Japan, etc. for United Kingdom, etc
1	10 mm outer diameter stainless steel tube for connecting the Thermodiluter head raw gas inlet to the aerosol source, length 200 mm	
1	6 mm outer diameter stainless steel tube for connecting the Thermodiluter head waste gas outlet to the waste gas return, length 200 mm	

Qty.	Description
1	Pneumatic connection plug for self-sealing measuring gas outlet coupling
8	O-ring kit for sealing pneumatic connector
1 pr	Heat protection finger gloves

Table 2-2
Model 379030 Thermal Conditioner Air Supply Packing List

Qty.	Description	
1	Model 379030 control unit	
1	Model 379030 accessories box, containing:	
1	Screwdriver for secondary dilution mixing chamber 31	
1	Operating manual (this manual)	
1	Gas connectors for 4 mm ID tubes	
1	IEC power cord	for Switzerland for Germany, France, Italy, Korea, etc. for USA, Canada, Japan, etc. for United Kingdom, etc
1	Swagelok nut 8 mm OD SS-8M2-1	
1	Stainless steel tube 8/6 mm x 70 mm length	
1	Swagelok PTFE front ferrule 8 mm T-8M3-1	
1	Swagelok PTFE back ferrule 8 mm T-8M4-1	

CHAPTER 3

Installation and Setup

This chapter describes the installation and setup of the Model 379020A Thermodiluter and the Model 379030 Thermal Conditioner. If your system includes the Model 379020A only, follow only those instructions relevant to that device.

Installation and Setup Steps

1. If necessary, install the Model 379020A Thermodiluter in the 19” rack of the Model 379030 Thermal Conditioner. This step is necessary only if you are field-installing the Model 379020A.
2. Prepare the Thermodiluter disk and block.
3. Connect the pneumatic and electrical cables of the Thermodiluter head to the Model 379020A control unit.
4. Connect power cord(s) to the control unit(s).
5. Install the Thermodiluter Head in the exhaust pipe or stack.
6. Connect the sampling probe to the Thermodiluter head and the exhaust gas tubing to an available offtake.
7. If the instrument is to be remotely controlled, refer to Model 379032A Digital Control Unit Manual (TSI P/N 6004321) for instructions on connecting the Model 379032A Digital Control Unit to the Model 379020A (and 379030).
8. Connect an appropriate particle sensor to the Model 379020A control unit or the Model 379030 control unit.

N o t e
Numbers – e.g. 31) = dilution setting potentiometer – refer to the operating elements illustrated in Chapter 1, "System."

Install Control Unit in 19” Rack (Optional)

If the Model 379030 is part of your system and the Model 379020A and Model 379030 was not factory installed, install the Model 379020A Thermodiluter control unit into the 19” rack of the Model 379030 Thermal Conditioner as follows:

1. Remove the four retaining screws from the 379020A Thermodiluter control unit (see Figure 3-1).
2. Hold the back of the control unit housing and carefully pull the Thermodiluter module forward and free of the housing (see Figure 3-2).
3. Remove the four retaining screws from the left side of the Model 379030 Thermal Conditioner housing (see Figure 3-3) and discard the blank cover.
4. Carefully slide the 379020A Thermodiluter module into the Model 379030 Thermal Conditioner housing (see Figure 3-4).
5. Make certain the aerosol connections on the back of the Thermodiluter align with the Model 379030 Thermal Conditioner housing (see Figure 3-4). The quick connect coupling on the back of the Thermodiluter module used for diluted gas opens and closes automatically when the Thermodiluter is installed in the Model 379030 housing.

Connect Pneumatic and Electrical Cables

Connect the pneumatic and electrical cables between the 379020A Thermodiluter control unit and the Thermodiluter head. These cables have bayonet connections, and the cables can be connected in either direction.

To use a bayonet connection:

1. Align the tabs of the cable connector with the cutouts on the connectors off the control unit and the Thermodiluter head.
2. Press in on the cable connector and turn the connector to the right ¼ turn, to secure the connection.
3. Check the connection by gently pulling on the connector.

Connect Power

Connect power to the control unit as follows:

1. Connect the female end of the power cord (see accessories kit) to the connector on the back of the control unit housing.
2. Connect the male end of plug to a suitable power outlet.

The main switch is located on the back of the housing, just below the power connection. The main fuse (or fuses) is (are) located between the switch and the power connection.

Supply voltage:	90 to 240 V, 50/60 Hz, max. 300 VA
Fuse type:	Slow blow fuse 250 V, 5 A, t, 5 x 20 mm

W A R N I N G
Replace blown fuses only with the same type of fuse. If a fuse repeatedly blows, the instrument must be returned to TSI for repair.

Mounting of the Thermodiluter Head

The Thermodiluter head is designed for direct mounting to a tail pipe or stack. Tests of different sampling probes have shown that particle loss due to anti-isokinetic effects can be neglected for all types of probes shown in Figure 3-1 in nanoparticle measurement in the size range from a few tenths to a few hundred nm.

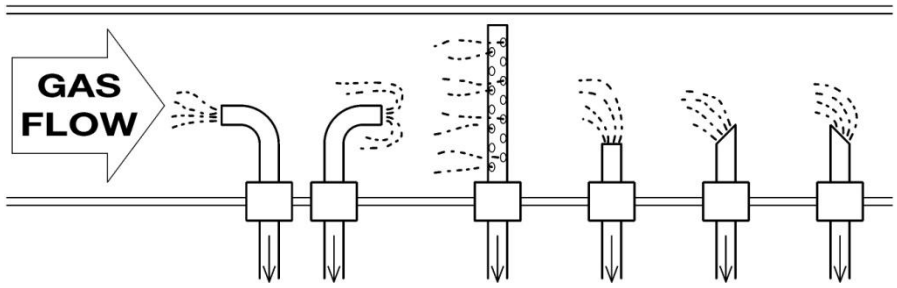


Figure 3-1
Different Types of Sampling Probes

An example for how to mount the Thermodiluter head is shown in Figure 3-2. The sample inlet tube should be kept as short as possible while the raw gas return path can be longer.

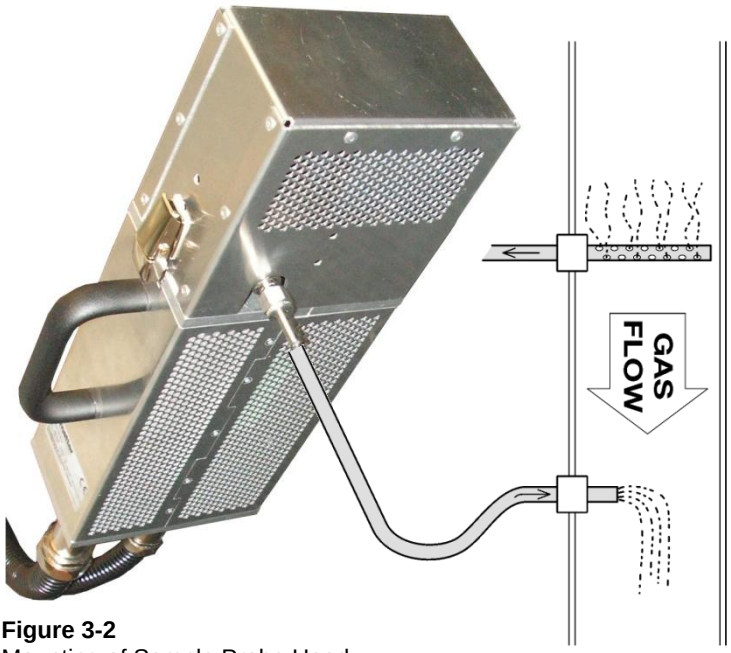


Figure 3-2
Mounting of Sample Probe Head

More attention should be paid to inhomogeneous particle concentration across the tail pipe or stack diameter. To compensate its influence, a sampling probe according to Figure 3-2 is recommended. The exhaust is sampled through holes of 1...2 mm diameter for averaging the sampling across the tail pipe or stack diameter.

Connect Raw Gas Output

Connect the undiluted gas output on the pump of the Model 379020A and the excess measuring gas output of the Model 379030 (if used) to an exhaust suction system.

Notes: The two gases must be independently connected to the exhaust suction. The pulsation of the 379020A pump might have an influence on the flow regulation in the air supply of the 379030.

When the 379020A exhaust probe is connected to undiluted engine exhaust the tube connected to the 379020A pump outlet can fill with liquid from condensation when the exhaust is cooled down.

Remote Operation

If the instrument is to be remotely controlled, refer to the Model 379032A Digital Control Unit User's Manual (TSI P/N 6004321) for instructions on connecting the Model 379032A Digital Control Unit to the Model 379020A (and 379030).

Aerosol Tubing

The Model 379020A Rotating Disk Thermodiluter is using the principle of hot dilution which means that the sample probe head block and dilution air are heated up to temperatures of 80°C, 120°C or 150°C, adjustable on the dial 32). This method keeps evaporated liquids above their dew points, during and after the dilution, and avoids the generation of volatile nanoparticles by nucleation. Its main advantage is that the diluted aerosol is not mixed with additional nanoparticles caused by the sampling and dilution process. The diluted aerosol provides, therefore, genuine information about the particles stemming from the combustion process.

Exhaust of combustion processes can pollute the parts which conduct the undiluted gas, depending on the particle concentration and characteristics. To guarantee safe and accurate function and to prevent damage of the unit, please consider the following points:

- Follow the instructions for cleaning and service maintenance described in Chapter 6, "Maintenance".
- To prevent condensation in the undiluted gas tube do not switch on the raw gas pump before the dilution block is heated up to the temperature set on dial 32) or the remote control software.
- To avoid condensation in the undiluted gas, ensure that the temperature of the tubes between the exhaust pipe or stack and the exhaust probe is not lower than the selected block temperature.
- Heat up and isolate the undiluted gas tubes and keep them as short as possible to minimize particle loss by diffusion and coagulation.
- In case of high dust concentration in the exhaust (e.g., coal or wood combustion) use a cyclone or an impactor between sampling tube and Thermodiluter head to precipitate particles larger than approx. 5 µm. For long time sampling (more than a few hours) it is recommended to clean the sampling tube by periodically blowing compressed air back into the tube. This can be done by using two valves, one to protect the exhaust probe while the other valve is opened to the compressed air supply.

Loss of particles can be minimized if the following instructions are observed in the sampling lines from the aerosol source to the sensors.

Diffusion Losses

Loss of particles by diffusion in the gas tubes cannot be avoided but can be calculated or read from diagrams like the one in Appendix B.

Example:

Particle size:	30 nm	Diffusion losses according	
Length of gas tube:	3 m	to diagram in Appendix:	approx. 2.3 %/m
Sample flow:	1 l/min	total diffusion losses:	approx. 7 %

The diffusion losses are proportional to the length of the gas tube, inverse proportional to the sample flow and independent to the tube inner diameter. Reference: William C. Hinds (1999): “Aerosol Technology, Properties, Behaviour, and Measurement or Airborne Particles,” *John Wiley & Sons*, page 164, table 7.6.

Tube Properties

In general, tubes of highly insulating material are not qualified for the sampling of nanoparticles. Particle loss by electrostatic effects can be much higher compared to the calculated diffusion losses.

- For this reason, ***do not*** use Teflon®, standard silicone or PVC tubing.
- Metallic tubes (e.g., steel, copper, brass) are free from particle loss, except by diffusion.
- Flexible tubes made of electrically conductive material have been found to behave similar to metallic tubing.

Handling of Quick Couplings

The quick coupling for diluted gas outlet 37) at the back side of the control unit plug-in unit is opened/closed automatically when the unit is put into an appropriate device like the secondary dilution unit 379030.

The couplings at the front side have to be handled by the operator if the diluted aerosol is drawn through port 33) or if another offtake than the exhaust pipe is used to remove the excessive undiluted waste gas from the waste gas outlet of the control unit 36).

Figure 3-3 shows how a tube is disconnected from the quick coupling. Pushing down the button at the top of the quick coupling will release the plug which can then be pulled out.

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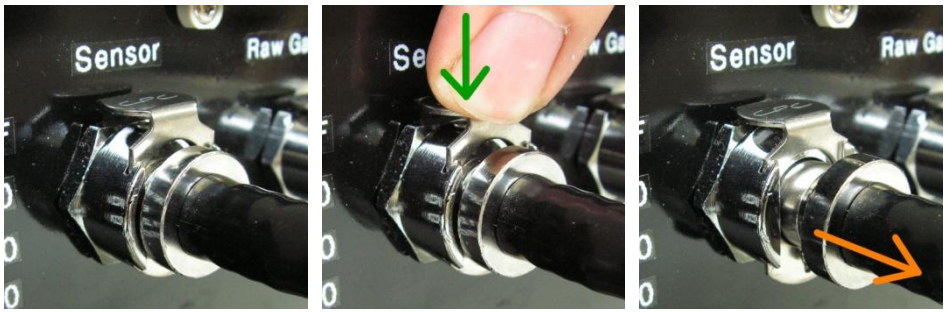
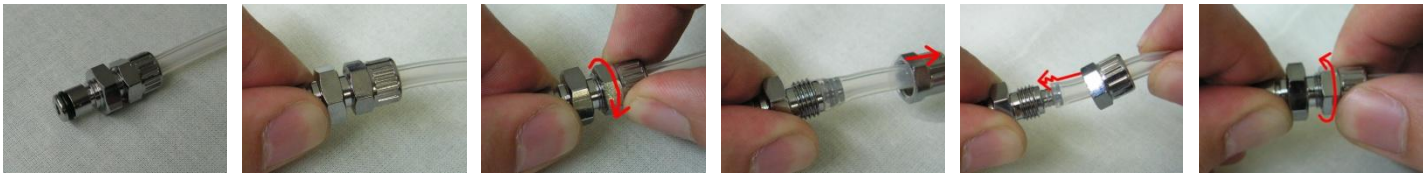


Figure 3-3
Handling of Quick Couplings at the Control Unit Front Side

Connect Another Offtake to the Control Unit

The plugs of the waste gas bridge 35) can be used to connect the waste gas outlet 36) of the control unit to a separate offtake. To remove the bridge, loosen the sleeve nut following the pictures C and D in Figure 3-4.



A and B: one end of the waste gas bridge with plug

C and D: remove the bridge tubelet

E and F: install another tube

Figure 3-4
Exchange of the Bridge at the Waste Gas Bridge Plug

The tube can then be pulled from the Fitting. Slip the sleeve nut over the new tube leading to the offtake. Put the tube over the fitting and tighten the sleeve nut according to pictures E and F.

W A R N I N G

Aerosol
Undiluted aerosol may escape from the control unit if the waste gas outlet of the Thermodiluter head 6) is connected to an exhaust pipe and the plug of the waste gas bridge 35) is connected to the waste gas return port of the control unit 34) inhibiting the self-sealing function of the quick coupling. ***Never*** leave the unused plug of the disassembled waste gas bridge in the waste gas return coupling 34).

Preparation, Heating Up Phase

The dilution can be chosen with a higher and a lower dilution range, depending on the number of cavities of the disk 21).

Note
In all instructions of this manual, higher dilution ration DR = 1/DF means lower dilution factor DF and vice versa.

Preparation of Thermodiluter Disk and Block

Clean surfaces of Thermodiluter disk 21) and Thermodiluter block 22) are necessary to ensure correct diluting function and long durability. Ensure the accurate cleanliness of these parts as follows:

WARNING
The dilution block is heated up to temperatures up to 150°C/302°F. Avoid any skin contact to hot parts. Use heat protection gloves (enclosed with the Model 379020A accessories) for any handling while parts of the Thermodiluter head are hot, especially when exchanging the disk 21).

- Open the protection hood latch 9) and remove the hot parts protection hood 8).
- Loosen the cap holder nuts 16) and remove the pressure compensation cap 15).
- Loosen the cap holder bolts 17) out of the aerosol/duct block 23) as shown in Figure 3-5A.
- Remove the fast lock ring 19) from the shaft 18) by pushing it in axial direction towards the Thermodiluter block and pulling it radially so that the shaft neck can slide through the slit according to Figure 3-5B and Figure 3-5C.
- Remove the Thermodiluter disk fixation cap 20) by pulling it in axial direction from the shaft following Figure 3-5D.
- Pull the Thermodiluter disk 21) from the shaft as shown in Figure 3-5E.

A: remove the cap holder bolts

B and C: remove the fast lock ring

D: remove the disk fixation cap

E: remove the Thermodiluter disk

Figure 3-5
Removal of the Rotating Thermodiluter Disk for Cleaning Disk and Block Surface

- Select the Thermodiluter disk according to the desired dilution range. For lower dilution factors, choose the 10 cavities disk, for higher dilution factors the one with 8 cavities.
- Clean disk and block surfaces with a cleaning alcohol and a clean soft paper wipe. TSI recommends using pure (99.8%) ethanol for analysis.
- Dry the surfaces with another paper wipe and remove possible lints by blowing them away with compressed air.
- Put the selected disk back on the shaft. Make sure the disk torque transfer notch meets the drive bolt crossing the shaft.
- Reassemble the Thermodiluter components in reversed order. Ensure that the rubber gasket is properly inserted into its notch when mounting the pressure compensation cap 15)

Setting up the Model 379020A Dilution System

- Connect the electrical cable 4) and the multiple pneumatic tubes 3) between control unit 2) and Thermodiluter head 1).
- Connect the Thermodiluter head directly or via heated tubes to the exhaust pipe. Keep the tube length as short as possible to minimize the influences of coagulation and particle losses (see Diffusion Losses and Tube Properties earlier in this chapter).
- Make sure the waste gas outlet of the control unit 36) is either connected to an offtake or to the inlet for waste gas return 34) when the raw aerosol is fed back to the exhaust via raw gas outlet of the Thermodiluter head 6).
- Connect your sensor(s) to the diluted gas connection on the front 33) or on the back 37) side of the control unit.
- Make sure the raw gas pump switch 24) is in “OFF” position (down).
- Connect the power supply cord to the mains connector 43), switch on the mains switch 42) and make sure the mains switch remains accessible during operation.
- Choose the heating temperature for the Thermodiluter block 22) and dilution air on dial 32).
- Ensure a certain diluted gas flow by drawing connected sensor(s) or by actively fed dilution air. The unit requires a minimal flow of approx. 0.4 L/min in the measuring gas channel to keep the dilution air heating in operation.
- When no gas is drawn by the sensor(s), the “dilution factor” LED 7) lights red independently of the setting of the dilution setting potentiometer 31). It will turn to green when dilution air flow is detected and the rotational speed of the Thermodiluter disk is within the specified range.
- Wait until the “block and dilution air heating” LED 27) lights green and indicates that the set temperature is reached.
- Switch on the raw gas pump to feed raw gas to the dilution air and therefore start real dilution.

Precautions for Measurement Upstream of Particle Traps

Particle traps for diesel emissions increase the pressure on the upstream side of trap. This back pressure is usually within the range of 150 mbar for correctly operating particle traps. Nevertheless, traps can build up pressures on the upstream side far above 150 mbar when the regeneration process is not carried out in due time, of if too much ash from the fuel additive is accumulated in the trap.

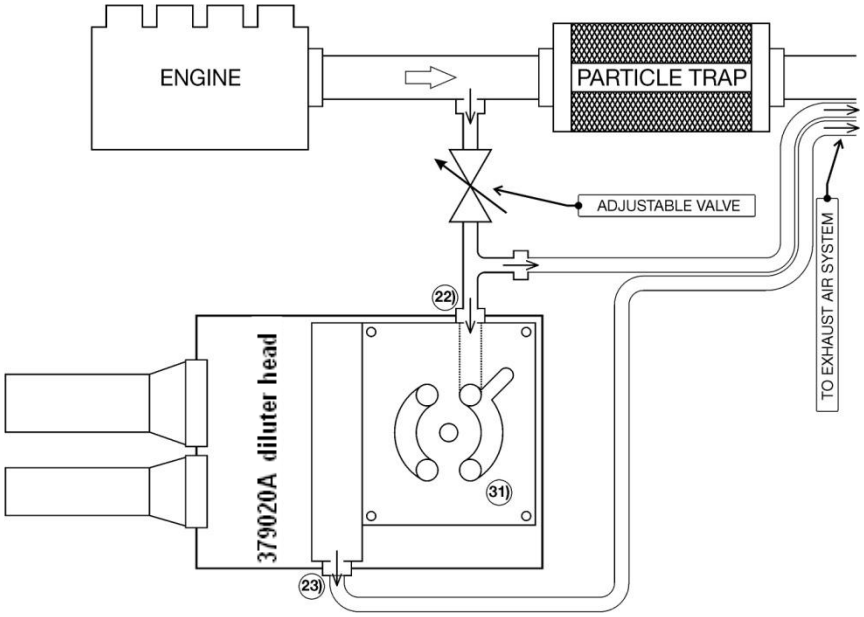


Figure 3-6
Measurement Setup if Raw Gas Pressure exceeds 300 mbar

The Model 379020A Thermodiluter head can handle up to 400 mbar pressure relative to ambient conditions for low rotation frequencies meaning high dilution factors. Any pressure difference between the raw aerosol inlet and ambient conditions leads to a significantly higher disk surface wear. TSI recommends ***not*** exceeding 300 mbar in continuous operation.

You may protect your Model 379020A Thermodiluter head by introducing a valve and an opening between exhaust pipe and Thermodiluter head to reduce the pressure. The valve has to be adjusted to an opening, where more than 2 L/min are flowing through the valve over the whole pressure range upstream of the trap. Lead the waste gas to an exhaust air system.

Verification of Correct Operation

During the heating up phase, the correct operation of the dilution system can be checked as follows:

- Connect your sensor(s) to the diluted gas connection on the front 33) or on the back 37) side and draw gas while the peristaltic pump switch 24) is “OFF” (down) and the dilution potentiometer 31) is on zero position.
- Remove the hot parts protection hood 8). The pressure compensation cap 15) has to remain installed over Thermodiluter disk 21) and block 22).
- Increase the dilution ratio on the potentiometer. The disk must start to rotate with increasing frequency. The rotational speed can be observed at the coupling element shown in Figure 3-7 when the hot parts protection hood 8) is removed.

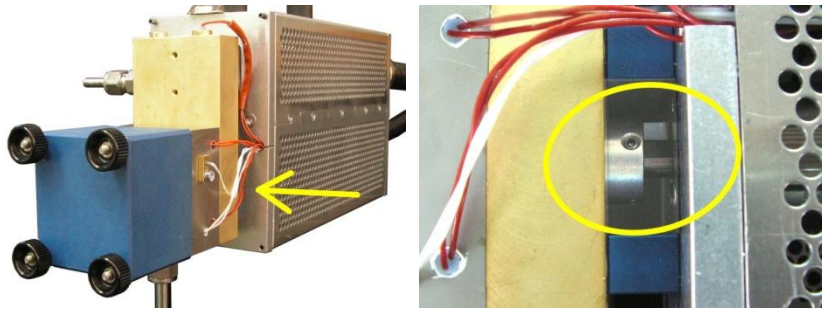


Figure 3-7
Coupling Element

No disk rotation may be caused by:

- No gas is drawn by the connected sensors.
- Too strong friction leading to blocked disk on block surface. The electric current of the rotation drive is controlled. The “Motor” LED 26) lights red when an upper current limit is exceeded due to mechanical overload. This faulty can mostly be removed by checking and cleaning disk and block surfaces according to Preparation of Thermodiluter Disk and Block.
- Too high pressure of the raw gas. To inhibit a lifting of the disk from the block surface caused by pressurized raw gas, the compensation cap ensures raw gas pressure surrounding the Thermodiluter disk. The force induced by this compensation pressure leads to more friction between disk and block surface. If the raw gas pressure exceeds 400 mbar, the disk rotation may be inhibited, especially in combination with worn or polluted disk and block surfaces. You may reduce the disk surrounding pressure by introducing a valve between source and Thermodiluter following Precautions for Measurement Upstream of Particle Traps.

- Some leakage of the pneumatic system. Please check the multiple pneumatic connectors at the control unit and the Thermodiluter head. Figure 3-2 helps you to understand the path of dilution air/diluted aerosol.
- Electrical or mechanical failure which needs to be repaired by the manufacturer or instructed service staff.

CHAPTER 4

Operating Instructions

This chapter describes the controls and connectors for both the Model 379020A Thermodiluter and the Model 379030 Thermal Conditioner. It also provides instructions for operating and controlling the instrument whether the Model 379020A is used in a stand-alone mode or it is part of a system incorporating the Model 379030.

Operational Considerations

When using the Model 379020A Rotating Disk Thermodiluter and the Model 379030 Thermal Conditioner Air Supply, there are a number of operational considerations you need to take into account:

- Combustion exhaust can pollute the parts that conduct the undiluted gas.
- The loss of particles from diffusion in the gas tubes cannot be completely avoided.
- Particle loss by electrostatic effects can be significant and require the use of appropriate tubing.
- Using a particle trap increases the pressure on the upstream side of the trap so precautions for measuring upstream of particle traps is important.
- Due to attachment of low volatile substances on the surface of the evaporation tube the thermal conditioner may produce particles itself if operated at temperatures above the previous operation point.

Combustion Exhaust

The Model 379020A Rotating Disk Thermodiluter uses the principle of hot dilution, which means that the sample probe head block and dilution air are heated to 80°C, 120°C or 150°C. This method keeps evaporated liquids above their dew point during and after dilution and avoids generating volatile nanoparticles by nucleation.

Diluted aerosol is not mixed with additional nanoparticles caused by the sampling and dilution process, which means that the diluted aerosol provides accurate information about the particles stemming from the combustion process.

The combustion exhaust can pollute the parts that conduct the undiluted gas, depending on particle concentration and characteristics. To provide safe operation, accurate measurements, and prevent damage of the unit, please consider the following:

- Review the instructions for service and maintenance described in Chapter 6.
- To prevent condensation in the undiluted gas tube, do not switch on the raw gas pump before the dilution block is heated to the set temperature.
- To avoid condensation in the undiluted gas, ensure that the temperature of the tubes between the exhaust pipe (or stack) and the exhaust probe is not lower than the selected block temperature.
- To minimize particle loss by diffusion and coagulation, heat and isolate the undiluted gas tubes and keep them as short as possible. Where dust concentration is high in the exhaust (for example, coal or wood combustion), use a cyclone or an impactor between the sampling tube and the Thermodiluter head to precipitate particles larger than approximately 5 µm.
- For long sample times (more than a few hours), TSI recommends the sampling tube be cleaned periodically by blowing compressed air into the tube. This can be done using two valves, one to protect the exhaust probe while the other valve is opened to the compressed air supply.

Thermo Dilution

Figure 4-1 provides a schematic plot of the mass concentration of a volatile compound against the temperature of the surrounding gas. In a dilution tunnel, both the concentration and the temperature of the substance are reduced (path A -> B). During dilution, the compound passes its dew point and nucleates into nanodroplets (curve N). Subsequent secondary dilution (B -> D) reduces the number concentration of the droplets but is unable to evaporate them because of a hysteresis effect between nucleation and evaporation.

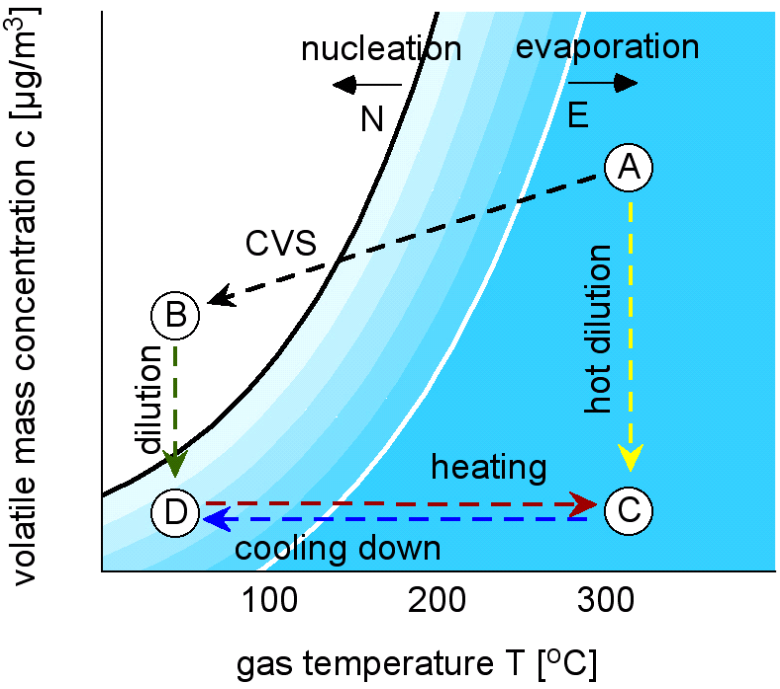


Figure 4-1
Methods for Diluting Engine Emissions

To avoid the formation of nanodroplets, it is useful to have direct sampling from the hot exhaust in combination with hot dilution (A -> C).

Given a sufficient dilution factor, the volatiles will not nucleate during subsequent cooling (C -> D) even though the same final state is assumed as through dilution tunnel and secondary dilution (A -> B -> D). However, in some applications (for example, measurement from a CVS tunnel), direct sampling is not possible and nanodroplets already exist in the gas sample (B). In those cases, the diluted gas sample (D) has to be heated above the evaporation point of the compound (D -> C, crossing curve E). As with hot dilution, the compound remains in vapor phase upon subsequent cooling (C -> D).

The combination of diluter and heater (B -> D -> C-> D) is known as Thermo Diluter. Hot dilution is realized in TSI rotating disk diluters. Together with TSI rotating disk diluter the 379030 forms a complete Thermo Diluter system (Figure 4-1).

Model 379020A Controls and Connectors

Figure 4-2 shows the front of the Model 379020A control unit.

Figure 4-3 shows the back of the Model 379020A control unit when it is used in a stand-alone mode (not installed in the Model 379030 cabinet).

Figure 4-4 shows the back of the Model 379020A control unit as it appears before being integrated into the 19" case of the Model 379030. The Model 379020A cannot be used as shown in the figure; it must mounted in either its stand-alone case or in the 19” case.

Note: The waste gas return bridge always connects the two waste gas ports in normal operation. The exception to this is when the control unit is connected to an offtake other than the exhaust pipe, where undiluted waste gas is usually fed back to the control unit.

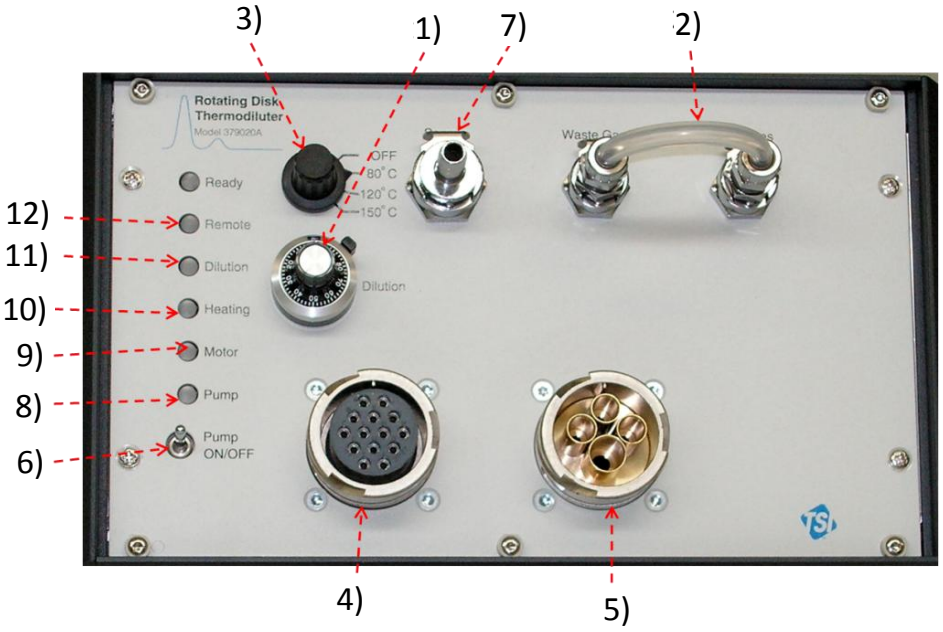


Figure 4-2
Model 379020A Front View

Table 4-1
Controls and Connectors Model 379020A (Front)

No	Label	Description
1	**Dilution**	10-turn potentiometer sets the dilution factor. The appropriate dilution factor needs to be calculated using the calibration data sheet (see Figure 4-8). The minimum and maximum limits depend on the temperature setting.
2	**Waste Gas Bridge**	Waste gas/return bridge for connection to an offtake other than the exhaust pipe.
3	**Temperature Dial**	Sets the temperature of the Thermodiluter block and dilution air. Options are: Off, 80°C, 120°C, and 150°C. If the device is remotely operated, any temperature between 40°C and 150°C can be set.
4	**Electrical Connector**	Connects power to the Thermodiluter head.
5	**Pneumatic Connector**	Connects gas input and output to the Thermodiluter head
6	**Pump ON/OFF**	Switches raw gas pump on (up) and off (down).
7	**Sensor Outlet**	Self-sealing quick connect coupling for gas output to the sensor(s)
8	**Pump LED**	Indicates the status of the raw gas pump: Green: running. Red: error. Dark: OFF.
9	**Motor LED**	Indicates the status of the pump motor. Green: rotating. Red: error. Dark: motor stopped.
10	**Heating LED**	Indicates the status of the heating element. Green: OK. Red: error. Dark: OFF. Orange: heating up.
11	**Dilution LED**	Indicates the dilution. Green: OK. Red: dilution factor out of specified range.
12	**Remote LED**	Indicates whether the device is remotely controlled. Green: device is remotely controlled. Dark: device is not remotely controlled.
13	**Ready LED**	Indicates overall system status. Green: OK. Dark: at least one signal is not OK.

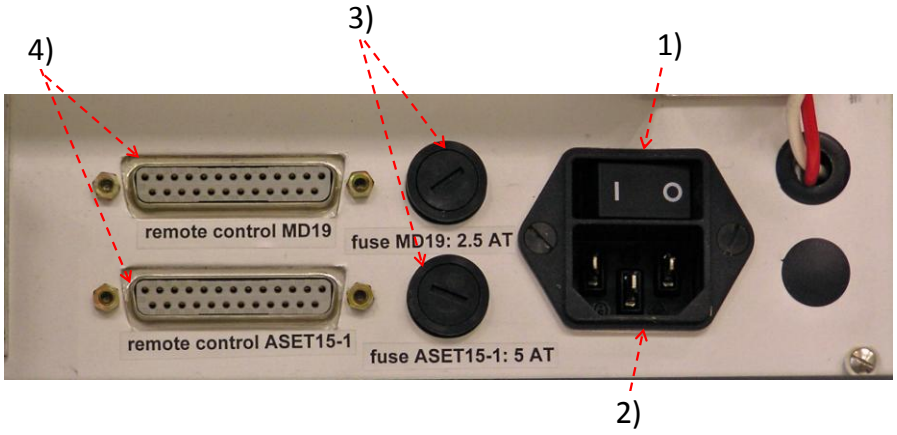


Figure 4-3
Model 379020A-30 Back View (connections)

Table 4-2
Controls and Connectors Model 379020A (Back View)

No	Description
1	Main on/off switch.
2	Female power cord connector.
3	Fuses; 250 V
4	Remote control interface connectors: 25 pin D-Sub female.

Stand-Alone Operation of Model 379020A

When operating the Model 379020A as a stand-alone instrument, proceed as follows:

1. Check that the electrical and pneumatic cables between the control unit and Thermodiluter head are correctly installed.
2. Verify the Thermodiluter head is directly to an exhaust pipe or to an appropriate probe connected to the exhaust pipe. Tube length should be as short as possible to minimize the influences of coagulation and particle losses (see Chapter 3, Diffusion Losses and Tube Properties).
3. Make certain the waste gas outlet of the control unit is either connected to an offtake or to the inlet for waste gas return (if the raw aerosol is fed back to the exhaust via raw gas outlet of the Thermodiluter head.
4. If necessary, connect the power supply cord to the main power connector.
5. Switch on the main power switch of the Model 379020A.
6. Verify the particle sensor(s) are connected to the “Sensor” connection on the front of the control unit, and make certain the sensor is providing sufficient air flow. The Model 379020A requires a minimal flow of approx. 0.4 L/min to keep the dilution air heating in operation.

   If the particle sensor does not provide for enough air flow, the Dilution LED turns red (independent of the setting of the dilution potentiometer). When the dilution air flow is within specifications and the rotational speed of the Thermodiluter disk is within the specified range, the Ready LED turns green.
7. Make sure the raw gas pump switch is in the down position (OFF).
8. Choose the heating temperature for the Thermodiluter block and dilution air.
9. Wait for the Heating LED glows green to indicate the set temperature has been reached.
10. Set the potentiometer to zero and start the internal pump by flipping switch to its "ON" position (up) to draw raw gas into the Thermodiluter head to mix with the dilution air and start dilution.

11. Increase the potentiometer setting. This reduces the dilution factor. Observe the reading of your sensor(s) to find an optimal dilution value. Depending on tube lengths, response time is from a few seconds to 30 sec.

12. Read the setting (0 to 10.0 = 0 to 100 %) of the potentiometer and calculate the dilution ratio as follows:

    dilution factor DF = X · f[°C] /pot[%]
    calibration factor X = nominal 1500 (10 cavities disk) and 15000 (8 cavities disk). Refer to calibration sheet for specific factors.

    Example: Potentiometer set at 40 %, 10 cavities disk,
    f(120 °C) = 1.11 DF = 1500 · 1.11 / 40 = 41.6

    Ensure that:
    - The “Heating” LED indicates that the temperature chosen on dial is reached.
    - The “Dilution” LED glows green to indicate that the set dilution is within the specified range.
    - The “Ready” LED lights to confirm no error signals.
    - The disk is rotating continuously (see below to verify correct operation).

13. Monitor the particle sensor readings and adjust the dilution potentiometer to provide the desired dilution of the sample aerosol.

Model 379030 Controls and Connections

Figure 4-4 shows the front of the Model 379030 Control Unit.

Figure 4-5 shows the back of the Model 379030 Control Unit with the safety cage in place.

Figure 4-6 shows the back of the Model 379030 Control Unit with the safety cage removed.

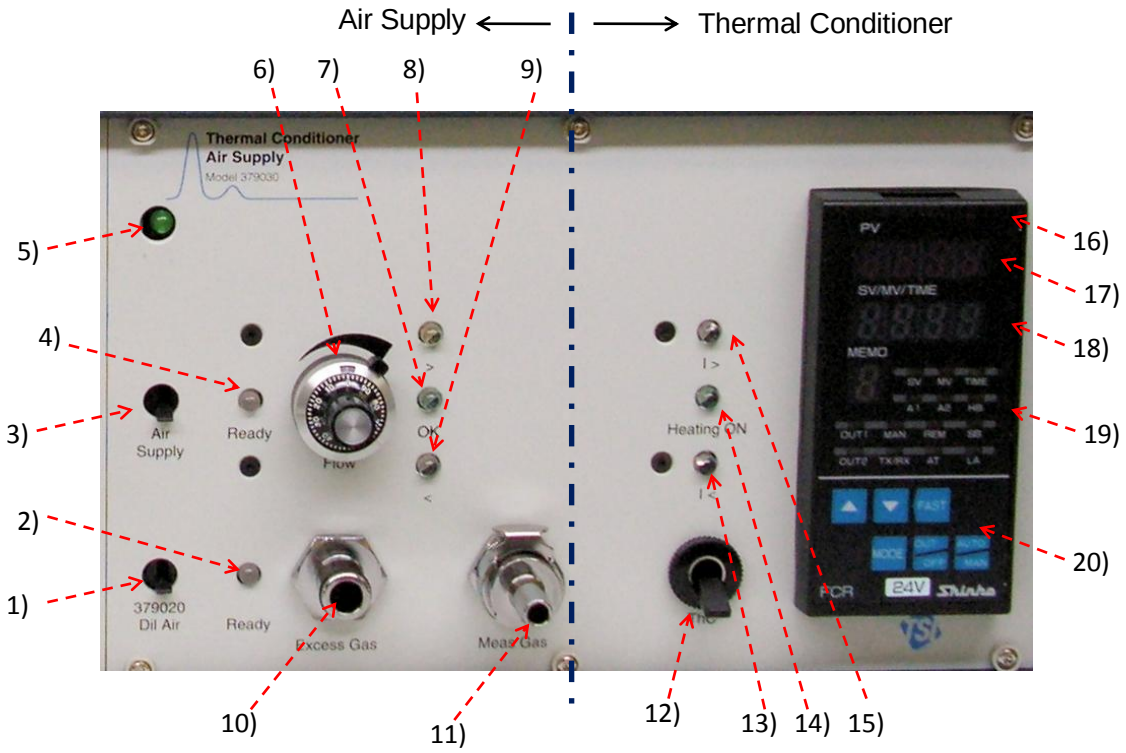


Figure 4-4
Model 379030 Front View

Table 4-3
Controls and Connectors Model 379030 (Front)

No	Label	Description
1	DIL-Air	Switches dilution air on (up) and off (down).
2	Ready LED	Indicates dilution air status. Green: ready for use, Dark: not ready for use.
3	Air Supply	Switches the air supply on (up) and off (down).
4	Ready LED	Indicates air supply status. Green: ready for use. Dark: not ready.
5	Remote LED	Indicates whether the system is being controlled remotely. Green indicates remote operation. Dark indicates local operation.
6	FLOW	10-turn potentiometer to adjust air supply for 2nd dilution air.
7	OK LED	Indicates measured excess air flow is from .3 to 1.5 L/min (green).
8	>	Indicates measured excess air flow is greater than 1.5 L/min (yellow).
9	<	Indicates measured excess air flow is less than .3 L/min(red).
10	EX Air	Quick connect for excess air (output).
11	MEAS Gas	Quick connect for measured gas (sensor output).
12	ThC	Switches thermal conditioning heating on (up) and off (down).
13	| <	Indicates ThC heating current is too low (red).
14	Heat On	Indicates ThC heating current it OK (green).

No	Label	Description
15	|>	Indicates ThC heating current is too high (red).
16		Temperature controller for evaporation tube.
17	PV	Indicates measured (diluted) gas temperature.
18	SV/MV/TIME	Indicates diluted gas temperature set value.
19		Indicates status field.
20		Control field.

W A R N I N G

Skin burn
The Thermal Conditioner pipe of the Model 379030 is heated up to 400°C/752°F. Pipes and other parts on the back side of the device may be hot and should not be touched.

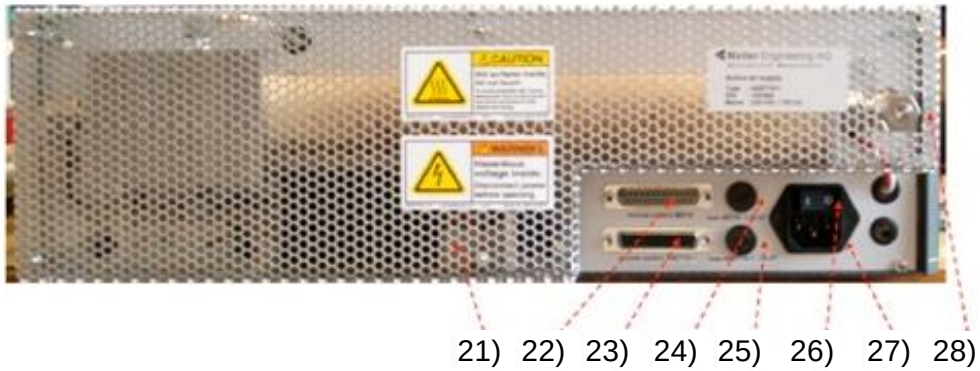


Figure 4-5
Model 379030 Back View (with safety cage in place)

Table 4-4
Controls and Connectors Model 379030 (Back with safety cage in place)

No	Description
21	Safety cage.
22	Analog interface for connecting the Model 379020A.
23	Analog/digital interface for this unit (Model 379030). For connecting Model 379032A Digital Control Unit (optional).
24	Fuse, 1.25 A (230 V), 2.5 A (100/110 V) slow blow for Model 379030.
25	Fuse, 2 A (230 V), 4 A (100/110 V) slow blow for Model 379020A.
26	Main power switch.
27	Female power cord receptacle.
28	Cap cover on inlet of evaporation tube.

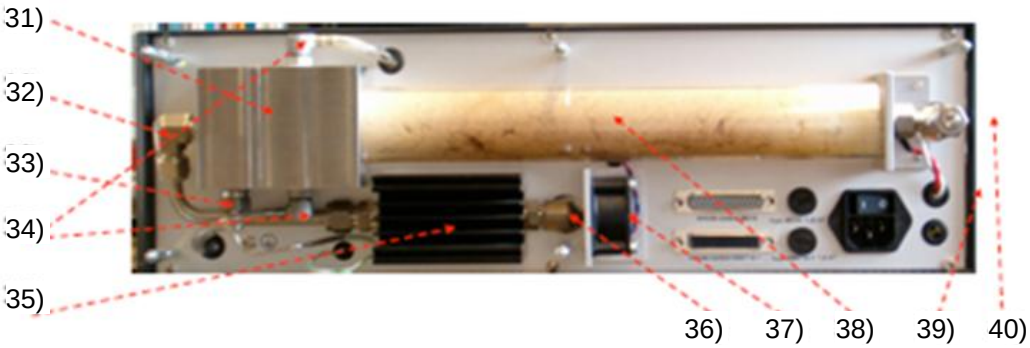


Figure 4-6
Model 379030 Back View (safety cage removed)

Table 4-5
Controls and Connectors Model 379030 (Back with safety cage removed)

No	Description
31	Secondary dilution mixing chamber.
32	Measured gas output from mixing chamber.
33	Connector for thermocouple in evaporation tube.
34	Gas inlet for secondary dilution air.
35	Cooler.
36	Measuring gas output to front panel connection.
37	Fan for gas cooling.
38	Evaporation tube.
39	Electrical cable to heater.
40	Measuring gas inlet of evaporator tube.

Thermal Conditioning Heating Procedure

The procedure for using thermal conditioning is as follows:

1. Switch on the **DIL AIR** pump (up) of the Thermal Conditioner control unit and wait for the **READY LED** to glow green, which indicates flow is within specified tolerance of ±3 %.

   The temperature inside the evaporation tube is measured in the gas stream. Heating only makes sense when the **DIL-AIR** pump is switched on and the diluted gas from the Thermodiluter passes through the evaporation tube.

   Note: There is no risk of damage from overheating when no gas passes through the evaporation tube.

2. Switch on the Temperature Controller by pressing the **OUT/OFF** switch in the control field (see Figure 4-7).

   Enter the temperature set value as follows:

   a. Press **MODE** in the control field.

   b. Adjusting the value using the up and down arrow keys.

   c. Press **MODE** again.

Figure 4-7
Thermal Conditioner Temperature Control.

3. Switch on the heater using the **ThC** toggle switch (up). A green LED indicates the heating current is within specifications.
4. Wait until the measured gas temperature, **PV**, agrees with the set value, **SV**, within ±2 °C. The **HEAT ON LED** glows green continuously during the heating up phase. The LED starts blinking when the measured gas temperature approaches the set value.
5. When the sample gas temperature reaches its set value, the heating on/off-duty cycle stabilizes.
6. It takes approximately 3 minutes to heat from ambient to 200°C and 4 minutes to heat to 300°C.

Operation of Model 379020A/379030

When operating the Model 379020A and 379030 as a system, proceed as follows:

1. Check that the electrical and pneumatic cables between the Thermodiluter control unit and Thermodiluter head are correctly installed.
2. Verify the Thermodiluter head is directly connected to an exhaust pipe or to an appropriate probe connected to the exhaust pipe. Tube length should be as short as possible to minimize the influences of coagulation and particle losses (see Chapter 3, Diffusion Losses and Tube Properties).
3. Make certain the waste gas outlet of the Thermodiluter control unit is either connected to an offtake or to the inlet for waste gas return (if the raw aerosol is fed back to the exhaust via raw gas outlet of the Thermodiluter head.
4. If necessary, connect the power supply cord to the main power.
5. Switch on the main power switch on the back of the 379020A/379030.
6. Make sure the raw gas pump switch is in the down position (OFF).
7. On the Thermodiluter control unit, choose the heating temperature for the Thermodiluter block and dilution air.
8. Wait for the Heating LED to glow green to indicate the set temperature has been reached.
9. Switch on the “raw gas pump” to draw raw gas into the Thermodiluter head to mix with the dilution air and start dilution.
10. Toggle the **Dil Air** pump switch up (on) and verify Air Supply switch is down (off).
11. Verify the particle sensor(s) are connected to the “MEAS gas” connection on the front of the Thermal Conditioner control unit, and make certain the sensor is providing sufficient air flow. The Model 379030 requires a minimal flow of approx. 0.4 L/min to keep the dilution air heating in operation.

    If the sensor does not provide for enough air flow, the Dilution LED turns red (independent of the setting of the dilution potentiometer). When the dilution air flow is within specifications and the rotational speed of the Thermodiluter disk is within the specified range, the Ready LED turns green.
12. Set the potentiometer on the Thermodiluter control unit to 1.00 (mechanical zero position).
13. Switch **AIR SUPPLY** up (on). The Air Supply LED turns green. If the connected particle sensor draws more than 1.2 L/min the red LED turns **ON**. Increase the flow **QAS** of the secondary dilution air on the potentiometer until green **LED OK** lights.
14. Increase the potentiometer by 0.1 to 0.3 units, and note the dilution factor.

15. If the **LED OK** is already green with the potentiometer adjusted to 1.00, it indicates the connected particle sensor draws less than 1.2 L/min. Measurement can start and no secondary dilution is required (for reducing thermophoretic losses. The total dilution factor is the product of the factors for the primary dilution of the Thermodiluter and the secondary dilution of the Thermal Conditioner taking the thermophoretic losses into account. The thermophoretic losses are shown in Figure 4-12 as a function of the secondary dilution factor.

    For example:

    Thermodiluter dilution factor = 30 Secondary dilution factor = 3 Thermophoretic loss = 10%

    Total dilution factor = 30 x 3 x 100/(100 – 10) = 100

16. Monitor the particle sensor readings and adjust the dilution potentiometer to provide the desired dilution of the sample aerosol.

Note: Wait at least 10 seconds before restarting the **AIR SUPPLY** after termination with toggle switch in order to avoid short peak flows in the order of 20 L/min on the **MEAS GAS** output.

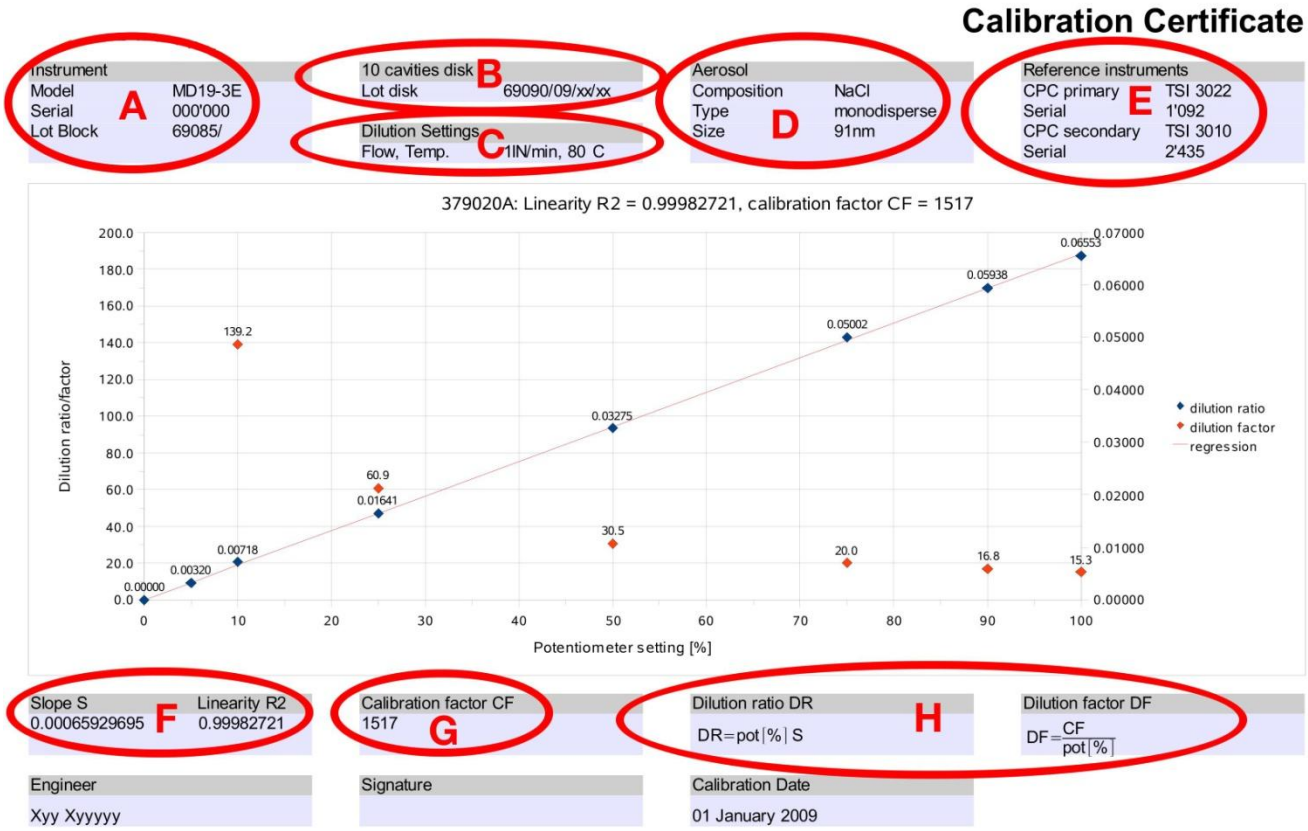
Dilution Factors

Abbreviations

DR	Dilution ratio	e.g.,1/20 = 0.05
DF	Dilution factor	e.g., 20
pot[%]	Setting of potentiometer 10)	0...10 corresponds to 0...100 %
X	Calibration factor	nominal 1500 (10 cavities disk) and 15000 (8 cavities disk). Refer to calibration sheet for specific factors.
f[°C]	Temperature correction factor	f(OFF) = 0.83 f(80 °C) = 1.00 f(120 °C) = 1.11 f(150 °C) = 1.20
Fd	Flow of diluted aerosol	Determined by the connected sensor(s)

Calibration Certificate

Figure 4-8 shows an example of a Model 379020A Rotating Disk Thermodiluter calibration certificate. The plot in the center of the calibration sheet visualizes the linearity of the data collected during the calibration procedure. The calibration setup details are described in the boxes at the top, the resulting values at the bottom of the calibration certificate.



A Identification of the calibrated device — Thermodiluter type and serial number

B Identification of the installed Thermodiluter disk: — Disk type, production lot, serial number)

C Dilution settings — Dilution air flow drawn by the sensor downstream the Thermodiluter, dilution air and head temperature

D Calibration aerosol properties — Material, description of size distribution

E Calibration laboratory equipment description

F Summary of the data collected in terms of the calibration procedure

G Calibration factor CF=1/S

H Description how dilution ratio DR and dilution factor DF can be calculated out of the calibration factor CF and the potentiometer setting pot[%].

Figure 4-8
Calibration Certificate

Adjustable Dilution Ranges

N o t e
The dilution factor depends on the temperature in the exhaust Thermodiluter block 22) which can be heated up to different temperatures. The nominal dilution range from 1:15 to 1:3000 refers to a block temperature of 80°C set on dial 32. Correction factors have to be applied when operated at other temperatures.

The Thermodiluter is calibrated on a nominal range from 1:15 to 1:3000. This corresponds to a dilution factor setting on potentiometer 31) of:

- *dilution factor DF = 1500* / pot[%], for 10 cavities disk*
- *dilution factor DF = 15,000* / pot[%], for 8 cavities disk*

**for more accurate dilution measurement, choose the factors listed on the calibration sheet.*

These nominal ranges refer to a heating temperature of 80 °C selected on dial 32). If other temperatures are chosen, the formula for the dilution factor has to be compensated by the f[°C] factors mentioned above.

- *dilution factor DF = f[°C] · X / pot[%]*

The dilution ratio has a linear relationship to the rotation frequency of the disk and the dilution air flow Fd. The rotation frequency is:

frot ~ adjusted dilution ratio · Fd

Fd is given by the gas flow drawn by the connected sensor(s). To compensate its influence, Fd is measured and electronically multiplied with the set value for the dilution ratio.

The dynamic range of the rotation frequency is limited to a nominal frequency of approx. 2.5 Hz when potentiometer 10) is set to 100 % and the dilution air flow Fd is 1.5 l_N/min.

When Fd[l_N/min] · pot[%] exceeds 150, the “Dilution” LED 28) indicates that the rotational speed is over range. Figure 4-9 illustrates the adjustable ranges of dilution factor DF depending on Fd and the number of cavities on the disk. This figure shows that for Fd > 1.5 lN/min potentiometer 31) must be set to a value below 100 % where the “Dilution” LED is not lit up.

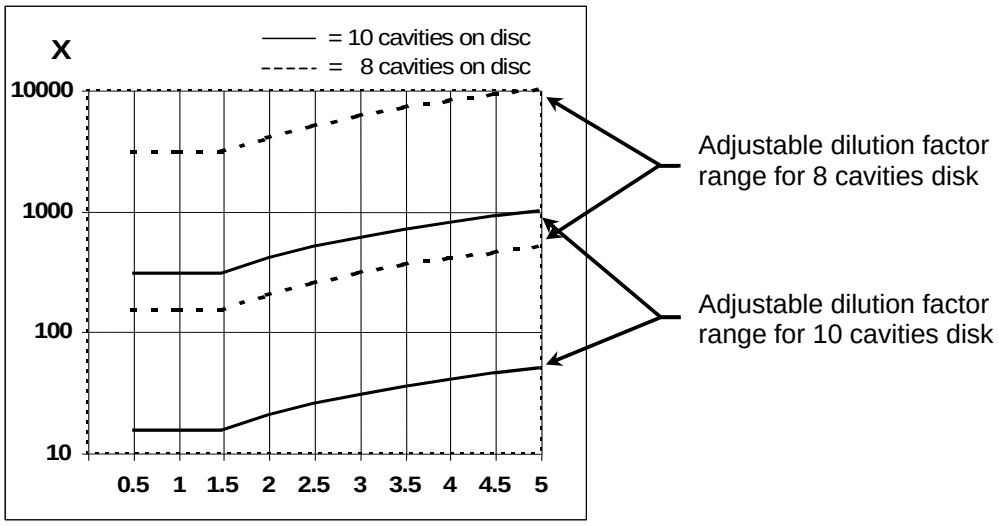


Figure 4-9
Dilution Factor Ranges

Manual Dilution Setting

- Wait until the “Heating” LED 27) lights green and indicates that the Thermodiluter block and the dilution air heating are heated up to the temperature chosen on dial 32).
- Set potentiometer 31) to zero and start the internal pump by putting switch 24) to "ON" position (up).
- Draw some gas with the sensor(s) connected to the measuring gas outputs on the front 33) or on the back side 37) of the control unit. Since there is no rotation, the sensor(s) draw(s) particle free air from ambient air through dilution air input 38) and internal particle filter.
- Increase the potentiometer setting and therefore reduce the dilution factor while observing the reading of your sensor(s) to find an optimal dilution adjustment. Depending on the tube lengths, response time will be from a few seconds to 30 sec.
- Read the setting (0...10.0 = 0...100 %) of the potentiometer 31) and calculate the dilution ratio as follows:
  dilution factor DF = X · f[°C] /pot[%]
  calibration factor X = nominal 1500 (10 cavities disk) and 15000 (8 cavities disk). Refer to calibration sheet for specific factors.

Example: Potentiometer set at 40 %, 10 cavities disk,
f(120 °C) = 1.11 DF = 1500 · 1.11 / 40 = 41.6

- Ensure that:
  - ✓ The “Heating” LED 27) indicates that the temperature chosen on dial 32) is reached.
  - ✓ The “Dilution” LED 28) lights green and indicates that the set dilution is within the specified range.
  - ✓ The “Ready” LED 30) confirms no error signal occurs.
  - ✓ The disk is rotating continuously (see Chapter 3, "Verification of Correct Operation").

Pollution of the Evaporation Tube (379030)

Due to the attachment of low volatile substances on the surface of the evaporation tube, the thermal conditioner may produce particles itself if operated at temperatures above the previous operation point. In this case, the attached volatile material evaporates and may re-nucleate and be measured by the connected particle sensor.

TSI recommends that when increasing the temperature you should flush the thermal conditioner with filtered air until none of the undesired particles are detected, a process that can take up to 20 minutes.

When sampling with varied temperatures, start with the highest temperature and progress to the lowest temperature.

Measure Loss of Volatile Particles in the Evaporation Tube (379030)

If you want to measure the loss of volatile particles in the evaporation tube by evaporation, connect a particle sensor as follows:

1. Remove the safety cage from the Model 379030 by removing the five retaining nuts (see Figure 4-6).
2. Remove the closing plug from the T-gas connection.
3. Mount a short stainless steel tube to the T-gas connection using the stainless nut and the two PTFE ferrules (see accessories).
4. Reinstall the safety cage before you connect the tube to your sensor on the steel tube.

Drawing measuring gas on the inlet to the evaporation tube reduces the flow in the evaporation tube and therefore influences the setting of the dilution factor. To evaluate the secondary dilution factor it is absolutely necessary that the flow drawn by the sensor connected to the evaporation tube inlet is known.

The flow difference between sensor flow on or off can be measured at pin 5 of the interface connector (1 to 5 V DC = 0 to 5 L/min -> 1.25 V/L/min).

Example:
Connected sensor: CPC drawing 0.3 L/min (vol. flow at 1013 mbar/23°C)
Measuring gas flow from evaporation tube: 1.5 to 0.3 = 1.2 L/min
Dilution factor at pot.-setting 2: dil.-factor = (1.2+1.5)/1.2 = 2.25 (instead of 2)
If sensor flow = Q_S: dil.-factor = {(1.5 - Q_S)+pot.-setting x 1.5)}/ (1.5 - Q_S)

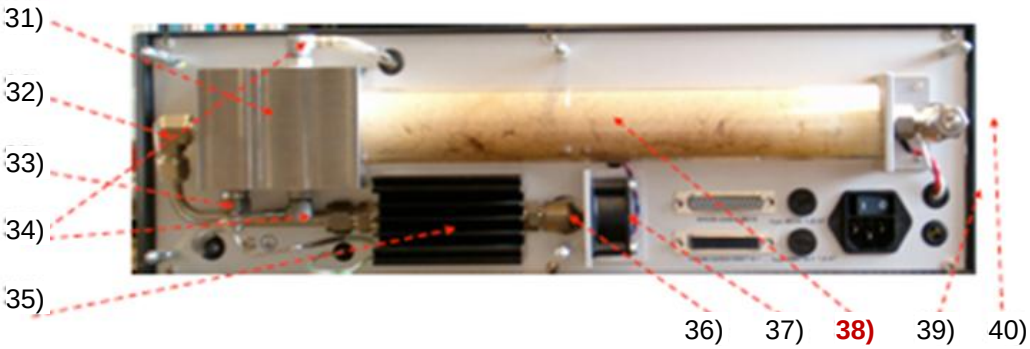


Figure 4-10
Model 379030 Back View (Evaporation tube is number 38)

379030 Air Supply Control LEDs

Figure 4-11 illustrates the setting of the secondary dilution air in the air supply portion of the Model 379030.

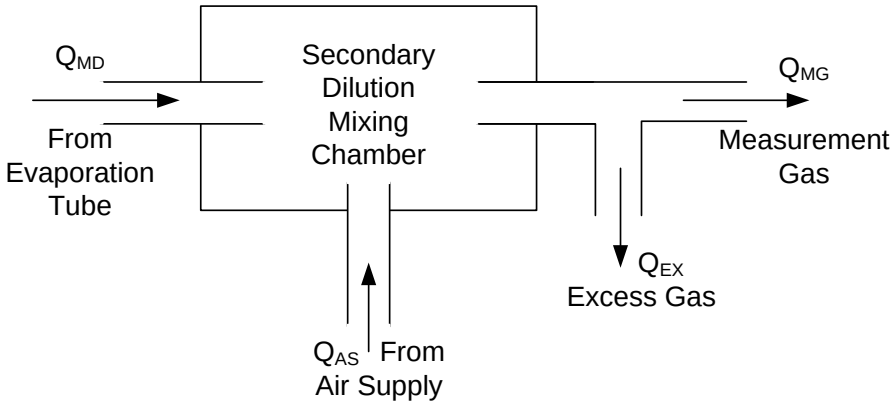


Figure 4-11
Secondary Dilution in 379030

As indicated, aerosol from the Thermal Conditioner with flow Q_{MD} (standard 1.5 L/min) enters the secondary dilution mixing chamber. Secondary diluted measuring gas with flow Q_{MG} is drawn by the instrumentation connected to the measuring gas output.

It is evident that Q_{AS} must be adjusted to a value where $Q_{MD} + Q_{AS} > Q_{MG}$.

The excess flow $Q_{EX} = Q_{MD} + Q_{AS} - Q_{MG}$ is internally measured and examined in relation to three criteria and indicated with the control LEDs.

- Green **LED OK** is on when Q_{EX} is in the recommended flow range from 0.3. to 1.5 L/min.

- Yellow LED > is on when Q_{EX} is >1.5 L/min. Q_{EX} is above the recommended range but still acceptable. In case the connected particle sensor is sensitive to differential pressures other than ambient it has to be noted that a positive pressure builds up on the measuring gas output with increasing Q_{EX}. The pressure increases as follows:

Q_{EX}	0.5	1.5	3	4.5	6
p[mbar]	0.2	0.5	2.0	3.8	6.1

- Red LED **>** is on when Q_{EX} is <0.3 L/min or negative (flow is in the opposite direction).

Model 379030 Flow Calibration

The Model 379030 is an adjustable diluter in which two calibrated flows Q_{MD} and Q_{AS} are mixed in a secondary dilution mixing chamber. Q_{MD} is adjusted and calibrated to a standard flow of 1.5 L/min.

Q_{AS} is set using the10-turn potentiometer or via analog input signal. The reading on the potentiometer (from 1.00 to 11.00) and the input signal range (0 to 10 V DC) correspond to a Q_{AS} from 0 to 15 L/min.

With Q_{MD} = 1.5 L/min, the potentiometer reading corresponds directly to the secondary dilution factor.

Examples:

Pot.-setting = 2 →QAS = 1.5 L/min: Dil.-factor = (QAS + QMD)/ QMD = 3.0/1.5 = 2
Pot.-setting = 5 →QAS = 6.0 L/min: Dil.-factor = (QAS + QMD)/ QMD = 7.5/1.5 = 5

Thermophoretic Losses

Figure 4-12 shows the thermophoretic losses in the evaporation tube of the Model 379030 when heated to 300°C (measured with 82 nm soot particles).

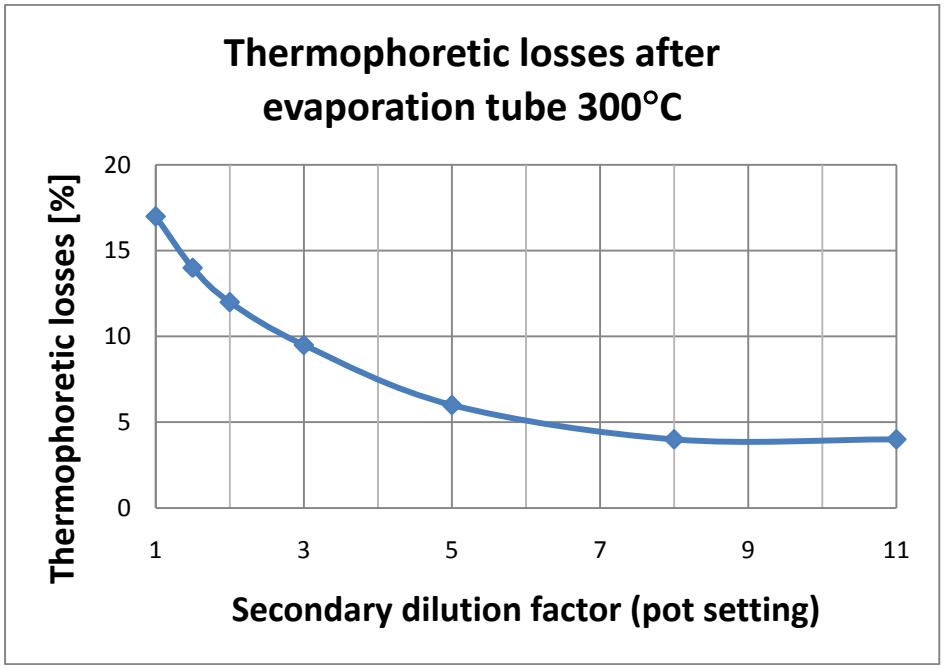


Figure 4-12
Thermophoretic Losses at 300°C

Analog Input/Output

The dilution factor DF may be set by an external source or read by an external measurement device. The dilution factor set by the potentiometer 31) will be ignored if 5 VDC are applied to the remote control pin and of the connector at the back side of the control unit. The analog voltage signal on the dilution factor pin will then replace the potentiometer setting.

- Dilution factor DF = X · f[°C] / (10 · Up[V])
- Range: Up = 0...10 VDC
- Calibration factor X = nominal 1500 (10 cavities disk) and 15000 (8 cavities disk). Refer to calibration sheet for specific factors.

Example: Up = 4 V, 10 cavities disk, f(120°C) = 1.11 -> DF = 1500 · 1.11 / (10 · 4) = 41.625

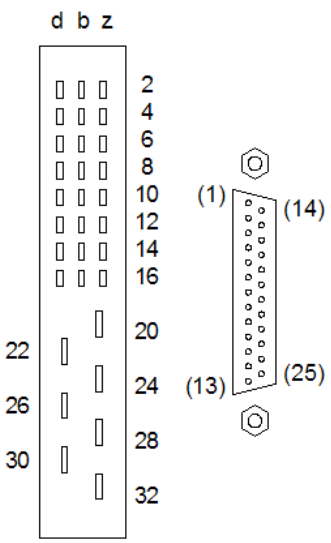
The pin assignment of the analog input/output connector is described in Chapter 5, "Electrical Connections".

CHAPTER 5

Electrical Connections

Analog/Digital Interface

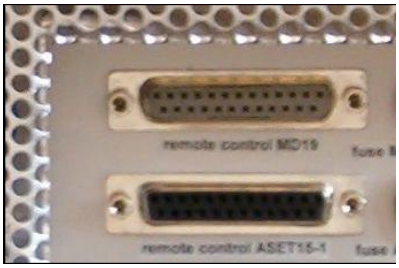
Several relevant control and indication signals of the dilution unit are located on connectors on the back side for measurement with high ohmic (R_{in} > 1 MΩ) instruments, programming with low ohmic DC-voltage sources, or as relay contacts for function indication. The F24/H7 connector is on the back of the 379020A module (inside case) and the D-sub connector is on the back of the cabinet.



3U/42HP	Plug-in Unit	F24/H7 Connector 18)	Laboratory Case 25-pin D-sub Female Connector 21)	F24/H7 pin	D-sub pin	Signal Description	Analog/Digital	Input/Output	Signal Range
				2d	-2	Dilution air flow Fd	A	O	0...10 VDC = 0...5 lN/min
				4d	-16	Set dilution factor	A	I	0...10 VDC = 0...100 %
				6d	-5	Motor speed (4.3 mV/1/min)	A	O	0...10 VDC = 0...2.7685 1/s
				6b	-17	Digital ground	D		0 VDC for digital inputs/outputs
				8z	-18	Raw gas pump ON / OFF	D	I	0 VDC: OFF 5 VDC: ON
				10d	-8	Raw gas temperature	A	O	0...10 VDC = 0...250 °C
				10b	-20	Raw gas pressure	A	O	0...10 VDC = 0...2000 mbar
				12b	-9	Instrument ready	D	O	0 VDC: error 5 VDC: ready
				12z	-21	Remote control ON/OFF	D	I	0 VDC: local 5 VDC: remote
				14d	-24	Analog ground	A		0 VDC for analog inputs/outputs
				14z	-10	Set block temperature	A	I	0...10 VDC = 0...200 °C
				16b	-25	Thermodiluter block temperature	A	O	0...10 VDC = 0...200 °C
				16z	-11	Analog ground	A		0 VDC for analog inputs/outputs
				28z		Power supply L			100...230 VAC 50/60 Hz
				30d		Power supply N			100...230 VAC 50/60 Hz
				32z		Protection earth PE			

REMOTE Operation

Pin out of 379030 interface connector REMOTE communication with 379030 is possible with analog and digital in- and outputs via the back side 25-pole D-sub female connector 23).



- Digital in-/outputs are standard 5 V logic levels
- Analog in-/outputs are 0 – 10 V DC-signals Signal specifications

Signal specifications

Digital inputs	High-Level: > 3 V DC, Low Level < 0.7 V DC, Ri > 10 kOhm
Digital outputs	High-Level: 5+/- 0.2 V DC, Low Level < 0.7 V DC, Ra < 3.5 kOhm
Analog inputs	Ri > 1 MΩ
Analog outputs	Source current <= 5 mA

Pin	Signal	Subject	Range
1	Analog output	Thermal Conditioner measured temperature	0 to 10 V DC = 0 to 400°C
2	Analog input	Thermal Conditioner temperature set value	0 to 10 V DC = 0 to 400°C
3	COM	(-) for analog in- and outputs	
4	Digital output	Thermal conditioner, Iheat too high, LED I> 15) red	
5	Analog output	Excess meas. gas flow on connector EX AIR 10)	1 to 5 V DC = 0 to 5 L/min
6	Analog input	Set value for secondary dilution air flow	2.5 to 10 V DC = 0 to 15 L/min
7	Not connected		
8	Not connected		
9	Digital input	Air supply flow ON/OFF	
10	Not connected		
11	Analog output	379020A -Dilution Air, controlled on 1.5 L/min mass flow	Fix value within 3.2 to 3.8 V
12	Digital input	REMOTE operation ON/OFF, LED REMOTE 5) green	
13	GND	(-)for digital in- and outputs	
14	Digital output	Air supply flow control error, LED READY 4) red	
15	Digital output	Thermal conditioner, Iheat too low, LED I< 13) red	
16	Digital input	Thermal conditioner, heating ON/OFF	
17	Digital output	MD19 Dil air flow control error, LED READY 2) red	
18	Analog output	Measured value of secondary dilution air flow	2.5 to 10 V DC = 0 to 15 L/min
19	Digital output	Excess meas. gas flow < 0.3 L/min, LED < 9) red	
20	Not connected		
21	Not connected		
22	Not connected		
23	Not connected		
24	Digital input	379020A DIL AIR ON/OFF	
25	COM	(-) for analog in- and outputs	

Main Power Supply

Connect the power cord plug to a grounded power socket. The IEC connector 43) on the back side of the laboratory case includes the power switch 42). The fuse holder 44) is located on the back side of the case. The one phase power cord delivered with the instrument is equipped with a country-specific plug and protective earth ground connection.

Mains supply voltage:	90 ... 240 V, 50/60 Hz, max. 300 VA
Fuse type:	slow switching fuse 250 V, 5 A, t, 5 x 20 mm

W A R N I N G

In case of a blown fuse, replace it only with the specified type of fuse. If the fuse is repeatedly blown, the dilution unit must be sent to the manufacturer or to an instructed service station for checking and repair.

Remote Control

The Model 379020A Rotating Disk Thermodiluter can be remote controlled when used together with a 379032A digital control unit which can be connected to an Ethernet network.

The remote control and data acquisition software NanoMet is delivered together with model 379032A.

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CHAPTER 6

Maintenance

This chapter provides information on servicing and maintaining the Model 379020A and 379030.

Caution

When disconnecting the pneumatic connection between exhaust probe and control unit, precautions must be taken to ensure that condensed matter which can drop out from the undiluted gas tube does not pollute the environment.

Disk and Block

Thermodiluter Block and Disk Cleaning

WARNING

Skin burn

The dilution block 22) and attached parts such as the Thermodiluter disk 21), fixation cap 20), fast lock ring 19), drive shaft 18), and pressure compensation cap 15) are heated up to 150°C/302°F. Let the parts cool down before carrying out the manipulations described below!

The Thermodiluter head and especially the undiluted gas tubes are exposed to very high dust concentrations, depending on the instrument's application. Cleaning of the Thermodiluter block and disks is essential for long lasting performance and reliability of the instrument.

- Clean the disk and the surface of the exhaust probe block with a cleaning solvent. Take care that no dust remains in the cavities. Clean them with cotton swabs if necessary.
- The inside of the Thermodiluter block can be contaminated with dust after long series of measurements in high dust concentrations. Clean the disconnected tubing by carefully blowing compressed air through the raw gas inlet 5), the waste gas outlet 6) and ports B and C of the pneumatic Thermodiluter head connector.

Caution

Never blow out the tubing without removing the Thermodiluter disk 21) and without pneumatically disconnecting the Thermodiluter head from the control unit. The overpressure resulting from blowing with compressed air may damage Thermodiluter components and sensor(s) installed downstream the Thermodiluter.

- Select the disk 21) according to the desired dilution range. For lower dilution factors, choose the disk with 10 cavities, for higher dilution factors the one with 8 cavities.

Disk and Block Lifetime

If careful cleaning of disk and block surfaces is performed every 8 operating hours and the Thermodiluter is operated without pressure difference between raw gas and ambient, at least 1000 operating hours are expected for one disk-block combination.

The disk is made out of a ceramic material with a polymer coating while the block is made of a hardened stainless steel. If the disk is not used until the polymer coating is completely worn, but exchanged before the ceramics get in touch with the steel surface, the disk can be exchanged easily by the operator and no block exchange will be necessary. For this item, either several individually calibrated disks can be ordered together with the Model 379020A Rotating Disk Thermodiluter, or some non-calibrated disks can be purchased. Due to narrow manufacturing tolerances, the error caused by non-calibrated disks will max. 8 % for the 8-cavities disk and max. 4 % for the 10-cavities disk.

Higher raw gas pressure significantly enhances disk polymer surface wear and therefore reduces the disk lifetime.

It is recommended to send the device once a year back to TSI for service and calibration, like it is mandatory if PMP compliant measurements are achieved.

Multiple Pneumatic Tube Between Thermodiluter Head and Control Unit

The multiple pneumatic tube 3) between Thermodiluter head 1) and the control unit 2) consists of 3 tubes with inner diameter 4 mm and one tube with inner diameter 6 mm, integrated into a flexible, protective tube. Two of these tubes conducting the undiluted gas from the Thermodiluter head to the membrane pump in the control unit and back to the Thermodiluter head for waste gas return are strongly exposed to dust and acid condensate from the sampled raw gas. They need a periodical cleaning service after a series of measurements:

- Disconnect the multiple pneumatic tube 3) from the control unit 2) and the Thermodiluter head 1).
- Ensure that dust and liquid blown out of the tube cannot pollute the environment.
- Blow carefully compressed air from a pressure air pistol or a pressurized dispenser into ports B and C of one of the two connectors of the multiple pneumatic tube. The ports are labeled in Figure 6-1.

- Check the O-ring seals in the connectors of the pneumatic connection and replace them if necessary (see also Chapter 2, "Packing List").

Figure 6-1
Connector of the Pneumatic Connection Tube

Caution
When disconnecting the pneumatic connection between the exhaust head and the control unit, make certain the condensed matter, which can drip out from the undiluted gas tube, does not pollute the environment.

Pump Service

The membrane pump inside the control unit case has to ensure the raw aerosol flow through the Thermodiluter head. The aerosol then is drawn to the control unit and guided back to the Thermodiluter head for being returned into the exhaust pipe.

When the undiluted gas flow is significantly reduced by pollution in the pump, correct Thermodiluter function can be constricted. It is recommended to check the raw gas flow at the Thermodiluter head inlet every 50 operating hours using a flow meter like a rotometer or mass flow meter. If the raw gas flow falls below 1.2 l/min even with freshly cleaned connection tubes according to Multiple Pneumatic Tube Between Thermodiluter Head and Control Unit, the pump should be replaced or cleaned.

It is expected that this pump cleaning or replacement can get necessary every 200 to 1000 operating hours, depending on the polluting properties of the measured raw gas. A tube and pump cleaning kit is available from TSI. Alternatively, it can be done by TSI.

Pump Lifetime

Pumps have a limited life time due to mechanical abrasion:

- Pump for primary dilution air (10,000 to 15,000 hrs operating time).
- Air supply pump for secondary dilution air below the two flow sensors (5,000 to 10,000 hrs).

Pump failures are indicated by:

The primary dilution air pump should be replaced when the Ready LED remains red after the “Pump” is switched on.

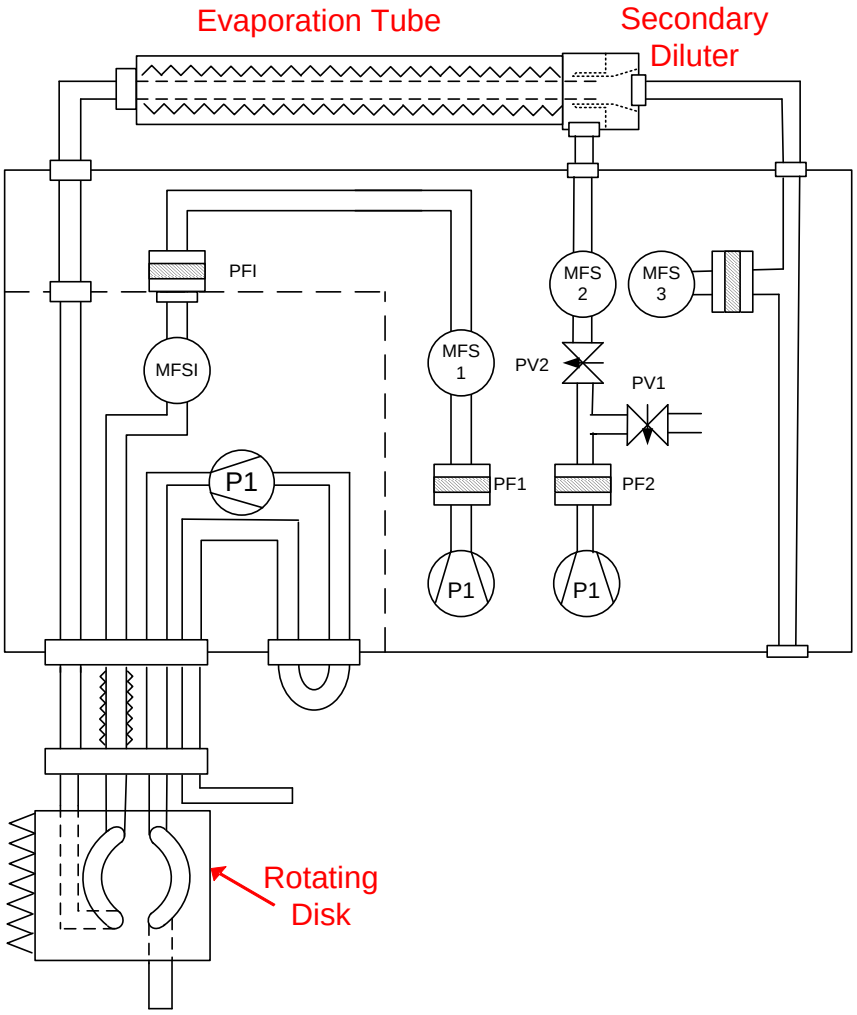

Figure 6-2
Pneumatic diagram for 379030 Thermal Conditioner Air Supply

The air supply pump should be replaced when the Ready LED remains red after the “Air Supply” pump is switched on. This LED is also red when the particle filter PF2 (see block diagram Figure 6-2) inside the holder is overloaded with particles in the ambient air or from abrasion in the pump.

Check this possibility by bypassing the filter before the pump is replaced.

Replacing Pumps

To get access to the pumps mentioned above for replacement first dismount the cover of the 19” case after loosening the two screws on the back side with a 3 mm hexagonal key.

The pumps are below the 24 V DC power supply which can be removed from the DIN rail.

Storage, Acclimatization

Fast ambient temperature changes may result in condensed water on and inside the instrument. This may cause serious damage of electronic parts, e.g., the controller or safety devices.

- Do ***not*** store the instrument outdoors, the storage environment must be clean and dry.
- After long time storage or transport with cold ambient condition or thermal fluctuation, the instrument requires a slow adaptation to the local ambient condition before starting up.
- If condensed water has been formed, wait at least 12 hours before installation and starting up.
- Avoid mechanical damage and agitation.
- Storage temperature range: -10°C to +60°C.

Short Circuit Protection

The thermal conditioner heating element has two LEDs that can indicate as short circuit.

The Red LED **I<** is on when the current is below the lower set value. Most probable reason is a disconnection in the heating current circuit.

The Red LED **I>** is on when the current is above the upper set value. A protection circuit sets the current immediately to zero to protect the device against damages in case of the most probable error a short circuit. After a few seconds the heating is repeatedly switched on but again immediately disconnected when the measured current remains above the upper set value.

Note: *If this happens, immediately switch off the ThC heating element. The device must be checked and repaired by TSI.*

Evaporation Tube Service

Chemical compounds in the primary diluted measuring gas can be deposited on the inside surface of the evaporation tube of the Thermal Conditioner. Depending on their evaporation temperature, they can be produce nucleation particles in the heating up process.

As previously recommended, such artifact particles should be avoided by feeding filtered particle free air into the primary diluter when the temperature in the Thermal Conditioner is increased to a higher set value.

The best procedure to clean the evaporation tube is to heat the evaporation tube to its maximum temperature (400°C) and feed filtered particle free air through it. Leave the temperature at 400°C until no particles are detected by the particle sensor. Depending on the degree of pollution, this procedure can take up to 60 minutes.

Perform this procedure before or after longer measuring programs.

Operation Environment Requirements

Caution
Read this section carefully before setting up Model 379020A Rotating Disk Thermodiluter. TSI is ***not*** liable if the instrument is damaged, caused by the operation environment not meeting the requirements. The Model 379020A Rotating Disk Thermodiluter is designed to be installed in a laboratory, test stand, or a temporary test setup. The instrument is ***not*** intended to be used outdoors or in a dusty or wet environment.

IP protection degree	IP 20. Model 379020A is protected against accidental contact to dangerous parts of the instrument. It is ***not*** protected against intrusion of sand, dust, or water. For safe and reliable operation, avoid operation in dusty or wet environments.
Operating temperature range	The operating ambient temperature range is +10°C to +40°C if free air circulation around the device is ensured.
Humidity range	The ambient relative humidity range (RH) is 0% to 90%, max. 80%@31°C, noncondensing.
Shocks and vibration	Avoid operation under any kind of shock or vibration.

Storage, Acclimatization

Rapid ambient temperature changes can result in water condensation on and inside the instrument. This may cause serious damage of electronic parts. For that reason:

- Do ***not*** store the instrument outdoors; the storage environment must be clean and dry.
- After long storage or when transporting the instrument in cold ambient conditions or where the temperature fluctuates, the device requires a slow warm up to local ambient conditions before use.
- If water condensate has formed on the device, wait at least 12 hours before installation and start up.

Replacement Parts, Optional Accessories, and Service

Table 6-1
Replacement Parts and Optional Accessories for Model 379020A Rotating Disk Thermodiluter

Part Number	Part Description
379027	Cyclone for 379020A
379032A	Digital Control Unit
1137001	Filter primary dilution air 379030
1137002	Filter secondary dilution air 379030
1137003	Plastic tube for sample gas (3 m)
1137004	Heating cartridge set
1137005	Peristaltic Pump 60L/h 24 VDC
1137006	Tubing for new peristaltic pump (98019)
1137008	10 cavity disk - not calibrated (379020A)
1137009	8 cavity disk - not calibrated (379020A)
1137010	Roller for peristaltic pump
1137011	O-rings for 3m connection tubes (qty. 6)
1137014	Dilution Block for 379020A
1137018	Absolute filter 379020A (2 units)
1137019	Membrane Pump

Table 6-2
Replacement Parts for Model 379030 Thermal Conditioner Air Supply

Part Number	Part Description
1137001	Particle Filter for 379030
1137301	Rotary Valve Pump 21 L/min, 24 VDC
1137302	Rotary Valve Pump 3.1 L/min, 12 VDC
1137303	379030 filter 0.02m/99.9999%

Table 6-3
Service

Model	Description
QU-379020	Evaluate and Repair of 379020/A
QU-379030	Evaluate and Repair of 379030
CL-379020A	Standard calibration 379020A or disk(s)
CL-379030	Standard calibration 379030
CL-PMP379020A-30	PMP-calibration for the 379020A-30
PMP-379020A	PMP Calibration 379020A
RP-379020A	Repair and Calibration 379020A
1137015	Yearly Service Pack 379020A and 379030 (Cal., pump, heat elements, filters, O-ring) disk sold separately

APPENDIX A

Specifications

Table A-1
Model 379020A Rotating Disk Thermodiluter Specifications*

Aerosol	Exhaust gases or air containing nano particles	
Particle size	< 1 µm	
Raw gas flow	Approx. 2 L/min	
Measuring gas flow	Full dilution range:	0.5...1.5 lN/min
	@ High dilution factors	up to 5 lN/min
Differential Pressure	Between raw gas channel and ambient conditions: 100 to +100 mbar (with no effect on sample flows up to 5 L/min).	
Raw gas pressure	Up to 300 mbar relative to ambient for low dilution (high rotational speed) Up to 400 mbar relative for short time and high dilution	
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 x 258 mm x 312 mm (5.8 in. x 10.2 in. x 12.3 in.)	
Weight	Approx. 8 kg (17.6 lbs)	
Inputs/Outputs	Functions can be controlled by analog (0 to 10V) signals via 25-pin D-sub female connector on back panel	
Local operation	Pump switch, temperature dial, dilution potentiometer, LED indicators	
Remote operation	– Via Ethernet in combination with CU-1 ET v 2.0 or CU-2 – Controlled with analog DC signals 0...10 VDC	
Assembly	– Together with ASET15 integrated in 19" case – Stand alone in a 3U / 42HP laboratory case	
Weight	Thermodiluter head: ca. 4.5 kg Control unit in laboratory case: ca. 5.6 kg **Total: ca. 13.2 kg** Pneumatical and electric connections: ca. 3.1 kg	
Operating conditions	T_{amb}: 10 ... 40 °C 10....90% relative humidity, non-condensing	
Calibration	– Standard calibration with 90 nm NaCl particles in air, Thermodiluter temp: 80°C – PMP calibration possible if integrated in ViPR system	
Sample Inlet Conditions		
Flow Rate	Approximately 1.0 L/min	
Differential Pressure[1]	-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	
Diluter		
Separate Exhaust Probe with rotating disk diluter	Yes; heated diluter	
Temperature Settings	OFF, 80, 120, or 150°C	
Nominal Dilution Ranges[2]		
10-cavity Disk	15:1 to 300:1	
8-cavity Disk	150:1 to 3000:1	

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 below 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,

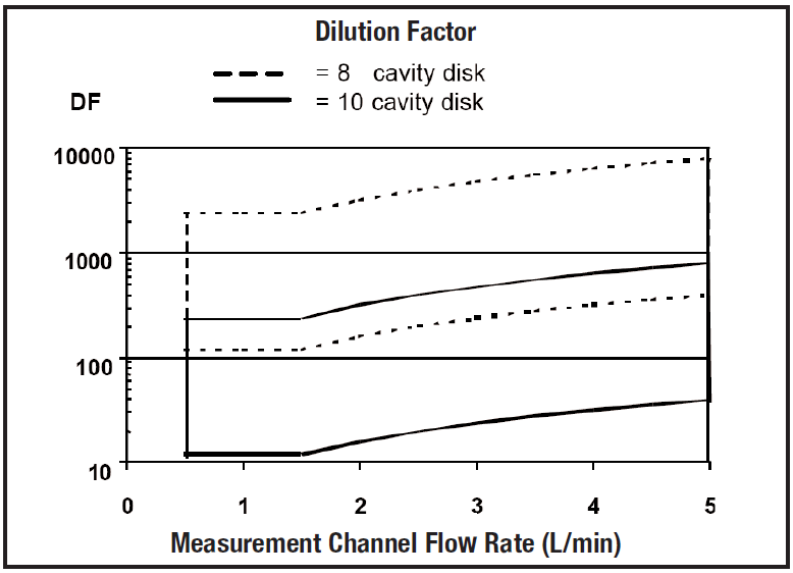

Figure A-1
Dilution range as function of measurement channel, flow rate and number of cavities on the disk

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
Connections to Instrument	Swagelok® fitting for 6 mm OD tube
Exhaust Probe	
Sample Probe	Stainless steel tube connected to dilution block via Swagelok fitting (8 mm 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 three silicon and one conductive plastic tube (3 m length)
Electrical	Multi-pole electrical cable housed in a flexible, metal protective tube (3 m length)
Dimensions (HWD)	180 mm x 280 mm x 90 mm (7 in. x 11 in. x 3.5 in.)
Weight	Approx. 2.5 kg (5.5 lb)

Conformity	Model 379020A Rotating Disk Thermodiluter is in conformity with the following standards or other related documents:	
	EN 61326-1 : 2006 / B1	Electrical equipment for measurement, control and laboratory use. EMC requirements.
	EN 61010-1 : 2001	Safety requirements for electrical equipment for measurement, control and laboratory use.
	EN 61000-3-2 : 2006	Electromagnetic compatibility (EMC) – Limits for harmonic current emissions
	EN 61000-3-3 : 1995	Electromagnetic compatibility (EMC) – Limitation of voltage fluctuations and flicker in low-voltage supply systems and therefore is in conformity with the following European Directives in their current versions:
	2004/108/EG	Electromagnetic compatibility
	2006/95/EG	Low voltage directive

[1]Between raw gas channel and ambient conditions
[2]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 A-1 for nominal dilution range.

**Specifications are subject to change without warning.*

Table A-2
Model 379030 Thermal Conditioner Air Supply Specifications*

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 back panel.
Control Unit	
Dimensions (HWD)	146 mm x 485 mm x 530 mm (5.75 in. x 19 in. x 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 379020A; 460W when combined with 379020A).

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APPENDIX B

Technical Data

Diffusion Losses

In Chapter 3, "Diffusion Losses" the procedure to estimate diffusion losses in tubes was described. Figure B-1 shows some curves from which the approximate particle loss can be determined depending on particle size and aerosol.

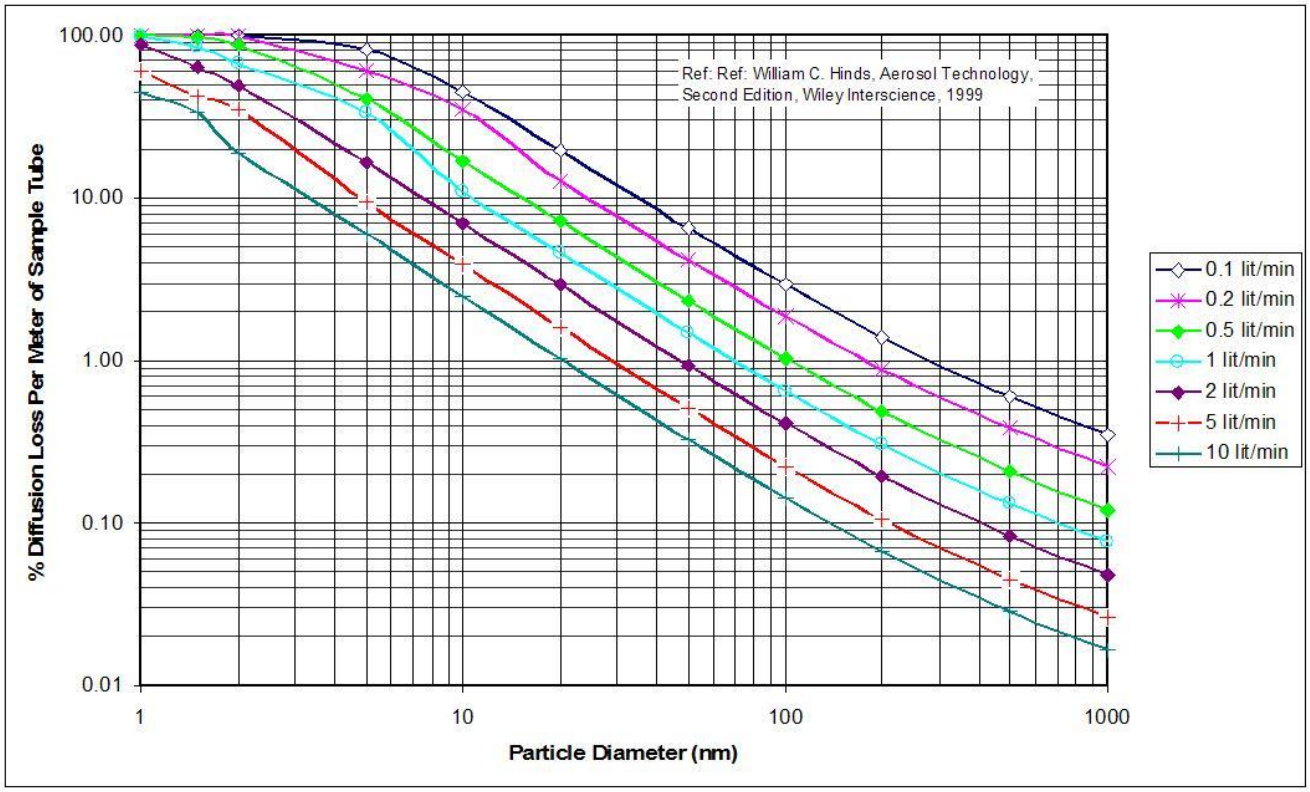

Figure B-1
Particle Loss According to: William C. Hinds, Aerosol Technology, Second Edition, Wiley Interscience, 1999

Swagelok® Fittings

The Model 379020A Thermodiluter head is equipped with one Swagelok® 10-mm fitting at its raw gas inlet 5) and one Swagelok® 6-mm fitting at the waste gas outlet 6). The enclosed or any other metallic 10- and 6-mm tubes can safely be connected following the original Swagelok® instructions which are downloaded from www.swagelok.com.

Figure B-2 shows how the components of a Swagelok® fitting and a steel tube are arranged, and how the sleeve nut is tightened.

Swagelok® Tube Fitting Instructions for 1 in. (25 mm) and Smaller Fittings

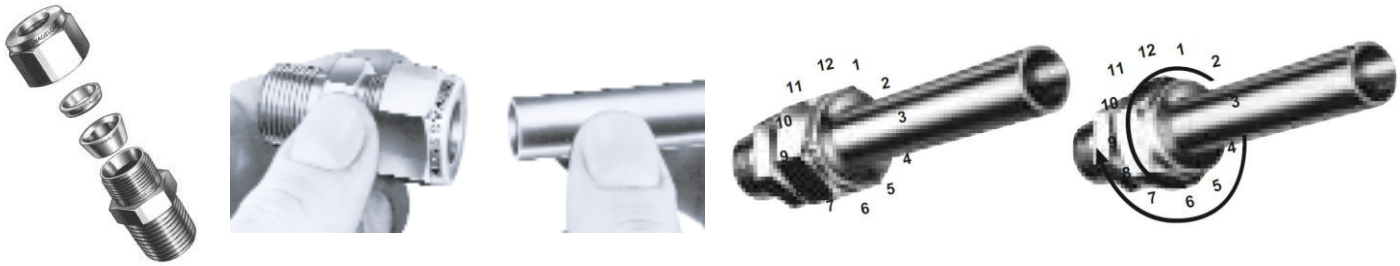

Figure B-2
Arrangement of the Swagelok® Tube Fitting

Installation

Note

These instructions apply to traditional fittings and fittings with the advanced back-ferrule geometry.

1. Insert tubing into the Swagelok® tube fitting.
2. Make sure that the tubing rests firmly on the shoulder of the tube fitting body and that the nut is finger-tight.
3. Scribe the nut at the 6 o'clock position.
4. While holding fitting body steady, tighten the nut 1¼ turns to the 9 o'clock position.

Reassembly Instructions

You may disassemble and reassemble a Swagelok® tube fitting, port connector, cap, and plug many times.

1. Insert tubing with pre-swaged ferrules into the fitting body until the front ferrule seats.
2. Rotate the nut with a wrench to the previously pulled-up position. At this point, a significant increase in resistance will be encountered.
3. Tighten slightly with a wrench.

Definitions, Units, and Conversion Table

Pressure	Pascal	Bar	Pound per square inch
	(Pa)	(bar)	(psi)
1 Pa	1	$1.0 \cdot 10^{-5}$	$1.450 \cdot 10^{-4}$
1 bar	$1.0 \cdot 10^{5}$	1	14.504
1 psi	6 894.8	0.0689	1

Length	Meter	Centimeter	Millimeter	Micrometer	Nanometer	Inch
	(m)	(cm)	(mm)	(µm)	(nm)	(") = (in)
1 m	1	100	1 000	$1.0 \cdot 10^{6}$	$1.0 \cdot 10^{9}$	39.37
1 cm	0.01	1	10	$1.0 \cdot 10^{4}$	$1.0 \cdot 10^{7}$	0.3937
1 mm	0.001	0.1	1	1 000	$1.0 \cdot 10^{6}$	0.0394
1 µm	$1.0 \cdot 10^{-6}$	$1.0 \cdot 10^{-4}$	1.001	1	1 000	$3.937 \cdot 10^{-5}$
1 nm	$1.0 \cdot 10^{-9}$	$1.0 \cdot 10^{-7}$	$1.0 \cdot 10^{-6}$	0.001	1	$3.937 \cdot 10^{-8}$
1 " = 1 in	0.0254	2.54	25.4	$2.54 \cdot 10^{4}$	$2.54 \cdot 10^{7}$	1

Temperature	Celsius	Fahrenheit
	(°C)	(°F)
0 °C	0	32
100 °C	100	212
0 °F	-17.78	0
100 °C	37.78	100

T[°C] = (T[°F]-32)/1.8

T [°F] = T[°C] · 1.8 + 32

Mass	Kilogram	Gram	Pound	Ounce
	(kg)	(g)	(lb)	(oz)
1 kg	1	1 000	2.205	35.27
1 g	0.001	1	0.0022	0.0353
1 lb	0.4536	453.6	1	16
1 oz	0.0283	28.35	0.0625	1

Volumetric	Cubic Meter	Liter	Milliliter	Cubic Inch	Cubic Foot
	(m^3)	(l)	(ml) = (ccm)	(cin)	(cft)
1 m^3	1	1 000	$1.0 \cdot 10^{6}$	61 024	35.315
1 l	0.001	1	1000	61.024	0.0353
1 ml = 1 ccm	$1.0 \cdot 10^{-6}$	0.001	1	0.061	$3.531 \cdot 10^{-5}$
1 cin	$1.639 \cdot 10^{-5}$	0.0164	16.387	1	$5.787 \cdot 10^{-4}$
1 cft	0.0283	28.317	$2.832 \cdot 10^{4}$	1728	1

Volumetric current		
	(l_N / min)	(m^3 / h)
1 l_N / min	1	0.06
1 m^3 / h	16.667	1
1 l_N =	1 013.5 mbar	

Units								
Length	m	meter	cm	centimeter	mm	millimeter	nm	nanometer
Mass	kg	kilogram	g	gram				
Time	h	hour	min	minute	s	second		
Electricity	A	ampère	V	volt	VA	voltampère	Ω	ohm

System Overview and Description of all Components

1) Model 379020A Thermodiluter head

2) Model 379020A control unit

3) Multiple pneumatic tube between Thermodiluter head and control unit
Tube A) Particle free dilution air duct to the Thermodiluter head
Tube B) Waste gas return to the Thermodiluter head
Tube C) Raw gas duct from the Thermodiluter head to the membrane pump inside the control unit
Tube D) Diluted measuring gas duct to the control unit and connected sensors

4) Electrical cable between Thermodiluter head and control unit

5) Raw gas inlet into Thermodiluter head: 10 mm Swagelok® fitting

6) Waste gas outlet from Thermodiluter head to the exhaust pipe: 6 mm Swagelok® fitting

7) Handle

8) Hot parts protection hood

9) Protection hood latch

10) Connector to multiple pneumatic tube 3)

11) Connector to electrical cable 4)

12) Temperature sensors

13) Thermodiluter block heating cartridges

14) Dilution air heating cartridge

15) Pressure compensation cap

16) Cap holder nuts

17) Cap holder bolts

18) Thermodiluter disk drive shaft

19) Fast lock ring

20) Thermodiluter disk fixation cap

21) Rotating Thermodiluter disk

22) Thermodiluter block

23) Aerosol/air duct block

24)	Raw gas pump switch:	up: ON	down: OFF		
25)	Raw gas pump LED:	green: running	red: error	dark: OFF	
26)	Actuation motor LED:	green: rotating	red: error	dark: motor stopped	
27)	Block and dil. air heating LED:	green: OK	red: error	dark: OFF	orange: heating up
28)	Dilution factor LED:	green: OK	red: dilution factor out of specified range		
29)	Remote LED:	green: device is remote controlled			
30)	All signals ready LED:	green: OK		dark: at least one signal not OK	

31) 10 turn potentiometer for dilution setting

32) Dial for temperature setting of block and dilution air heating

33) Self-sealing quick coupling for measuring gas output to sensor(s)

34) Quick coupling for waste gas inlet for return to the Thermodiluter head

35) Waste gas return bridge / tubelet for connection to another offtake than the exhaust pipe

36) Quick coupling for waste gas outlet to an offtake

37) Self-sealing quick coupling for measuring gas output to sensor(s) or secondary dilution

38) Quick coupling for dilution air input to Model 379020A

39) Ventilator

40) Connector to electronic circuit

41) Remote control interface connector: 25 pin D-Sub female

42) Mains switch

43) Mains connector

44) Fuse MD19 250 V, 5.0 A, t

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