ENVIRONMENTAL SAMPLING SYSTEM MODEL 3031200

USER'S MANUAL

P/N 6001630, REVISION D
JULY 2015

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ENVIRONMENTAL SAMPLING SYSTEM MODEL 3031200

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Manual History

The following is a manual history of the Model 3031200 Environmental Sampling System (Part Number 6001630).

Revision	Date
A	March 2008
B	January 2009
C	March 2009
D	July 2015

Warranty

Part Number 6001630 / Revision D / July 2015

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

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Safety

This section gives instructions to promote safe and proper handling of the Model 3031200 Environmental Sampling System.

There are no user-serviceable parts inside the system. Refer all repair and maintenance to a qualified technician. All maintenance and repair information in this manual is included for use by a qualified technician.

To prevent problems, take these precautions:

- Do ***not*** remove any parts from the system unless you are specifically told to do so in this manual.
- Do ***not*** remove the system housing or covers while power is supplied to the system.

C a u t i o n
If the Model 3031200 is used in a manner **not** specified by the manufacturer, the protection provided by the equipment may be impaired.

Description of Caution Symbol

The following symbol and an appropriate caution statement are used throughout the manual and on the Model 3031200 to draw attention to any steps that require you to take cautionary measures when working with the Model 3031200:

Caution

C a u t i o n
Caution means ***be careful***. It means if you do not follow the procedures prescribed in this manual you may do something that might result in equipment damage, or you might have to take something apart and start over again. It also indicates that important information about the operation and maintenance of this instrument is included.

Warning

W A R N I N G
Warning means that unsafe use of the instrument could result in serious injury to you or cause irrevocable damage to the instrument. Follow the procedures prescribed in this manual to use the instrument safely.

Caution or Warning Symbols

The following symbols may accompany cautions and warnings to indicate the nature and consequences of hazards:

	Warns you that uninsulated voltage within the instrument may have sufficient magnitude to cause electric shock. Therefore, it is dangerous to make any contact with any part inside the instrument.
	Indicates the connector is connected to earth ground and cabinet ground.

About This Manual

Purpose

This is an instruction manual for the operation and handling of the Model 3031200 Environmental Sampling System.

Related Product Literature

- **Model 3031/3031-1Ultrafine Particle Monitor Manual** (P/N 6001631 TSI Incorporated)
- **Model 3034 Scanning Mobility Particle Sizer Manual** (P/N 1980482 TSI Incorporated)
- **Model 3708 Flow Splitter Manual** (P/N 1933708 TSI Incorporated)
- **Model 3772/3771 Condensation Particle Counter Manual** (P/N 1980529 TSI Incorporated)
- **Model 3775 Condensation Particle Counter Manual** (P/N 1980527 TSI Incorporated)
- **Model 3776 Ultrafine Condensation Particle Counter Manual** (P/N 1980522 TSI Incorporated)
- **Model 3781 Water-based Condensation Particle Counter Manual** (P/N 1930111 TSI Incorporated)
- **Model 3785 Water-based Condensation Particle Counter Manual** (P/N 1933001 TSI Incorporated)
- **Model 3786 Ultrafine Water-based Condensation Particle Counter Manual** (P/N 1930072 TSI Incorporated)
- **Model 3936 Scanning Mobility Particle Sizer™ Spectrometer Manual** (P/N 1933796 TSI Incorporated)
- **Model 4140 General Purpose Thermal Mass Flowmeter Manual** (P/N 1980383 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.

If the comment sheet has already been used, send your comments to:

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CHAPTER 1

Product Overview

This chapter describes the Model 3031200 Environmental Sampling System, shown in Figure 1-1, and gives an overview of how it works.

Product Description

The Model 3031200 Environmental Sampling System is an accessory for use with a wide variety of TSI particle sizers and counters, including Ultrafine Particle Monitor, Scanning Mobility Particle Sizer™ spectrometers and Condensation Particle Counters. It provides representative sampling and proper conditioning of ambient aerosol for accurate size distribution and particle number measurements.

The Model 3031200 consists of standard components conveniently packaged together for you. Combine these components with your choice of appropriate length sample tubes and vacuum source for easy setup in the field.

The Model 3031200 consists of:

- **Standard PM_{10} inlet**: Provides standardized size-selective sampling of outdoor aerosol.
- **Sharp cut PM_1 cyclone**: Removes large particles to avoid contamination of the particle measurement system.
- **Flow splitter**: Splits the inlet sample flow to enable sub-sampling a portion of the flow into the particle measurement system.
- **Nafion® dryer**: Conditions the sample to reduce effects of relative humidity on the aerosol.
- **Tube Connector**: Connects the PM_1 cyclone to a 1¼" diameter sampling tube.

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Figure 1-1
Model 3031200 Environmental Sampling System

CHAPTER 2

Unpacking and Setting Up the System

Use the information in this chapter to unpack and setup the Model 3031200 Environmental Sampling System.

Packing List

As you unpack the shipping container, make certain the shipment is complete. Table 2-1 gives a packing list for the Environmental Sampling System. The pre-assembled parts can be seen in Figure 2-1.

Table 2-1
Environmental Sampling System Packing List

Qty.	Description	Part No.

1	Model 3031200 Environmental Sampling System
	• PM_{10} Inlet
	• Flow Splitter Assembly, consisting of:
	  ○ PM_1 Sharp Cut Cyclone
	  ○ Flow Splitter
	• Dryer Assembly, consisting of:
	  ○ Nafion® Dryer
	  ○ Pressure Gauge Assembly
	  ○ Needle Valve
	• Filter Assembly, consisting of:
	  ○ Particle Filter
	  ○ Polyethylene (PE) Tubing
	• Tube Connector
	• Polyethylene (PE) Tubing
	• Tygon® Tubing
		3031200

1	Model 3031200 Environ. Sampling System Manual	6001630

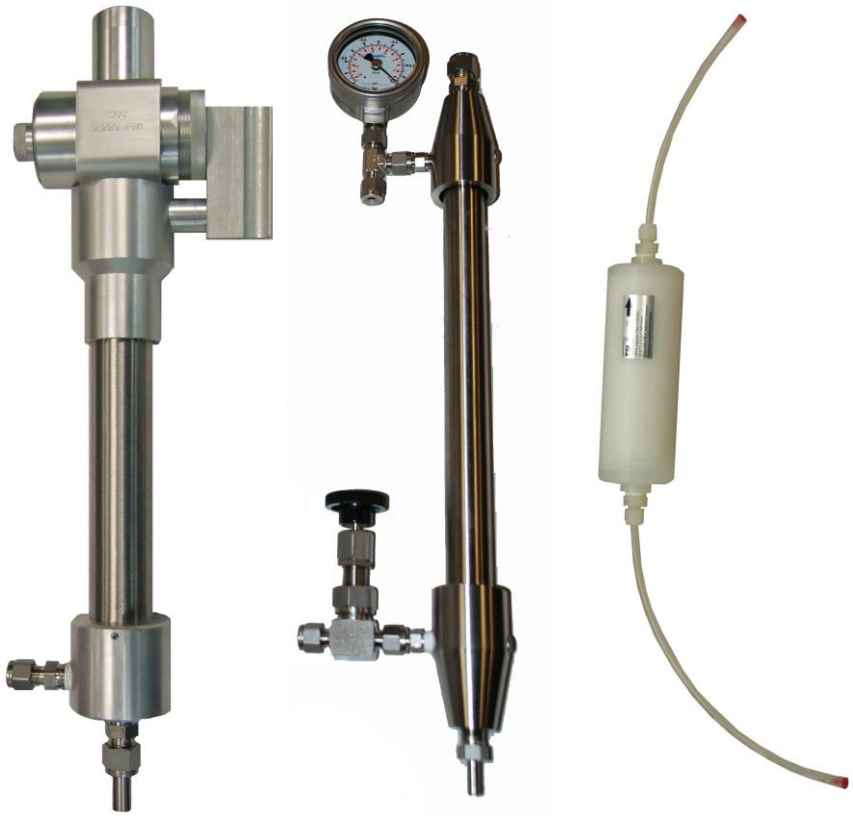

Figure 2-1
The Three Pre-Assembled Parts of the Environmental Sampling System (from left): Flow Splitter Assembly, Dryer Assembly, and Filter Assembly

Since some items will vary depending on a particular installation, the 3031200 Environmental Sampling System does ***not*** include the following parts potentially needed to install the system at the sampling location:

Table 2-2
User-supplied parts for Environmental Sampling System

Qty	Description
As needed	1¼" diam. Stainless steel tubing (extension between PM_{10} inlet and PM_1 cyclone). Make sure the end of the stainless steel tube has been cleaned and machined with a 30-45 degree chamfer to prevent damaging the O-rings and to provide a good sealing surface for the O-rings in the PM_{10} inlet. To ensure a good fit into the tube connector and the PM_{10} inlet, the outer diameter of the tube should be machined to 1.246" ±0.002" (31.65 mm ±0.05 mm) for a length of 1.5" (38 mm).
1	Roof port to feed sampling tube through roof of shelter

Qty	Description
as needed (1 per tubing extension)	1¼" diam. Swagelok® union (Swagelok® part # SS-2000-6) ***Note**: A Tube Connector for the first tubing extension is included.*
as needed	Depending on the roof port and height of the PM_{10} inlet above the roofline, a tripod or guy-wires may be required to stabilize the PM_{10} inlet on the roof.
as needed	Hardware to mount the dryer and filter and to provide support to the stainless steel tubing.
1	Vacuum pump (TSI Model 3033 Oil-free vacuum pump is recommended)
1	TSI 4140 Flowmeter or equivalent
2	Swagelok® ¼" Tube Fitting Union (SS-400-6, TSI 1601275) to couple TSI 4140 Flowmeter to supplied PE tubing
as needed	(Optional) TSI 370800 4-way flow splitter

Figure 2-2 shows a schematic of the Environmental Sampling System.

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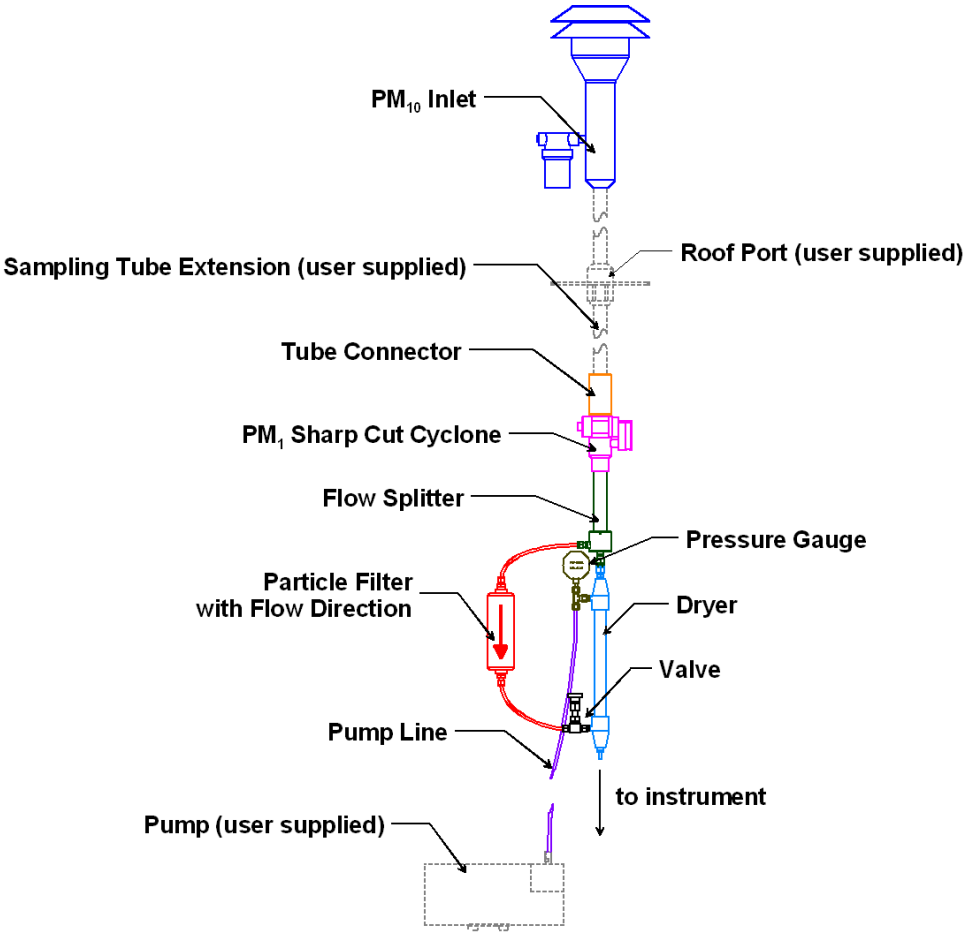

Figure 2-2
Schematic of the Inlet System, Showing all Components of the System

Unpacking Instructions

The Model 3031200 is shipped partly assembled. Make sure you have all the user-supplied parts (see Table 2-2) and hardware listed in Table 2-1 before assembling the system. The roof port should be installed prior to installing the system.

Refer to Figure 2-2 to begin assembling the Environmental Sampling System:

1. Attach the filter assembly to the dryer assembly (observe correct orientation of the filter, with the exit of the filter attached to the dryer assembly).
2. Mount the dryer assembly and particle filter securely (customer supplied fittings).

3. Attach the flowsplitter assembly to the dryer assembly with the 3/8" Swagelok® connector at the top of the dryer. Attach the other tube from the filter assembly to the flow splitter assembly.

4. If an extension is needed for the sampling system, mount the 1¼" stainless steel tube through the roof port. Depending on the roof port and height of the PM_{10} inlet above the roofline, a tripod or guy-wires may be required to stabilize the PM_{10} inlet on the roof. Attach the tube to the sampling system with the tube connector. Make sure the end of the stainless steel tube has been cleaned and machined with a 30–45 degree chamfer to prevent damaging the O-rings and to provide a good sealing surface for the O-rings in the tube connector. To ensure a good fit into the tube connector, the outer diameter of the tube should be machined to 1.246 "±0.002" (31.65 mm ±0.05 mm) for a length of 1.5" (38 mm).

   Further sampling tube extensions can be attached using 1¼" Swagelok® unions. The center of the air entrance should be 2.0 ± 0.2 m (78.7 ±7.87") above the horizontal surface (roof).

   Note: *As the tube connector uses O-rings for sealing, it cannot support any weight. Therefore, both the inlet system with the cyclone and the sampling tube need to be supported.*

5. Install the PM_{10} inlet on the end of the 1.25-inch diameter stainless steel tube. Make sure the end of the stainless steel tube has been cleaned and machined with a 30-45 degree chamfer to prevent damaging the O-rings and to provide a good sealing surface for the O-rings in the PM_{10} inlet. The PM_{10} inlet sits on top of the stainless steel tubing. To ensure a good fit into the PM_{10} inlet, the outer diameter of the tube should be machined to 1.246" ±0.002" (31.65 mm ±0.05 mm) for a length of 1.5" (38 mm).

6. Connect the system to a pump using the supplied PE tubing. Connect the tube to the bottom port of the Swagelok® tee mounted to the vacuum gauge.

Figure 2-3
The Environmental Sampling System Installed in a Sampling Station

Leak Testing the Environmental Sampling System

Before running the Model 3031200 Environmental Sampling System, it is recommended to leak test the system. To run a leak test, follow the steps below:

1. Remove the PM_{10} inlet and plug the sampling tube.
2. Remove the connection between the Nafion® dryer and the sampling instrument. Plug the connection at the dryer.
3. With the needle valve fully open, turn on the pump for the purge flow. The pressure should drop to about -0.9 bar on the pressure gauge.
4. Turn off the pump, reconnect the sampling system to the sampling instruments, unplug the sampling tube and reconnect the PM_{10} inlet.

If this test reveals a leak (pressure drop less than -0.9 bar), check all connections and O-rings. If necessary, replace O-rings and/or tighten Swagelok® connections. ***Do not*** overtighten the Swagelok® connections, as nylon ferrules are used in most places.

Running the Environmental Sampling System

To use the Model 3031200 Environmental Sampling System, turn on the vacuum pump to draw air through the dryer. The Dryer purge flow rate has to be adjusted based on the sample flow rate. The total flow rate of the sampling system is 16.7 L/min. Using a flowmeter, adjust the dryer purge flow with the needle valve to a value that adds up to 16.7 L/min. Table 2-3 shows some examples of sample- and purge flow rates. For the Nafion® dryer to work correctly in this setup, the pressure reading for the purge flow (pressure gauge at the top of the dryer) needs to read -0.5 bar or lower (total pressure 0.5 bar or lower).

Table 2-3
Example Flow Rates for the Environmental Sampling System

Sample Flow (L/min)	Purge Flow (L/min)
1	15.7
3	13.7
5	11.7

Optional Accessories

The Environmental Sampling System can be used with the Model 3033 Vacuum Pump. This oil-free vacuum pump works well with the 3031200 Environmental Sampling System, providing adequate pumping for the desired dryer purge flows.

A TSI Model 4140 Flowmeter is useful when setting up the sampling system and also to check its performance. It can be used to balance the sample and purge flows for different setups.

If more than one instrument is used to measure air from the 30312000 Environmental Sampling System, a TSI Model 3708 4-Way Flow Splitter is recommended. This flow splitter divides the sample flow into four equivalent sample streams that can be measured independently.

CHAPTER 3

Maintenance

This chapter gives maintenance and service procedures for the Model 3031200 Environmental Sampling System.

Periodic Maintenance

Periodic cleaning of several portions of the Environmental Sampling System is necessary to ensure proper performance. The following parts should be cleaned regularly:

- PM_{10} inlet
- PM_1 sharp cut cyclone
- Flow splitter

In addition to this, the particle filter needs replacing occasionally as well.

Please note that the actual service intervals depend on the aerosol concentration entering the unit.

Table 3-1
Maintenance Schedule

Maintenance Task	Maintenance Interval
Replace the aerosol filter cartridge	Every year
Clean the PM_{10} inlet	Every 6 months
Clean the PM_1 sharp cut cyclone	Every 1 month/6 months (see text below)
Clean the flow splitter	Every 6 months or as needed
Clean the sampling tube	Every 6 months or as needed
Clean the Nafion® dryer	Every year or as needed

Replacing the Filter Cartridge

The particle filter cartridge used in the Environmental Sampling System needs to be replaced when it reaches its maximum loading. A reduced flow through the filter is an indication that the filter needs to be replaced. It should also be replaced if it gets exposed to water (condensation from the sampling system).

To replace the filter, follow these steps:

1. Turn off the pump for the dryer purge flow.
2. Disconnect the tubing from the filter.
3. Remove the Swagelok® connectors from the filter. Clean the threads from any Teflon® tape that remains on them.
4. Install the Swagelok® connectors in the new particle filter, using Teflon® tape as necessary.
5. Attach the tubing to the Swagelok® connectors. Observe the correct flow direction (see also Figure 2-2) for the filter (flow is from Flow Splitter to Dryer).
6. Turn on pump and restart sampling.

Cleaning the PM_{10} Inlet

Particles larger than 10 µm in aerodynamic diameter will be removed by this inlet. Therefore, the inlet needs to be cleaned on a regular basis to ensure optimal operation. The suggested interval is 6 months, but this can change depending on particle concentrations.

To clean the inlet, refer to Figure 3-1 and follow the steps below:

1. Remove the inlet from the sampling line.
2. Remove the water collector, empty and clean it.
3. Unscrew the top of the inlet and clean the impaction plate in the bottom part with a lint-free wipe and distilled water. If the inlet is very dirty, use a non-abrasive detergent solution. Rinse the parts well to prevent future sample contamination with the detergent.
4. Check that all O-rings are free from nicks and cuts. If necessary, replace the O-rings.

   O-rings:

Louvered inlet	1-036 (TSI 2501133)	1 x
Impactor body (outlet)	1-026 (TSI 2501551)	2 x

5. Reassemble the unit and mount it on the sampling line.

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Figure 3-1
The Components of the PM_{10} Inlet. The Impaction Surface is Located in the Bottom Part.

Cleaning the PM_1 Cyclone

The Sharp Cut Cyclone needs regular cleaning to ensure correct operation. The interval between cleanings depends on the particulate concentration in the air sampled. At average concentrations of ~10 µg/m^3, a one-month interval is recommended for the grit pot, and a six-month interval for the rest of the cyclone. It is suggested to start with a shorter interval (2 weeks) at the beginning until experience has been gained what intervals are appropriate.

To clean the grit pot, refer to Figure 3-2 and follow the steps below:

1. Unscrew the grit pot.
2. Using a lint-free wipe and distilled water, clean the grit pot of visible spots.
3. Inspect the O-ring to make sure it doesn't have any nicks or cuts. Clean the O-ring with alcohol and regrease it lightly. If the O-ring is damaged, replace it with a BUNA-N O-ring.

4. Reassemble the impactor by screwing in the grit pot. Tighten the grit pot finger-tight.

To clean the cyclone, refer to Figure 3-2 and follow the steps below:

1. Remove the cyclone from the sampling line.
2. Pull off the transfer tube. If it is too tight to remove by hand, use a rigid plastic lever to pry it off.
3. Unscrew the top cap and the grit pot.
4. Using a lint-free wipe and distilled water, clean all parts of visible spots. Most material deposits in the grit pot and at the bottom of the cyclone body cone. If necessary, ethanol, isopropanol or acetone can be used to clean the cyclone parts. Parts can also be cleaned using an ultrasonic bath.
5. Inspect all O-rings to make sure they do not have any nicks or cuts. Clean the O-rings with alcohol and re-grease them lightly. If the O-rings are damaged, replace them with BUNA-N O-rings.

   O-rings:

Transfer tube:	1-015 (TSI 2501890)	4 x
Top cap, grit pot:	1-028 (TSI 2501028)	2 x
Cyclone exit:	1-026 (TSI 2501551)	2 x

6. Reassemble the impactor by screwing in the top cap and the grit pot, and by installing the transfer tube. Tighten the top cap and grit pot finger-tight.
7. Install the cyclone in the sampling line and restart sampling.

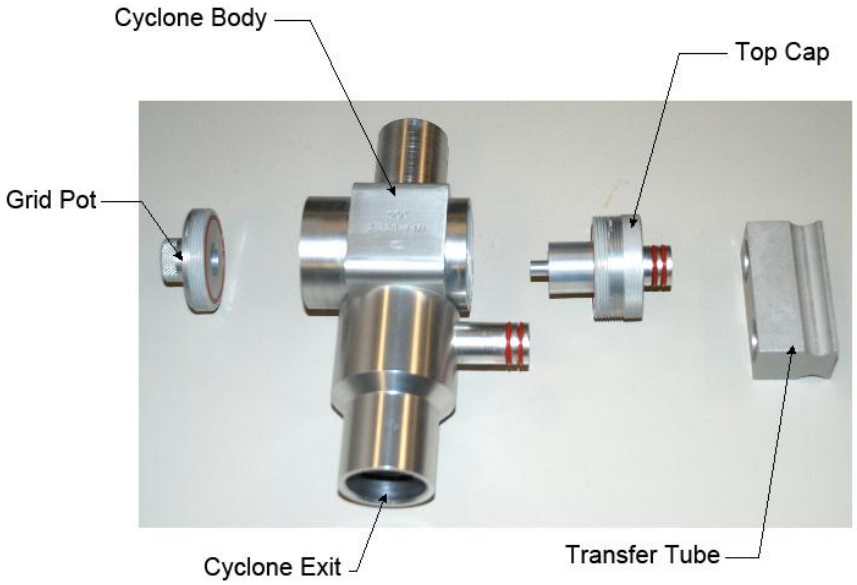

Figure 3-2
The Components of the Sharp Cut Cyclone

Cleaning the Flow Splitter

The flow splitter should not need cleaning on a regular basis, but it might be good to check for condensation and deposits at the bottom of the tube, especially in humid environments.

To clean the flow splitter, follow the steps below:

1. Remove the Sharp Cut Cyclone from the top of the flow splitter.
2. Remove the tubing to the particle filter by loosening the Swagelok® connector.
3. Remove the flow splitter from the dryer by loosening the Swagelok® connector on the top of the dryer.
4. Using a 1/16" Allen wrench, loosen the set screw in the side of the lower housing. Remove the upper housing by pulling it out straight.
5. Clean the inside of the lower housing and the side port (connection to particle filter) with a lint-free wipe and distilled water.
6. Inspect the O-ring to make sure it doesn't have any nicks or cuts. Clean the O-ring with alcohol and regrease it lightly. If necessary, replace it.

   O-ring:

Lower housing	1-218 (TSI 6001563)	1 x

7. Insert the upper housing into the lower housing until it is fully seated. Tighten the set screw.
8. Install the flow splitter onto the dryer and tighten the Swagelok® connector.
9. Install the cyclone and the rest of the Environmental Sampling System.
10. Attach the tubing to the particle filter and tighten the Swagelok® connector.

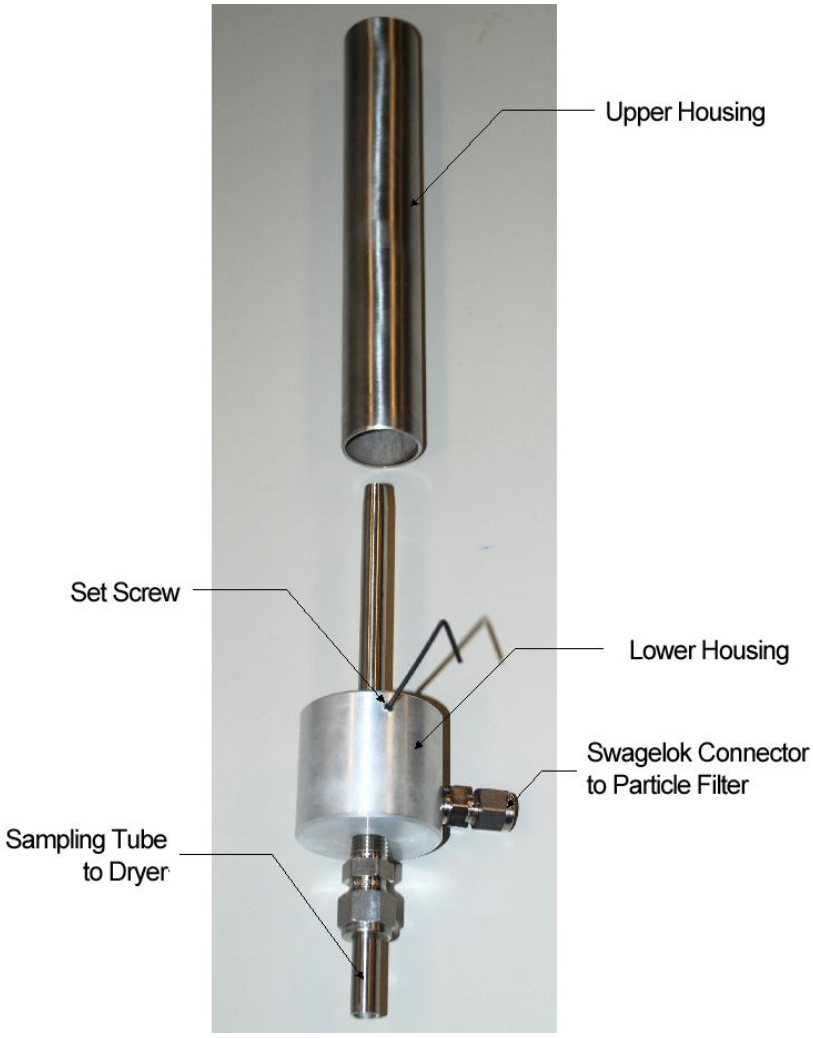

Figure 3-3
The Components of the Flow Splitter

Cleaning the Dryer

The dryer tubes can get clogged depending on sampling conditions. If this happens, the flow through the dryer will be reduced, and the particle transmission will also be reduced. To clean the dryer, refer to detailed instructions on the Perma Pure website at:
http://www.permapure.com/resources/pdf-downloads/

A copy of Perma Pure's Tech Note #3 on Nafion® Dryer Cleaning Procedures can be found in Appendix C.

CHAPTER 4

Troubleshooting

This chapter describes common difficulties that may arise when using the Model 3031200 Environmental Sampling System.

- No sample flow
- Reduced pressure drop on purge flow
- Increased pressure drop on purge flow
- Low particle count
- Wet particles
- Wrong particle size distribution

Table 4-1
Troubleshooting

Symptom	Recommendations
No or low sample flow	• Check that measuring instruments are turned on and work correctly • Check sampling line between 3031200 Environmental Sampling System and instruments for obstructions and kinks • Check dryer—make sure the flow is still as desired. • Check cyclone for obstructions • Check PM_{10} inlet for obstructions
Reduced pressure drop on dryer purge flow	• Check that pump is running • Check pumping line for obstructions and kinks
Increased pressure drop on dryer purge flow	• Check setting of valve • Check particle filter • Check pump port on flow splitter for obstructions
Low particle count	• Check and clean cyclone • Check and clean PM_{10} inlet • Check sample lines and tubing for obstructions and kinks • Check that all components are connected correctly • Check dryer for obstructions
Wet particles	• Check dryer purge flow • Check humidity—dryer might not work well at high ambient humidity
Wrong particle size distribution	• Check and clean cyclone • Check and clean PM_{10} inlet

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CHAPTER 5

Contacting Customer Service

This chapter gives directions for contacting people at TSI Incorporated for technical information.

Technical Contacts

- If you have any difficulty installing the Environmental Sampling System, or you have technical or application questions about the Environmental Sampling System, contact a service engineer at TSI Incorporated, telephone 1-800-874-2811 (USA) or 651-490-2811.
- If the Environmental Sampling System does not operate properly, or you are returning it or any of its components for service or repair, contact TSI Customer Service, telephone 1-800-874-2811 (USA) or 651-490-2811. E-mail support is available at technical.service@tsi.com or our website at service.tsi.com.

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APPENDIX A

Model 3031200 Specifications

The following specifications list the most important features of the Model 3031200 Environmental Sampling System.

Table A-1
Specifications* of the 3031200 Environmental Sampling System

Max. particle size	1 µm (approx.) aerodynamic diameter
Recommended flow rate	16.7 L/min at inlet, up to 5 L/min at sampling port
Main tubing diameter	1.25 inch outer diameter, 0.062 inch wall thickness
Humidity reduction	Sample reduced to less than 50% RH at sampling port for given flow rates
Particle transmission efficiency†	82% at 25 nm; 87% at 40 nm; 93% at 60 nm; 97% at 150 nm and 100% at 300 nm

*Specifications are subject to change without notice.

†Measured at 16.7 L/min inlet flow and 5 L/min sample flow.

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APPENDIX B

Theory of Operation

How the Environmental Sampling System Operates

The Model 3031200 Environmental Sampling System consists of PM_{10} inlet, a PM_1 Sharp Cut Cyclone, a Flow Splitter, and a Nafion® Dryer. This section explains the basic principles of operation of these components.

PM_{10} Impactor Inlet

The PM_{10} Impactor inlet removes particles with an aerodynamic diameter larger than 10 µm. Particles entrained in the sampled air are accelerated through a nozzle in the inlet. The air is then pumped out of the inlet through three ports, with the opening of these ports located above the opening of the nozzle (see Figure B-1). Particles with an aerodynamic diameter of less than 10 µm will follow the gas stream lines and be pumped to the exit of the inlet (and be sampled by an instrument downstream, green lines in Figure B-1), whereas particles with an aerodynamic diameter of more than 10 µm will impact on the bottom of the impaction chamber (red lines in Figure B-1).

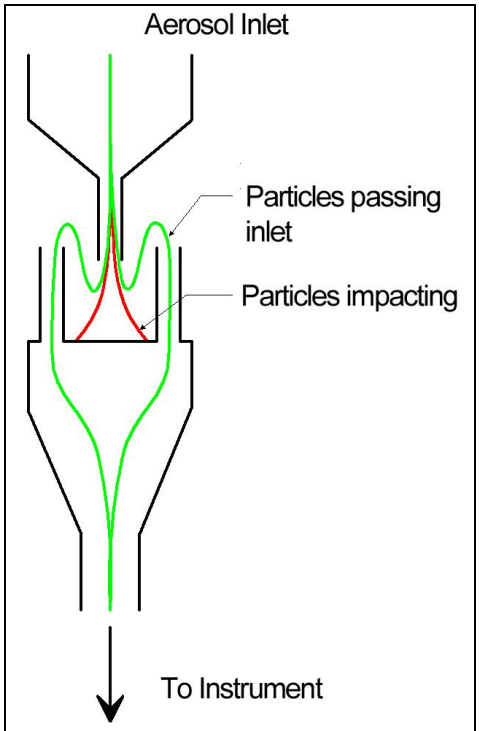

Figure B-1
Principle of an Impactor Inlet

Tolocka et al.[1] report a cut point of 9.9 –to10.7 µm and a sharpness[2] of ~ 1.3 to 1.4, which equals a GSD of ~ 0.72 to 0.76 for this inlet.

[1] Tolocka, Michael P., Peters, Thomas M., Vanderpool, Robert W., Chen, Fu-Lin and Wiener, Russell W. (2001) 'On the Modification of the Low Flow-Rate PM10 Dichotomous Sampler Inlet', Aerosol Science and Technology, 34:5, 407 - 415

[2] Sharpness is defined as $\left(\frac{D_{16}}{D_{84}}\right)^{0.5}$, which equals $\sqrt{\frac{1}{GSD^2}}$

PM_1 Sharp Cut Cyclone

The PM_1 Sharp Cut Cyclone removes particles with an aerodynamic diameter of more than 1 µm. Particles enter the cyclone through a tube and are then exposed to a swirling air current in the cyclone body. The air is directed into the grit pot and exits back through the center of the cyclone body and to the exit. Particles with an aerodynamic diameter of less than 1 µm follow the gas stream lines and exit the cyclone, whereas particles with an aerodynamic diameter of more than 1 µm impact either in the cyclone body or in the grit pot.

Lab tests on the Sharp Cut Cyclone show a cut point (D50) of 1.04 µm and a sharpness of 1.17[3,4] (GSD = 0.85).

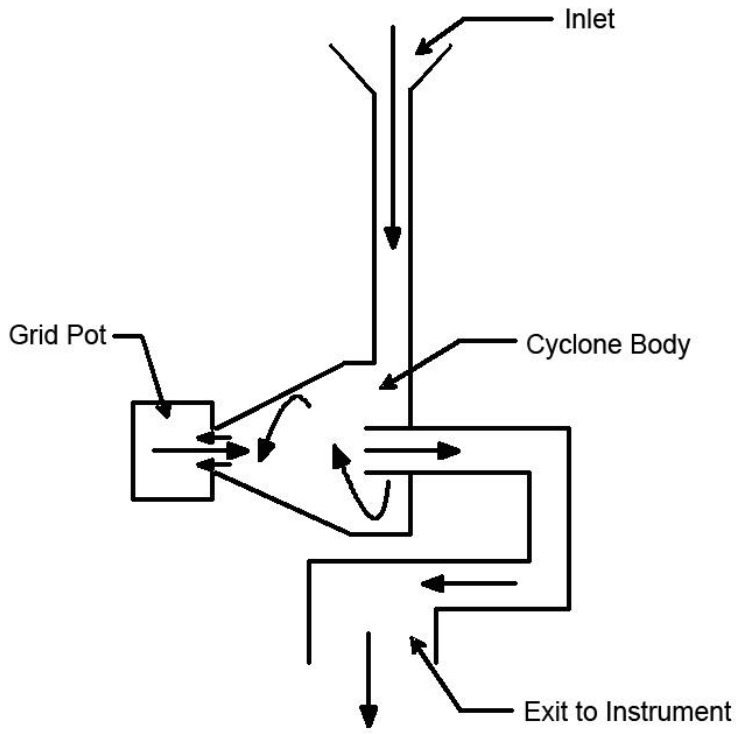

Figure B-2
Schematic of the PM_1 Sharp Cut Cyclone (figure has been adapted form SCC-2.229 Instruction Manual, BGI, Inc. Waltham MA)

3 R. Gussman -- BGI Tech Report. "Evaluation of a Sharp Cut Cyclone for PM1 Sampling", Jan. 2000. http://www.bgiusa.com/aam/scc_btr.pdf

4 Gussman, R. A., Kenny, L. C., Labickas, M. and Norton, P. (2002) 'Design, Calibration, and Field Test of a Cyclone for PM 1 Ambient Air Sampling', Aerosol Science and Technology, 36:3, 361 - 365

Flow Splitter

The flow splitter allows the air flow from the inlet (16.7 L/min) to be split into a sample flow and a side flow, which is used as the purge flow for the Nafion® dryer (see schematic). The flow splitter samples part of the flow from the center of the air flow to deliver it to instruments downstream. The side flow is sampled from the outside of the air flow.

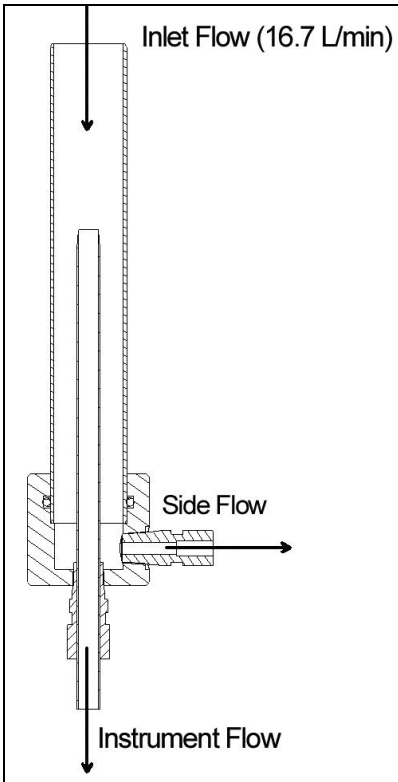

Figure B-3
Schematic of the Flow Splitter

Nafion® Dryer

The Nafion® dryer removes particle bound water from the sampled aerosol. Particle laden air is passed through the Nafion® tubes, and the water is absorbed by the tubes. Particle free air is passed in a counterflow as purge flow past the outside of the tubes and removes the water from the tubes, thus allowing them to absorb more water from the sample air. Water vapor pressure differential between the sample flow and the purge flow drives the drying action. For best performance, the purge air should be dry, but running the dryer with slightly humid purge air at a lower pressure, which leads to a lower water vapor pressure, will give adequate results.

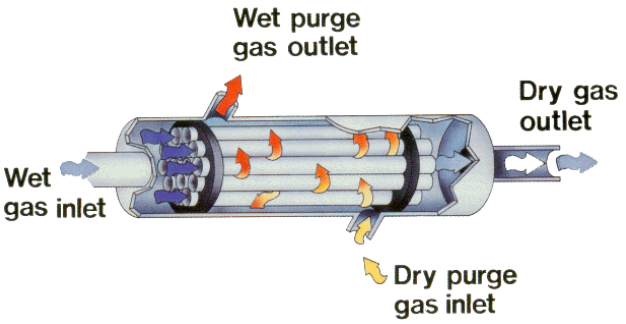

Figure B-4
Schematic of the Nafion® Dryer (Graphic courtesy of Perma Pure, LLC, Toms River, NJ)

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APPENDIX C

Nafion® Dryer Cleaning Procedures

The following is a copy of Perma Pure LLC's Tech Note #3.

PD-Series Nafion® Dryer Cleaning Procedures

Overview

Performance of PD-Series dryers may decline over time due to buildup of residues on the inside or outside of the Nafion® tubing within the dryer. This procedure describes the various steps required to clean a PD-Series dryer to restore it to normal performance.

General Description

PD-Series dryers contain multiple strands of Nafion® tubing with appropriate fittings at each end for connection of gas lines. A shell tubing of inert material surrounds the Nafion® tubing, permitting purging of the Nafion® with dry gas. Fittings for connection of a purge gas to each end of the shell are also included.

PD-Series dryers may be constructed with:

1. Various numbers (50, 100, or 200) of strands of 0.030" OD Nafion® tubing
2. Nafion® tubing of various lengths (12", 24", 48", or 72")
3. Most headers are constructed of cast epoxy, some have molded polypropylene (PP)
4. Shell/fittings are of various materials (PP, Teflon®-coated aluminum or stainless steel SS)
5. Various flow rate capacities up to 40 liters per minute.

Failure of dryers during operation may occur due to three causes:

1. Collapse of the tubing due to negative sample pressure.
2. Introduction of liquid water into the tubing rather than water vapor.

3. Clogging of the tubing, internally or externally.
    a. Physical blockage of the tubing will prevent sample flow.
    b. Occlusion of the surface of the tubing (externally with oil from the purge air or internally with deposits from the sample) will prevent water from permeating through the tubing wall.

Cleaning of a PD-Series dryer requires the following general steps:

1. Remove the dryer element (Nafion® tubing bundle) from the housing.
2. Remove any visible deposits from the ends of the headers.
3. Rinse the dryer element in an appropriate solvent.
4. Dry the dryer element by blowing dry air through it.

or

3. Soak the dryer element in 10% nitric acid at 80°C for 2 hours.
4. Rinse the dryer element with DI water to remove the acid.
5. Dry the dryer element.
6. Reassemble the dryer element into its housing.
7. Test the assembled dryer for leaks and flow.

Procedures

A. General Guidelines

Caution
IMPORTANT: Operator must wear gloves at all times when handling Nafion® tubing to protect the tubing from contamination with skin oils.

1. The work area should be kept clean and orderly.
2. Food and drink should be kept away from the work area.
3. Although Nafion® is not hazardous, the nature of any sample residues within the dryer is unknown. Harsh solvent(s) are used to clean the Nafion® tubing. Wear proper protective equipment, including at a minimum protective eyewear and rubber gloves. If acids are used to clean the tubing, a lab coat or coverall is recommended.

B. Disassembly of the PD-Series Dryer

1. Disconnect the sample inlet and sample outlet lines from the dryer. If adequate access to the dryer is available, it is unnecessary to disconnect the purge inlet and outlet lines.
2. Remove the front nut (end fitting) from each end of the dryer. Take care not to turn the coupling (middle fitting with connection for purge gas) while removing front nut, as this may twist the Nafion® tubing element inside.

3. Wearing rubber gloves, grasp the end of the Nafion® tubing epoxy header at one end of the dryer and pull it out sufficiently to expose the two O-rings on it.
4. Remove the O-rings. Repeat this process and remove the O-rings from the other end of the dryer.
5. Slide the Nafion® tubing element (bundle) out of the housing.

C. Inspection and Preliminary Cleaning of the PD-Series Dryer Element

1. Visually inspect the Nafion® tubing element. Look for discoloration of the Nafion®.
    a. Nafion® tubing will discolor over time in normal operation, turning yellow, then progressively darker. This is normal, and does not seriously affect performance. Completely black Nafion® is a sign of overheating during operation.
    b. Other colors (red for copper, green or blue for stainless steel, etc.) indicate contamination with salts from corroded metal upstream from the dryer.
    c. Solid residues may be deposited within the dryer. Very dark residues are likely oils or tars (residues of organic compounds). Waxy yellow solids may be an indication of ammonium salts (commonly formed when ammonia is injected into stack gas exhausts as part of the DeNOX process).
    d. High-boiling liquid residues may be deposited within the dryer. Dark oily liquids are likely sulfuric acid residues.
    e. If tubes are bent or broken, refer to Repair Procedures.
2. Remove any solids or other visible deposits from the outside of the tubing and from the epoxy header.
    a. Brush or scrub away any solids deposited on sample inlet header.
    b. Wipe off any dust or liquid residues from the tubing and header with a clean soft cloth.
3. Blow clean, dry air through the sample outlet end of the header to remove any entrained particles.
4. If contamination with oil or organics is suspected, the dryer may be rinsed with a hydrophobic organic solvent. Most standard degreasing solvents are acceptable as long as they ***do not*** mix with water (are non-polar). An example would be hexane.
    a. Rinse the outside of the dryer element tubing with the solvent.
    b. Force the solvent through the inside of the tubing. This may be accomplished with a plastic squeeze bottle or syringe.
    c. Blow dry air through the dryer element tubing to remove solvent residues and to dry it thoroughly.
    d. If this cleaning is sufficient, follow reassembly and testing instructions below.

D. Thorough Cleaning (Acid Wash) of the PD-Series Dryer Element

If solid residues are present, the dryer should be washed with acid to remove the residues and to recondition the Nafion® (restore it to its original, sulfonic acid form).

1. Prepare a bath of 10% nitric acid (HNO_3) in a suitable container. The container should withstand exposure to nitric acid and heating.
2. Immerse the Nafion® tubing into the nitric acid bath, taking care not to wet the epoxy headers. About 1.5 inches (4 cm) of tubing as well as the header should remain out of the acid.
3. ***Do not*** sharply bend the Nafion® tubing during this cleaning process. If the bath is large enough to permit the tubing to flex gradually, the headers may be draped over the edge of the container. Alternately, the dryer element may be suspended over the bath with the headers clamped vertically.
4. A magnetic stirring hotplate should be used if available. If not, the acid container should be heated in some fashion and stirred periodically.

C a u t i o n

HEATING OF THE ACID BATH WILL GENERATE NOXIOUS FUMES. The cleaning process should be performed in a fume hood or very well ventilated area. Covering the container with a loose plastic lid will minimize the fumes.

C a u t i o n

RUBBER GLOVES AND PROTECTIVE EYEWEAR MUST BE WORN. Nitric acid at this concentration will stain and/or irritate the skin and injure the eyes if splashed.

5. Heat the acid bath to 70° to 80°C, and soak the Nafion® dryer element for one hour with occasional stirring (a magnetic stirring bar set on low if possible).
6. Remove the dryer from the acid bath. The acid bath may be covered and reused until it shows significant discoloration.

E. Rinsing the PD-Series Dryer Element

1. Rinse the outside of the tubing and of the headers with deionized (DI) water at room temperature to remove the nitric acid residues.

C a u t i o n

RUBBER GLOVES AND PROTECTIVE EYEWEAR MUST BE WORN. Nitric acid at this concentration will stain and/or irritate the skin and injure the eyes if splashed.

a) Briefly force DI water through the inside of the tubing. This may be accomplished with a plastic squeeze bottle or syringe. ***Do not*** immerse the headers of the dryer element in water or excessively wet the tubing inside the headers. Nafion® tubing swells when exposed to water. If the tubing inside the epoxy headers becomes too wet, it may swell sufficiently to crack the rigid epoxy header.

C a u t i o n

DEIONIZED WATER MUST BE USED. Nafion® is a cationic exchange material, and when exposed to liquid water will exchange the hydrogen from the sulfonic acid with any cations in the water. The acid treatment has just reversed this process. ***Do not*** immediately remove the hydrogen, which will seriously degrade the dryer performance.

C a u t i o n

RUBBER GLOVES AND PROTECTIVE EYEWEAR MUST BE WORN. Nitric acid at this concentration will stain and/or irritate the skin and injure the eyes if splashed.

F. Drying the PD-Series Dryer Element

1. Blow clean, dry air through the dryer element to remove any residual water.
   a) Begin blowing dry air through the dryer element quickly after wetting the element. This will minimize the risk of damage to the dryer due to swelling of the tubing.
   b) Continue blowing dry air through the element for several minutes. This will reduce any swelling and restore the dryer to normal size (length).

G. Reassembly of the PD-Series Dryer

1. Wearing rubber gloves, insert the dryer element into its housing.
2. Install the two O-rings onto the header at one end of the dryer element. The smaller O-ring is installed first.
3. Push the header with the O-rings installed into the housing until the second header appears at the other end of the housing.
4. Grasp the end of the second header, pull it out slightly to expose it, and install the two O-rings on this end.
5. Center the element in the housing with the O-rings equally spaced from the ends of each header.
6. Install the front nut onto each end of the housing and tighten, taking care not to turn the coupling while tightening the front nut.
7. Connect the sample inlet and outlet lines.
8. If the purge was disconnected and the dryer was removed from its mounting bracket, connect the purge lines and the mounting bracket. Note that the purge inlet is at the opposite end from the sample inlet.

H. Testing of the Assembled PD-Series Dryer for Leaks and Flow.

1. After reassembly, the dryer should be tested for leaks and for flow. Please refer to Procedures # PD-006, PD-010, or PD-010A as appropriate.

Index

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