Impactor Selection Guide

Aerosol Research

Application Note (A4)

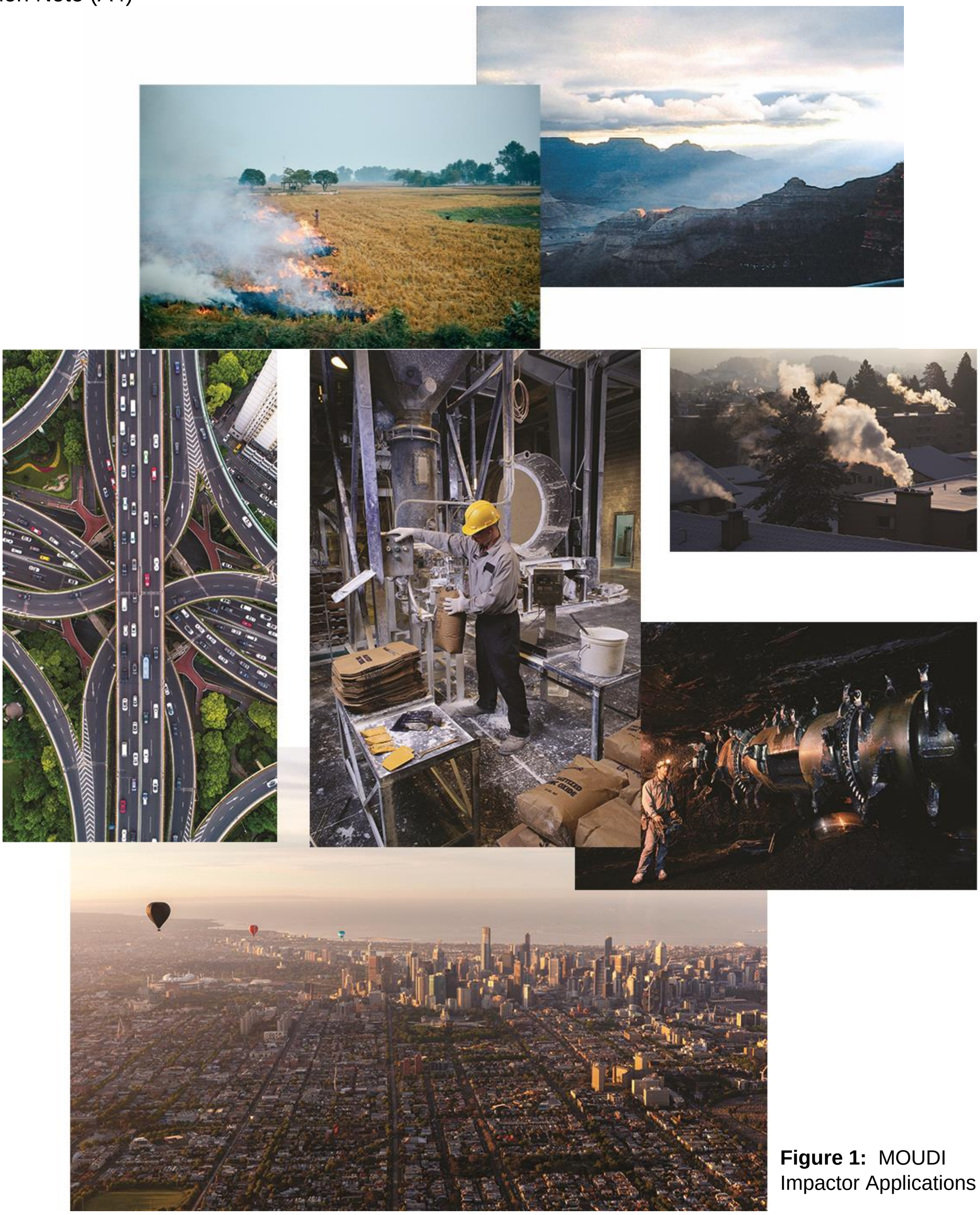

Figure 1: MOUDI Impactor Applications

Introduction

Cascade impactors are aerosol instruments designed to allow researchers to collect size-fractionated aerosol samples onto removable substrates. This permits gravimetric and chemical analysis to be conducted on differing particle size fractions. Impactors can be used for a wide variety of applications, including ambient sampling, material science, instrument validation, vehicle emissions, biomass burning, and other industrial processes.

TSI® offers the MOUDI™[1] series of impactors, useful for a wide variety of applications. With this MOUDI™ series, TSI® is a leading provider in cascade impactors, offering models to suit every need.

For What Applications Can Impactors be Used?

The most common use for impactors is sampling ambient air. That said, impactors have been used for many other applications, and the scientific literature illustrates this rich diversity of applications and scientific questions. A few of the many applications for MOUDI™ impactors are illustrated in Figure 1. For a more detailed look at the various applications for these impactors, please see the application note "Chemical Analysis of MOUDI™ Impactor Samples." Peer-reviewed publications illustrating a range of MOUDI™ applications are included in the References section.

How do Impactors Work?

Impactors collect airborne particles in a size-segregated fashion to permit offline analysis. The particles are collected by impacting them onto a surface, or 'substrate'. This is done in a sequential – or 'cascading' – fashion, where largest particles are collected first, and smallest particles are collected last.

The number of size-segregated samples (size fractions) varies by impactor model. TSI® Incorporated's suite of cascade impactors can collect particles with D_{50}[2] aerodynamic diameters (cutpoints) from 10 nm to 10 µm, in 3 to 13 different size fractions. The number of stages determines the size resolution of the collected samples, and consequently determines the level of detail of the data produced from the analysis of these collected samples.

The upper particle size sampled is often influenced by regulatory requirements, such as PM_{10}[3] and $PM_{2.5}$. The smallest sampled particle size is often selected based upon the user's research questions. In some cases, practical restrictions (for example, opposition to the use of oil in a vacuum pump, or inability to accommodate a heavy pump) may put a limit on the smallest particle size that the user will be able to collect.

[1] "MOUDI" stands for Micro-Orifice Uniform Deposit Impactor.
[2] Aerodynamic Diameter at which 50% of the particles are collected onto the substrate.
[3] PM stands for Particulate Matter with the number provided representing the D_{50} cutpoint of the upper particle size sampled (i.e. PM2.5 means particles smaller than 2.5 µm).

How Do I Choose Which Impactor is Right for My Needs?

What Factors are Important?

When selecting an impactor, several factors need to be considered; see Table 1.

Knowing what size fractions you would like to sample is usually the most important criteria to keep in mind when choosing an impactor. Once that has been preliminarily determined, attention turns to the question of sample analysis: what analytical technique(s) will you use, and what are their detection limits? If you are concerned you will be near the limit of detection frequently, use an impactor with a higher flow rate (or consider lengthening your sampling time, if your experimental design allows this). If you have a constraint on your flow rate (for example, if you are conducting a chamber experiment), then choose the impactor that offers you the best balance of flow rate, size fractions, and sample mass sufficiency.

Table 1: Factors to Consider when Selecting a MOUDI™ Impactor

Primary Questions	What size fractions would you like to measure?
	Will you analyze your particles using an offline technique (and if so, what technique), or do you want live-time mass measurement?
Secondary Questions	What concentration of aerosol are you anticipating you will sample?
	Do you have any restrictions on what flow rate you can afford for the impactor to draw?

TSI® has numerous models of cascade impactors; an overview of each group is provided below. Keep the factors listed in Table 1 in mind as you learn about the available impactor models. The Impactor Selection Flow Chart in Figure 5 can help you choose the model that is right for your needs.

TSI® MOUDI™ Impactor Models

Classic

TSI® MOUDI™ series impactors (Models 100S4 and 110NR) are most commonly used for sampling 12- or 24-hour samples in rural and urban environments, but can be used for a wide variety of applications. They operate at a 30 L/min flow rate.

Figure 2: 135-6B MiniMOUDI™ Impactor, with optional cowl inlet installed

MiniMOUDI™

The MiniMOUDI™ impactors are ideal for personal sampling. They have a design flow rate of 2 L/min, which is supplied by a pump that can be worn by the user. The three models of MiniMOUDI™ have three different smallest cutpoints; users can go down to 0.56 µm, 0.18 µm, or 0.056 µm. Figure 2 shows the six-stage 135-6 MiniMOUDI impactor with the cowl inlet. This inlet is ideal for personal sampling; see the footnotes of Table 2 for more information on the available inlets for MiniMOUDI impactors.

Rotating-Stage Impactors (‘NanoMOUDI™’)

The NanoMOUDI™ impactors represent a significant step forward from the traditional, non-rotating impactors. This ‘step forward’ consists of two major changes: rotating stages, and a digital user interface. The Model 120R NanoMOUDI™ is shown in Figure 3.

Figure 3: 120R NanoMOUDI™ impactor: exterior (left) and interior (right)

Rotating Stages

The impaction stages of the NanoMOUDI impactors rotate during sampling. This rotation results in the sampled particles being deposited over a wider area on the substrate, relative to non-rotating impactors.

To understand why this is valuable, imagine a non-rotating impactor. As particles are collected on the collection substrate, they can begin to accumulate, forming a three dimensional deposit under each nozzle. The formation of these deposits (each shaped roughly like a shallow cone, or pyramid) can deteriorate impactor performance by increasing particle bounce, permitting particle re-entrainment, and/or potentially clogging the nozzle.

To combat against these negative effects, NanoMOUDI impactors are equipped with rotating stages. When the stage is rotated relative to the nozzle plate, the impacted particles are deposited in a more uniform manner across the impaction surface. This increases the amount of particle mass that can be collected without negatively affecting impactor performance.

Digital Interface

NanoMOUDI impactors have a digital display interface. This interface enables the user to:

- Define sampling time intervals. For example, a researcher could set the impactor to sample every day during morning rush hour only, or from midnight to noon.
- Create a sampling protocol from the stored data to support the quality of the sample and subsequent sample analysis. The impactor stores the measured cabinet temperature, stage pressures, and time in an evenly-spaced manner throughout the specified sampling period.
- Remotely check into the impactor to verify uptime (runtime). A convenient software tool mirrors the impactor controls to the computer screen of an internet-connected researcher and enables download of the saved data remotely.

Data may also be downloaded from NanoMOUDI impactors via the instrument's serial port.

High-Flow Impactors

In addition to the MOUDI™ series, the **High Flow Impactor (Model 135B)** is especially advantageous when sampling in clean ambient environments, where low particle concentrations will require larger sampling volumes. As such, it operates at a sample flow rate of 100 L/min.

One unique feature of the high-flow impactors is that their nozzle plates are designed to facilitate a high degree of data quality for users who intend to conduct multiple offline analyses for each substrate. In such a case, it is commonplace to cut the substrate material into two or four equal pieces. To facilitate the equal division of substrates for this purpose, TSI® offers specially-designed nozzle plates with high-flow impactors. These nozzle plates distribute the nozzles symmetrically across the stage area in four quadrants, leaving a '+'-shaped area with no deposited aerosol.

Refer to Table 2 and/or Figure 5 when selecting an impactor model. Please feel free to contact TSI® for support in selecting the impactor that is right for your needs.

Figure 4: 130 High-Flow Cascade Impactor.

(continued on next page)

Table 2: Key Specifications for all Models of MOUDI™ Impactors from TSI® Incorporated

		Size-segregated sample collection, to permit offline analysis								Real-time mass-based size distribution
		Classic		**Mini-MOUDI ****			**Rotating (NanoMOUDI™)**		**High Flow**	
		100S4	**110NR**	**135-6B**	**135-8B**	**135-10B**	**120R**	**125R**	**131B**	**140**
# of stages*		3	10	6	8	10	10	13	6	6
D50 (µm) of pre-separating inlet	18						X			
	2.5									X
Stage Cutpoints (µm)	10	X	X	X	X	X	X	X	X	
	5.6		X	X	X	X	X	X		
	3.2		X	X	X	X	X	X		
	2.5	X							X	
	1.8		X	X	X	X	X	X		
	1.4								X	
	1.0	X	X	X	X	X	X	X	X	
	0.96									X
	0.8									
	0.56		X	X	X	X	X	X		
	0.51									X
	0.4								X	
	0.32		X		X	X	X	X		
	0.305									X
	0.25								X	
	0.18		X		X	X	X	X		
	0.156									X
	0.1		X			X	X	X		
	0.074									X
	0.056		X			X	X	X		
	0.045									X
	0.032							X		
	0.018							X		
	0.010							X		
Stage diam. (mm)		47		37			47	47 & 90‡	75	*N/A*
Stage rotation		No					Yes‡		No	
Flow rate (L/min)		30		2			30	10	100	10
Pressure drop (kPa)		1	41	1	10	40	40	90	5	50

* The pre-separating inlet, included in some models, does not count towards the total number of stages.

**Mini-MOUDI impactors come with a 3/8" OD straight tube inlet. A "cowl" inlet – ideal for personal sampling – may be ordered separately using PN # 0135-78-0021.

‡ Model 125R has two stage diameters: the upper 10 stages are 47 mm (and rotating), while the lower three stages are 90 mm (and non-rotating).

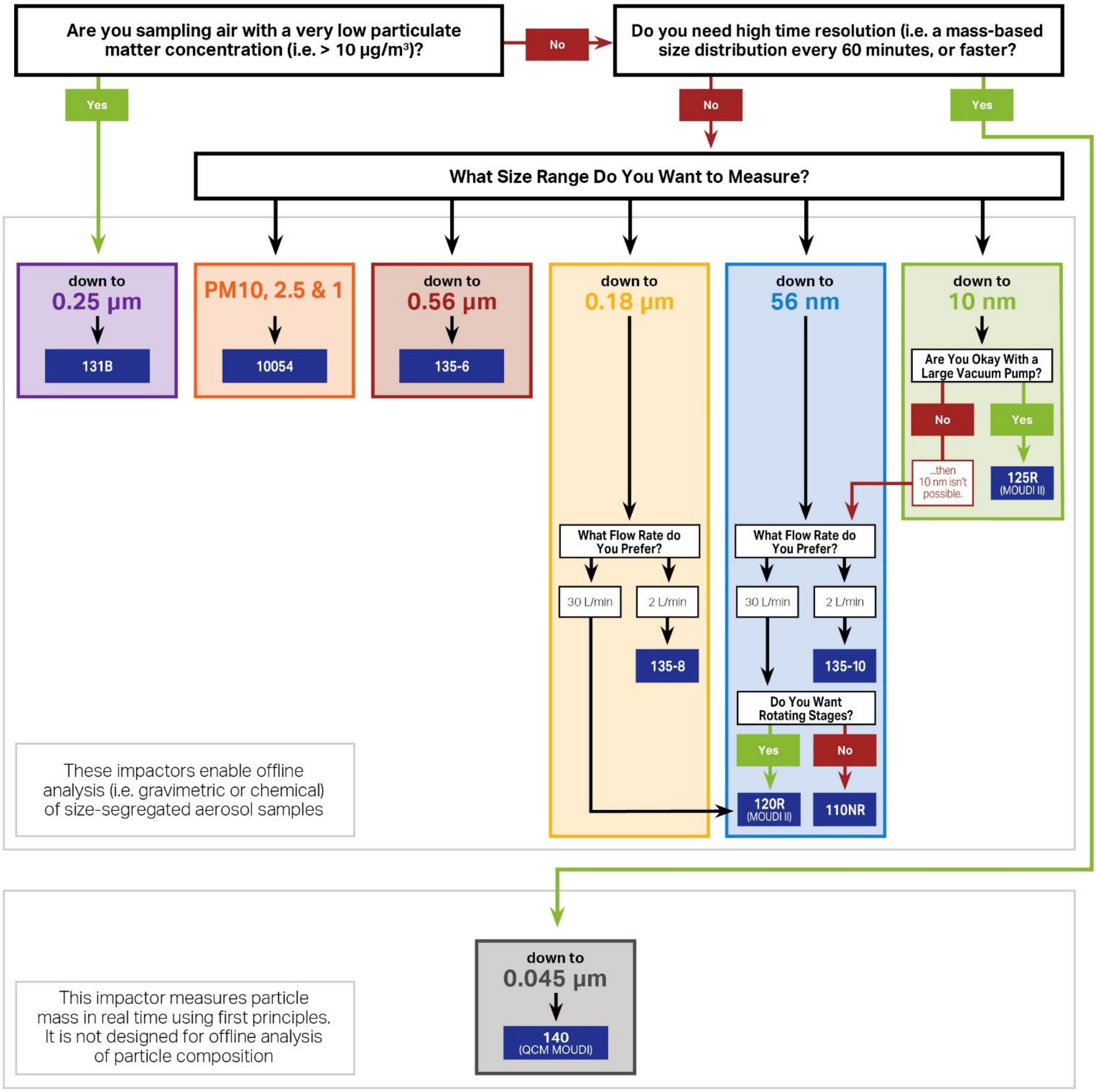

Figure 5: Impactor Selection Flow Chart

What Accessories Do I Need?

MOUDI™ impactors require certain accessories for their operation: pumps and substrates are mandatory, while other accessories may be optional in some cases. Table 2 lists accessories that are specific to the various MOUDI™ impactor designs.

Pumps

Pumps are a key accessory for MOUDI™ impactors, as they provide the sample flow through the device. The pumps specified in Table 3 have been selected because they can accommodate both the flow rate required by the impactor, as well as the pressure drop imposed by the impactor once the final filter is installed. For some researchers, pump capacity and type can be significant concerns; if this is the case, the impactor model should be selected with these considerations in mind.

Table 3: Pumps Recommended for use with MOUDI™ Impactors

<table>
<tr><th rowspan="2">Model</th><th rowspan="2">Flow Rate (L/min)</th><th colspan="4">Pumps</th></tr>
<tr><th>110V</th><th>220-230V, EU</th><th>220V, UK</th><th>Type*</th></tr>
<tr><td>100S4</td><td rowspan="2">30</td><td>0100-01-0079</td><td>not available</td><td>not available</td><td rowspan="6">Carbon vane</td></tr>
<tr><td>110NR</td><td>0100-01-1050</td><td>0100-01-1051</td><td>0100-01-1052</td></tr>
<tr><td>135-6B</td><td rowspan="3">2</td><td rowspan="2">0135-75-5007 (charger)</td><td colspan="2" rowspan="2">0135-75-5008 (charger)</td></tr>
<tr><td>135-8B</td></tr>
<tr><td>135-10B</td><td colspan="3">Order both 3033 and 135-10-FTG-KIT</td></tr>
<tr><td>120R</td><td>30</td><td>0120-98-1051</td><td colspan="2">0120-98-1050</td></tr>
<tr><td>125R</td><td>10</td><td>0125-98-0100</td><td>0125-98-0101</td><td>not available</td><td>Oil-sealed</td></tr>
<tr><td>131B</td><td>100</td><td>0130-01-1051</td><td>0130-01-1050</td><td>0130-01-1052</td><td>Carbon vane</td></tr>
<tr><td>140</td><td>10</td><td>included</td><td>included</td><td>included</td><td>Diaphragm</td></tr>
</table>

* For impactor models where the final stage has a D50 cutpoint ≥ 56 nm (see Table 2), a carbon vane pump is appropriate. Since the 125R impactor has stages with D50 cutpoints below 56 nm, it requires the use of an oil-sealed vacuum pump. This more powerful pump is required in order to achieve the lower pressures needed for these lower stages.

Substrates

Substrates are removable materials that are placed onto the impaction stages within an impactor; they are necessary for all impactor models except the 140 QCM MOUDI. Substrates are held in place with clamping rings, and over the course of impactor operation the sampled particles deposit to the substrate surface. After sampling is done, the substrates are removed for analysis. Impermeable materials such as aluminum foil can be used as substrates. Permeable materials such as filters can also be used; when filters are used as substrates, however, air does not flow through them.

The offline analytical technique that will be used to analyze samples – gravimetric, chemical, or both – may sometimes make some substrate materials more desirable than others. For example, an aluminum foil substrate may interfere with a chemical analysis of metals in the sampled aerosol. Literature review is a valuable tool when determining what substrate material to choose. Table 4 lists substrates available for the various models of impactors.

Substrate Masks

Substrate masks are used when applying silicone spray to impactor substrates; see ‘Surface Spray’, below. The mask ensures that the spray is deposited only to the portion of the substrate surface where it should be. Substrate masks are included with all impactor purchases. If additional mask(s) are desired, order using the part numbers listed in Table 4.

Spacers

Spacers are like washers that fit between the stages of an impactor. Generally speaking, the purpose of a spacer is to permit the use of thicker-than-usual substrates (such as quartz fiber filter, for example), while also preserving the cutpoints of the impactor stages. If substrates thinner than 0.1 mm will be used, spacers are not needed.

Substrates thicker than 0.1 mm may be preferred in some cases due to their chemical composition; for example, an aluminum foil substrate (which is thin) may interfere with the chemical analysis of metals in the sampled aerosol, but a quartz fiber filter (which is thick) would not. Table 4 provides part numbers for such spacers, to permit use of substrates thicker than 0.1 mm.

Table 4: Accessories for all Models of Impactor from TSI® Incorporated

Model	Substrates*	Substrate mask	Spacers‡	Spare Sets
100S4	0100-47-AF	0100-98-1053	0100-01-5018	0100-98-1006
110NR	0100-47-AF	0100-98-1053	0100-01-5018	0110-98-1005
135-6B	0135-01-0014	*not available*	*not available*	*not available*
135-8B				
135-10B				
120R	0100-47-AF	0100-98-1053	0120-98-9006	0120-98-1036
125R**	0100-47-AF; 0122-96-5222	0100-98-1053; 0122-98-1020	0122-98-5026; 0122-98-5023	0122-98-1010; 0122-98-1011
131B	0130-75-AF	0130-98-1010	*not available*	*not available*
140‡‡	*not applicable*	*not applicable*	*not applicable*	0140-01-1010; 0140-98-1308

* Substrates: All substrates listed above are aluminum foil. Glass fiber filters at diameters of 37-, 47-, and 90-mm diameter are also available from TSI®, as are quartz fiber filters at 47-mm diameter; contact TSI® to order. Membrane filters (for example, PTFE, polycarbonate, nylon, and PVC) can also be used with MOUDI™ impactors.

**NanoMOUDI™ impactor Model 125R uses two different stage diameters; the first 10 stages are 47 mm, while the bottom three stages are 90 mm. Because of this design, the row of Table 4 that applies to 125R lists multiple part numbers within each cell. Within the columns for 'Substrate', 'Substrate mask', and 'Spare Sets', the part numbers before and after the semicolon (;) pertain to 47 mm and 90 mm, respectively. In the 'Spacers' column, the first part number (-5026) is a kit containing spacers for both the 47-mm and the 90-mm stages (Qty. 12 and 3, respectively), while the second part number (-5023) is a kit containing Qty 10 of the spacers for the 90-mm stages.

‡ Spacers come in kits. Order Qty. 1 of the PN provided to receive enough spacers to operate a MOUDI™ impactor when using thicker substrates.

‡‡ For the QCM MOUDI 140, it is possible to purchase a spare impactor stage stack, and also a single replacement crystal; the associated part numbers are before and after the semicolon, respectively, in the 'Spare Sets' cell within the '140' row.

Spare Sets of Impaction Plates

It can be convenient to have a second set of impaction plates. This allows you to bring a new set of substrates to an impactor that is currently sampling, perform an exchange, and carry your samples – protected– back for analysis. Spare sets as shown in Figure 6 are available for several MOUDI™ Impactors, as listed in Table 4.

Surface Spray

This silicone spray is applied to substrates to minimize particle bounce. One can of the spray is included with all impactor purchases. Additional spray may be purchased using PN 0100-96-0559.

Figure 6: Spare Sets of Impaction Plates

Lubrication Grease

This grease is used on O-rings that are located in the body of the impaction stages. One container of grease is included with purchase of any MOUDI™ impactor. Additional grease may be ordered using PN 0100-96-0558.

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