



IMPACTOR SELECTION GUIDE

AEROSOL RESEARCH

APPLICATION NOTE (US)

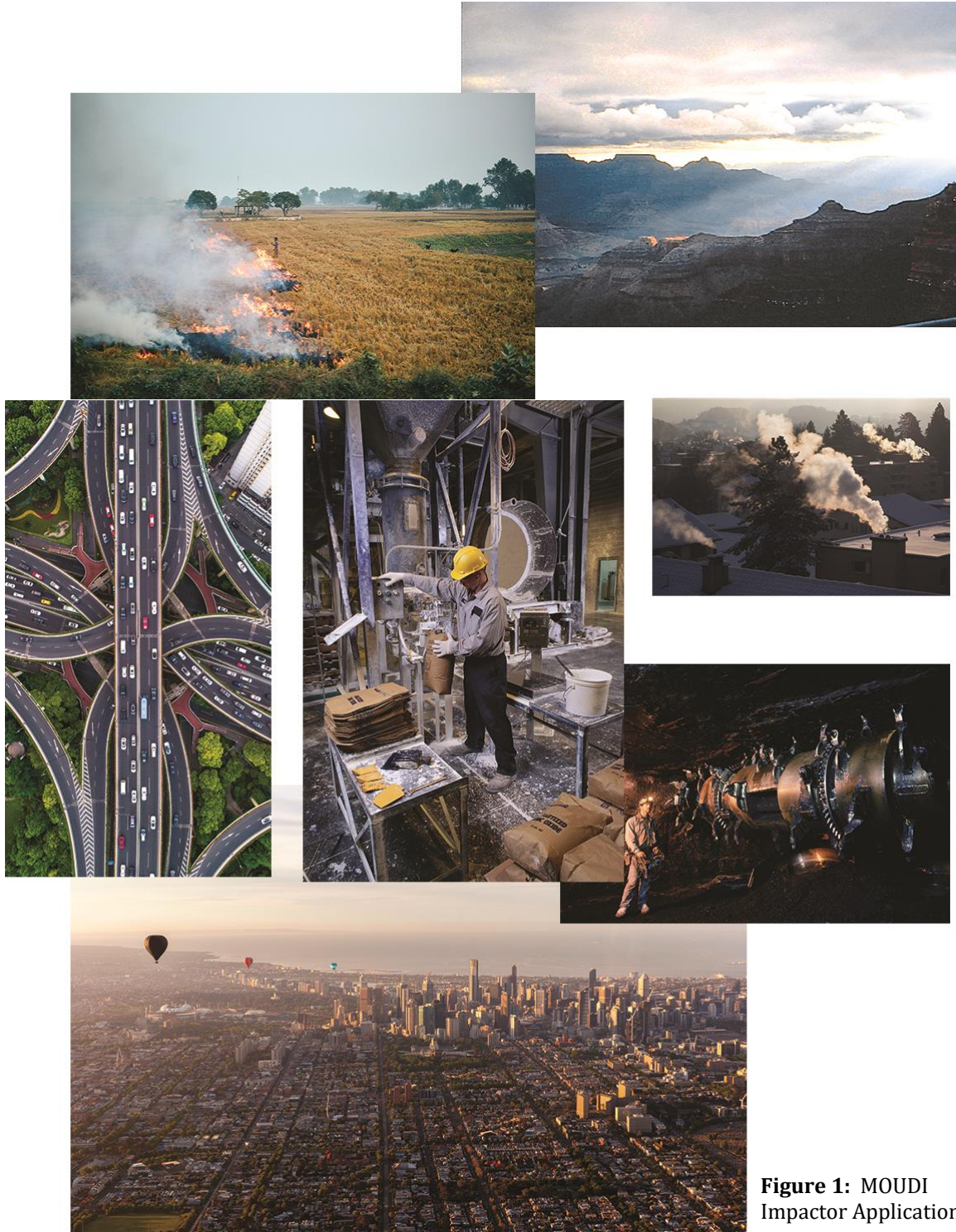


Figure 1: MOUDI
Impactor Applications



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 PM₁₀³ 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. PM_{2.5} 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.

TSI® has numerous models of cascade impactors, and they fall into four groups; 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.

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

Primary Questions	What size fractions would you like to measure?
	What will your offline analytical technique be?
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® MOUDI™ Impactor Models

Classic, Non-Rotating Impactors

TSI® **MOUDI™ series** impactors operate at flow rates of 10 and 30 L/min. These impactors 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.

MiniMOUDI™ Impactors

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.



Figure 2: 135-6 MiniMOUDI Impactor

NanoMOUDI™ Impactors

The NanoMOUDI™ impactors represent a significant step forward from the classic, 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.

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.



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

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 (HFI) series** is a group of six impactors that operate at 100 L/min of volumetric flow. This highest flow rate is especially advantageous when sampling in clean ambient environments, where low particle concentrations will require larger sampling volumes. Figure 4 shows the Model 130 impactor, with five stages.

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.



Figure 4: 130 High-Flow Cascade Impactor.

The high-flow impactors are not represented in the Impactor Selection Flow Chart (Figure 4). The primary application for high-flow impactors is ambient sampling, particularly in relatively clean background areas. If you are considering a High-Flow impactor for this or for another application, be sure to examine Table 2 to determine which model of high-flow impactor will suit your needs best.

Selecting an Impactor Model

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.

Refer to Table 3 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.

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

	Non-Rotating Impactors						MOUDI II / NanoMOUDI			High-Flow Impactors					
	Classic			MiniMOUDI**			120R	122R	125R	128	129	130a	130b	131a	131b
	100S4	100NR	110NR	135-6	135-8	135-10									
# of stages*	3	8	10	6	8	10	10	13	13	3	4	5	5	6	6
18 µm-cutpoint inlet		X					X	X							
Stage Cutpoints (µm)	10	X	X	X	X	X	X	X	X	X	X			X	X
	5.6		X	X	X	X	X	X	X						
	3.2		X	X	X	X	X	X	X						
	2.5	X								X	X	X	X	X	X
	1.8		X	X	X	X	X	X	X						
	1.4											X	X	X	X
	1.0	X	X	X	X	X	X	X	X	X	X		X		X
	0.8											X		X	
	0.56		X	X	X	X	X	X	X						
	0.4											X	X	X	X
	0.32		X	X		X	X	X	X						
	0.25										X	X	X	X	X
	0.18		X	X		X	X	X	X						
	0.1			X			X	X	X						
	0.056			X			X	X	X						
0.032								X	X						
0.018								X	X						
0.010								X	X						
Stage diam. (mm)	47			37			47	47 & 90 [†]		75					
Stage rotation	No						Yes [†]			No					
Flow rate (L/min)	30			2			30		10	100					
Pressure drop (kPa)	1	11	41	1	10	40	40	90	90	0.6	4	5	5	5	5

*The 18-micron inlet, included in some models, does not count towards the total number of stages.

**Mini-MOUDI impactors may be ordered with a cowl inlet (ideal for personal sampling) by placing an 'A' at the end of the part number (for example, 135-6A), or with a 'cone' (3/8" OD straight tube) inlet by placing a 'B' at the end of the part number (for example, 135-6B).

[†]Models 122R and 125R have two stage diameters: the upper 10 stages in each impactor are 47 mm (and rotating), while the lower three stages are 90 mm (and non-rotating).

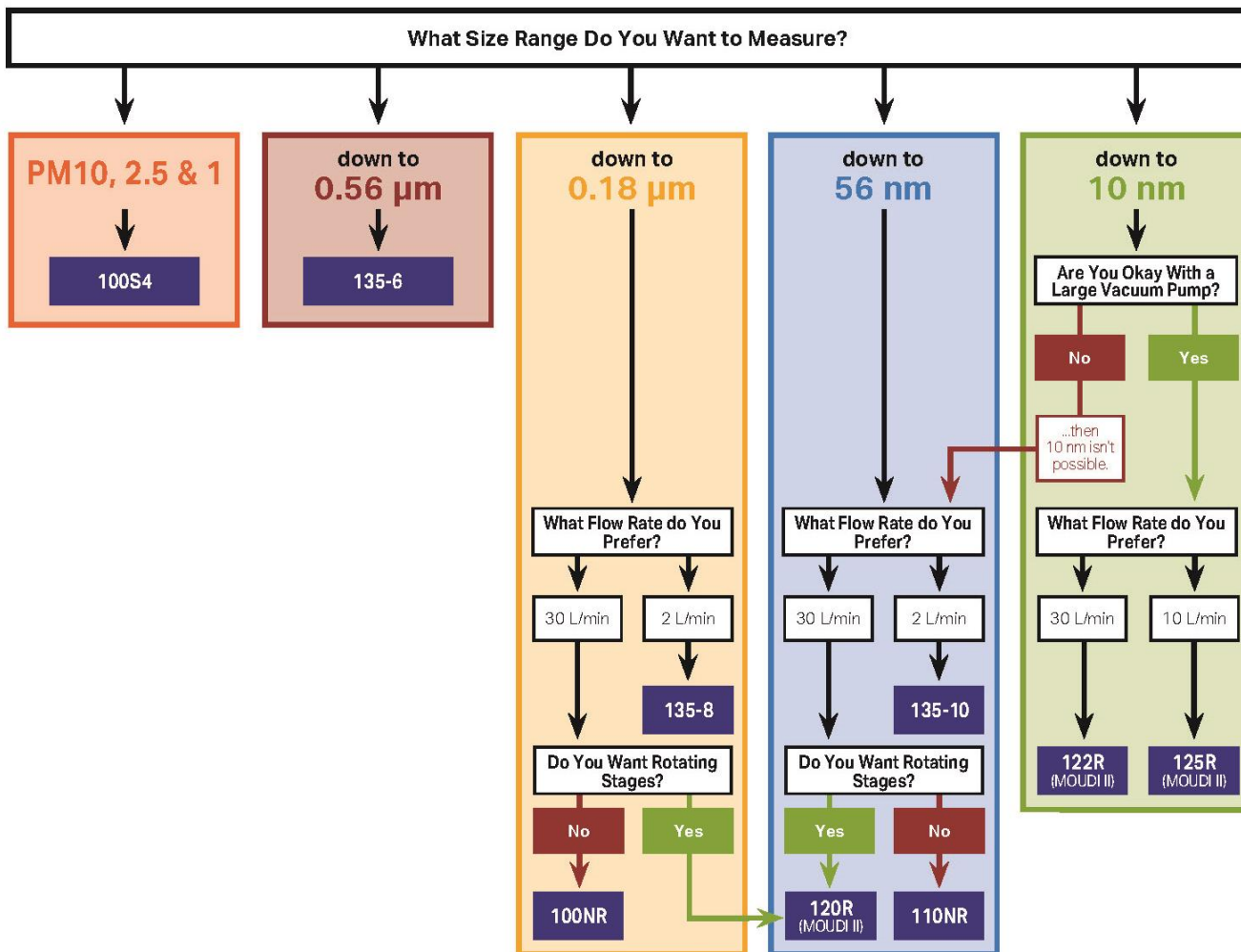


Figure 5: Impactor Selection Flow Chart

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 a significant concern; 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

Model	Flow Rate (L/min)	Pumps			Type*
		110V	220-230V, EU	220V, UK	
100S4	30	0100-01-0079	<i>not available</i>	<i>not available</i>	Carbon vane
100NR		0100-01-1050	0100-01-1051	0100-01-1052	
110NR					
135-6	2	0135-75-5007 (charger)	0135-75-5008 (charger)		
135-8					
135-10		0135-01-0100	0135-01-0101	0135-01-0102	
120R	30	0120-98-1051	0120-98-1050		
122R		0122-01-2011 (US, 230V)	0122-01-2016	<i>not available</i>	Oil-sealed
125R		0125-98-0100	0125-98-0101	<i>not available</i>	
128	100	0130-01-1051	0130-01-1050	0130-01-1052	Carbon vane
129					
130a					
130b					
131a					
131b					

* For impactors with a smallest cutpoint stage of 56 nm or larger (see Table 1), a carbon vane pump is appropriate. Impactors with stages smaller than 56 nm, however, will require the use of an oil-sealed vacuum pump 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 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 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. Thicker substrates may be preferred in some cases due to their chemical composition; for example, an aluminum foil substrate may interfere with the chemical analysis of metals in the sampled aerosol. Table 4 provides part numbers for such spacers, to permit use of substrates thicker than 0.1 mm. If substrates thinner than 0.1 mm will be used, spacers are not needed.

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
100NR				0100-98-1005
110NR				0110-98-1005
135-6	0135-01-0014	<i>not available</i>	<i>not available</i>	<i>not available</i>
135-8				
135-10				
120R	0100-47-AF	0100-98-1053	0120-98-9006	0120-98-1036
122R**	0100-47-AF;	0100-98-1053;	0122-98-5026;	0122-98-1010;
125R**	0122-96-5222	0122-98-1020	0122-98-5023	0122-98-1011
128	0130-75-AF	0130-98-1010	<i>not available</i>	<i>not available</i>
129				
130a				
130b				
131a				
131b				

*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 122R uses two different stage diameters; the first 10 stages are 47 mm, while the bottom three stages are 90 mm. Model 125R has this same design. Because of this design, the row(s) of Table 4 that apply to 122R and 125R list 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.

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.



Figure 6: Spare Sets of Impaction Plates

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.

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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