

TISCH ENVIRONMENTAL
Model 20-800

Ambient Cascade Impactor (Non-viable)
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PREFACE

Tisch Environmental, Inc. is a third generation family owned business. The owners Wilbur J. Tisch and James P. Tisch have been involved in the High Volume Air Pollution field for the last 20 years. Started in March of 1998, they would like to welcome you to their company.

The intent of this manual is to instruct the user with unpacking, assembly, operating and calibration techniques. For information on air sampling principles, procedures and requirements please contact the local Environmental Protection Agency Office serving your area.

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1. GENERAL INFORMATION

1.1 Introduction

The Tisch Ambient Eight-Stage Cascade Impactor (Impactor) is a high sample-rate, multiple orifice and multiple stage Inertial Impactor. A Cascade Impactor is a multi-stage impaction device used to separate airborne particles into aerodynamic size classes.¹ When applied to ambient air sampling, the particulate entrained in the aerosol is sampled through a series of stacked stages which contain multiple orifices with sequentially smaller diameters. Ambient air enters the circular inlet of the Pre-Impactor Size Selective Inlet (High Capacity Pre-Separator) and cascades through the succeeding orifice stages with successively higher orifice velocities from Stage #0 to Stage #7. Successively smaller aerodynamic sized particles are inertially impacted onto a collection media. Sub-micrometer particles ($<1.0\mu\text{m}$) which pass through Stage #7 are collected by filtration on a glass micro-fiber filter media (Final Filter). The sampled air is drawn through the Cascade Impactor using a Vacuum Pump or calibrated flow system and controlled to a constant sample rate. The design sample flow rate of the Tisch Eight Stage Ambient Cascade Impactor is 28.3 ALPM (actual liters/minute). A sample flow rate of ± 1.5 ALPM during a sample event insures the aerodynamic separation of particles maintain the theoretical calibration curves.

1.2 Description

The Tisch Ambient Eight-Stage Cascade Impactor is an aluminum alloy mechanical inertial separator designed to aerodynamically separate ambient particulate into multi fractions in the range of $10\mu\text{m}$ AED (Aerodynamic Equivalent Diameter) to filtration collection of sub-micron particles 0 to $0.43\mu\text{m}$. Use of a Pre-Impactor Size Selective Inlet (High-Capacity Pre-Separator) is used when applications with larger than $9.0\mu\text{m}$ AED particles are present. The Pre-Separator is designed to remove large particles, which due to inertial energy can cause particle-bounce inside a classical Cascade Impactor and be measured incorrectly. The Pre-Separator is a large capacity, single-jet impactor where the total suspended particulate air sample is drawn in through a single inlet nozzle, accelerated, and only particles $<9.0\mu\text{m}$ AED exit to be further aerodynamically separated in the Cascade Impactor Stages.

The Tisch Model 20-800 series of Cascade Impactors are designed for applications in ambient air where Non-Viable (Non-Biological) aerosol is to be collected and measured for its concentration by aerodynamic particle size. The concentration of particulate is calculated by pre and post weighing of the 81mm sample substrates located below each Orifice Stage. As particles pass through each successively smaller diameter orifice stage the sample rate is accelerated. As the aerosol exits each orifice it will curve around the impaction sample substrate. Particles which have an aerodynamic diameter and inertia that can not stay in the sample air stream break free from the flow and collect by impaction onto the sample substrate. By subsequently making the orifice diameter smaller on each Stage of the Cascade Impactor, the particles are increased in velocity and the aerodynamic separation of particles over a large range can be determined.

The first commercial Cascade Impactor was introduced in 1945 in the United Kingdom by Dr. K.R. May Ph.D. and design and data published in the *Journal of Scientific Instruments* #22. The design uses a single orifice jet impacting onto a glass microscope slide and four successive Stages with decreasing orifice diameters. The "May Impactor" remains a valuable laboratory tool even today with a well characterized and precise particle separation efficiency. Its only limitation is the sample flow rate is low and the glass slides require grease-coatings to collect the sample for analysis.

The Tisch Ambient Eight-Stage Cascade Impactor concept was designed and published by Dr. Aerial Andersen in Provo, Utah in 1958 (*Journal of Bacteriology* #76). In an attempt to improve collection efficiency Dr. Andersen developed the multiple Stage, multiple-Orifice Cascade Impactor. The unique design of multiple orifice jets in one stage allowed for higher sampler flow rates and a larger sample substrate to collect greater mass concentration for weighing accuracy and later chemical speciation analysis. The design has been utilized by many researchers in the Environmental, Industrial Hygiene and



Pharmaceutical industries for thirty years and has been extensively tested and verified for characterization. Several commercial copies of the original design are being fabricated in world today.

The Tisch Ambient Eight-Stage Cascade Impactor is machined from aircraft alloy aluminum to a high precision of tolerances. The physical design and attention to tolerances of design and orifice hole diameters insures the reproducibility of accurate size selective data. However, to insure that these machine tolerances are maintained each and every Orifice on each successive Stage is verified using both a manual machine-pin-gauge test as well as an optical comparator.

For special applications where verification and actual physical calibration using liquid and solid NIST traceable aerosol standards is needed, contact Tisch for availability and calibration procedure.

1.3 Specifications

Impactor:

Size: 7.75" Height x 4.25" Diameter

Weight: 3.95 lbs.

System Components:

One (1) Alloy Aluminum Inlet Cone

Eight (8) Alloy Aluminum Orifice Stages Numbered (0 to 7)

One (1) Alloy Aluminum Filter Stage Numbered (F)

One (1) Alloy Aluminum Base Plate with Three (3) Hold-Down Springs

Nine (9) Stainless Steel Sample Substrate Collection Plates (81mm Diameter)

Vacuum Tubing

Operation Manual

Carrying Case

Options:

Size-Selective Inlet (High-Capacity Pre-Separator)

81mm Glass Micro-Fiber Sample Substrates Open Center for Stages 0 and 1

81mm Glass Micro-Fiber Sample Substrates for Stages 2, 3, 4, 5, 6, 7 and F

Model PM 700 IP/C Pharmaceutical Inlet Induction Port (Special Inlet Induction prior to Size Selective Inlet (High-Capacity Pre-Separator) for Metered and Powder Dose Inhaler Testing.

Vacuum Pump:

28.3 ALPM Design Sample Rate

115 VAC 60 Hz

220VAC 50 Hz

12 VDC

Sample Flow Rate:

28.3 ALPM at ± 1.5 ALPM

Differential Pressure:

13.6" Water at 28.3 ALPM Sample Rate and Glass Fiber Substrates/Filter

2. UNPACKING AND INSTALLATION

2.1 Unpacking and Installation

Note: If any damage to the shipment is noticed BEFORE unpacking, a claim must be filed with the commercial freight carrier as quickly as possible. If any damage occurred during shipment, please notify Tisch after notification of the commercial carrier.

Remove the Impactor Carrying Case from the shipping container. Open the case and identify items against the shipping documents and specifications detailed in section 1.3. Notify Tisch for any discrepancies.

Keep the shipping and packing material for future travel.

2.2 Siting

The Tisch Ambient Eight-Stage Cascade Impactor is designed to be operated in the vertical position only. The Impactor is designed to be used in ambient air applications where non-corroding aerosol may be measured for particle sizing. It is advisable the Impactor be operated in an area whose temperature is between +5°C and +40°C and the relative humidity is not condensing and does not exceed 90% . The Impactor should be located in a level, vibration-free environment.

2.3 Bench Top Installation

Locate the Tisch Impactor on a bench surface that will allow the installation of the sample substrates and filter media. Allow adequate ventilation of sample air around the Impactor Inlet.

3. PRINCIPLE OF OPERATION

3.1. Aerodynamic Particle Sizing

The design of the Tisch Ambient Eight-Stage Cascade Impactor has evolved over time with use and calibration data.

The human respiratory tract is an aerodynamic classifying system for airborne particles.^{2,4} The Impactor is designed as a substitute for the human respiratory tract to collect and separate particulate matter according to its aerodynamic size and property. The fraction of inhaled particles retained in the human respiratory system and the site of deposition vary with size, shape, density and all physical properties of the particles that constitute aerodynamic dimensions^{2,3,6,7} (Figure 1). Because the human lung penetration curves are known to be of unit density spherical particles. The Impactor has been characterized and tested for particle size separation (cut-point)¹². Therefore as long as a standard model of the Impactor is used according to standard laboratory operating procedures, the individual Impactor Stage distribution of collected particle mass will indicate the extent to which the aerosol sampled would have penetrated the human respiratory system. This information is vital to environmentalist, aerosol physicists and industrial hygienists for determining health risk and epidemiology.¹⁵

Early testing and fundamental aerosol science was conducted in the early 1950's by Ranz and Wong (*Industrial Hygiene and Industrial Medicine* Vol.5 1952).

This scientific study indicated that the collection of ambient particulate by an obstacle in its path of flight is a function of what is defined as the "Inertial Impaction Parameter". This can be calculated as:

$$K = \frac{C_p U \rho D_p^2}{18 \mu D_c}$$

Where:

- U = Relative Velocity of the air flow
- ρ = Particle Density
- D = Particle Diameter
- μ = Gas Viscosity
- D_c = Diameter of the Orifice Jet
- C = Cunningham Slip-Correction Factor

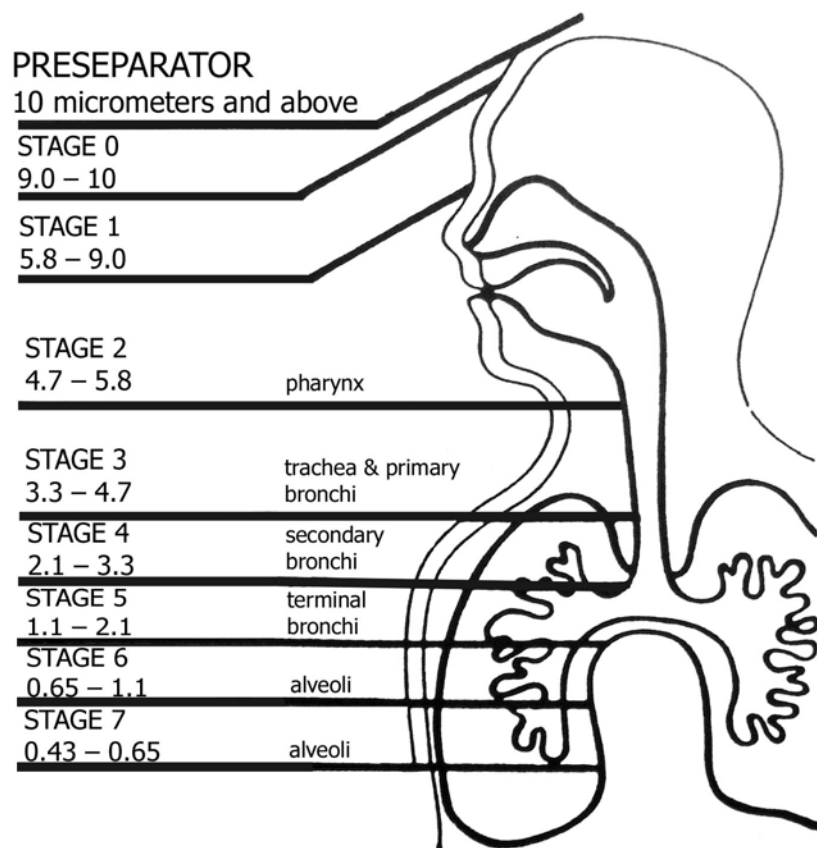


FIGURE 1. TISCH MODEL TE 20-800 SIMULATES THE HUMAN RESPIRATORY SYSTEM

Calculated data, as a result of operating a Cascade Impactor, is presented as a 50% effective cut-off diameter (ECD). The Tisch Eight Stage Ambient Cascade Impactor contains multiple round orifice jets on each Stage and a flat collection media. Calculating the 50% effective cut-off diameter yields a value of 0.14 for the inertial impaction parameter K for this device.

The Cunningham Slip-Correction Factor for indoor applications of 21°C and 760mm Hg atmospheric conditions is equal to:

$$C = 1 + 0.16 \times 10^{-4} / D_p$$

The Cunningham Slip-Correction Factor corrects for the physical changes that as particle diameters approach the mean free path length of the gas molecules, the particle tend to “slip” between the gas molecules more easily and therefore are capable to cross the bulk flow stream lines of the sampled air. The collection efficiency of a sampler is therefore slightly greater than would be mathematically predicted by inertial impaction theory for particle diameters in the 1.0 to 2.0 micrometer AED size. The overlapping of particle cut-off sizes between Stages, which is naturally inherent in all Cascade Impactors, is minimized in the Tisch design. Ranz and Wong (1952) stated that as a particle passes through a round orifice jet, its nearness to the axis of the jet is one of the factors that determines whether or not the particle will reach the impaction substrate surface. The Tisch Impactor have multiple small, round orifice jets to maximize the fractionation sharpness. The travel of the particle is thus confined near the axis of the orifice jet.

Multiple studies and laboratory calibrations using NIST traceable wet and dry aerosol standards have confirmed that particles larger than 9.0µm AED have a potential to bounce and not impact. These can then become re-entrained into the sample air-stream and typically cascade to the last Stage and skew the results of the filter sample. The Tisch Size Selective Inlet (High-Capacity Pre-Separator) is designed to be an integral part of the sample to eliminate this large particle bounce.

3.2. Cascade Impactor

The Tisch Ambient Eight-Stage Cascade Impactor consists of a Pre-Separator Size Selective Inlet, Seven Orifice Stages, Nine Substrate Collection Plates, One Filter Stage and Base Plate. All components are aircraft alloy-aluminum and compressed together to make a leak-free seal with three Spring-Clamps. Silicone Rubber O-Rings make dynamic seals between each stage. (Figure 2)



FIGURE 2. TISCH EIGHT-STAGE NON-VIABLE IMPACTOR



The Tisch Impactor includes a Pre-Separator Size Selective Inlet. The device consists of a single inlet nozzle that accelerates the aerosol into a chamber. Three vent tubes exit the chamber and carry the <9 μ m AED particles into the Impactor. This size selective inlet is designed to remove all large particles and collect up to 10.0 grams of mass particulate before overloading.

Each of the aluminum Orifice Stages contain either 96, 400 or 201 precision machined orifices drilled in a circular repeating pattern. These orifices are verified by Tisch to be identical within tolerances on each specific stage, and decrease in diameter from Stage 0 to 7. Consequently, with a constant sample flow-rate of 28.3 actual liters a minute (ALPM) the Orifice velocities increase in each succeeding Stage. When sampled air is drawn through the Impactor the multiple Orifice Jets on each Stage direct the airborne particles toward an impaction surface directly below each Orifice. This impaction surface is referred to as the Substrate and an 81mm diameter glass micro-fiber filter media is typically used.

Collection directly onto the Stainless Steel collection plate is ideal for laboratory procedures where the sample is collected and removed by washing to calculate concentration on a wet chemistry mass basis. The aerodynamic dimension of a particle is determined by the fact if it is impacted on a given stage. All particles with insufficient inertia to break out of the sample flow streamlines to be impacted on the first collection plate will follow the air path through the exhaust vents and into the following Stage. It will then either be impacted on the next collection plate or passed to the succeeding Impactor Stage. The jet velocity of each succeeding Orifice Stage increases until the back-up filter collects the sub-micron particles by filtration.

The Tisch Impactor is considered a complete total collection ambient particulate inertial separation device utilizing both impaction and filtration.

The Impactor can be supplied complete as a complete system including a carrying case, sample substrates, filter media, vacuum hose and operation manual. A vacuum pump and flow controller system is optional.

The Tisch Ambient Eight-Stage Cascade Impactor is used with a set sample flow-rate of 28.3 ALPM (1.0 Actual Cubic Foot/Minute). This sample rate must remain constant during a sample event to insure the correct and stable Orifice Jet velocities to insure proper size separation.

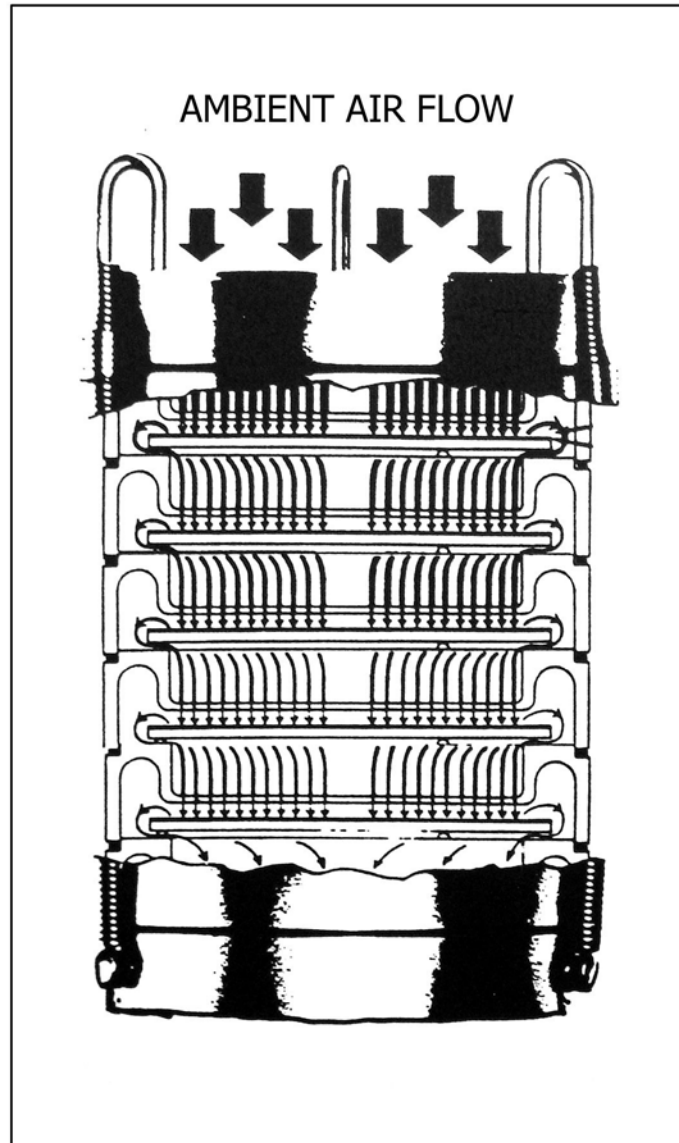


FIGURE 3. CROSS SECTIONAL VIEW OF AMBIENT IMPACTOR

3.3. Theory and Calculations

The calculation of Stage Cut-Off Diameters can be determined based on the following formulas and information. The Effective Cut-Off Diameter (ECD) is commonly referred to as the D_{50} of the Impactor Stage. The Tisch Impactor is calibrated in terms of the "Cut-Off Diameter" which can be described as the aerodynamic diameter of a particle which is collected with 50% efficiency by a given Impactor Stage (Ranz and Wong, 1952).

Stage Number	Number of Orifice Jets	Diameter of Orifice Jet (cm)
0	96	0.255
1	96	0.189
2	400	0.091
3	400	0.071
4	400	0.053
5	400	0.034
6	400	0.025
7	201	0.025
F	340	81mm Filter Media

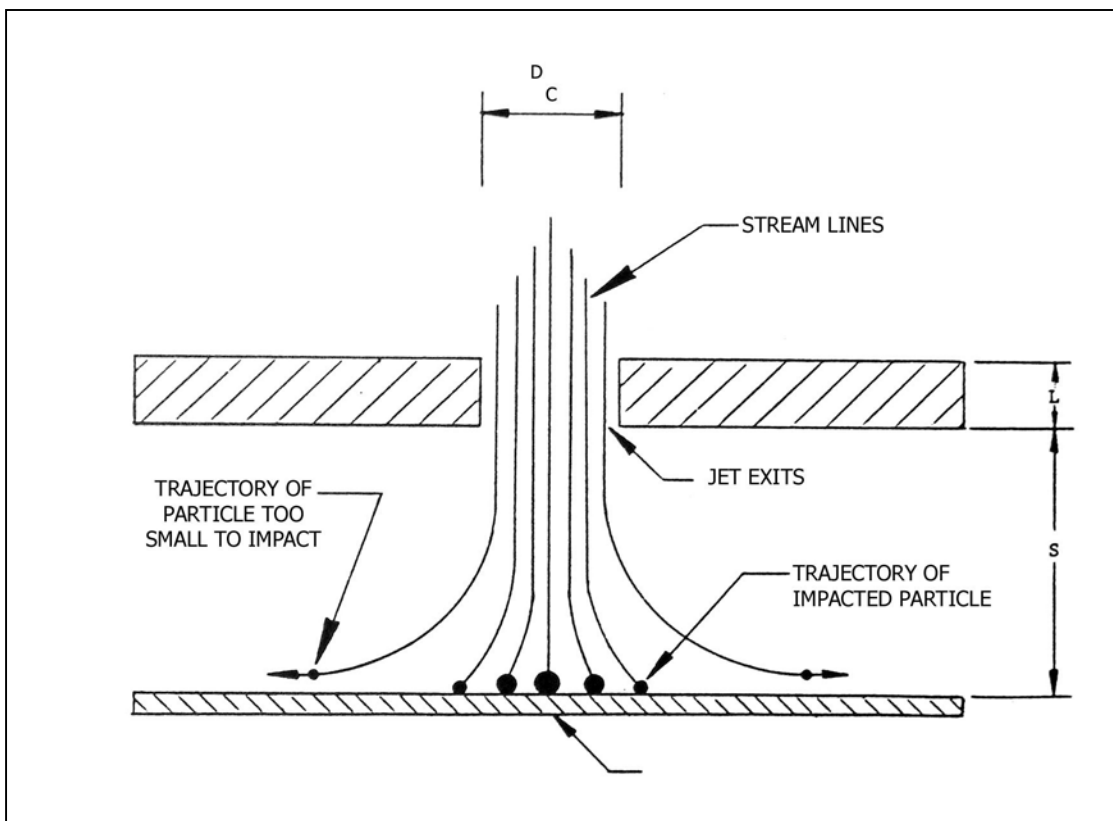


FIGURE 4. THEORY OF A CASCADE IMPACTOR

4. GETTING STARTED SAMPLING

4.1 General Information

If sampling an aerosol where particles greater than 9.0 μ m AED are suspected it is advisable to use the Size-Selective Inlet (High Capacity Pre-Separator) to reduce any particle bounce of large particles on Stages 0 and 1.

When using the Size-Selective Inlet (High Capacity Pre-Separator) remove the standard Inlet Cone assembly above Stage 0. The Pre-Separator has a base with three indentations which should be aligned above the Spring Clips to hold the Impactor tightly together.

4.2 Assembly

The Orifice Stages, Size Selective Inlet and collection substrates must be clean of any contamination before sampling. Use of a mild detergent and water are adequate for cleaning. A rinse with distilled-deionized water is preferred, but not mandatory. An ultrasonic laboratory cleaner is an excellent means of cleaning the assembly.

Note: Do not try to brush or use wire to clean an Orifice Jet as this will cause damage. Use only a non-abrasive cleaner and non-reactive detergent. All components of the Impactor are alloy aluminum. The Silicone Rubber O-Rings can be removed before cleaning. Rinsing of the Impactor Stages with Acetone to increase drying and preventing water streaks is a good technique.

The Orifice Stages should only be handled by the edges to prevent contamination from human contact on the sampling or collection surfaces. Visually check each Orifice Stage to validate that none of the Orifice Jets are blocked. If an Orifice Jet is found partially or completely blocked first use a clean compressed air blast to clean out the debris.

The Tisch Ambient Eight-Stage Impactor assembly consists of an Inlet Cone, Nine Orifice Jet Stages, Eight Collection Substrate Plates and a Filter Stage (F). The Size Selective Inlet (High Capacity Pre-Separator) is optional and replaces the Inlet Cone when used. The Orifice Stages are numbered sequentially starting with 0, 1, 2, 3, 4, 5, 6, 7 and F. Stage 0 is an Orifice Jet Stage only and has no Collection Substrate Plate on top. Stage F hold the Collection Substrate Plate for Orifice Stage 7 and also contains an internal O-Ring to hold an 81mm backup filter media.

The Tisch Impactor assembly begins by placing Orifice Stage F on top of the Base Plate on a flat top surface. A laboratory, gravimetrically weighed 81mm glass micro-fiber filter media is placed inside Orifice Stage F. The O-Ring holds the filter media in place during sampling.

Note: Care should be taken when handling the filter media while inserting and removing to prevent tearing or loss of sample.

Sampling with Use of Glass Micro-Fiber Substrates:

Place one (solid) Stainless Steel Substrate Collection Plate on top of Orifice Stage F with the curved side facing upward. Three indented stand-offs index the plate to the correct position and prevents movement during the sample event. Place and center a pre-weighed 81mm glass micro-fiber substrate on top of the Collection Plate. Normally the rougher side faces the up side and collects the sampled particles.

Note: If sampling directly onto the Stainless Steel Substrate Collection Plate invert the Plate so the curved side faces downward. The sample will now be collected directly onto the clean metal Collection Plate.



This procedure is repeated for Orifice Stage 7, 6, 5, 4, 3, 2 and 1. The 0 Stage does not have a Collection Plate on top. Either the Inlet Cone or Size Selective Inlet (High Capacity Pre-Separator) is placed on top of Orifice Stage 0.

Note: There are two special open center Stainless Steel Substrate Collection Plates in each set. These are used for Orifice Stage 1 and 2 only. Orifice Stages 3, 4, 5, 6 and 7 all use solid Stainless Steel Substrate Collection Plates.

Please note that it is important for proper operation that the Substrate Collection Plate fits properly on the Orifice Jet three stand-offs to insure jet to plate spacing and even distribution of sample onto the substrate.

Note: When the Impactor is using Glass Micro-Fiber or other Substrate material centered in the Substrate Collection Plate the Impactor must be operated in a vertical position.

After the Impactor Orifice Jet Stages and Inlet Cone have been assembled, connect the three Spring Clips up and over the top of the Impactor. Center the Clip into the three indentations in either the Inlet Cone or Size Selective Pre-Separator. The Impactor is now ready for sample collection.

Connect the male hose-barb connector on the Impactor Base Stage to the intake (Vacuum) port of the vacuum pump or sample flow device using a thick-wall vacuum hose. Note: The Impactor will require sample flow rate calibration if various lengths of hose are used. Refer to Section 5.4 for Impactor Sample Flow Rate.

4.3 Sampling

Sampling commences by providing power to the vacuum source and the control valve is set to provide 28.3 ALPM sample rate through the Impactor. Normally sample events are of short time duration and therefore the differential pressure across the F Stage with the absolute filter does not change. If an exceptionally dirty sample or extra long sample duration is expected it may involve the operator adjusting the sample flow rate to maintain the flow at 28.3 ALPM for the entire sample event. Note: PM 200 provides as an option a volumetrically flow controlled and timed vacuum system for users who wish un-manned operation and electronic verification of a sample event.

During the sampling event, the flow rate may change from initial to final by 2% due to readings taken when the vacuum pump is cold versus hot. It is important to remember to calibrate the Impactor flow system after the vacuum pump system has come to equilibrium.

The particle size range collected on each of the eight Substrate Plates depends on the Orifice Stage velocity, the distance between an Orifice exit, the collection surface and the collection characteristics of the substrate media used to collect the particles. Use of bare collection plates is sometimes necessary for chemical analysis, but also increases the risk of particle bounce. Impaction grease can be used on bare collection plates to improve the collection efficiency. Use of glass micro-fiber media is encouraged since it is easily handled and standard laboratory weighing procedures are in place in most commercial laboratories.

The combination of a constant Impactor sample flow rate and successively smaller diameter Orifices increases the jet-velocity of Impactor air as it cascades through the Impactor. This results in the impaction of progressively smaller particles in succeeding Orifice Stages. Figure 6 shows a view of a single Orifice Jet and the particle and flow trajectories. The Tisch Impactor design sample flow rate is 28.3 ALPM which fractionates particles in a range from 9.0 to 0.3 micrometers aerodynamic diameter. Particles too small to be impacted on the last Collection Plate are collected on the final absolute filter, F.

Normal sampling periods are typical of several minutes to an hour.

Note: Fifteen micrograms (15 μ g) of particle mass increase on any one Collection Substrate may be suspect to overloading and a cause of error. Whenever overloading occurs, the small impaction points on the substrate break and become re-entrained in the sample air and contaminate Sample Substrates downstream. Sometime a visual indication of a faint black line leading away from the black spot (impaction point) on the substrate is an indication of overloading.

After the Impactor sample event concludes, the Impactor is disassembled. The Size Selective Pre-Separator is brushed out using a soft camel-hair paint brush onto tared Glyciene paper or a tared container and conditioned. The Sample Substrates or Stainless Steel Collection Plates are removed and replaced with new sample media. After conditioning in a temperature and humidity controlled laboratory weighing room for 24 hours the sample can be weighed and the particulate mass chemically analyzed for mass weight change and chemical speciation.

Since many ambient air particulate have hygroscopic and chemically active characteristics, all Impactor sample collection media should be pre and post conditioned to laboratory conditions before weighing. Filter weighing should be made on an analytical pan balance to an accuracy of ± 0.02 mg and a precision of ± 0.01 mg.

4.4 Analysis

The analytical technique dictates the type of sample collection substrate media to be used in the Tisch Impactor. Glass micro-fiber filter media has been provided in 81mm diameter substrates with both open centers for Orifice Stages 0 and 1 and solid centers for Orifice Stages 2, 3, 4, 5, 6, 7 and F. Glass micro-fiber media is an excellent choice for gravimetric weighing and analysis but a poor media for chemical analysis or optical measurements.

Stainless Steel Substrate Collection Plates can be used both as a dish to hold the fiber media or inverted and sample collected directly onto the metal surface. If this second media is selected it is typically for applications where the collected sample is washed off the plate after sampling and subsequent chemical analyses is performed.

It should be kept in mind that whenever an Impactor sample has been collected, the particle size has already been concluded. To analyze the speciation of the size distributed sample a laboratory procedure may be applied for chemical speciation in lieu of gravimetric weighing.

4.5 Data

Steps for Determination of Data:

- a) Gravimetrically determine the change in initial and final weight of each Impactor stage including the weight of the Size Selective Pre-Separator and Final Filter.
- b) Add the measured weight changes to calculate the Total Particulate weight collected for all Stages, Pre-Separator and Final Filter.
- c) Divide the Mass measured on each individual Stage by the total Mass collected (step b) to determine the percentage (%) of the total Mass collected in each size fraction (Table 1).
- d) The particle density is normally assumed as 1.0 g/m^3 unless a specific density is applied for the application. This particle density is used to report the individual particle sizes as the Equivalent Aerodynamic Diameter (AED).

Note: The Size Selective Pre-Separator Mass should be added to Impactor Stage 0 and the sum of both fractions is larger than the Dp_{50} for Stage 0. The Pre Separator has approximately the same size cut-point as Impactor Stage 0 therefore the two are combined.

- e) Using Figure 1, select the lower size (smallest number) for each particle size range. This number represents the Effective Cut-Off Diameter (ECD) for each Impactor Stage. This ECD can also be determined by viewing Figure 6.
- f) Graph the results of the particle size analysis on Log-Probability paper with the Effective Cut-Off Diameter as the Ordinate and the cumulative percent less-than the particle size range by weight as the Abscissa (Figure 7).
- g) Assuming a log-normal particle size distribution, the particle size Geometric Standard Deviation (σ_g) is determined by :

$$\sigma_g = \frac{84.13 \% \text{ Diameter}}{50\% \text{ Diameter}} = \frac{50.5 \text{ Diameter}}{15.87\% \text{ Diameter}}$$

Whenever these two Standard Deviations are not equal (such as represented in a Bimodal size distribution), the Impactor measured size distribution is not represented by a straight line and therefore not truly log-normal. A preferred method of presenting the Standard Deviation is:

$$\sigma_g = \left(\frac{84.13 \% \text{ Diameter}}{15.87 \% \text{ Diameter}} \right)^{1/2}$$

It is commonly accepted the Particulate Size Distribution should be presented in graphical form rather than reporting the Mass Mean Diameter and the Standard Geometric Deviation. By plotting the ECD and cumulative percent the particle concentration for any particle size range can be determined.

Note: Contact Tisch for information regarding a PC based Cascade Impactor Software Program which is compatible with all Tisch inertial size separation products.

- h) Refer to Table 1 and Figures 5 and 6. Approximately 97% of this hypothetical size fraction sample is respirable ($< 7\mu\text{m}$ AED) according to the American Council of Governmental Industrial Hygienists (ACGIH). The mean particle diameter is determined to be $2.0\mu\text{m}$ AED and that the Standard Geometric Deviation is $1.9\mu\text{m}$ AED.

Stage	TARE (g)*	Final (g)	Net (mg)	% in size range	Cumulative % less than size range	Size range micrometers	ECD micrometers
Pre-separator	0	0.00009	0.09	0.7)	98.7	10.0 & above	10.0
0	1.000	1.00009	0.09	0.6)		9.0 – 10.0	9.0
1	1.000	1.00017	0.17	1.2)	97.5	5.8 – 9.0	5.8
2	1.000	1.00082	0.82	5.7	91.8	4.7 – 5.8	4.7
3	1.000	1.00194	1.94	13.6	78.2	3.3 – 4.7	3.3
4	1.000	1.00472	4.72	33.1	45.1	2.1 – 3.3	2.1
5	1.000	1.00431	4.31	30.2	14.9	1.1 – 2.1	1.1
6	1.000	1.00100	1.00	7.0	7.9	0.7 – 1.1	0.7
7	1.000	1.00082	0.82	5.7	2.2	0.4 – 0.7	0.4
Backup Filter	1.000	1.00031	0.31	2.2	0	0 – 0.4	0
			14.27				

TABLE 1. TABULAR PRESENTATION OF PARTICLE SIZE DATA

FIGURE 5 IMPACTOR THEORETICAL IMPACTION CURVES

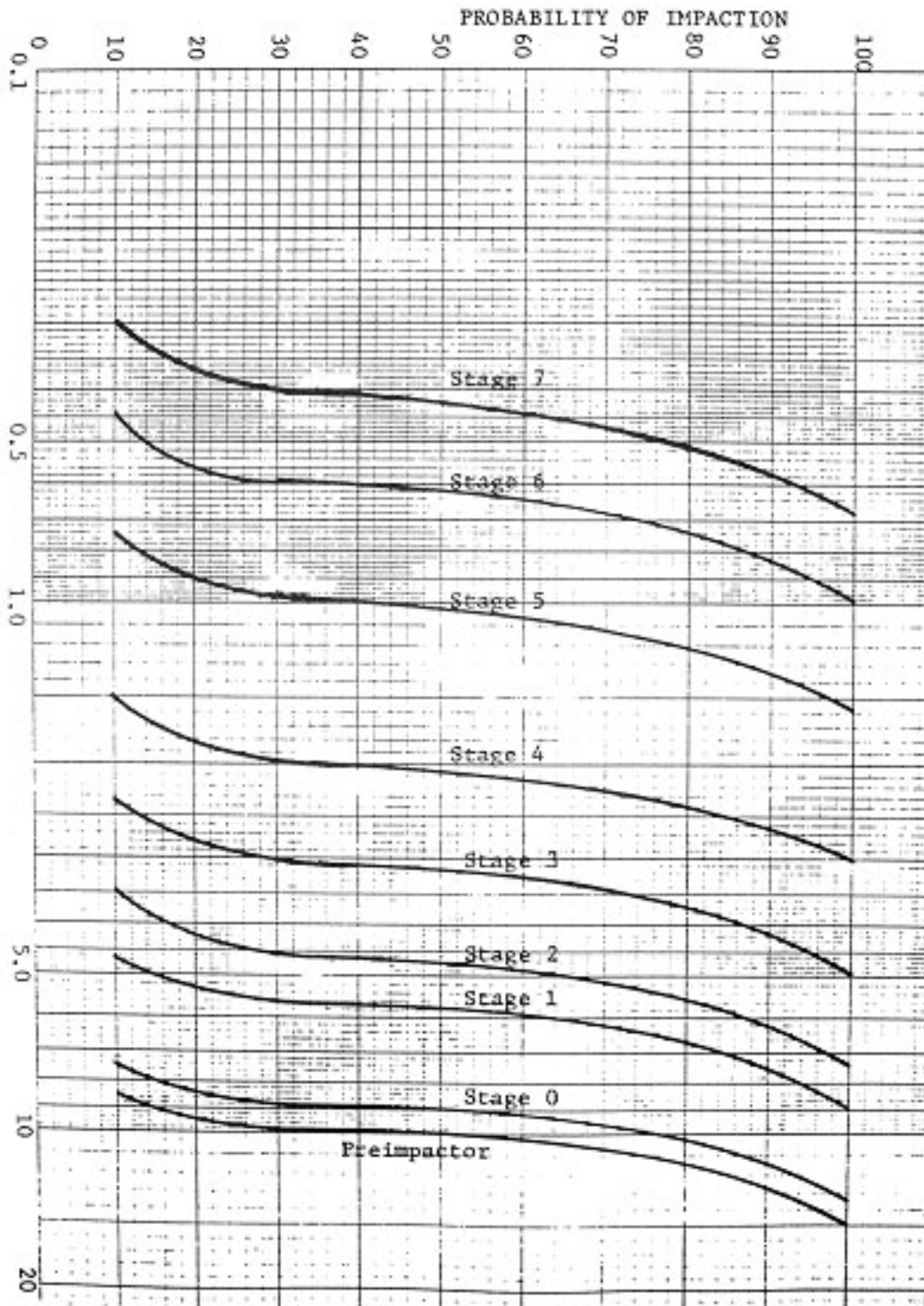


FIGURE 5. IMPACTOR THEORETICAL IMPACTION CURVES

Particle Diameter (Microns)	Percent In Size Range	Cumulative Percent Less Than
≥ 9.0	1.3	98.7
5.8 - 9.0	1.2	97.5
4.7 - 5.8	5.7	91.8
3.3 - 4.7	13.6	78.2
2.1 - 3.3	33.1	45.1
1.1 - 2.1	30.2	14.9
0.7 - 1.1	7.0	7.9
0.4 - 0.7	5.7	2.2
0 - 0.4	2.2	0

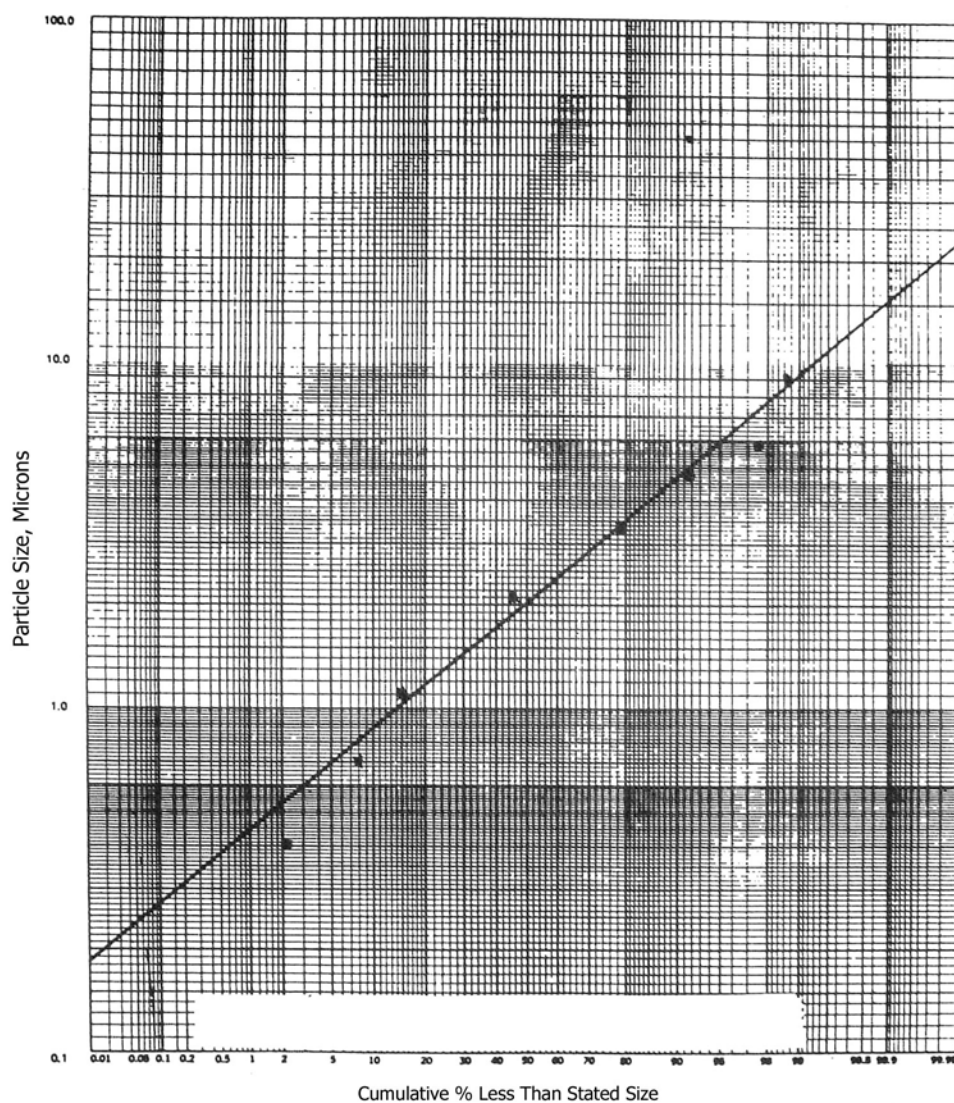


FIGURE 6. AERODYNAMIC PARTICLE SIZE IMPACTION GRAPH

5. MAINTENANCE AND CALIBRATION

5.1 Impactor Orifice Diameter

Each Tisch Ambient Eight-Stage Cascade Impactor is factory calibrated by physically checking each Orifice on each Stage physically with certified machinist Gauge Pins and also an Optical Comparator.

A sample of an individual Calibration Certificate and Impactor Quality Control Form follows. Each Tisch Cascade Impactor is supplied with a certificate of Orifice diameter validation.

Factory re-certification can be performed by contacting the Tisch factory and requesting a Return Authorization number.

Additionally, for users who require a certificate and validation of an individual Tisch Cascade Impactor, Laboratory Aerosol Verification Tests (LAVT) are available upon request. These NIST traceable standard tests involve individual Impactor testing with both solid and wet aerosol standards and determination of the Cascade Impactor true dynamic calibration to a known laboratory standard. Unfortunately these tests are not easily performed and require special instrumentation and personnel. Tisch has contracted a leading laboratory with national trace-ability and rating to perform these tests at a set fee.

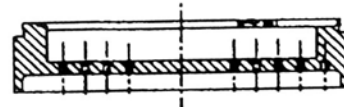
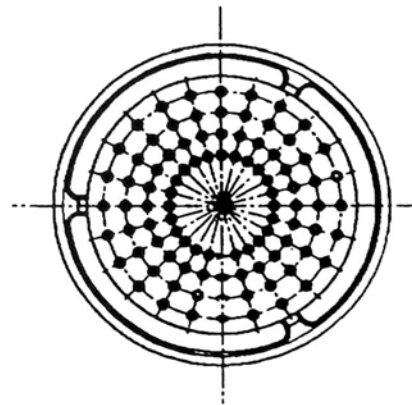
CALIBRATION CERTIFICATE IMPACTOR Q.C. FORM PLATE '0'

HOLE CIRCLE	NUMBER OF HOLES	HOLE DIAMETER	TOL +/- .025 mm	CIRCLE DIAMETER	ANGLE BETWEEN
A	✓ 24	2.55mm	✓	30.48	15°
B	✓ 24	2.55mm	✓	43.18	15°
C	✓ 24	2.55mm	✓	55.88	15°
D	✓ 24	2.55mm	✓	68.58	15°

Checked by: *[Signature]*

Date: 9/27/99

Serial Number: 012



↑
Holes to be checked
From this direction

FIGURE 7. CALIBRATION CERTIFICATE AND IMPACTOR QUALITY FORM(EXAMPLE)

5.2 Vacuum pump or Sample Flow Assembly

The Tisch Ambient Eight-Stage Cascade Impactor is designed to operate at 28.3 ALPM sample rate. A standard vacuum pump system with approximately 30 ALPM free-air flow is typically adequate for sampling.

Note: Use of rotary vane vacuum pumps are discouraged since the exhaust, regardless of muffler, generate fine particulate of carbon which can be introduced into the Impactor as sample.

Use of Diaphragm Vacuum Pumps are encouraged, however please note that some pumps pulsate due to the piston designs and can cause flow pulsation's within the Impactor disturbing the size separation. An Adequate pulsation-dampner or plenum should be used with all Diaphragm Vacuum Pumps.

The differential pressure at room temperatures and sea level is approximately 13.6 inches of water column. This pressure should not vary considerably unless the Impactor has a multiple hour sample event or used in a non-ambient particle laden environment.

A volumetric flow-controlled vacuum system is available from Tisch for users who wish to have a complete Inertial Separator Sampling System. Please contact the factory for information.

5.3 Leak Check

Prior to a sample event a leak check and sample flow-rate verification steps should be performed.

A leak check can be performed using two procedures depending on the vacuum system being used.

- a) A rubber stopper or plug is placed into the Pre-Separator Inlet or Impactor Inlet Cone. Pull approximately a 280mm Hg vacuum (-15"Hg) with the vacuum source. Operate with a vacuum gauge and shut-off valve in-line between the Impactor and vacuum source. Pull the vacuum, shut valve and immediately record the vacuum reading. After one minute the vacuum should approximately be the same indicating there is no leak.

Note: Carefully and slowly remove the cork at the top of the impactor to allow the system to come to atmospheric conditions.

- b) For systems using a volumetric flow control system begin by closing off the Impactor Inlet using a rubber stopper. Pull a half atmosphere vacuum, approximately a negative 380mm Hg or -15"Hg vacuum. Determine if any leak is measured with the flow device.

5.4 Periodic Maintenance

It is advised the Impactor and all accessories be cleaned according to the procedures outlined in Section 4.2.

Proper maintenance of the vacuum pump or vacuum source should be maintained according to the manufacturers suggestion on an annual basis.

Tisch recommends that the Silicone O-Rings on the Impactor be changed at least every 24 months to prevent cracking and leaks.

6. ACCESSORIES AND SPECIAL APPLICATIONS

Pharmaceutical applications call for special Impactor entry devices which vary in different configurations according to method. The IP/C Induction Port is a right-angle device which fits above the Tisch Pre-Separator and allows the attachment of pharmaceutical inhalers for testing.

This device seats into the Pre-Separator with an O-Ring seal and should be cleaned according to the procedures outlined in Section 4.2

7. REFERENCES AND ADDITIONAL READING