

**A New Automated Filter Tester for Low Efficiency,  
HEPA Grade, and Above Filter Media and Cartridges**  
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Brian R. Johnson, Sandra K. Herweyer,  
Edward M. Johnson, and Jugal K. Agarwal  
TSI Incorporated  
500 Cardigan Road  
Shoreview, MN 55126

## A NEW AUTOMATED FILTER TESTER FOR LOW EFFICIENCY, HEPA GRADE, AND ABOVE FILTER MEDIA AND CARTRIDGES

By: Brian R. Johnson, Sandra K. Herweyer, Edward M. Johnson, and Jugal K. Agarwal, TSI Incorporated  
P.O. Box 64394, 500 Cardigan Road, St. Paul, MN 55164

### Abstract

An automated filter tester for production testing of filter media, filter cartridges, and respirator cartridges has been developed. Filter penetrations from 100 to 0.001% (efficiencies of 0 to 99.999%) can be measured with this tester using NaCl, DOP, or other oils as the challenge aerosol.

The automated filter tester's unique oil generator produces dioctyl phthalate aerosol with a 0.18 micrometer geometric number mean diameter with a geometric standard deviation of 1.6. This is accomplished by initial aerosol generation with Retec nebulizers and further conditioning with a coarse filter to narrow the size distribution.

A new photometer designed specifically for filter testing has been incorporated into this tester. This photometer features fast response and purge times, automatic gain selection, and a three position switching valve with a straight-through aerosol path on the inlet of the device. A solid-state laser diode and photodetector with 45 degree off-axis collection optics are used to measure aerosol concentrations from 1 microgram per cubic meter to over 100 milligrams per cubic meter.

Test data, including penetration, pressure drop, and flow rate, is output by the tester in three ways: via the digital display, through the front panel printer, and by the RS-232 serial port. The measurement ranges of the tester include: filter penetrations down to 0.001%, filter pressure drop up to 150 mm of water, and challenge aerosol flow rates up to 100 liters per minute.

Comparison penetration data between the new automated filter tester and the commonly used Q-127 hot DOP machines show that the two methods have a one-to-one correlation.

### Introduction

The demand for quality filters and filter media has seen enormous growth in the past decade. A few applications which have increased the demand for filters are: clean rooms in the semiconductor and pharmaceutical industries, filtering in Nuclear power facilities, and the increased use of particulate respirators in the workplace. Whether particulates are filtered to increase the yield in a semiconductor manufacturing situation, or to decrease the health risk for workers in hazardous environments, the ability of a filter to capture particulate matter is imperative for its user.

Efficiency and pressure drop testing of filters is required to determine filter quality. The efficiency of a filter is the ratio of the concentration of challenge aerosol retained in a filter during a test to the concentration which passes through. The pressure drop is a measure of the resistance of the filter to a given flow rate. Generally, the best filter for an application will have the lowest pressure drop at the required efficiency.

Traditionally, filter testing equipment falls into two categories. The first category consists of complete, commercially available testers which employ: flame photometry with NaCl, laser particle counting, or photometry with hot DOP. An example of this is the Q-127 which uses thermally generated DOP aerosol and a photometer. These machines were developed several years ago and lack the automation that is possible today. The other category is component systems that are put together using commercially available detection instrumentation and aerosol generators. While taking advantage of the latest technology, such systems require considerable technical expertise and expense to build and operate.

This paper describes a new automated filter tester (TSI Model 8110) that has been developed to meet the need for a complete turn-key tester based on current technology. It can operate with both solid (NaCl) and liquid (DOP, paraffin oil) aerosols. The importance of a complete automated tester is that it provides a test measurement rather than a group of instruments.

Data correlation of the results of new testing methods with traditional test methods is important for several reasons. With correlation, new data can be compared to past data to determine if there has been any long-term changes in production quality. In addition, data taken with a new method can be translated into a standard "language" for filter efficiency reporting, such as Q-127 data in the United States. A correlation study to compare the new solid-state photometer based tester with the Q-127 hot DOP type tester is presented.

### Technical Description of Tester

The new tester was designed to meet several needs, these include: ease of operation, accurate results, repeatable results--without operator variability, low maintenance, and fast test times.

A picture of the new automated filter tester is shown in figure 1. To operate the tester, the operator would simply insert a filter into the filter holder and press the "close" buttons to start a test. When the microprocessor controlled test is finished, the filter holder opens and the flow rate, pressure drop, and % penetration is given. A flow schematic of the tester is shown in figure 2.

The generated aerosol is mixed with dilution air in the drying/mixing chamber. This aerosol is then routed to the filter holder to challenge the test filter. The photometer measures the aerosol concentration before and after the filter. The flow rate is measured by monitoring the pressure drop across an orifice with an electronic pressure transducer. The pressure drop across the filter is also measured with an electronic pressure transducer which is connected to pressure taps before and after the test filter.

Some important design components of the new tester are: aerosol generation, aerosol detection, and the microprocessor controlled self-check diagnostics. These are described in detail in the following sections.



Figure 1. TSI's Model 8110 Automated Filter Tester



Figure 2. Flow schematic of TSI's Model 8110 Automated Filter Tester

#### Aerosol Generation

The new tester includes two different aerosol generation systems. One is designed for liquid (oil) aerosol generation. The other is designed for solid (salt) aerosol generation. Both systems use Retic nebulizers which generate submicrometer particles by producing a fine spray of solution and impacting out the larger droplets. This paper will focus on use of the oil (DOP) generator for correlation with the Q-127 hot DOP machines.

The oil aerosol produced by the Retic nebulizers passes through a coarse filter before exiting the generator. This coarse filter narrows the oil size distribution. A diagram of the oil generator is shown in figure 3. The DOP used to challenge filters has a geometric mean diameter of 0.18 micrometers with a geometric standard deviation of 1.6, as measured by a Differential Mobility Particle Size Analyzer (DMPS) manufactured by TSI Incorporated, St. Paul, MN.

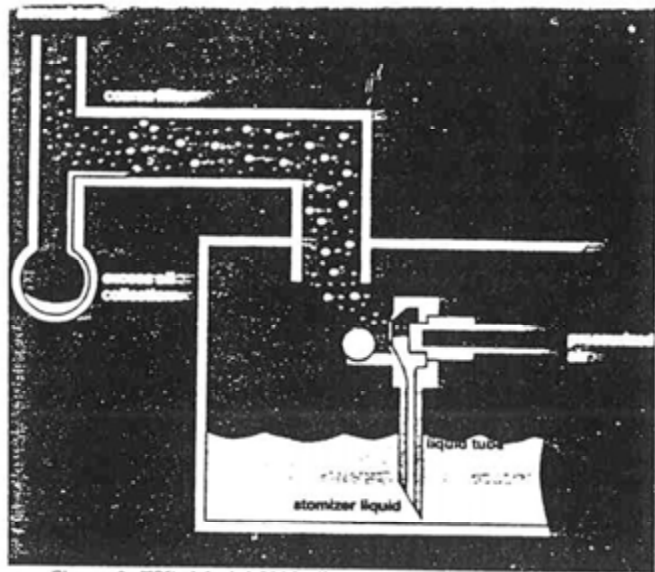


Figure 3. TSI's Model 8110 oil generator

#### Aerosol Detection

A light scattering photometer is used to make concentration measurements upstream and downstream of the test filter. A schematic of the photometer is shown in figure 4.

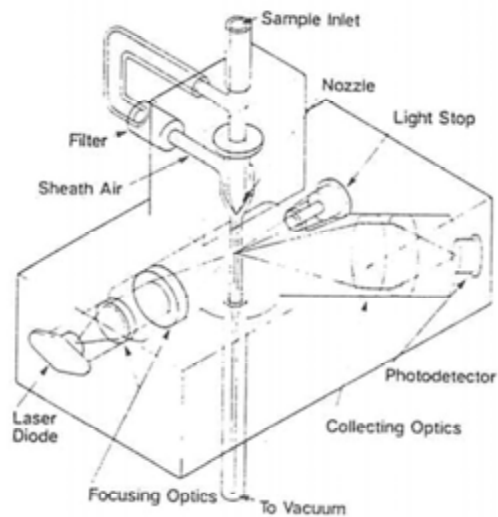


Figure 4. Photometer Schematic

The aerosol entering the photometer is split into two flow paths. One path is directed through a high efficiency filter and serves as clean sheath air around the aerosol sample being measured. The sheath air isolates the sample aerosol by encompassing it as it passes through the photometer, keeping the photometer optics clean as well as reducing the purge time between measurements.

The light scattering chamber contains a 5 milliwatt laser diode light source which is focused onto the aerosol stream. A laser diode light source

was chosen because it is more stable than conventional white light sources which tend to change intensity over time. In addition, a laser diode light source can be collimated and focused more efficiently than a white light source.

The aerosol detection is accomplished by focusing the light scattered by the aerosol onto a photodiode. The total light scatter is converted to a voltage which is proportional to the aerosol concentration being measured. A photodiode offers stability over time. The collection optics are located 45 degrees off-axis from the light source to minimize light scattering variations due to changes in particle diameter. Forward scattering techniques accentuate the effect of larger particles which have a large portion of scatter in the forward direction.

#### Microprocessor Diagnostics

Statistical diagnostics. To ensure proper operation, the microprocessor based filter tester performs internal self-diagnostics during operation. One diagnostic feature is validation of the filter penetration data each time a filter is tested. The penetration data is validated by analyzing the downstream concentration signal. An accurate downstream signal is typically the area of most concern with a photometer-based filter tester. The signal downstream of a high efficiency filter can be near the background level of a photometer. To ensure a good measurement of the downstream signal, the statistical uncertainty in the data is computed. First, the downstream uncertainty is calculated as shown in equation 1.

$$\text{Downstream Uncertainty} = 2 \times \frac{\text{Variance of data points}}{\text{Number of data points}}^{1/2} \quad (1)$$

This downstream uncertainty is then related to the total uncertainty of the penetration measurement as shown by equation 2.

$$\text{Penetration Uncertainty} = \frac{\text{Downstream Uncertainty}}{\text{Upstream Signal}} \quad (2)$$

This penetration uncertainty is compared to the overall penetration measured. If the penetration uncertainty is greater than 10% of the total penetration measured, the test is invalidated. No data is output for an invalid test. This statistical check on the penetration verifies that the measured signal downstream of the filter is adequate and stable for a proper penetration measurement.

Other self-checks. In addition to the statistical analysis program, the tester monitors the photometer background level and upstream aerosol concentration level to alert the operator if a problem is diagnosed.

#### Data Correlation

As with all new technology, the problem arises in relating new test results with "standard" test results which have been collected over many years. To determine the correlation of the new tester with that of the Q-127 type hot DOP tester a correlation study was performed. This study included the testing of flat sheet glass fiber media produced by Lydall Incorporated, Technical Papers Division of Rochester, New Hampshire. Ten grades of filter media spanning the range of penetrations from 0.001% to 85% (ULPA to ASHRAE) were tested.

Both testers operated with dioctyl phthalate (DOP). The Q-127 tester uses a thermally generated DOP vapor. The new tester uses room temperature DOP aerosol produced by Retec nebulizers which is further conditioned by passing through a coarse filter. The flowrate through the media being tested was 32 liters per minute. The graph illustrates the correlation of the test results.

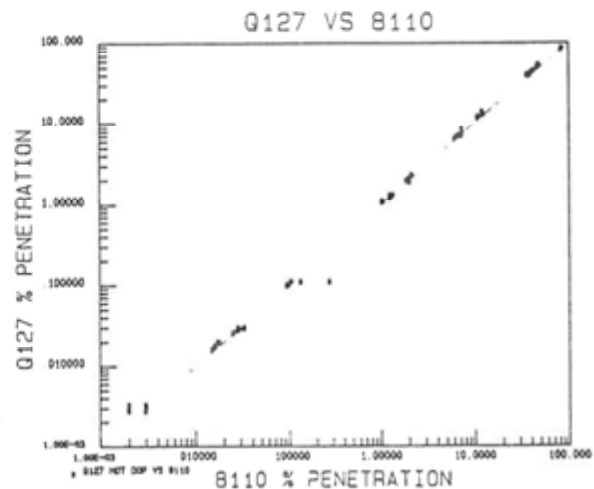


Figure 5. Q-127 versus TSI Model 8110 AFT

As can be seen from the graph, the line has a slope near one, with a y intercept of zero. This gives approximately a one-to-one correlation. A linear regression analysis performed on the test data resulted in a correlation coefficient of 0.9994. This indicates good agreement between the results of the two filter testers.

#### Conclusions

The new automated filter tester (TSI's Model 8110) can provide an automated filter test to measure penetrations from 0.001% to 100% (efficiencies of 99.999% to 0%) with statistical verification. The tester incorporates current technology to insure that operator variability and excessive maintenance is eliminated.

The new tester generates room temperature DOP, as well as other oils, by using Retec nebulizers for initial aerosol generation. The aerosol is then passed through a coarse filter to narrow the particle size distribution before exiting the generator.

The laser diode based, microprocessor controlled photometer offers an alternative to white light based photometers. The laser diode offers a stable light source which will not vary its intensity over time. In addition, the new microprocessor controlled photometer does not require rezeroing by the operator.

Clean sheath air which encompasses the aerosol entering the photometer eliminates downtime due to photometer maintenance requirements.

The correlation of the new tester with the Q-127 type hot DOP tester shows that the two methods have basically a one-to-one correlation. Therefore,

the data taken with the new tester can be interpreted to Q-127 data without further data conversion.

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**TSI Incorporated** – 500 Cardigan Road, Shoreview, MN 55126 U.S.A

<b>USA</b>	Tel: +1 800 874 2811	E-mail: <a href="mailto:particle@tsi.com">particle@tsi.com</a>	Website: <a href="http://www.tsi.com">www.tsi.com</a>
<b>UK</b>	Tel: +44 149 4 459200	E-mail: <a href="mailto:tsiuk@tsi.com">tsiuk@tsi.com</a>	Website: <a href="http://www.tsiinc.co.uk">www.tsiinc.co.uk</a>
<b>France</b>	Tel: +33 491 11 87 64	E-mail: <a href="mailto:tsifrance@tsi.com">tsifrance@tsi.com</a>	Website: <a href="http://www.tsiinc.fr">www.tsiinc.fr</a>
<b>Germany</b>	Tel: +49 241 523030	E-mail: <a href="mailto:tsigmbh@tsi.com">tsigmbh@tsi.com</a>	Website: <a href="http://www.tsiinc.de">www.tsiinc.de</a>
<b>India</b>	Tel: +91 80 41132470	E-mail: <a href="mailto:tsi-india@tsi.com">tsi-india@tsi.com</a>	
<b>China</b>	Tel: +86 10 8260 1595	E-mail: <a href="mailto:tsibeijing@tsi.com">tsibeijing@tsi.com</a>	

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