ISO 16890-2 AIR FILTERS FOR GENERAL VENTILATION: DETERMINING FRACTIONAL EFFICIENCY

APPLICATION NOTE AFT-005 (US)

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Introduction to ISO 16890

The new test standard ISO 16890 (published in November of 2016) for the testing of HVAC filters is intended to harmonize the two main world standards currently in existence. Those standards are EN 779, which is the standard in Europe, and ASHRAE 52.2, which is the standard in the United States. Other regions of the world typically follow one or the other of these standards.

The ISO 16890 standard is gradually replacing the EN 779 regulation in Europe and all European nations are expected to adopt the standard by May 2018 (concluding a transition period of 18 months). This new standard was developed under what is called the Vienna agreement which means that European countries are obligated to adopt an international standard where one exists. One of the most important differences between ISO 16890 and EN 779 is the replacement of current filter classification defined in the EN 779:2012 standard at the European level for Class G1 to F9 air filters.

Because of the numerous other standards and building codes that refer to HVAC standards, there will be a phase in period that will vary in length for different countries. The United States and other countries outside of Europe are not obligated to adopt this new standard but it is expected that a gradual transition to this ISO standard will occur.

The World Health Organization (WHO) and other environmental authorities have called attention to the negative impact of particulate matter (PM) on human health (World Health Organization 2002; Dockery *et al.*, 1993). In order to work towards testing ventilation filters in a manner that reflects the nature (and terminology) of PM pollution, ISO 16890 specifies that filter efficiencies will be calculated regarding how successfully they remove PM_1, $PM_{2.5}$, and PM_{10} particle sizes. While EN 779 measures fractional efficiency in the particle size range of 0.2 to 2.0 µm, the ISO 16890 standard expands the size range to larger particles (0.3 to 10 µm). The smaller end of the particle size range will be set at 0.3 µm, in accordance with ASHRAE 52.2.

The new ISO 16890 standard comes in four parts. The second part, ISO 16890-2, specifies the types of instruments and equipment necessary for testing filter efficiency as a function of particle size which will be the focus of this application note. Details concerning duct geometry, particle generation, particle sampling, and particle measurement are described in the other parts of the standard.

Instruments compliant with each of the key steps—particle generation, particle sampling, and particle measurement—are available from TSI. This application note will guide you from the aerosol generation to the aerosol measurement to better understand which TSI product(s) you will need to be compliant with ISO 16890-2. Additionally, a webinar covering how TSI instrumentation can be used to test to ISO 16890-2 is available at https://vimeo.com/207607041.

How ISO 16890 Compares to EN 779 and ASHRAE 52.2

ISO 16890 can be viewed as a 'hybrid' of the two most common ventilation filter testing standards in the world: EN 779 and ASHRAE 52.2. The basic features of each of those standards are summarized below, and in Table 1.

EN 779 uses liquid (oil) aerosol and covers the size range from 0.2 to 2.0 µm. It also includes a required conditioning step where a sample of the filter media is immersed in isopropyl alcohol (IPA) as a way of discharging electrostatic media to determine the effect of that discharge on the filter's efficiency. Efficiency of the media is tested both before and after IPA discharge.

ASHRAE 52.2 uses solid (KCl salt) aerosol over a size range of 0.3 to 10 µm. Solid particles are used to since filters with lower efficiency can show the effects of particle bounce (particles bouncing off the filter instead of being captures) which does not occur with liquid particles. This standard also includes an optional conditioning step (Appendix J) where the filter is loaded with ultrafine particles to simulate the ultrafine particles that are the dominant particle size range in urban environments.

Table 1:
Comparison of key specifications of EN 779, ISO 16890, and ASHRAE 52.2 ventilation filter test standards

<table>
<tr><th colspan="2"></th><th>EN 779</th><th>ISO 16890</th><th>ASHRAE 52.2</th></tr>
<tr><td colspan="5">Generation</td></tr>
<tr><td rowspan="2">Oil</td><td>Composition</td><td>Required (DEHS)</td><td>Allowed
Use of aerosols other than DEHS must demonstrate equivalency to DEHS.</td><td rowspan="2">Not permitted</td></tr>
<tr><td>Generation</td><td>0.2 to 3 μm. Laskin nozzle-style generator required.</td><td>A Laskin nozzle-style generator is permissible, but not required.</td></tr>
<tr><td rowspan="3">Salt</td><td>Composition</td><td rowspan="3">Not permitted</td><td>Allowed
Use of aerosols other than KCl must demonstrate equivalence to KCl.</td><td>Required (KCl)</td></tr>
<tr><td>Generation</td><td>The generator must meet specified geometric requirements in order to achieve a ~40 second residence time to permit drying.</td><td>Generator geometry and residence time not specified; resulting particles must be dry and cover the 0.3 to 10 μm range with “sufficient concentration.”</td></tr>
<tr><td>Conditioning</td><td colspan="2">A Boltzmann electrostatic charge distribution must be achieved through use of either a) an alpha or beta radiation source with a minimum activity of 185 MBq, or b) a corona discharge ionizer, minimum current 3 μA.</td></tr>
<tr><td colspan="5">Sampling</td></tr>
<tr><td colspan="2"></td><td colspan="3">Sampling must be conducted within 10% of perfectly isokinetic conditions, via a probe of electrically conductive material.</td></tr>
<tr><td colspan="5">Measurement</td></tr>
<tr><td colspan="2" rowspan="2">Optical</td><td>Required
Minimum instrument counting efficiency of 50% at 0.2 μm.</td><td>Required
Minimum instrument counting efficiency of 50% at 0.3 μm.</td><td>Allowed
Minimum instrument counting efficiency of 50% at 0.3 μm.</td></tr>
<tr><td colspan="3">Optical detectors set up for EN 779 or to ASHRAE 52.2 will satisfy ISO 16890 without change.</td></tr>
<tr><td colspan="2">Aerodynamic</td><td colspan="2">Not permitted</td><td>Allowed
Equivalency to an optical technique must be demonstrated for KCl.</td></tr>
</table>

Equipment Required to Test to ISO 16890-2

Generally speaking, filter testing with aerosol particles requires the following steps:

- Aerosol Generation
- Aerosol Sampling (from the test duct, in an isokinetic fashion)
- Aerosol Measurement (size and/or concentration)

ISO 16890-2 provides specifications for the instruments necessary in each of these steps in order to test in compliance with the standard. TSI instrumentation meeting these specifications is described below. To simplify the control of these various instruments, the Component Filter Test System (CFTS) may be used; the CFTS is also described below.

Aerosol Generation

As a hybrid of EN 779 and ASHRAE 52.2, ISO 16890 allows either salt or oil aerosol (that is, either solid or liquid aerosol) to be used for filter testing.

Liquid Phase Aerosol Generation: Model 9307-6 or Model 9307 Oil Droplet Generator

TSI provides two types of Laskin nozzle generator that fulfill the requirements of ISO 16890: the TSI Oil Droplet Generator Model 9307 (single jet) and the model 9307-6 (six jet); see Figure 1. These two generators are designed to generate large amounts of seed particles in a high speed flow tunnel environment such as an ISO 16890 test duct. These generators are typically used with olive oil, but can also be used with other fluids such as DEHS. As the model 9307-6 has six nozzles, it has a higher output concentration than the model 9307, which has one nozzle. A typical size distribution of aerosols generated by a model 9307 is shown in Figure 3.

Figure 1: 9307-6 and 9307 Laskin Nozzle Generators

Solid Phase Aerosol Generation: Model 8108 Large Particle Aerosol Generator

TSI's Large Particle Aerosol Generator, model 8108, meets the requirements of the ISO 16890-2 and is capable of producing a highly concentrated salt aerosol. Figure 2 shows both a photo and a schematic of the generator, including pump. The generator column includes a spray nozzle, drying cylinder and electronic air ionizer to give the particles a Boltzmann charge distribution as specified in the standard. A typical size distribution of KCl aerosols generated by the model 8108 is shown in Figure 3.

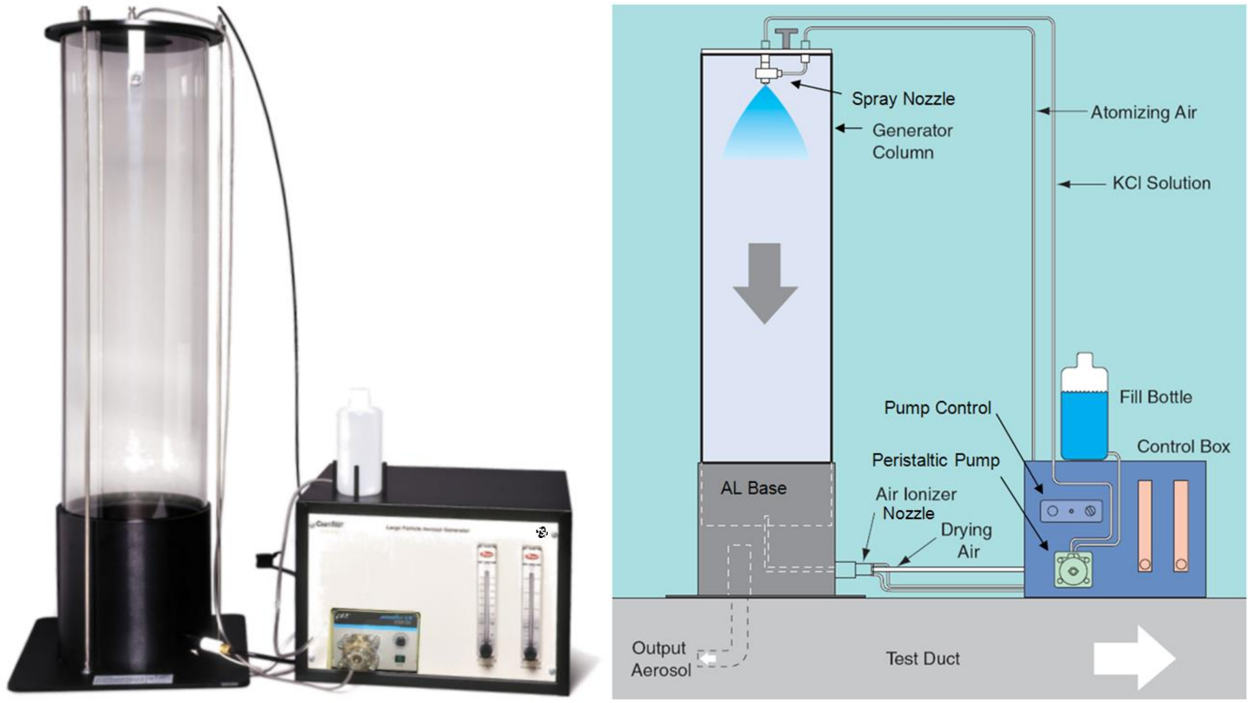

Figure 2: 8108 Large Particle Aerosol Generator (left), and its schematic (right)

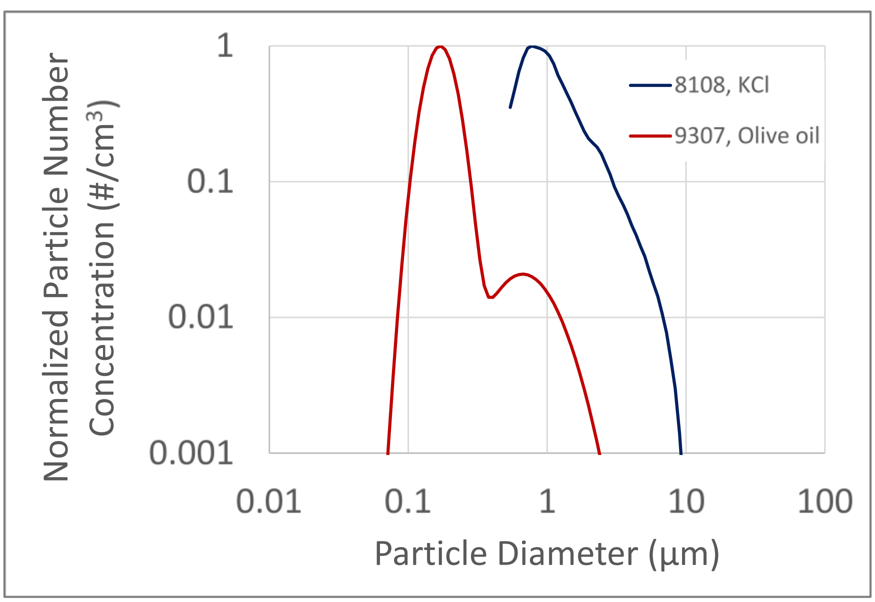

Figure 3: Typical (normalized) size distributions of aerosol produced by the 8108 and 9307 particle generators. Both of these generators are compatible with ISO 16890-2.

Aerosol Sampling

When sampling aerosol from the test duct, both upstream and downstream of the filter under test, care must be taken to ensure that the sampling process is isokinetic. Isokinetic sampling is important to ensure that the sample of particles directed towards the measurement instrument is representative of the particles in the duct, and does not have a size bias.

With *iso* meaning "equal" and *kinetic* relating to "movement" or "motion," isokinetic sampling requires that the velocity of the air in the duct or sampling stream be identical to the velocity of the air entering the sampling probe. A common way to achieve this isokinetic status is to pay attention to the geometry of the sampling duct and sampling probe. The relevant parameters are:

- The cross-sectional area of the sampling duct
- The volumetric flow within the sampling duct
- The cross-sectional area of the sampling probe opening
- The volumetric flow traveling through the sampling probe

These four parameters determine the velocity of the air in the duct, and the velocity of the air at the entrance to the probe.

$$\text{Velocity} = \frac{\text{Probe Flow}}{\text{Probe Cross Sectional Area}} = \frac{\text{Duct Flow}}{\text{Dust Cross Sectional Area}}$$

When sampling is isokinetic, all particles (regardless of size) are sampled in a representative manner by the probe. This results in trustworthy, accurate particle measurement data. ISO 16890-2 specifies that sampling must be conducted within 10% of perfectly isokinetic conditions.

Model 1130011 Isokinetic Coupler and Sampling Probe

TSI's Isokinetic Coupler and Sampling Probe, model 1130011, makes it easy to perform isokinetic sampling in a standard ISO 16890-2 duct. The duct dimensions specified in ISO 16890-2 are identical to those specified by EN 779 and ASHRAE 52.2 (2' x 2', 2000 cfm; 610 x 610 mm, 3400 m^3/h). When used with TSI's Optical Particle Counter (described below) in a test duct of the parameters given above, it results in isokinetic sampling, ensuring reliable data. The Isokinetic Coupler and Sampling Probe are shown in Figure 4.

The design flow rate of the OPS is 1 L/min; the flow rate through an ASHRAE duct is more than 56,000 times higher than this. Achieving isokinetic sampling in this environment would pose significant challenges, if only 1 L/min were removed from the duct. To address this challenge, TSI's Isokinetic Coupler and Sampling Probe was designed to sample 7 L/min from the duct, and to discard 6 L/min to a pump before allowing the remaining 1 L/min to be sampled into the OPS.

This design requires achieving isokinetic sampling at two locations. The first location is the most obvious – the probe tip must sample isokinetically from the duct. As the 7 L/min sample moves down the sampling probe; however, it must be split isokinetically a second time, between the 6 L/min "waste" flow and the 1 L/min flow that will go to the OPS. Both of these splits are done isokinetically, and a user can have confidence in the quality of particle measurements made by the OPS when using the Isokinetic Coupler and Sampling Probe.

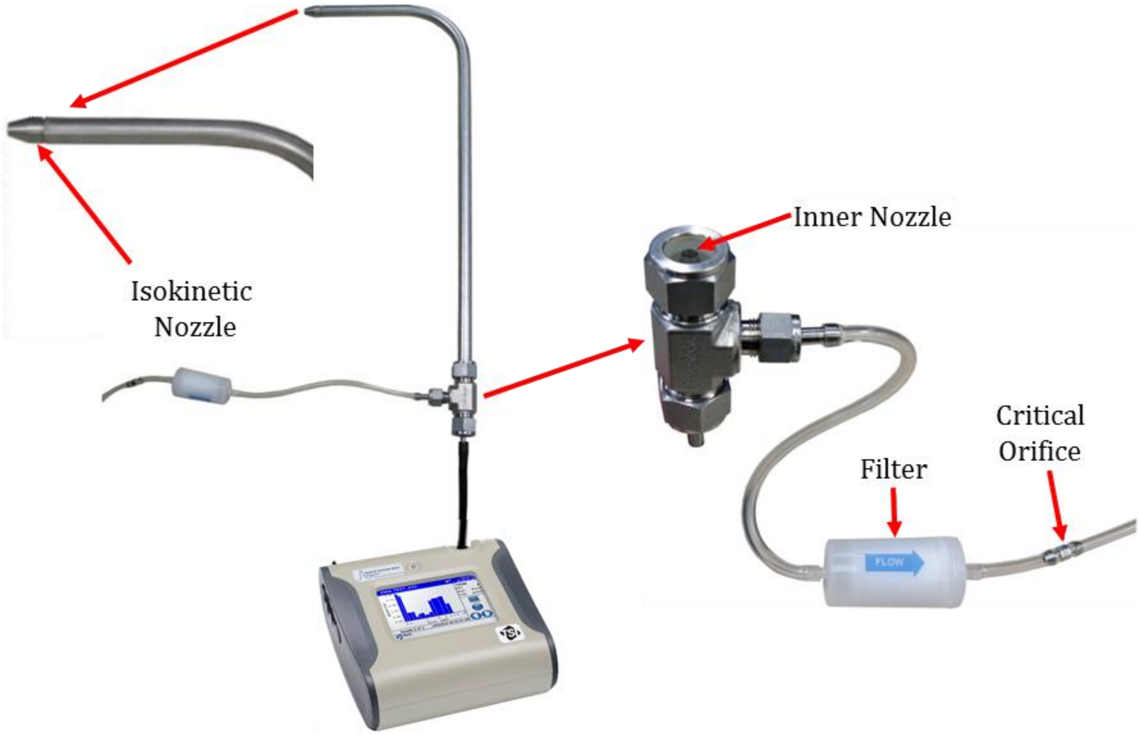

Figure 4: TSI's Optical Particle Counter (OPS, lower left), shown with the Isokinetic Coupler and Sampling Probe. The isokinetic coupler (large "tee") is an interface that provides a second isokinetic sample split between the sampling probe and the OPS inlet; the unmeasured portion of the probe's flow is pulled away by a vacuum pump (model 3032, not shown).

Aerosol Measurement: Model 3330 Optical Particle Sizer

The ISO 16890 standard clearly specifies the use of an aerosol particle counter that is capable of both particle counting and optical particle sizing.

The Optical Particle Sizer model 3330 covers a wide particle size range (0.3 to 10 µm) with user-adjustable size channels, and completely meets the requirement of the ISO 16890-2 standard. The OPS 3330 has a proven history of being used in ASHRAE 52.2 testing and other filter testing applications. Figure 5 shows the OPS and a schematic of its most critical working components.

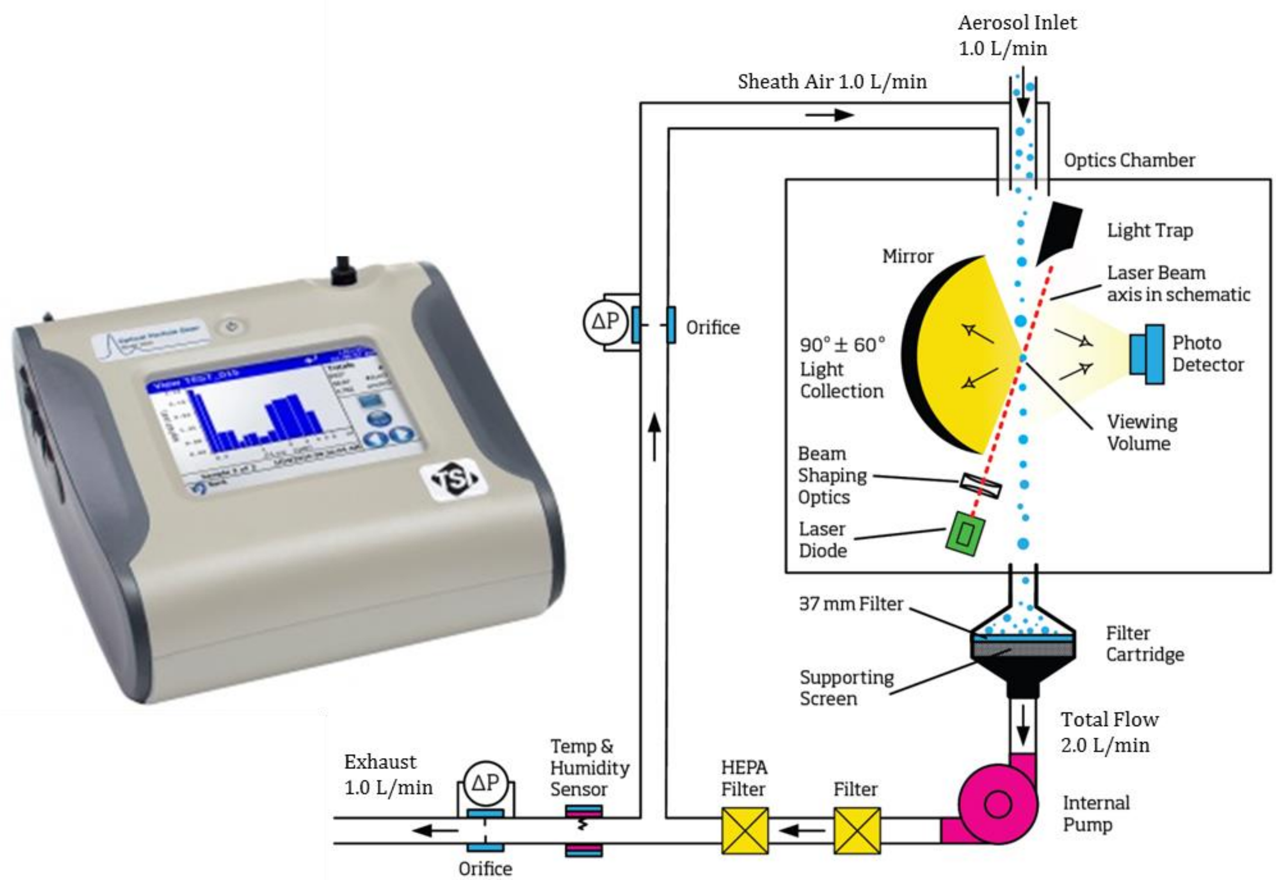

Figure 5: TSI's Optical Particle Sizer (left), and its schematic (right).

Communication and Control System: Model 3150 Component Filter Test System (CFTS)

As for all filter test application, TSI always gives you the possibility to control your test rig and collect data from TSI particle instruments (i.e. OPS 3330). The Component Filter Test System (CFTS), model 3150, consists of software and hardware module to centralize control of your filter test system for all your custom filter testing needs. A screenshot of the CFTS software is shown in Figure 6.

It offers analog / digital inputs and outputs to measure flow using a variety of flow measurement techniques and to control suction devices, such as pumps or blowers. The CFTS does not include the duct, pumps or blowers, pressure transducers, valves, flowmeters, or filters, but rather allows central control of these required components, along with all necessary TSI particle instruments. Other parameters can be read such as temperature, pressure and relative humidity. It can control flow (by supplying a DC voltage to a variable frequency drive used to control the blower) and log sensor data for test reports. The software allows you to define a test protocol and to create a report from the measurement data. If desired it will also plot a fractional efficiency curve.

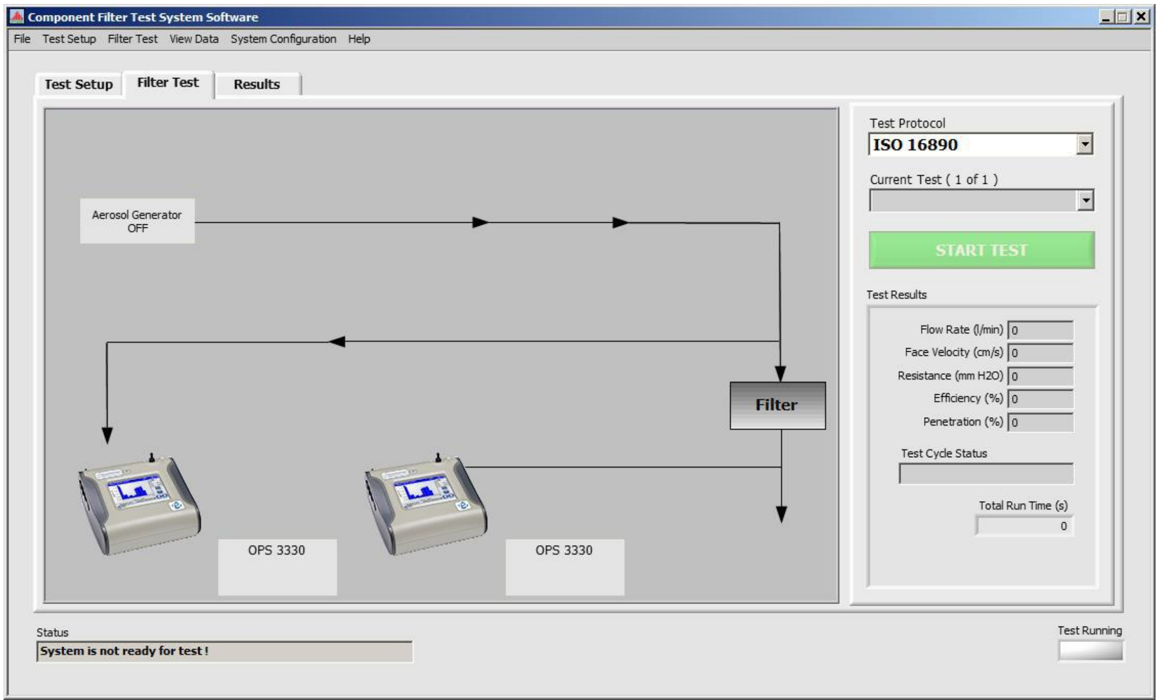

Figure 6: Screen capture of the CFTS software. The CFTS is compatible with numerous particle detectors; the Optical Particle Sizers (OPSs) depicted here measure particle sizes across the entire size range relevant to ISO 16890-2.

A Note about Flat-Sheet Media Testing

Some members of the filter media industry may be interested in testing to ISO 16890, but doing so with their flat sheet media. The motivation behind this interest is in knowing how the media would behave when assembled in a filter; this filter would be tested according to ISO 16890. As ISO 16890 is intended for fully-assembled filters, and not for flat-sheet media, flat-sheet media cannot truly be tested in accordance with this standard. The media behavior can be investigated, though, using very similar equipment and procedures. To get a first approximation of how the media will perform in a final product you should test the media at the same velocity (called face velocity) as the media will have in the final product. The face velocity can be determined by dividing the flow rate in the test duct by the surface area of the filter media (in the final filter). By using the same velocity when testing the flat sheet media you will get similar filter efficiency and pressure drop to what you can expect in the final filter.

The one significant change that needs to take place is that the aerosol concentration exiting the generator needs to be lowered significantly. This is because for ventilation filter testing, the generator output is injected into a large duct carrying a volumetric flow of 2,000 ft^3/min (cfm); since flat sheet media cannot be tested at such a high flow rate, using the same generator output would result in a problematically rich aerosol concentration. The concentration may be lowered by using a different generator, or possibly through a dilution step. Contact TSI for further guidance in this regard.

Conclusion

TSI's wide range of particle products enable filtration professionals to conduct tests in accordance with a variety of filter test standards, including the new ISO 16890. The components that are described in this application note are:

- Model 3150 Component Filter Test System (CFTS)
- Model 9307-6 or Model 9307 Oil Droplet Generator
- Model 8108 Large Particle Aerosol Generator (KCl)
- PN 1130011 Isokinetic Sampling Probe and Coupler
- Model 3330 Optical Particle Sizer

Note
In 2017 TSI runs the MULTIUNIT promotion offering a multiple unit discount for the purchase of two or more Optical Particle Sizers. Please contact your TSI sales representative for more details on this special limited time offer.

References

ISO 16890-2:2016. Air filter for general ventilation – Part 2: Measurement of fractional efficiency and air flow resistance.

EN 779:2012. Particulate air filters for general ventilation – Determination of the filtration performance.

ANSI/ASHRAE 52.2-2012. Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size. ISSN 1041-2336.

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Dockery, D., Popc, C., Xu, X., Spengler, J., Ware, J. (1993). An association between air pollution and mortality in six U.S. cities. *NEJM* **329(24):**1753-1759.

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