DUSTTRAK™ DRX AEROSOL MONITOR THEORY OF OPERATION

APPLICATION NOTE EXPMN-002

The Models 8533 and 8534 are not versions of the basic DUSTTRAK™ II Aerosol Monitor, they are advanced versions known as the DRX models. The DUSTTRAK Model 8533 is a desktop instrument while the Model 8534 is a handheld. The primary difference between the basic single-channel DUSTTRAK II photometer and the Advanced DRX models are in the ability of the DRX advanced models to measure size fractions of the sampled aerosol in addition to making a mass based photometric measurement. This employs a **patent pending** method to simultaneously measure size segregated mass fraction concentrations (PM_1, $PM_{2.5}$, Respirable/PM_4, PM_{10}/Thoracic, and TPM) over a wide concentration range (0.001–150 mg/m^3) in real time. This method combines a photometric measurement to cover the mass concentration range and a single particle detection measurement to be able to size discriminate the sampled aerosol.

The schematic is very similar to that of the basic DUSTTRAK II Aerosol Monitor. Aerosol is drawn in to the sensing chamber in a continuous stream using a diaphragm pump. Part of the aerosol stream is split ahead of the sensing chamber and passed through a HEPA filter and injected back in to the chamber around the inlet nozzle as sheath flow. The remaining flow, called the sample flow passes through the inlet entering the sensing chamber. Here, it is illuminated by a sheet of laser light. This sheet of laser light is formed from a laser diode. First, the light emitted from the laser diode passes through a collimating lens and then through a cylindrical lens to create a thin sheet of light. A gold coated spherical mirror captures a significant fraction of the light scattered by the particles and focuses it on to a photodetector.

The signal processing is however very different from a typical photometer. Although the voltage across the photodetector, which is proportional to the mass concentration, is used to determine the concentration of the aerosol, the individual pulses from the photometer are also used to make single particle measurements. As shown in the schematic below, the photodiode signal is separated in to two components: the photometric signal and the single particle pulses. The voltage across the photodetector is proportional to the $PM_{2.5}$ fraction of the total sampled aerosol over a wide range of concentrations. The voltage is then multiplied by a calibration constant which is determined from the ratio of a known $PM_{2.5}$ mass concentration of the test aerosol to the voltage response of the DUSTTRAK DRX Aerosol Monitor. Typically, the test aerosol is Arizona Test Dust (or ISO 12103-1, A1 test Dust). The single particle pulses are calibrated to measure the aerodynamic size of the A1 test dust. To reduce coincidence error, only particles greater than 1 µm are recorded. The particle mass is calculated and recorded in one of the four size segregated mass fractions (PM_1, $PM_{2.5}$, Respirable/PM_4, PM_{10}/Thoracic, and TPM). The size segregated mass concentration is obtained as follows:

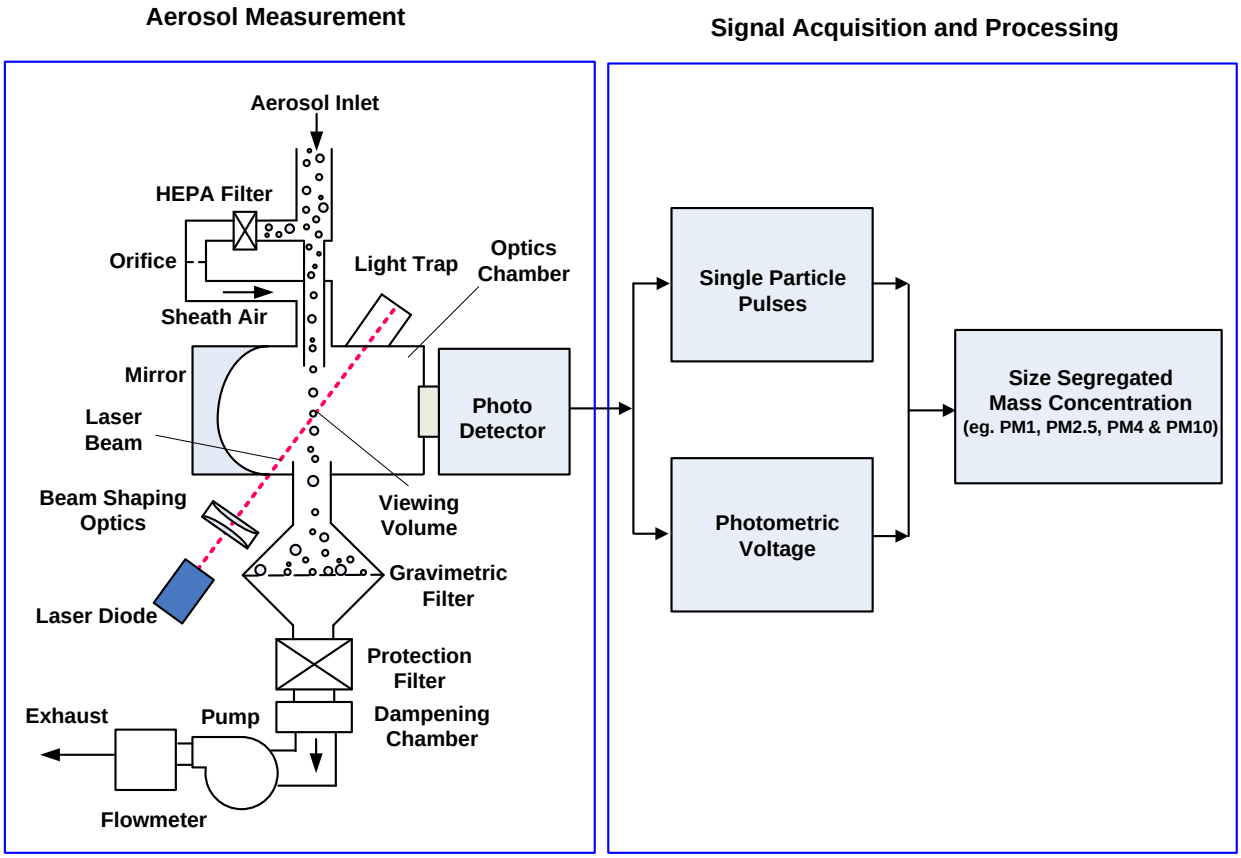
$PM_1 = PM_{2.5} – PM_{1\text{-}2.5}$

$PM_{2.5}$ = Photometric signal × calibration factor

Respirable / $PM_4 = PM_{2.5} + PM_{2.5\text{-}4}$

PM_{10} / Thoracic = $PM_4 + PM_{4\text{-}10}$

$TPM = PM_{10} + PM_{>10}$



The algorithms used by the DUSTTRAK DRX Aerosol Monitor yield a mass measurement technique that is superior to either a basic photometer or Optical Particle Counter (OPC). While photometers can be used at high mass concentrations, they do not give any size information (unless used with size selective inlet conditioners) and significantly underestimate particle mass contributed by large particles. On the other hand, OPCs provide size information, however they cannot be used at high mass concentration. The DUSTTRAK DRX Aerosol Monitor is able to combine the advantages of both the measurement techniques to improve the overall accuracy of the mass measurement.

The DUSTTRAK DRX Aerosol Monitor is able to measure mass concentrations with greater accuracy because of its ability to measure single particles >1 µm, since the photometric signal is less sensitive to large particles. In addition, the DUSTTRAK DRX compensates for coincidence error using a dead-time correction algorithm. Furthermore, the DUSTTRAK DRX Aerosol Monitor converts the single particle pulses to aerodynamic size by proprietary factory or custom calibrations, significantly reducing mass calculation errors due to particle density, refractive index and shape on the calculated mass concentration. As a result, the DUSTTRAK DRX Aerosol Monitor size segregated mass fraction measurement has the size resolution of an OPC along with a much higher mass concentration range like a typical photometer.

Although the DUSTTRAK DRX monitor comes with a couple of calibration impactors, they are recommended for use only during custom calibrations. The greatest advantage of using the DUSTTRAK DRX Aerosol Monitor over other photometers in the market including the DUSTTRAK II Aerosol Monitor basic is the lack of need for a size-selective inlet conditioner. PM_1, $PM_{2.5}$, Respirable/PM_4, PM_{10}/Thoracic and TPM fractions can all be measured simultaneously without the use of any size-selective inlet conditioners.

To improve the accuracy of the mass measurement, the unit can be calibrated with gravimetric sample(s) by conducting side-by-side comparisons with the DUSTTRAK DRX Aerosol Monitor readings to gravimetric samples. On the Desktop Model 8533, a 37-mm filter cassette sampler can be inserted in-line with the aerosol stream at the outlet of the optics chamber allowing the user to perform a gravimetric analysis without the need for using an external pump and filter holder.

At TSI, the DUSTTRAK DRX Aerosol Monitor is calibrated against a reference photometer (Model 8587) that is gravimetrically calibrated to ISO 12103-1, A1 test dust (Arizona Test Dust). This test dust has a wide size distribution covering the entire size range of the DUSTTRAK DRX Aerosol Monitor and is representative of a wide variety of ambient aerosols.

The optics inside the DUSTTRAK DRX Aerosol Monitor is kept clean by surrounding the aerosol stream with a sheath of clean filtered air. This sheath air confines the aerosol to a narrow stream and prevents particles from circulating around the optics chamber and depositing on the optics. It reduces coincidence errors in the single particle measurements and make the pulse height more uniform by retaining the particles within the Gaussian profile of the laser beam that produces more uniform pulse widths regardless of where the particles enter the inlet nozzle. Sheath flow also improves the response time of the instrument. The user can also access the sheath and main flow filters that need to be changed periodically to maintain the flow ratio between the sample flow and sheath flow a constant. The DUSTTRAK DRX's firmware will automatically detect the life of those filters and warn the user to change them before the pressure drop across those filters become excessive.

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