

Technical Bulletin

Comparison of the performance of the Thermo Scientific TEOM 1400a with 8500C FDMS and the TEOM 1400a with 8500B FDMS monitors for the measurement of PM_{2.5}

Introduction

Thermo Scientific released the first Filter Dynamics Measurement System (FDMS) for the TEOM monitor in 2002. This early system was determined to be California Approved Sampler for both PM_{2.5} and PM₁₀ by the California Air Resources Board in 2002. A flow controller and a field modification developed for TEOM 1400a allowed the 8500 FDMS to evolve into the 8500B FDMS version, and was used successfully for many of years. In 2006, the “C” version of the 8500 FDMS was developed, which utilized a more efficient dryer and included other changes. During the development of the 8500C FDMS, a field test was performed in Bakersfield, California, to compare the performance of the 8500B FDMS and 8500C FDMS equipped TEOM monitors. The results of this comparison are presented.

Filter Dynamics Measurement System

PM_{2.5} is a complex mixture of chemical species in a range of physical sizes that varies significantly with season and location and can include both non-volatile and semi-volatile materials. Ammonium nitrate, semi-volatile organic material, and water are semi-volatile materials, while other components are non-volatile in the context of ambient PM measurements. Many studies show that there is a loss of semi-volatile material from the collected samples using some continuous monitors as well single event filter samples, including the US EPA PM_{2.5} reference method.

The FDMS was designed to take advantage of the TEOM real-time mass measurement system to address these issues by characterizing the semi-volatile and non-volatile portions of ambient PM_{2.5} as present in the atmosphere at the time of collection. When sampling ambient aerosol, the sample filter in the TEOM monitor collects the incoming ambient aerosol, which includes both the non-volatile as well as semi-volatile material. Because of the self-referencing nature of the FDMS equipped TEOM monitors, the FDMS equipped TEOM monitors are able to measure and correct for the presence of semi-volatile material present in the collected sample.

During operation, the FDMS equipped TEOM monitors alternately sample ambient aerosol and then sample through a chilled reference filter for equal time periods. During normal sampling, or the base period, the TEOM sample filter is measuring mass increase from the ambient aerosol as well as any mass changes of collected the semi-volatile material. During the reference period of sampling, the sampled ambient aerosol is filtered in the chilled filter conditioner and no

incoming ambient aerosol is measured by the mass sensor and only changes to the amounts of semi-volatile material previously collected on the sample filter are measured. The switch between the base and reference measurement periods occurs every six minutes and the monitor calculates the base and reference mass concentrations for these switch periods at the end of each successive measurement.

The reference mass concentration is then subtracted from the base mass concentration to determine the near real-time ambient mass concentration. In this way the FDMS system determines the total atmospheric aerosol mass concentration including volatile and semi-volatile components as they exist in the atmosphere at the time of collection. The system then subtracts the calculated reference concentration from the calculated base mass concentration giving a net ambient aerosol mass concentration which represents the mass concentration of ambient aerosol as it exists at the time of sample collection.

Thermo Scientific TEOM 1400a with 8500C FDMS

The Thermo Scientific TEOM 1400a with 8500C FDMS (8500C FDMS) is the current version of the 8500 FDMS equipped line of TEOM 1400a ambient PM monitors. The “C” version of the FDMS utilizes a more efficient dryer for better performance, an updated version of the switching valve, and a modified cooler/filter arrangement to allow for easier filter access compared to earlier versions of the 8500 FDMS. Previously, the chilled filter was located inside the box of the 8500 FDMS and used a threaded filter holder inserted in the chiller. Removal and insertion of the chilled filter was, at times, difficult due to the position of the filter holder. In the new configuration, the filter holder is accessed through a panel on the left side of the 8500FDMS enclosure and instead of a threaded connection, the filter holder is attached using a bayonet fitting allowing easier access and better sealing of the filter holder in the chiller. With the update to the 8500 FDMS, the basic performance should be identical.



In the development of the new dryer for the 8500C FDMS, the drying performance of the original dryer and the new Thermo Scientific designed dryer were compared. The two dryers were tested at a temperature of 25°C and an inlet dewpoint of 20°C (about 75% RH) over a range of purge gas pressures from 12 in. Hg to 25 in. Hg purge gas vacuum. Higher vacuum represents better pump performance in the system. The 8500 FDMS systems were designed to operate at a vacuum level of 18 in. Hg or greater.

The results of these tests are shown in Figure 1 and shows that even at low vacuum levels, the new Thermo Scientific dryer is able to sufficiently dry the sample gases. At design levels, the decrease in sample dewpoint is at least 5°C lower than with the original dryer.

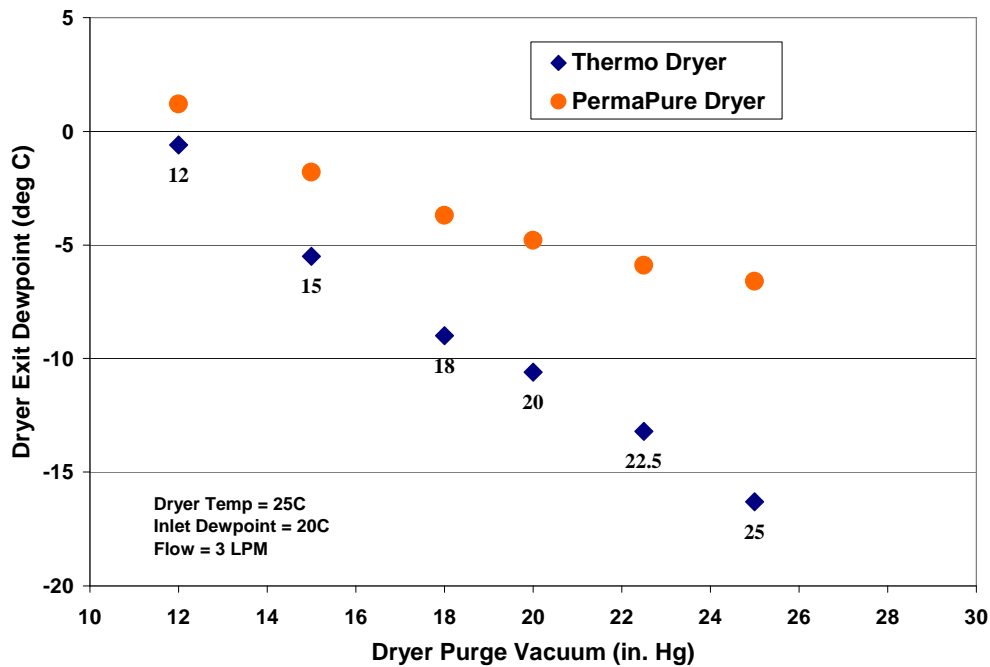


Figure 1. Comparison of drying performance between the Thermo Nafion dryer and the PermaPure dryer used in the FDMS. Sample and purge flow rate was 3 LPM, dryer temperature was 25°C, and the inlet sample dewpoint was 20°C.

Results

During the development of the “C” version of the 8500 FDMS, a field test was performed in Bakersfield, California, to compare the performance of the 8500B FDMS and 8500C FDMS versions of the units. The testing occurred during January and February 2006 and was conducted in the same location as the initial evaluation of the 8500A FDMS performed by the California Air Resources Board in 2001-2002. The test program was performed in two sequential phases with 20-30 days of sampling for each of the two sampling periods. During phase one, an 8500B FDMS was installed on TEOM Unit 1 and an 8500C FDMS was installed on TEOM Unit 2 allowing for a direct comparison between the two models of 8500 FDMS equipped TEOM monitors. During the second phase of testing, an 8500C FDMS was installed on TEOM Unit 1 and the 8500C FDMS was left on TEOM Unit 2, comparing the precision between two identical

TEOM 1400a monitors equipped with 8500C FDMS units. 24-hour averages were calculated for each sampling day to compare the results from the two monitors.

Figure 2 is a graph of the results of the two comparisons. In the graph there are two sets of data along with two linear regression lines. The first set of data, the solid blue line with the circular data points, is a the comparison of TEOM Unit 1 with the 8500B FDMS (y-axis) and TEOM Unit 2 with the 8500C FDMS (x-axis). The comparison shows an excellent correlation (R^2) of 0.998 with a slope of 0.975 and an intercept of 1.197. For this data set the average mass concentrations of the two monitors over this test segment were $29.4 \mu\text{g}/\text{m}^3$ and $29.3 \mu\text{g}/\text{m}^3$ for the 8500B FDMS and 8500C FDMS units respectively.

The second set of data in Figure 2, the broken red line with the triangle data points, shows the comparison of TEOM Unit 1 with the 8500C FDMS and TEOM Unit 2 with the original 8500C FDMS. For this comparison, the slope was 1.005 with an intercept of -0.533. The correlation again was excellent with an R^2 of 0.995. During this second period of testing the average mass concentrations for TEOM Unit 1 and TEOM Unit 2 were $20.23 \mu\text{g}/\text{m}^3$ and $19.73 \mu\text{g}/\text{m}^3$ respectively.

With this comparison, the TEOM 1400a with 8500B FDMS and the TEOM 1400a with 8500C FDMS are shown to provide nearly identical results. Even though there are slight differences in the slope and intercept values, comparing the average data values over the test period yield identical results from the two configured TEOM units.

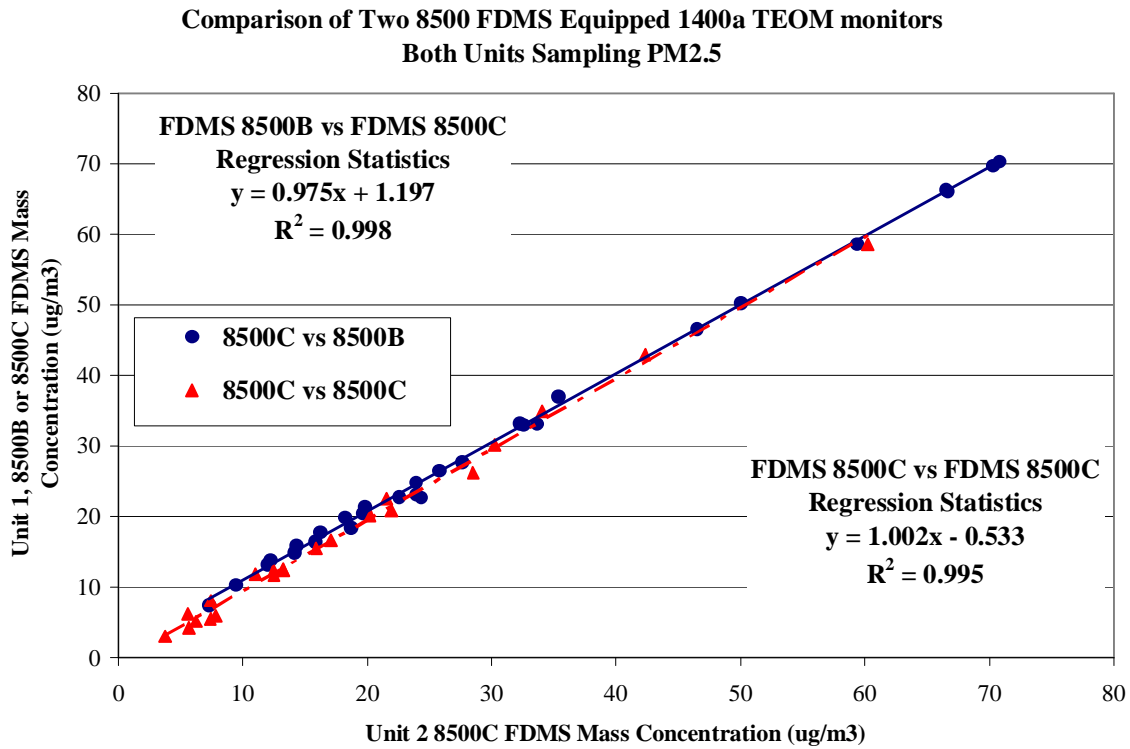


Figure 2. Comparison of two TEOM 1400a monitors. Unit 1 was tested with a 8500B FDMS version and compared to a 8500C FDMS version during one phase of testing. During the second phase of testing, the 8500B FDMS on Unit 1 was replaced with an 8500C FDMS.