Final Report for the Texas $PM_{2.5}$ Sampling and Analysis Study

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1.0 INTRODUCTION

1.1 Study Objectives

TRC Environmental Corporation (TRC) and its subcontractor, Desert Research Institute (DRI), assisted the City of Houston and its collaborators, the Texas Natural Resource Conservation Commission and the Houston Regional Monitoring Network, in sampling and analyzing $PM_{2.5}$ samples taken over the course of one year from 03/11/97 to 03/12/98. The objectives of this study were to:

- Determine the levels of $PM_{2.5}$ in Houston and other cities in Texas,
- Determine the chemical composition of $PM_{2.5}$ in Houston and other cities in Texas, and
- Determine the background levels and chemical composition of $PM_{2.5}$ transported into Houston.

An additional study objective was to determine the potential differences in $PM_{2.5}$ concentrations and composition between the DRI samplers, which used stainless steel or Teflon-coated components, and the proposed Federal Reference Method samplers, which specify anodized aluminum for inlet and downtube components.

In addition, Shell Oil sponsored monitoring at an indoor site from 09/13/97 to 03/12/98.

1.2 Background

The U.S. Environmental Protection Agency (EPA) has revised National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$ and PM_{10} (mass of particles with aerodynamic diameters less than 2.5 and 10 μm, respectively) (U.S. EPA, 1997a). These standards require: 1) three-year average of annual 98th percentile 24-hour $PM_{2.5}$ not more than 65 $\mu g/m^3$ at community-exposure monitors; 2) three-year average of annual and spatially averaged $PM_{2.5}$ not more than 15 $\mu g/m^3$ at community exposure monitors; 3) three-year average of annual 99th percentile 24-hour PM_{10} not more than 150 $\mu g/m^3$; and 4) three-year average of annual average PM_{10} not more than 50 $\mu g/m^3$. Measurements to determine compliance with the $PM_{2.5}$ standards are to be taken with Federal Reference Methods (FRM) specified by design and performance standards (U.S. EPA, 1997b) at locations that represent particles that people breathe where they live, work, and play.

At the onset of this study, the revisions to the NAAQS for particulate matter had been proposed but not yet passed. The City of Houston and its collaborators, the Texas Natural Resource Conservation Commission (TNRCC) and Houston Regional Monitoring (HRM) Network wanted to obtain data on $PM_{2.5}$ mass concentrations and chemical compositions in Houston and four other cities (Corpus Christi, Dallas, El Paso, and San Antonio) in Texas prior to promulgation of the final rule.

1.3 Technical Approach

During the sampling period from 03/11/97 to 03/12/98, 24-hour $PM_{2.5}$ mass measurements were acquired from 15 sites throughout the state of Texas, using DRI's MEDVOL particle samplers (Chow et al., 1993a). All of the Teflon filters were analyzed for mass by gravimetry and a selected subset of the Teflon and quartz fiber filters were subjected to full chemical analysis as documented in Section 2.2.4.

1.4 Guide to Report

This section has stated the background and objectives of the Texas $PM_{2.5}$ Sampling and Analysis Study. Section 2 documents the ambient monitoring network and the unified data base compiled from these measurements. The ambient data base is assembled, validated, and documented in Section 3. Section 4 examines the temporal and spatial variations of PM concentrations. A summary, conclusions, and recommendations are contained in Section 5. The bibliography and references are assembled in Section 6. Field and analysis validation flags are listed in Appendices A and B, respectively.

2.0 SAMPLING NETWORK

2.1 Ambient Network

Twenty-four-hour $PM_{2.5}$ samples on filters were taken at nine sites in the greater Houston area and at four other cities in Texas - Corpus Christi, Dallas, El Paso, and San Antonio. Sampling for $PM_{2.5}$ took place every sixth day, corresponding to EPA's PM_{10} sampling schedule, at all sites but Mauriceville (SM) and Galveston (HG). Sampling at these two sites took place on alternate PM_{10} sampling days, once every 12 days. Up to 15 additional samples were taken at each site, the days chosen by forecasting special meteorological conditions.

One additional sampler was rotated among Houston area sites HT, HC and H3 to obtain collocated precision data. This sampler was fitted with an anodized aluminum denuder head that was designed to remove nitric acid from the sampling stream prior to the filter packs. This collocated sampler spent two months at each of three Houston sites, one month with the denuder on and one month with it off.

Approximately half-way through the study period, starting on 09/13/97, an additional sampler was added to the study to test indoor air quality at the Shell Westhollow Technology Center and was designated as site HS. The sampler was identical in configuration to the samplers used outdoors throughout the study area and it maintained the same every sixth day sampling schedule, but did not take part in forecast sampling days.

Table 2-1 gives the site locations, purpose of site, site codes, responsible agencies, and the sampling frequency. Figure 2-1 shows seven of the greater Houston area sites omitting the Mauriceville (SM) and Galveston (HG) sites. Each site had a $PM_{2.5}$ sampler capable of taking two samples simultaneously, one on a Teflon-membrane filter and one on a quartz-fiber filter.

2.2 Ambient Particulate Measurements

2.2.1 PM Sampler

The DRI MEDVOL particle sampler used in this study, has been used in many aerosol and visibility studies over the past decade. These include the major western urban visibility/aerosol studies, such as the 1987-1988 Metro Denver Brown Cloud Study, the Phoenix/Tucson Urban Haze Study, the Dallas-Fort Worth Winter Haze Project, and San Joaquin Valley projects.

Figure 2-2 is a schematic of the DRI sampler and Figure 2-3 shows the sampler configuration. The sampler consists of a Teflon-coated aluminum plenum to which a $PM_{2.5}$ or PM_{10} inlet is attached. Up to 12 sampling ports within the plenum are controlled by solenoid valves which divert flow from one channel to the next by means of a programmable timer. These ports accept filters which have been pre-loaded into open-faced 47 mm Savillex filter

Table 2-1. Sampling sites in the Texas $PM_{2.5}$ Sampling and Analysis Study.

Area/City	Site Type	Site Code	Sampling Schedule	Site Address
Greater Houston	Industrial	HC	1/6	9525 Clinton Dr.
Greater Houston	Industrial	H3	1/6	1504 Haden Dr.
Greater Houston	Industrial	H7	1/6	Baker and Decker Road
Greater Houston	Backgound/Transport	HG	1/12	8715 Cessna St., Galveston, TX.
Greater Houston	Backgound/Transport	HT	1/6	16822 Kitzman St. NW Harris County
Greater Houston	Backgound/Transport	SM	1/12	Intersection of Texas Hwys 62 and 12, Mauriceville
Greater Houston	Population Exposure	HW	1/6	3333 Hwy 6 South
Greater Houston	Indoor Air Quality	HS	1/6	333 Hwy 6 South
Greater Houston	Population Exposure	HM	1/6	9726 Monroe
Greater Houston	Population Exposure	HB	1/6	4420 Bingle
Greater Houston	Collocated	CO	1/6	
Corpus Christi	Population Exposure	CC	1/6	1111 Navigation Blvd.
Dallas	Population Exposure	DA	1/6	717 S. Akard
El Paso	Population Exposure	EP	1/6	222 S. Campbell St.
San Antonio	Population Exposure	SA	1/6	900 E. Durango Blvd.

Figure 2-1. Sampling locations (i.e., HT, HB, HW, H3, HC, H7, HM) in the Greater Houston area for the Texas $PM_{2.5}$ Sampling and Analysis Study between 03/11/97 and 03/12/98.

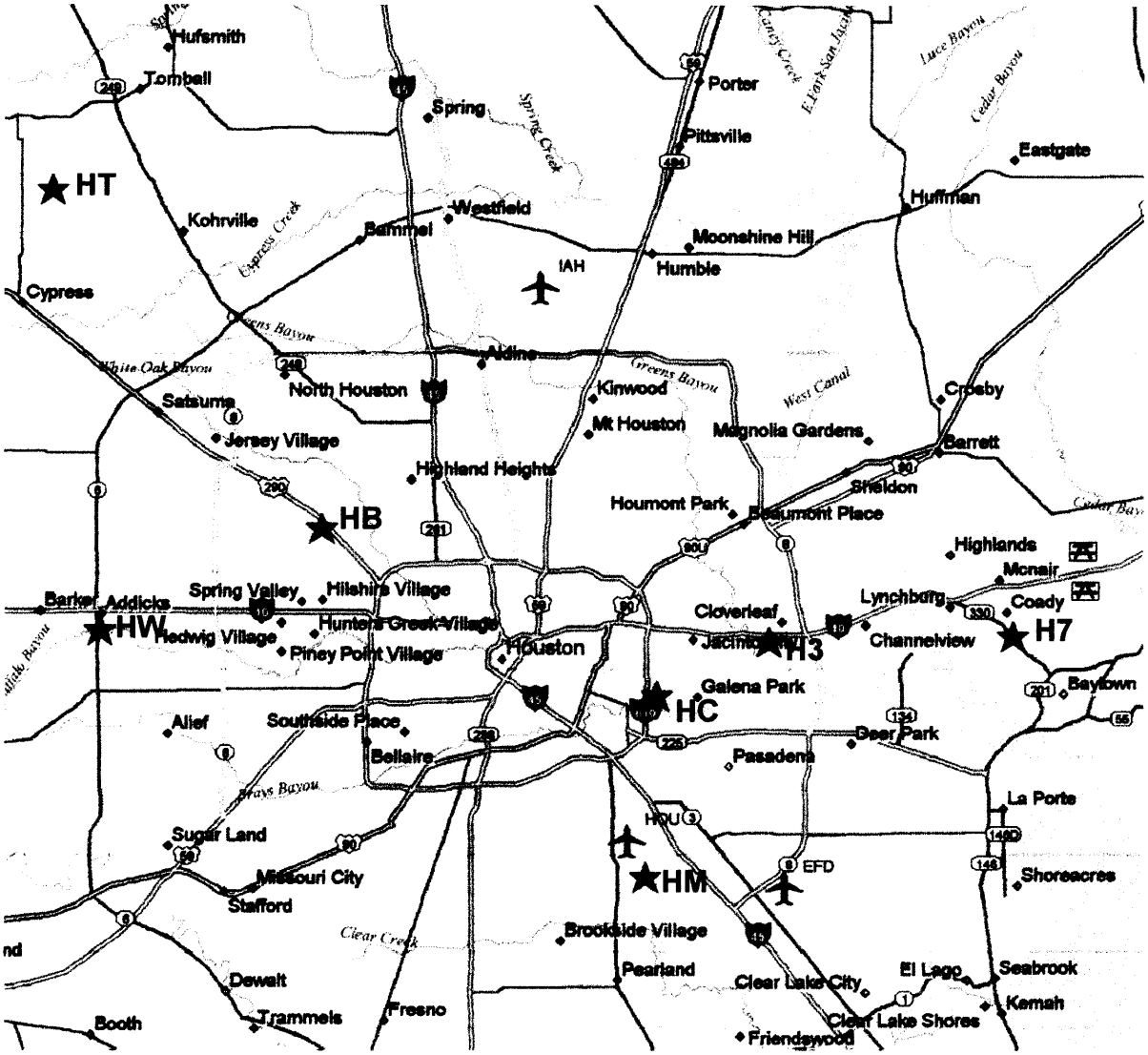


Figure 2-2. Schematic of DRI MEDVOL particle sampler.

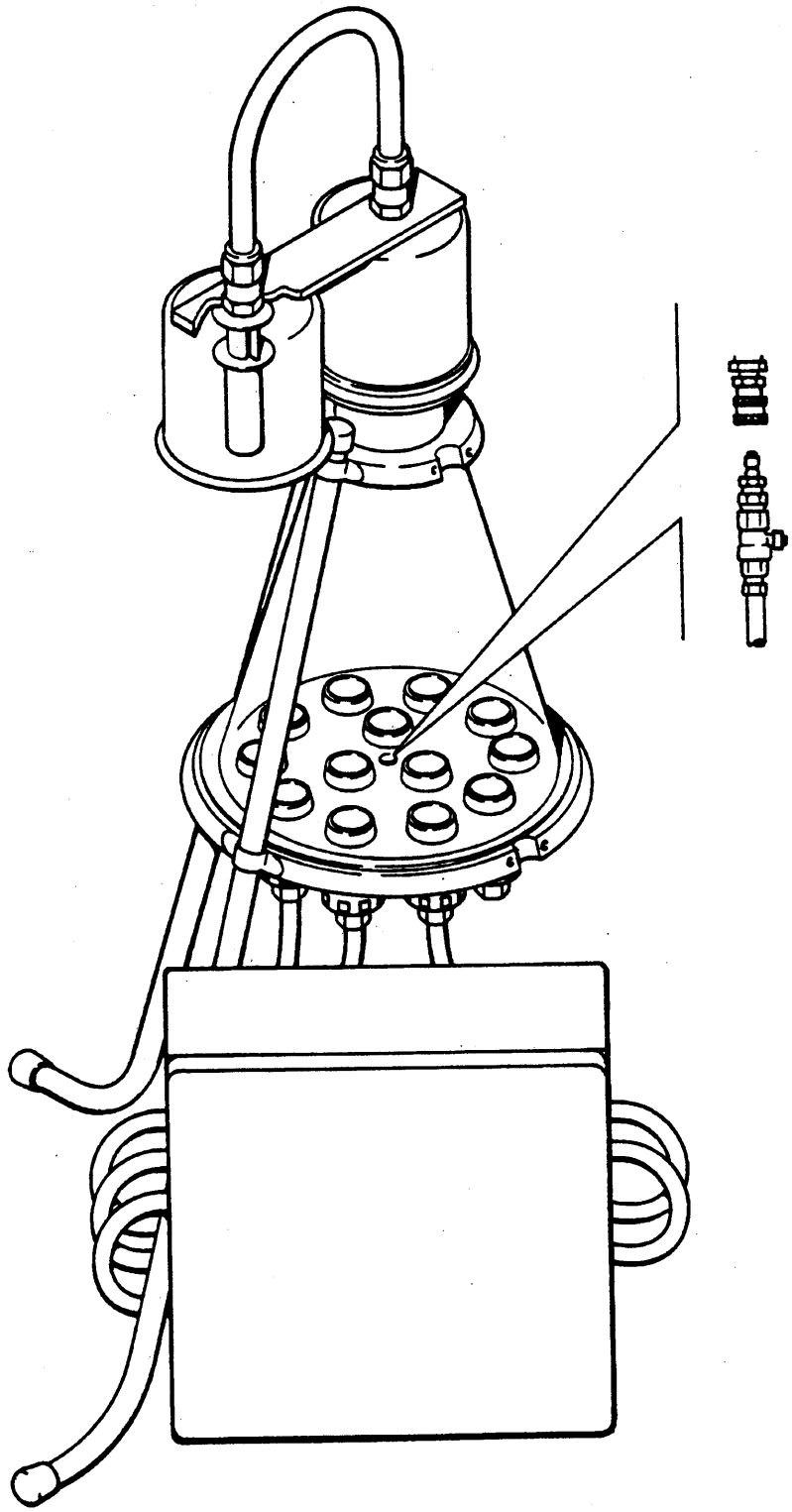
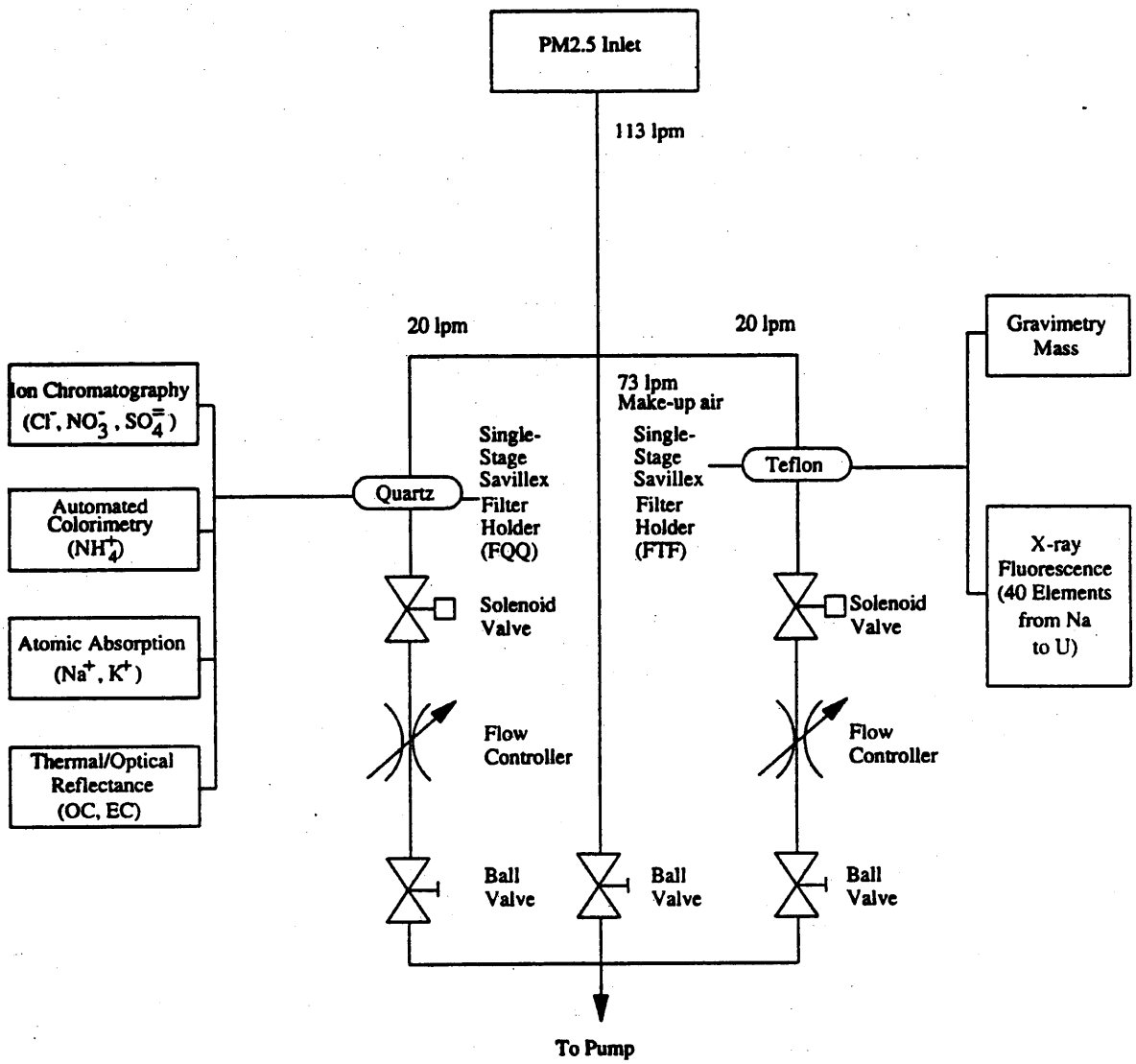


Figure 2-3. Schematic diagram of the sampler configuration used in the Texas $PM_{2.5}$ Sampling and Analysis Study between 03/11/97 and 03/12/98.



holders. The holders are plugged into quick disconnect fittings on the DRI MEDVOL particle sampler. The sample flow can be divided for simultaneous collection on two or more filter media. The differential pressure volumetric flow controller splits the flow between filters and maintains a constant flow rate despite filter loading.

The flow rate is controlled by maintaining a constant pressure across a valve with a differential pressure regulator. Flow rates of 20 to 55 liters per minute (L/min) can be drawn through each of the two filter packs simultaneously; flow rates of 110 L/min can be drawn through a single filter pack. The remaining flow rate needed by the inlet is drawn through a makeup air port. The sampler inlet can be configured for $PM_{2.5}$ or PM_{10} size cuts. For this study, the $PM_{2.5}$ size fraction is transmitted through a Bendix/Sensidyne 240 cyclone and into a plenum. A flow rate of 20 L/min was drawn through each of the two filter packs for each of the 24-hour sampling periods.

2.2.2 PM Filter Media

Lippmann (1989), Lee and Ramamurthi (1993), Watson and Chow (1993; 1994), and Chow (1995) evaluate substrates for different sampling and analyses. Based on these evaluations, the filters used in the Texas $PM_{2.5}$ Sampling and Analysis Study are: 1) Gelman (Ann Arbor, MI) polymethylpentane ringed, 2.0-µm pore size, 47-mm PTFE Teflon-membrane filters (#RPJ047) for mass and elemental analysis; and 2) Pallflex (Putnam, CT) 47mm diameter, pre-fired quartz-fiber filters (#2500 QAT-UP) for carbon and ion analyses; and 3) Whatman (Clifton, NJ) 41 cellulose fiber 47-mm filter (#1441047) impregnated with sodium chloride for ion analysis of nitrate.

2.2.3 Filter-Pack Configuration

Figure 2-4 shows an example of the Savillex filter holder used in this study. The filter packs for all but the collocated sampler contained only a single stage, containing either the Teflon-membrane or quartz-fiber filter. The collocated sampler is equipped with a double stage filter pack with a quartz-fiber filter on the first stage and a sodium-chloride-impregnated cellulose-fiber filter on the second stage.

2.2.4 PM Chemical Analyses

Teflon-membrane filters were analyzed for mass by gravimetric analysis and for Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Br, Rb, Sr, Y, Zr, Mo, Pd, Ag, Cd, In, Sn, Sb, Ba, La, Au, Hg, Tl, Pb, and U by x-ray fluorescence (XRF) analysis (Watson et al., 1998) at the Desert Research Institute's Environmental Analysis Facility in Reno, NV. The quartz-fiber filters were also analyzed by the Desert Research Institute's Environmental Analysis Facility for chloride (Cl^-), nitrate (NO_3^-) and sulfate ($SO_4^=$) by ion chromatography (Chow and Watson, 1998a); for ammonium (NH_4^+) by automated colorimtery; for soluble potassium (K^+) and soluble sodium (Na^+) by atomic absorption spectrophotometry; and for organic carbon (OC) and elemental carbon (EC) by thermal/optical reflectance carbon analysis (Chow et al., 1993c; Watson and Chow, 1993, 1994; Chow and Watson, 1998b). The sodium-chloride-impregnated cellulose-fiber filters were analyzed for nitrate (NO_3^-), using the same procedures applied to the quartz-fiber filters.

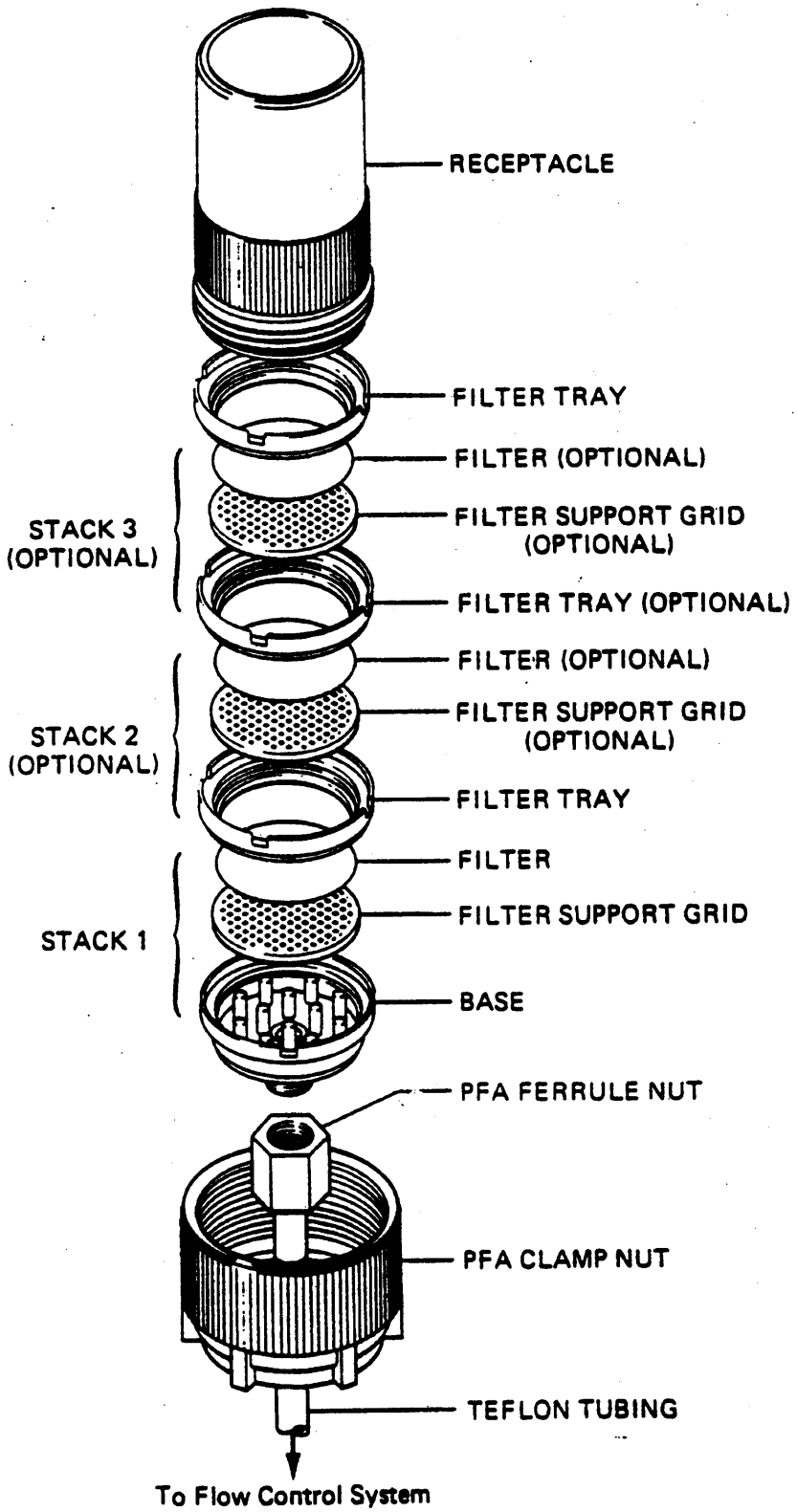



Figure 2-4. Exploded view of the Savillex filter holder used in the Texas $PM_{2.5}$ Sampling and Analysis Study between 03/11/97 and 03/12/98.