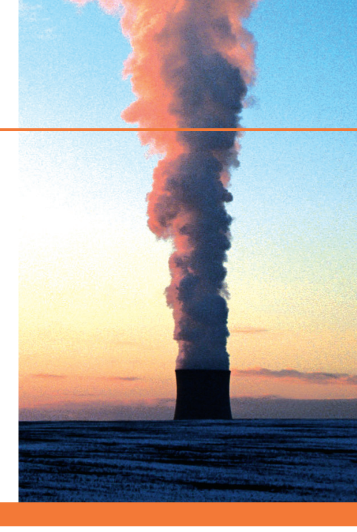

A Particle Sizer for Real-time Measurement OF RAPIDLY CHANGING AEROSOLS

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TSI® Incorporated recently launched the Fast Mobility Particle Sizer™ (FMPS™) Model 3091 (figure 1). The FMPS measures airborne particle size distributions in the nanometre size range with high time and size resolution. This technique allows simple and comprehensive measurement of rapidly changing aerosols such as are found in stacks, chimneys, ducts and even in ambient urban air.

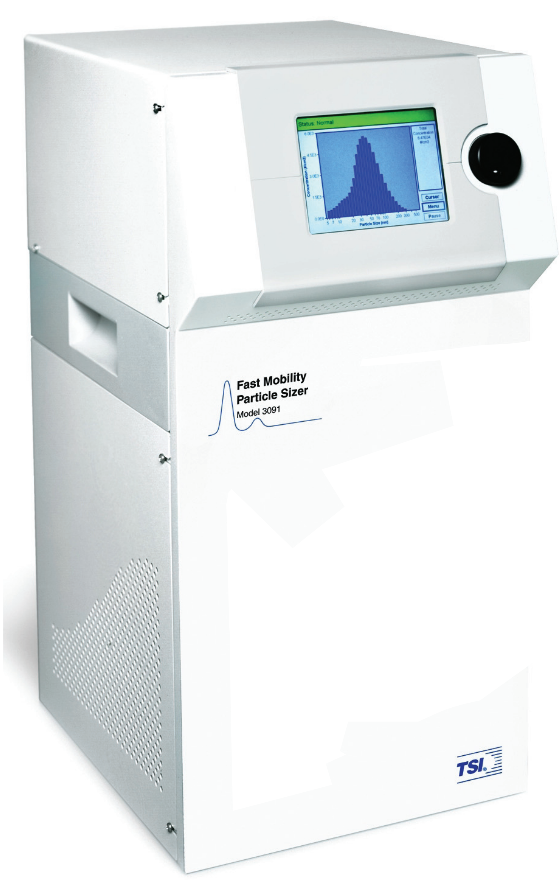

Figure 1. TSI's Model 3091 Fast Mobility Particle Sizer spectrometer

TSI has been a specialist manufacturer of aerosol instrumentation for over 40 years. Our first commercial aerosol instrument, The Whitby Aerosol Analyser was introduced in the mid 1960's. Since then the strategy of TSI has remained the same; to push forward the development of analytical technology, not simply because we can, but because there is a real, demonstrated need and application. During the past 40 years plus, aerosol science and instrumentation has taken many significant leaps forward, many of them due to TSI's progressive Research and Development programs. Obviously improvements in micro processing and IT have had a big impact, not only on the instruments themselves but also on the process involved in the designing of those instruments, speeding up the time from inception to production and so reducing development costs and adding to the efficiency of TSI and therefore our reaction to our customers' demands. In recent times TSI have made progress in a number of areas from being world leaders in Particle Image Velocimetry and Hand held Test and Measurement instruments to the area that we will concentrate on in this article, that of measuring ultrafine aerosol size distributions in "real time".

The Scanning Mobility Particle Sizer™ (SMPS™) which has become one of the mainstays of the aerosol researcher around the world, is used to study everything from ambient aerosols to manmade products and has developed step by step as our understanding of the physical processes involved has also increased. However the SMPS is still, as the name suggests a "scanning" system, with a high resolution particle size distribution taking maybe 30-60 seconds to complete. For the vast majority of applications this system has become the defacto standard with a huge bibliography from across the world. It also has the added flexibility of being able to be modified by the selection of various components, such as interchangeable Condensation Particle Counters (CPCs), Differential Mobility Analyzers (DMAs), and impactors which allows the user to optimise instrument configuration to best meet their needs. Scan time was always a major concern for some applications where the physical nature of the aerosol is rapidly changing, has an active nucleation phase or may contain volatile materials, in addition there are situations where the aerosol is still in the process of reacting with the atmosphere or has to be "stored" prior to the measurement. The demand to study and measure in environments such as that produced from an internal combustion engine running a variable drive cycle has increased enormously. This has been partially driven by the promulgation of legislation and control related to the health effects of nano-materials, in the atmosphere, in industry and other environments. The development of such control limits requires the study and monitoring of such environments to a much greater degree than ever before. It is not only the mass of the particles that holds importance to the researcher but number concentration may also be important. Indeed the every decreasing size of these particles suggests that the number concentration of these atmospheres may well be an even more appropriate parameter than mass. This, added to the requirements of scientists around the world to look at ever smaller particles in ever more challenging environments has lead to a growing demand for "real time" measurement techniques.

In response to this growing demand TSI entered into a partnership with researchers at the University of Tartu in Estonia who had over 20 years of experience in the use of a charger and multiple detector method which they had developed as the Electrical Aerosol Spectrometer (EAS). This method had been used within the University to study a variety of aerosols and had a well proven record; however the instrument was not suitable for general use, the complexity of its design and the heavy weight were two limiting factors. TSI licensed their technique and used it to develop the specification for the Fast Mobility Particle Sizer (FMPS). It was a potent combination, the University's expertise in the technique allied with the engineering, design skills and aerosol science knowledge of TSI as well as our detailed appreciation of market requirements, lead to the design and production of an instrument that is portable, easy to use but which has the power to yield the comprehensive and reliable results that our customers are looking for.

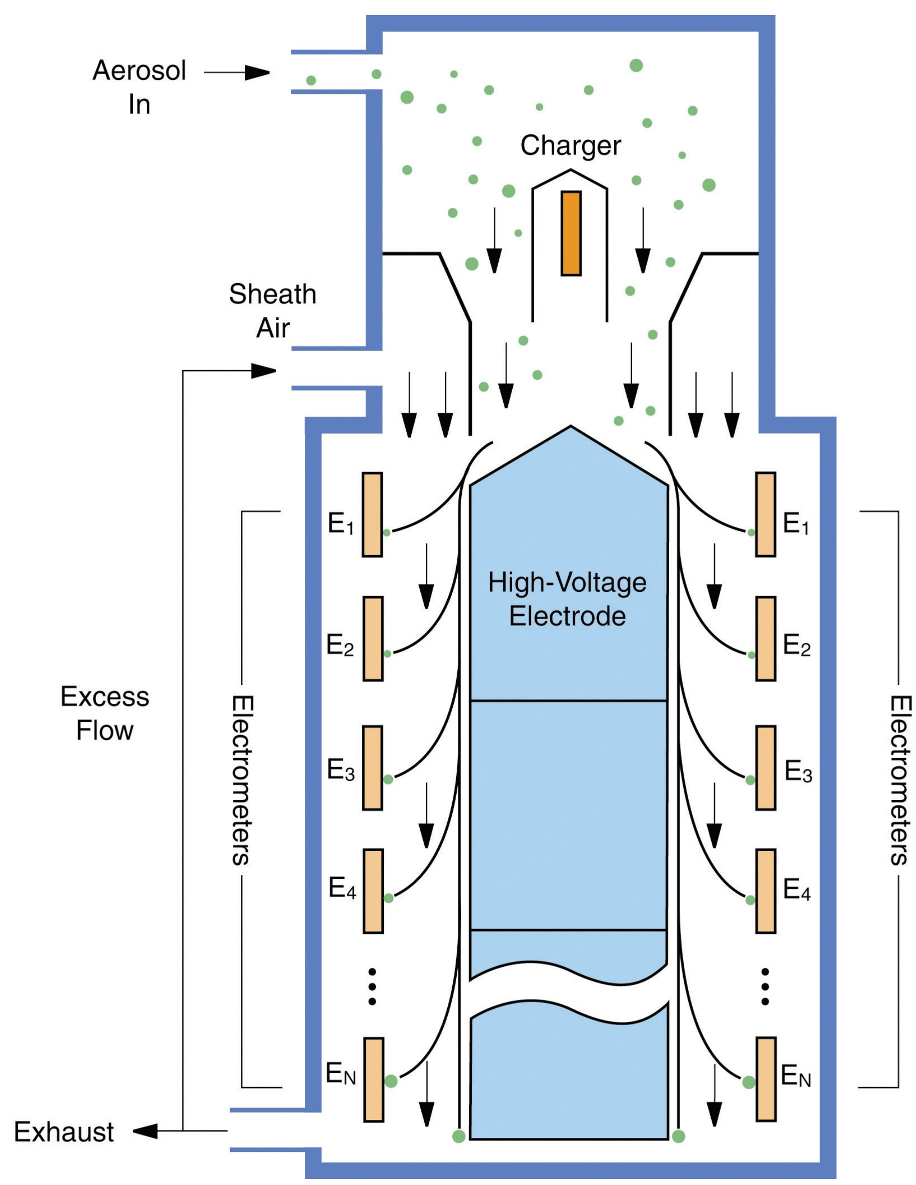

Figure 2. FMPS flow schematic

The FMPS spectrometer draws an aerosol sample into the inlet continuously (Figure 2). Using a corona charger, particles are charged to a precisely predictable distribution. The charged particles then enter the measurement region along the surface of a high-voltage electrode. They move down the length of the electrode alongside a sheath of HEPA-filtered air which separates them from a

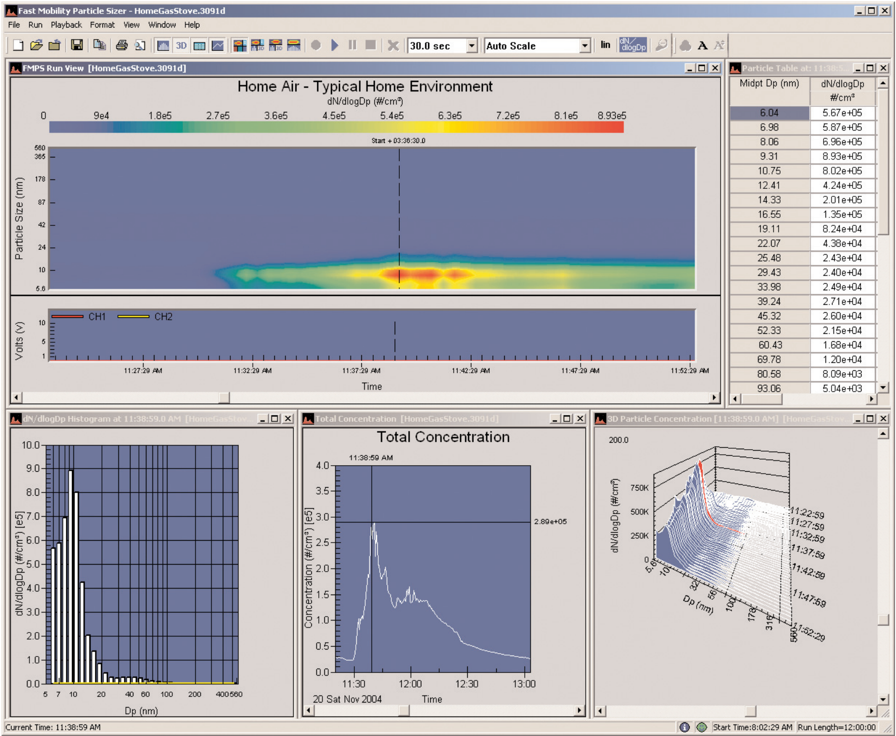

Figure 3. FMPS software, multi view window.

series of annular electrometer electrodes. As electrical potential is applied to the electrode an electrical field develops that repels particles outwards along a trajectory defined by their electrical mobility.

When particles strike the electrometers, they transfer the charge they carry to the electrometer where it is measured in real time. A particle with a high electrical mobility strikes an electrometer near the top of the measurement region, while a particle with lower electrical mobility travels farther and strikes an electrometer lower down the stack. This technique produces a real time set of concentration signals within a well defined and controlled set of size ranges.

The FMPS weighs in at 32Kg (70lbs) and will operate from a domestic power supply. The unit is a standalone system with all the pumps etc contained within the one box. The instrument has a warm up period of only 8 minutes, and can be moved in to place, powered up and ready to go in a very short time. With an aerosol flow rate of 10 L/min the FMPS produces a full particle size distribution in the range of 5.6 – 560 nm every second and when connected to a PC via a RS232 port, stores it automatically according to user defined protocols. The Windows® based software can report the data in a number of formats, including a 3D plot, which can be replayed at a range of speeds, along with the usual comprehensive range of statistical and graphical options that industry has come to expect from TSI (figure 3). Once a sample is complete and stored the data can be displayed in a variety of formats, which enables the user to comprehensively study different episodes and incidents within a data set without distorting the data set in any way. If even more flexibility is required the data can easily be exported as a complete run, or as a selected segment of the run, in a number of different formats. The software also allows for external and programmed starts as well as a manual start. A single file will record up to 12 hours of data, but it can also accomadate the storage of multiple files for ease of data management when the unit is in automatic mode and unattended for longer periods. Your only limit is the amount of data that the PC can store! A typical 20 minute run has a file size of approximately 195 Kb. The FMPS can also receive analogue inputs from two external sources, such as CPCs, to enable information from multiple sources to be synchronized and viewed together. Another primary feature of the FMPS is the use of very low noise level electrometers which enables the FMPS to measure a dynamic concentration range greater than 5 orders of magnitude. It reports this data with a resolution of 16 channels per decade of size, for a total of 32 channels.

The flexibility and robustness of he FMPS lends itself to measurement scenarios that have previously been almost impossible to satisfy. One such scenario is the “On Road” measurement of ultrafine particle size distributions. The FMPS was fastened in to the back of a MPV along with a Water based Condensation Particle Counter (WCPC) and a GPS unit. The two additional units where connected to the FMPS via data ports to synchronize the information from the three instruments. Power to the units was supplied via the car battery and a simple inverter. A sample line was connected to the FMPS and passed over the roof of the vehicle to sample the air in front of the car. Known pollution hot spots were driven through to determine how the particle count and size distribution changed second by second. The test system was also used for “chase” experiments where the car followed various vehicles along the road at different, (safe!) distances to study the plume of particles left by that vehicle. In another experiment two FMPS units were used; one measured the atmosphere inside the car while the other looked at the outside air. The team found that the air inside the vehicle quickly became polluted with particles as it passed through the exhaust plume, but that the outside concentration reduced more quickly than that inside the car as the plume was left behind.

Other situations include stack measurement of ultrafine particle distribution, for instance on an incinerator or a fossil fuelled power plant. The FMPS can easily be taken into difficult areas such as stack measurement platforms. The FMPS’s light weight and maneuverability makes such measurements a very practical and valid possibility. In the past long sample lines had to be used, or particulate material would be collected on inline filters at the back of a cross stack sampling probe. These techniques have always mitigated against the measurement of number concentration and size distribution of ultrafine particles as they would be lost in the transmission lines or contribute so little mass that filter based mass concentration measurements were unusable. With the FMPS it is now possible to have a particle size distribution analyzer close to the source, so eliminating losses and giving a “real time” account of the particle emission profile. The FMPS has its own built in sampling pump and operates at atmospheric pressure so there are no concerns about changing the structure of the sample or losing any of the volatile components that may have condensed into the sampled particles. These results can then be linked to all the other analyses that are routinely completed as part of a stack evaluation.

TSI also manufactures the Model 3090 Engine Exhaust Particle Sizer™ (EEPS™) which uses the same measurement technology as the FMPS but “goes ten times faster” and provides a full particle size distribution in 0.1 seconds, making it an effective tool for measuring particle emissions and characterizing after-treatment devices during extremely short lived aerosol events.

The instruments mentioned in this article are a small selection of those offered by TSI, for more information on these or any other instrument from our full range of over 200 please visit our web site at www.tsi.com or E mail particle-europe@tsi.com.