® Knowledge Beyond Measure.

Fast Mobility Particle Sizer™ Spectrometer

Model 3091

Measures size distribution and number concentration of rapidly changing submicrometer aerosol particles in real-time

Ideal for a Wide Range of Applications

The Fast Mobility Particle Sizer™ (FMPS™) 3091 spectrometer measures aerosol particles in the range from 5.6 to 560 nanometers, offering a total of 32 channels of resolution (16 channels per decade). The FMPS™ spectrometer uses an electrical mobility technique similar to the TSI® Scanning Mobility Particle Sizer™ (SMPS™) spectrometer. However, instead of a Condensation Particle Counter (CPC), it uses multiple, low-noise electrometers for particle detection. As a result, its unique design enables particle size distribution measurements with one-second resolution, letting users visualize particle events and changes in particle size distribution in real-time.

The FMPS™ spectrometer operates at a high sample flow rate (10 L/min) to minimize diffusion losses of ultrafine and nanoparticles. It also operates at ambient pressure to prevent evaporation of volatile particles, requires no consumables, and can be configured to measure a single run or multiple runs continuously for up to 12 hours per run length.

The model 3091 is conveniently packaged in a single cabinet for ease of transport, setup, and operation. Using the large, color VGA display and control knob, you can select parameter settings, interrogate instrument status, and view size distribution information. A full-featured software program combines data collection and analysis. Software highlights include a variety of graphing options, including 3D playback of size distribution and concentration versus time, data export, and the ability to input individual effective densities per channel to calculate a continuous output of total particulate mass.

The combination of features makes the FMPS™ spectrometer ideal for measuring the dynamic behavior of submicrometer particles over a wide range of applications, including particle formation and growth studies, indoor air quality measurements, environmental research, urban canyon studies, and transient emission studies of stacks, boilers, wood burners, and much more.

An Advanced Particle Sizing Solution

Measures size distribution and number concentration of rapidly changing submicrometer aerosol particles in real-time with superior resolution.

Features and Benefits

The FMPS™ spectrometer 3091 offers features and benefits that are important to industrial and environmental researchers working with rapidly changing aerosols:

Real-time measurements.
Visualize submicrometer particle size distributions and events with one-second resolution.

Wide size range.
Measure submicrometer aerosols from 5.6 to 560 nanometers in a total of 32 channels (16 channels of size per decade).

Wide dynamic concentration range.
Very sensitive electrometers* measure particle concentrations across a broad range (greater than five orders of magnitude, as shown in Figure 1), making the FMPS™ well-suited for a wide variety of applications.

Ease of use.
Simply connect the sample line, connect the power, switch the instrument ON, and let it warm up. Once warm (approximately ten minutes), the status changes to "Normal" and the instrument is ready to make measurements. It's really that easy!

The front panel includes a large, color VGA display and control knob so you can select parameter settings and interrogate instrument operating status quickly.

The display is updated in real time and can be configured for a variety of settings, including auto-range, linear or log scale, and normalized concentration (dN/dlogDp) for comparison to other instruments.

Flexible data management.
A full-featured software program (Figure 2) combines data collection and analysis. View up to 12 hours of data in a file at a time, and then "zoom in" on the time scale to view interesting episodes. Data can be displayed, replayed, and exported in many different ways. The software also displays and plays back three-dimensional plots of size distribution and particle concentration versus time, so you can visualize particle events as they occur.

High sample flow rate.
The FMPS™ spectrometer operates at a high sample flow rate of 10 L/min, greatly reducing particle sampling losses due to diffusion. All flows are controlled using microprocessor-controlled, internal pumps corrected for temperature and barometric pressure.

No radioactive neutralizer.
This spectrometer operates using a unipolar diffusion charger to place a predictable charge on the particles. As a result, there are no special licensing concerns regarding radioactive materials.

Proven technology.
The technology was developed originally at the University of Tartu in Estonia. It combines detection from an array of electrometers with electrical mobility classification. TSI® engineers built on this extensive knowledge, combining it with experience gained developing the Scanning Mobility Particle Sizer™ (SMPS™) spectrometer.

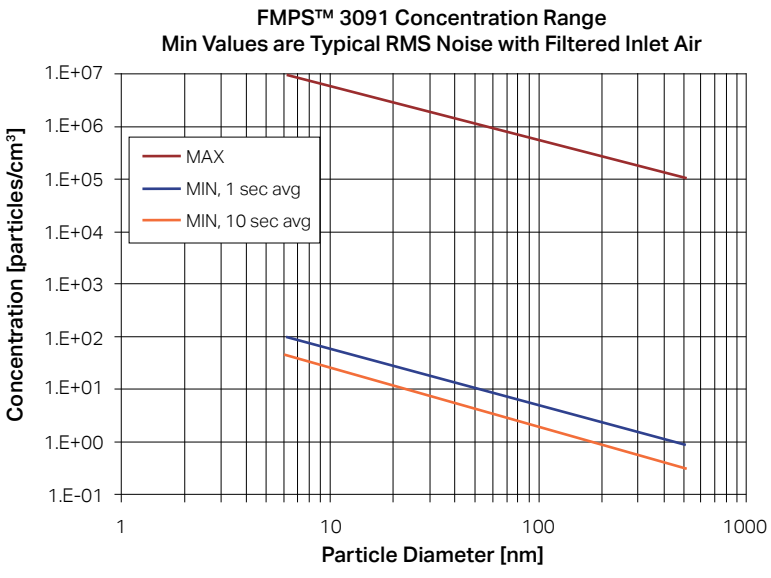

Figure 1. The maximum measurable concentration is shown in red. The minimum RMS noise level varies with averaging time.

*Patent No. 7,230,431

What Makes This Spectrometer Unique

Electrical Mobility Diameter
Building on nearly 40 years of expertise with electrical mobility measurement techniques, TSI® continues its tradition of developing cutting-edge instrumentation with a spectrometer designed specifically for real-time, submicrometer particle sizing. The standard submicrometer sizing method, a TSI® Scanning Mobility Particle Sizer™ (SMPS™) spectrometer, requires about 30 to 60 seconds to measure a single size distribution. Therefore, the SMPS™ method does not lend itself to measuring rapidly changing aerosols.

The FMPS™ spectrometer uses a unique charging system and multiple electrometers to get signals from all particle sizes simultaneously. The electrometer current data is processed in real-time using a high-performance DSP. The data algorithm corrects for multiple charges, image charge, and the time delay between electrometers. Data is processed further to give results in 32 equally spaced (log-scale) size channels. Measurements are displayed on the instrument in real-time and sent to a computer for long-term storage, display, and playback.

Applications
Real-time measurements and accurate sizing make the model 3091 an effective measurement tool for a wide variety of applications. While SMPS™ spectrometers provide significantly higher size resolution, they are best suited for measuring relatively stable aerosols. The FMPS™ spectrometer gives you the ability to visualize particle distributions with one-second resolution.

Typical applications include:
- Particle formation and growth studies
- Indoor air quality measurements
- Environmental research
- Urban canyon studies
- Transient emission studies of stacks, boilers, and burners

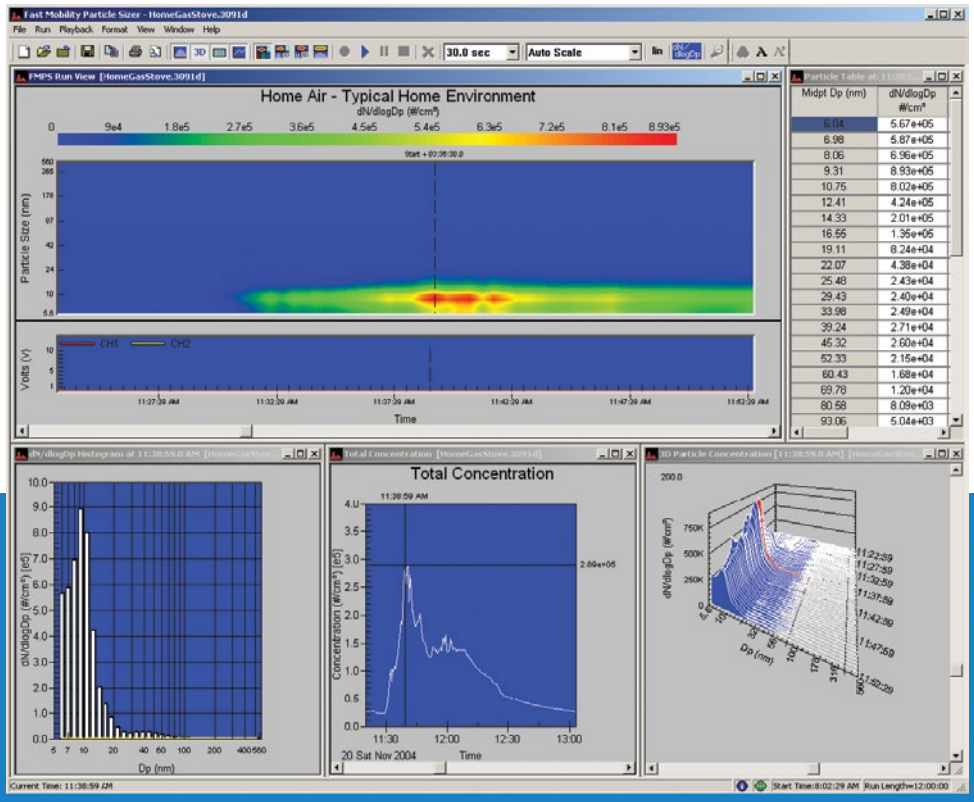

Figure 2. FMPS™ software offers advanced options for data display, such as Run View, concentration histogram, and 3D particle concentration graphs.

Powerful Software with All the Right Features

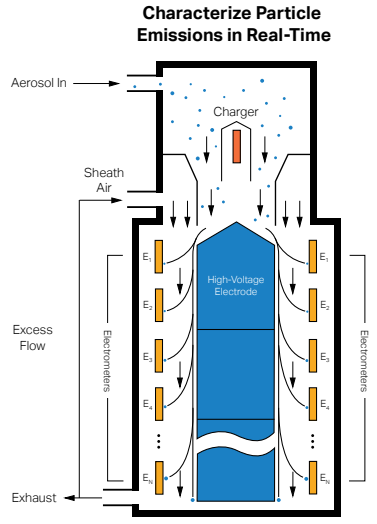

Figure 3. FMPS™ Flow Schematic

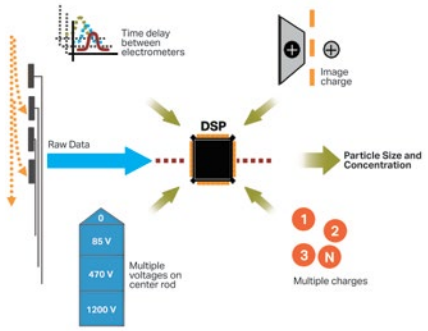

Figure 4. Data Inversion Schematic

Particle Table at: 11:28:59.0 AM (HomeGasStove.3091d)

Midpt Dp (nm)	dN/dlogDp #/cm³	Surface nm²/cm³	Volume nm³/cm³	Mass µg/m³	Density g/cm³
6.04	5.67e+05	6.50e+07	6.54e+07	7.85e-02	1.20
6.98	5.87e+05	8.99e+07	1.05e+08	0.125	1.20
8.06	6.96e+05	1.42e+08	1.91e+08	0.229	1.20
9.31	8.93e+05	2.43e+08	3.77e+08	0.453	1.20
10.75	8.02e+05	2.91e+08	5.22e+08	0.626	1.20
12.41	4.24e+05	2.05e+08	4.24e+08	0.509	1.20
14.33	2.01e+05	1.30e+08	3.10e+08	0.373	1.20
16.55	1.35e+05	1.16e+08	3.20e+08	0.384	1.20
19.11	8.24e+04	9.46e+07	3.01e+08	0.361	1.20
22.07	4.38e+04	6.70e+07	2.47e+08	0.296	1.20
25.48	2.43e+04	4.96e+07	2.11e+08	0.253	1.20
29.43	2.40e+04	6.52e+07	3.20e+08	0.384	1.20
33.98	2.49e+04	9.04e+07	5.12e+08	0.614	1.20
39.24	2.71e+04	1.31e+08	8.59e+08	1.03	1.20
45.32	2.60e+04	1.68e+08	1.27e+09	1.52	1.20
52.33	2.15e+04	1.85e+08	1.61e+09	1.85	1.15
60.43	1.68e+04	1.93e+08	1.94e+09	2.14	1.10
69.78	1.20e+04	1.84e+08	2.14e+09	2.14	1.00
80.58	8.09e+03	1.65e+08	2.22e+09	2.11	0.950
93.06	5.04e+03	1.37e+08	2.13e+09	1.91	0.900
107.46	3.07e+03	1.11e+08	1.99e+09	1.69	0.850
124.09	2.17e+03	1.05e+08	2.17e+09	1.74	0.800
143.30	1.60e+03	1.03e+08	2.46e+09	1.85	0.750
165.48	1.35e+03	1.17e+08	3.21e+09	2.25	0.700
191.10	1.01e+03	1.16e+08	3.69e+09	2.40	0.650
220.67	559.9	8.57e+07	3.15e+09	1.89	0.600
254.83	257.5	5.25e+07	2.23e+09	1.23	0.550
294.27	101.7	2.77e+07	1.36e+09	0.678	0.500
339.82	19.4	7.04e+06	3.98e+08	0.179	0.450
392.42	10.7	5.17e+06	3.38e+08	0.135	0.400
453.16	6.11	3.94e+06	2.98e+08	0.104	0.350
523.30	5.66	4.87e+06	4.25e+08	0.127	0.300
Median (nm)	**9.39**	**42.0**	**122.7**	**89.3**	---
Mean (nm)	**11.4**	**63.9**	**138.9**	**112.7**	---
Geo. Mean (nm)	**9.93**	**36.2**	**103.4**	**81.7**	---
Mode (nm)	**9.31**	**10.75**	**191.10**	**191.10**	---
Geo.Std.Dev.	**1.59**	**3.46**	**2.50**	**2.58**	---
Total	**2.89e+05**	**2.22e+08**	**2.36e+09**	**1.98**	---

Figure 5. Table View

The FMPS™ software is your interface for data collection and analysis. Select from a variety of predefined window arrangements to display the data you want. Once data collection begins, particle size distributions are displayed with one-second resolution to enable measurements to be viewed in real- time. The particle concentration range displayed can be configured for a specified maximum, or set to auto scale. Data can be displayed in a variety of formats during data collection and post-acquisition analysis. As shown in Figure 2, five main views can be displayed simultaneously. These include the Run View, a 2D Histogram of size distribution versus concentration, a Table View, a total concentration graph, and a 3D graph of size distribution and concentration versus time. The Run View (a 2D color contour plot) gives users a tool to quickly analyze large amounts of data and find interesting events to zoom in and analyze in greater detail using other views.

The Table View (Figure 5) and 2D Histogram (Figure 6) are two ways of showing the same concentration versus particle size data. The table includes number concentration for each size channel and also weightings for surface area and volume. By entering an effective density for each particle size, mass concentration can be calculated and output. The table includes statistics such as median, mean, geometric mean, mode, geometric standard deviation, and total concentration. The 2D Histogram can display any of the weightings that are available in the table using either linear or log scaling. View boundaries can be set on the histogram that will limit the range over which the statistics are calculated.

A key feature of the 2D Histogram is the “in range” concentration indicators that appear while collecting and analyzing data. As shown in Figure 6, both the maximum (Red) and minimum (Yellow) concentration ranges are indicated to give users confidence that measurements are within the specified operating range of the instrument and are valid.

A 3D graph of size distribution and concentration versus time (Figure 7) makes it easy to view the changing size distribution of aerosol over time. Measurements can be replayed for a unique “movie” view.

Measurements can be started manually, triggered externally, or scheduled to begin at a specific time (Figure 8). The software provides user-selectable run lengths up to 12 hours. In addition, measurements can be repeated at user-selected time intervals. The software has a data export function for customized data handling requirements. Data can be exported to a text or spreadsheet file either automatically and continuously as data is collected or manually following data collection.

All instrument status parameters and controls that can be accessed from the FMPS™ front-panel display can also be viewed and controlled via the software (Figure 9). Status and operating parameters include instrument flow rates, column voltages, charger currents, sheath air temperature, and inlet pressure. Operation of the flows, chargers and column voltages also can be turned on and off via software. The electrometer readings, size distribution and total concentration can be measured and monitored before data collection begins.

FMPS™ Spectrometer Operation

The instrument draws an aerosol sample into the inlet continuously (Figure 3). Particles are charged positively to a predictable level using a corona charger. Charged particles are then introduced to the measurement region near the center of a high-voltage electrode column and transported down the column via HEPA-filtered sheath air. A positive voltage applied to the electrode creates an electric field that repels the particles outward according to their electrical mobility.

Charged particles strike the respective electrometers and transfer their charge. A particle with high electrical mobility strikes an electrometer near the top, whereas a particle with lower electrical mobility strikes an electrometer lower in the stack. This arrangement, using highly sensitive electrometers, allows for concentration measurements of multiple particle sizes simultaneously.

The model 3091 uses a sophisticated, real-time data inversion to deconvolute the data. Figure 4 illustrates how the inversion accounts for variability in particle charge, image charge, multiple voltages on the center rod, and time delay between the electrometers to present a size distribution that corresponds to a specific time. As a result, the FMPS™ technique dramatically increases the time resolution of particle-size and concentration measurements, which is extremely useful for the study of rapidly changing aerosols.

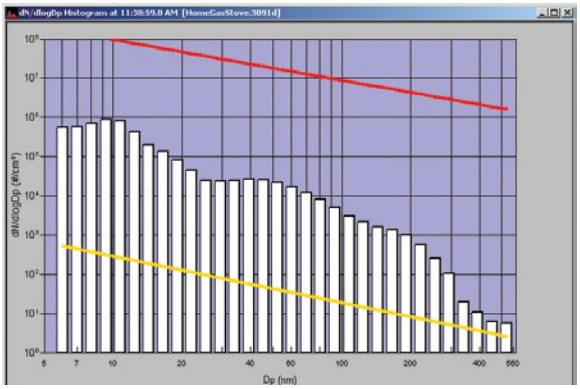

Figure 6. 2D Histogram with log scaling shows both minimum (RMS noise) and maximum concentration ranges.

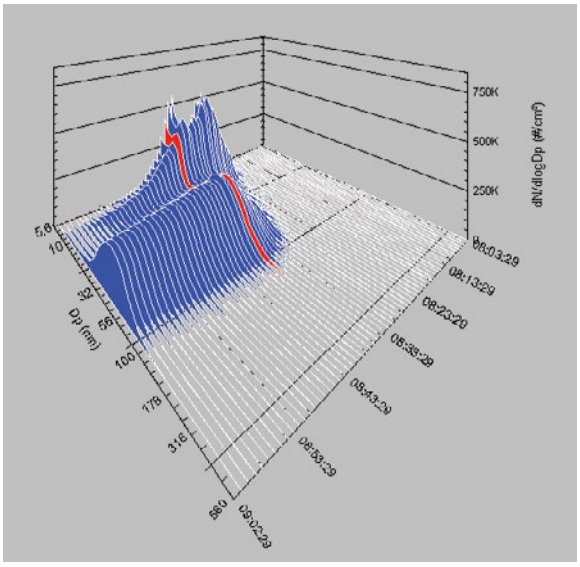

Figure 7. 3D graph shows the transition from nucleation to accumulation mode from a gas stove aerosol source as the burner warmed up.

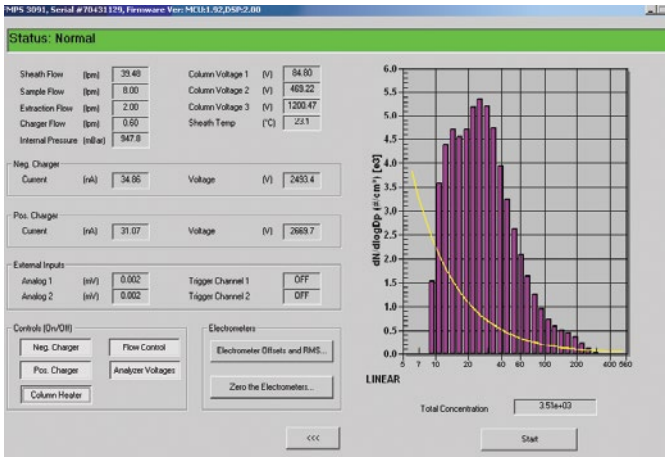

Figure 9. Instrument Status Window with histogram displayed

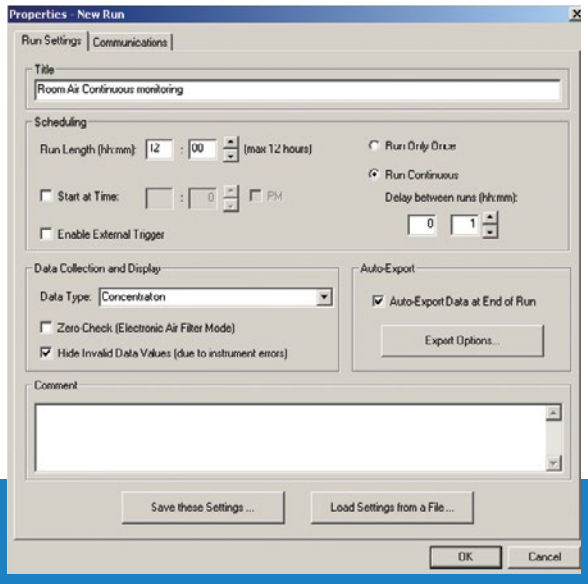

Figure 8. Run Properties Window

Specifications

Fast Mobility Particle Sizer™ Spectrometer

Model 3091

Operating Features

Particle Size Range	5.6 to 560 nm
Particle Size Resolution	16 channels per decade (32 total)
Electrometer Channels	22
Charger Operating Mode	Unipolar diffusion charging
Inlet Cyclone 50% Cutpoint	1 µm
Time Resolution	1 size distribution/sec

Flow Rates

Aerosol Sheath Air	10 L/min 40 L/min

Environmental Conditions

Inlet Aerosol Temperature	10 to 52°C
Operating Temperature	0 to 40°C
Storage Temperature	-20 to 50°C
Atmospheric Pressure	70 to 103 kPa (700 to 1034 mbar) Correction Range
Humidity	0 to 90% RH (noncondensing)

Communications Features

User Interface FMPS™ software	Rotary knob and display,
Front-Panel Display	6.4-inch color VGA LCD
Computer Requirements	Pentium® 4 processor, 2 GHz speed or better, at least 512 MB RAM, Windows® XP, or Windows 7 (32-bit or 64-bit) operating systems
Communications	9-pin RS-232

Electrical Features

Analog Input	Two analog input channels, 0 to 10 V
Trigger Input	Two trigger input channels, potential-free contact closure or 3.3 V pulled to GND
Electrical Outputs	Trigger output channel, potential-free contact closure

Physical Features

Dimensions (H x W x D)	70.4 × 34.3 × 43.9 cm (27.7 × 13.5 × 17.3 in.)
Weight	32 kg (70 lb)
Aerosol Inlet	3/8-in. OD (without inlet cyclone)
Cyclone Inlet	3/8-in. OD
Exhaust/Outlet	3/8-in. OD
Power Requirements	100 to 240 VAC, 50/60 Hz, 250 W

Acknowledgments

The Fast Mobility Particle Sizer™ (FMPS™) spectrometer was developed by TSI® under license from Airel, Ltd. of Tartu, Estonia. We gratefully acknowledge the contributions from the dedicated scientists at Airel during the development of this instrument.

To Order

Fast Mobility Particle Sizer Spectrometer

Specify	Description
3091	FMPS™ spectrometer and software

Computer must be purchased separately.

Specifications reflect typical performance and are subject to change without notice.

Knowledge Beyond Measure.

TSI Incorporated - Visit our website **www.tsi.com** for more information.

USA	Tel: +1 800 874 2811	**India**	Tel: +91 80 67877200
UK	Tel: +44 149 4 459200	**China**	Tel: +86 10 8219 7688
France	Tel: +33 1 41 19 21 99	**Singapore**	Tel: +65 6595 6388
Germany	Tel: +49 241 523030		

P/N 5001476 Rev E (A4)

Printed in U.S.A.