Thermo Fisher Scientific

UK Report on the Equivalence of the PM_{10} TEOM 1405-F

June 2013

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TITLE OF THE METHOD

The following text has been approved by the UK Certification Committee as being an accurate description of the set-up of the instrument, and it is recommended that this text is repeated on the MCERTS certificate.

The instrument tested was the **TEOM 1405-F with PM_{10} pre-separator** measuring system consisting of the following parts:

- USEPA style PM_{10} sampling inlet operating at 16.7 l/min;
- Flow splitter with flows split to 3 and 13.7 l/min;
- Sampling tubes;
- FDMS (Filter Dynamics Measurement Systems) tower;
- TEOM (Tapered Element Oscillating Microbalance) mass sensor;
- Mass Flow Controllers;
- Vacuum pump.

The operation of instruments in permutations other than the above is not covered by this report, and is not recommended for approval without further consideration by the UK Certification Committee for the implications of any variations.

EXECUTIVE SUMMARY

The Thermo Fisher Scientific Tapered Element Oscillating Microbalance (TEOM) 1405-F Filter Dynamic Measurement System (FDMS) with USEPA style 16.7 l/min PM_{10} pre separator (herein referred to as the PM_{10} TEOM 1405-F) has been tested in compliance with the requirements set out in the "Annex to the MCERTS Performance standards for Ambient Air Quality Monitoring Systems[1]" (herein referred to as MCERTS for UK Particulate Matter). The instrument is shown to meet the requirements and is suitable to be declared equivalent to the PM_{10} reference method in the United Kingdom (UK).

The PM_{10} TEOM 1405-F Candidate Method (CM) was tested against the Sven Leckel LVS3 European Reference Method (RM) over a series of four field campaigns split equally between Germany (two tests) and the UK (two tests). The operation of the instruments was undertaken by TÜV Rheinland in Germany, and the National Physical Laboratory (NPL) in the UK. Both organisations have appropriate ISO17025 accreditations which are included herein (Section 5). Calculations of the between sampler uncertainties of the TEOM PM_{10} 1405-F and the expanded uncertainties relative to the reference method were undertaken by Bureau Veritas (BV). These calculations were audited by TÜV Rheinland. BV has provided overall project management to the delivery of the programme in the UK.

A series of intensive laboratory tests was undertaken by TÜV Rheinland that go beyond the requirements set out in MCERTS for UK Particulate Matter. Additionally, the instruments were leak tested and flow tested by NPL and TÜV Rheinland throughout the four field campaigns (Sections 8.1 and 8.2). The Maintenance Interval is discussed herein (Section 8.3). Data Capture has been calculated in accordance with MCERTS for UK Particulate Matter (Section 11).

Calculations of the suitability of the data relative to the pollution climate within the UK were undertaken by BV.

This report sets out the findings of the field campaigns, laboratory testing and pollution climate calculations. The report is structured to include the 17 numbered sections required in Section 6 of MCERTS for UK Particulate Matter[1]. This combined report is fully compatible with all the requirements of MCERTS for UK Particulate Matter[1], including its reporting structure. It will be used to provide the MCERTS Certification Body, and its certification committee, with the evidence required to assess whether all the testing carried out is compliant with all the requirements of MCERTS for UK Particulate Matter[1].

Sections of the report have been copied with permission from the PM_{10} TEOM 1405-F TÜV Rheinland Report[2] and addendum notice relating to software version[3]. Where this text is used, it is clearly marked and placed within a light blue text box within this report. Within these Sections, text relating to German Legislation has been replaced with text relating to UK legislation; some figures that were in German have been translated in to English; and some minor changes have been made for grammar. Sections have been added to discuss the implications of the findings of TÜV Rheinland for the UK.

Bureau Veritas wish to thank TÜV Rheinland and NPL for their contributions to this report.

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1 Annex to the MCERTS Performance standards for Ambient Air Quality Monitoring Systems: Requirements of the UK Competent Authority for the Equivalence Testing and Certification of Automated Continuous and Manual Discontinuous Methods that Monitor Particulate Matter in Ambient Air. http://uk-air.defra.gov.uk/documents/MCERTS_for%20UK_Particulate_Matter_final.pdf

2 Report on the suitability test of the ambient air quality measuring system TEOM 1405-F Ambient Particulate Monitor with PM_{10} pre-separator of the company Thermo Fisher Scientific for the component PM_{10}. Report number 936/21209885/B dated 25 November 2011. www.qal1.de/en/hersteller/thermo.htm

3 Notice in relation to software upgrade from 1.55 to 1.56 dated 6 July 2012. www.qal1.de/en/hersteller/thermo.htm

The following tables and notes summarise the findings in relation to MCERTS for UK Particulate Matter.

Certification Range: PM_{10} 0 to 1000 µg/m^3

Ambient temperature range: 8ºC to 25ºC

Table 1: Summary of the test results. The data in this table relate to the instrument without correction for slope and/or intercept. See Note 1.

Test	Results	MCERTS Specification
Constancy of the sample volumetric flow	-0.096%	To remain constant within ± 3% of the rated value
Tightness of the sampling system	2% Note 2	Leakage not to exceed 1% of the sampled volume
Between sampler/instrument uncertainty for the standard method **PM_{10}**		
Full data set	0.48 µg/m^3	≤2 µg/m^3
<30 µg/m^3	0.46 µg/m^3	Not specified
≥30 µg/m^3	0.55 µg/m^3	Not specified
Between sampler/instrument uncertainty for the candidate method **PM_{10}**		
Full data set	1.09 µg/m^3	≤2.5 µg/m^3
<30 µg/m^3	1.03 µg/m^3	≤2.5 µg/m^3
≥30 µg/m^3	1.35 µg/m^3	≤2.5 µg/m^3
Expanded uncertainty calculated at 50 µg/m^3 for **Instrument SN 20006**		
Full data set	9.0%	≤25%
<30 µg/m^3	12.3%	Not specified
≥30 µg/m^3	9.4%	≤25%
Individual sites	Note 3	
Teddington Summer	23.7%	≤25%
Cologne Winter	6.2%	≤25%
Bornheim Summer	20.1%	≤25%
Teddington Winter	15.2%	≤25%
Expanded uncertainty calculated at 50 µg/m^3 for **Instrument SN 20107**		
Full data set	9.1%	≤25%
<30 µg/m^3	13.1%	Not specified
≥30 µg/m^3	11.6%	≤25%
Individual sites		
Teddington Summer	17.2%	≤25%
Cologne Winter	9.4%	≤25%
Bornheim Summer	21.0%	≤25%
Teddington Winter	14.1%	≤25%
Other Requirements		
Maintenance Interval	Four weeks	≥Two weeks
Data Availability (SN20006)	94.5%	≥90%
Data Availability (SN20107)	98.6%	≥90%
Number of UK Tests	2	≥1
Number of Reference Methods	2	≥1

Note 1: As the intercept was statistically significantly different from zero based upon 2 standard deviations, test results were also subjected to correction coefficients for intercept. Expanded uncertainties for the Candidate Method were calculated for both uncorrected datasets as well as data that have been adjusted for intercept. The CM fulfils the relevant Data Quality Objective of EU Directive 2008/50/EC when used without correction, though the highest individual expanded uncertainty specified in GDE2010 as being required to be below 25 % is marginally reduced if correction for intercept by subtracting 0.395 µg/m^3 is employed. Intercept correction is not required in order to make the instrument equivalent, but it is essential that thorough and frequent on-going QA/QC procedures are employed (as prescribed in fprEN12341:2013[4] and CEN/TS16450[5]) including to precisely quantify analyser baseline performance and ensure the continued correct operation of the FDMS drier.

Table 2: Summary of the slope, intercept and expanded uncertainties with and without intercept correction.

PM_{10} 1405-F	Calculated slope of all paired data	Calculated intercept of all paired data (µg/m^3)	Expanded uncertainty of all paired data	Range of individual expanded uncertainties
Uncorrected data	0.994	0.395	8.4%	6.2% to 23.7%
Data corrected for intercept by subtracting 0.395	0.994	0.000	8.5%	6.6% to 22.2%

Note 2: The leak test procedure for the 1405-F is an internal manufacturer's procedure, implemented in the instruments in order to avoid serious damage to the instrument. The check on tightness must be performed using this internal procedure. All of the leak tests conducted passed the manufacturer's leak test specifications.

Note 3: A study of pollution climate relevant to sites in the UK and Germany has demonstrated that in all cases the particulate geometric mean criteria are met and at least one site meets the lower threshold and higher threshold criterion for wind speed, ambient temperature, ambient dew point and semi volatile nitrate content. The pollution climate criteria are satisfied for all the equivalence tests.

Note 4: For the purposes of quality control of these monitors in the field, as with all PM instruments that are not the reference method, the 1405 series FDMSs should be calibrated on a test site at intervals against the gravimetric reference methods EN 12341[6] or EN 14907[7] as applicable, and as given in the recommendations of the GDE 2010[8] and CEN/TS16450[5].

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4 CEN Final Draft Standard fprEN12341:2013 Ambient air - Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2,5}$ mass concentration of suspended particulate matter.

5 CEN Technical Specification CEN/TS16450:2013 Ambient air - Automated measuring systems for the measurement of the concentration of particulate matter (PM_{10}; $PM_{2,5}$)

6 CEN Standard EN 12341:1998. Air Quality – Determination of the PM_{10} fraction of suspended particulate matter – Reference method and field test procedure to demonstrate reference equivalence of measurement methods.

7 CEN Standard EN 14907:2005. Reference Gravimetric Measurement Method for the Determination of the $PM_{2.5}$ mass fraction of suspended particulate matter in Ambient Air.

8 Guidance for the Demonstration of Equivalence of Ambient Air Monitoring Methods, EC Equivalence Group, January 2010, http://ec.europa.eu/environment/air/quality/legislation/pdf/equivalence.pdf

GENERAL INFORMATION

1. Summary of Principles of the Candidate Method

1.1 Measuring Principle

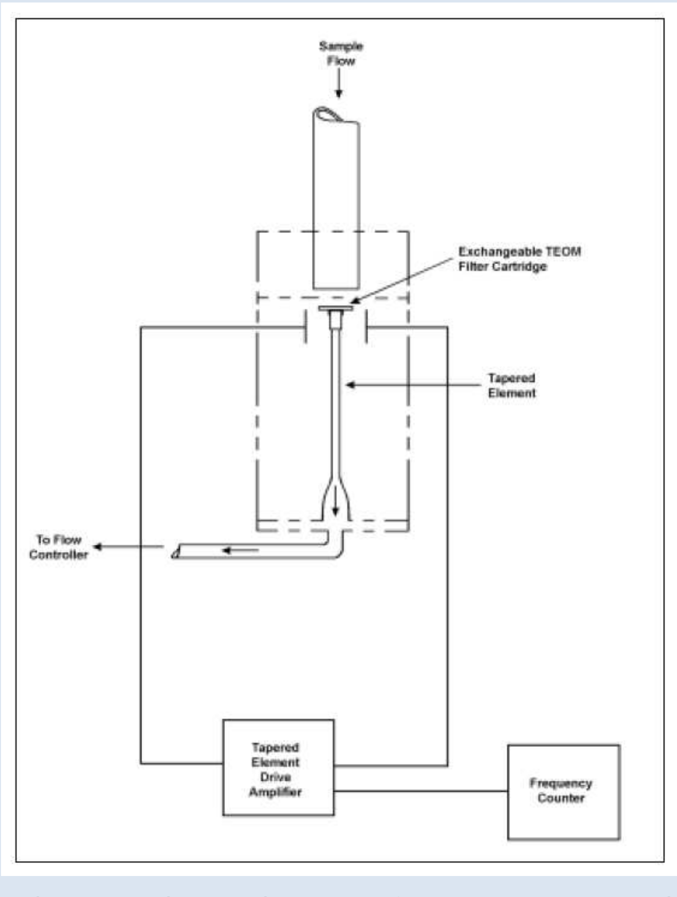
The following text is copied with minor alterations from Section 3.1 of the TÜV Rheinland Report[2].

The ambient air measuring system TEOM1405-F Ambient Particulate Monitor is based on the measuring principle of oscillating micro weighing.

For the weighing principle, which is used in the TEOM mass transducer in the measuring system TEOM 1405-F Ambient Particulate Monitor, the change in mass determined with the sensor, results from the measurement of the change in frequency of the tapered element.

The tapered element at the heart of the mass detection system is a hollow tube, clamped on one end and free to oscillate at the other. An exchangeable TEOM filter cartridge is placed over the tip of the free end. The sample stream is drawn through this filter and then down the tapered element.

Figure 1: Schematic set-up of the mass transducer



The tapered element oscillates precisely at its natural frequency. An electronic control circuit senses this oscillation and, through positive feedback, adds sufficient energy to the system to overcome losses. An automatic gain control circuit maintains the oscillation at a constant amplitude. A precision electronic counter measures the oscillation frequency with a 10-second sampling period.

The tapered element is, in essence, a hollow cantilever beam with an associated spring rate and mass. As in any spring-mass system, if additional mass is added, the frequency of the oscillation decreases. This can be seen by observing the frequency on the display of the device, and operating the monitor both with and without a filter in place

In a spring-mass-system the frequency is obedient to the following equation:

$$F = \sqrt{\frac{K}{M}}$$

With F = Frequency

K = Spring rate

M = Mass

K and M are consistent units. The relation between mass and frequency change can me expressed as follows:

$$dm = K_0\left(\frac{1}{f_1^2} - \frac{1}{f_0^2}\right)$$

with dm = Mass change

K_0 = Spring constant (incl. of the mass conversion)

f_0 = Initial frequency [Hz]

f_1 = End frequency [Hz]

After transposing the equation, it can be solved for the spring constant K_0.

$$K_0 = \frac{dm}{\frac{1}{f_1^2} - \frac{1}{f_0^2}}$$

Therefore, K_0 (= calibration constant of the device) can be determined easily by measuring the frequencies with and without known mass (e.g. with a pre-weighed TEOM-Filter from the K_0-calibration kit).

1.2 Functionality of the Measuring System

The following text is copied with minor alterations from Section 3.2 of the TÜV Rheinland Report[2].

The particle sample passes the PM_{10} pre-separator with a flow rate of 16.67 l/min (1 m³/h). Subsequently, the flow is directed over a flow-splitter and divided into two sub-flows – the PM_{10}-flow of 3 l/min and the bypass-flow of 13.67 l/min. The PM_{10}-flow is directed to the actual measuring system TEOM 1405-F *via* the FDMS-unit. There it is secreted to the respective TEOM-filter (constantly heated at 30 ℃) and the secreted mass of particles is qua ntified.

To take into account non-volatile as well as volatile particulate during the measuring, the FDMS technology is used. The FDMS-unit is placed between the flow-splitter and the measuring device TEOM 1405-F in the so called FDMS-tower. The FDMS-unit automatically compensates for the loss of the semi-volatile particulate using a switching valve and two operation modes – the base mode and the reference mode.

Every six minutes the switching valve changes the sampling flow rate from base to reference mode. In the base mode the sampling is done on a straight way *via* a dryer directly to the oscillating filter. In the reference mode the air flow is directed through a cooled filter after the dryer, to remove and restrain the non-volatile and volatile part of the particulate from the sample.

During normal operation the temperature of the cooler is maintained at constantly 4℃.Based on the mass concentration measuring during the base- and reference-mode, the FDMS-system updates every six minutes the 1h-average of the following results:

Base-MC Particle concentration of the particle-loaded sampling flow.

Ref-MC Particle concentration of the particle-free sampling flow after passing through the cooled filter.

MC Base-MC adjusted for Ref-MC Base-mass-concentration (normally positive) minus reference-mass-concentration (negative, in case mass of the filter evaporates).

After the mass determination, the sampling flows are directed over a mass flow rate regulator. To guarantee a constant sampling volume flow at the inlet, taking into account the ambient temperature and pressure, the volume flow control shall be operated in the mode “active/ actual”.

1.3 Candidate Instrument Scope and Layout

The following text is copied from Section 3.3 of the TÜV Rheinland Report[2]. This Section has been edited in order to reduce the number of photographs. In accordance with the requirements of MCERTS for UK Particulate Matter[1], discussion on the operating procedures of the instrument is given in Appendix A. The manual for the PM_{10} TEOM 1405-F is given in Appendix F.

The tested measuring unit consists of PM_{10}-sampling inlet, flow splitter, the respective sampling tubes, a tripod to support the sample tubes, the measuring device TEOM 1405-F including FDMS-tower, the vacuum pump with its respective power supply cord and cables as well as adapters, the roof lead-through including a flange and a manual in German/English.

The testing was performed with software version 1.51 (2009). During the testing the software was constantly developed and optimized up to the version 1.55. During the development, problems with the touch screen display were resolved, e.g. there have been problems with the button “reboot“ during a possible system crash.

Subsequent to the approval of the instrument in Germany, a further software update was made and released as version 1.56. This update was approved by the German Government[3]. The carried out modifications from 1.55 to 1.56 comprise the following points:

- As default the measuring devices record each 6 minutes the updated moving hourly average values. In the past the measuring system started immediately after reaching the status “ready for measurement” with the determination and recording of the measured values in the 6-min interval without taking care of a correct synchronization to the full hour. Because of this, sometimes no exact synchronization of the measured values to the full hour was possible. This is now changed by the software update, so that after the start of the measuring system, the system always first waits for the next full hour for determination and recording of the measured values and then stores the data in the following intervals hh:00 – hh:06 – hh:12 – hh:18 – hh:24…hh:54. This update of the software increases easy operation of the measuring system and has no influence on the performance of the measuring system, because only the first hour after starting up the system might be affected by possible delays due to the applied change.
- Furthermore a couple of small bugs in the software have been corrected, which exclusively increase the safe operation of the systems and have no influence on the performance of the systems themselves.

Within the scope of the testing, after the second field test site (Teddington (Summer)) a modification of the measuring system from configuration C to D was made. In the following lab test and the two field test campaigns in Germany, no negative influence on the instrument performance could be observed. Table 3 summarises the components that were changed on the instruments.

Figure 2: Overview of complete system TEOM 1405-F Ambient Particulate Monitor including American PM_{10}-sampling inlet (Original style, p/n 57-000596-0001).

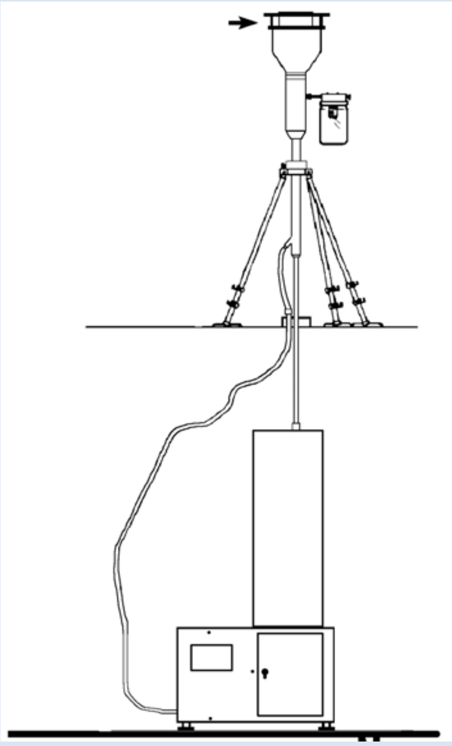


Figure 3: Measuring device TEOM 1405-F Ambient Particulate Monitor (1st system from left) in measuring station

Table 3: Instrument modifications after field test site "Teddington (Summer)"

No.	Component	Configuration C	Configuration D	Reason	Assessment
1	Mass Transducer Hinge	Belville washer spring with machined hinge blocks	Coil compression spring	Simplification of the manufacturing	No influence on the instrument performance
2	Mass Transducer Latch	High force screw latch	Consistent force hook latch	Simplification of the operability	No influence on the instrument performance
3	Mass Transducer Shipping Bracket	Not available	Removable plate couples mass transducer to enclosure	For the protection of the device during transport.	No influence on the instrument performance
4	Air Tube, Tower top interface	Rubber isolators between bulkhead fitting and cover	Direct connection using bulkhead fitting	Simplification of the manufacturing	No influence on the instrument performance
5	Diverter valve shipping bracket	Not available	Bracket coupling valve to tower	For the protection of the device during transport.	No influence on the instrument performance
6	Air tube / Valve coupler	Direct connection between weldment air tube and valve fitting	Sorbothane isolator between weldment air tube and valve fitting	Higher flexibility, compensation of thermal stress in the material.	Improvement of the instrument performance due to increased operating reliability.

Table 4 contains a list of the most important device-related characteristics of the particulate ambient air measuring device TEOM 1405-F Ambient Particulate Monitor.

Table 4: Device-related characteristics TEOM 1405-F Ambient Particulate Monitor (manufacturer information)

Dimensions / Weight	**TEOM 1405-F Ambient Particulate Monitor**
Measuring device	432 x 483 x 1400 mm / 33 kg (without pump)
Sampling tube	approx. 0.3 m between Inlet and Flow-Splitter + 1 m between Flow-Splitter and inlet of central unit
Sampling inlet	US, Original Style
Energy supply	100/115/230 V, 50/60 Hz
Power input	Approx. 100-130 W (normal operation), central unit Approx. 550-600 W (normal operation), pump
Ambient conditions	

Temperature	+8 - +25 ℃
Humidity	Non condensing
Sampling flow rate (Inlet)	16.67 l/min = 1 m³/h
Flow-rate PM_{10}-Path Flow-rate Bypass	3 l/min 13.67 l/min
Filter material (TEOM)	Pallflex TX40
Mass measured values	MC moving 1h-average, updated every 6 minutes 1-Hr-MC moving 1h-average, updated every 60 minutes on the full hour 8-Hr-MC moving 8h-average, updated every 60 minutes on the full hour 12-Hr-MC moving 12h-average, updated every 60 minutes on the full hour 24-Hr-MC moving 24h-average, updated every 60 minutes on the full hour
Detector	Mass transducer
Checks	Cont.: Noise < 0.1 µg Frequency in the range 150-400 Hz Discont.: Check of the calibration constant K_O
Parameter instrument temperatures	
Nominal value for the following instrument temperatures: Mass transducer cap Mass transducer case PM_{10} air tube	 30 ℃ 30 ℃ 30 ℃
Parameter FDMS	
Dryer type Temperature dryer (normal conditions): Dew point of the air flows (normal conditions): Pump vacuum:	NAFION-Dryer, Type C 4 ℃ at >2 ℃ Warning message > 510 mm Hg
Storage capacity data (internal)	500.000 Data set (>2000d when storage in a 6-minute interval)
Device in- and outputs	1 x 25-pin USER I/O interface for analogue in- and output and digital output 1 x RS232 interface for the communication *via* RP Comm Software or AK Protocol 1 x Ethernet-interface for the connection with a PC for data transfer and remote control *via* ePort Software 2 x USB-interfaces for the direct data download and for Firmware-update

2. Scope of Equivalence Testing

As discussed in Section 1, the PM_{10} TEOM 1405-F is based on the measuring principle of oscillating micro weighing with correction for the loss of volatile particulates from the oscillating filter. The Reference Method conversely takes 24 hour samples on to filters which are weighed on a balance before and after sampling. As such, there are significant differences between the Candidate and Reference methods, necessitating that the full test procedures are undertaken as discussed in MCERTS for UK Particulate Matter.

There should be a total of at least four field tests of at least 40 data points at locations. The field test was carried out at the following test sites (Table copied from the TÜV Rheinland Report[2]):

Table 5: Field test sites

No.	Measuring test site	Period	Characterisation
1	Teddington (UK), winter	12/2009 – 03/2010	Urban background
2	Teddington (UK), summer	04/2010 – 07/2010	Urban background
3	Cologne (Germany), parking lot, winter	01/2011 – 05/2011	Urban background
4	Bornheim (Germany), motorway parking lot,	07/2011 – 10/2011	Rural structure + traffic influence

As all of the field tests were conducted before the publication of MCERTS for UK Particulate Matter (31st July 2012), allowances are made for the scope of the field tests:

1. It is not necessary that all the field test sites have a similar pollution climate similar to that of the UK, though these calculations are presented herein;
2. There is a requirement for there to be only at least one UK field test, though the PM_{10} TEOM 1405-F had two UK tests;
3. There is no requirement that two collocated reference methods are used for each field test, though two reference methods were used in all four tests;
4. There is no requirement for there to be at least 90 % data availability, though these calculations are presented herein.

3. Conditions for which Equivalence is Claimed

The requirements of CEN/TS16450:2013[5] are that measurement ranges are defined as:

- 0 µg/m^3 to 1000 µg/m^3 as a 24-hour average value; and
- 0 µg/m^3 to 10000 µg/m^3 as a 1-hour average value if applicable.

At the measuring devices, measuring ranges up to a maximum of 0 to 1000000 µg/m^3 can be set.

A measurement range of 0 to 1000 µg/m^3 is recommended in the TÜV Rheinland Report[2] as a "default setting of the analogue output for European conditions". It is recommended that this is also adopted for UK purposes.

While the concentrations observed in the four field campaigns were significantly lower than these measurement ranges - as the equivalence calculations have been made relative to the 24 hour Reference Method - we suggest that the PM_{10} TEOM 1405-F is certified for the measurement range:

- 0 µg/m^3 to 1000 µg/m^3.

The pollution climate calculations are presented in Section 15. These calculations show that the requirements for the sites to be of a similar pollution climate to the UK, and for there to be a suitable range of wind speed, temperature, dew point and volatile components are all met. The field test sites utilised cover urban background, rural and traffic locations. We propose, therefore, that this instrument is suitable for use at urban background, rural and traffic locations within the UK.

4. Sources of Uncertainty for the Reference Method

The reference methods used in the field tests were the Small filter device “Low Volume Sampler LVS3” manufactured by Sven Leckel GMBH (Berlin, Germany). The samplers were operated with 47 mm Emfab (Teflon-coated glass fibre) filters manufactured by Pall (Port Washington, New York, USA). These instruments are single-shot samplers that require the filters to be changed manually, and are defined in the current PM_{10} standard (EN12341:1998[6]).

While Emfab filters are not listed in the 1998 standard, they are allowed in the later $PM_{2.5}$ standard (EN14907:2005[7]) as well as the final draft of the revised PM_{10} and $PM_{2.5}$ standard (fprEN12341:2013[4]).

The weighing procedures employed are summarised in Appendix B. Weighing procedures have been updated since the current PM_{10} standard EN12341:1998[6] was published. The weighing procedures herein were conducted to the $PM_{2.5}$ standard EN14907:2005[7]. The final draft of the revised PM_{10} and $PM_{2.5}$ standard fprEN12341:2013[4] requires a weighing procedure that is almost identical to that of EN14907:2005[7], and differs primarily in that the RH range has been reduced from 45 - 55 % to 45 - 50 %.

In terms of the physical differences between the LVS3 and the final draft of the revised PM_{10} and $PM_{2.5}$ standard, the final draft of the revised PM_{10} and $PM_{2.5}$ standard states the following:

“The present European Standard represents an evolution of earlier European Standards (EN 12341:1998 and EN 14907) through the development of the 2,3 m^3/h sampler to include sheath air cooling, the ability to cool filters after sampling, and the ability to monitor temperatures at critical points in sheath air cooling the sampling system. It is recommended that when equipment is procured, that it complies fully with the present European Standard. However, older versions of these 2,3 m^3/h samplers that do not employ sheath air cooling, the ability to cool filters after sampling, or the ability to monitor temperatures at critical points in the sampling system have a special status in terms of their use as reference samplers. Historical results obtained using these samplers will remain valid. These samplers can still be used for monitoring purposes and for equivalence trials, provided that a well justified additional allowance is made to their uncertainties.”

As the field tests of the PM_{10} TEOM 1405-F pre date the publication of the finalised standard and it’s enacting through a revised Air Quality Directive, it is not necessary to consider the difference between the instrument used and the future standard. However, for completeness, the potential effects are as follows:

In the herein described field tests, the filters were manually changed in the LVS3s within 15 minutes of the sampling stopping and immediately transferred to the filter conditioning room (both UK and Germany); refrigerated (UK); or stored inside at 20 ºC (Germany). This removes the need for the instrument to automatically change filters and then cool the sampled filters. A difference between the reference method used and the future PM_{10} standard is that there is sheath air cooling in the later standard. As the filters were changed between 7 and 10 am each morning, this is before the ambient temperature reached a level capable of volatilising ammonium nitrate from the sampled filters, and it is expected that losses due to the absence of sheath air cooling would be minimal.

5. Competencies of the Laboratories Involved

Two organisations (TUV Rheinland and NPL) were involved in the field and laboratory testing.

TÜV Rheinland Energie und Umwelt GmbH are accredited for the following work areas according to ISO 17025[9]:

- Determination of emissions and ambient airs of air pollution and odour substances;
- Inspection of correct installation, function and calibration of continuously running emission measuring devices including systems for data evaluation and remote monitoring of emissions;
- Suitability testing of measuring systems for continuous monitoring of emissions and ambient airs, and of electronic systems for data evaluation and remote monitoring of emissions

The accreditation is valid up to 31-01-2013. DAkkS-register number: D-PL-11120-02-00.

The National Physical Laboratory are accredited for the following work areas according to ISO 17025:

- determination of particulate mass collected on filters; and
- determination of particulate analyser flow rates.

These services were last accredited on the 22nd October 2012, and the 28th November 2012 respectively by the United Kingdom Accreditation service (UKAS).

Extracts of the ISO 17025 accreditations are given in Appendix C.

9 ISO Standard 17025:2005 General requirements for the competence of testing and calibration laboratories

LABORATORY TEST PROGRAMME

6. Parameters Tested in the Laboratory Programme

As the Candidate Method is not a variation of the Reference Method, only two tests are required to be undertaken in the laboratory in accordance with MCERTS for UK Particulate Matter. These include:

- Constancy of the sample Volumetric Flow; and
- Tightness of the Sampling System.

It is also necessary to consider the:

- Maintenance Interval.

These tests were undertaken and are discussed in detail in Sections 7 and 8. These tests were undertaken under field conditions rather than laboratory conditions.

A number of other tests were undertaken by TÜV Rheinland in accordance with the requirements of the German Government. These tests are:

- Measured value display;
- Easy maintenance;
- Functional test;
- Set up times and warm up times;
- Instrument design;
- Unintended adjustment;
- Data output;
- Certification ranges;
- Negative output signals;
- Failure in the mains voltage;
- Operating states;
- Switch-over;
- Instrument software;
- Repeated standard deviation at zero point;
- Repeated standard deviation at reference point;
- Linearity (Lack of fit);
- Sensitivity coefficient of the surrounding temperature;
- Sensitivity coefficient of the electric voltage;
- Standard deviation from paired measurements;
- Long-term drift;
- Equivalency of the sampling system;
- Reproducibility of the sampling systems ;
- Calibration;
- Cross-sensitivity;
- Averaging effect.

These tests are not detailed in this report, and further details can be found in the TÜV Rheinland Report[2].

7. Laboratory Test Procedures Used

The laboratory test was carried out with two identical devices of TEOM 1405-F Ambient Particulate Monitor measuring system with the serial numbers SN 20006 and SN 20107. These are the same two devices as were used in the field tests.

In order to improve the clarity of the report, the Laboratory test procedures used (Section 7) and the Laboratory test results (Section 8) are considered together for each of the three tests in turn.

8. Laboratory Test Results

8.1. Constancy of Sample Volumetric Flow

MCERTS for UK Particulate Matter[1] lists the following requirement for constancy of the sample volumetric flow:

> *"Constancy of the sample volume flow, is tested as specified in the MCERTS Standard, using selective filters loaded with particulates to 80%, 50% and 0% of the maximum permissible filter loading specified, and the constancy of the sample volumetric flow is recorded as a 3 minute average every 30 minutes for at least 24 hours – to remain constant within ± 3% of the rated value"*

The following text is copied with minor alterations from Section 6.1 - 5.4.7 of the TÜV Rheinland Report[2].

Equipment

A flow meter was provided.

Performance of test

The sample volumetric flow was calibrated before the first field sampling test site and tested for its accuracy before each field sampling test site, using a dry gas meter or a mass flow meter, and readjusted if necessary.

For the measuring device TEOM 1405-F Ambient Particulate Monitor, a total flow rate of 16.67 l/min at the inlet is split in two sub flows, the PM_{10}-path with 3 l/min and the Bypass with 13.67 l/min.

To determine the constancy of the relevant sample volumetric flow, a flow rate for PM_{10} and a total flow rate for the test site Cologne (Winter), which partly was characterized by high concentrations and filter loads up to >50 %, were recorded in the candidates and the flow rates were evaluated on a 24 h-basis.

Evaluation

From the determined average for the flow rate, average, standard deviation, and maximum and minimum values were defined.

Assessment

The results from the performed flow rate checks before each field test site are represented in Table 6.

Table 6: Summary of the Flow Check Results

Flow rate check before		SN 20006		SN 20107	
Test site		[l/min]	Deviation from nominal value [%]	[l/min]	Deviation from nominal value [%]
Teddington (Winter)	PM_{10}	3.02	0.67	3.02	0.67
	Total	16.61	-0.36	16.77	0.60
Teddington (Summer)	PM_{10}	3.14	4.66	3.07	2.33
	Total	17.35	4.08	16.96	1.74
Cologne (Winter)	PM_{10}	2.96	-1.33	3.05	1.67
	Total	16.40	-1.62	16.22	-2.70
Bornheim (Summer)	PM_{10}	3.08	2.67	2.80	-6.67
	Total	16.73	0.36	16.73	0.36

Detailed representation of the test results

In Table 7 and Table 8 the determined parameter for the flow are shown. Figure 4 to Figure 9 on the following pages show the graphical representation of the flow measurements at both candidates SN 20006 and SN 20107.

Table 7: Parameter for the total flow measurement (24h-average, Cologne (Winter)), SN 20006

No. of 24h values	Average [l/min]	Dev. from nominal value [%]	Std. Dev. [l/min]	Max [l/min]	Min [l/min]
106	16.65	-0.096	0.02	16.77	16.56

Table 8: Parameter for the total flow measurement (24h-average, Cologne (Winter)), SN 20107

No. of 24h values	Average [l/min]	Dev. from nominal value [%]	Std. Dev. [l/min]	Max [l/min]	Min [l/min]
106	16.67	0.001	0.02	16.73	16.59

Conclusion for UK Purposes

As the highest deviation from the nominal value is -0.096%, it is this value that should be transferred to the MCERTS certificate. This is less than the required ± 3%. The flow rate tests were done under flow conditions at a variety of filter loadings as opposed to 0%, 50 % and 80% of the mass load as prescribed in MCERTS for UK Particulate Matter[1]. The variable filter load is not a requirement in Technical Specification CEN/TS16450[5].

Figure 4: *Time series of the PM-concentration [µg/m³] and the filter load [%], Candidate SN 20006, Cologne (Winter)*

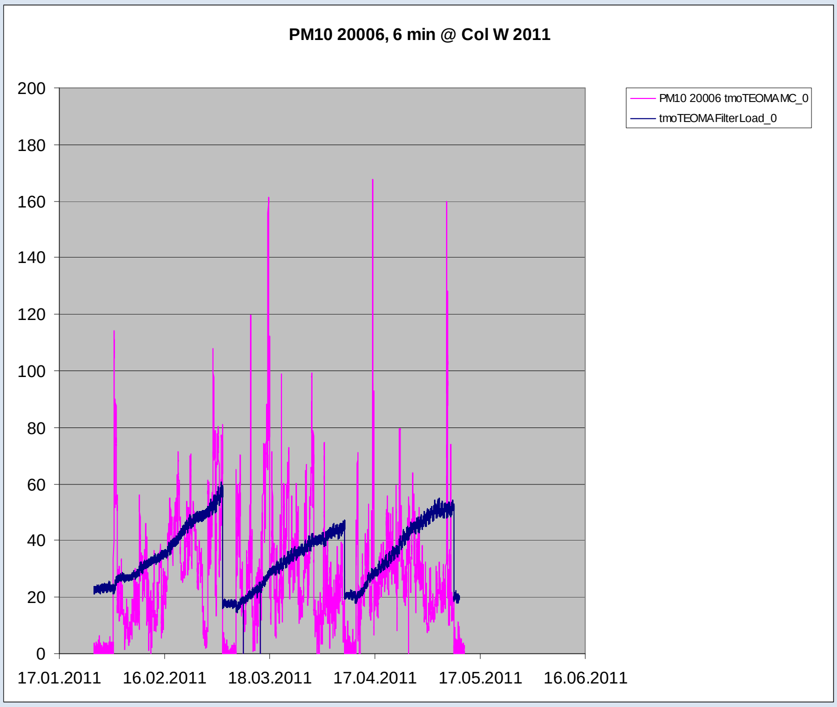


Figure 5: *PM_{10}-flow rate at candidate SN 20006, Cologne (Winter)*

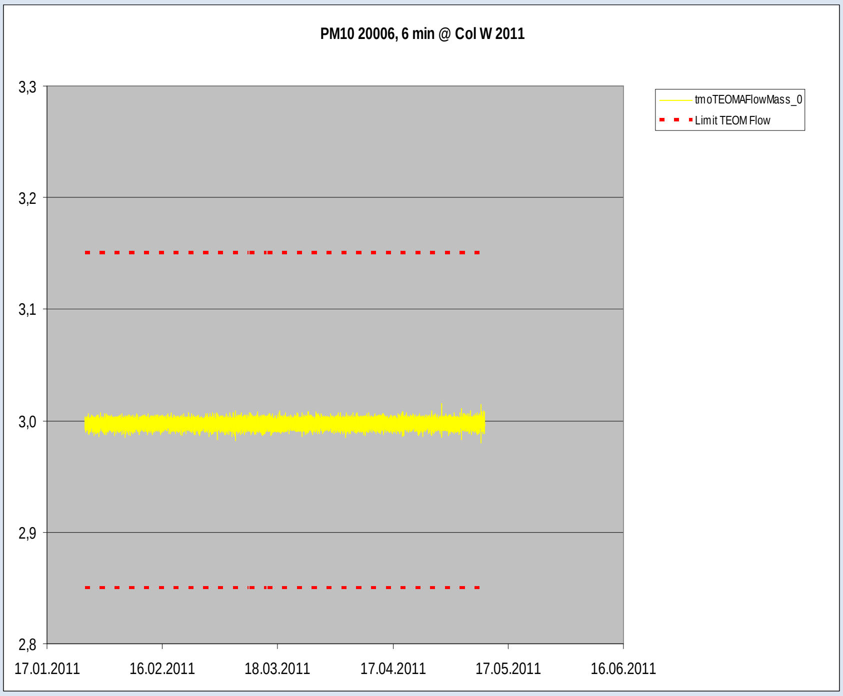


Figure 6: Total flow rate at candidate SN 20006, Cologne (Winter)

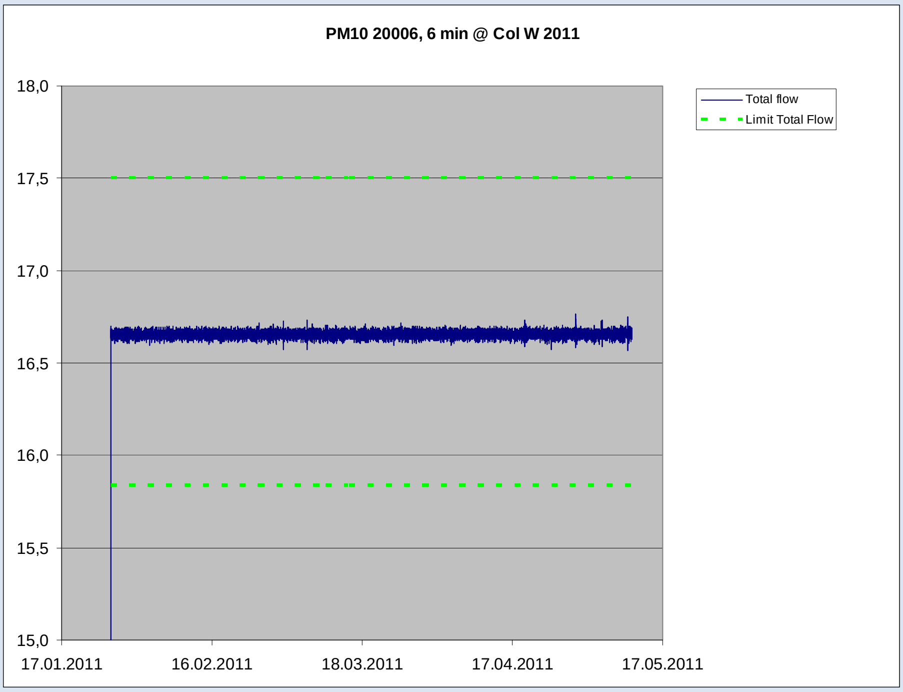


Figure 7: Course of time of the PM-concentration [µg/m³] and the filter load [%],Candidate SN 20107, Cologne (Winter)

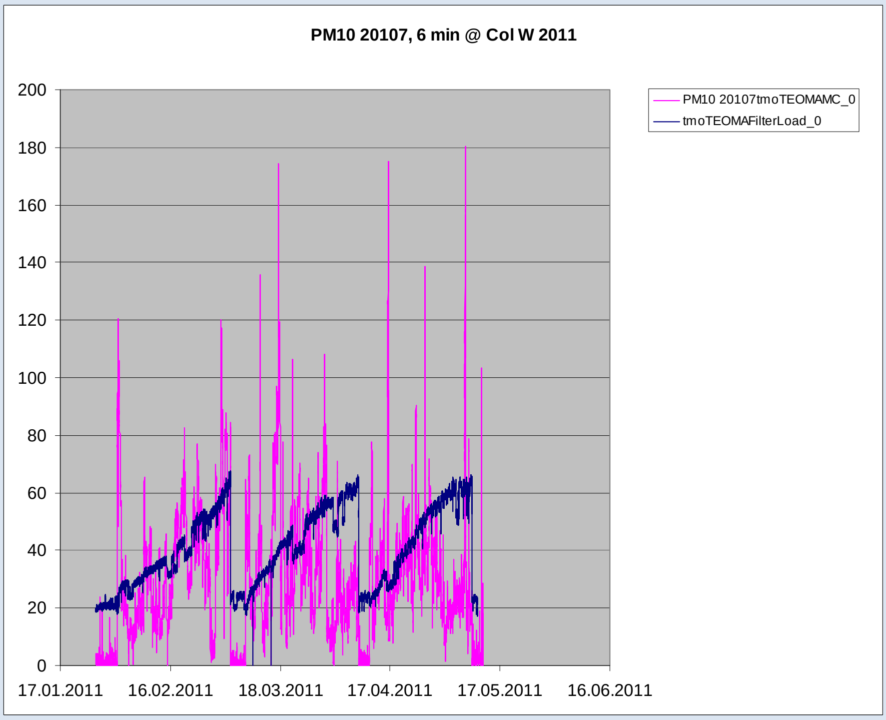


Figure 8: PM_{10}-flow rate at candidate SN 20107, Cologne (Winter)

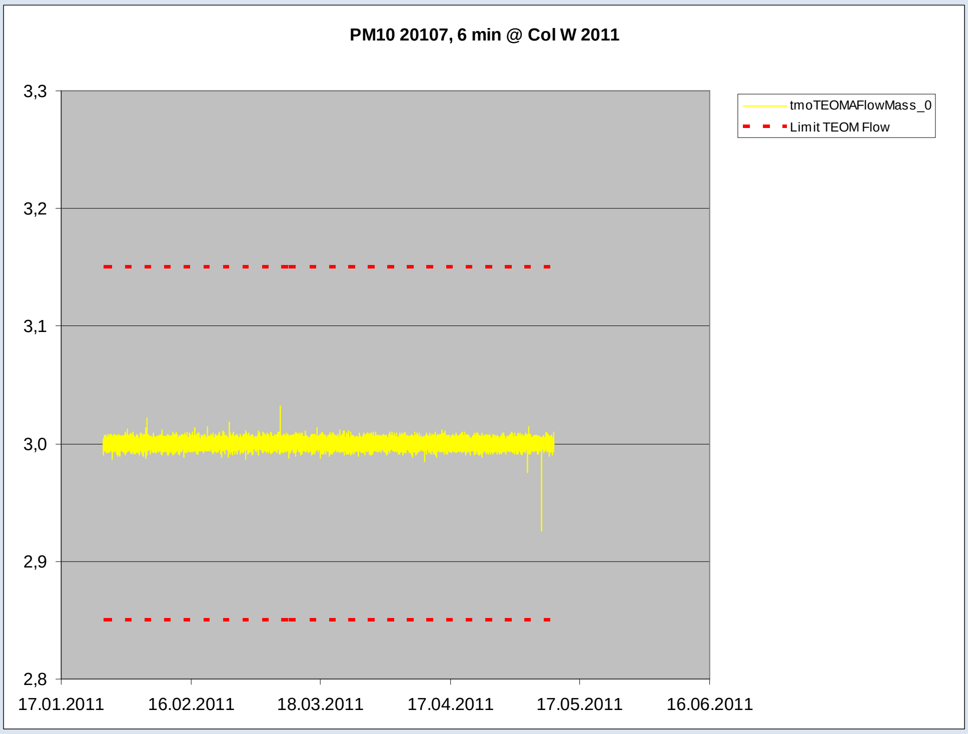
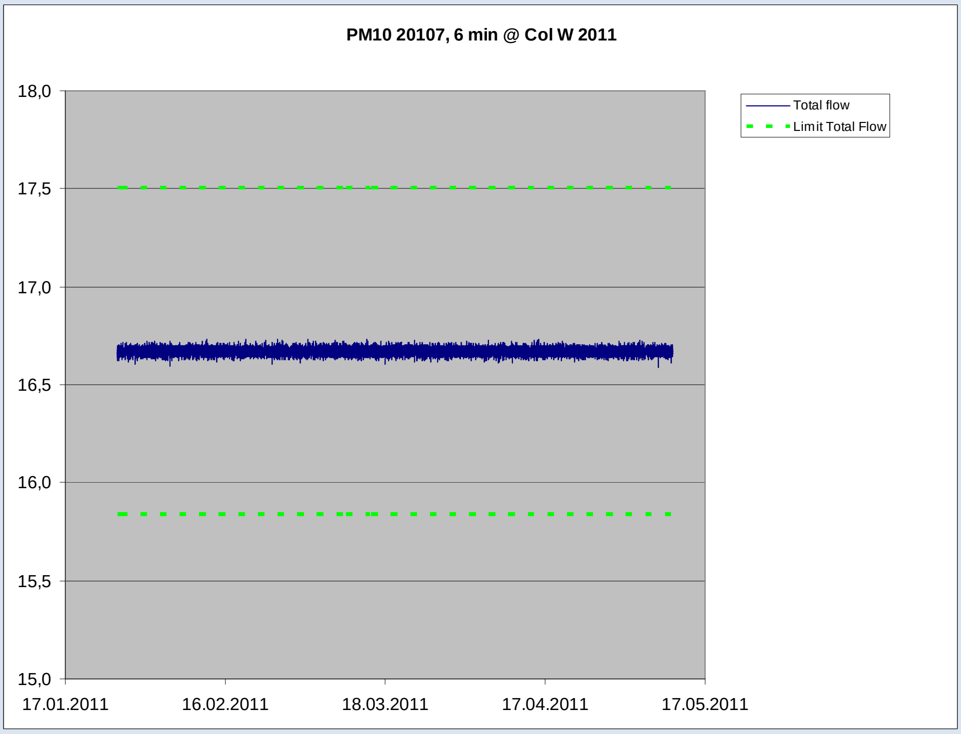


Figure 9: Total flow rate at candidate SN 20107, Cologne (Winter)



8.2. Tightness of the Measuring System

MCERTS for UK Particulate Matter[1] lists the following requirement for the tightness of the measuring system:

> *"The leak tightness of the sampling system is carried out using flow and pressure monitoring equipment to determine the leak rate of the entire instrument where feasible, or by evaluating the leaks of different parts separately. The tests can be made by measuring the volume flow at the inlet and outlet of the system, or by determining the pressure – to achieve the performance criterion shall not exceed 1 % of the sample volume."*

The following text is copied with minor alterations from Section 6.1 - 5.4.8 of the TÜV Rheinland Report[2].

Equipment

Adapter for flow rate check/ tightness check

Performance of test

The TEOM 1405-F Ambient Particulate Monitor can perform a tightness check using an internally implemented "tightness check assistant".

The tightness check assistant compares the different measured values between zero flow (with the vacuum turned off) and flow through the device when the inlet is blocked (ideally again a zero flow should be measured).

The tightness check is considered as passed when the flow values with a blocked inlet deviate no more than 0.15 l/min from zero flow at the PM_{10}-path and no more 0.60 l/min from zero flow at the bypass-path.

The tightness check includes the base path as well as the reference path.

The tightness check may only be performed using the tightness check assistant in order to avoid damages of the instrument.

This procedure has been carried out at the beginning of each field test site.

It is recommended to check the tightness of the TEOM 1405-F once a month using the described procedure.

Evaluation

The tightness check *via* the tightness check assistant was done at the beginning of each field test site.

The criteria for approving the tightness check implemented by the manufacturer – a deviation of the flow values at a blocked inlet of no more than 0.15 l/min from zero flow at the PM_{10}-path and no more 0.60 l/min from zero flow at the bypass-path – were approved as appropriate parameters for the monitoring of the device tightness.

The tightness check may only be performed using the tightness check assistant to avoid damage to the instrument.

Assessment

The criteria for passing the tightness check implemented by the manufacturer – a deviation of the flow values at a blocked inlet of no more than 0.15 l/min from zero flow at the PM_{10}-path and no more than 0.60 l/min from zero flow at the bypass-path – were approved by TÜV Rheinland as appropriate parameters for the monitoring of the device tightness.

The tightness check may only be performed using the tightness check assistant to avoid damages of the instrument.

Detailed representation of the test results

Table 9 contains the determined values from the tightness check

Table 9: Results of the tightness check during field test expressed as l/min

		SN 20006			SN 20107		
		Limit [l/min]	Base [l/min]	Reference [l/min]	Limit [l/min]	Base [l/min]	Reference [l/min]
Teddington (Winter)	PM_{10}	0.15	-0.01	-0.01	0.15	-0.06	0.06
	Bypass	0.60	0.0	0.0	0.60	0.16	0.19
Teddington (Summer)	PM_{10}	0.15	0.0	0.0	0.15	0.04	0.04
	Bypass	0.60	0.14	0.14	0.60	-0.07	-0.07
Cologne, (Winter)	PM_{10}	0.15	-0.06	-0.06	0.15	0.04	0.04
	Bypass	0.60	0.11	0.11	0.60	0.0	0.0
Bornheim (Summer)	PM_{10}	0.15	-0.05	-0.05	0.15	0.06	0.06
	Bypass	0.60	0.07	0.08	0.60	0.0	0.0

Table 10 shows the same results as Table 9 expressed as a percentage by dividing by the flow rate. This table is not presented in the TÜV Rheinland Report, and is included here for UK purposes.

Table 10: Results of the tightness check during field test expressed as %

		SN 20006			SN 20107		
		Limit [%]	Base [%]	Reference [%]	Limit [%]	Base [%]	Reference [%]
Teddington (Winter)	PM_{10}	5.00	-0.33	-0.33	5.00	-2.00	2.00
	Bypass	4.39	0.00	0.00	4.39	1.17	1.39
Teddington (Summer)	PM_{10}	5.00	0.00	0.00	5.00	1.33	1.33
	Bypass	4.39	1.02	1.02	4.39	-0.51	-0.51
Cologne, (Winter)	PM_{10}	5.00	-2.00	-2.00	5.00	1.33	1.33
	Bypass	4.39	0.80	0.80	4.39	0.00	0.00
Bornheim (Summer)	PM_{10}	5.00	-1.67	-1.67	5.00	2.00	2.00
	Bypass	4.39	0.51	0.59	4.39	0.00	0.00

Conclusion for UK Purposes

As the greatest leak detected is 2.00%, it is this value that should be transferred to the MCERTS certificate. This is greater than the required 1%; however, the leak test procedure for the 1405-F is an internal manufacturer's procedure, implemented in the instruments in order to avoid serious damage to the instrument. The check on tightness must be performed using this internal procedure. All of the leak tests conducted passed the manufacturer's leak test specifications, and it is recommended that this performance is sufficient in order to warrant approval of the instrument subject to an explanation being provided on the MCERTS certificate.

8.3. Maintenance Interval

MCERTS for UK Particulate Matter[1] lists the following requirement for the Maintenance Interval of the measuring system:

> *"Frequency of the QA/QC checks etc. shall be the same as those intended for the operational field conditions, to the extent that it is demonstrated that no additional uncertainty terms would arise during subsequent field operation (e.g. greater drift occurs between calibrations due to longer periods between checks). Otherwise an extra uncertainty term shall be added to provide the overall uncertainty during operational field conditions, and this then shall conform to the Directive's data quality objectives [Directive 2008/50/EC Annex I, and GDE2010 Annex D]."*

Within Directive 2008/50/EC[10] there is no guidance as to the maintenance interval. Within GDE2010[8], it is recommended that maintenance is required as per the manufacturer's instructions. There is however no guidance as to an absolute maintenance interval.

Within CEN/TS16450[5] there is very clear guidance, namely: "*The maintenance interval is the longest time without intervention as recommended by the manufacturer.*" During this period the instrument shall not need any maintenance or adjustment. The minimum maintenance interval is defined as "*at least 14 days*".

For the MCERTS certification process for instruments assessed prior to the launch of MCERTS for UK Particulate Matter[1], the minimum maintenance interval was defined as two weeks.

Further, the TÜV Rheinland Report[2] defines the minimum maintenance interval as:

> *"The maintenance interval of the measuring system shall be determined during the field test and specified. The maintenance interval should be three months, if possible, but at least two weeks."*

It is therefore recommended that the minimum maintenance interval is defined as ≥ 2 weeks.

The following text is copied with minor alterations from Sections 6.1 – 4.1.2 and 6.1 – 5.2.7 of the TÜV Rheinland Report[2].

Equipment

No additional equipment is required.

Performance of test

This test was done in order to determine which maintenance procedures are required at which period to maintain correct functionality of the measuring system. Moreover, the results of the drift test for zero and span point according to the long-term drift were included into the determination of the maintenance interval.

Necessary regular maintenance works were carried out according to the instructions of the operating manual.

Evaluation

No unacceptable drifts were detected for the measuring systems during the entire field test period.

The following maintenance works should be carried out:

1. Check of device status: The device status can be monitored and controlled by controlling the system itself or controlling it online.
2. In general the sampling inlet shall be cleaned according to the manufacturer's instructions taking into account the local suspended particulate matter concentrations (during suitability test every 4 weeks).
3. A monthly change of the TEOM-Filter (as well when a filter loading >90% is reached) is necessary.
4. Simultaneously with the change of the TEOM-filter, the cooled 47 mm-filter of the FDMS-unit has to be changed.
5. According to the manufacturer's instructions, a monthly check of the sensors for ambient air and ambient pressure shall be done.
6. According to the manufacturer's instructions, a monthly leak-check shall be done.
7. According to the manufacturer's instructions, a monthly check of the flow rate shall be done.
8. Every 6 months (or if necessary) the inline-filter for PM_{10}- and the Bypass-path shall be changed in order to avoid a contamination of the flow rate regulator.
9. Once a year (or if necessary) the cooler, the switching valve and the air inlet system shall be cleaned.
10. Once a year the calibration of the mass transducer has to be checked using the K_0-check kit.
11. Once a year (or if necessary) the dryer of the FDMS-unit shall be changed or refurbished. For the monitoring/ securing of a proper dryer performance, the manufacturer recommends to monitor a pump vacuum (nominal: > 510 mm Hg) and a dew point of the air flow (nominal: <2 ℃ at 4 ℃ cooler temperature) as well as to carry out periodical (at least once a year) zero point checks (running of the measuring device with zero-filter at the inlet).
12. Every 18 months (or if necessary) the sampler pump shall be maintained or renewed.

To carry out the maintenance works the instruction of the manual (chapter 5) are to be taken into account. All works can usually be carried out with commonly available tools.

Assessment

Maintenance works can be carried out with commonly available tools taking reasonable time and effort. For the maintenance works as per points 3, 4, 6 and 10, the device is switched to setup-mode. The restart of the normal measuring process occurs after one hour after having finished the check and after having left the setup-mode. The maintenance works as per points 8, 9, 11 and 12 can only be done when shutting off the measuring device. These works come up every 6 or 12 months. In the remaining time, maintenance works are limited to the check of contaminations, plausibility checks and eventual status/ error messages.

Detailed representation of the test results

The maintenance works were carried out during the test in accordance with the instructions given in the manual. No problems were noticed while following the described procedures. All maintenance works could be done with customary tools without taking much time and effort.

Conclusion for UK Purposes

The maintenance interval is defined by necessary maintenance procedures and is 4 weeks, and this is this value that should be transferred to the MCERTS certificate. This is greater than the required ≥ 2 weeks. Further information as to the maintenance procedures required is given in Appendix D.

FIELD EQUIVALENCE TEST PROGRAMME

9. Field Test Locations, Periods and Conditions

The following text is copied with minor alterations from Section 4.3 of the TÜV Rheinland Report[2].

The field test was carried out at the following test sites:

Table 11: Field test sites

No.	Measuring test site	Period	Characterisation
1	Teddington (UK), winter	12/2009 – 03/2010	Urban background
2	Teddington (UK), summer	04/2010 – 07/2010	Urban background
3	Cologne, parking lot, winter	01/2011 – 05/2011	Urban background
4	Bornheim, motorway parking lot, summer	07/2011 – 10/2011	Rural structure + traffic influence

Figure 10 to Figure 13 show the course of time of the PM_{10}-concentrations at the field test sites which were recorded with the reference measuring device.

Figure 10: Time Series of the PM_{10}-concentrations (Reference) at the test site: Teddington, winter

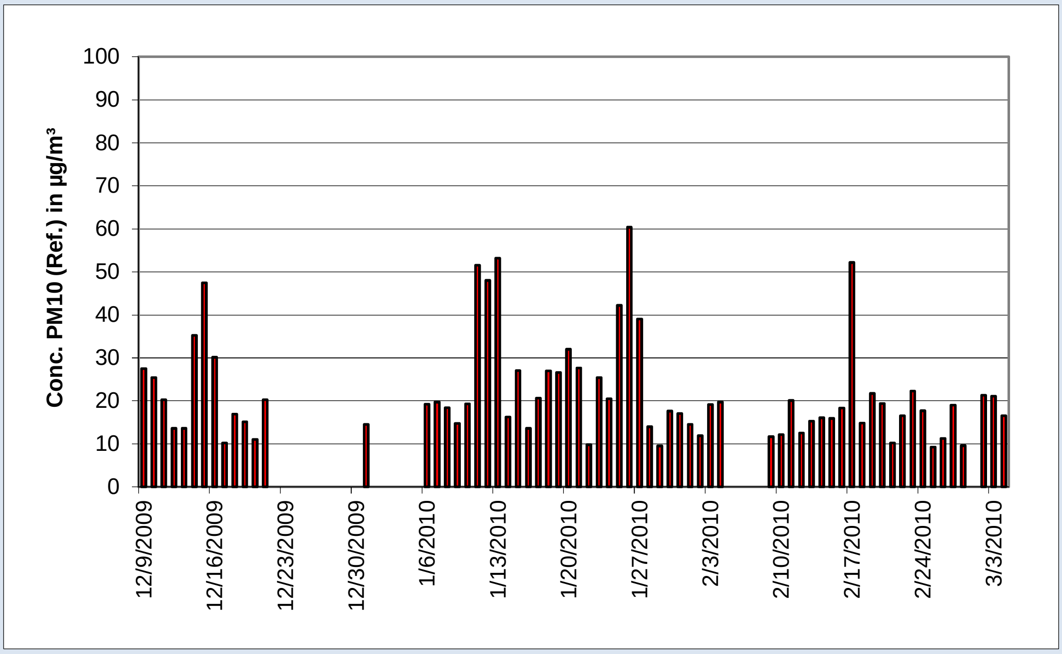


Figure 11: Time Series of the PM_{10}-concentrations (Reference) at the test site: Teddington, summer

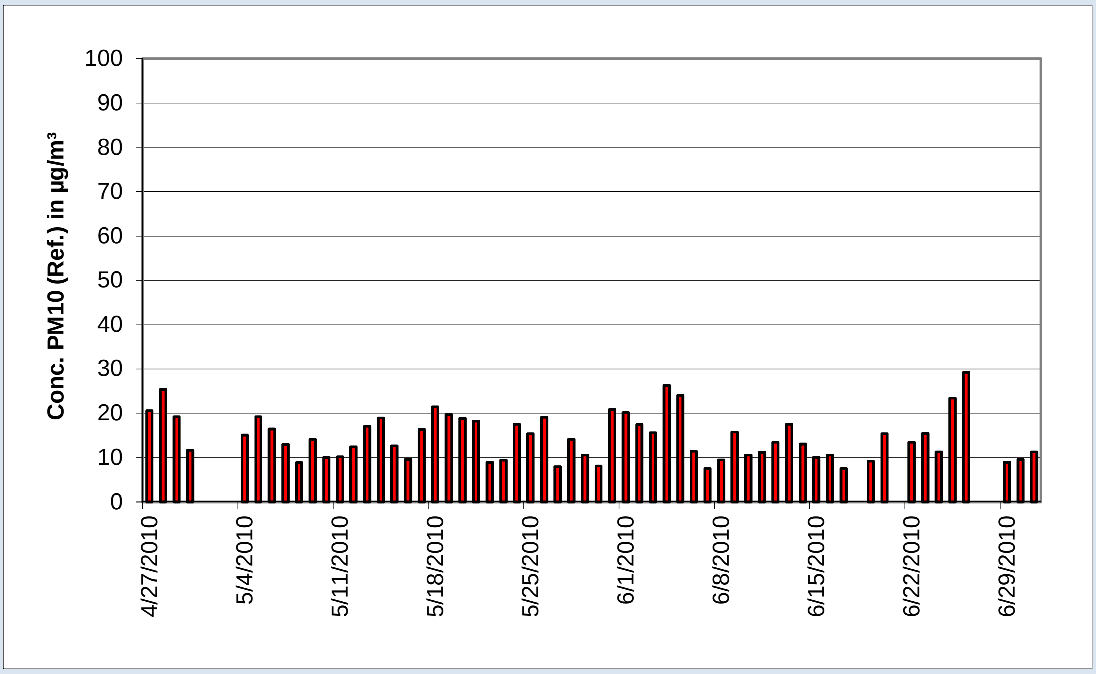


Figure 12: Time Series of the PM_{10}-concentrations (Reference) at the test site: Cologne, parking lot, winter

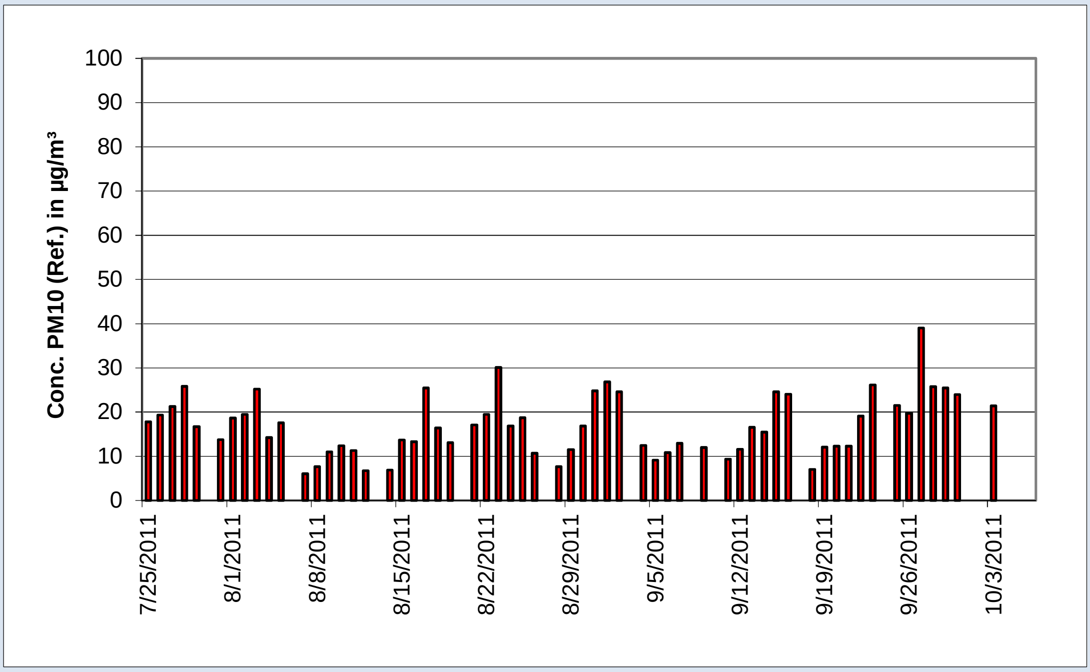
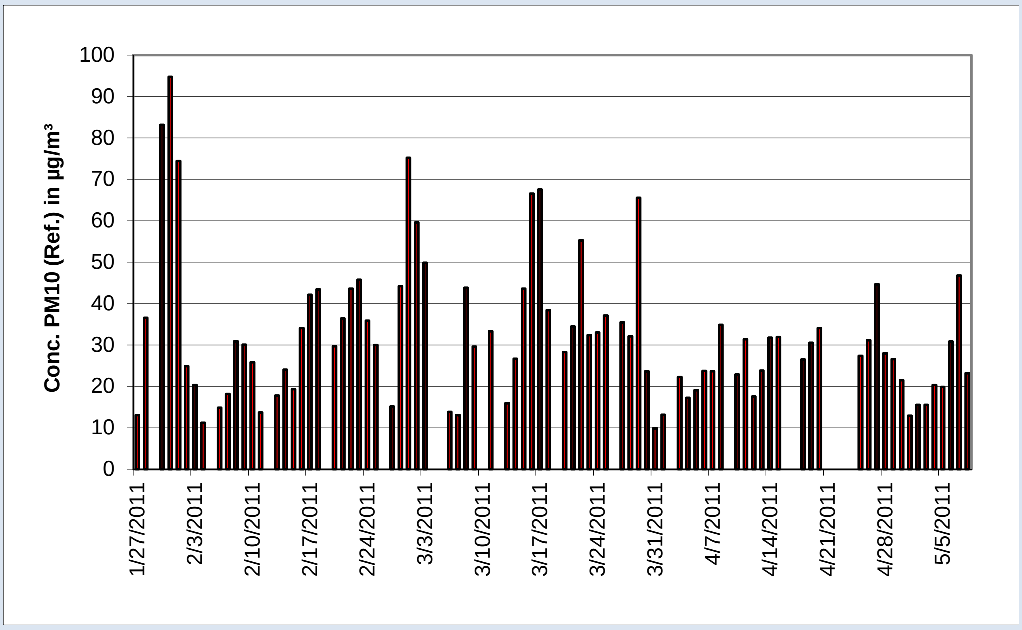


Figure 13: *Time Series of the PM_{10}-concentrations (Reference) at the test site: Bornheim, motorway parking lot, summer*



The following figures show the measuring cabinet at the field test sites Teddington, Cologne (parking lot) and Bornheim (motorway parking lot)

Figure 14: *Field test site Teddington*

Figure 15: Field test site Cologne, parking lot

Figure 16: Field test site Bornheim, motorway parking lot

Besides the measuring device for the determination of particulate ambient air, a device for the determination of meteorological characteristics was installed at the cabinet/ measuring test site. A continuous determination of ambient temperature, ambient pressure, relative humidity, wind velocity, wind direction and the amount of precipitation was made. The 30 minute (Germany) and 15 minute (UK) averages were recorded.

The following Table 12 contains therefore not only an overview on the most important meteorological data of the four test sites but also an overview on the PM conditions during the test. Section 15 gives a detailed analysis of these results.

Table 12: Ambient conditions at the field test sites, expressed as daily averages

	Teddington (UK), winter	Teddington (UK), summer	Cologne. parking lot, winter	Bornheim, motorway parking lot, summer
No. of paired values reference	67	59	83	59
Ratio $PM_{2.5}$ / PM_{10} [%]				
Range	38.8 – 90.6	30.2 – 92.3	38.8 – 93.5	24.1 – 70.6
Average	67.7	59.2	67.7	54.1
Ambient temperature [℃]				
Range	-3.7 – 9.8	6.7 – 23.2	-3.8 – 22.1	13.2 – 24.5
Average	3.1	15.4	8.8	17.9
Ambient pressure [kPa]				
Range	97.9 – 103.7	99.7 – 102.6	99.2 – 103.1	99.6 – 101.8
Average	100.6	101.2	101.3	100.7
Rel. humidity [%]				
Range	62.9 – 98.3	43.9 – 86.7	34.2 – 94.2	53.8 – 86.9
Average	87.6	63.7	67	73.9
Wind velocity [m/s]				
Range	0.0 – 2.5	0.1 – 2.3	0.3 – 7.1	0.3 – 2.9
Average	0.6	0.8	2.3	1.2
Precipitation [mm]				
Range	0.0 – 23.1	0.0 – 9.4	0.0 – 33.0	0.0 – 51.7
Average	2.3	0.7	1.4	3.3

10. Description of Equipment and Test Procedures

The following text is based upon Section 4.3 of the TÜV Rheinland Report[2].

Equipment Deployed

The field test was carried out with two identical systems with the serial numbers:

Device 1: SN 20006

Device 2: SN 20107

The following additional equipment was used for the field test:

- Measurement cabinet of TÜV Rheinland for the PM_{10} TEOM 1405-Fs. Air-conditioned to approximately 20 ℃;
- Measurement trailer of Defra for the LVS3s. Air-conditioned to approximately 20 ℃;
- Weather station (WS 500 manufactured by ELV Elektronik AG (German sites)) (MK III series manufactured by Rainwise, Bar Harbor, Maine, USA (UK Sites)) for the determination of meteorological characteristics such as air temperature, air pressure, air humidity, wind velocity, wind direction and rainfall;
- Two reference samplers LVS3 for PM_{10} (Manufacturer Sven Leckel Gmbh);
- Gas meter, dry (German Sites);
- 1 mass flow rate measuring device Type 4043 (Manufacturer: TSI) (German Sites);
- 1 mass flow rate measuring device Type Bios volumeter (Manufacturer: BIOS, Butler, New Jersey, USA) (UK Sites)
- 1 mass flow rate measuring device Type TetraCal venturi (Manufacturer: BGI, Waltham, Massachusetts, USA) (UK Sites)
- Measuring device Metratester 5 (Manufacturer: company Gossen Metrawatt) for the determination of power consumption;
- Zero-filter for external zero point check; and
- K_0-check kit.

The installation of the cabinet and trailer and the arrangement of the sampling probes were characterized by the following dimension.

- Height cabinet roof: 2.50 m;
- Height of the sampling for the Candidate:1.10 m above the cabinet roof and 3.61 m above ground;
- Height of the sampling for the Candidate: 0.5 m above the cabinet roof and 3.01 m above ground;
- Height of the wind vane: 4.5 m (Germany) and 2.5 m (UK) above ground

Reference Method

The following devices were used during the field test in accordance with EN 12341:1998[6].

Small filter device ”Low Volume Sampler LVS3”

Manufacturer: Ingenieurbüro Sven Leckel, Leberstraße 63, Berlin, Germany
Date of manufacture: 2007
PM_{10}-Sampling inlet

Two reference devices or PM_{10} were simultaneously operated during the testing with a controlled volume flow of 2.3 m³/h. The accuracy of the volume flow control is below <1 % of the nominal volume flow under standard conditions.

During the field tests, QA/QC procedures were periodically undertaken on the LVS3 devices in accordance with the manufacturer's instructions. The instruments were leak checked, and the flow rates were checked typically at the same time as they were on the Candidate Methods (Section 8). In all cases, the results of the QA/QC checks were within the required limits, and no maintenance was required on the LVS3 devices.

The electronic measuring equipment of the LVS3 small filter device displays the incoming sampling air volume in standard or operating m^3 as soon as the sampling is complete.

To determine the PM_{10} concentration, the laboratory performed a gravimetric determination of the amount of suspended particulate matter on the respective filters. The obtained result was then divided by the respective volume of sampling air in operating m^3.

The impaction plates of the PM_{10} sampling inlets of the reference devices were cleaned approximately every 2 weeks and lubricated with silicone-grease, in order to guarantee a safe separation and secretion of the particulate.

In general the sampling inlet shall be cleaned according to the manufacturer's instructions while taking into account the local suspended particulate matter concentrations.

The flow rate was tested on each reference device prior to and after each change of location with a mass flow meter, which could be connected to the air inlet of the systems *via* a hose assembly.

The measuring devices have been installed in the field test in such a way, that only the sampling inlets are located above the roof of the measurement cabinet. The central units of the reference systems were installed inside the climate-controlled measurement cabinet.

EN 12341:1998[6] defines a sampling period of 24 h. However - at lower concentration levels a longer, at higher concentration levels a shorter sampling period is permissible.

The sampling period was constantly set to 24 h during the field tests (10 am – 10 am for Teddington and Cologne, and 7 am – 7 am for Bornheim). Filters were changed manually within 15 minutes of finishing sampling, and were then refrigerated; stored inside at 20 ºC; or transferred directly to the filter conditioning room. The weighing procedures employed are summarised in Appendix B.

All paired reference values, determined during the field tests, were subject to statistical testing according to Grubbs (99 %) to prevent influences of obviously implausible data on the measuring results. Paired values, which are identified as significant outliers can be discarded until the critical value of the test statistic is exceeded. The January 2010 version of the Guidance[8] stipulates that not more than 2.5 % of the paired values in total for each field test site may be identified and removed as outliers.

It was agreed between TÜV Rheinland and BV not to discard any measured value for the candidates, unless the implausibility is caused due to technical reasons.

Table 13 shows an overview on the amount of paired values (reference) which were recognized and removed as significant outliers at each test site.

Table 13: Results Grubbs-outlier test – Reference PM_{10}

Graph Number	Site	Sampler	Number of data-pairs	Maximum Number that can be deleted	Number Identified	Number Deleted	Number of data-pairs remaining
A	Teddington Summer	PM_{10} KFG	61	2	2	2	59
B	Cologne Winter	PM_{10} KFG	84	2	1	1	83
C	Bornheim Summer	PM_{10} KFG	59	1	0	0	59
D	Teddington Winter	PM_{10} KFG	69	2	3	2	67

The data pairs removed are described in Table 14 and shown graphically in Figure 17 through to Figure 20:

Table 14: Removed data pairs reference PM_{10} according to Grubbs

Test site	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]
Teddington (Winter)	22.12.2009	32.7	34.3
Teddington (Winter)	05.01.2010	20.1	18.7
Teddington (Summer)	21.06.2010	14.1	15.7
Teddington (Summer)	28.06.2010	17.9	19.4
Cologne (Winter)	04.03.2011	83.3	87.5

Figure 17: Grubbs test results for the PM_{10} reference method, Teddington (Winter)

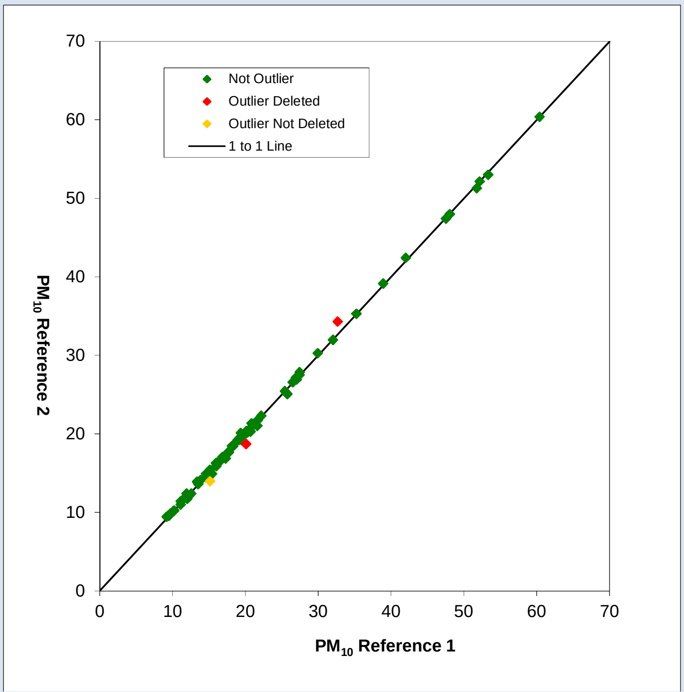


Figure 18: Grubbs test results for the PM_{10} reference method, Teddington (Summer)

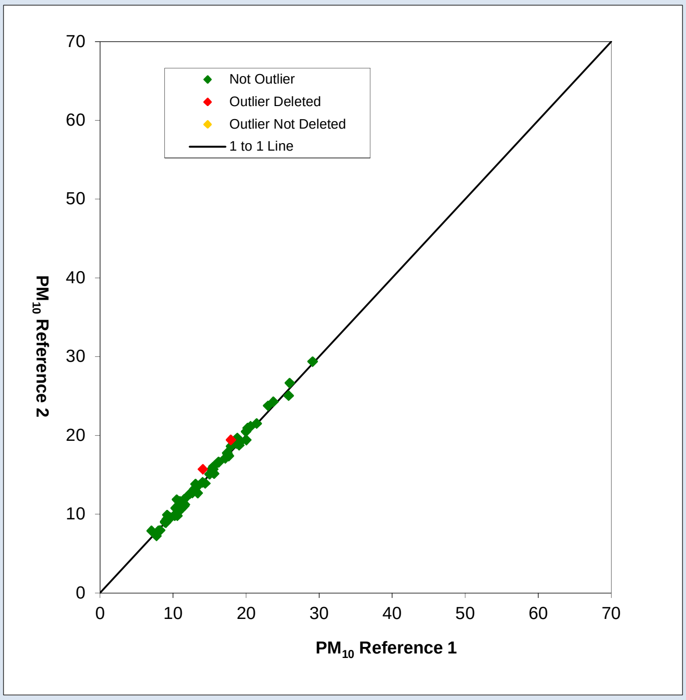


Figure 19: Grubbs test results for the PM_{10} reference method, Cologne (Winter)

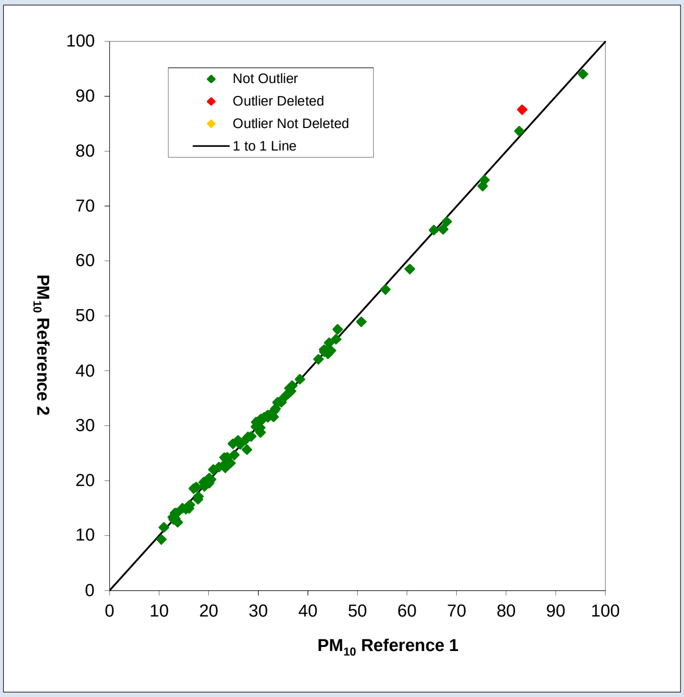
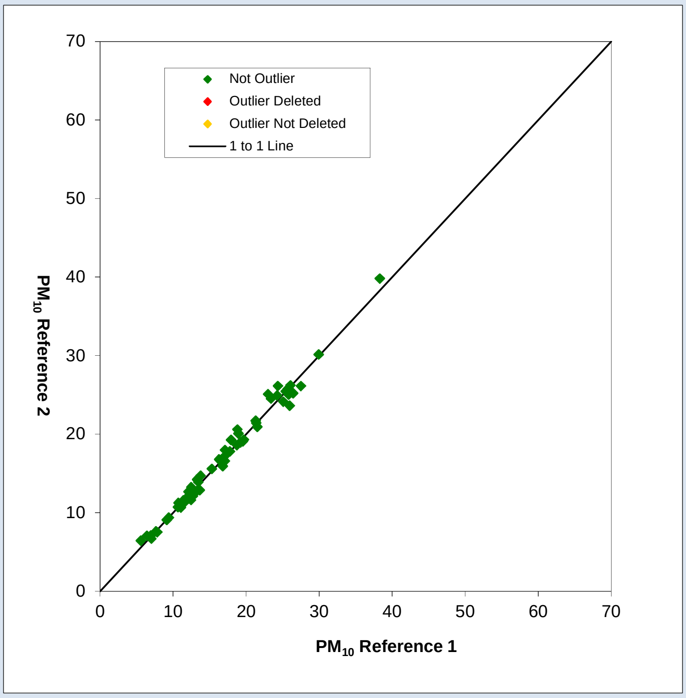


Figure 20: Grubbs test results for the PM_{10} reference method, Bornheim (Summer)



Candidate Method

Two PM_{10} TEOM 1405-F Ambient Particulate Monitor-systems were simultaneously operated during each field test.

The flow rate was tested on each candidate device prior to and after each change of location with a mass flow meter, which could be connected to the air inlet of the systems *via* a hose assembly.

The measuring devices have been installed in the field test in such a way, that only the sampling inlets and the flow splitter are located above the roof of the measurement cabinet. The central units of both candidates were installed inside the climate-controlled measurement cabinet.

On each day that a reference method filters was either installed or removed, the candidate instruments were manually checked, by observing if there were any warning messages displayed on the instrument. The data were downloaded approximately twice a week, and were processed by BV (UK Sites) and TÜV Rheinland (German Sites). Time series of the data parameters were plotted and any anomalies were flagged for further discussion with the manufacturer.

It was agreed between TÜV Rheinland and BV not to discard any measured value for the candidates, unless the implausibility is caused due to technical reasons. In general, only small sections of data were deleted for short periods after a filter change, audit or maintenance when it was clear from the trends in the mass, base and reference data that the instrument had not fully stabilised.

24 hour averages were calculated only for days where there was greater than 90 % data capture.

The PM_{10} sampling inlets of the candidates were cleaned approximately every 4 weeks. The candidate instruments were operated and maintained in accordance with the manufacturer's instructions.

11. Data Availability of the Candidate Method

MCERTS for UK Particulate Matter[1] lists the following requirement for the Availability of the measuring system:

> *"The fraction of the total and consecutive monitoring time during all the field trials involved in the equivalence testing programme for which data of acceptable quality are collected. The times required for scheduled calibrations and maintenance shall not be included. The method for calculating this fractional time is given in Section 5.2 Eq.2. Availability defined here is the same as the minimum data capture requirements given in the data quality objectives in Directive 2008/50/EC for the relevant pollutant."*

Where Directive 2008/50/EC[10] defines a data capture of 90 %.

The following text is copied with minor alterations from Section 6.1 - 5.2.8 of the TÜV Rheinland Report[2].

Equipment

Not required for this test.

Performance of test

Start time and end time of the availability tests were defined by the start and end of the field tests at each test site. All measurement interruptions, *e.g.* due to system outage or maintenance works, were considered for this test.

Evaluation

Table 15 and Table 16 show a compilation of the operation, maintenance and malfunction times. The measuring systems have been operated over a time period of 328 measuring days (SN 20006) and 294 measuring days (SN 20107) during field test. This time period includes 14 days of zero-filter operation for SN 20006 and 13 days of zero-filter operation for SN 20107.

Data loss caused by external influences, which cannot be attributed to the devices themselves, have been recorded on 19.01.2010, 10.03.2011 and 14.03.2011 (power outage). Therefore, the total operating time is reduced to 325 (SN 20006) and 291 (SN 20107) measuring days.

The following malfunctions of the devices have been observed:

SN 20006:

- On 28.05.2010 it was detected that the output measured values have been very noisy after the zero-filter operation. The problem was a leaking switching valve, which was not changed until 11.06.2011 due to communication problems. All measured values between 28.05.2011 and 11.06.2011 were rejected.

SN 20107:

- On 28.09.2011 the device had to be stopped in order to fix a leak.

No further malfunctions of the devices have been observed.

The regular cleaning of the sampling inlets in the maintenance interval, the change of the TEOM-filter, the 47 mm-filter (approximately every 4 weeks) and the regular check of the flow rates respectively of the tightness can lead to outages of more than 2 hours per device, especially when all is done on one day. The affected daily averages in this case have been rejected.

10 DIRECTIVE 2008/50/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 May 2008 on ambient air quality and cleaner air for Europe http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:EN:PDF

Assessment

The availability was 94.5 % for SN 20006 98.6 % for SN 20107 without outages due to test conditions, or 88.6 % for SN 20006 and 92.1 % for SN 20107 including outages due to test conditions. The high amount of downtime days (15 days) for SN 20006 caused by the leak switching valve cannot be fully attributed to the TEOM 1405-F itself, since a prompt repair was not possible due to communication problems.

Detailed representation of the test results

Table 15 and Table 16 show a compilation of the operation, maintenance and malfunction times.

Table 15: Determination of availability (without test-related outages)

		Device 1 (SN 20006)	Device 2 (SN 20107)
Operating time	d	325	291
Outage time	d	15	1
Maintenance	d	3	3
Actual operating time	d	307	287
Availability	%	94.5	98.6

Table 16: Determination of availability (including test-related outages)

		Device 1 (SN 20006)	Device 2 (SN 20107)
Operating time	d	325	291
Outage time	d	15	1
Maintenance	d	22	22
Actual operating time	d	288	268
Availability	%	88.6	92.1

Conclusion for UK Purposes

As discussed in Section 2 , as all of the field tests were conducted before the publication of MCERTS for UK Particulate Matter[1] (31st July 2012), it is not necessary to assess this criteria for the PM_{10} TEOM 1405-F. However; in the interest of completeness, this information should be included on the MCERTS certificate.

12. Field Test Uncertainty Calculations

12.1 Introduction

The MCERTS for UK Particulate Matter[1] uses the same methodology as that employed in the 2010 version of the GDE[8]. A series of five criteria must be fulfilled in order to prove equivalence.

1. Of the full dataset at least 20 % of the results obtained using the standard method shall be greater than the upper assessment threshold specified in 2008/50/EC for annual limit values *i.e.*: 28 µg/m³ for PM_{10} and currently 17 µg/m³ for $PM_{2.5}$.

2. The intra instrument uncertainty of the candidate must be less than 2.5 µg/m³ for all data and for two sub datasets corresponding to all the data split greater than or equal to and lower than 30 µg/m³ or 18 µg/m³ for PM_{10} and $PM_{2.5}$ respectively.

3. The intra instrument uncertainty of the reference method must be less than 2.0 µg/m³.

4. The expanded uncertainty (W_{CM}) is calculated at 50 µg/m³ for PM_{10} and 30 µg/m³ for $PM_{2.5}$ for each individual candidate instrument against the average results of the reference method. For each of the following permutations, the expanded uncertainty must be less than 25 %:

   - Full dataset;
   - Datasets representing PM concentrations greater than or equal to 30 µg/m³ for PM_{10}, or concentrations greater than or equal to 18 µg/m³ for $PM_{2.5}$, provided that the subset contains 40 or more valid data pairs;
   - Datasets for each individual test site.

5. Preconditions for acceptance of the full dataset are that: the slope b is insignificantly different from 1: $|b-1| \leq 2 \cdot u(b)$, and the intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$. If these preconditions are not met, the candidate method may be calibrated using the values obtained for slope and/or intercept of all paired instruments together.

The fulfilment of the 5 criteria is checked in the following Sections:

Criteria 1 and 2 are discussed in Section 12.2.

Criteria 3,4 and 5 are discussed in Section 12.3.

Criterion 5 is further discussed in Section 12.4.

12.2 Determination of uncertainty between systems under test u_{bs}

In this Section, Criteria 1 and 2 are assessed, namely:

1. Of the full dataset at least 20 % of the results obtained using the standard method shall be greater than the upper assessment threshold specified in 2008/50/EC for annual limit values *i.e.*: 28 µg/m³ for PM_{10} and currently 17 µg/m³ for $PM_{2.5}$.
2. The intra instrument uncertainty of the candidate must be less than 2.5 µg/m³ for all data and for two sub datasets corresponding to all the data split greater than or equal to and lower than 30 µg/m³ or 18 µg/m³ for PM_{10} and $PM_{2.5}$ respectively.

The following text is copied with minor alterations from Section 6.1 5.4.9 of the TÜV Rheinland Report[2].

Equipment

Not required for this minimum requirement.

Performance of test

The test was carried out at four different sites during field test. Different seasons and varying concentrations for PM_{10} were taken into consideration.

Of the complete data set, at least 20 % of the concentration values determined with the reference method, shall be greater than the upper assessment threshold according to 2008/50/EC[10]. For PM_{10} the upper assessment threshold is at 28 µg/m³.

At each test site at least 40 valid data pairs were determined. Of the complete data set (4 test sites, 237 valid data pairs for SN 20006, 230 valid data pairs for SN 20107), in total 23.3 % of the measured values are above the upper assessment threshold of 28 µg/m³ for PM_{10}. The measured concentrations were referred to ambient conditions.

Evaluation

The uncertainty between the candidates u_{bs} must be ≤ 2.5 µg/m³. An uncertainty of more than 2.5 µg/m³ between the two candidates is an indication that the performance of one or both systems is not sufficient and the equivalence cannot be declared.

The uncertainty is determined for:

- All test sites together (complete data set)
- 1 data set with measured values ≥ 30 µg/m³ for PM_{10} (Basis: averages of reference measurement)

Furthermore the evaluation of the following data sets is done:

- Each test site individually
- 1 data set with measured values < 30 µg/m³ for PM_{10} (Basis: averages of reference measurement)

The in-between-instrument uncertainty u_{bs} is calculated from the differences of all 24-hour results of the simultaneously operated candidate systems according to the following equation:

$$u_{bs}^2 = \frac{\sum_{i=1}^{n}(y_{i,1} - y_{i,2})^2}{2n}$$

with $y_{i,1}$ and $y_{i,2}$ = results of the parallel measurements of individual 24h-values i
n = number of 24h-values

Assessment

The in-between-uncertainty between the candidates u_{bs} is with a maximum of 1.35 µg/m³ for PM_{10} below the required value of 2.5 µg/m³.

Detailed representation of the test results

Table 17 shows the calculated values for the uncertainty between systems under test u_{bs}. The graphical representation is shown in Figure 21 through to Figure 27.

Table 17: Uncertainty between systems under test u_{bs} for the candidates SN 20006 and SN 20107, measured component PM_{10}

Candidate	Test site	No. of values	Uncertainty u_{bs}
SN			µg/m³
20006 / 20107	**All test sites**	**251**	**1.09**
Single test sites			
20006 / 20107	Teddington (Winter)	46	1.10
20006 / 20107	Teddington (Summer)	49	0.78
20006 / 20107	Cologne (Winter)	88	1.15
20006 / 20107	Bornheim (Summer)	68	1.20
Classification *via* reference value			
20006 / 20107	**Values ≥ 30 µg/m³**	**46**	**1.35**
20006 / 20107	Values < 30 µg/m³	169	1.03

Figure 21: Results of the parallel measurements with the candidates SN 20006 / SN 20107, measured component PM_{10}, all test sites

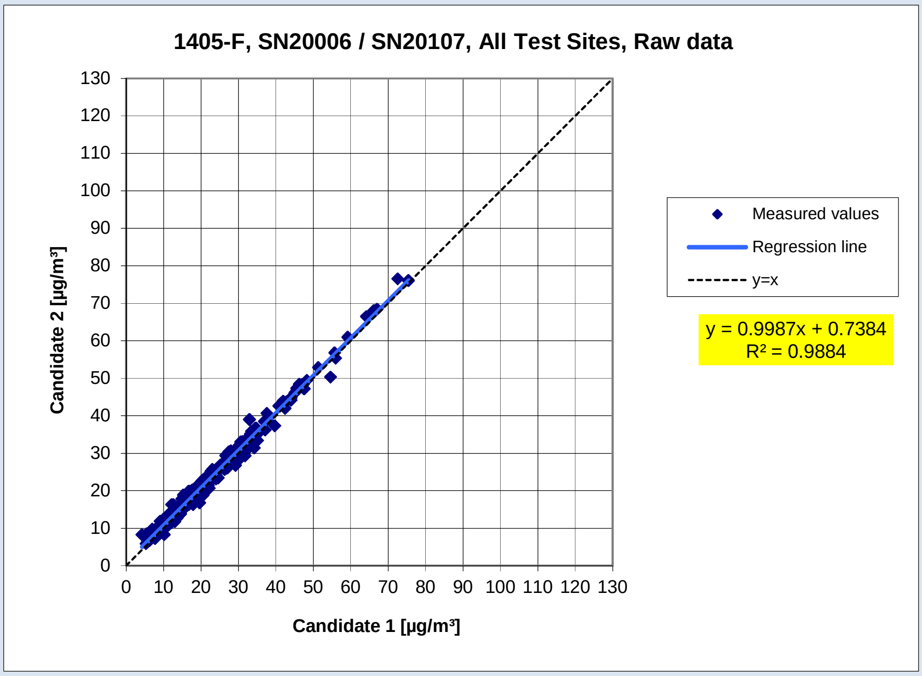


Figure 22: *Results of the parallel measurements with the candidates SN 20006 / SN 20107, measured component PM_{10}, test site Teddington (Winter)*

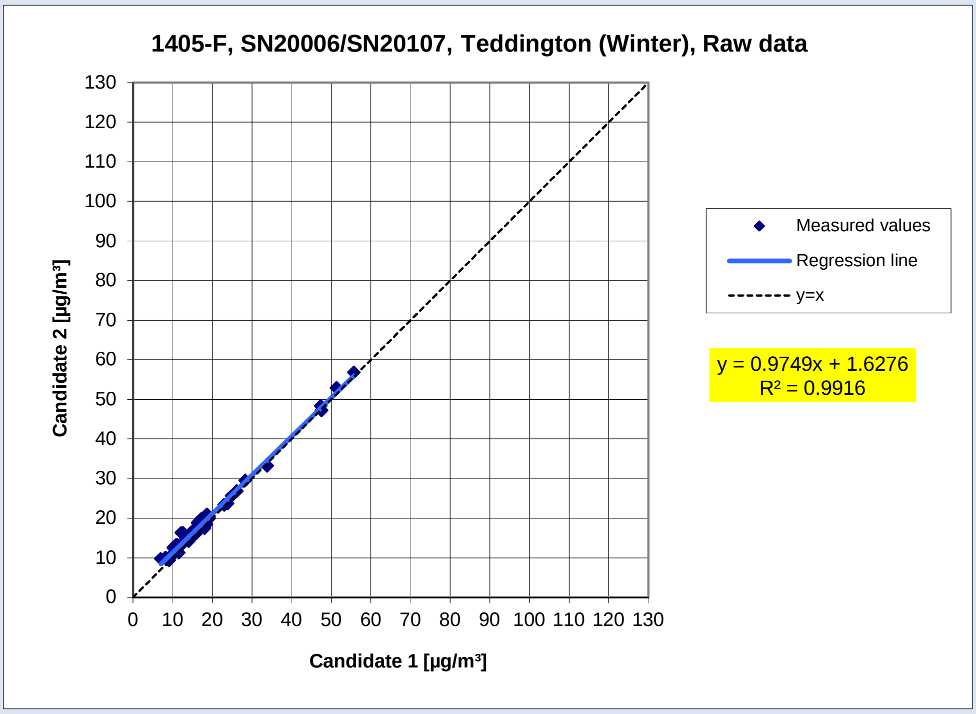


Figure 23: *Results of the parallel measurements with the candidates SN 20006 / SN 20107, measured component PM_{10}, test site Teddington (Summer)*

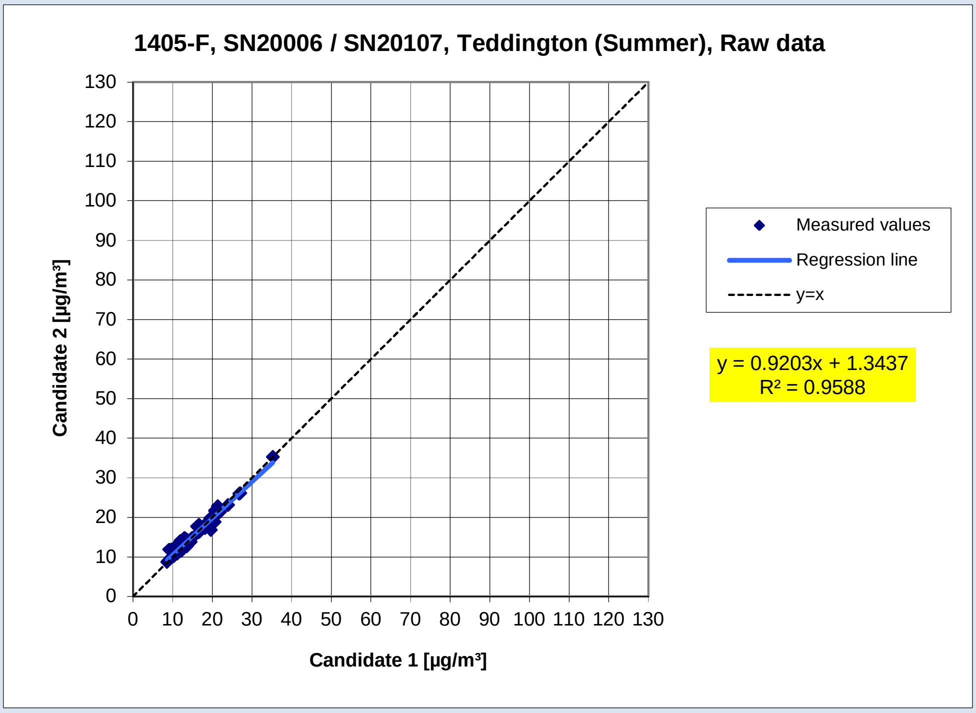


Figure 24: Results of the parallel measurements with the candidates SN 20006 / SN 20107 measured component PM_{10}, test site Cologne (Winter)

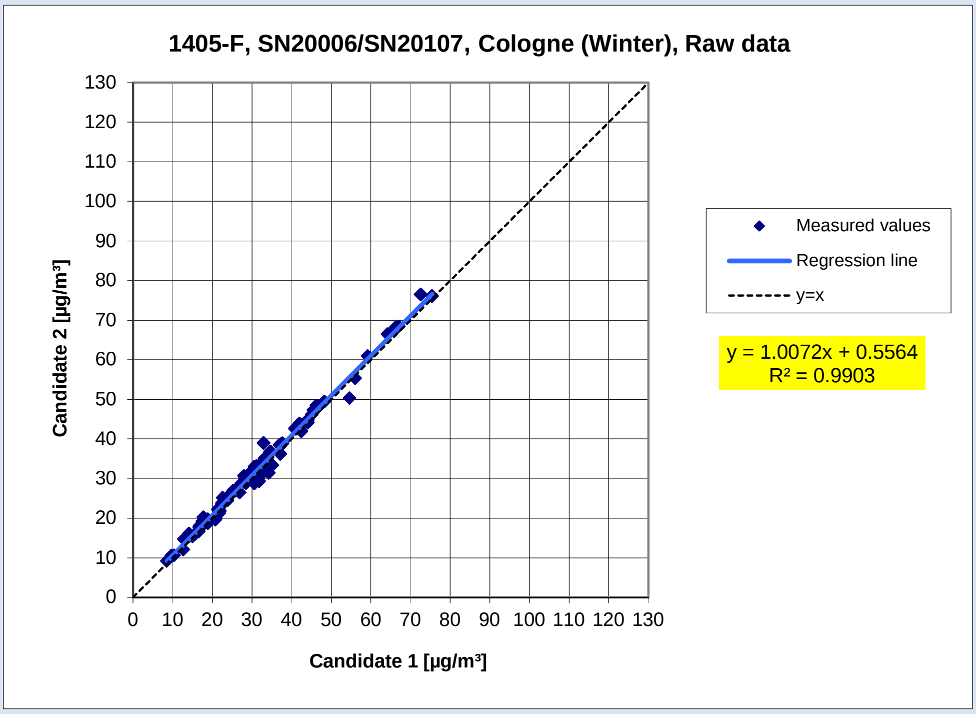


Figure 25: Results of the parallel measurements with the candidates SN 20006 / SN 20107, measured component PM_{10}, test site Bornheim (Summer)

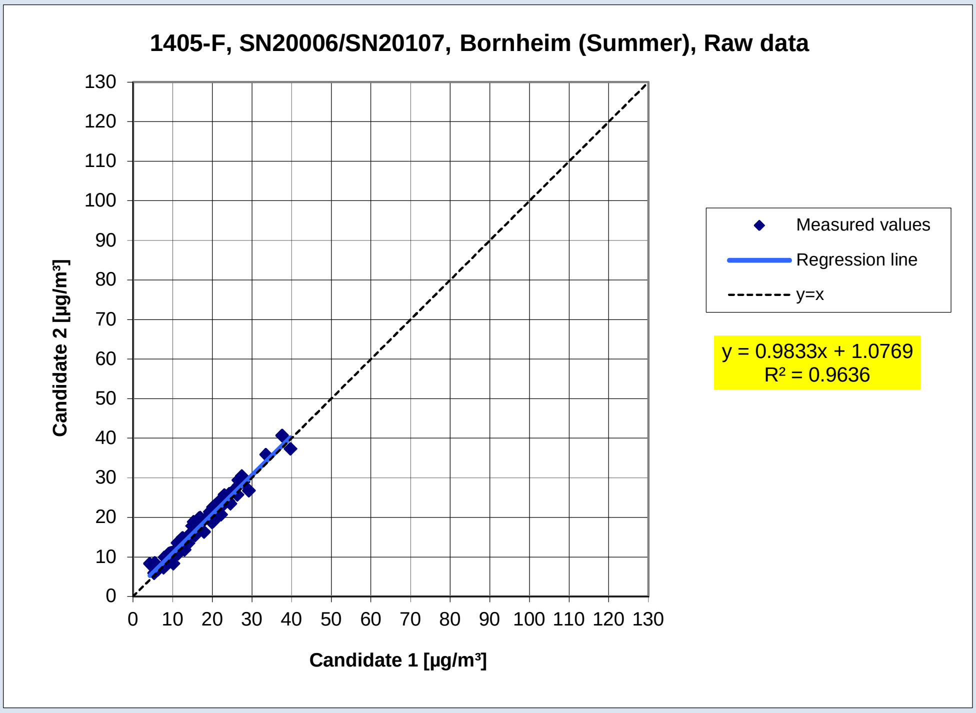


Figure 26: Results of the parallel measurements with the candidates SN 20006 / SN 20107, measured component PM_{10}, all test sites, values ≥ 30 µg/m³

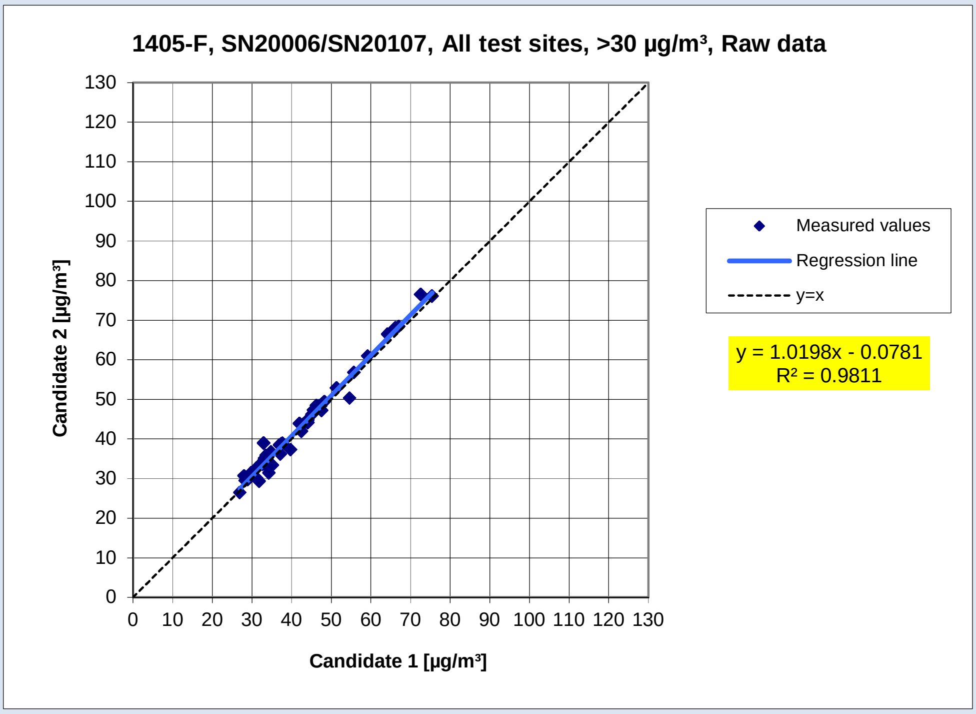
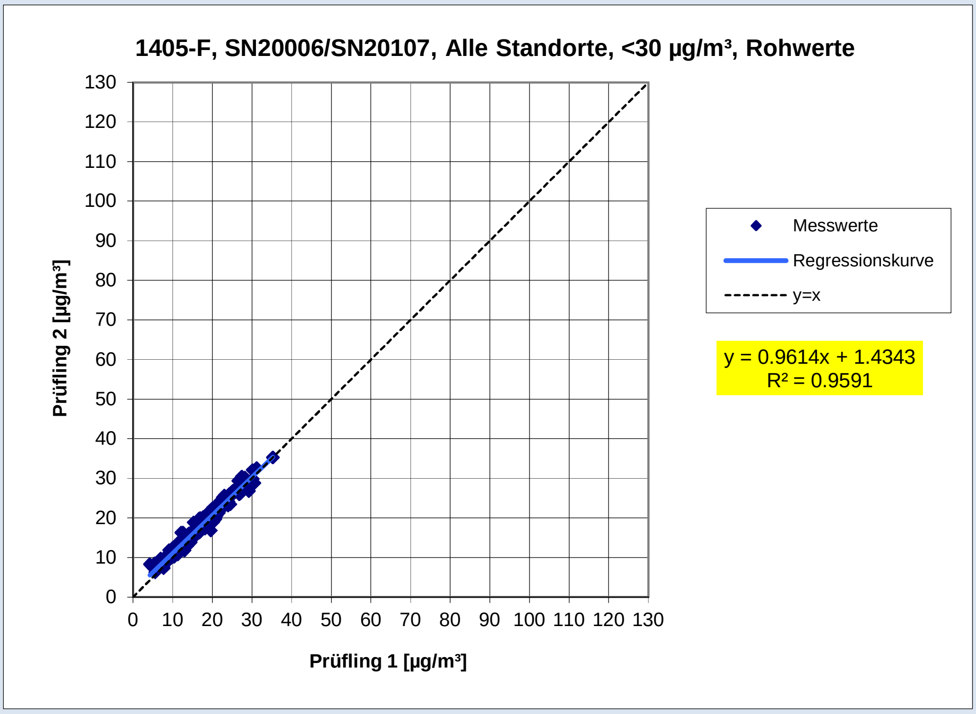


Figure 27: Results of the parallel measurements with the candidates SN 20006 / SN 20107, measured component PM_{10}, all test sites, values < 30 µg/m³



Conclusion for UK Purposes

As at least 20 % of the results obtained using the standard method are greater than 28 µg/m³, criterion 1 is fulfilled. There is no requirement in MCERTS for UK Particulate Matter for this information to be placed upon the MCERTS certificate.

As the intra instrument uncertainty of the candidate method is less than 2.5 µg/m³ for all data and for two sub datasets corresponding to all the data split greater than or equal to and lower than 30 µg/m³, criterion 2 is fulfilled. These three intra instrument uncertainties should be placed on the MCERTS certificate.

12.3 Calculation of the expanded uncertainty of the instruments

In this Section, Criteria 3,4 and 5 are assessed, namely:

3. The intra instrument uncertainty of the reference method must be less than 2.0 µg/m³.
4. The expanded uncertainty (W_{CM}) is calculated at 50 µg/m³ for PM_{10} and 30 µg/m³ for $PM_{2.5}$ for each individual candidate instrument against the average results of the reference method. For each of the following permutations, the expanded uncertainty must be less than 25 %:
   - Full dataset;
   - Datasets representing PM concentrations greater than or equal to 30 µg/m³ for PM_{10}, or concentrations greater than or equal to 18 µg/m³ for $PM_{2.5}$, provided that the subset contains 40 or more valid data pairs;
   - Datasets for each individual test site.
5. Preconditions for acceptance of the full dataset are that: the slope b is insignificantly different from 1: $|b-1| \le 2 \cdot u(b)$, and the intercept a is insignificantly different from 0: $|a| \le 2 \cdot u(a)$. If these preconditions are not met, the candidate method may be calibrated using the values obtained for slope and/or intercept of all paired instruments together.

The Excel functions used to calculate the orthogonal regression was taken directly from the JRC Excel tool published in 2004 to calculate expanded uncertainties of PM equivalence datasets[11]. This tool has been superseded and is no longer available for download. The mathematics within the 2004 tool have been validated by both TÜV Rheinland and BV to give an identical result to the equations specified in GDE2010[8]. In CEN/TS16450:2013, the same orthogonal methodology is allowed, though a number of other orthogonal regression methods are now also permissible.

In all cases the uncertainty of the reference method was calculated for each individual dataset in accordance with GDE2010. As in all cases there were two reference methods available, it was not necessary to use the recommended default uncertainty of 0.67 for any of the calculations.

The following text is copied with minor alterations from Section 6.1 5.4.10 of the TÜV Rheinland Report[2].

Equipment

Not required for this minimum requirement.

Evaluation

The calculation of the in-between-instrument uncertainty u_{ref} of the reference devices is carried out prior to the calculation of the expanded uncertainty of the candidates.

The in-between-instrument uncertainty u_{ref} of the reference devices shall be ≤ 2 µg/m³. These results are discussed in the detailed description of results below.

11 File: Test for EquivalenceV31004.xls formerly available to download from: http://ec.europa.eu/environment/air/quality/legislation/assessment.htm

A linear correlation $y_i = a + bx_i$ is assumed between the results of both methods in order to evaluate the comparability of the candidates y and the reference procedure x. The correlation between the average values of the reference devices and the candidates is established by orthogonal regression.

Regression is calculated for:

- All test sites
- Each test site separately
- 1 data set with measured values $PM_{10} \geq 30$ µg/m³ (Basis: average value of reference measurement)

For further evaluation, the results of the uncertainty u_{c_s} of the candidates compared with the reference method are described with the following equation, which describes u_{CR} as a function of the PM concentration x_i:

$$u_{CR}^2(y_i) = \frac{RSS}{(n-2)} - u^2(x_i) + [a + (b-1)x_i]^2$$

With RSS = Sum of the (relative) residuals from orthogonal regression

$u(x_i)$ = random uncertainty of the reference procedure if value u_{bs}, which is calculated for using the candidates, can be used in this test

The sum of the (relative) residuals RSS is calculated by the following equation:

$$RSS = \sum_{i=1}^{n} (y_i - a - bx_i)^2$$

Uncertainty u_{c_s} is calculated for:

- All test sites
- Each test site separately
- 1 data set with measured values ≥ 30 µg/m³ (Basis: average values of the reference measurement)

Preconditions for acceptance of the full dataset are that:

- The slope b is insignificantly different from 1: $|b - 1| \leq 2 \cdot u(b)$

and

- The intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$

Where u(b) and u(a) are the standard uncertainties of the slope and intercept, respectively calculated as the square root of their variances. If these preconditions are not met, the candidate method may be calibrated according to GDE2010[8]. The calibration shall only be applied to the full dataset.

The combined uncertainty of the candidates $wc_{,CM}$ is calculated for each data set by combining the contributions according to the following equation:

$$w_{c,CM}^2(y_i) = \frac{u_{CR}^2(y_i)}{y_i^2}$$

For each dataset, the uncertainty $w_{c,CM}$ is calculated at the level of y_i = 50 µg/m³ for PM_{10}.

The expanded relative uncertainty of the results of the candidates is calculated for each data set by multiplication of $w_{c,CM}$ with a coverage factor k according to the following equation:

$$W_{CM} = k \cdot w_{CM}$$

In practice: k=2 for a large n

The highest resulting uncertainty W_{CM} is compared and assessed with the requirements on data quality of ambient air measurements according to 2008/50/EC[10]. Two results are possible:

1. $W_{CM} \leq W_{dqo}$ → Candidate method is accepted as equivalent to the standard method.

2. $W_{CM} > W_{dqo}$ → Candidate method is not accepted as equivalent to the standard method.

The specified expanded relative uncertainty W_{dqo} for particulate matter is 25 %[10].

Assessment

The determined uncertainties W_{CM} without application of correction factors lay for all observed data sets beneath the defined expanded relative uncertainty W_{dqo} of 25 % for particulate.

The following Table 18 shows an overview of the results of the equivalence check for the candidate PM_{10} TEOM 1405-F Ambient Particulate Monitor for PM_{10}. For the case, that a criterion is fulfilled or not, the text is represented in green or red colour. Furthermore the five criteria from Section 12.1 are shaded as per the key.

Table 18: Overview equivalence test TEOM 1405-F Ambient Particulate Monitor for PM_{10}

PM10 1405F FDMS	23.3% > 28 µg m-3	Orthogonal Regression				Between Instrument Uncertainties	
	WCM / %	nc-s	r2	Slope (b) +/- ub	Intercept (a) +/- ua	Reference	Candidate
All Data	8.4	215	0.973	0.994 +/- 0.011	0.395 +/- 0.291	0.48	1.09
< 30 µg m-3	12.0	169	0.882	1.055 +/- 0.028	-0.567 +/- 0.501	0.46	1.03
> 30 µg m-3	9.5	46	0.963	0.992 +/- 0.029	0.218 +/- 1.274	0.55	1.35

SN 20006	Dataset	Orthogonal Regression				Limit Value of 50 µg m-3	
		nc-s	r2	Slope (b) +/- ub	Intercept (a) +/- ua	WCM / %	% > 28 µg m-3
Individual Datasets	Teddington Summer	42	0.895	1.112 +/- 0.057	0.055 +/- 0.883	23.71	2.4
	Cologne Winter	74	0.987	0.992 +/- 0.013	0.327 +/- 0.461	6.23	55.4
	Bornheim Summer	55	0.931	1.134 +/- 0.041	-2.097 +/- 0.750	20.10	3.6
	Teddington Winter	66	0.987	0.959 +/- 0.014	-1.549 +/- 0.337	15.22	16.7
Combined Datasets	< 30 µg m-3	186	0.860	1.069 +/- 0.029	-1.377 +/- 0.528	12.26	2.2
	> 30 µg m-3	51	0.966	0.986 +/- 0.026	-0.104 +/- 1.147	9.36	100.0
	All Data	237	0.970	0.994 +/- 0.011	-0.170 +/- 0.294	9.01	23.2

SN 20107	Dataset	Orthogonal Regression				Limit Value of 50 µg m-3	
		nc-s	r2	Slope (b) +/- ub	Intercept (a) +/- ua	WCM / %	% > 28 µg m-3
Individual Datasets	Teddington Summer	57	0.927	1.065 +/- 0.039	0.807 +/- 0.605	17.19	1.8
	Cologne Winter	74	0.978	1.005 +/- 0.017	0.710 +/- 0.609	9.35	55.4
	Bornheim Summer	54	0.906	1.112 +/- 0.047	-0.860 +/- 0.859	21.03	3.7
	Teddington Winter	45	0.983	0.934 +/- 0.019	0.108 +/- 0.455	14.07	13.3
Combined Datasets	< 30 µg m-3	184	0.886	1.052 +/- 0.026	-0.062 +/- 0.467	13.06	2.2
	> 30 µg m-3	46	0.949	1.010 +/- 0.034	-0.139 +/- 1.526	11.60	100.0
	All Data	230	0.970	0.996 +/- 0.011	0.795 +/- 0.292	9.07	21.7

KEY
- Criterion 1
- Criterion 2
- Criterion 3
- Criterion 4
- Criterion 5
- Other

The check of the five criteria from Section 12.1 resulted as follows:

Criterion 1: Greater than 20 % of the data are greater than 28 µg/m³.

Criterion 2: The intra instrument uncertainty of the candidates is smaller than 2.5 µg/m³.

Criterion 3: The intra instrument uncertainty of the reference is smaller than 2.0 µg/m³.

Criterion 4: All of the expanded uncertainties are below 25 %.

Criterion 5: The slope and the intercept are not significant for the "All data" comparison for SN 20006. The intercept for SN 20107 is significantly greater than allowed.

Other: The evaluation of the All data set for both candidates together shows that the AMS demonstrates a very good correlation with the reference method with a slope of 0.994 and an intercept of 0.395 at an expended total uncertainty of 8.4 %.

The January 2010 version of The Guidance is ambiguous with respect to which slope and intercept should be used to correct a candidate should it fail the test for equivalence. After communication with the convenor of the EC working group, which is responsible for setting up the Guide (Theo Hafkenscheid), it was decided that the requirement of the November 2005 version of The Guidance are still valid, and that the slope and intercept from the orthogonal regression of all the paired data should be used. These are shaded gold and marked ‘other’ in the key on the above Table 18.

The 2006 UK Equivalence Report[Error! Bookmark not defined.] highlighted that there was a flaw in the mathematics required for equivalence as per the November 2005 version of The Guidance as it penalised instruments that were more repeatable (Appendix E Section 4.2 therein). This same flaw is copied in the June 2010 version. It is the opinion of TŰV Rheinland and BV that the PM_{10} TEOM 1405-F Ambient Particulate Monitor is indeed being penalised by the mathematics for being highly repeatable. It is proposed that the same pragmatic approach is taken here that was previously undertaken in earlier studies. Namely: as some of the individual data set slopes are greater than 1, and some are less, there should be no need to correct the data for this slope offset.

In this particular case the slope for the “All data” comparison was 0.994, therefore no slope correction could be done.

The intercept for the “All data” comparison is 0.395. Therefore, in Section 12.4, an additional evaluation using the respective intercept calibration factor for the datasets is performed.

The reworked version of the Guidance of January 2010 requires that when operating in networks, a candidate method needs to be tested annually at a number of sites and that the number of the instruments to be tested is dependent on the expanded measurement uncertainty of the device. The respective realisation is the responsibility of the network operator or of the responsible authority of the member state. However TÜV Rheinland and BV recommend that the expanded uncertainty for the full data set is referred to for this, namely 8.4 %, which again would require an annual test at 2 measurement sites.

Detailed representation of the test results

Table 19 shows an overview on the uncertainties between the reference devices u_{ref} from the field tests. The datasets are show graphically in Figure 28 to Figure 40.

Table 19: In-between-instrument uncertainty u_{ref} of the reference devices for PM_{10}

Reference device	Test site	Amount values	Uncertainty u_{bs}
Nr.			µg/m³
1 / 2	Teddington (Winter)	67	0.22
1 / 2	Teddington (Summer)	59	0.33
1 / 2	Cologne (Winter	83	0.62
1 / 2	Bornheim (Summer)	59	0.57
1 / 2	All test sites	268	0.48

Figure 28: *Reference vs. candidate, SN 20006 & SN 20107, measured component PM_{10}, all test sites*

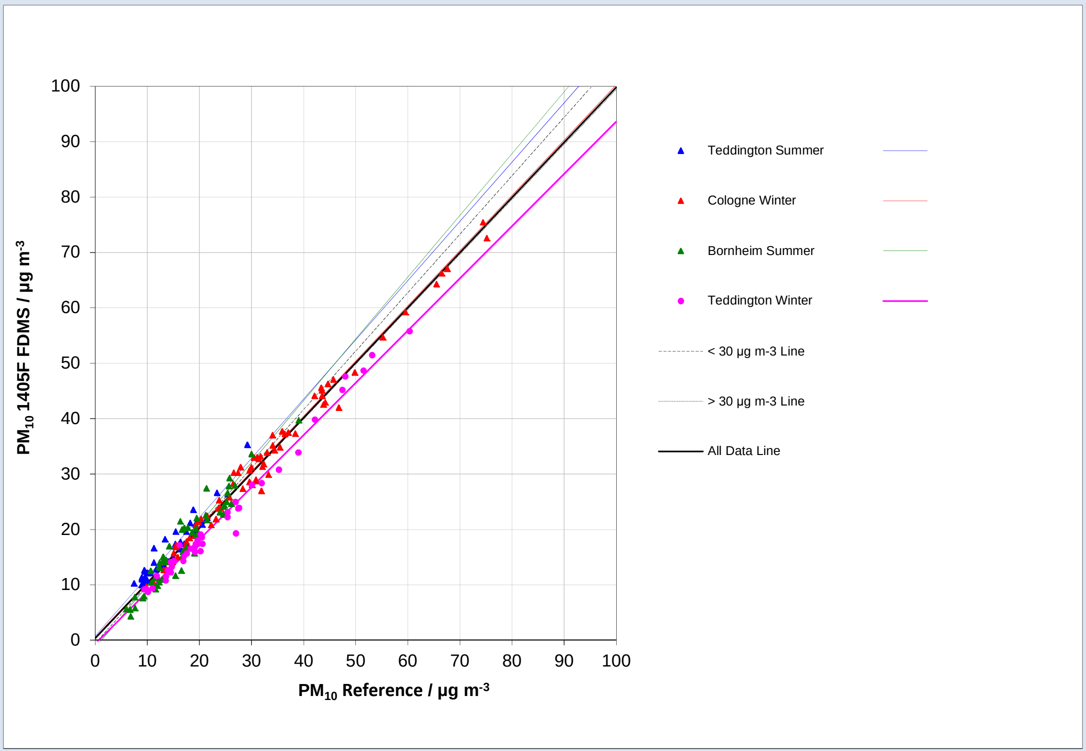


Figure 29: *Reference vs. candidate, SN 20006, measured component PM_{10}, all test sites*

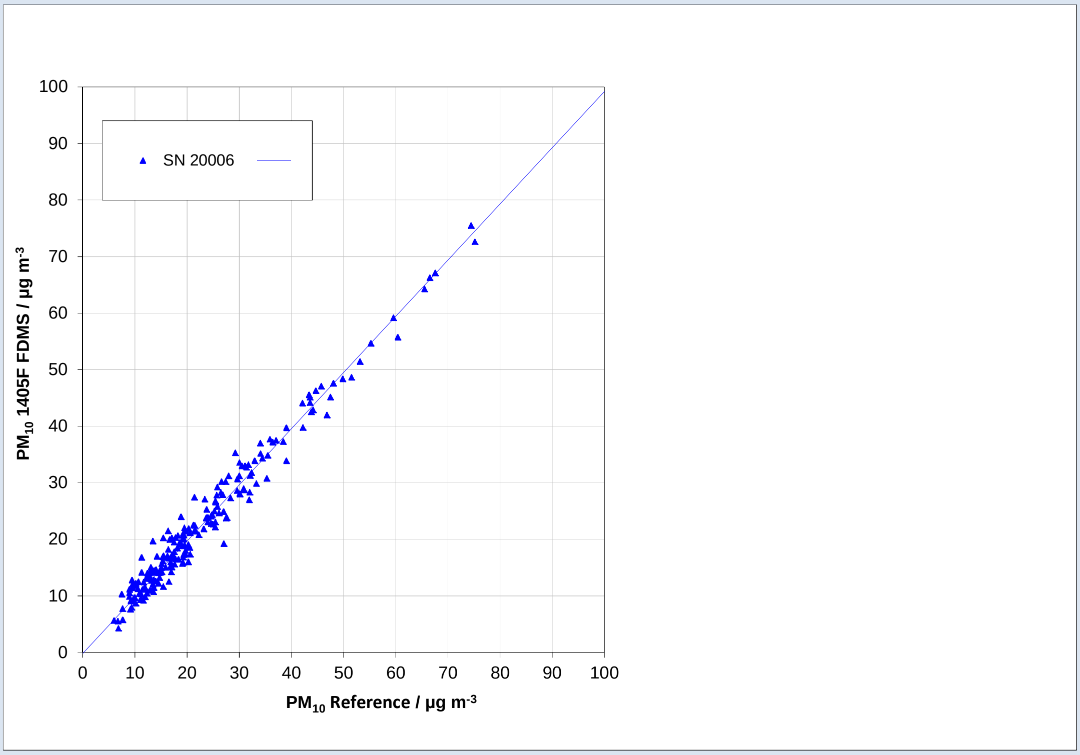


Figure 30: Reference vs. candidate, SN 20107, measured component PM_{10}, all test sites

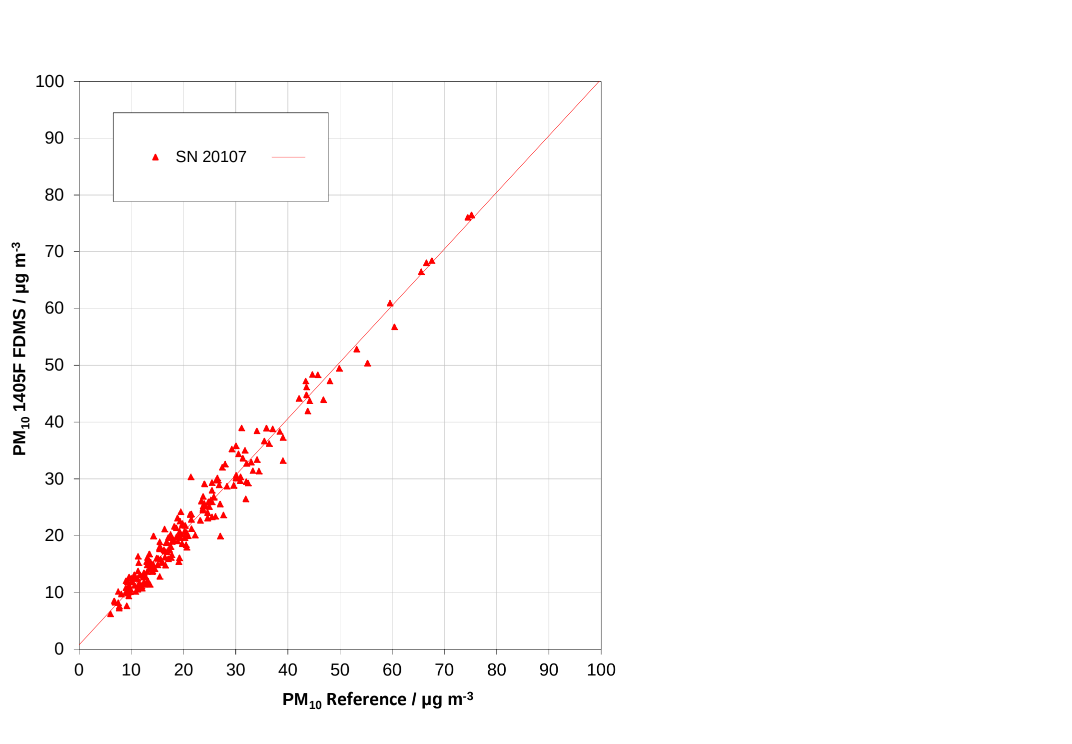


Figure 31: Reference vs. candidate, SN 20006, measured component PM_{10}, Teddington (Winter)

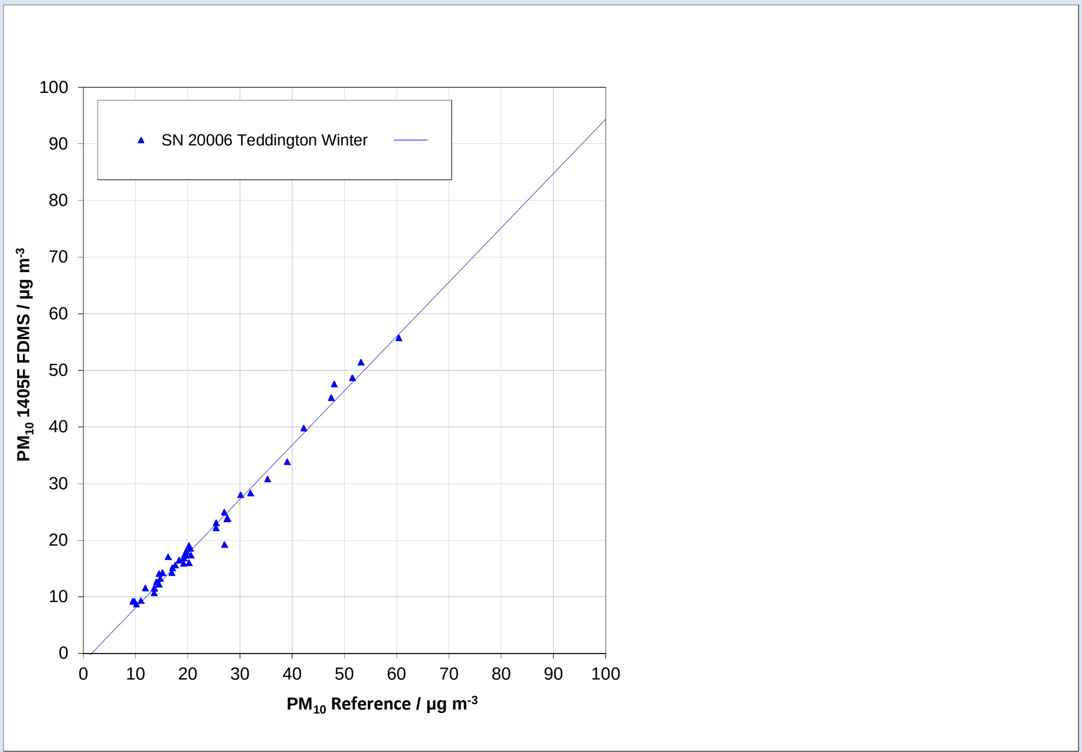


Figure 32: Reference vs. candidate, SN 20107, measured component PM_{10}, Teddington (Winter)

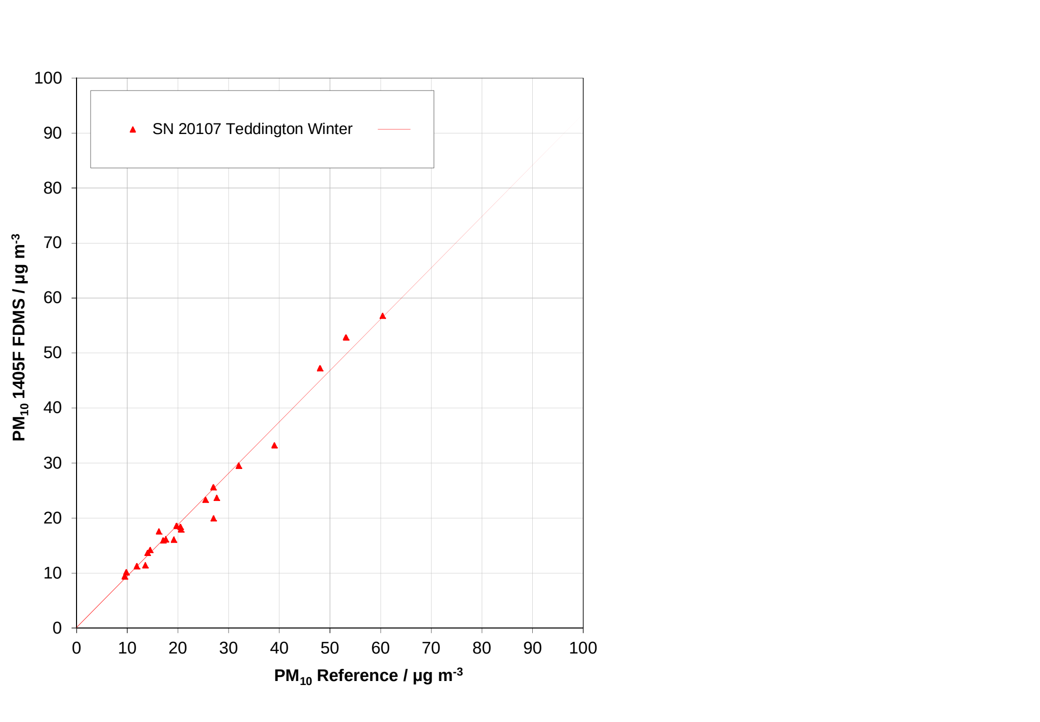


Figure 33: Reference vs. candidate, SN 20006, measured component PM_{10}, Teddington (Summer)

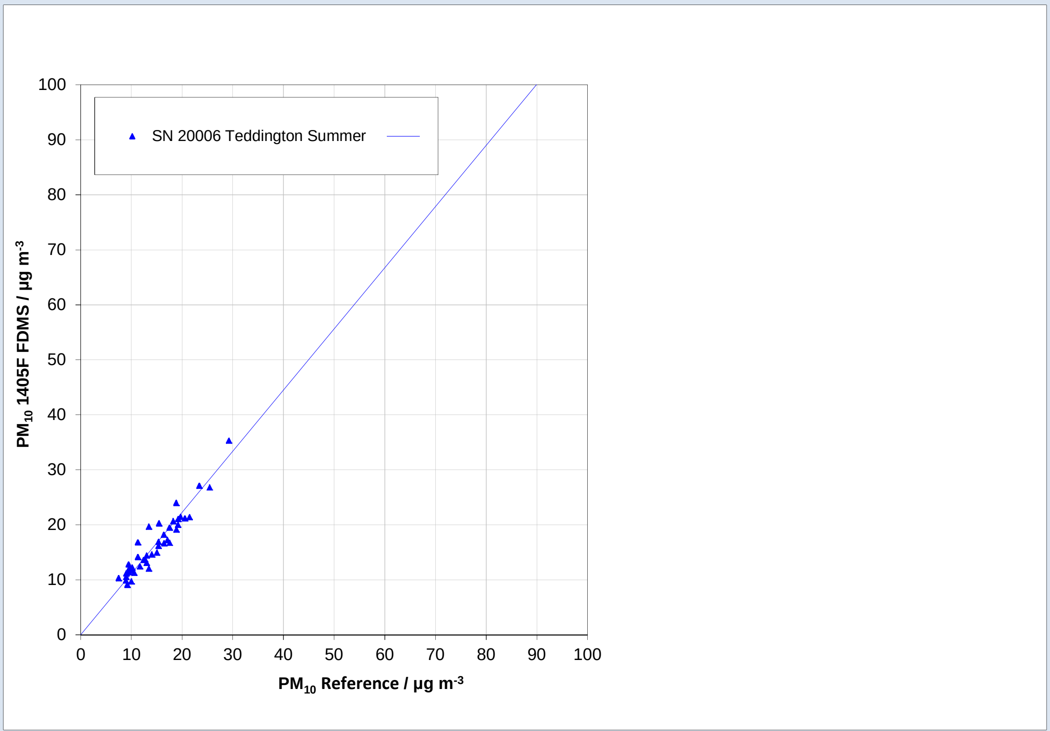


Figure 34: Reference vs. candidate, SN 20107, measured component PM_{10}, Teddington (Summer)

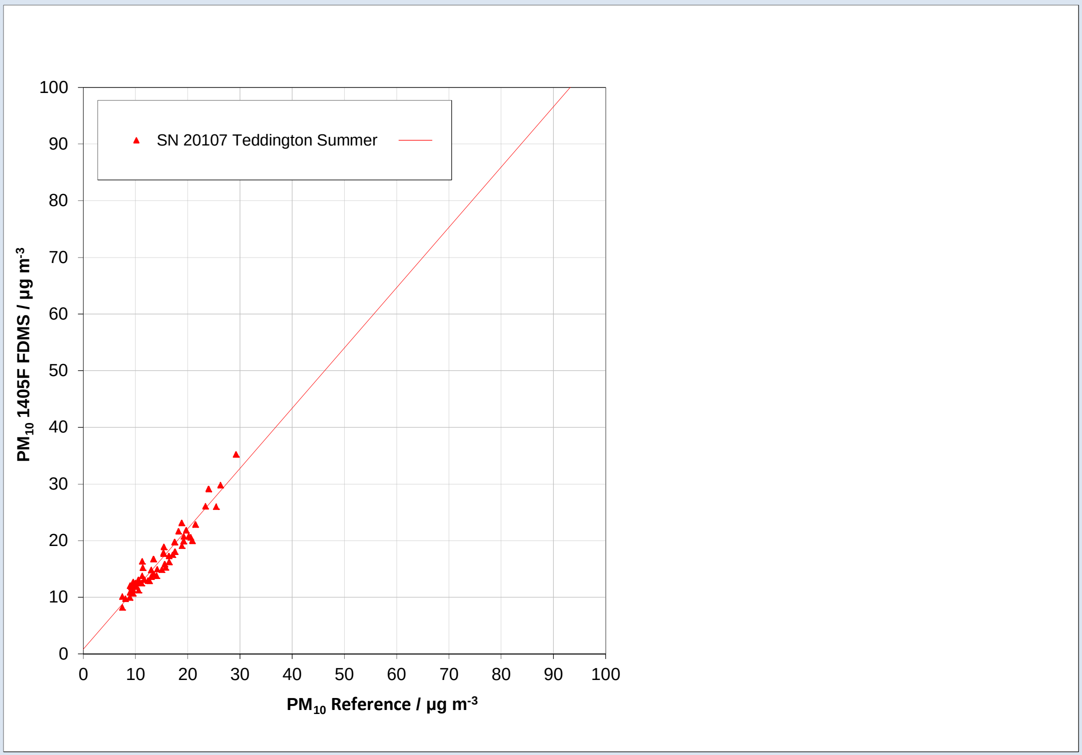


Figure 35: Reference vs. candidate, SN 20006, measured component PM_{10}, Cologne (Winter)

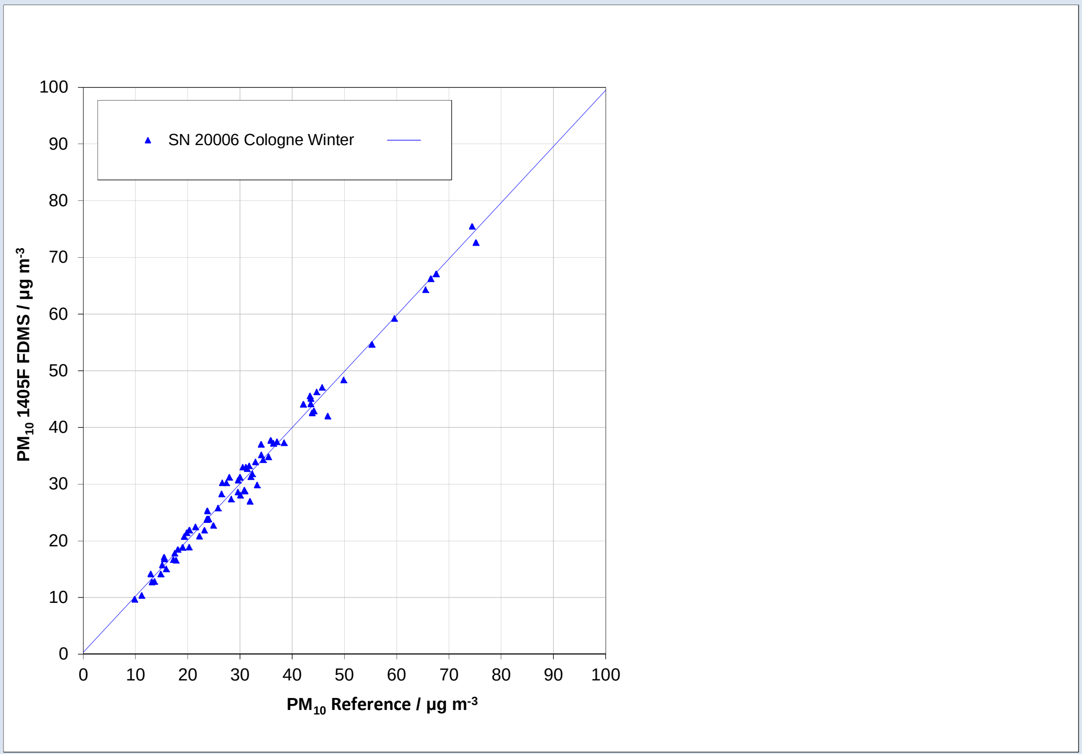


Figure 36: Reference vs. candidate, SN 20107, measured component PM_{10}, Cologne (Winter)

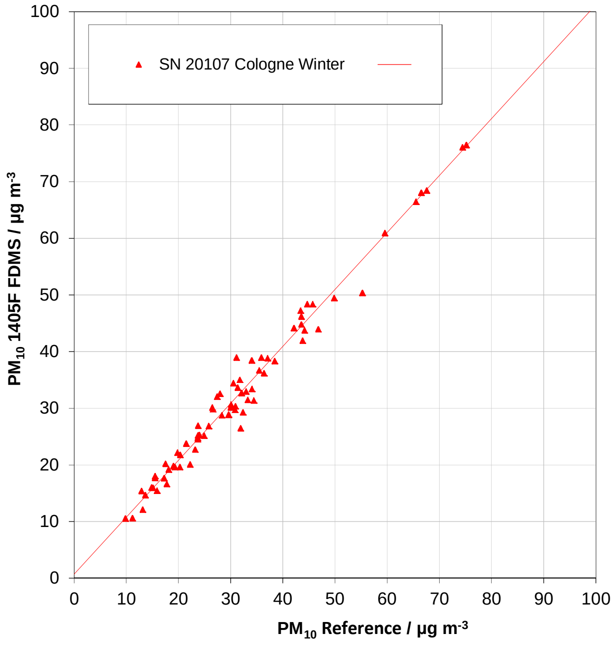


Figure 37: Reference vs. candidate, SN 20006, measured component PM_{10}, Bornheim (Summer)

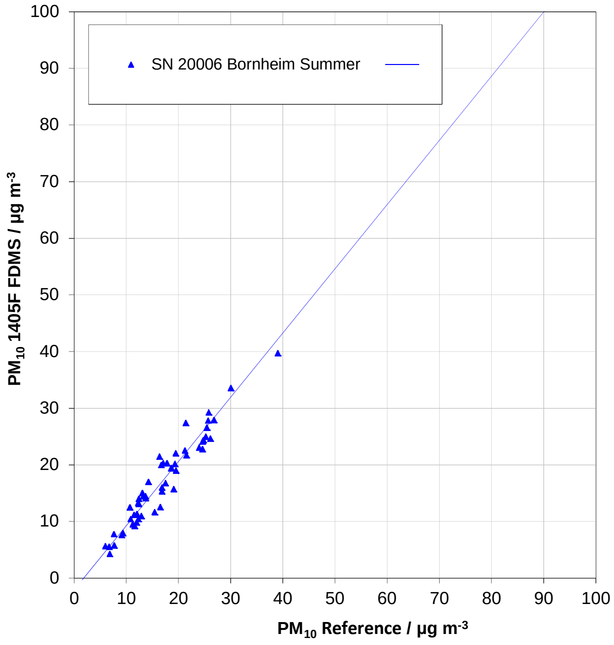


Figure 38: Reference vs. candidate, SN 20107, measured component PM_{10}, Bornheim (Summer)

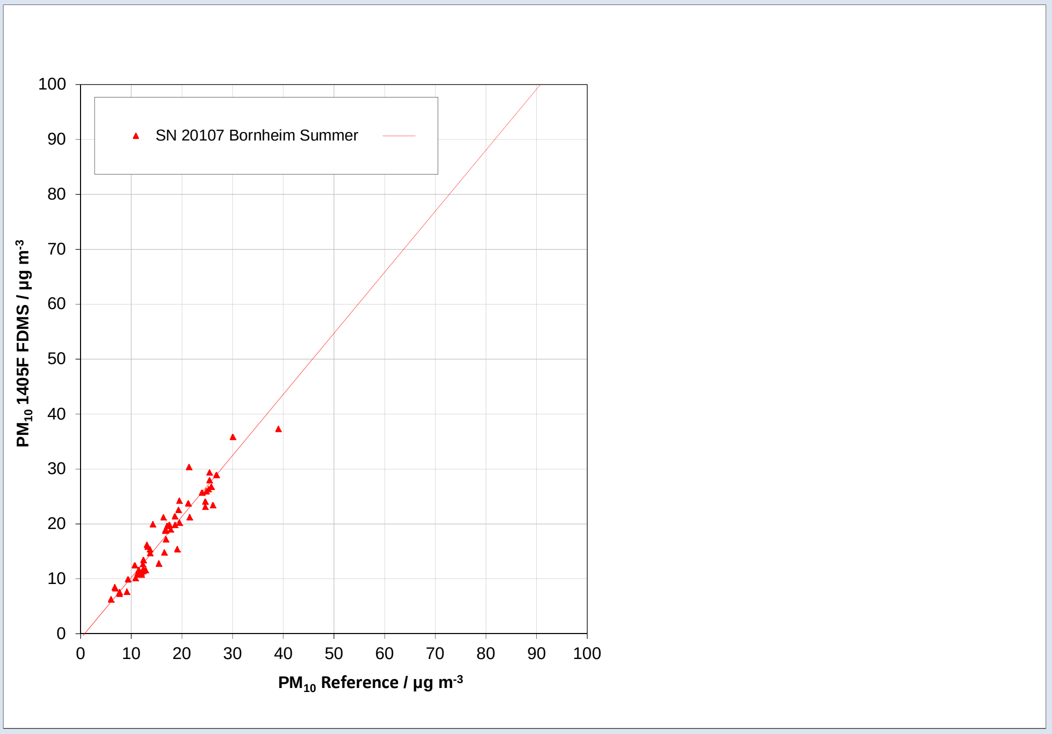


Figure 39: Reference vs. candidate, SN 20006, measured component PM_{10}, values ≥ 30 µg/m³

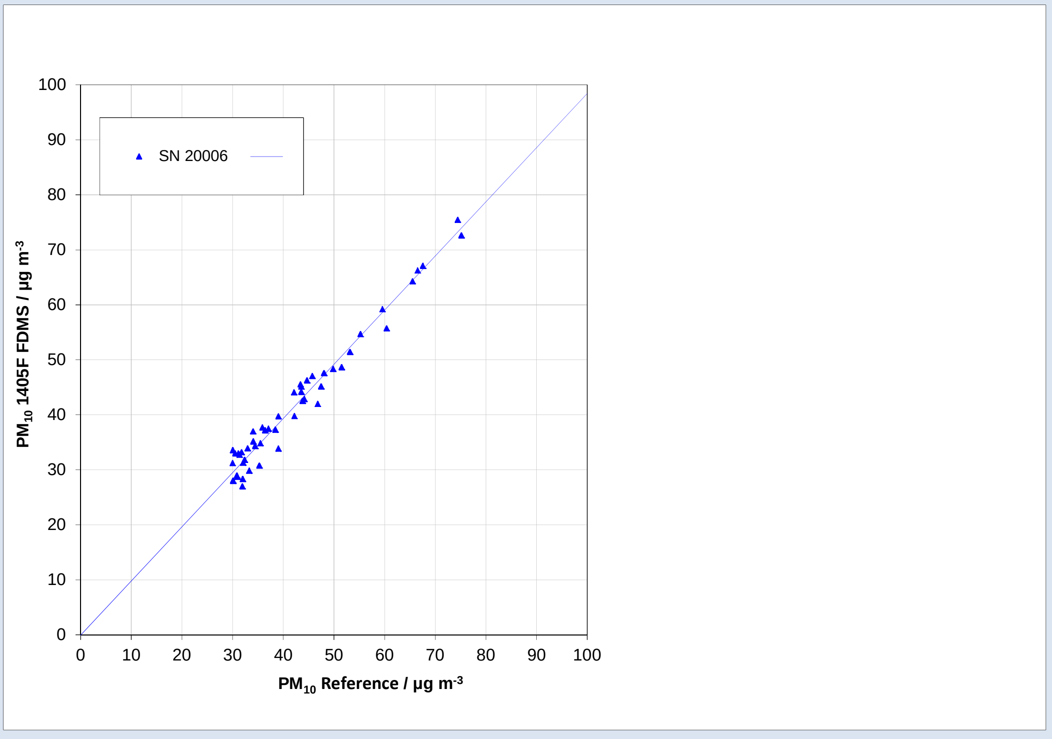
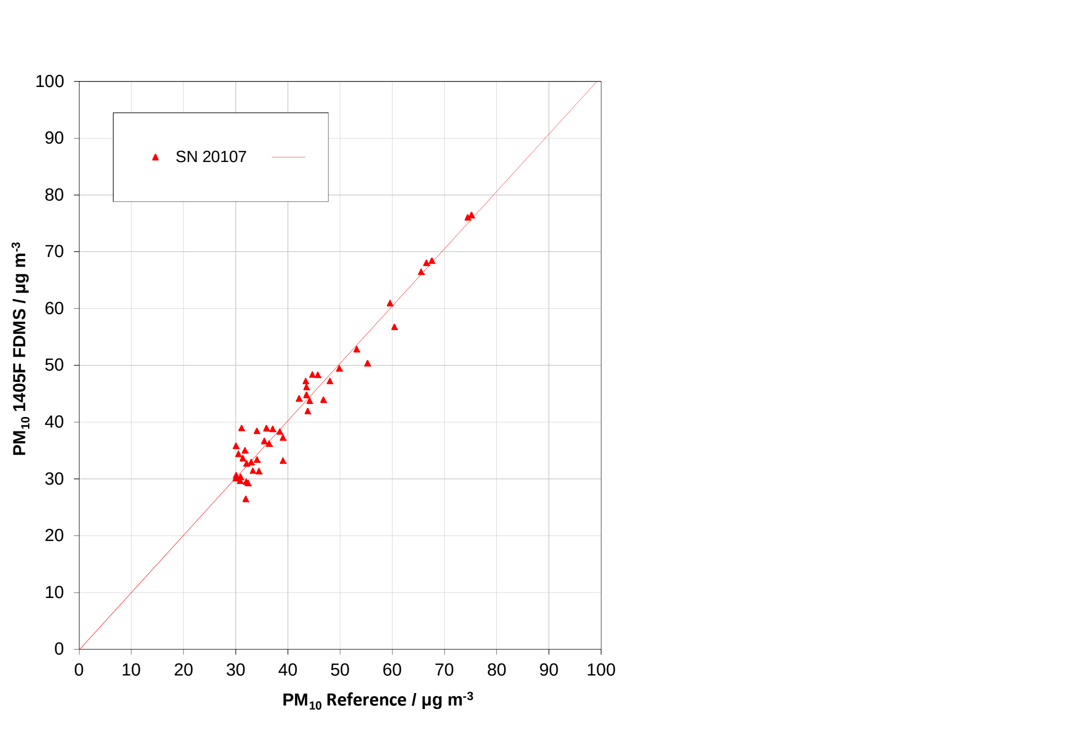


Figure 40: Reference vs. candidate, SN 20107, measured component PM_{10}, values ≥ 30 µg/m³



Conclusion for UK Purposes

As the intra instrument uncertainty of the reference method is less than 2.0 µg/m³ for the all data dataset, criterion 3 is fulfilled. Further, the intra instrument uncertainty of the reference method is less than 2.0 µg/m³ for two sub datasets corresponding to all the data split greater than or equal to and lower than 30 µg/m³, though there is no requirement for this objective to be achieved. These three intra instrument uncertainties should be placed on the MCERTS certificate.

The required expanded uncertainties are all less than 25%. These should be shown on the MCERTS certificate. As such, criterion 4 is fulfilled. The expanded uncertainties of the datasets less than 30 µg/m³ were also calculated. These should also be shown on the MCERTS certificate, but there is no requirement that they be below 25 %.

The intercept of the All Data dataset for SN20107 is statistically different from 0. This requires further investigation, and this is covered in Section 12.4.

12.4 Application of correction factors and terms

In this Section, Criterion 5 is assessed, namely:

5. Preconditions for acceptance of the full dataset are that: the slope b is insignificantly different from 1: $|b-1| \leq 2 \cdot u(b)$, and the intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$. If these preconditions are not met, the candidate method may be calibrated using the values obtained for slope and/or intercept of all paired instruments together.

The following text is copied with minor alterations from Section 6.1 5.4.11 of the TÜV Rheinland Report[2].

Equipment

Not required for this minimum requirement.

Evaluation

If evaluation of the raw data according to Section 12.4 leads to a case where $W_{CM} > W_{dqo}$, which means that the candidate systems is not regarded equivalent to the reference method, it is permitted to apply a correction factor or term resulting from the regression equation obtained from the full data set. The corrected values shall satisfy the requirements for all data sets or subsets. Moreover, a correction factor may be applied even for $W_{CM} \leq W_{dqo}$ in order to improve the accuracy of the candidate systems.

Three different cases may occur:

a) Slope b not significantly different from 1: $|b-1| \leq 2u(b)$,
intercept a significantly different from 0: $|a| > 2u(a)$

b) Slope b significantly different from 1: $|b-1| > 2u(b)$,
intercept a not significantly different from 0: $|a| \leq 2u(a)$

c) Slope b significantly different from 1: $|b-1| > 2u(b)$
intercept a significantly different from 0: $|a| > 2u(a)$

With respect to a)

The value of the intercept a may be used as a correction term to correct all input values y_i according to the following equation.

$$y_{i,corr} = y_i - a$$

The resulting values of $y_{i,corr}$ may then be used to calculate the following new terms by linear regression:

$$y_{i,corr} = c + dx_i$$

and

$$u_{c\_s}^2(y_{i,corr}) = \frac{RSS}{(n-2)} - u^2(x_i) + [c + (d-1)x_i]^2 + u^2(a)$$

with u(a) = uncertainty of the original intercept a, the value of which has been used to obtain $y_{i,corr}$.

Algorithms for the calculation of intercepts as well as slopes and their variances by orthogonal regression are described in detail in the 2010 GDE[8].

With respect to b)

The value of the slope b may be used as a factor to correct all input values y_i according to the following equation.

$$y_{i,corr} = \frac{y_i}{b}$$

The resulting values of $y_{i,corr}$ may then be used to calculate the following new terms by linear regression:

$$y_{i,corr} = c + dx_i$$

and

$$u^2_{c\_s}(y_{i,corr}) = \frac{RSS}{(n-2)} - u^2(x_i) + [c + (d-1)x_i]^2 + x_i^2 u^2(b)$$

with u(b) = uncertainty of the original slope b, the value of which has been used to obtain $y_{i,corr}$.

Algorithms for the calculation of intercepts as well as slopes and their variances by orthogonal regression are described in detail in the 2010 GDE[8].

With respect to c)

The values of the slope b and of the intercept a may be used as correction terms to correct all input values y_i according to the following equation.

$$y_{i,corr} = \frac{y_i - a}{b}$$

The resulting values of $y_{i,corr}$ may then be used to calculate the following new terms by linear regression:

$$y_{i,corr} = c + dx_i$$

and

$$u^2_{c\_s}(y_{i,corr}) = \frac{RSS}{(n-2)} - u^2(x_i) + [c + (d-1)x_i]^2 + x_i^2 u^2(b) + u^2(a)$$

with u(b) = uncertainty of the original slope b, the value of which has been used to obtain $y_{i,corr}$ and with u(a) = uncertainty of the original intercept a, the value of which has been used to obtain $y_{i,corr}$.

Algorithms for the calculation of intercepts as well as slopes and their variances by orthogonal regression are described in detail in in the 2010 GDE[8].

The values for $u_{c\_s,corr}$ are used for the calculation of the combined relative uncertainty of the candidate systems after correction according to the following equation:

$$w^2_{c,CM,corr}(y_i) = \frac{u^2_{c\_s,corr}(y_i)}{y_i^2}$$

For the corrected data set, uncertainty is calculated at the daily limit value $w_{c,CM,corr}$ by taking as y_i the concentration at the limit value.

The expanded relative uncertainty $W_{CM,corr}$ is calculated according to the following equation:

$$W_{CM',corr} = k \cdot w_{CM,corr}$$

In practice: k=2 for large number of available experimental results

The highest resulting uncertainty W_{CM} is compared and assessed with the requirements on data quality of ambient air measurements according to 2008/50/EC[10].Two results are possible:

1. $W_{CM} \leq W_{dqo}$ → Candidate method is accepted as equivalent to the standard method.
2. $W_{CM} > W_{dqo}$ → Candidate method is not accepted as equivalent to the standard method.

The specified expanded relative uncertainty W_{dqo} for particulate matter is 25 %[10]

Assessment

The candidate systems fulfil the requirements on the data quality of ambient air quality measurements during the test already without application of correction factors.

The evaluation of the “All data” comparison for both candidate nevertheless delivers a significant intercept for SN 20107 (see Table 18). The intercept for the “All data” comparison is 0.395. For this reason an intercept correction for the “All data” comparison was performed and all data sets re-evaluated with the corrected values. All data sets comply with the specifications on the data quality after the correction. The improvement of the expanded measuring uncertainty is only relatively marginal.

GDE 2010[8] requires that when operating in networks, a candidate method needs to be tested annually at a number of sites corresponding to the highest expanded uncertainty found during equivalence testing. These criteria are banded in 5 % steps (GDE2010, point 9.9.2, table 6). We have to bear in mind that the highest determined expanded uncertainty lays before the correction of the intercept for SN 20107 in Bornheim (Summer) in the range 20 % to 25 % and after the correction of the intercept SN 20107 in Bornheim (Summer) in the range 15 % to 20 %.

The application of a correction factor for the TEOM 1405-F Ambient Particulate Monitor for PM_{10} therefore slightly improves the expanded measuring uncertainties, but does not bring a decisive advantage. The demonstration of equivalence of the TEOM 1405-F Ambient Particulate Monitor for PM_{10} can also be shown without the application of correction factors and terms.

The respective realization of the above mentioned requirement on on-going QA/QC in networks is the responsibility of the network operator or of the responsible authority of the member state. However TÜV Rheinland and BV recommend, that the expanded uncertainty for the full data set is referred to for this, namely 8.4 % (uncorrected dataset) respectively 8.5 % (dataset after offset-correction), which again would require an annual test at two measurement sites.

Detailed representation of the test results

Table 20 shows the results of the evaluations of the equivalence check after the application of the correction factor for the intercept on the complete data set.

Table 20: Summary of the results of the equivalence check, SN 20006 & SN 20107, after intercept correction

PM10 1405F FDMS	23.3% > 28 µg m-3	Orthogonal Regression				Between Instrument Uncertainties	
	WCM / %	nc-s	r2	Slope (b) +/- ub	Intercept (a) +/- ua	Reference	Candidate
All Data	8.5	215	0.973	0.994 +/- 0.011	0.000 +/- 0.291	0.48	1.09
< 30 µg m-3	11.0	169	0.882	1.055 +/- 0.028	-0.962 +/- 0.501	0.46	1.03
> 30 µg m-3	9.8	46	0.963	0.992 +/- 0.029	-0.177 +/- 1.274	0.55	1.35

SN 20006	Dataset	Orthogonal Regression				Limit Value of 50 µg m-3	
		nc-s	r2	Slope (b) +/- ub	Intercept (a) +/- ua	WCM / %	% > 28 µg m-3
Individual Datasets	Teddington Summer	42	0.895	1.112 +/- 0.057	-0.340 +/- 0.883	22.24	2.4
	Cologne Winter	74	0.987	0.992 +/- 0.013	-0.068 +/- 0.461	6.62	55.4
	Bornheim Summer	55	0.931	1.134 +/- 0.041	-2.492 +/- 0.750	18.70	3.6
	Teddington Winter	66	0.987	0.959 +/- 0.014	-1.944 +/- 0.337	16.76	16.7
Combined Datasets	< 30 µg m-3	186	0.860	1.069 +/- 0.029	-1.772 +/- 0.528	11.31	2.2
	> 30 µg m-3	51	0.966	0.986 +/- 0.026	-0.499 +/- 1.147	10.09	100.0
	All Data	237	0.970	0.994 +/- 0.011	-0.565 +/- 0.294	9.55	23.2

SN 20107	Dataset	Orthogonal Regression				Limit Value of 50 µg m-3	
		nc-s	r2	Slope (b) +/- ub	Intercept (a) +/- ua	WCM / %	% > 28 µg m-3
Individual Datasets	Teddington Summer	57	0.927	1.065 +/- 0.039	0.412 +/- 0.605	15.76	1.8
	Cologne Winter	74	0.978	1.005 +/- 0.017	0.315 +/- 0.609	8.89	55.4
	Bornheim Summer	54	0.906	1.112 +/- 0.047	-1.255 +/- 0.859	19.65	3.7
	Teddington Winter	45	0.983	0.934 +/- 0.019	-0.287 +/- 0.455	15.56	13.3
Combined Datasets	< 30 µg m-3	184	0.886	1.052 +/- 0.026	-0.457 +/- 0.467	11.92	2.2
	> 30 µg m-3	46	0.949	1.010 +/- 0.034	-0.534 +/- 1.526	11.58	100.0
	All Data	230	0.970	0.996 +/- 0.011	0.400 +/- 0.292	8.86	21.7

Conclusion for UK Purposes

As the required expanded uncertainties were all below 25 % before correction for intercept, it is not compulsory to intercept correct the PM_{10} TEOM 1405-F. Correction for intercept is shown to be marginally beneficial, as the intercept for both instruments is not significantly different from 0 after correction. The MCERTS certificate should show the range of required expanded uncertainties both before and after correction for intercept. Intercept correction is not required in order to make the instrument equivalent, but it is essential that thorough and frequent on-going QA/QC procedures are employed (as prescribed in fprEN12341:2013[4] and CEN/TS16450[5]) including to precisely quantify analyser baseline performance and ensure the continued correct operation of the FDMS drier. As the criterion specifically states that a correction "may" be made, by taking this approach, Criterion 5 is fulfilled.

13. Discussion on the number of Reference Methods Used

As all of the field tests were conducted before the publication of MCERTS for UK Particulate Matter[1] (31st July 2012), there is no requirement that two collocated reference methods are used for each field test.

In all four field tests, two reference method instruments were used, and as such the field tests go beyond the requirements of MCERTS for UK Particulate Matter.

14. Discussion on the number of UK Field Tests

As all of the field tests were conducted before the publication of MCERTS for UK Particulate Matter[1] (31st July 2012), there is a requirement for there to be only at least one UK field test.

The PM_{10} TEOM 1405-F had two UK tests, and as such the field tests go beyond the requirements of MCERTS for UK Particulate Matter.

PARTICULATE MATTER POLLUTION CLIMATE EVALUATION

15. Pollution Climate Calculations

15.1 Introduction

MCERTS for UK Particulate Matter[1] sets out a mechanism for proving whether field campaigns from other Member States are at a similar Pollution Climate to the UK. This is based upon an extensive study of the existing pollution climate within the UK[12].

The methodology centres on a number of parameters. Primary of these is that it is required to prove that the geometric mean of the PM_{10} or $PM_{2.5}$ concentrations during individual campaigns are within the range prescribed in Table 21 below for a specific site type. There is also the requirement that at least 6 calendar months of data should be available, though allowances are made for instruments that were tested before MCERTS for UK Particulate Matter was published.

Table 21: Range of geometric mean concentrations for each site type in the UK calculated using 2007-2010 PM_{10} data, with this data factored to estimate the $PM_{2.5}$ geometric mean ranges.

Site Type	Geometric Mean PM_{10} Range (µg m^{-3})	Geometric Mean $PM_{2.5}$ Range (µg m^{-3})
Background (urban or suburban)	11.9 – 25.7	8.4 - 18.1
Traffic	10.9 – 42.3	7.7 - 29.8
Rural	4.3 – 18.1	3.0 - 12.8
Industrial	13.8 – 24.6	9.7 - 17.4

Additionally there is a requirement that at least one of the four field tests of at least 40 data pairs has at least 10 % of days where there was a high percentage, and at least one of the four field tests of at least 40 data pairs has at least 10 % of days where there was a low percentage of:

- Wind Speed;
- Ambient Temperature; and
- Ambient Dew Point.

Further, there is a requirement that at least one of the four field tests of at least 40 data pairs has at least 5 % of days where there was a high percentage, and at least one of the four field tests of at least 40 data pairs has at least 5 % of days where there was a low percentage of:

- Semi Volatile PM component.

The low and high thresholds are summarised in Table 22. For wind speed, different requirements are placed on whether the anemometer was mounted at a height of 10 m, 5 m or 2.5 m above ground level and as to whether the measurements were undertaken in a rural or urban area.

12 Characterising the PM climate in the UK for Equivalence Testing, D Green & G Fuller, King's College London Environmental Research Group, June 2012
uk-air.defra.gov.uk/reports/cat13/1207190952_DefraCharacterisingThePMClimateInTheUKForEquivalenceTestingV3.pdf

Table 22: Low and high thresholds and the requisite number of daily means for PM_{10} and $PM_{2.5}$ equivalence tests to be carried out outside these thresholds, whichever is appropriate (as a percentage of the number of measurements within one comparison) for semi-volatile PM mass concentrations and for selected meteorological conditions.

Threshold	Semi-volatile / Nitrate (µg m-3)		Wind speed (m/s)							Ambient Temperature (ºC)		Ambient Dew Point (ºC)	
	Threshold	%	Threshold: 10 metres Urban	10 metres Rural	5 metres Urban	5 metres Rural	2.5 metres Urban	2.5 metres Rural	%	Threshold	%	Threshold	%
Low	3.2	5	2.9	6	0.7	5.1	0.3	4.2	10	7.6	10	3.9	10
High	6.3	5	5.2	12.4	1.2	10.6	0.6	8.8	10	16.1	10	10.8	10

All of the concentration and meteorological data measured in the field tests for this study are given in Appendix E.

15.2 Geometric Mean Calculations

The results of the geometric mean calculations are summarised in Table 23. Where criteria are met they are shaded green, and where they are not met they are shaded red. In order to prevent weighting the calculations to specific days of the year: for each day of the year if more than one year's worth of reference method data was available, then the geometric mean of all available years was taken for this day. The geometric mean was then calculated for the entire year using these geometric means for each day of the year.

In all cases, the geometric means are within the prescribed range. All of the sites employed in the testing of the PM_{10} TEOM 1405-F are only used for equivalence testing purposes, and as such while greater than 6 months' worth of data have been collected at each site, the number of calendar days is slightly lower than 6 months' worth for Bornheim. In order to demonstrate that the area around Cologne is within the prescribed range, a Nord-Rhein Westphalia (NRW) network site for which three years of PM_{10} reference method data are available (Cologne-Chorweiler in a suburban area to Cologne) is also presented. This site is within the prescribed range of 130 km to all Cologne-Bonn area field test sites, and as such, the data from all sites in the Cologne area are shown to have a similar pollution climate to the UK. Further evidence can be found in the extensive study of the UK Pollution Climate, where data from the Cologne area were proven to be of a similar pollution climate to the UK[12].

Table 23: Site Name, Country, Site Classification, number of days, number of calendar days, prescribed range and geometric mean for reference method measurements of PM_{10} made in each site employed for the testing of the PM_{10} TEOM 1405-F. PM_{10} calculations for Cologne Chorwelier are also shown.

Site	Country	Classification	PM_{10} Days	Calendar Days	Allowed Range			Geometric Mean
Cologne, Parking Lot	Germany	Urban Background	400	228	11.9	to	25.7	22.6
Bornheim	Germany	Traffic	204	164	10.9	to	42.3	17.9
Cologne-Chorweiler	Germany	Suburban	889	365	11.9	to	25.7	22.6
Teddington	UK	Urban Background	502	281	11.9	to	25.7	15.6

15.3 Semi Volatile, Wind Speed, Ambient Temperature and Ambient Dew Point Calculations

Ambient Temperature, relative humidity and wind speed measurements were obtained from meteorological stations collocated with the instruments. The anemometer height was 2.5 m above ground in the UK test sites and 4.5 m in above ground in the German test sites. The German anemometer was assumed to be 5 m above ground for the purposes of the Pollution Climate calculations, as this is the closest category for which a comparison is available. Ambient dew points were calculated from the ambient temperature and the relative humidity. It is recognised that during periods of 100 % relative humidity this will lead to an underestimation of the ambient dew point, and therefore the percentage of days with the ambient dew point higher than the prescribed threshold may in actuality be greater. In all cases, the wind speed data are assumed to be urban rather than rural. The reason for this is that MCERTS for UK Particulate Matter calculations of rural wind speed were performed on data obtained from anemometers in coastal locations. Conversely, all of the sites employed in the field tests were non-coastal and exhibited a large degree of surface roughness.

Semi volatile component calculations were obtained by averaging the reference channel of the four PM_{10} and $PM_{2.5}$ 1405-F FDMSs. For the UK field tests, on days where these volatile fraction data were not available, the average of the 8500 series FDMSs at nearby London Teddington and London Bloomsbury were used. For the German field tests, on days where these volatile fraction data were not available, the ammonium nitrate concentration obtained from the analysis of reference method filters at Cologne Chorweiler was used. These remote sites are significantly within the 130 km distance restriction from imposed upon the use of volatile fraction data from remote sites. In recognition that both ammonium and nitrate ions can form compounds with nitrate and ammonium respectively (e.g. ammonium sulphate or sodium nitrate), the ammonium nitrate calculation was taken as whichever was the lower of:

1. assuming all ammonium ions were a part of ammonium nitrate; and
2. assuming all nitrate ions were a part of ammonium nitrate.

For nearly all days, the lower value for ammonium nitrate was obtained by assuming all nitrate was held in ammonium nitrate.

The results are summarised in Table 24 where criteria are met they are shaded green, and where they are not met they are shaded red. As discussed in Section 15.1, there is the requirement that for each instrument type, at least one site of at least 40 data pairs must meet the high threshold for each criteria, and at least one site of at least 40 data pairs must meet the low threshold for each criteria. For the PM_{10} TEOM 1405-F, at least one site of at least 40 data pairs meets the lower threshold and at least one site of at least 40 data pairs meets the higher threshold for each of Wind Speed, Ambient Temperature, Ambient Dew Point and Semi Volatile. As such, the Wind Speed, Ambient Temperature, Ambient Dew Point and Semi Volatile criteria are fully met for the PM_{10} TEOM 1405-F.

15.4 Conclusions

The geometric mean calculations for each of the three test sites are met. Further, in all cases, at least one site meets the lower threshold and at least one site meets the higher threshold for each of Wind Speed, Ambient Temperature, Ambient Dew Point and Semi Volatiles. As such, the pollution climate criteria are fully met for the PM_{10} TEOM 1405-F.

This information should be referenced on the MCERTS Certificate, but there is no requirement to give any detailed information as to the specific findings of the Pollution Climate calculations.

Table 24: Wind Speed, Ambient Temperature, Ambient Dew Point and Semi Volatile calculations for the PM_{10} TEOM 1405-F.

PM_{10} TEOM 1405-F	Wind Speed				Temperature			Dew Point			Semi Volatile		
	Category	Count	Lower / %	Higher / %	Count	Lower / %	Higher / %	Count	Lower / %	Higher / %	Count	Lower / %	Higher / %
Bornheim Summer	5 m urban	49	8.2	32.7	49	0.0	93.9	49	0.0	75.5	52	82.7	0.0
Cologne Winter	5 m urban	74	1.4	75.7	74	33.8	24.3	74	58.1	1.4	74	36.5	27.0
Teddington Winter	2.5 m urban	67	37.3	41.8	67	89.6	0.0	67	79.1	0.0	67	50.7	10.4
Teddington Summer	2.5 m urban	57	14.0	52.6	57	0.0	70.2	57	12.3	36.8	57	73.7	0.0

CONCLUSIONS

16. Discussion Relative to Data Quality Objectives

Air Quality Directive 2008/50/EC[10] has two data quality objectives for Particulate Matter. One is that the uncertainty is below 25 %, and the other is that the minimum data capture is 90 %. The mechanisms to prove these are set out in GDE2010[8] and MCERTS for UK Particulate Matter[1], and these mechanisms have been followed herein.

The uncertainty was demonstrated to be below 25 % in Section 12.3. The minimum data capture was demonstrated to be above 90 % in Section 11. As such, the data quality objectives have been fully achieved.

17. Overall Conclusions

The PM_{10} TEOM 1405-F fully meets the requirements set out in MCERTS for UK Particulate Matter [1]. The pollution climate calculations (Section 15) show that the requirements for the sites to be of a similar pollution climate to the UK, and for there to be a suitable range of wind speed, temperature, dew point and volatile components are all met. The field test sites utilised cover urban background, rural and traffic locations. We propose, therefore, that this instrument is suitable for use at urban background, rural and traffic locations within the UK.

The Executive Summary summarise the findings in relation to MCERTS for UK Particulate Matter[1]. The text has been agreed by the UK certification committee and is repeated on the MCERTS certificate. Below is a summary of the rationale behind these decisions.

A measurement range of 0 to 1000 µg/m³ is recommended in the TÜV Rheinland Report[2] as a "default setting of the analogue output for European conditions". It is recommended that this is also adopted for UK purposes.

The Test for the Constancy of Volumetric Flow was discussed in Section 8.1. As the highest deviation from the nominal value is -0.096%, it is this value that should be transferred to the MCERTS certificate. This is less than the required ± 3%. The flow rate tests were done under flow conditions at a variety of filter loadings encountered during the field tests as opposed to 0%, 50 % and 80% of the mass load as prescribed in MCERTS for UK Particulate Matter[1]. The variable filter load is not a requirement of CEN/TS16450[5].

The Leak Test procedure was discussed in Section 8.2. As the greatest leak detected is 2.00%, it is this value that should be transferred to the MCERTS certificate. This is greater than the required 1%; however, the leak test procedure for the 1405-F is an internal manufacturer's procedure, implemented in the instruments in order to avoid serious damage to the instrument. The check on tightness must be performed using this internal procedure. All of the leak tests conducted passed the manufacturer's leak test specifications, and it is recommended that this performance is sufficient in order to warrant approval of the instrument subject to an explanation being provided on the MCERTS certificate.

The maintenance interval was discussed in Section 8.3. The maintenance interval is defined by necessary maintenance procedures and is 4 weeks, and this is this value that should be transferred to the MCERTS certificate. This is greater than the required ≥ 2 weeks.

A series of intensive laboratory tests was undertaken by TÜV Rheinland that go beyond the requirements set out in MCERTS for UK Particulate Matter. It is not required to report the results of these tests on the MCERTS certificate.

MCERTS for UK Particulate Matter[1] requires that there should be a total of at least four field tests of at least 40 data points at locations. As all of the field tests were conducted before the publication of MCERTS for UK Particulate Matter (31st July 2012), allowances are made for the scope of the field tests:

1. It is not necessary that all the field test sites have a similar pollution climate similar to that of the UK, though these calculations were presented in Section 15. It was shown that the pollution climate criteria are fully met for the PM_{10} TEOM 1405-F. This information should be referenced on the MCERTS Certificate, but there is no requirement to give any detailed information as to the specific findings of the Pollution Climate calculations;
2. There is a requirement for there to be only at least one UK field test, though the PM_{10} TEOM 1405-F had two UK tests. This information should be included on the MCERTS certificate;
3. There is no requirement that two collocated reference methods are used for each field test, though two reference methods were used in all four tests. This information should be included on the MCERTS certificate;
4. There is no requirement for there to be at least 90 % data availability, though these calculations were presented in Section 11, where it was shown that the availability of both candidate instruments was greater than 90 %. This information should be included on the

MCERTS certificate.

The field test data were discussed in Section 12. MCERTS for UK Particulate Matter[1] use the same methodology as that employed in the 2010 version of the GDE[8]. A series of five criteria must be fulfilled in order to prove equivalence.

1. Of the full dataset at least 20 % of the results obtained using the standard method shall be greater than the upper assessment threshold specified in 2008/50/EC for annual limit values *i.e.*: 28 µg/m³ for PM_{10} and currently 17 µg/m³ for $PM_{2.5}$.
2. The intra instrument uncertainty of the candidate must be less than 2.5 µg/m³ for all data and for two sub datasets corresponding to all the data split greater than or equal to and lower than 30 µg/m³ or 18 µg/m³ for PM_{10} and $PM_{2.5}$ respectively.
3. The intra instrument uncertainty of the reference method must be less than 2.0 µg/m³.
4. The expanded uncertainty (W_{CM}) is calculated at 50 µg/m³ for PM_{10} and 30 µg/m³ for $PM_{2.5}$ for each individual candidate instrument against the average results of the reference method. For each of the following permutations, the expanded uncertainty must be less than 25 %:
   - Full dataset;
   - Datasets representing PM concentrations greater than or equal to 30 µg/m³ for PM_{10}, or concentrations greater than or equal to 18 µg/m³ for $PM_{2.5}$, provided that the subset contains 40 or more valid data pairs;
   - Datasets for each individual test site.
5. Preconditions for acceptance of the full dataset are that: the slope b is insignificantly different from 1: $|b-1| \leq 2 \cdot u(b)$, and the intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$. If these preconditions are not met, the candidate method may be calibrated using the values obtained for slope and/or intercept of all paired instruments together.

As at least 20 % of the results obtained using the standard method are greater than 28 µg/m³, criterion 1 is fulfilled. There is no requirement in MCERTS for UK Particulate Matter for this information to be placed upon the MCERTS certificate.

As the intra instrument uncertainty of the candidate method is less than 2.5 µg/m³ for all data and for two sub datasets corresponding to all the data split greater than or equal to and lower than 30 µg/m³, criterion 2 is fulfilled. These three intra instrument uncertainties should be placed on the MCERTS certificate.

As the intra instrument uncertainty of the reference method is less than 2.0 µg/m³ for the all data dataset, criterion 3 is fulfilled. Further, the intra instrument uncertainty of the reference method is less than 2.0 µg/m³ for two sub datasets corresponding to all the data split greater than or equal to and lower than 30 µg/m³, though there is no requirement for this objective to be achieved. These three intra instrument uncertainties should be placed on the MCERTS certificate.

The required expanded uncertainties are all less than 25%, and as such, criterion 4 is fulfilled. These should be shown on the MCERTS certificate. The expanded uncertainties of the datasets less than 30 µg/m³ were also calculated. These should also be shown on the MCERTS certificate, but there is no requirement that they be below 25 %.

As the required expanded uncertainties were all below 25 % before correction for intercept, it is not compulsory to intercept correct the PM_{10} TEOM 1405-F. Correction for intercept is shown to be marginally beneficial, as the intercept for both instruments is not significantly different from 0 after correction. The MCERTS certificate should show the range of required expanded uncertainties both before and after correction for intercept. Intercept correction is not required in order to make the instrument equivalent, but it is essential that thorough and frequent on-going QA/QC procedures are employed (as prescribed in fprEN12341:2013[4] and CEN/TS16450[5]) including to precisely quantify analyser baseline performance and ensure the continued correct operation of the FDMS drier. As the criterion specifically states that a correction “may” be made, by taking this approach, Criterion 5 is fulfilled.

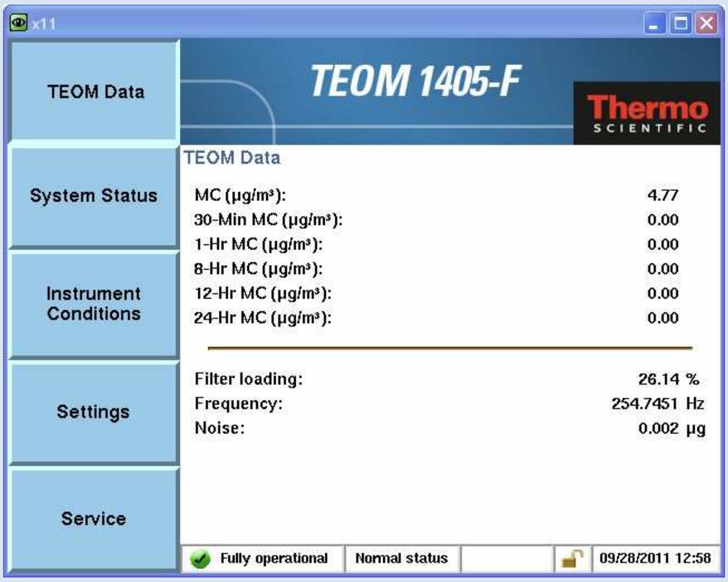
APPENDICES

A. Operating Procedures

The following text is copied with minor alterations from Section 3.3 of the TÜV Rheinland Report[2].

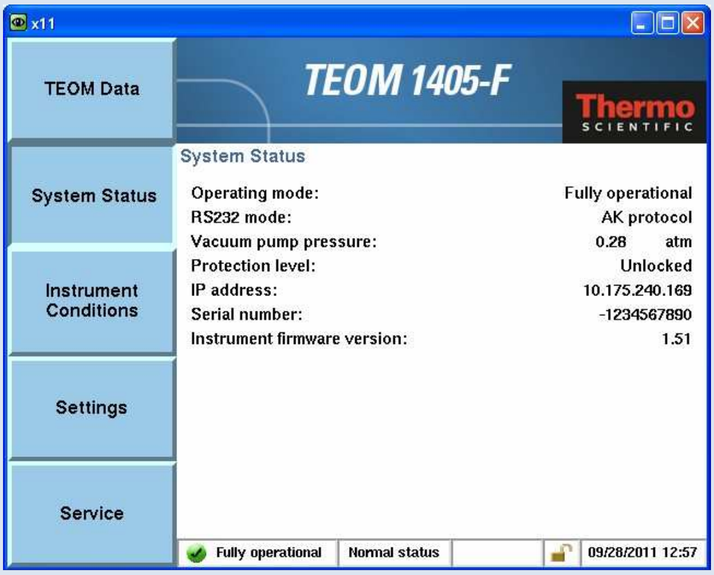
The measuring device is operated *via* touch screen at the front of the device. The user can retrieve data and instrument information, change parameters as well as perform tests and controls of the functionality of the measuring device.

Figure 41: Main window of the user display



On the first level the main window of the user display is located – here the current time, the current date, the instrument status (normal/ warning), the current operational condition (e.g. fully operational, stabilizing…), the mass concentration values (MC (= moving hourly mean, every 6 minutes updated), 30 min. (presently not implemented) 1h-, 8h-, 12h- and 24h-averages), the vibration frequency, the noise of the mass measuring and the loading of the TEOM-filter are displayed.

Figure 42: Menu: System status (here software version 1.51)



In the menu “System Status“, status information of the instrument can be looked at. At this place, also the current software version can be looked at.

In the case of warning messages an additional button appears in the centre of the display: “View Warnings“. After its confirmation, the pending warning messages can be looked at. In addition, an overview of the warning messages can be received at any time by clicking at the triangular warning symbols located at the right of the “TEOM Data“-button.

Figure 43: Warning messages display (triangular warning symbol + button “View Warnings“)

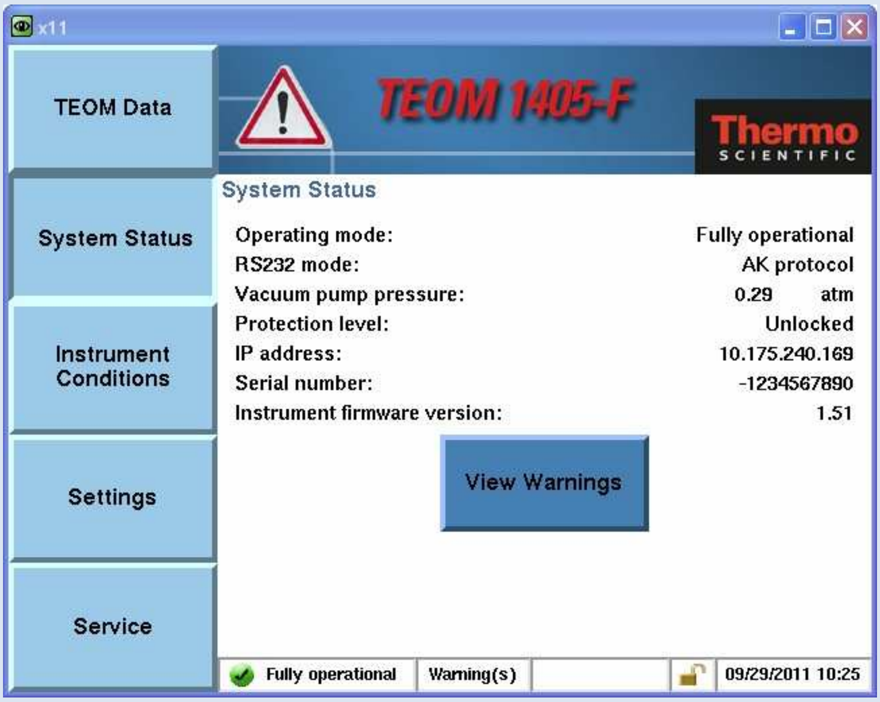
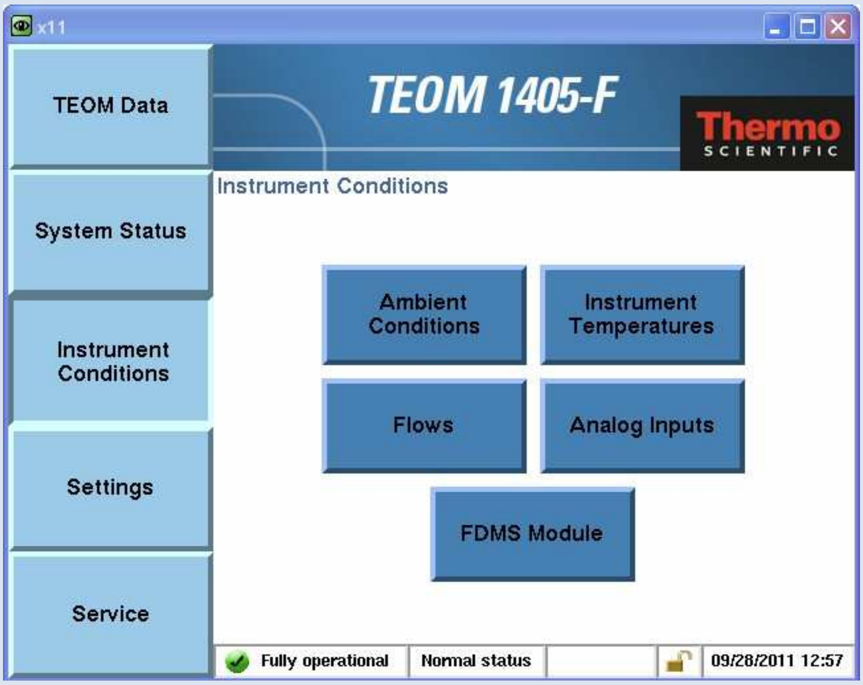
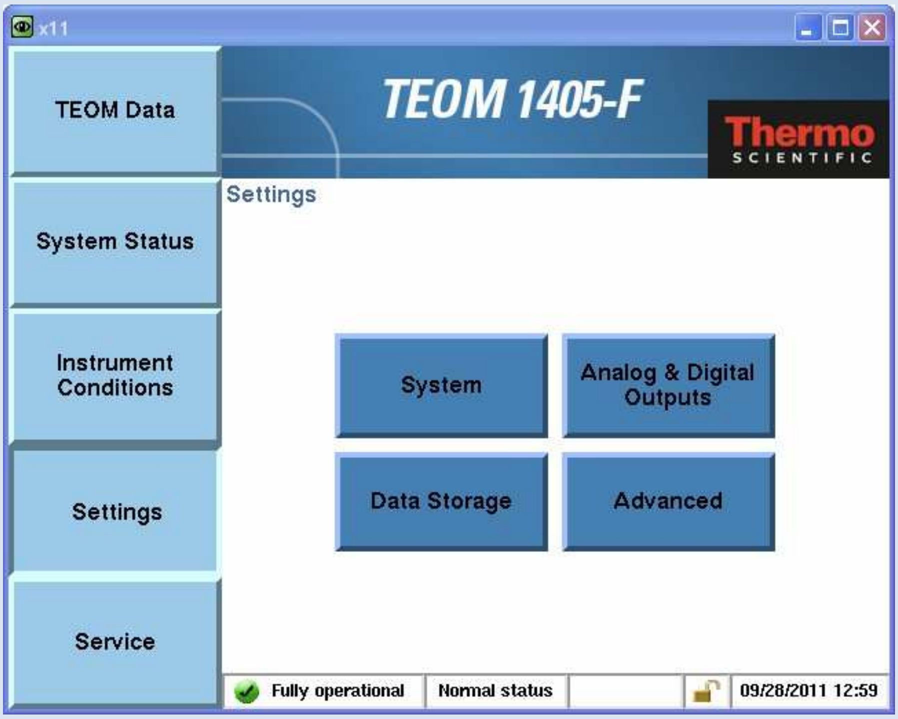


Figure 44: Menu: Instrument conditions



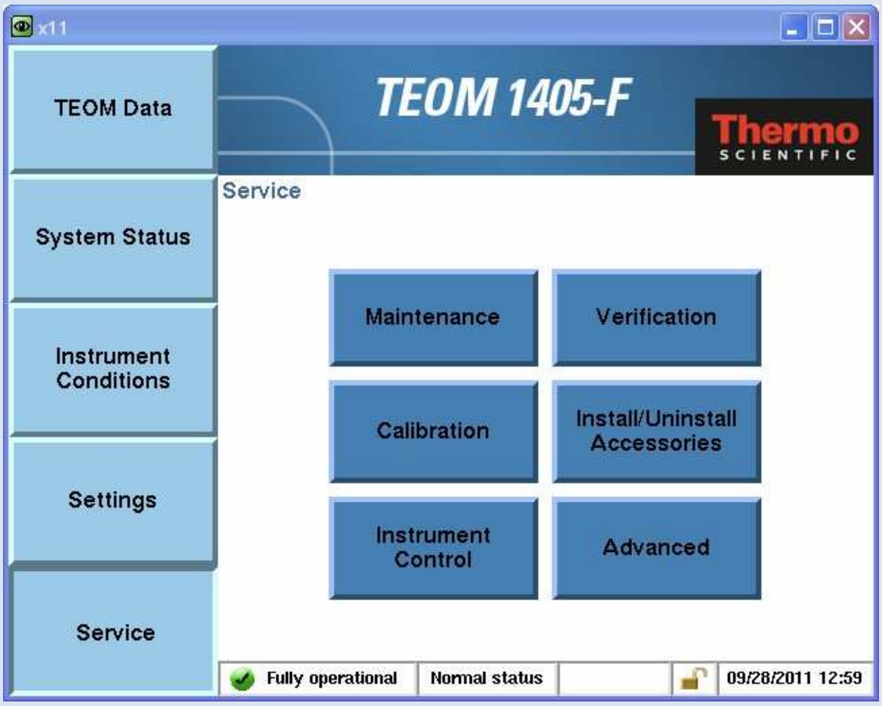
In the menu “Instrument conditions“, the user may control and modify different settings of the instrument regarding temperature and flow rates as well as inform him about ambient conditions of the instrument.

Figure 45: Menu: Settings



In the menu “Settings“, the user has access to system-, data- and advanced settings. At this point e.g. date/ time can be set, the password protection can be activated, analogue and digital output can be parameterized or the calibration constant K_0 can be displayed.

Figure 46: Menu: Service



In the menu "Service", all implemented procedures for the instrument maintenance (e.g. change of TEOM-filter, cleaning of the cooler etc.), instrument checking (flow rate, leak test, check of the calibration constant K_0…), instrument calibration (flow rate, temperature- and pressure sensors) and other functionalities can be obtained.

By using the maintenance assistant of the software, the user is lead step by step through maintenance- and audit-work via different screens. Therefore no manual is needed at the test site for the performance of this work.

Besides the direct communication via operating keys/ display, extensive possibilities exist to communicate via different analogue outputs, RS232-interfaces, USB-interfaces as well as Ethernet-interfaces.

The following possibilities are available:

- 1 x 25-pin USER I/O interface for analogue in- and output and digital output.
- 1 x RS232-interface for the communication via RP Comm or HyperTerminal software
- 1 x Ethernet-interface for the connection to a PC for the data transfer and remote control via ePort software.
- 2 x USB-interfaces for direct data download and firmware update.

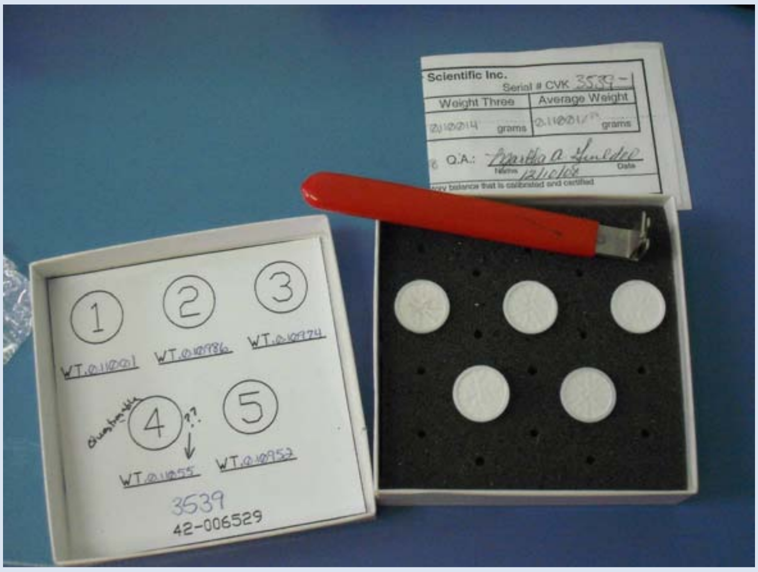
For the external zero point check of the measuring system and for the check of the calibration constant K_0, a zero-filter is installed at the instrument inlet. The use of this filter enables the provision of particulate-free air.

Figure 47: Zero-filter during field test

By means of the available shut-off valve, a leak test of the measuring system according to chapter 3 of the manual can also be performed with the zero-filter.

To check the calibration constant K_0 a special filter kit with pre-weighed TEOM-filters is used.

Figure 48: Set of filters for the check of the calibration constant K_0



B. Filter Weighing Procedures

The following text is copied with minor alterations from Appendix 2 of the TÜV Rheinland Report[2]. Figures that were in German have been replaced with Figures in English.

B.1 German test sites (Cologne and Bornheim)

Carrying out the weighing

All weightings are done in an air-conditioned weighing room. Ambient conditions are 20 ℃ ±1 ℃ and 50 % ±5 % relative humidity, which conforms to the requirements of Standard EN 14907[7].

The filters used in the field test are weighed manually. The filters (including control filters) are placed on sieves for the purpose of conditioning to avoid overlap.

The specifications for pre- and post-weighing are specified beforehand and conform to the Standard.

Table 25: Pre and post weighing specifications.

Before sampling = pre-weighing	After sampling = post-weighing
Conditioning 48 h + 2 h	Conditioning 48 h + 2 h
Filter weighing	Filter weighing
Re-conditioning 24 h +2 h	Re-conditioning 24 h + 2 h
Filter weighing and immediate packaging	Filter weighing

The balance is always kept ready for use. An internal calibration process is started prior to each weighing series. The standard weight of 200 mg is weighed as reference and the boundary conditions are noted if nothing out of ordinary results from the calibration process. Deviations to prior measurements conform to the Standard and do not exceed 20 µg (refer to Figure 49). All six control filters are weighed afterwards and a warning is displayed for control filters with deviations > 40 µg during evaluation. These control filters are not used for post-weighing. Instead, the first three acceptable control filters are used while the others remain in the protective jar in order to replace a defective or deviating filter, if necessary.

Figure 50 shows an exemplary process over a period of more than 4 months.

All filters which deviate more than 40 µg between the first and second weighing are excluded during the pre-weighing process. Filters which deviate more than 60 µg are not considered for evaluation after post-weighing, as conforming to standards.

Weighed filters are packed in separate polystyrene jars for transport and storage. These jars remain closed until the filter is placed in the filter holder. Virgin filters can be stored in the weighing room for up to 28 days before sampling. Another pre-weighing is carried out if this period is exceeded.

Sampled filters can be stored for not more than 15 days at a temperature of 23 ℃ or less. The filters are stored at 7 ℃ in a refrigerator.

Filter evaluation

The filters are evaluated with the help of a corrective term in order to minimize relative mass changes caused by the weighing room conditions.

Equation:

$$Dust = MF_{post} - (M_{Tara} \times (MKon_{post} / MKon_{pre})) \quad (F1)$$

$MKon_{pre}$ = average mass of the 3 control filters after 48 h and 72 h pre-weighing

$MKon_{post}$ = average mass of the 3 control filters after 48 h and 72 h post-weighing

M_{Tara} = average mass of the filter after 48 h and 72 h pre-weighing

MF_{post} = average mass of the loaded filter after 48 h and 72 h post-weighing

Dust = corrected dust mass of the filter

This shows that the method becomes independent from weighing room conditions due to the corrective calculation. Influence due to the water content of the filter mass between virgin and loaded filter can be controlled and do not change the dust content of sampled filters. Hence, Point EN 14907[7] 9.3.2.5 is fulfilled.

The below example of the standard weight between November 2008 and February 2009 shows that the allowed deviation of not more than 20 µg on the previous measurement is not exceeded.

Figure 49: Stability of standard weight

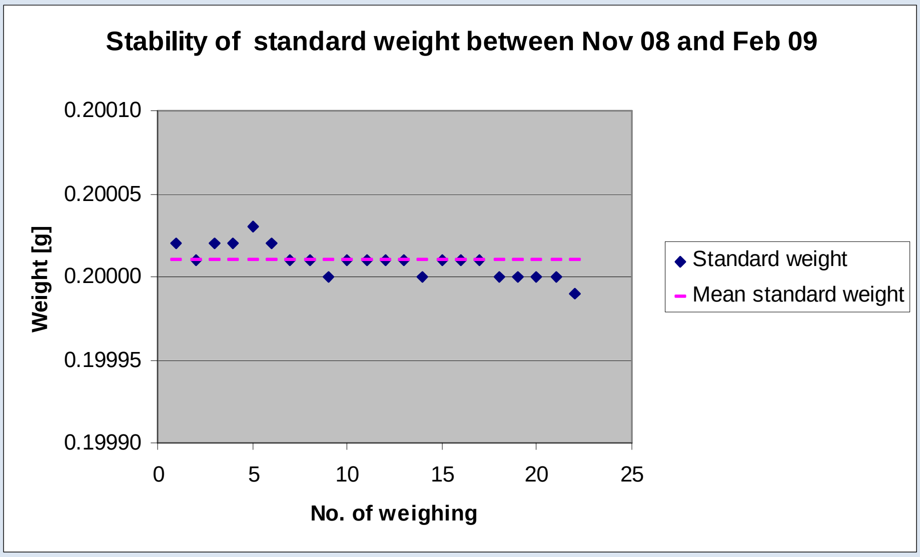


Table 26: *Stability standard weight*

Date	Weighing No.	Standard weight g	Difference to the previous weighing µg
12.11.2008	1	0.20002	
13.11.2008	2	0.20001	-10
10.12.2008	3	0.20002	10
11.12.2008	4	0.20002	0
17.12.2008	5	0.20003	10
18.12.2008	6	0.20002	-10
07.01.2009	7	0.20001	-10
08.01.2009	8	0.20001	0
14.01.2009	9	0.20000	-10
15.01.2009	10	0.20001	10
21.01.2009	11	0.20001	0
22.01.2009	12	0.20001	0
29.01.2009	13	0.20001	0
30.01.2009	14	0.20000	-10
04.02.2008	15	0.20001	10
05.02.2009	16	0.20001	0
11.02.2009	17	0.20001	0
12.02.2009	18	0.20000	-10
18.02.2009	19	0.20000	0
19.02.2009	20	0.20000	0
26.02.2009	21	0.20000	0
27.02.2009	22	0.19999	-10

Highlighted yellow = average value

Highlighted green = lowest value

Highlighted blue = highest value

Figure 50: *Stability of the control filters*

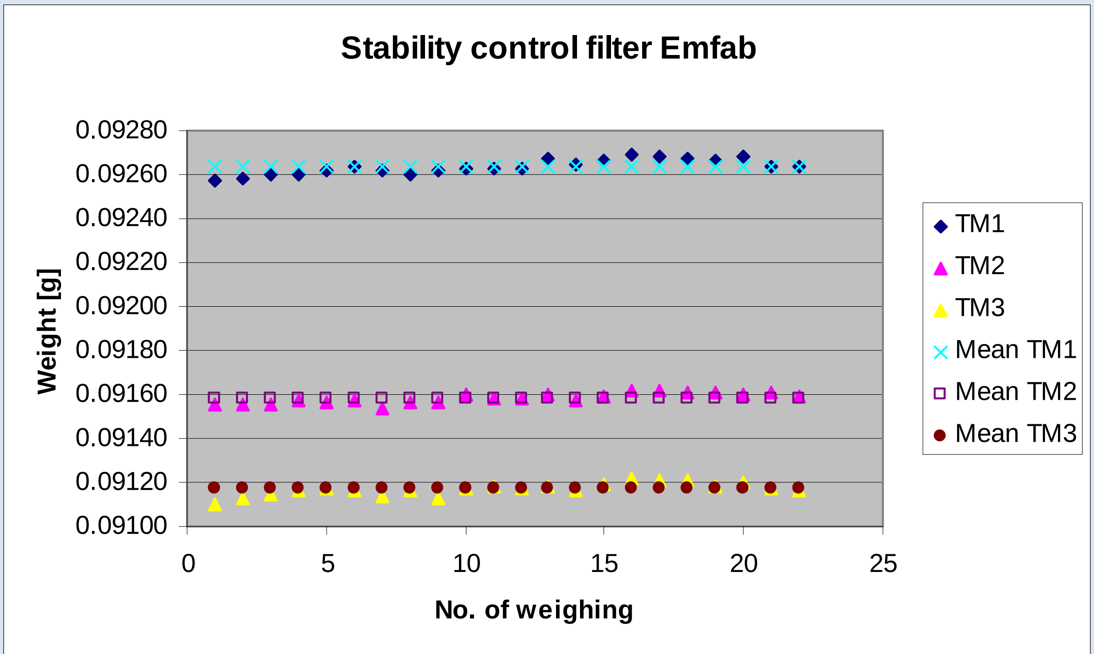


Table 27: Stability of the control filters

	Control filter No.		
Weighing No.	TM1	TM2	TM3
1	0.09257	0.09155	0.09110
2	0.09258	0.09155	0.09113
3	0.09260	0.09155	0.09115
4	0.09260	0.09157	0.09116
5	0.09262	0.09156	0.09117
6	0.09264	0.09157	0.09116
7	0.09262	0.09154	0.09114
8	0.09260	0.09156	0.09116
9	0.09262	0.09156	0.09113
10	0.09263	0.09160	0.09117
11	0.09263	0.09158	0.09118
12	0.09263	0.09158	0.09117
13	0.09267	0.09160	0.09118
14	0.09265	0.09157	0.09116
15	0.09266	0.09159	0.09119
16	0.09269	0.09162	0.09122
17	0.09268	0.09162	0.09121
18	0.09267	0.09161	0.09121
19	0.09266	0.09161	0.09118
20	0.09268	0.09160	0.09120
21	0.09264	0.09161	0.09117
22	0.09264	0.09159	0.09116
Average	0.09264	0.09158	0.09117
Standard deviation	3.2911E-05	2.4937E-05	2.8558E-05
relative standard deviation	0.036	0.027	0.031
Median	0.09264	0.09158	0.09117
lowest value	0.09257	0.09154	0.09110
highest value	0.09269	0.09162	0.09122

Highlighted yellow = average value

Highlighted green = lowest value

Highlighted blue = highest value

B.2 UK test sites (Teddington)

Implementation of Weighing Protocols

NPL (National Physical Laboratory) were subcontracted to weigh filters manually for the field study. In line with EN14907 filters were kept in the weighing room for less than 28 days; the glove box used for weighing was maintained at (20 ± 1) ℃ and (50 ± 5) %; and filters were weighed twice before and after sampling. *Table 28* summarizes the conditioning and weighing timescales utilised:

Table 28: conditioning and weighing timescales

Pre Sampling	Post Sampling
Condition minimum of 48 hours Weigh Filters Condition 24 hours Weigh Filters	Condition 48 hours Weigh Filters Condition 24 hours Weigh Filters

At the start of each weighing session the balance was exercised to remove mechanical stiffness, and then calibrated. At the start and end of each batch of filters, a 50 and 200 mg check weight were weighed. In line with the recommendations of the UK PM Equivalence Report[Error! Bookmark not defined.], filters were weighed relative to a 100 mg check weight, and not a tare filter, as the latter was shown to lose mass over time. Four filters were weighed between check weights, as the balance drift over time had been shown to be small.

The **Check weight Mass (CM)** of the filter was calculated for each weighing session using **E B.1** below:

$$CM = \frac{\left(m_{check,Beg} + m_{check,End}\right)}{2} \qquad \textbf{E B.1}$$

Where:

$M_{check,bef}$ = Mass of check weight weighed immediately prior to sample filter.

$M_{check,aft}$ = Mass of check weight weighed immediately after sample filter.

The **Relative Mass (RM)** of the filter was calculated for each weighing session using **E B.2** below:

$$RM = m_{filter} - CM \qquad \textbf{E B.2}$$

Where:

m_{filter} = Mass of sample filter

Particulate Mass (PM) is calculated using the following equation in accordance with EN14907.

$$PM = \left(\frac{RM_{End1} + RM_{End2}}{2}\right) - \left(\frac{RM_{Beg1} + RM_{Beg2}}{2}\right) \qquad \textbf{E B.3}$$

Where:

Pre1 denotes weighing session 1 prior to sampling

Pre2 denotes weighing session 2 prior to sampling

Post1 denotes weighing session 1 after sampling

Post2 denotes weighing session 2 after sampling

Pre Spread (S_{Pre}), Post Spread (S_{Post}) and Blank Spread (S_{Blank}) were calculated using the following equations:

$$S_{Pre} = RM_{Anf1} - RM_{Anf2} \quad \textbf{E B.4}$$

$$S_{Post} = RM_{End1} - RM_{End2} \quad \textbf{E B.5}$$

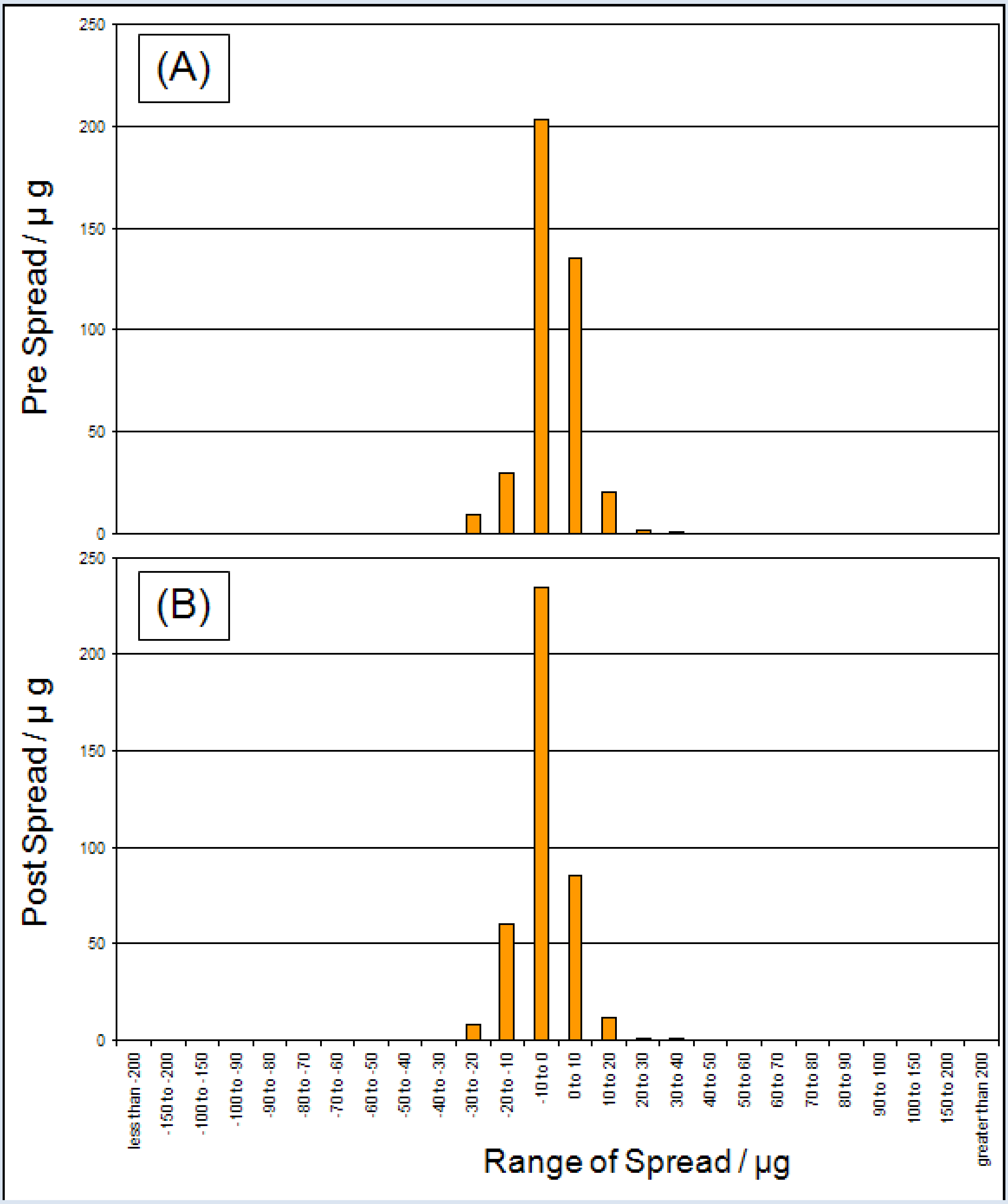
$$S_{Blank} = \left(\frac{CM_{End2} + CM_{End1}}{2} \right) - \left(\frac{CM_{Anf2} + CM_{Anf1}}{2} \right) \quad \textbf{E B.6}$$

As with the UK PM Equivalence Report[12], it was not possible to weigh all filters within the 15 day timeframe suggested in EN14907. However, as filters were removed immediately from the reference samplers and placed in the refrigerator, it was not necessary to determine if $T_{Ambient}$ exceeded 23 ºC. It is felt that as 15 days was impractical for a relatively small scale field study, it is less likely to be attainable if this methodology were adopted by a National or Regional network, and as such, the methodology employed herein is representative of how the reference samplers would be operated in practice.

Analysis of Protocols Employed

The distributions of pre and post weight for all Emfab filters weighed relative to the tare filter and check weight are shown in Figure 51. If filters lose relative mass between weightings, then the distribution will be shifted to the right, whereas if there is a gain in the relative mass the distribution will shift to the left. EN14907 states that unsampled filters should be rejected if the difference between the masses of the two pre weightings is greater than 40 µg. Similarly, EN14907 states that sampled filters should be rejected if the difference between the masses of the two post weightings is greater than 60 µg. Filters were not rejected based on these criteria. The observed distributions of repeat mass measurements are considered unlikely to have had a significant effect on the results.

*Figure 51: Distribution for Emfab filters of (**A**) Pre spread weighed relative to the check weight and (**B**) Post spread weighed relative to the check weight.*



C. ISO17025 Accreditations

Figure 52: ISO17025 Accreditation deed of TÜV Rheinland Energie und Umwelt GmbH

DAkkS Deutsche Akkreditierungsstelle

Deutsche Akkreditierungsstelle GmbH

Beliehene gemäß § 8 Absatz 1 AkkStelleG i.V.m. § 1 Absatz 1 AkkStelleGBV
Unterzeichnerin der Multilateralen Abkommen
von EA, ILAC und IAF zur gegenseitigen Anerkennung

Akkreditierung

Die Deutsche Akkreditierungsstelle GmbH bestätigt hiermit, dass die

TÜV Rheinland Energie und Umwelt GmbH

mit ihrer

Messstelle für Immissionsschutz (Environmental Protection)
Am Grauen Stein, 51105 Köln

und ihrer unselbständigen Messstelle

Robert-Koch-Straße 27, 55129 Mainz

die Kompetenz nach DIN EN ISO/IEC 17025:2005 besitzt, Prüfungen in folgenden Bereichen durchzuführen:

Bestimmung (Probenahme und Analytik) von anorganischen und organischen gas- oder partikelförmigen Luftinhaltsstoffen im Rahmen von Emissions- und Immissionsmessungen; Probenahme von luftgetragenen polyhalogenierten Dibenzo-p-Dioxinen und Dibenzofuranen bei Emissionen und Immissionen; Probenahme von faserförmigen Partikeln bei Emissionen und Immissionen; Ermittlung von gas- oder partikelförmigen Luftinhaltsstoffen mit kontinuierlich arbeitenden Messgeräten; Bestimmung von Geruchsstoffen in Luft; Kalibrierungen und Funktionsprüfungen kontinuierlich arbeiten-der Messgeräte für Luftinhaltsstoffe einschließlich Systemen zur Datenauswertung und Emissionsfernüberwachung; Eignungsprüfungen von automatisch arbeitenden Emissions- und Immissionsmesseinrichtungen einschließlich Systemen zur Datenauswertung und Emissionsfernüberwachung; Feuerraummessungen; Ermittlung der Emissionen und Immissionen von Geräuschen; Ermittlung von Geräuschen und Vibrationen am Arbeitsplatz;
Modul Immissionsschutz

Die Akkreditierungsurkunde gilt nur in Verbindung mit dem Bescheid vom 13.05.2011 mit der Akkreditierungsnummer D-PL-11120-02 und ist gültig bis 31.01.2013. Sie besteht aus diesem Deckblatt, der Rückseite des Deckblatts und der folgenden Anlage mit insgesamt 32 Seiten.

Registrierungsnummer der Urkunde: **D-PL-11120-02-00**

Berlin, 13.05.2011

i. V. Valbuena
Andrea Valbuena
Abteilungsleiterin

Siehe Hinweise auf der Rückseite

Deutsche Akkreditierungsstelle GmbH

Standort Berlin
Spittelmarkt 10
10117 Berlin

Standort Frankfurt am Main
Gartenstraße 6
60594 Frankfurt am Main

Standort Braunschweig
Bundesallee 100
38116 Braunschweig

Die Akkreditierung erfolgte gemäß des Gesetzes über die Akkreditierungsstelle (AkkStelleG) vom 31. Juli 2009 (BGBl. I S. 2625) sowie der Verordnung (EG) Nr. 765/2008 des Europäischen Parlaments und des Rates vom 9. Juli 2008 über die Vorschriften für die Akkreditierung und Marktüberwachung im Zusammenhang mit der Vermarktung von Produkten (Abl. L 218 vom 9. Juli 2008, S. 30).
Die DAkkS ist Unterzeichnerin der Multilateralen Abkommen zur gegenseitigen Anerkennung der European co-operation for Accreditation (EA), des International Accreditation Forum (IAF) und der International Laboratory Accreditation Cooperation (ILAC). Die Unterzeichner dieser Abkommen erkennen ihre Akkreditierungen gegenseitig an.

Der aktuelle Stand der Mitgliedschaft kann folgenden Webseiten entnommen werden:
EA: www.european-accreditation.org
ILAC: www.ilac.org
IAF: www.iaf.nu

Figure 53: ISO17025 Accreditation deeds of NPL (excerpts).

Schedule of Accreditation
issued by
United Kingdom Accreditation Service
21 - 47 High Street, Feltham, Middlesex, TW13 4UN, UK

0002 Accredited to ISO/IEC 17025:2005	**NPL Management Ltd** Issue No: 047 Issue date: 22 October 2012	
	Hampton Road **Teddington** **Middlesex** **TW11 0LW**	**Contact: Customer Helpline** **Tel: +44 (0)20 8943 7070** **Fax: +44 (0)20 8943 6184** **E-Mail: measurement_services@npl.co.uk** **Website: www.npl.co.uk**
Testing performed by the Organisation at the locations specified below		

Locations covered by the organisation and their relevant activities

Laboratory locations:

Location details		**Activity**	**Location code**
Address Hampton Road Teddington Middlesex TW11 0LW	**Local contact** Mr Tahir Maqba Customer Services Manager Tel: +44 (0)20 8943 6796 Fax: +44 (0)20 8943 6184 E-Mail: tahir.maqba@npl.co.uk Website: www.npl.co.uk	**Support Functions:** Quality System Quality Audit Administration **Testing:** Mechanical, metallurgical, physical and chemical testing **Sampling and Testing:** Stack Emissions Testing	A
Address University of Huddersfield Queensgate Huddersfield Building T4/04 HD1 3DH	**Local contact** Lisa Leonard Tel: +44 (0) 20 8943 8716 Fax: +44 (0) 208 614 0482 E-mail: lisa.leonard@npl.co.uk Website: http://www.npl.co.uk/huddersfield	**Testing:** Dimensional testing	D

Site activities performed away from the locations listed above:

Location details	**Activity**	**Location code**
Customers' premises/sites	Sampling and analysis	B
Customer Sites requiring Stack Emissions Testing	Stack Emissions Testing	C

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0002 Accredited to ISO/IEC 17025:2005	**Schedule of Accreditation** issued by **United Kingdom Accreditation Service** 21 - 47 High Street, Feltham, Middlesex, TW13 4UN, UK **NPL Management Ltd** **Issue No:** 047 **Issue date:** 22 October 2012

Testing performed by the Organisation at the locations specified

Materials/Products tested	Type of test/Properties measured/Range of measurement	Standard specifications/ Equipment/Techniques used	Location Code
WORKPLACE AND AMBIENT ATMOSPHERIC POLUTANTS, AND OTHER GAS SAMPLES (cont'd)	Chemical Tests (cont'd)		
Volatile organic compounds using pumped sorbent tubes	0.0001 to 200 ml/m^3 (ppm v/v) for some individual species	Documented in-house method based on MDHS 60 and 72 and ISO standard TC/146/SC2/N142 using Gas Chromatography with a FID end point QPDQM/B/527	A
	Physical Tests		
Volatile organic compounds using sorbent sampler tubes	0.0001 to 200 ml/m^3 (ppm v/v) for some individual species with opinions and interpretations based on NIST research library	Documented in-house method based on BS EN ISO 16017-1&2, UK HSE MDHS 63, 72 & 80 using an automated thermal desorber gas chromatogram with a mass spectrometer and optional simultaneous flame ionisation detector (ATD/GC/MS-FID)	A
Total mercury from glass adsorption tubes containing gold-coated silica	Total mercury	Thermal desorption-atomic fluorescence spectroscopy. Documented in-house method QPAS/B/544 in accordance with BS EN 15852:2010	A
Weight of suspended particulate matter	25 ug to 7 mg equivalent to 1 µg/m^3 for a 1 m^3/hour sampler to 120 µg/m^3 for a 2.3 m^3/hour sampler	Documented in-house method based on BS EN 14907:2005	A
Pumped and diffusive sorbent tubes	C2 to C10 hydrocarbons, Nitrogen dioxide Nitrogen monoxide Sulphur dioxide Volatile organic compounds	Documented in-house methods QPDQM/B/522, 523, 525, 526, 527	B

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Schedule of Accreditation

issued by

United Kingdom Accreditation Service

21 - 47 High Street, Feltham, Middlesex, TW13 4UN, UK

UKAS CALIBRATION 0478 Accredited to ISO/IEC 17025:2005	NPL Management Ltd Issue No: 058 Issue date: 28 November 2012	
	Hampton Road **Teddington** **Middlesex** **TW11 0LW**	**Contact: Customer Helpline** **Tel: +44 (0)20 8943 7070** **Fax: +44 (0)20 8943 6184** **E-Mail: measurement_services@npl.co.uk** **Website: www.npl.co.uk**
Calibration performed by the Organisation at the locations specified below		

Locations covered by the organisation and their relevant activities

Laboratory locations:

Location details		Activity	Location code
Address National Physical Laboratory Hampton Road Teddington Middlesex TW11 0LW	**Local contact** Mr Tahir Maqba, Customer Services Manager Tel: +44 (0)20 8943 6798 Fax: +44 (0)20 8943 6184 Email: tahir.maqba@npl.co.uk	Calibration Acoustics Chemical Dimensional Electromagnetic Fibre optics Flow Force Humidity Mass Optical Pressure Radiological Temperature Time and Frequency Ultrasonics	Teddington
Address Wraysbury Reservoir Coppermill Road Wraysbury Middlesex TW19 5NW	**Local contact** Mr G Hayman Tel: +44 (0)20 8943 7172 Email: gary.hayman@npl.co.uk	Calibration Underwater Acoustics	Wraysbury

Site activities performed away from the locations listed above:

Location details	Activity	Location code
Customers' sites or premises The customers' site or premises must be suitable for the nature of the particular calibrations undertaken and will be the subject of contract review arrangements between the laboratory and the customer.	Calibration Time and Frequency Humidity Chemical *(Environmental air quality monitoring instruments)*	Customers' sites

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0478 Accredited to ISO/IEC 17025:2005	**Schedule of Accreditation** issued by **United Kingdom Accreditation Service** 21 - 47 High Street, Feltham, Middlesex, TW13 4UN, UK **NPL Management Ltd** **Issue No:** 058 **Issue date:** 28 November 2012

Calibration performed by the Organisation at the locations specified

Measured Quantity Instrument or Gauge	Range	Calibration and Measurement Capability (CMC) Expressed as an Expanded Uncertainty (*k* = 2)	Remarks	Location Code
INSTRUMENTS FOR AIR QUALITY MONITORING				Customers' sites
Analyser Calibration	NOx 200 ppb to 2 ppm SO_2 150 ppb to 1 ppm O_3 30 ppb to 1 ppm CO 0.5 ppm to 45 ppm	4.0 %	Two point (zero and span) calibration. An assessment of uncertainty due to analyser repeatability and linearity is also undertaken.	
Determination of on site standard concentration	NOx 200 ppb to 2 ppm (NO and NO_2) SO_2 150 ppb to 1 ppm CO 0.5 ppm to 45 ppm	4.0 %		
NO_2 molybdenum converter efficiency test	100 ppb to 250 ppb NO_2	1.5 %	Reaction of NO with O_3	
Sample system collection efficiency	NO_2 50 ppb to 150 ppb SO_2 50 ppb to 150 ppb O_3 50 ppb to 150 ppb CO 6 ppm to 12 ppm	1.5 % absolute 1.0 % absolute 1.5 % absolute 1.0 % absolute		
Analyser span noise test	Range as analyser calibration	2.0 ppb		
Analyser zero noise test	NOx, NO, SO_2, O_3, CO	1.0 ppb		
Particulate analyser calibration	0 $mg.m^{-3}$ to 1 $mg.m^{-3}$	1.5 %	Using 4 pre-weighed masses	
Particulate analyser flow rate test	1 slm to 10 slm 10 slm to 40 slm	1.5 % 2.0 %	Volumetric and mass flow	
BINARY GAS MIXTURES				
Nitric oxide in nitrogen	200 nmol/mol to 2 µmol/mol	3.0 % relative		

END

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D. Maintenance Procedures

The following text is copied with minor alterations from Section 7 of the TÜV Rheinland Report[2].

Works in the maintenance interval (4 weeks)

The following procedures are required to be undertaken at regular intervals:

- Regular visual inspection / telemetric monitoring
- Check, if device status is o.k.
- Check, if there are no error messages
- Check, if there are no contaminations
- Check of the instrument functions according to the instructions of the manufacturer
- Maintenance of the sampling inlet according to the instructions of the manufacturer
- Monthly change of the TEOM-filters (or in case the filter load >90 % is reached)
- Simultaneously with the change of the TEOM-filters, the cooled 47 mm-filter of the FDMS-unit have to be changed.
- Every 4 weeks: plausibility check of temperature, pressure sensors, if necessary re-calibration
- Every 4 weeks: leak check
- Every 4 weeks: check of the flow rate, if necessary re-calibration

Apart from that follow the manufacturer's directions and recommendations.

Further maintenance works

The following works are necessary in addition to the regular works in the maintenance interval:

- Every 6 months (or when necessary) the Inline-filter for PM_{10}- and Bypass-path shall be changed to avoid a contamination of the flow rate regulator.
- Once a year (or when necessary) the cooler, the switching valve and the air inlet system are to be cleaned.
- Once a year the calibration of the mass measuring transducer is to be checked using the K_0-test kit.
- The dryer inside the FDMS-unit has to be change or refurbished once a year or when necessary. For the monitoring/ securing of a correct dryer performance the manufacturer recommends to observe the pump vacuum (nominal: > 510 mm Hg) and the dew point of the air flow (nominal: <2℃ at 4℃ cooler temperatu re) and periodically perform a zero point test (operation of the measuring device with zero-filter at the entrance).
- Every 18 months or when necessary the sampling pump must be maintained or renewed.

Further details are provided in the user manual.

E. Field Test Data

Table 29: Site; Start Date, LVS3 Concentration; CM concentration; Ambient Temperature; RH; Ambient Dew Point; and Volatile Components used.

Site	Start Date and Time	PM10 LVS3 1 / µg/m3	PM10 LVS3 2 / µg/m3	20006 Mass / µg/m3	20107 Mass / µg/m3	Ambient Temp / °C	RH / %	Ambient Dew Point / °C	WS / m/s	Volatile / µg/m3	Volatile Notes	Remark
Teddington Winter	09 Dec 09 10:00	27.5	27.5	23.8		9.8	94.1	8.9	0.1	1.2	Average of 4 1405Fs	
Teddington Winter	10 Dec 09 10:00	25.4	25.4	22.2		3.9	90.9	2.5	0.2	1.9	Average of 4 1405Fs	
Teddington Winter	11 Dec 09 10:00	20.3	20.2	16.0		5.7	93.8	4.8	0.4	3.1	Average of 4 1405Fs	
Teddington Winter	12 Dec 09 10:00	13.5	13.6	11.5		5.8	83.9	3.3	0.8	2.2	Average of 4 1405Fs	
Teddington Winter	13 Dec 09 10:00	13.4	13.9	11.5		4.2	87.7	2.4	0.5	2.5	Average of 4 1405Fs	
Teddington Winter	14 Dec 09 10:00	35.3	35.3	30.8		3.4	88.8	1.8	0.2	4.9	Average of 4 1405Fs	
Teddington Winter	15 Dec 09 10:00	47.6	47.4	45.2		-0.6	87.5	-2.4	0.2	7.6	Average of 4 1405Fs	
Teddington Winter	16 Dec 09 10:00	30.0	30.3	28.0		1.5	96.9	1.1	0.2	7.2	Average of 4 1405Fs	
Teddington Winter	17 Dec 09 10:00	10.2	10.1	8.7		1.3	85.2	-1.0	2.4	2.1	Average of 4 1405Fs	
Teddington Winter	18 Dec 09 10:00	16.9	17.0	14.2		-0.8	86.6	-2.7	0.9	3.4	Average of 4 1405Fs	
Teddington Winter	19 Dec 09 10:00	15.4	14.9	14.3		-0.1	85.9	-2.2	0.2	4.6	Average of 4 1405Fs	
Teddington Winter	20 Dec 09 10:00	11.1	11.0	9.3		-0.9	87.3	-2.7	0.1	2.2	Average of 4 1405Fs	
Teddington Winter	21 Dec 09 10:00	20.2	20.4	19.0		1.1	97.3	0.8	0.3	3.9	Average of 4 1405Fs	
Teddington Winter	22 Dec 09 10:00			32.9	20107 not yet started	-2.1	98.3	-2.3	0.0	4.5	Average of 4 1405Fs	PM10 Grubbs outlier
Teddington Winter	23 Dec 09 10:00			17.8		2.8	95.9	2.3	0.4	4.6	Average of 4 1405Fs	
Teddington Winter	24 Dec 09 10:00			18.3		4.1	94.1	3.2	0.3	3.2	Average of 4 1405Fs	
Teddington Winter	25 Dec 09 10:00			12.2		4.1	94.5	3.3	0.2	2.7	Average of 4 1405Fs	
Teddington Winter	26 Dec 09 10:00			8.0		5.9	90.2	4.4	0.3	2.1	Average of 4 1405Fs	
Teddington Winter	27 Dec 09 10:00			7.2		2.4	86.2	0.4	0.3	0.8	Average of 4 1405Fs	
Teddington Winter	28 Dec 09 10:00			23.3		3.7	88.6	2.0	1.2	4.6	Average of 4 1405Fs	
Teddington Winter	29 Dec 09 10:00			10.8		4.8	95.9	4.2	1.7	3.3	Average of 4 1405Fs	
Teddington Winter	30 Dec 09 10:00			11.3		4.3	93.1	3.3	1.9	2.0	Average of 4 1405Fs	
Teddington Winter	31 Dec 09 10:00	15.2	13.9	12.2		2.3	81.8	-0.5	1.1	1.4	Average of 4 1405Fs	
Teddington Winter	01 Jan 10 10:00			16.1		-0.1	88.3	-1.8	0.2	1.7	Average of 4 1405Fs	
Teddington Winter	02 Jan 10 10:00			15.0		1.6	87.2	-0.3	0.1	2.0	Average of 4 1405Fs	
Teddington Winter	03 Jan 10 10:00			20.9		-1.6	88.3	-3.2	0.3	3.2	Average of 4 1405Fs	
Teddington Winter	04 Jan 10 10:00					-3.7	97.2	-4.1	0.0	8.5	Average of Teddington and Bloomsbury 8500s	Zero filter
Teddington Winter	05 Jan 10 10:00	20.1	18.7	18.4		0.8	89.9	-0.6	0.7	2.6	Average of 4 1405Fs	PM10 Grubbs outlier
Teddington Winter	06 Jan 10 10:00	19.2	19.3	16.9		-2.3	94.3	-3.1	0.7	2.8	Average of 4 1405Fs	PM2.5 Grubbs outlier
Teddington Winter	07 Jan 10 10:00	19.4	20.1	17.4		-1.2	91.1	-2.5	0.5	2.9	Average of 4 1405Fs	
Teddington Winter	08 Jan 10 10:00	18.3	18.4	16.5		-1.6	91.1	-2.9	0.8	3.7	Average of 4 1405Fs	
Teddington Winter	09 Jan 10 10:00	14.6	14.9	13.2		0.9	79.3	-2.3	1.8	2.0	Average of 4 1405Fs	
Teddington Winter	10 Jan 10 10:00	19.5	19.2	17.3		1.4	90.5	0.0	0.7	2.6	Average of 4 1405Fs	
Teddington Winter	11 Jan 10 10:00	51.8	51.3	48.7		1.5	86.0	-0.6	0.3	7.5	Average of 4 1405Fs	SN 20107 Zero filter
Teddington Winter	12 Jan 10 10:00	48.1	48.0	47.6	47.2	1.4	85.9	-0.7	1.5	7.6	Average of 4 1405Fs	
Teddington Winter	13 Jan 10 10:00	53.4	53.0	51.4	52.8	1.5	94.8	0.7	0.1	8.0	Average of 4 1405Fs	
Teddington Winter	14 Jan 10 10:00	16.2	16.3	17.1	17.5	2.5	97.0	2.1	0.1	3.9	Average of 4 1405Fs	
Teddington Winter	15 Jan 10 10:00	26.9	27.1	19.2	19.9	5.6	90.0	4.1	1.8	5.0	Average of 4 1405Fs	
Teddington Winter	16 Jan 10 10:00	13.5	13.6	10.7	11.4	5.7	96.3	5.2	0.4	2.3	Average of 4 1405Fs	
Teddington Winter	17 Jan 10 10:00	20.6	20.6	17.3	17.9	4.1	93.9	3.2	0.1	1.9	Average of 4 1405Fs	
Teddington Winter	18 Jan 10 10:00	27.1	26.9	24.9	25.6	6.2	97.8	5.9	0.1	3.8	Average of 4 1405Fs	
Teddington Winter	19 Jan 10 10:00	26.5	26.6			6.4	83.7	3.8	1.4	9.5	Average of Teddington and Bloomsbury 8500s	Power supply interrupted
Teddington Winter	20 Jan 10 10:00	32.0	31.9	28.3	29.5	3.0	92.1	1.8	0.2	5.2	Average of 4 1405Fs	
Teddington Winter	21 Jan 10 10:00	27.5	27.9	23.9	23.7	6.1	85.2	3.8	1.1	6.2	Average of 4 1405Fs	
Teddington Winter	22 Jan 10 10:00	9.7	9.8	9.2	10.1	7.6	95.0	6.9	0.5	2.9	Average of 4 1405Fs	
Teddington Winter	23 Jan 10 10:00	25.8	25.1	23.1	23.3	4.8	87.0	2.9	0.2	5.2	Average of 4 1405Fs	
Teddington Winter	24 Jan 10 10:00	20.7	20.3	18.5	18.4	4.4	91.1	3.0	0.1	4.1	Average of 4 1405Fs	
Teddington Winter	25 Jan 10 10:00	42.0	42.4	39.8		3.2	80.0	0.0	0.9	3.7	Average of 4 1405Fs	
Teddington Winter	26 Jan 10 10:00	60.4	60.4	55.7	56.7	0.0	83.2	-2.5	0.5	5.8	Average of 4 1405Fs	
Teddington Winter	27 Jan 10 10:00	38.9	39.1	33.9	33.2	4.4	85.5	2.2	0.3	6.7	Average of 4 1405Fs	
Teddington Winter	28 Jan 10 10:00	13.9	14.1	12.6	13.7	5.5	86.4	3.4	0.5	5.0	Average of 4 1405Fs	
Teddington Winter	29 Jan 10 10:00	9.4	9.6	9.2	9.4	1.3	76.9	-2.3	0.9	1.9	Average of 4 1405Fs	
Teddington Winter	30 Jan 10 10:00	17.6	17.6	15.6	16.2	-0.9	84.4	-3.2	0.2	2.5	Average of 4 1405Fs	
Teddington Winter	31 Jan 10 10:00	17.3	16.9	15.1	15.9	0.0	91.2	-1.3	0.1	2.4	Average of 4 1405Fs	
Teddington Winter	01 Feb 10 10:00	14.7	14.4	14.1	14.2	3.1	83.9	0.7	0.4	2.7	Average of 4 1405Fs	
Teddington Winter	02 Feb 10 10:00	12.0	11.7	11.6	11.2	5.9	89.6	4.3	0.3	3.3	Average of 4 1405Fs	
Teddington Winter	03 Feb 10 10:00	19.2	19.2	15.9	16.1	6.7	91.0	5.3	0.2	3.2	Average of 4 1405Fs	
Teddington Winter	04 Feb 10 10:00	19.7	19.8	18.0	18.6	7.6	86.1	5.4	1.3	3.8	Average of 4 1405Fs	
Teddington Winter	05 Feb 10 10:00					7.2	84.9	4.8	0.6	2.3	Average of Teddington and Bloomsbury 8500s	Inlet -> Zero filter
Teddington Winter	06 Feb 10 10:00					5.1	89.7	3.5	0.6	5.2	Average of Teddington and Bloomsbury 8500s	Zero filter
Teddington Winter	07 Feb 10 10:00					3.8	85.1	1.5	0.8	7.1	Average of Teddington and Bloomsbury 8500s	Zero filter
Teddington Winter	08 Feb 10 10:00				19.9	1.4	82.1	-1.3	2.0	2.3	Average of 4 1405Fs	SN 20006 Zero filter->Inlet
Teddington Winter	09 Feb 10 10:00	11.6	11.8	10.8	11.8	3.2	77.7	-0.3	1.3	0.9	Average of 4 1405Fs	
Teddington Winter	10 Feb 10 10:00	12.0	12.4	10.9	13.2	1.1	70.1	-3.7	1.8	0.9	Average of 4 1405Fs	

Site	Start Date and Time	PM10 LVS3 1 / µg/m3	PM10 LVS3 2 / µg/m3	20006 Mass / µg/m3	20107 Mass / µg/m3	Ambient Temp / °C	RH / %	Ambient Dew Point / °C	WS / m/s	Volatile / µg/m3	Volatile Notes	Remark
Teddington Winter	11 Feb 10 10:00	20.2	20.1	16.3	18.8	2.3	74.1	-1.9	1.1	2.2	Average of 4 1405Fs	
Teddington Winter	12 Feb 10 10:00	12.6	12.4	10.1	12.5	3.0	76.5	-0.8	1.1	1.9	Average of 4 1405Fs	
Teddington Winter	13 Feb 10 10:00	15.1	15.4	11.2	13.2	2.4	82.4	-0.3	0.5	1.9	Average of 4 1405Fs	
Teddington Winter	14 Feb 10 10:00	16.0	16.3	12.6	16.3	2.2	91.8	1.0	0.1	4.2	Average of 4 1405Fs	
Teddington Winter	15 Feb 10 10:00	16.0	15.9	13.5	15.2	3.3	89.7	1.8	0.1	4.5	Average of 4 1405Fs	
Teddington Winter	16 Feb 10 10:00	18.2	18.5	15.4	17.0	3.7	94.6	2.9	0.1	3.0	Average of 4 1405Fs	
Teddington Winter	17 Feb 10 10:00	52.2	52.1	47.4	48.4	3.4	78.8	0.0	0.3	6.4	Average of 4 1405Fs	
Teddington Winter	18 Feb 10 10:00	14.8	14.8	12.2	16.2	3.7	92.6	2.6	0.7	4.4	Average of 4 1405Fs	
Teddington Winter	19 Feb 10 10:00	21.7	21.7	18.7	20.9	0.8	87.5	-1.0	0.2	4.3	Average of 4 1405Fs	
Teddington Winter	20 Feb 10 10:00	19.3	19.5	17.3	19.8	1.7	87.9	-0.1	0.2	4.7	Average of 4 1405Fs	
Teddington Winter	21 Feb 10 10:00	10.2	10.2	8.2	10.0	5.3	92.2	4.1	0.5	3.2	Average of 4 1405Fs	
Teddington Winter	22 Feb 10 10:00	16.6	16.5	13.4	14.9	3.1	88.2	1.3	1.4	2.0	Average of 4 1405Fs	
Teddington Winter	23 Feb 10 10:00	22.2	22.3	17.6	19.8	4.8	92.2	3.6	0.8	3.4	Average of 4 1405Fs	
Teddington Winter	24 Feb 10 10:00	17.8	17.7	14.7	15.9	8.4	91.6	7.1	0.5	3.0	Average of 4 1405Fs	
Teddington Winter	25 Feb 10 10:00	9.2	9.4	8.6	9.7	7.7	88.1	5.9	1.0	2.7	Average of 4 1405Fs	
Teddington Winter	26 Feb 10 10:00	11.2	11.4	10.4	11.2	6.4	77.0	2.7	0.7	1.0	Average of 4 1405Fs	
Teddington Winter	27 Feb 10 10:00	18.9	19.2	18.1	17.5	7.8	88.4	6.0	0.7	3.6	Average of 4 1405Fs	
Teddington Winter	28 Feb 10 10:00	9.6	9.6	7.0	9.7	3.4	88.5	1.7	0.5	-0.7	Average of 4 1405Fs	
Teddington Winter	01 Mar 10 10:00			26.2	26.8	4.1	78.0	0.6	0.2	1.6	Average of 4 1405Fs	
Teddington Winter	02 Mar 10 10:00	21.7	21.0	18.6	20.5	6.4	62.9	-0.2	0.9	3.2	Average of 4 1405Fs	
Teddington Winter	03 Mar 10 10:00	20.9	21.3	17.8	19.7	4.7	71.6	0.0	2.5	1.8	Average of 4 1405Fs	
Teddington Winter	04 Mar 10 10:00	16.5	16.6	15.2	16.6	2.1	72.0	-2.5	1.0	1.2	Average of 4 1405Fs	
Teddington Summer	27 Apr 10 10:00	20.2	20.9	21.2	20.6	14.8	64.1	8.1	0.3	3.5	Average of 4 1405Fs	
Teddington Summer	28 Apr 10 10:00	25.8	25.0	26.8	26.0	15.6	61.9	8.3	0.5	4.3	Average of 4 1405Fs	
Teddington Summer	29 Apr 10 10:00	19.2	19.3	21.1	20.7	14.2	76.8	10.2	0.2	3.9	Average of 4 1405Fs	
Teddington Summer	30 Apr 10 10:00	11.5	11.9	12.4	13.1	12.6	76.4	8.6	0.4	2.2	Average of 4 1405Fs	
Teddington Summer	01 May 10 10:00			12.1	11.5	12.4	75.3	8.1	0.5	2.5	Average of 4 1405Fs	
Teddington Summer	02 May 10 10:00			8.6	8.7	7.4	76.5	3.6	1.8	1.0	Average of 4 1405Fs	
Teddington Summer	03 May 10 10:00			13.6	12.7	7.7	60.1	0.4	1.7	1.0	Average of 4 1405Fs	
Teddington Summer	04 May 10 10:00	15.0	15.1	15.0	14.8	7.9	66.2	2.0	0.8	2.2	Average of 4 1405Fs	
Teddington Summer	05 May 10 10:00	18.8	19.7	20.0	19.9	12.1	64.2	5.5	0.8	4.8	Average of 4 1405Fs	
Teddington Summer	06 May 10 10:00	16.2	16.6	16.6	16.2	10.9	59.1	3.2	1.2	3.5	Average of 4 1405Fs	
Teddington Summer	07 May 10 10:00	12.9	13.1	14.4	13.6	9.9	64.5	3.5	1.4	2.7	Average of 4 1405Fs	
Teddington Summer	08 May 10 10:00	8.9	8.9	9.9	10.0	8.6	78.3	5.1	1.1	1.9	Average of 4 1405Fs	
Teddington Summer	09 May 10 10:00	14.1	14.0	14.6	13.8	9.2	69.6	4.0	1.0	2.4	Average of 4 1405Fs	
Teddington Summer	10 May 10 10:00	10.2	9.8	11.8	12.5	9.5	56.5	1.3	1.4	2.0	Average of 4 1405Fs	
Teddington Summer	11 May 10 10:00	10.6	9.8	12.2	12.0	6.7	66.1	0.8	0.6	1.7	Average of 4 1405Fs	
Teddington Summer	12 May 10 10:00	12.3	12.5	13.6	12.9	8.1	61.1	1.1	0.6	2.0	Average of 4 1405Fs	
Teddington Summer	13 May 10 10:00	17.2	17.1	17.3	17.5	9.7	59.8	2.2	0.3	3.8	Average of 4 1405Fs	
Teddington Summer	14 May 10 10:00	19.1	18.7	19.2	19.1	12.0	58.0	4.0	0.4	3.3	Average of 4 1405Fs	
Teddington Summer	15 May 10 10:00	12.7	12.7	13.8	12.9	12.5	60.3	5.0	0.4	2.1	Average of 4 1405Fs	
Teddington Summer	16 May 10 10:00	9.5	9.6	11.4	11.3	11.3	82.3	8.4	0.2	1.2	Average of 4 1405Fs	
Teddington Summer	17 May 10 10:00	16.2	16.6	18.2	17.3	12.8	63.0	5.9	0.4	1.3	Average of 4 1405Fs	
Teddington Summer	18 May 10 10:00	21.5	21.5	21.4	22.8	14.1	62.0	6.9	0.4	2.6	Average of 4 1405Fs	
Teddington Summer	19 May 10 10:00	20.0	19.4	21.5	21.8	16.0	68.8	10.2	0.1	1.9	Average of 4 1405Fs	
Teddington Summer	20 May 10 10:00	18.7	19.0	24.0	23.1	18.1	72.3	13.0	0.1	3.2	Average of 4 1405Fs	
Teddington Summer	21 May 10 10:00	17.9	18.6	20.7	21.6	18.9	62.4	11.6	1.2	5.0	Average of 4 1405Fs	
Teddington Summer	22 May 10 10:00	9.0	8.9	10.5	12.1	18.2	60.0	10.3	1.2	3.0	Average of 4 1405Fs	
Teddington Summer	23 May 10 10:00	9.3	9.6	12.8	12.5	21.7	51.3	11.2	0.3	2.5	Average of 4 1405Fs	
Teddington Summer	24 May 10 10:00	17.5	17.6	19.5	19.7	20.5	54.6	11.1	1.4	2.4	Average of 4 1405Fs	
Teddington Summer	25 May 10 10:00	15.6	15.2	16.9	17.8	15.0	54.5	5.9	2.3	1.8	Average of 4 1405Fs	
Teddington Summer	26 May 10 10:00	19.1	19.0			13.2	66.0	7.0	1.0	2.3	Average of Teddington and Bloomsbury 8500s	Zero filter
Teddington Summer	27 May 10 10:00	8.0	7.9			13.3	58.9	5.4	0.4	2.4	Average of Teddington and Bloomsbury 8500s	Zero filter-> Inlet
Teddington Summer	28 May 10 10:00	14.4	13.9		15.0	15.2	59.6	7.4	0.6	1.7	Average of 4 1405Fs	SN 20006 noisy signal
Teddington Summer	29 May 10 10:00	10.5	10.7		11.2	14.1	82.5	11.2	1.0	1.6	Average of 4 1405Fs	SN 20006 noisy signal
Teddington Summer	30 May 10 10:00	8.2	7.9		9.7	14.6	52.9	5.1	1.6	0.9	Average of 4 1405Fs	SN 20006 noisy signal
Teddington Summer	31 May 10 10:00	20.6	21.1		20.0	14.3	72.1	9.4	0.6	2.2	Average of 4 1405Fs	SN 20006 noisy signal
Teddington Summer	01 Jun 10 10:00	20.0	20.5		20.7	13.0	86.7	10.8	0.4	4.4	Average of 4 1405Fs	SN 20006 noisy signal
Teddington Summer	02 Jun 10 10:00	17.7	17.4		19.7	17.4	55.2	8.3	0.7	3.6	Average of 4 1405Fs	SN 20006 noisy signal
Teddington Summer	03 Jun 10 10:00	15.5	15.7		15.8	17.5	51.8	7.5	1.6	2.4	Average of 4 1405Fs	SN 20006 noisy signal
Teddington Summer	04 Jun 10 10:00	26.0	26.6		29.8	20.3	55.5	11.1	0.5	4.4	Average of 4 1405Fs	SN 20006 noisy signal
Teddington Summer	05 Jun 10 10:00	23.8	24.3		29.1	22.1	60.2	14.1	0.4	5.6	Average of 4 1405Fs	SN 20006 noisy signal
Teddington Summer	06 Jun 10 10:00	11.6	11.2		15.2	18.2	68.1	12.2	0.6	3.1	Average of 4 1405Fs	SN 20006 noisy signal
Teddington Summer	07 Jun 10 10:00	7.8	7.2		8.2	15.8	73.9	11.2	0.5	2.7	Average of 4 1405Fs	SN 20006 noisy signal
Teddington Summer	08 Jun 10 10:00	9.2	9.9		10.7	15.7	81.3	12.5	0.5	1.6	Average of 4 1405Fs	SN 20006 noisy signal
Teddington Summer	09 Jun 10 10:00	15.5	16.0		15.3	17.8	72.1	12.7	1.1	2.8	Average of 4 1405Fs	SN 20006 noisy signal
Teddington Summer	10 Jun 10 10:00	10.4	10.8		12.6	15.2	83.2	12.3	1.8	3.2	Average of 4 1405Fs	SN 20006 noisy signal
Teddington Summer	11 Jun 10 10:00	10.5	11.8		12.5	15.5	68.2	9.7	0.5	1.6	Average of 4 1405Fs	No ref.measurement PM2.5, Repair (leaking switching valve)
Teddington Summer	12 Jun 10 10:00	13.4	13.5	12.1	14.1	15.6	63.0	8.6	0.7	0.9	Average of 4 1405Fs	
Teddington Summer	13 Jun 10 10:00	17.4	17.7	16.7	18.1	16.9	65.8	10.5	0.7	1.5	Average of 4 1405Fs	

Site	Start Date and Time	PM10 LVS3 1 / µg/m3	PM10 LVS3 2 / µg/m3	20006 Mass / µg/m3	20107 Mass / µg/m3	Ambient Temp / °C	RH / %	Ambient Dew Point / °C	WS / m/s	Volatile / µg/m3	Volatile Notes	Remark
Teddington Summer	14 Jun 10 10:00	13.4	12.7	13.1	14.8	14.6	70.4	9.3	1.5	1.2	Average of 4 1405Fs	
Teddington Summer	15 Jun 10 10:00	10.2	9.8	9.7	11.9	14.4	56.1	5.8	1.8	1.3	Average of 4 1405Fs	
Teddington Summer	16 Jun 10 10:00	10.8	10.3	11.3	13.1	15.2	57.8	7.0	1.9	1.5	Average of 4 1405Fs	
Teddington Summer	17 Jun 10 10:00	7.1	7.9	10.3	10.1	17.6	58.5	9.4	1.6	1.6	Average of 4 1405Fs	
Teddington Summer	18 Jun 10 10:00			13.6	14.4	14.5	69.7	9.0	1.1	1.9	Average of 4 1405Fs	
Teddington Summer	19 Jun 10 10:00	9.1	9.3	9.1	11.8	12.5	55.8	3.9	1.5	0.9	Average of 4 1405Fs	
Teddington Summer	20 Jun 10 10:00	15.5	15.3	16.2	17.7	15.6	55.8	6.8	0.7	0.9	Average of 4 1405Fs	
Teddington Summer	21 Jun 10 10:00			20.6	18.8	19.8	55.1	10.5	0.4	1.6	Average of 4 1405Fs	PM10 Grubbs outlier
Teddington Summer	22 Jun 10 10:00	13.1	13.8	19.7	16.8	21.5	50.1	10.7	0.3	2.3	Average of 4 1405Fs	
Teddington Summer	23 Jun 10 10:00	15.3	15.7	20.3	18.9	21.8	52.4	11.6	0.3	2.7	Average of 4 1405Fs	
Teddington Summer	24 Jun 10 10:00	11.5	11.0	16.8	16.4	21.3	54.7	11.8	0.4	2.2	Average of 4 1405Fs	
Teddington Summer	25 Jun 10 10:00	23.0	23.8	27.1	26.1	21.9	56.1	12.7	1.0	3.4	Average of 4 1405Fs	
Teddington Summer	26 Jun 10 10:00	29.1	29.4	35.3	35.2	21.1	63.2	13.8	0.9	4.3	Average of 4 1405Fs	
Teddington Summer	27 Jun 10 10:00			19.8	18.2	22.8	50.3	11.9	0.3	2.6	Average of 4 1405Fs	
Teddington Summer	28 Jun 10 10:00			22.0	21.4	23.2	43.9	10.2	0.3	2.2	Average of 4 1405Fs	PM10 Grubbs outlier
Teddington Summer	29 Jun 10 10:00	8.9	9.0	11.1	10.9	21.5	70.2	15.8	0.2	1.7	Average of 4 1405Fs	
Teddington Summer	30 Jun 10 10:00	9.6	9.5	12.0	12.7	20.1	63.2	12.9	0.3	2.3	Average of 4 1405Fs	
Teddington Summer	01 Jul 10 10:00	11.0	11.6	14.2	13.8	21.9	58.8	13.5	0.6	2.0	Average of 4 1405Fs	
Cologne Winter	27 Jan 11 10:00	12.8	13.3			-0.2	72.1	-4.6	1.6	6.6	Nitrate is 2011 ion data on this date	Audits
Cologne Winter	28 Jan 11 10:00	36.3	36.8			-1.8	77.0	-5.3	1.3	8.0	Nitrate is 2011 ion data on this date	Audits
Cologne Winter	29 Jan 11 10:00					-2.1	77.0	-5.6	0.9	18.4	Nitrate is 2011 ion data on this date	Zero filter
Cologne Winter	30 Jan 11 10:00	82.7	83.7			-3.4	83.9	-5.7	0.7	16.4	Nitrate is 2011 ion data on this date	Zero filter
Cologne Winter	31 Jan 11 10:00	95.5	94.0			-3.8	86.9	-5.7	1.3	19.9	Nitrate is 2011 ion data on this date	Zero filter
Cologne Winter	01 Feb 11 10:00	75.3	73.6	75.5	76.0	-2.3	88.2	-4.0	2.1	5.7	Average of 4 1405Fs	
Cologne Winter	02 Feb 11 10:00	25.2	24.7	22.7	25.1	0.8	88.6	-0.9	3.1	6.4	Average of 4 1405Fs	
Cologne Winter	03 Feb 11 10:00	20.1	20.4	18.9	19.6	4.3	83.0	1.7	2.9	4.3	Average of 4 1405Fs	
Cologne Winter	04 Feb 11 10:00	11.0	11.4	10.4	10.6	9.9	72.4	5.2	6.9	2.4	Average of 4 1405Fs	
Cologne Winter	05 Feb 11 10:00			8.6	9.1	11.0	71.2	6.0	7.1	1.7	Average of 4 1405Fs	
Cologne Winter	06 Feb 11 10:00	14.8	15.0	14.1	16.0	8.2	69.5	2.9	3.9	2.0	Average of 4 1405Fs	
Cologne Winter	07 Feb 11 10:00	17.5	18.8	18.5	19.2	9.8	60.9	2.6	3.6	1.6	Average of 4 1405Fs	
Cologne Winter	08 Feb 11 10:00	30.6	31.3	28.7	30.3	3.2	77.0	-0.4	1.1	2.8	Average of 4 1405Fs	
Cologne Winter	09 Feb 11 10:00	29.6	30.6	28.1	30.6	6.1	67.6	0.5	3.2	5.3	Average of 4 1405Fs	
Cologne Winter	10 Feb 11 10:00	24.9	26.7	25.8	26.9	8.7	84.2	6.2	3.2	5.9	Average of 4 1405Fs	
Cologne Winter	11 Feb 11 10:00	13.2	14.1	12.8	14.7	8.9	93.5	7.9	2.0	4.5	Average of 4 1405Fs	
Cologne Winter	12 Feb 11 10:00			18.3	18.9	6.0	89.8	4.5	2.7	4.2	Average of 4 1405Fs	
Cologne Winter	13 Feb 11 10:00	17.0	18.5	16.6	16.6	6.3	81.1	3.3	4.2	3.4	Average of 4 1405Fs	
Cologne Winter	14 Feb 11 10:00	23.8	24.2	23.9	25.3	6.0	87.5	4.1	2.5	5.8	Average of 4 1405Fs	
Cologne Winter	15 Feb 11 10:00	19.0	19.7	20.8	19.6	5.4	86.9	3.4	3.5	4.7	Average of 4 1405Fs	
Cologne Winter	16 Feb 11 10:00	34.0	34.2	35.2	33.4	4.0	86.7	2.0	1.4	5.0	Average of 4 1405Fs	
Cologne Winter	17 Feb 11 10:00	42.2	42.1	44.1	44.1	4.1	76.8	0.4	1.7	4.9	Average of 4 1405Fs	
Cologne Winter	18 Feb 11 10:00	43.4	43.5	45.6	47.2	2.7	78.4	-0.7	1.5	4.9	Average of 4 1405Fs	
Cologne Winter	19 Feb 11 10:00			56.1	55.3	2.7	73.6	-1.5	4.5	8.0	Average of 4 1405Fs	
Cologne Winter	20 Feb 11 10:00	29.5	29.8	30.7	28.8	-0.5	67.1	-5.9	4.1	5.5	Average of 4 1405Fs	
Cologne Winter	21 Feb 11 10:00	36.6	36.2	37.2	36.2	-2.7	65.5	-8.3	3.1	6.3	Average of 4 1405Fs	
Cologne Winter	22 Feb 11 10:00	43.3	43.8	45.1	46.2	-1.6	56.2	-9.2	3.0	6.6	Average of 4 1405Fs	
Cologne Winter	23 Feb 11 10:00	45.7	45.7	47.1	48.3	1.2	59.6	-5.8	5.0	8.2	Average of 4 1405Fs	
Cologne Winter	24 Feb 11 10:00	36.0	35.8	37.7	38.9	2.2	94.2	1.4	2.6	8.3	Average of 4 1405Fs	
Cologne Winter	25 Feb 11 10:00	30.4	29.6	31.2	30.1	5.3	87.1	3.3	3.4	9.2	Average of 4 1405Fs	
Cologne Winter	26 Feb 11 10:00			18.9	18.8	6.3	86.0	4.1	4.3	8.0	Average of 4 1405Fs	
Cologne Winter	27 Feb 11 10:00	15.4	14.8	15.7	16.0	4.2	86.0	2.1	3.9	3.8	Average of 4 1405Fs	
Cologne Winter	28 Feb 11 10:00	44.7	43.7	42.9	43.7	3.8	83.3	1.2	0.9	7.9	Average of 4 1405Fs	
Cologne Winter	01 Mar 11 10:00	75.6	74.7	72.6	76.5	5.2	69.9	0.2	2.1	12.0	Average of 4 1405Fs	
Cologne Winter	02 Mar 11 10:00	60.6	58.5	59.2	60.9	4.8	54.7	-3.6	2.2	10.3	Average of 4 1405Fs	
Cologne Winter	03 Mar 11 10:00	50.8	48.9	48.3	49.5	3.7	50.4	-5.7	1.4	9.2	Average of 4 1405Fs	
Cologne Winter	04 Mar 11 10:00					3.4	67.8	-2.0	1.2	28.3	Nitrate is 2011 ion data on this date	PM10 Grubbs outlier; Inlet -> Zero filter
Cologne Winter	05 Mar 11 10:00					2.7	73.4	-1.6	2.2	16.0	Nitrate is 2011 ion data on this date	Zero filter
Cologne Winter	06 Mar 11 10:00	13.6	14.1			3.0	52.4	-5.8	1.9	3.2	Nitrate is 2011 ion data on this date	Zero filter
Cologne Winter	07 Mar 11 10:00	13.8	12.4			4.0	34.2	-10.4	5.1	2.8	Nitrate is 2011 ion data on this date	Zero filter
Cologne Winter	08 Mar 11 10:00	43.9	43.8	42.5	41.9	7.9	54.0	-0.8	2.3	6.2	Average of 4 1405Fs	
Cologne Winter	09 Mar 11 10:00	30.5	28.7	28.6	28.9	7.1	75.8	3.1	3.5	4.8	Average of 4 1405Fs	
Cologne Winter	10 Mar 11 10:00					9.2	68.9	3.8	5.3	6.4	Nitrate is 2011 ion data on this date	Power cut (complete)
Cologne Winter	11 Mar 11 10:00	33.5	33.1	29.9	31.5	8.1	69.5	2.9	3.8	2.8	Average of 4 1405Fs	
Cologne Winter	12 Mar 11 10:00			30.6	33.0	12.1	61.6	4.9	3.3	3.0	Average of 4 1405Fs	
Cologne Winter	13 Mar 11 10:00	16.2	15.6	15.0	15.4	11.2	77.3	7.4	2.0	1.6	Average of 4 1405Fs	
Cologne Winter	14 Mar 11 10:00	27.7	25.6			9.8	81.2	6.7	0.3	7.0	Nitrate is 2011 ion data on this date	Power cut (only Thermo)
Cologne Winter	15 Mar 11 10:00	44.1	43.1	44.1	44.8	12.3	66.2	6.2	2.2	6.7	Average of 4 1405Fs	
Cologne Winter	16 Mar 11 10:00	67.3	65.8	66.2	68.1	9.5	71.9	4.7	2.5	9.1	Average of 4 1405Fs	PM2.5 Grubbs outlier
Cologne Winter	17 Mar 11 10:00	68.0	67.1	67.1	68.4	5.7	86.9	3.7	4.7	8.7	Average of 4 1405Fs	
Cologne Winter	18 Mar 11 10:00	38.4	38.4	37.3	38.3	6.0	89.1	4.3	1.1	10.5	Average of 4 1405Fs	

Site	Start Date and Time	PM10 LVS3 1 / µg/m3	PM10 LVS3 2 / µg/m3	20006 Mass / µg/m3	20107 Mass / µg/m3	Ambient Temp / °C	RH / %	Ambient Dew Point / °C	WS / m/s	Volatile / µg/m3	Volatile Notes	Remark
Cologne Winter	19 Mar 11 10:00			18.4	19.1	5.0	59.5	-2.2	1.2	5.7	Average of 4 1405Fs	
Cologne Winter	20 Mar 11 10:00	28.6	28.0	27.3	28.7	5.3	57.7	-2.4	0.9	5.2	Average of 4 1405Fs	
Cologne Winter	21 Mar 11 10:00	34.7	34.3	34.3	31.4	6.9	56.5	-1.2	1.0	5.0	Average of 4 1405Fs	
Cologne Winter	22 Mar 11 10:00	55.7	54.8	54.7	50.3	9.4	62.7	2.6	1.1	10.0	Average of 4 1405Fs	
Cologne Winter	23 Mar 11 10:00	33.1	31.6	31.8	29.3	10.7	66.8	4.8	1.2	7.1	Average of 4 1405Fs	
Cologne Winter	24 Mar 11 10:00	33.3	32.7	33.9	32.9	10.9	67.2	5.1	1.0	6.7	Average of 4 1405Fs	
Cologne Winter	25 Mar 11 10:00	36.9	37.2	37.5	38.8	11.8	59.4	4.1	1.6	9.1	Average of 4 1405Fs	
Cologne Winter	26 Mar 11 10:00			17.6	19.1	7.7	64.8	1.5	1.5	4.5	Average of 4 1405Fs	
Cologne Winter	27 Mar 11 10:00	35.6	35.4	34.8	36.7	9.3	60.9	2.1	1.1	6.3	Average of 4 1405Fs	
Cologne Winter	28 Mar 11 10:00	32.4	31.9	31.3	32.7	7.2	60.2	0.0	1.9	6.3	Average of 4 1405Fs	
Cologne Winter	29 Mar 11 10:00	65.4	65.6	64.3	66.5	9.6	62.1	2.7	1.1	13.6	Average of 4 1405Fs	
Cologne Winter	30 Mar 11 10:00	24.0	23.4	23.8	24.5	12.6	66.7	6.6	2.4	6.7	Average of 4 1405Fs	
Cologne Winter	31 Mar 11 10:00	10.5	9.3	9.7	10.6	13.8	78.2	10.1	3.7	2.1	Average of 4 1405Fs	
Cologne Winter	01 Apr 11 10:00	13.3	13.0	12.7	12.1	13.9	78.1	10.1	2.3	3.2	Average of 4 1405Fs	
Cologne Winter	02 Apr 11 10:00			32.5	31.1	17.6	62.2	10.3	2.6	3.9	Average of 4 1405Fs	
Cologne Winter	03 Apr 11 10:00	22.1	22.4	20.8	20.1	10.9	85.3	8.5	2.0	4.7	Average of 4 1405Fs	
Cologne Winter	04 Apr 11 10:00	17.9	16.6	16.7	17.6	10.0	65.3	3.8	2.7	3.1	Average of 4 1405Fs	
Cologne Winter	05 Apr 11 10:00	19.2	19.0	18.8	19.8	11.8	71.9	6.9	2.1	3.5	Average of 4 1405Fs	
Cologne Winter	06 Apr 11 10:00	23.6	23.8	23.9	25.2	16.2	73.9	11.5	1.8	4.0	Average of 4 1405Fs	
Cologne Winter	07 Apr 11 10:00	23.2	24.2	23.7	24.8	13.8	67.2	7.8	3.0	5.4	Average of 4 1405Fs	
Cologne Winter	08 Apr 11 10:00	34.9	34.8			12.9	64.7	6.4	2.9	7.5	Nitrate is 2011 ion data on this date	Inlet -> Zero filter
Cologne Winter	09 Apr 11 10:00					11.3	59.8	3.8	1.3	1.6	Nitrate is 2011 ion data on this date	Zero filter
Cologne Winter	10 Apr 11 10:00	23.4	22.3			14.0	60.2	6.4	1.1	2.3	Nitrate is 2011 ion data on this date	Zero filter
Cologne Winter	11 Apr 11 10:00	31.3	31.5	32.7	33.6	16.0	58.8	7.9	3.9	2.4	Average of 4 1405Fs	
Cologne Winter	12 Apr 11 10:00	18.0	17.1	17.8	20.2	7.7	66.7	1.9	4.1	2.6	Average of 4 1405Fs	
Cologne Winter	13 Apr 11 10:00	24.4	23.2	25.3	26.9	10.1	57.1	2.0	2.0	3.0	Average of 4 1405Fs	
Cologne Winter	14 Apr 11 10:00	32.0	31.5	33.2	35.0	8.0	65.4	1.9	0.6	4.3	Average of 4 1405Fs	
Cologne Winter	15 Apr 11 10:00	31.9	31.9	27.0	26.5	10.4	53.6	1.4	1.2	2.9	Average of 4 1405Fs	
Cologne Winter	16 Apr 11 10:00			34.3	32.8	11.9	51.7	2.3	0.9	1.9	Average of 4 1405Fs	
Cologne Winter	17 Apr 11 10:00			21.8	21.2	11.4	53.7	2.3	1.2	2.3	Average of 4 1405Fs	
Cologne Winter	18 Apr 11 10:00	26.4	26.6	28.3	30.2	14.3	48.6	3.6	1.9	2.9	Average of 4 1405Fs	
Cologne Winter	19 Apr 11 10:00	30.3	30.7	33.0	34.4	15.5	52.4	5.8	1.2	2.6	Average of 4 1405Fs	
Cologne Winter	20 Apr 11 10:00	33.9	34.2	37.0	38.4	16.6	51.3	6.5	1.1	2.8	Average of 4 1405Fs	
Cologne Winter	21 Apr 11 10:00			34.5	36.7	17.8	54.1	8.4	0.7	2.7	Average of 4 1405Fs	
Cologne Winter	22 Apr 11 10:00			30.2	31.1	20.0	51.8	9.8	1.3	2.6	Average of 4 1405Fs	
Cologne Winter	23 Apr 11 10:00			40.8	42.6	18.0	58.0	9.6	0.7	2.8	Average of 4 1405Fs	
Cologne Winter	24 Apr 11 10:00			31.1	33.1	18.1	51.7	8.0	1.0	2.1	Average of 4 1405Fs	
Cologne Winter	25 Apr 11 10:00	27.4	27.4	30.2	32.1	16.8	50.3	6.4	1.2	2.2	Average of 4 1405Fs	
Cologne Winter	26 Apr 11 10:00	31.0	31.3	33.0	38.9	16.7	51.5	6.6	1.8	2.5	Average of 4 1405Fs	
Cologne Winter	27 Apr 11 10:00	44.3	45.1	46.3	48.4	10.8	90.4	9.3	0.7	7.6	Average of 4 1405Fs	No ref.measurement PM2.5
Cologne Winter	28 Apr 11 10:00	28.0	28.0	31.2	32.6	14.2	77.6	10.3	0.7	5.2	Average of 4 1405Fs	
Cologne Winter	29 Apr 11 10:00	25.9	27.3	30.2	29.8	17.2	56.8	8.5	1.7	2.7	Average of 4 1405Fs	
Cologne Winter	30 Apr 11 10:00	21.0	22.0	22.4	23.8	16.9	47.4	5.6	1.7	2.0	Average of 4 1405Fs	
Cologne Winter	01 May 11 10:00	13.0	12.9	14.1	15.4	14.8	44.5	2.8	1.6	2.1	Average of 4 1405Fs	
Cologne Winter	02 May 11 10:00	16.1	14.9	17.1	17.7	11.0	53.3	1.9	2.0	2.0	Average of 4 1405Fs	
Cologne Winter	03 May 11 10:00	15.9	15.1	16.8	18.0	10.0	49.4	-0.1	1.0	2.3	Average of 4 1405Fs	
Cologne Winter	04 May 11 10:00	20.5	20.2	21.9	21.8	9.7	61.5	2.6	1.3	2.9	Average of 4 1405Fs	
Cologne Winter	05 May 11 10:00	20.1	19.5	21.4	22.1	14.1	46.9	2.9	2.2	3.7	Average of 4 1405Fs	PM2.5 Grubbs outlier
Cologne Winter	06 May 11 10:00	30.7	31.1	29.0	29.7	18.6	41.1	5.1	2.5	2.7	Average of 4 1405Fs	
Cologne Winter	07 May 11 10:00	46.1	47.5	42.0	43.9	21.9	37.0	6.5	3.4	2.6	Average of 4 1405Fs	
Cologne Winter	08 May 11 10:00	23.4	23.0	21.8	22.7	22.1	34.7	5.8	4.1	1.4	Average of 4 1405Fs	
Bornheim Summer	25 Jul 11 07:00	17.8	17.8	20.3	19.0	17.2	73.8	12.5	0.8	1.0	Average of 4 1405Fs	
Bornheim Summer	26 Jul 11 07:00	19.6	19.1	20.2	22.5	17.0	78.4	13.2	1.1	2.6	Average of 4 1405Fs	
Bornheim Summer	27 Jul 11 07:00	21.5	20.9	22.5	23.7	17.3	84.8	14.7	0.7	4.2	Average of 4 1405Fs	
Bornheim Summer	28 Jul 11 07:00	26.5	25.2	29.3	26.7	17.7	85.6	15.3	0.6	5.5	Average of 4 1405Fs	
Bornheim Summer	29 Jul 11 07:00	16.8	16.6	20.0	18.8	16.9	76.2	12.7	2.9	3.6	Average of 4 1405Fs	
Bornheim Summer	30 Jul 11 07:00			11.2	11.4	14.5	80.4	11.2	2.3	1.6	Average of 4 1405Fs	
Bornheim Summer	31 Jul 11 07:00	13.3	14.2	14.1	14.7	13.4	76.2	9.3	0.9	1.2	Average of 4 1405Fs	
Bornheim Summer	01 Aug 11 07:00	18.0	19.2	19.4	21.4	19.1	68.1	13.1	0.9	1.4	Average of 4 1405Fs	
Bornheim Summer	02 Aug 11 07:00	19.0	20.1	19.0	20.2	23.2	60.8	15.2	1.5	1.2	Average of 4 1405Fs	
Bornheim Summer	03 Aug 11 07:00	24.4	26.1	25.0	26.3	19.7	82.9	16.7	1.1	2.7	Average of 4 1405Fs	
Bornheim Summer	04 Aug 11 07:00	13.8	14.7	17.0	19.9	22.3	71.6	16.9	0.8	3.2	Average of 4 1405Fs	
Bornheim Summer	05 Aug 11 07:00	17.1	18.0	16.8	19.8	20.6	75.8	16.2	1.1	1.5	Average of 4 1405Fs	
Bornheim Summer	06 Aug 11 07:00			11.2	13.5	19.3	85.0	16.7	1.4	1.5	Average of 4 1405Fs	
Bornheim Summer	07 Aug 11 07:00	5.6	6.4	5.6	6.3	17.8	64.0	10.9	1.5	1.2	Average of 4 1405Fs	
Bornheim Summer	08 Aug 11 07:00	7.9	7.5	5.8	7.6	15.5	74.7	11.0	2.5	-0.7	Average of 4 1405Fs	
Bornheim Summer	09 Aug 11 07:00	10.8	11.2			13.8	76.8	9.8	2.7	-0.1	Average of 4 1405Fs	Audit flow rate
Bornheim Summer	10 Aug 11 07:00	12.1	12.7	14.0	13.4	18.0	57.5	9.5	1.3	3.2	Average of 4 1405Fs	
Bornheim Summer	11 Aug 11 07:00	11.4	11.1	9.5	11.0	20.9	53.8	11.2	1.2	1.0	Average of 4 1405Fs	
Bornheim Summer	12 Aug 11 07:00	6.4	7.0	5.5	8.5	18.5	78.9	14.8	1.1	1.3	Average of 4 1405Fs	
Bornheim Summer	13 Aug 11 07:00			10.2	8.3	20.1	77.0	15.9	0.7	2.1	Average of 4 1405Fs	
Bornheim Summer	14 Aug 11 07:00	7.0	6.7	4.3	8.3	17.4	86.2	15.1	1.1	0.7	Average of 4 1405Fs	
Bornheim Summer	15 Aug 11 07:00	13.5	13.9	14.5	15.3	17.9	71.8	12.7	1.2	0.6	Average of 4 1405Fs	
Bornheim Summer	16 Aug 11 07:00	13.7	12.9	14.5	15.9	19.1	69.0	13.3	0.7	1.6	Average of 4 1405Fs	

Site	Start Date and Time	PM10 LVS3 1 / µg/m3	PM10 LVS3 2 / µg/m3	20006 Mass / µg/m3	20107 Mass / µg/m3	Ambient Temp / °C	RH / %	Ambient Dew Point / °C	WS / m/s	Volatile / µg/m3	Volatile Notes	Remark
Bornheim Summer	18 Aug 11 07:00	16.8	15.9	21.5	21.2	22.5	76.6	18.2	1.2	3.0	Average of 4 1405Fs	
Bornheim Summer	19 Aug 11 07:00	13.3	12.8	15.0	16.2	16.8	80.0	13.3	1.5	2.0	Average of 4 1405Fs	
Bornheim Summer	20 Aug 11 07:00			17.9	16.2	20.7	66.6	14.3	0.8	2.1	Average of 4 1405Fs	
Bornheim Summer	21 Aug 11 07:00	17.1	17.2	20.3	19.6	23.2	74.8	18.5	1.0	1.3	Average of 4 1405Fs	
Bornheim Summer	22 Aug 11 07:00	19.7	19.3	22.0	24.2	20.4	76.5	16.1	1.2	3.3	Average of 4 1405Fs	
Bornheim Summer	23 Aug 11 07:00	29.9	30.1	33.6	35.8	22.6	78.4	18.6	0.9	3.2	Average of 4 1405Fs	
Bornheim Summer	24 Aug 11 07:00	16.9	16.7	15.3	18.8	20.1	76.6	15.9	0.7	1.8	Average of 4 1405Fs	
Bornheim Summer	25 Aug 11 07:00	18.8	18.6	19.5	19.8	20.8	83.4	17.9	1.0	3.2	Average of 4 1405Fs	
Bornheim Summer	26 Aug 11 07:00	10.7	10.7	12.5	12.4	19.4	83.7	16.6	1.5	2.0	Average of 4 1405Fs	
Bornheim Summer	27 Aug 11 07:00			5.3	5.9	15.3	77.0	11.3	1.1	0.7	Average of 4 1405Fs	
Bornheim Summer	28 Aug 11 07:00	7.7	7.6	7.8	7.3	15.6	69.2	10.0	1.3	1.4	Average of 4 1405Fs	
Bornheim Summer	29 Aug 11 07:00	11.4	11.5	11.2	11.6	14.5	66.7	8.4	2.0	1.2	Average of 4 1405Fs	
Bornheim Summer	30 Aug 11 07:00	17.1	16.6	16.0	17.2	13.6	73.6	9.0	0.8	1.7	Average of 4 1405Fs	
Bornheim Summer	31 Aug 11 07:00	26.0	23.6	24.3	26.0	14.8	72.0	9.8	0.7	3.0	Average of 4 1405Fs	
Bornheim Summer	01 Sep 11 07:00	27.5	26.1	27.9	28.9	16.4	71.6	11.3	0.6	4.3	Average of 4 1405Fs	
Bornheim Summer	02 Sep 11 07:00	25.1	24.1	24.1	24.0	21.2	72.2	16.0	0.8	2.1	Average of 4 1405Fs	
Bornheim Summer	03 Sep 11 07:00			26.4	25.7	24.5	67.0	18.0	1.3	2.2	Average of 4 1405Fs	
Bornheim Summer	04 Sep 11 07:00	12.7	12.1	13.1	11.8	20.2	79.5	16.5	1.1	1.5	Average of 4 1405Fs	
Bornheim Summer	05 Sep 11 07:00	9.2	9.1	7.6	7.6	16.6	62.9	9.5	1.9	0.6	Average of 4 1405Fs	
Bornheim Summer	06 Sep 11 07:00	11.1	10.6	10.4	10.2	17.4	66.8	11.2	2.6	2.0	Average of 4 1405Fs	
Bornheim Summer	07 Sep 11 07:00	12.5	13.2	11.0	11.6	14.9	73.1	10.1	2.2	1.3	Average of 4 1405Fs	
Bornheim Summer	08 Sep 11 07:00			8.0	7.8	14.7	84.7	12.1	1.1	1.0	Average of 4 1405Fs	
Bornheim Summer	09 Sep 11 07:00	12.1	11.8	9.8	11.1	19.0	86.9	16.8	0.4	0.9	Average of 4 1405Fs	
Bornheim Summer	10 Sep 11 07:00			12.9	13.1	23.8	73.0	18.7	1.5	1.2	Average of 4 1405Fs	
Bornheim Summer	11 Sep 11 07:00	9.4	9.3	7.9	9.9	16.2	86.0	13.9	0.7	1.5	Average of 4 1405Fs	
Bornheim Summer	12 Sep 11 07:00	11.6	11.6	9.2	10.8	19.4	71.1	14.0	1.7	1.1	Average of 4 1405Fs	
Bornheim Summer	13 Sep 11 07:00	16.3	16.8	12.5	14.8	16.7	67.3	10.6	1.6	0.9	Average of 4 1405Fs	
Bornheim Summer	14 Sep 11 07:00	15.3	15.6	11.6	12.8	15.2	65.1	8.7	1.5	0.8	Average of 4 1405Fs	
Bornheim Summer	15 Sep 11 07:00	24.3	24.9	22.8	23.1	14.1	75.3	9.8	0.6	1.6	Average of 4 1405Fs	
Bornheim Summer	16 Sep 11 07:00	23.0	25.1			17.1	72.6	12.1	1.4	2.5	Nitrate is 2011 ion data on this date	Inlet -> Zero filter
Bornheim Summer	17 Sep 11 07:00					16.8	70.6	11.4	1.0	1.3	Nitrate is 2011 ion data on this date	Zero filter
Bornheim Summer	18 Sep 11 07:00	7.0	7.1			13.3	76.4	9.2	1.0	0.6	Nitrate is 2011 ion data on this date	Zero filter
Bornheim Summer	19 Sep 11 07:00	12.5	11.6	11.3	10.7	13.6	75.8	9.4	1.4	-0.6	Average of 4 1405Fs	
Bornheim Summer	20 Sep 11 07:00			13.3	12.7	15.6	78.0	11.8	0.5	1.1	Average of 4 1405Fs	
Bornheim Summer	21 Sep 11 07:00	12.4	12.3	10.5	11.4	16.9	69.5	11.3	0.8	0.9	Average of 4 1405Fs	
Bornheim Summer	22 Sep 11 07:00	19.2	18.9	15.7	15.4	15.2	72.2	10.2	1.2	1.0	Average of 4 1405Fs	
Bornheim Summer	23 Sep 11 07:00	26.1	26.2	24.7	23.4					1.7	Average of 4 1405Fs	
Bornheim Summer	24 Sep 11 07:00			22.3	20.6					1.3	Average of 4 1405Fs	
Bornheim Summer	25 Sep 11 07:00	21.3	21.7	21.7	21.2					1.0	Average of 4 1405Fs	
Bornheim Summer	26 Sep 11 07:00	18.8	20.6							1.3	Nitrate is 2011 ion data on this date	Audits
Bornheim Summer	27 Sep 11 07:00	38.3	39.8	39.7	37.3					3.4	Average of 4 1405Fs	
Bornheim Summer	28 Sep 11 07:00			27.8						3.6	Average of 4 1405Fs	SN 20107 leak repairs
Bornheim Summer	29 Sep 11 07:00			26.6	29.4					1.9	Average of 4 1405Fs	
Bornheim Summer	30 Sep 11 07:00	23.4	24.5	23.1	25.7	18.4	68.3	12.5	1.2	1.2	Average of 4 1405Fs	
Bornheim Summer	01 Oct 11 07:00			20.7	23.0	18.1	70.6	12.7	0.5	1.5	Average of 4 1405Fs	
Bornheim Summer	02 Oct 11 07:00			37.6	40.6	17.8	75.4	13.4	0.3	3.7	Average of 4 1405Fs	
Bornheim Summer	03 Oct 11 07:00	21.4	21.4	27.4	30.4	18.8	65.9	12.3	0.8	3.8	Average of 4 1405Fs	
Bornheim Summer	04 Oct 11 07:00			15.0	17.8	17.8	72.4	12.8	1.6	1.3	Average of 4 1405Fs	
Bornheim Summer	05 Oct 11 07:00			6.4	6.7	17.5	70.8	12.1	1.2	2.0	Average of 4 1405Fs	
Bornheim Summer	06 Oct 11 07:00			9.1	10.8	13.2	71.2	8.1	2.3	1.3	Average of 4 1405Fs	

F. Instrument Manual

TEOM® 1405-F

Ambient Particulate Monitor
with FDMS® Option

42-010978 Revision A.000 22Sep2009

Thermo SCIENTIFIC

Mention of specific product names (other than Thermo Fisher Scientific products) in this manual does not constitute an endorsement or recommendation by Thermo Fisher Scientific of that equipment.

Warranty

Seller warrants that the Products will operate substantially in conformance with Seller's published specifications, when subjected to normal, proper and intended usage by properly trained personnel, for 12 months from date of installation or 13 months from date of shipment, whichever is less (the "Warranty Period"). Seller agrees during the Warranty Period, provided it is promptly notified in writing upon the discovery of any defect and further provided that all costs of returning the defective Products to Seller are pre-paid by Buyer, to repair or replace, at Seller's option, defective Products so as to cause the same to operate in substantial conformance with said specifications. Replacement parts may be new or refurbished, at the election of Seller. All replaced parts shall become the property of Seller. Shipment to Buyer of repaired or replacement Products shall be made in accordance with the provisions of Section 5 of the Terms and Conditions of Sale agreement. Lamps, fuses, bulbs and other expendable items are expressly excluded from the warranty under Section 9 of the Terms and Conditions of Sale agreement.. Seller's sole liability with respect to equipment, materials, parts or software furnished to Seller by third party suppliers shall be limited to the assignment by Seller to Buyer of any such third party supplier's warranty, to the extent the same is assignable. In no event shall Seller have any obligation to make repairs, replacements or corrections required, in whole or in part, as the result of (i) normal wear and tear, (ii) accident, disaster or event of force majeure, (iii) misuse, fault or negligence of or by Buyer, (iv) use of the Products in a manner for which they were not designed, (v) causes external to the Products such as, but not limited to, power failure or electrical power surges, (vi) improper storage of the Products or (vii) use of the Products in combination with equipment or software not supplied by Seller. If Seller determines that Products for which Buyer has requested warranty services are not covered by the warranty hereunder, Buyer shall pay or reimburse Seller for all costs of investigating and responding to such request at Seller's then prevailing time and materials rates. If Seller provides repair services or replacement parts that are not covered by the warranty provided in Section 9 of the Terms and Conditions of Sale agreement., Buyer shall pay Seller therefore at Seller's then prevailing time and materials rates. With respect to spare parts, the above-referenced warranty applies, however, such warranty is limited to ninety (90) days from the date of shipment.

ANY INSTALLATION, MAINTENANCE, REPAIR, SERVICE, RELOCATION OR ALTERATION TO OR OF, OR OTHER TAMPERING WITH, THE PRODUCTS PERFORMED BY ANY PERSON OR ENTITY OTHER THAN SELLER WITHOUT SELLER'S PRIOR WRITTEN APPROVAL, OR ANY USE OF REPLACEMENT PARTS NOT SUPPLIED BY SELLER, SHALL IMMEDIATELY VOID AND CANCEL ALL WARRANTIES WITH RESPECT TO THE AFFECTED PRODUCTS. THE OBLIGATIONS CREATED BY THIS SECTION TO REPAIR OR REPLACE A DEFECTIVE PRODUCT SHALL BE THE SOLE REMEDY OF BUYER IN THE EVENT OF A DEFECTIVE PRODUCT. EXCEPT AS EXPRESSLY PROVIDED IN THIS SECTION 9, SELLER DISCLAIMS ALL WARRANTIES, WHETHER EXPRESS OR IMPLIED, ORAL OR WRITTEN, WITH RESPECT TO THE PRODUCTS, INCLUDING WITHOUT LIMITATION ALL IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. SELLER DOES NOT WARRANT THAT THE PRODUCTS ARE ERROR-FREE OR WILL ACCOMPLISH ANY PARTICULAR RESULT.

Safety Notice

Repair of instrumentation manufactured by Thermo Scientific should only be attempted by properly trained service personnel, and should only be conducted in accordance with the Thermo Scientific system documentation. Do not tamper with this hardware. High voltages may be present in all instrument enclosures. Use established safety precautions when working with this instrument.

The seller cannot foresee all possible modes of operation in which the user may attempt to use this instrumentation. The user assumes all liability associated with the use of this instrumentation. The seller further disclaims any responsibility for consequential damages. Use of this product in any manner not intended by the manufacturer will void the safety protection provided by the equipment, and may damage the equipment and subject the user to injury.

Equipment Rating

The following information can be used to determine the power service requirements of this product.

Line Voltage
440VA, 47-63 Hz

IMPORTANT. Disconnect the power cord from the power source (output) while servicing the instrument to prevent electrical hazard.▲

Environmental Ranges — The instrument and its sample pump must be installed in a weather-sheltered location that is heated in the winter and air conditioned in the summer.

Note. There may be hazardous line (wire) accessible inside the enclosure.▲

Installation Category — Category 11

FUSES

Ref Designation	Current Rating	Location
Main Fuse (2)	F, 4A, 250VAC	Input Module
F201	F, 5A, 250VAC	Power Distribution Board
F202	F, 4A, 250VAC	Power Distribution Board
F203	F, 1A, 250VAC	Power Distribution Board
F204	F, 2A, 250VAC	Power Distribution Board
F201-F206	F, 2A, 125VAC	Head Controller Board
F401-402	T, 6.3 250VAC	FDMS Board

Electrical/Safety Certifications

The product has been tested and has been documented to be in compliance with the following U.S. and Canadian safety standards:

UL Standard 61010-1:2004 2nd Edition
CAN/CSA C22.2 No. 1010-1:2004 2nd Edition

Thermo Fisher Scientific certifies that this product operates in compliance with the EC Directive 89/336/EEC in reference to electrical emissions and immunity. Specifically, the equipment meets the requirements of EN 61326-1:1998 for Immunity and Emissions. In addition, the hardware has been tested for personal or fire safety hazards in accordance with EN61010-1:2001 (Safety) in fulfillment of EC Directive 73/23/EEC.

Disposal of the Instrument

This product is required to comply with the European Union's Waste Electrical & Electronic Equipment (WEEE) Directive 2002/96/EC. It is marked with the WEEE symbol.

Thermo Fisher Scientific has contracted with one or more recycling/ disposal companies in each EU Member State, and this product should be disposed of or recycled through them. Further information on Thermo Fisher Scientific's compliance with these Directives, the recyclers in your country, and information on Thermo Fisher Scientific products which may assist the detection of substances subject to the RoHS Directive are available at: www.thermo.com/WEEERoHS.

Service Information

When you purchase Thermo Fisher Scientific products, you can depend on quality products and expert service. We know that your product's performance is critical to your business, and that you require it to deliver timely and reliable data. We are dedicated to helping you realize a maximum value in your technology investment by providing a high level of personal attention, premium technical assistance, and fast reliable response. Thermo Scientific offers a full suite of warranty and service contract programs designed to meet your specific support needs and keep your instrumentation operating at peak performance.

Section Revision List

As Thermo Fisher Scientific's instrumentation changes, so do our operating manuals. However, these changes may affect only one aspect of an instrument, while leaving the instrument as a whole unchanged. To explain these individual changes to our customers, Thermo Fisher Scientific will update only those sections of its operating manuals that are affected by the instrument updates or improvements.

To help our customers keep track of the changes to the TEOM 1405 sampler and its operating guide, following is a list of the sections with their respective revision numbers:

Section Number and Description	*Revision Number*
Section 1: Introduction	A.000
Section 2: Setup and Installation	A.000
Section 3: Basic Operation	A.000
Section 4: Screens and Settings	A.000
Section 5: Maintenance and Calibration Procedures	A.000
Appendix A: Troubleshooting	A.000
Appendix B: Serial Communication	A.000

Table of Contents

Section 1 Introduction

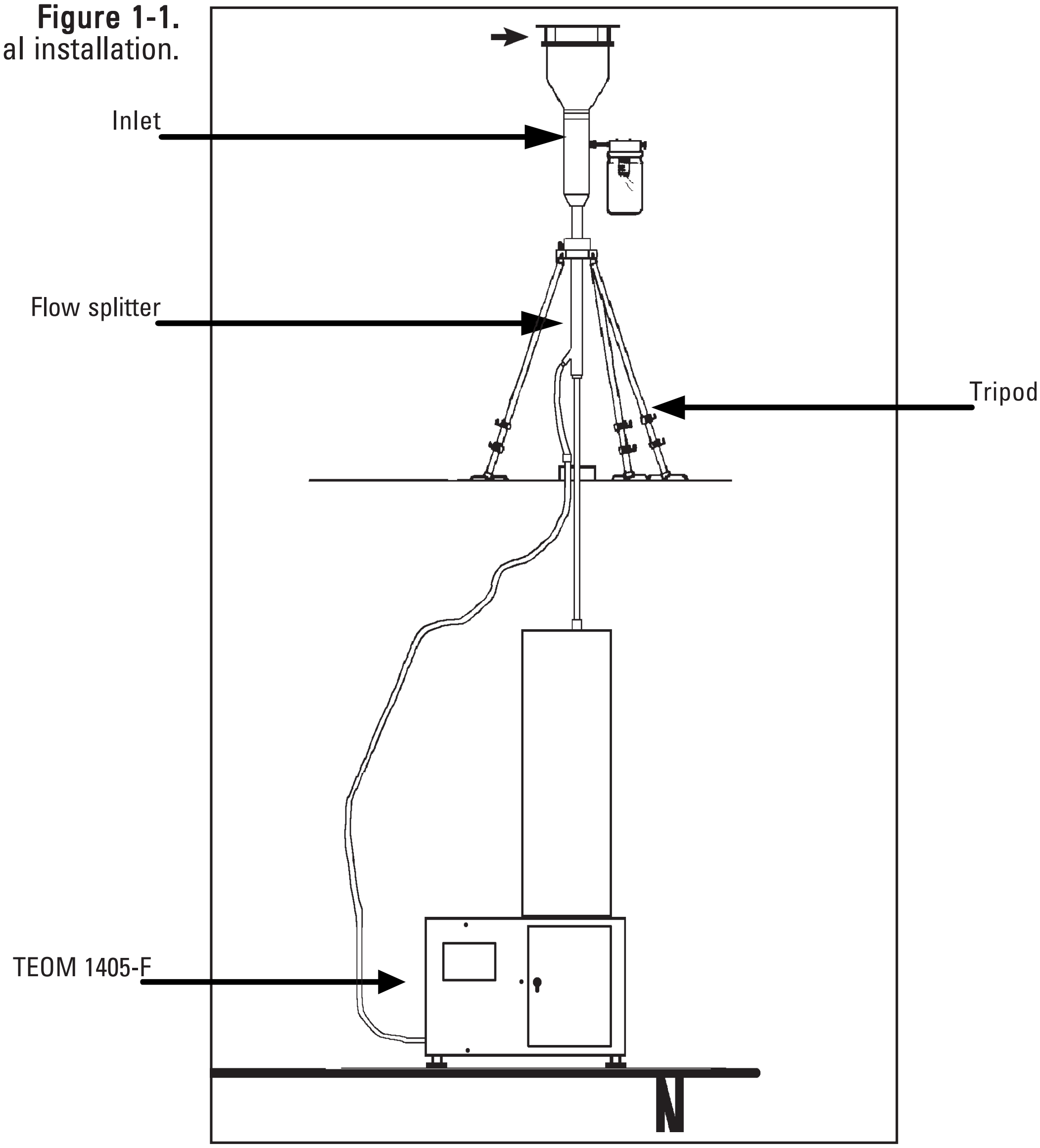
The TEOM® 1405-F Ambient Particulate Monitor with FDMS is a mass measurement monitor that incorporates the patented Tapered Element Oscillating Microbalance (TEOM) to measure particulate matter mass concentrations continuously. The TEOM 1405-F Monitor is a true "gravimetric" instrument that draws ambient air through a sample filter for collection at a constant flow rate. The monitor continuously weighs the filter calculating near real-time mass concentrations.

The 1405-F can be used to sample PM-10 by using a standard PM-10 inlet or can be used for PM-2.5 sampling by adding a cyclone in addition to the PM-10 inlet.

The TEOM 1405-F utilizes FDMS technology to provide a representative determination of the mass concentrations of the PM as it exists in ambient air. The FDMS unit automatically determines mass concentration measurements that account for both non-volatile and volatile PM components.

The TEOM 1405-F Monitor is composed of two major components (Figure 1-1): the sample inlet assembly and the TEOM 1405-F unit with FDMS system. The user enters the system parameters into the TEOM 1405-F unit using a color touch screen that is located on the front of the unit. The instrument's internal storage buffer can store a large amount of data for later viewing or downloading over a network connection. A USB connection allows easy downloads to a portable USB flash drive. Additionally, the system is furnished with software for personal computers to allow the user to download data and update instrument firmware. The instrument does not require a dedicated computer to function in the field. Analog outputs are available to transmit the measurements to a user's data acquisition system. Ethernet and RS232 ports allow for communication over a network or serial communications.

Figure 1-1.
Schematic of typical installation.



The sensor unit contains a mass measurement hardware system that monitors particles that continuously accumulate on the system's exchangeable TEOM filters. By maintaining a flow rate of 3 l/min through the sample channel, and measuring the total mass accumulated on the TEOM filter, the device can calculate the mass concentration in near real-time.

In addition, the TEOM 1405-F monitor is equipped with the FDMS System. The FDMS system is composed of the following components:

- air chiller/filter, dryer, and a switching valve that is used to direct the sample flows through system.

The FDMS™ Filter Dynamics Measurement System provides a representative determination of the particulate matter (PM) mass concentration as it exists in the ambient air. The FDMS unit automatically generates mass concentration measurements ($\mu g/m^3$) that account for both nonvolatile and volatile PM components.

Overview of Manual

This manual describes the installation and operation of the TEOM 1405-F Monitor. Follow the setup instructions contained in Section 2 and 3 before attempting to operate the unit.

This manual is divided into five sections. Sections 1 and 2 explain the system's hardware, while later sections describe the system's software and the setup and operation of the monitor. The following list provides an overview of the topics handled in each section of the manual:

Section 1: Introduction
This section provides an overview of the TEOM 1405 Monitor, as well as the theory of operation of the instrument's mass transducer.

Section 2: Setup and Installation
This section describes how to set up and install the system's hardware and sampling system.

Section 3: Basic Operation
This section provides instructions on how to turn on the instrument and initiate a sampling run. It also explains how to download data and how to leak check the instrument.

Section 4: Screens and Settings
This section explains how to set up the instrument's firmware and its operating modes.

Section 5: Maintenance and Calibration Procedures
This section describes the routine maintenance and verification procedures for the TEOM 1405 Monitor.

Appendix A: Troubleshooting
This appendix includes the information on deciphering status codes and as well as key schematics for troubleshooting purposes.

Appendix B: Serial Communication
This appendix includes information on the instrument's program register codes and built-in AK protocol.

Application Range

The TEOM 1405-F Monitor is a real-time device used for measuring the particulate matter mass concentration of particulate matter.

TEOM instruments are the only filter-based mass monitors that measure the mass of particulate matter suspended in gas streams in real time. This is made possible through the use of an inertial mass transducer patented in the U.S. and internationally by Thermo Fisher Scientific.

The monitor is ideally suited for applications demanding real-time air particulate matter monitoring in outdoor, indoor or industrial settings. It calculates mass concentration, mass rate and the total mass accumulation on the TEOM filter under the following conditions:

Flow rate through sample inlet	16.7 l/min (1 m^3/hr)
Main sample flow rate	3 l/min
Temperature of sample stream	30º C
Particulate matter mass concentration	less than 5 μg/m^3 to several g/m^3

Theory of Operation

The TEOM 1405-F Monitor is a true "gravimetric" instrument that draws ambient air through a sample filter at constant flow rate, continuously weighing the filter and calculates the near real-time mass concentration of the collected particulate matter. In addition, the instrument computes the 1-hour, 8-hour, 12-hour, and 24-hour averages of the mass concentration.

Utilizing the FMDS allows the TEOM 1405-F to provide representative measurement of the particulate matter (PM) mass concentration as it exists in the ambient air. The FDMS unit automatically generates mass concentration measurement (μg/m^3) that account for both nonvolatile and volatile PM components. To accomplish this the FDMS unit constantly samples ambient air, and using a switching valve to change the path of the sample flow, automatically compensates for the semi-volatile faction of the collected sample.

Every six minutes the switching valve alternates the sample flows between the base and reference sample periods. During the base period, sample is collected normally and the base mass concentration is determined. During the reference period, the flow is diverted through a chilled filter to remove and retain the non-volatile and volatile PM. Under normal operation, the chiller is maintained at a temperature of 4° C. However, under ambient conditions of high temperature and humidity, operating the chiller at 10° C is recommended to prevent condensation in the chiller during instrument operation.

Based upon mass concentration (MC) measurements obtained during the base and reference periods, the FDMS system updates a one-hour average of the following results every six minutes:

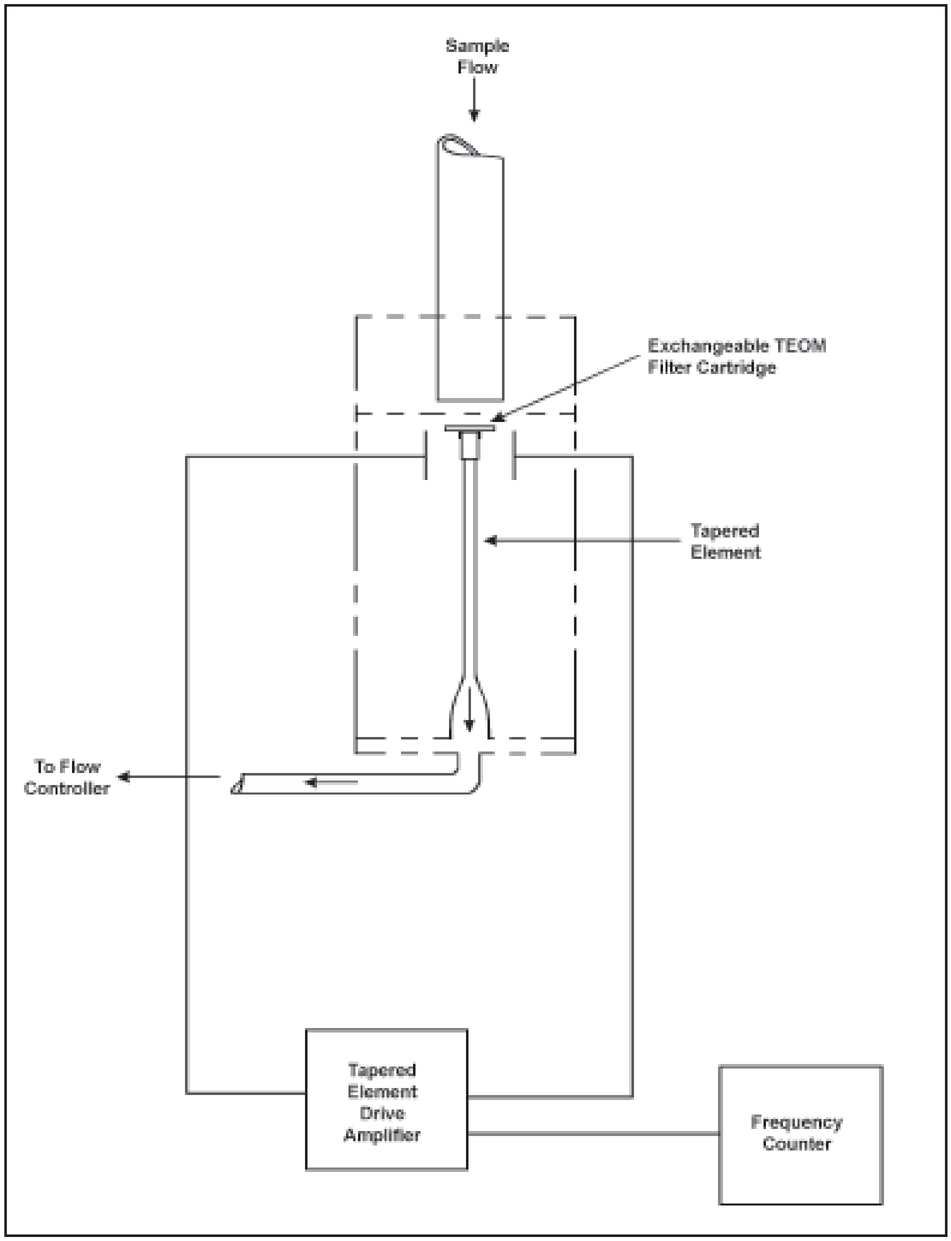
- Base mass concentration (Base MC) = PM concentration of the particle-laden sample stream.
- Reference mass concentration (Ref MC) = PM concentration of the particle-free sample stream, after passing through the chilled filter.
- Mass concentration (MC) = Base mass concentration (Base MC) adjusted by the reference mass concentration (Ref MC) — Base MC (usually positive) minus Ref MC (negative when mass volatilizes from the filter).

For example, the unit draws a base flow for six minutes and measures a mass concentration of 5 μg/m^3 (Base MC = 5). Then the unit draws a reference flow for six minutes and measures a mass concentration of -1 μg/m^3 (Ref MC = -1). Therefore, the mass concentration is 6 μg/m^3

Mass Transducer Operation

The weighing principle used in the tapered element oscillating microbalance (TEOM) mass transducer (Figure 1-2) is similar to that of a laboratory microbalance in that the mass change detected by the sensor is the result of the measurement of a change in a parameter (in this case, frequency) that is directly coupled via a physical law (or from first principles) to that mass change.

Figure 1-2.
Schematic of mass transducer.



The tapered element at the heart of the mass detection system is a hollow tube, clamped on one end and free to oscillate at the other. An exchangeable TEOM filter cartridge is placed over the tip of the free end. The sample stream is drawn through this filter, and then down through the tapered element.

The tapered element oscillates precisely at its natural frequency, much like the tine of a tuning fork. An electronic control circuit senses this oscillation and, through positive feedback, adds sufficient energy to the system to overcome losses. An automatic gain control circuit maintains the oscillation at a constant amplitude. A precision electronic counter measures the oscillation frequency with a 10-second sampling period.

The tapered element is, in essence, a hollow cantilever beam with an associated spring rate and mass. As in any spring-mass system, if additional mass is added, the frequency of the oscillation decreases. This can be seen by observing the frequency on the display of the TEOM 1405 unit (Section 4), and operating the monitor both with and without a filter in place.

In a spring-mass system the frequency follows the equation:

$$f = (K / M)^{0.5}$$

where:

f	=	frequency
K	=	spring rate
M	=	mass

K and M are in consistent units. The relationship between mass and change in frequency can be expressed as:

where:

$$dm = K_0 \frac{1}{f_1^2} - \frac{1}{f_0^2}$$

dm	=	change in mass
K_0	=	spring constant (including mass conversions)
f_0	=	initial frequency (Hz)
f_1	=	final frequency (Hz)

When this equation is rearranged, you can solve for the spring constant, K_0:

$$K_0 = \frac{dm}{\frac{1}{f_1^2} - \frac{1}{f_0^2}}$$

Thus, K_0 (the calibration constant for the instrument) can be easily determined by measuring the frequencies with and without a known mass (pre-weighed TEOM filter cartridge).

Mass Flow Controllers

The mass flow controllers (MFCs) in the TEOM 1405 Monitor are internally calibrated for a standard temperature and pressure of 25° C and 1 Atmosphere (1013.2 millibars or 760 mm Hg). The system can operate on "Active" or "Passive" flow to maintain constant volumetric flow at sample inlet. For *passive* flow control, the user must enter the seasonal average temperature (Ave. Temp.) and average barometric pressure (Ave. Pres.) at the measurement site to allow the instrument to sample at the correct volumetric flow rate (Section 4). The microprocessor calculates the correct mass flow set point ($Flow\_Rate_{STP}$) with this information using the following formula:

$$\text{FlowSP}_{\text{Passive}} = \text{FlowSP}_{\text{Vol}} \times \frac{P_{\text{AVG}}}{P_{STD}} \times \frac{\text{Temp}_{\text{STD}} + 273.15}{\text{Temp}_{\text{AVG}} + 273.15}$$

where:

$FlowSP_{PASSIVE}$	=	Control set point to mass flow controller (equivalent flow at 25° C and 1 Atmosphere)
$FlowSP_{Vol}$	=	Volumetric flow rate set point (l/min)
$Temp_{AVG}$	=	Average temperature entered by the user (°C)
$Temp_{STD}$	=	Standard temperature (25°C)
P_{AVG}	=	Seasonal average barometric pressure entered by the user (Atmospheres, where 1 Atmosphere = 1013.2 millibars or 760 mm Hg)
P_{STD}	=	Standard pressure (1 Atm)

Alternately, Active flow control can be set up to automatically measure the ambient temperature and pressure using the hardware supplied.

Note. When using actual conditions for active volumetric flow control, substitute the actual (local) temperature and pressure as measured by the instrument for the average temperature and pressure variables in equation above. ▲

PM-10 mass concentration data reported to the U.S. EPA must be referenced to standard cubic meters of air based on a standard temperature and pressure of 25° C and 1 Atmosphere (atm), respectively. For the instrument to report mass concentrations according to this EPA standard, the user must ensure that the standard temperature (Std. Temp.) and standard pressure (Std. Pres.) entered in the instrument equal 25° C and 1 Atmosphere (Section 4). These are the default values for the instrument.

$$\text{Flow\_Rate}_{\text{EPA}} = \text{Flow\_Rate}_{\text{STP}} \times \frac{\text{Std. Temp.} + 273.15}{273.15} \times \frac{1\,\text{atm}}{\text{Std. Pres.}}$$

The flow rates referenced internally by the instrument to 0° C are converted to EPA standard conditions.

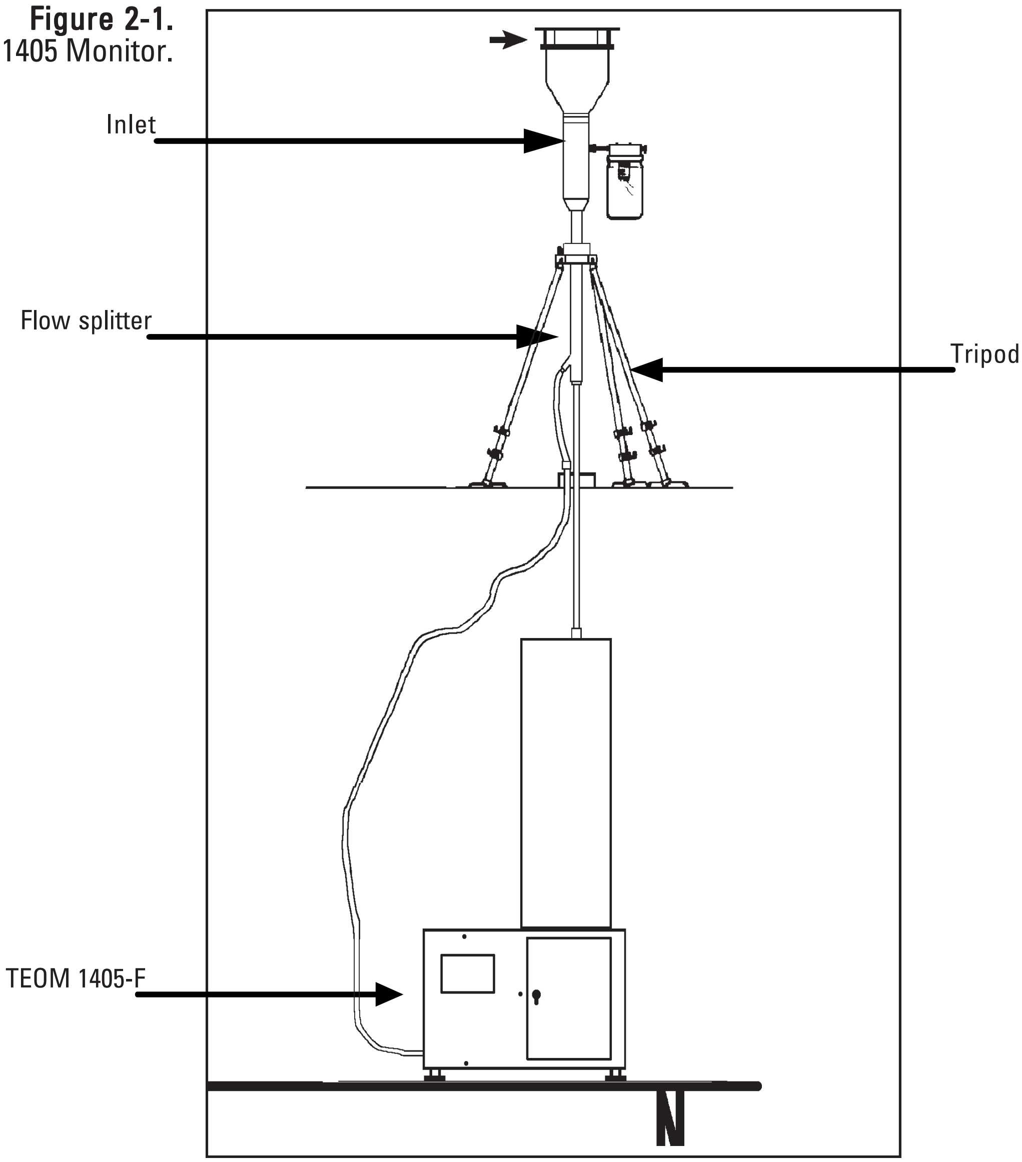
Note. When reporting concentrations to actual conditions, the system must be set for "Active" flow control (Section 4). This will ensure that the monitor uses the current actual values for temperature and pressure in the equation above. ▲

Section 2 Setup and Installation

This section describes the setup and installation of the TEOM 1405-F, including the pump, flow splitter, tripod, sample tube and sample inlet. After you have set up the system, you must perform a leak check on the monitor (Section 3) and install a TEOM filter (Section 5) in the mass transducer before starting a sample run.

If you want to install the monitor in an outdoor location, consult Thermo Fisher Scientific for specific site recommendations.

Figure 2-1.
TEOM 1405 Monitor.



Installation Considerations

The TEOM 1405-F may be located in any convenient indoor location which is maintained between 8° and 25° C (46° to 77° F). The user must run a sampling tube through the roof of the monitoring site (refer to the inlet installation instructions later in this section). The entrance to the sample inlet must be 1.8 to 2.1 m (70 to 82 inches) above the roof based on U.S. EPA requirements. Refer to local regulations for the actual inlet height requirements.

Although the TEOM monitor is inherently rugged, it is a precision instrument. The user will obtain the best operating conditions and longest instrument life when the unit is not exposed to extremes of weather. Filter exchange, in particular, may be best accomplished by a technician operating in an indoor environment where there is no possibility of rain or snow contaminating the filter.

Be sure to install the ambient temperature/humidity sensor. If you do not install the ambient temperature/humidity sensor, you must set the instrument to "Passive" flow control (Section 4) or the mass flow controller will attempt to control the sample flow as if the ambient temperature is absolute zero.

The sample line for the main channel should proceed in a straight, vertical line from the PM-10 inlet and to the inlet of the unit.

To achieve the best results, locate the TEOM sensor unit in an environment with relatively slow temperature fluctuations. Avoid sampling locations with direct exposure to sunlight or that are in close proximity to a heating or air-conditioning outlet. To avoid condensation in the sample tubing, Thermo Scientific strongly recommends that the user insulate the sample tube extensions with pipe insulation when operating the instrument in areas of high humidity.

Standard System Hardware

The TEOM 1405-F Monitor is supplied with the following components:

TEOM 1405-F unit
Temperature/humidity sensor and cable, 10 m
3/8" green tubing for bypass flow, 10 m
3/8" green tubing to pump, 5 m (16.5 ft)
2 Sample tubing extensions, 1 m (40")
Box of 20 TEOM filter cartridges (Pallflex TX40)
Filter exchange tool
Filter cassette
Box of 25 47mm FDMS filters
1 small filter element
1 large bypass filter element
Flow splitter
PM-10 inlet
Water trap filter assembly
Flow audit adapter/leak check kit
Cooler cleaning kit
Vacuum pump
2 Operating Manuals (one hard copy, one on CD)
Quick Start Guide
Pre-filter/silicone tubing

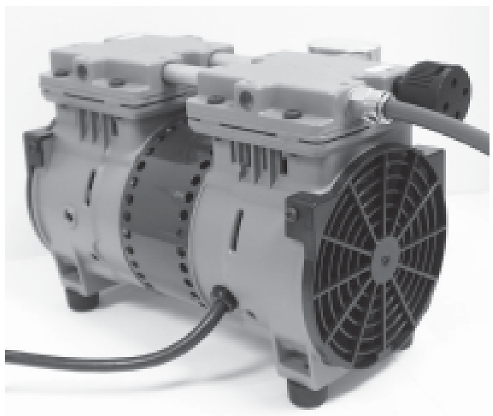
Pump Connections

Follow these steps to attach the pump:

1. Locate and cut the piece of the 15m green tubing into two pieces — one about (but not less than) 5m (the lengths may be precut). (The typical setup has 5m of tubing for the pump and 10m for the bypass line.)

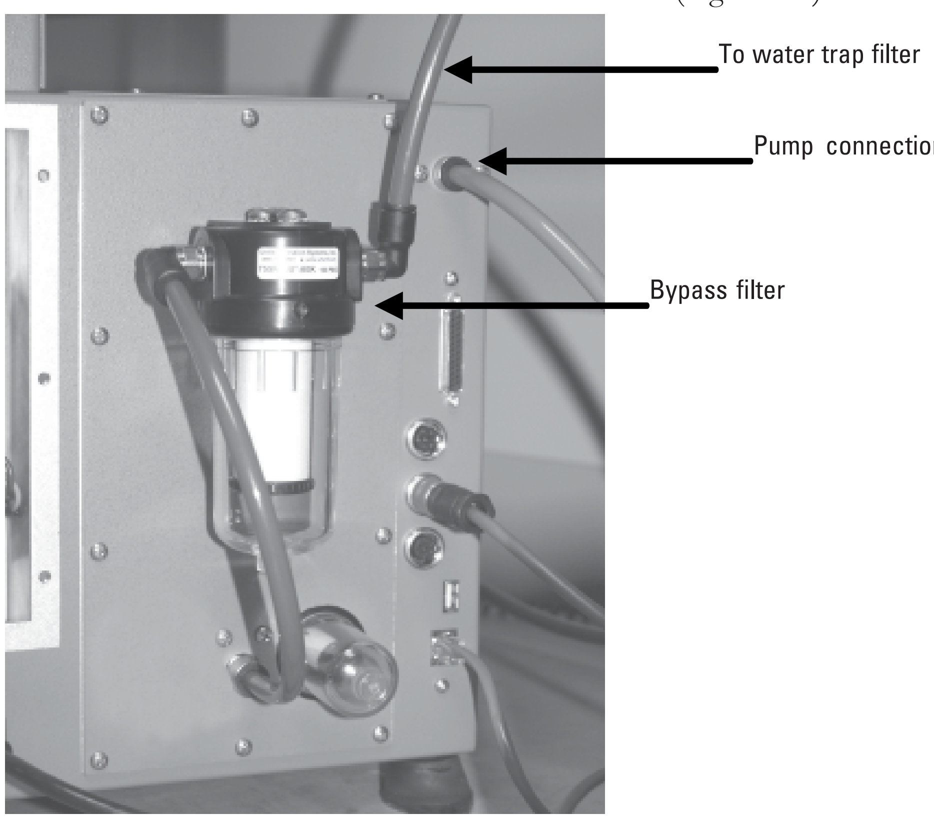
2. Locate the sample pump in a location to minimize vibrations effecting the instrument. Push the one end of the 5m pump tubing into the fitting on the vacuum pump (Figure 2-2).

Figure 2-2.
Vacuum pump.



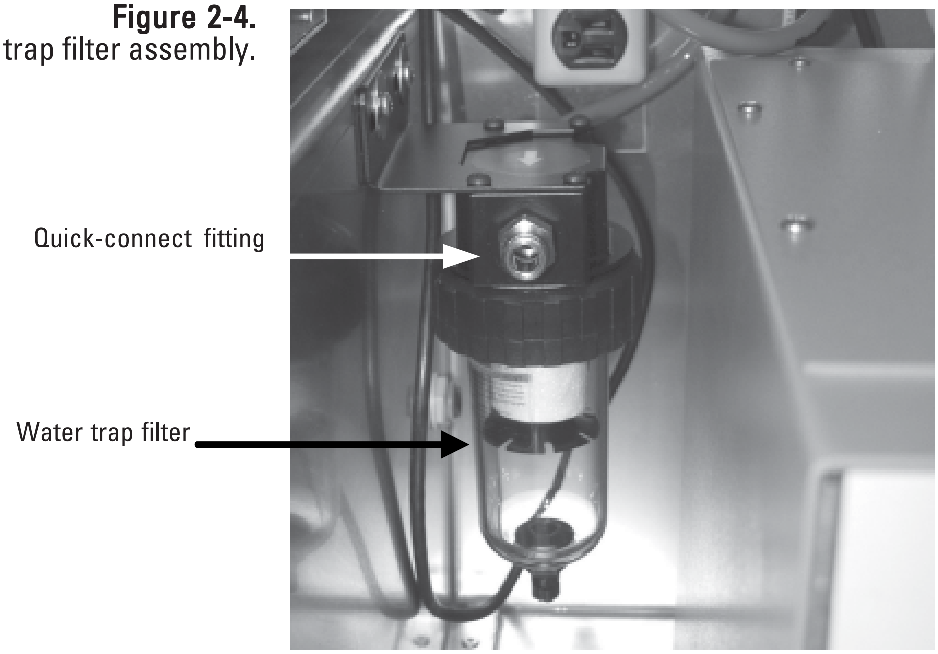
3. Push the other end of the 5m length of pump tubing into the pump connection on the back of the TEOM 1405 unit (Figure 2-3).

Figure 2-3.
Back of TEOM 1405 unit



4. Mount the water trap filter assembly near the 1405 unit (Figure 2-4). The water trap should be mounted at the low point of the tubing to the instrument.

Figure 2-4.
Water trap filter assembly.



Note. Drain the water trap as needed. ▲

5. From the 10m length of tubing for the bypass line, cut a piece of tubing long enough to reach from the water trap filter to the bypass filter on the back of the 1405 unit (Figure 2-3 and 2-4). Install the tubing into the quick-connect fittings on the water trap filter and bypass filter.

6. Insert one end of the remaining section of bypass tubing into the quick-connect fitting at the end of the coiled piece of tubing connected to the water trap filter.

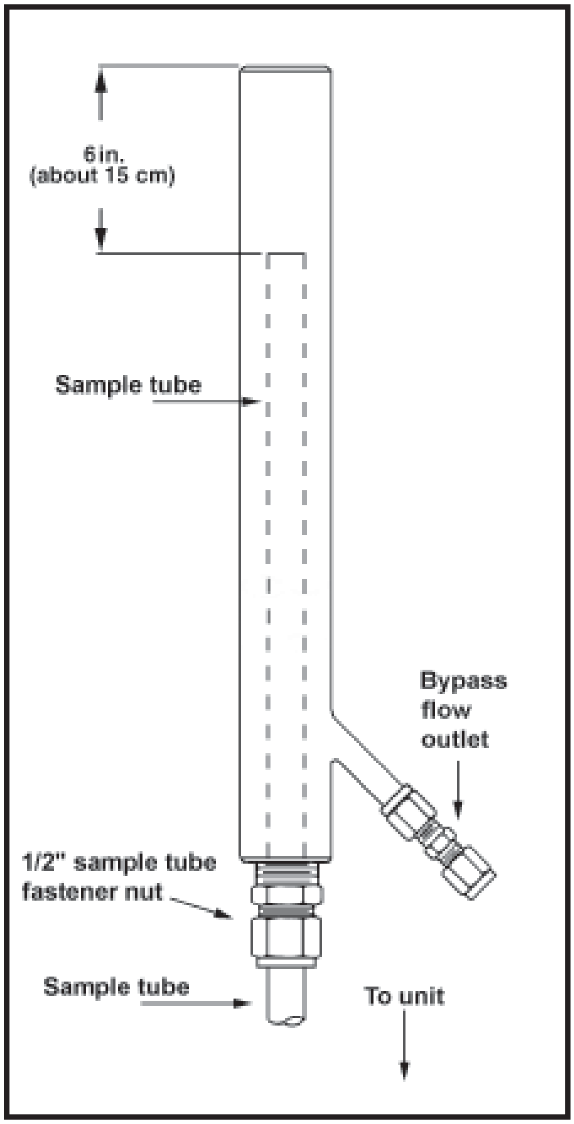
Note. The other end of the bypass tubing will be connected to the bypass connection on the flow splitter when you assemble and install the sample inlet (following section). ▲

Note. Thermo Scientific strongly recommends that you use the vacuum pump provided with the unit. If you choose to install a different pump, it must be oil-free and able to maintain a 21" Hg vacuum at a flow of 16.67 l/min. ▲

Adjusting the Flow Splitter

An isokinetic flow splitter (Figures 2-5 and 2-6) is used in combination with an automatic flow controller to divide the main/bypass flow into two components after the air stream passes through the size-selective inlet. The two sample flow components are the main flow (3 l/min) that flows to the TEOM mass transducer, and the bypass flow (12 l/min).

Figure 2-5.
Flow splitter.



Even though the flow splitter and sample tube are pre-assembled, verify the assembly position prior to use. Should it need to be re assembled, refer to the instructions that follow.

The tubing package is designed to use the short sample tube in the flow splitter.

To set up the flow splitter assembly:

1. Locate the flow splitter (Figures 2-5 and 2-6).

2. Loosen the 1/2-inch sample tube fastener nut and slide the sample tube down into the flow splitter so that the top of the installed sample tube (or flow adapter) is approximately 15.5 cm (6") from the top of the flow splitter (it must be between 5.75 and 6.25 inches from the top of the flow splitter) (Figure 2-7).

3. Tighten the 1/2-inch sample tube nut. Ensure that the top of the flow adapter remains between 5.75 and 6.25 inches from the top of the flow splitter (Figure 2-7).

Figure 2-6.
Bottom of the flow splitter.

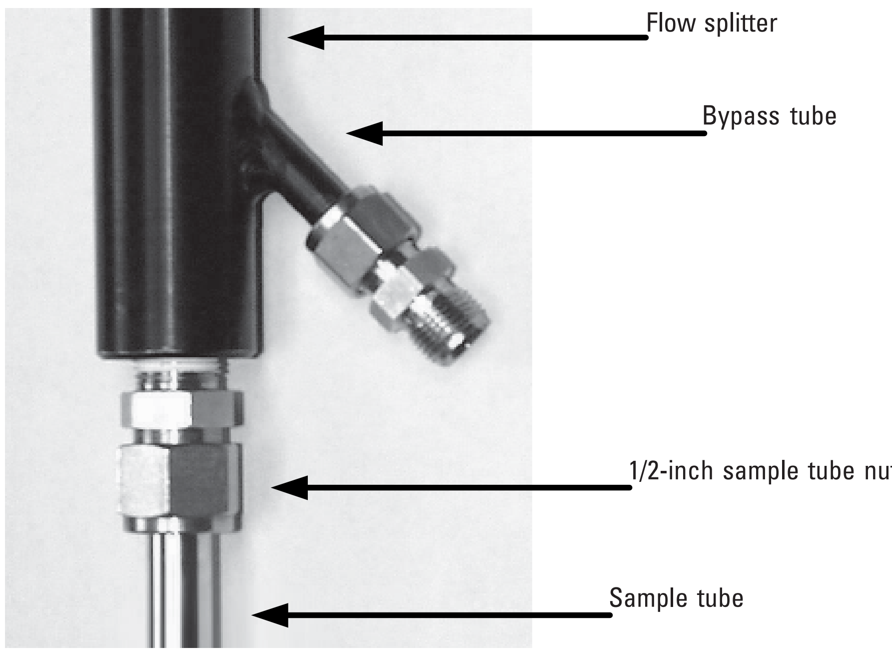
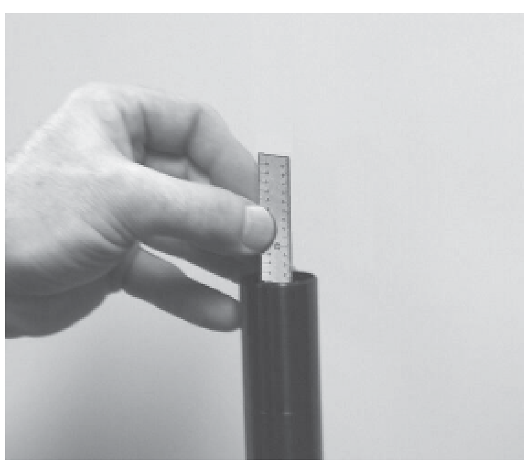


Figure 2-7.
Measuring the distance from the top of the sample tube to the top of the flow splitter.



Assembling the Tripod

An optional tripod is available for installation on the roof of a sampling building.

To assemble the tripod:

1. Locate a tripod foot and remove the rubber leg holder, if one is attached.
2. Place one leg of the tripod onto the tripod foot.
3. Place a metal bracket over the rubber base of the tripod leg and into the two slots on the tripod foot (Figure 2-8). Ensure that the bracket is placed over the rubber base on the end of the tripod leg.

Figure 2-8. Placing the metal bracket on the tripod foot.

4. Insert a plain washer then a lock washer onto each threaded end of the bracket, then install the nuts on the threaded ends of the bracket and tighten them with a 3/8" (or adjustable) wrench.

   Note. Hand-tighten both nuts on the bracket before tightening them with the wrench to ensure that the bracket is positioned properly on the tripod leg and tripod foot. ▲

5. Repeat steps 1 through 4 for each leg of the tripod.

Installing the Inlet

The TEOM 1405-F can be assembled with a variety of inlet configurations. For PM-10 sampling, only a traditional or modified PM-10 inlet is used. PM-2.5 and PM-1 sampling is accomplished by adding a cyclone to the inlet assembly downstream of the PM-10 inlet. Two types of cyclones are available for use in PM-2.5 sampling; the VSCC and the SCC (Figure 2-9). The VSCC is required for U.S. EPA sampling. For PM-1 sampling, a single type of cyclone is available.

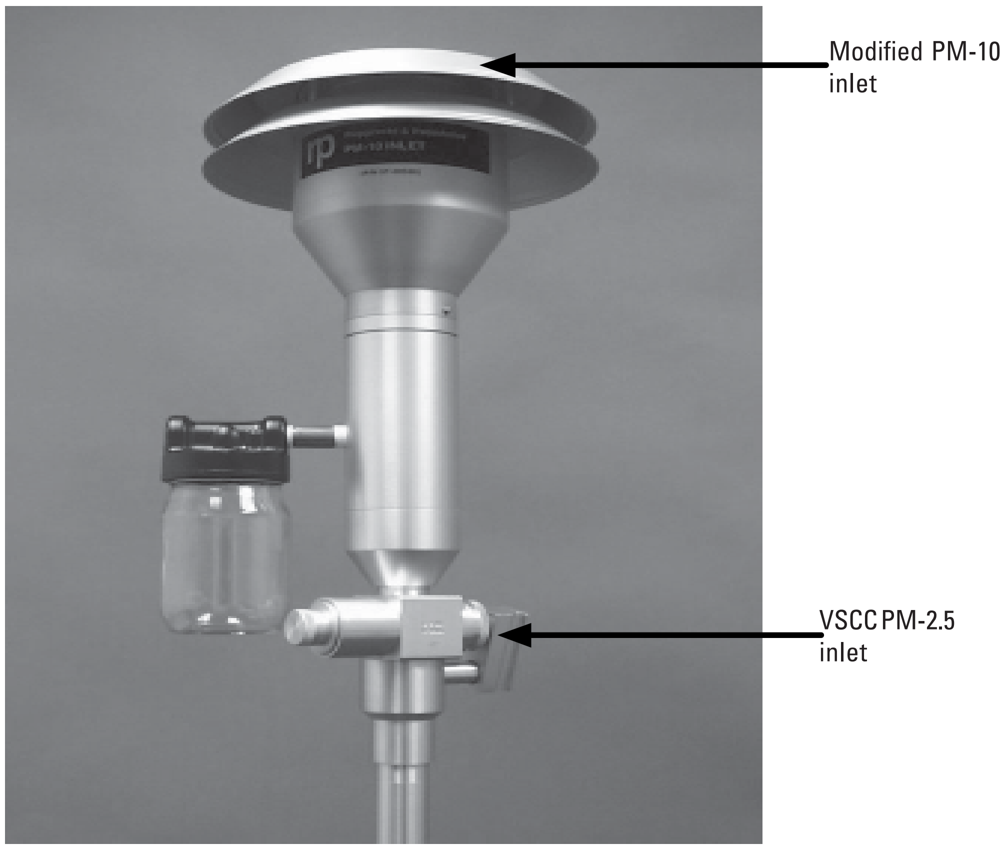


Figure 2-9.
Modified PM-10 Inlet installed.

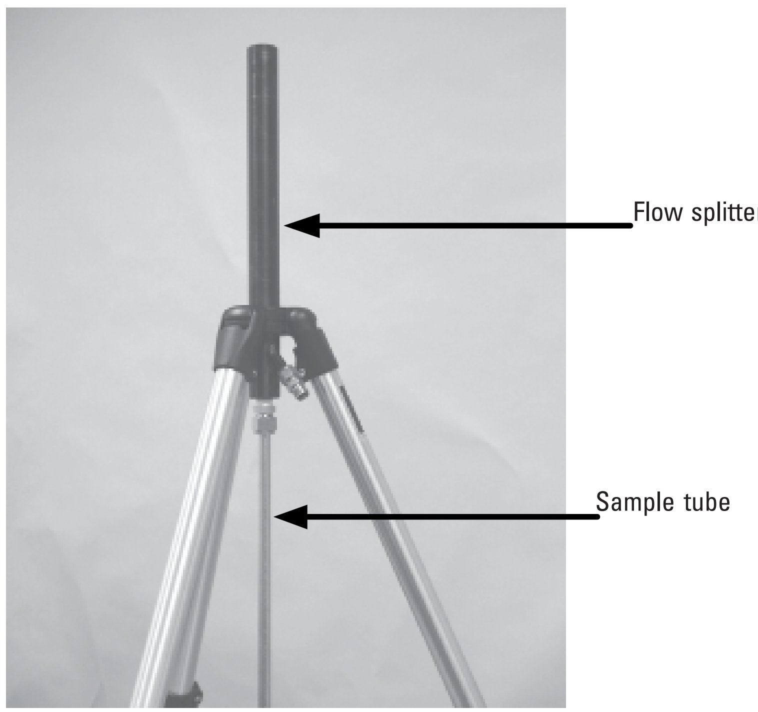
To install the inlet :

1. Set the 1405 unit on a bench or other support directly below the location of the inlet on the roof of the sampling structure (Figure 2-1). In its finished state, the entrance to the sample inlet must be 1.8 to 2.1 m (70 to 82 inches) above the roof.

   Note. This measurement may vary based on the inlet height required by the local regulatory agency. The height of the inlet is the same if sampling PM-10, PM-2.5 or PM-1. ▲

2. Install the assembled flow splitter into the tripod and lightly tighten the knob to ensure the flow splitter stays in place (Figure 2-10).

Figure 2-10.
Bottom of the flow splitter.



3. Measure and mark a spot in the roof directly above the 1/2-inch sample line on the top of the instrument.

   Note. In this example, a 4-inch hole was cut in the roof to accommodate a 4-inch PVC pipe and seal. The cap of the PVC pipe was then drilled to accommodate the sample line. ▲

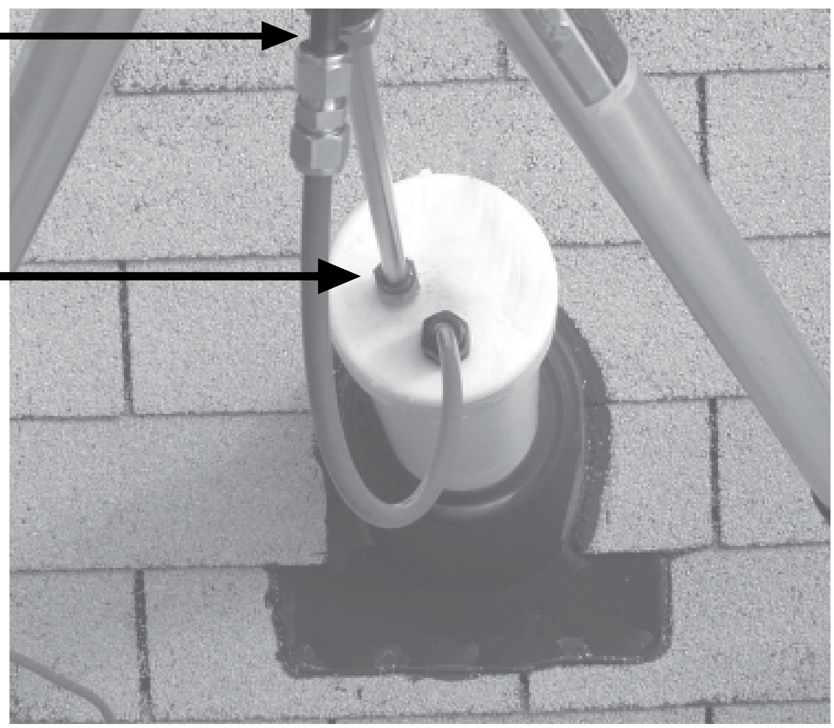
4. Drill the hole in the roof for the 1/2-inch sample line and another hole for the 3/8-inch bypass line tubing. (The bypass tubing may also be run through a window or other opening.)

5. Set the tripod on the roof above the 1405 unit and adjust the legs so the top of the tripod is above the roof opening.

Figure 2-11.
Installing the sample tubes and bypass line through the roof.

Flow splitter (with bypass)

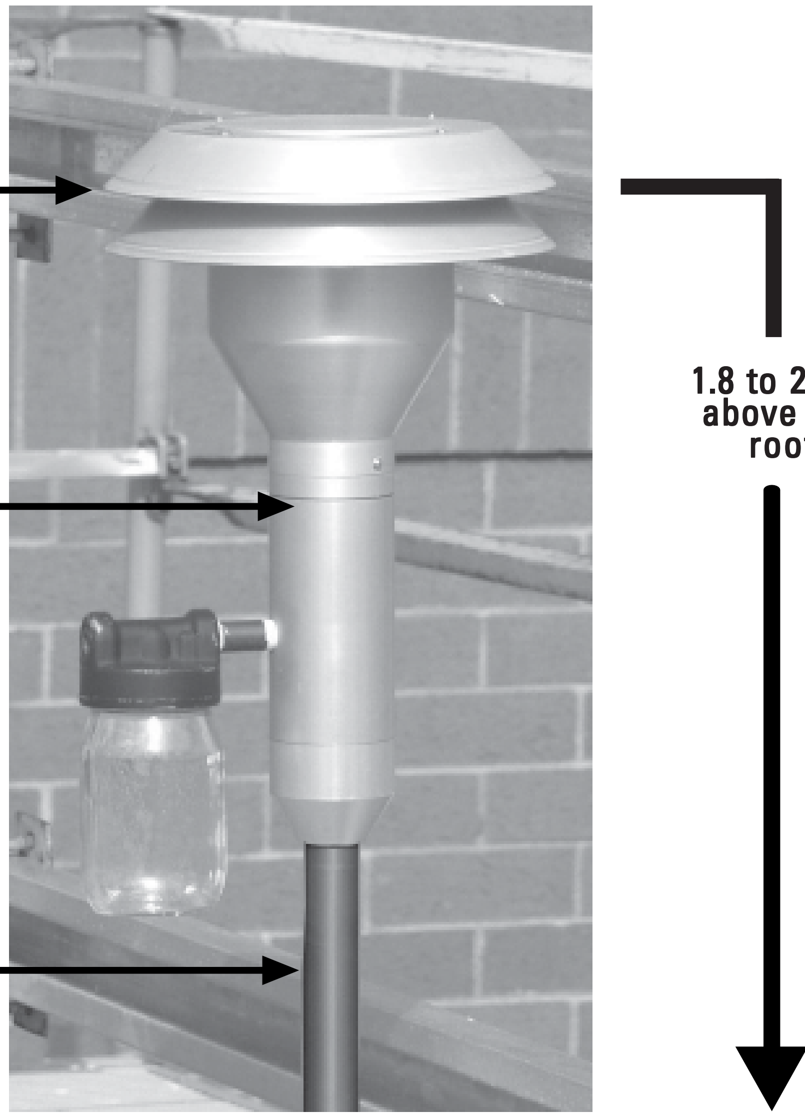
Sample tube extensions
(1 3/4-inch centers)



6. Install the slow splitter in the tripod and install the inlet assembly on top of the flow splitter. Adjust the tripod so the entrance to the sample inlet is 1.8 to 2.1 m (70 to 82 inches) above the roof (Figure 2-12).

   Note. This measurement may vary based on the inlet height required by the local regulatory agency. Verify height requirement prior to installation. Figure shows PM-10 inlet only. Height of PM-10 inlet is the same for PM-2.5 and PM-1. ▲

Figure 2-12.
Inlet installed.

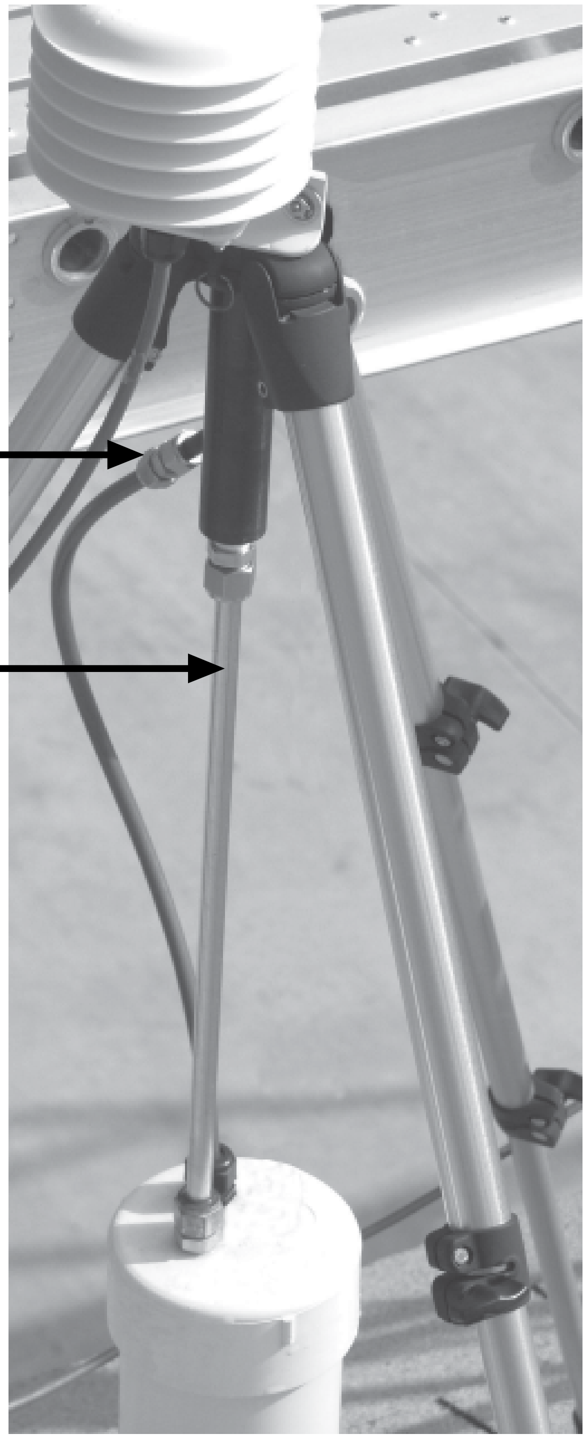


7. Center the tripod over the roof hole. Measure and cut the sample tube extensions from the top of the instrument, through the roof and connect to the flow splitter sample tube. Make sure to clean and deburr the cut ends of the sample tube extensions.

8. Connect the green bypass tubing (the other end is attached to the coiled tubing of the water trap filter) to the bypass fitting on the flow splitter using the 3/8-inch Swagelok fitting (Figure 2-13).

   Note. Ensure that the coiled tubing connected to the water trap filter is mounted vertically, so condensed water will drip into the water trap filter. ▲

Figure 2-13. Bypass tubing and sample tubes installed



9. Locate the ambient temperature and humidity sensor. Connect the sensor to the flow splitter using the U-bolt provided with the system (Figure 2-14).

10. Attach the sensor cable to the sensor and run the sensor cable to the instrument through an opening in the roof or through a window. Attach the sensor to the sensor connection on the back of the TEOM 1405 unit (Figure 2-15).

11. Fasten the tripod feet to the roof. The length and type of fasteners depends on the type of roof surface. The tripod feet also may be attached to a pallet or 3/4" marine plywood, with the pallet or plywood secured by concrete blocks or sand bags.

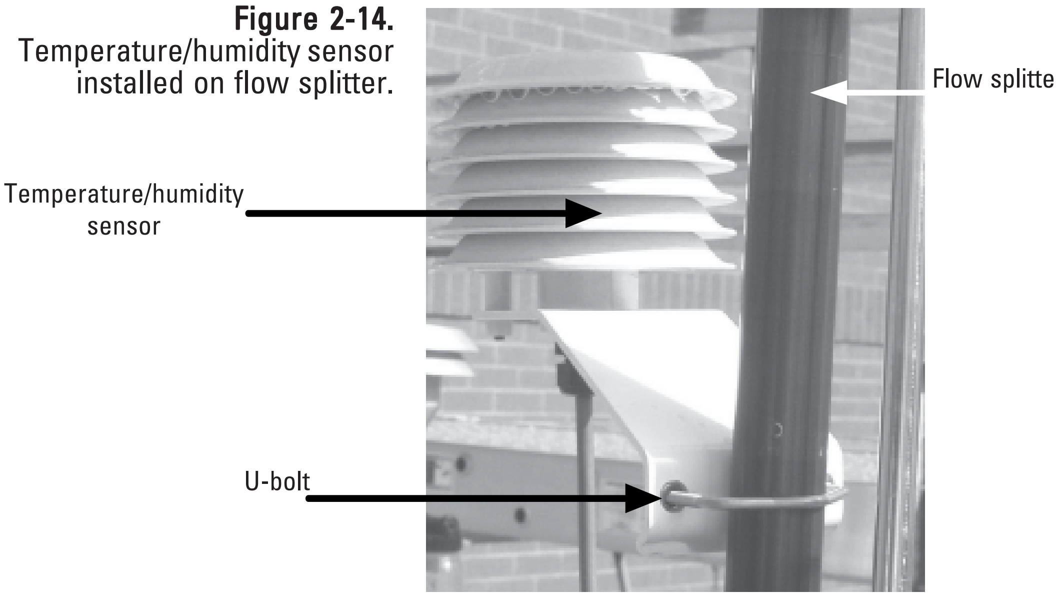


Figure 2-14. Temperature/humidity sensor installed on flow splitter.

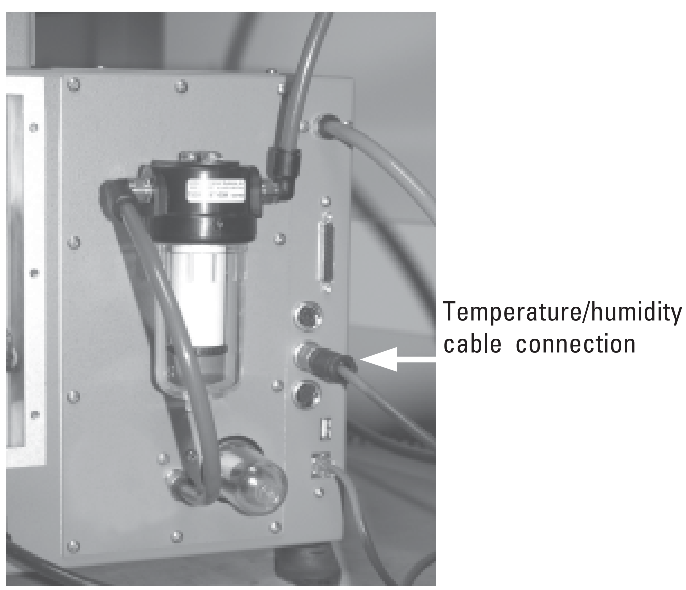


Figure 2-15. Temperature/humidity sensor connection of the back of the Series 1405 unit.

Applying Power to the Instrument

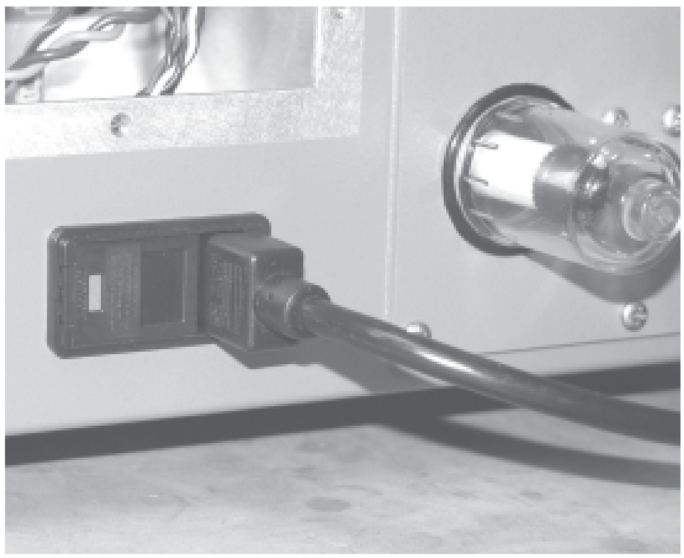
The TEOM 1405-F unit accepts all voltage inputs between 85 and 240 volts AC. The unit should be connected to an appropriate, code-approved electrical outlet for the sampler location. Contact a qualified electrician if there is doubt as to whether the power service for the instrument is adequate.

To turn on the monitor:

1. Install an appropriate power cord into the universal power connection on the back of the instrument at the appropriate voltage.

   Note. DO NOT attempt to bypass the grounding requirements for the unit. ▲

Figure 2-16. Power connection on back of unit.



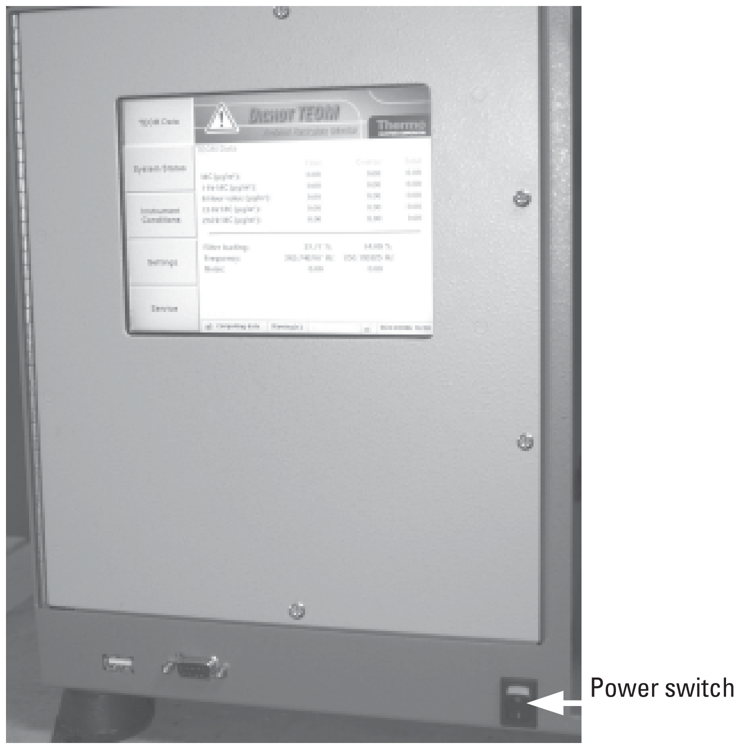
2. Install the other end of the power cord into an appropriate, easily accesible, grounded, code-approved electrical outlet.

   Note. Contact a qualified electrician if there is doubt as to whether the power service for the instrument is adequate. ▲

3. Press the "POWER" switch on the front panel of the control unit (Figure 2-17). The unit will begin its startup routine. After a few moments, the Title screen will appear on the control unit's display and then the TEOM Data (Main) screen. Refer to Sections 3 and 4 for information on the instrument's software screens.

4. Plug the pump into an appropriate power source to draw a sample stream through the system.

Figure 2-17.
Power switch.



The TEOM Data screen will show a warning message (Section 4) because the flow rates and temperatures are outside of tolerance ranges. The warning may remain active during the first 30 minutes after the power switch is pressed while the monitor warms up. The status warning icon automatically disappears after all flow rates and temperatures reach tolerance ranges. The monitor waits until the flow rates and temperatures stabilize within a narrow range before starting data collection. This ensures the validity of all data points computed by the system.

Note. Upon initial instrument start up, the values in the mass concentration fields are the running averages that are accumulated until a 1-hour time period has passed. The values are visible to provide the user with an indication that the instrument is functioning, after instrument power up or reset. These raw values are used for internal calculations only.

Turning Off the Instrument

If the instrument needs to be turned off, turn the power switch on the front of the unit to off (0).

Note. Wait at least 1 minute after shutdown before reapplying power to the unit.

The instrument may also be restarted without turning it off.

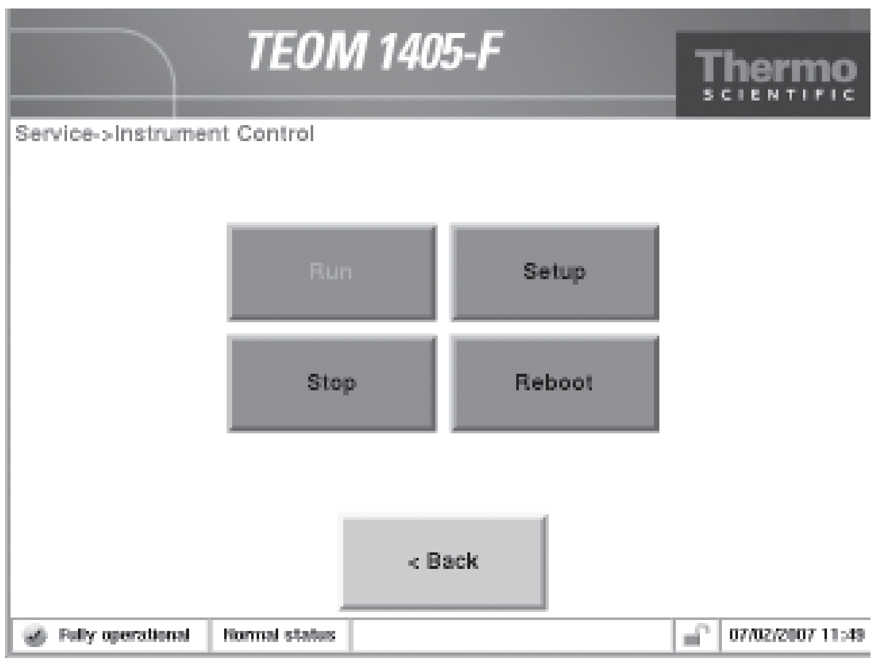
Restarting the Instrument

To restart the instrument:

1. In the Service screen (Section 4), select the **Instrument Control** button to display the Instrument Control screen (Figure 2-18).

2. Select the **Reboot** button.

Figure 2-18.
Instrument Control screen.



Using the Outdoor Shelter

Thermo Fisher Scientific offers an outdoor shelter for the 1405 unit. The shelter is fully climate controlled and includes space for the 1405 unit, pump and accessories such as a data logger or additional monitoring devices. It is available in both 120V and 240V version.

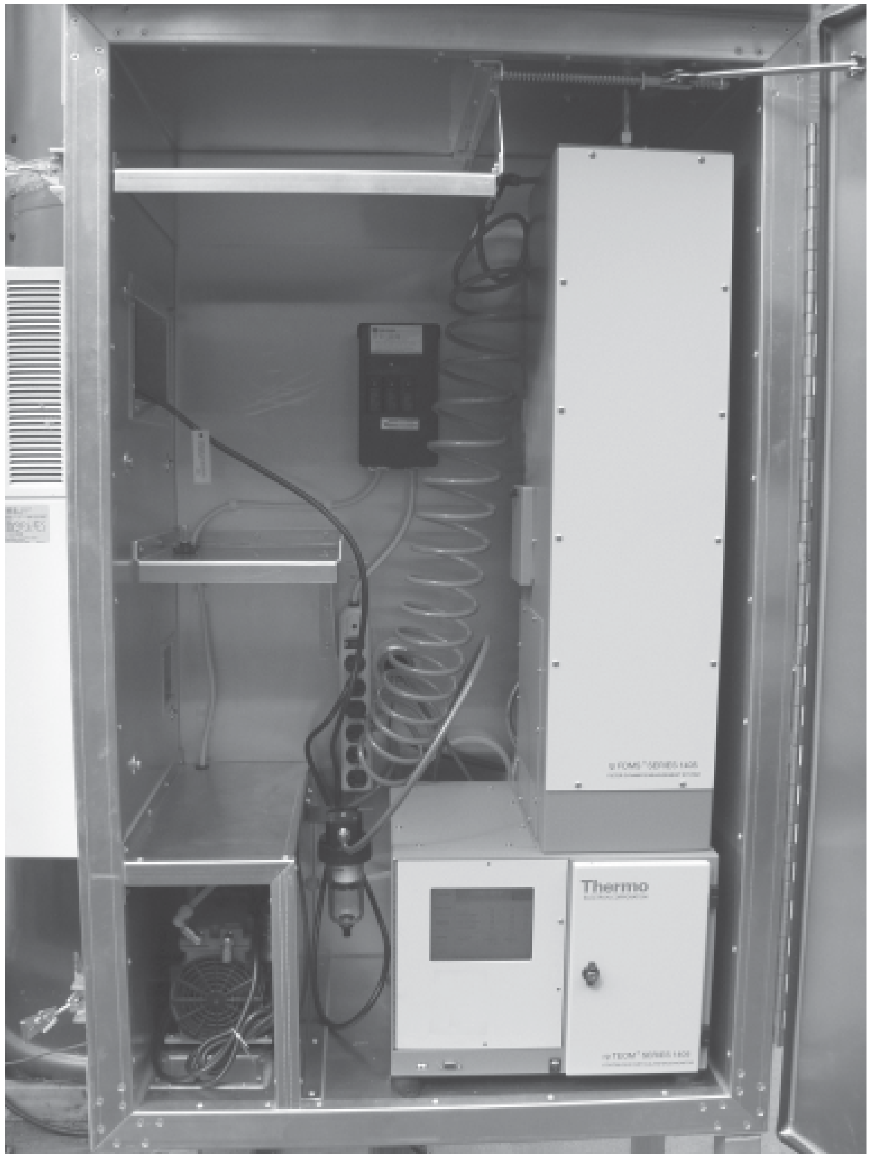


Figure 2-19. 1405 unit in the outdoor enclosure.

To install the 1405 unit in an outdoor shelter:

1. Before placing the 1405 unit or pump into the enclosure, install a 3/8-inch elbow fitting provided with the outdoor enclosure into the quick connect-fitting inside the pump compartment, where the pump tubing goes through the bulkhead into the enclosure. Install the other 3/8-inch elbows into the pump connection on the back of the 1405 unit and into the connection on the pump (Figures 2-20, 2-21 and 2-22).

Figure 2-20.
Enclosure.

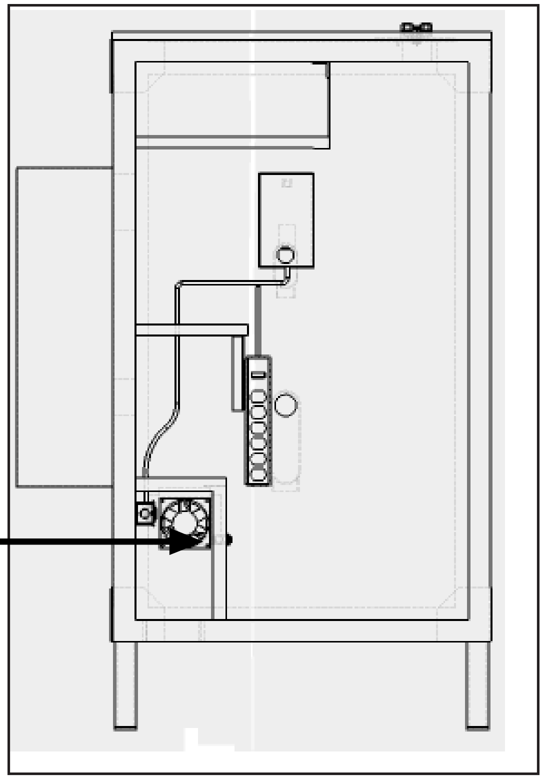
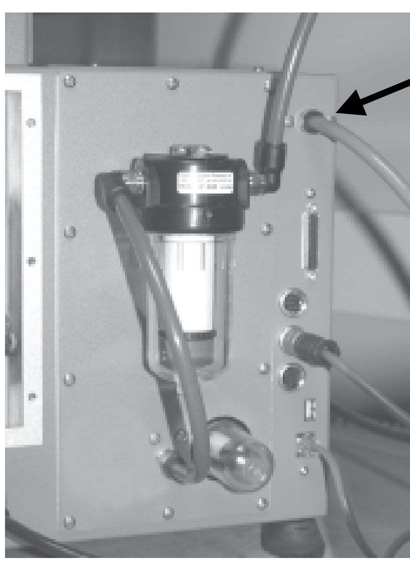
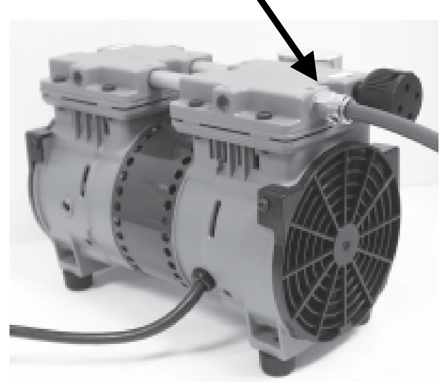


Figure 2-21 (left).
Back of the 1405 unit.

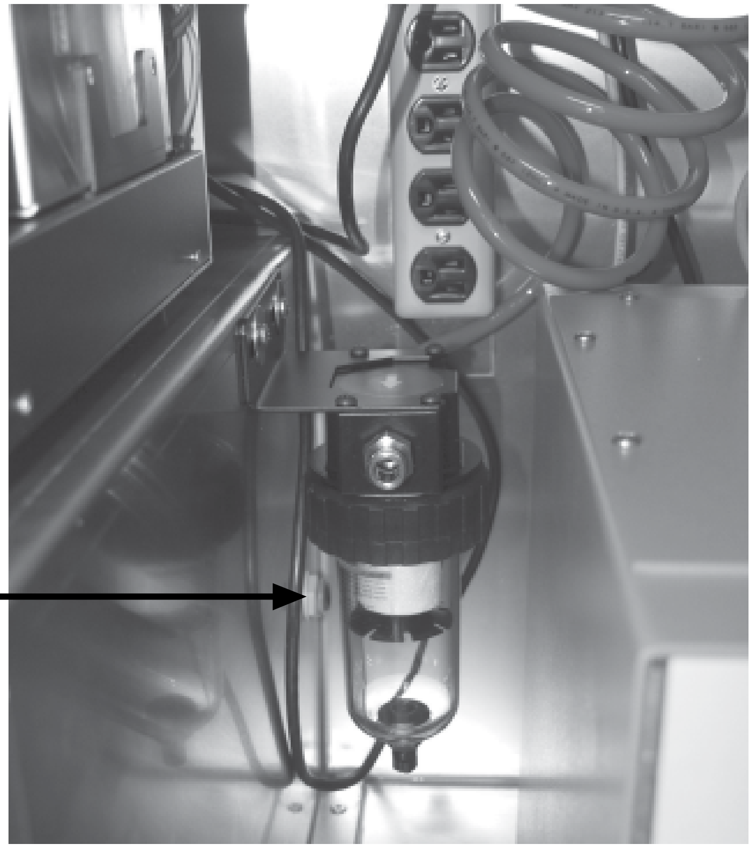
Figure 2-22 (right).
Pump.





2. Install the water trap filter and bracket into the two pre-drilled holes on the side of the pump compartment (Figure 2-23).

Figure 2-23.
Water trap filter.



3. Cut a 14-inch (.35m) piece of tubing from the 3-foot section that came with the enclosure package. Place the pump in the enclosure, and connect the elbow fitting on the pump (Figure 2-22) to the elbow fitting on the inside of the pump compartment using the 14-inch piece of tubing.

4. Locate and cut the piece of the 15m green tubing, that came in the 1405 packaging, into two pieces — one about (but not less than) 5m.

5. Install the one end of the 5m pump tubing into the quick-connect fitting on the outside bulkhead wall of the pump compartment (behind the water trap filter, Figure 2-23).

6. Place the 1405 unit into the enclosure install the other end of the 5m tubing that is connected to the bulkhead into the quick-connect elbow fitting for the pump connection on the back of the 1405 unit (Figure 2-21).

7. Select a location on the pump tubing to install the vacuum gauge. It should allow the gauge to be easily monitored (Thermo Scientific suggests a location about half a meter from where the tubing is installed in the pump connection on the back of the unit.) Cut the tubing and install the two ends into the quick-connect fittings on the vacuum gauge.

8. From the 10m length of tubing for the bypass line, cut a piece of tubing long enough to reach from the water trap filter to the bypass filter on the back of the 1405 unit (Figure 2-21 and 2-23). Install the tubing into the quick-connect fittings on the water trap filter and bypass filter.

   Note. The bypass tubing will be connected to the bypass connection on the flow splitter and to the water trap when you assemble and install the sample inlet on top of the enclosure later in this section. ▲

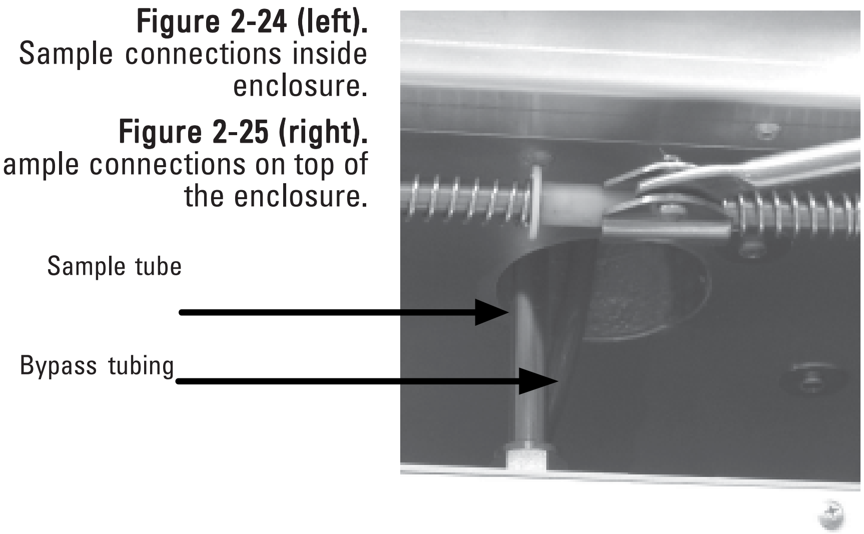
9. Ensure that the sample tube is properly installed in the flow splitter (refer to “Adjusting the Flow Splitter” earlier in this section).

10. Install the sample tube from the flow splitter through the roof opening (Figures 2-24 and 2-25).

   Note. Cap the extra opening in the enclosure roof. ▲

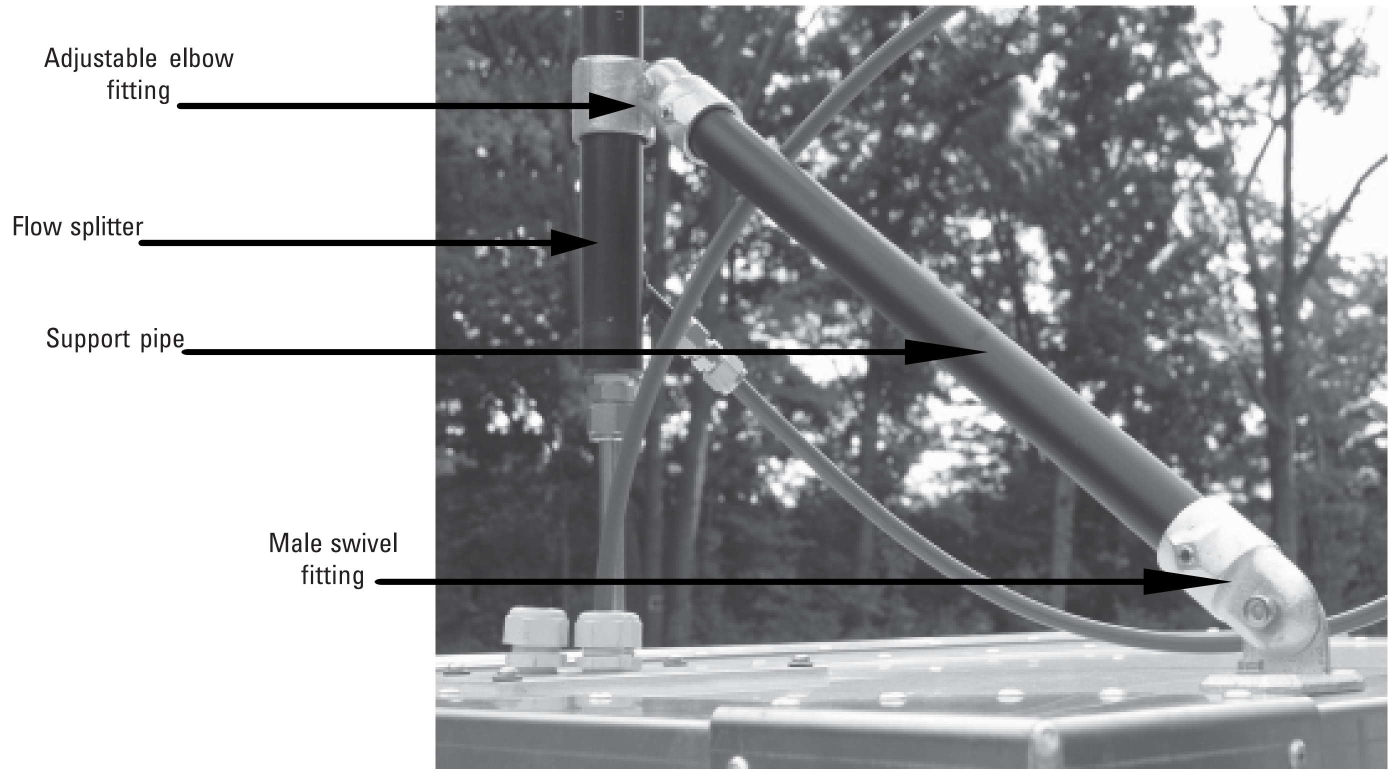
Figure 2-24 (left). Sample connections inside enclosure.

Figure 2-25 (right). Sample connections on top of the enclosure.



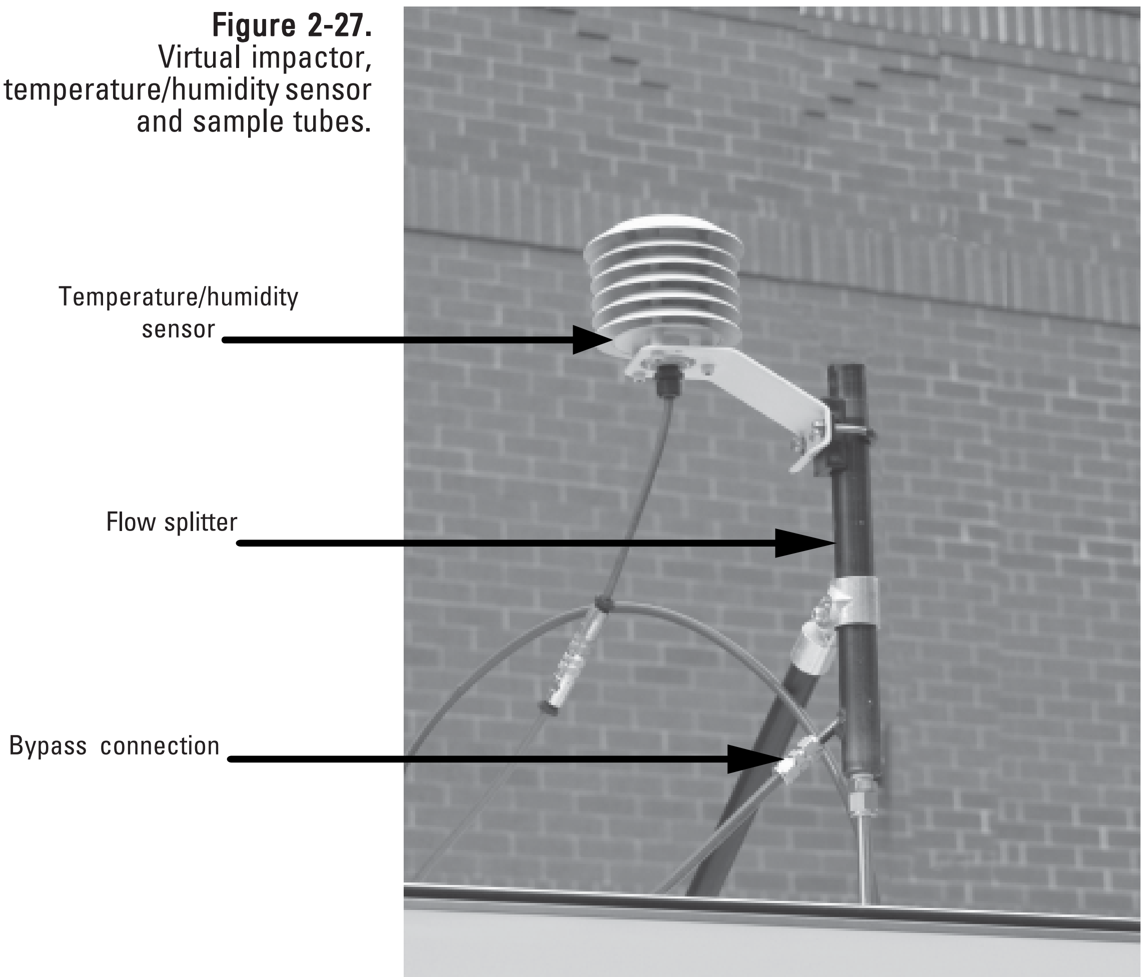
11. Install the adjustable elbow fitting and male swivel fitting from the enclosure package onto the piece of 19-inch section of pipe that came with the enclosure. Lightly tighten the screws. Install the elbow fitting and support pipe onto the flow splitter and enclosure top (Figure 2-26). Slide the support pipe up or down until the flow splitter is sitting plumb, then attach the arm to the shelter and tighten all the screws on the support arm.

Figure 2-26.
Support pipe connections.



12. Cut a piece of tubing from the remaining section of bypass tubing (step 8) long enough to reach from the bypass connection to the top of the 1405 unit. The section should be long enough to include a loop (Figure 2-27) to ensure there will be no kinks in the line when it enters the enclosure. Connect the bypass tubing to the bypass fitting on the flow splitter using the 3/8-inch Swagelok fitting (Figure 2-27). Insert the other end through the fitting on the roof (Figure 2-25) and into the enclosure about 4 to 6 inches. Connect the coiled tubing from the water trap filter to the bypass line near the top of the shelter with the quick-connect fitting. Ensure that the coiled water trap tubing is vertical (Figure 2-19).

Figure 2-27. Virtual impactor, temperature/humidity sensor and sample tubes.



13. Locate the ambient temperature and humidity sensor. Connect the sensor to the flow splitter using the U-bolt provided with the 1405 unit (Figure 2-27).

14. Attach the sensor cable to the sensor and run the sensor cable to the instrument through the opening in the back of the enclosure (Figure 2-28). Attach the sensor to the sensor connection on the back of the TEOM 1405 unit (Figure 2-29).

Note. The opening in the back of the enclosure can also be used for other connections, such as Ethernet connections. ▲

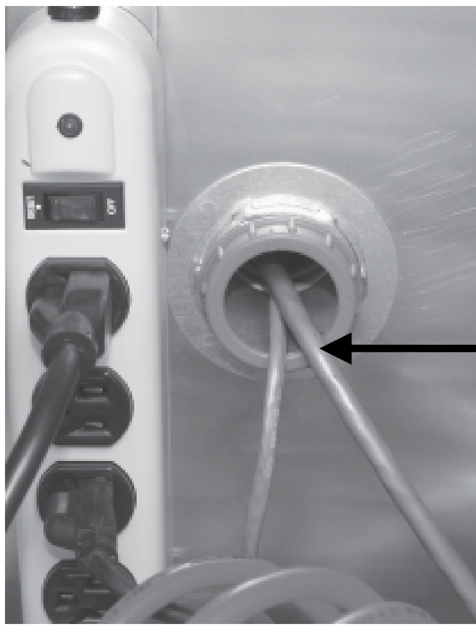


Figure 2-28. Temperature/humidity sensor cable entering the outdoor enclosure.

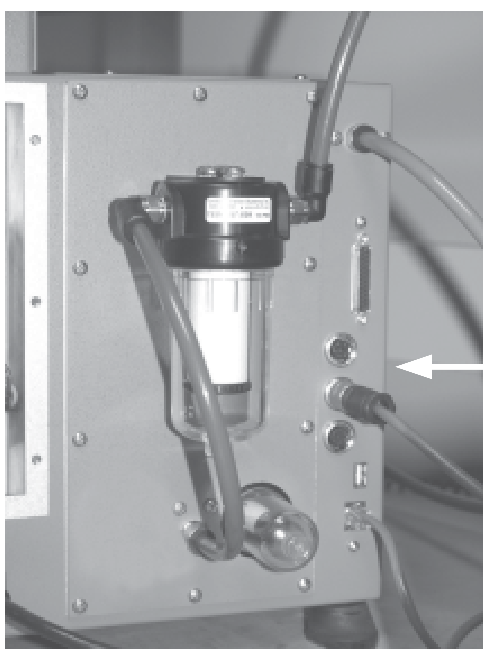


Figure 2-29. Temperature/humidity sensor connection of the back of the TEOM 1405-F unit.

15. Install the inlet (Figure 2-30).

Note. Drain the water trap as needed. ▲

Note. Thermo Scientific strongly recommends that you use the vacuum pump provided with the unit. If you choose to install a different pump, it must be oil-free and able to maintain a 21" Hg vacuum at a flow of 16.67 l/min. ▲

Figure 2-30. Outdoor enclosure with inlet installed.

Section 3 Basic Operation

This section describes the steps to begin data collection with the TEOM 1405-F monitor, as well as leak check the instrument and download data.

The instrument will not begin collecting data until the operating mode message in the status bar reads "Fully Operational" (Figure 3-1). Users must install clean, conditioned filters in the unit prior to sampling. Users can select flow rate, data and other settings while waiting for the unit to become fully operational.

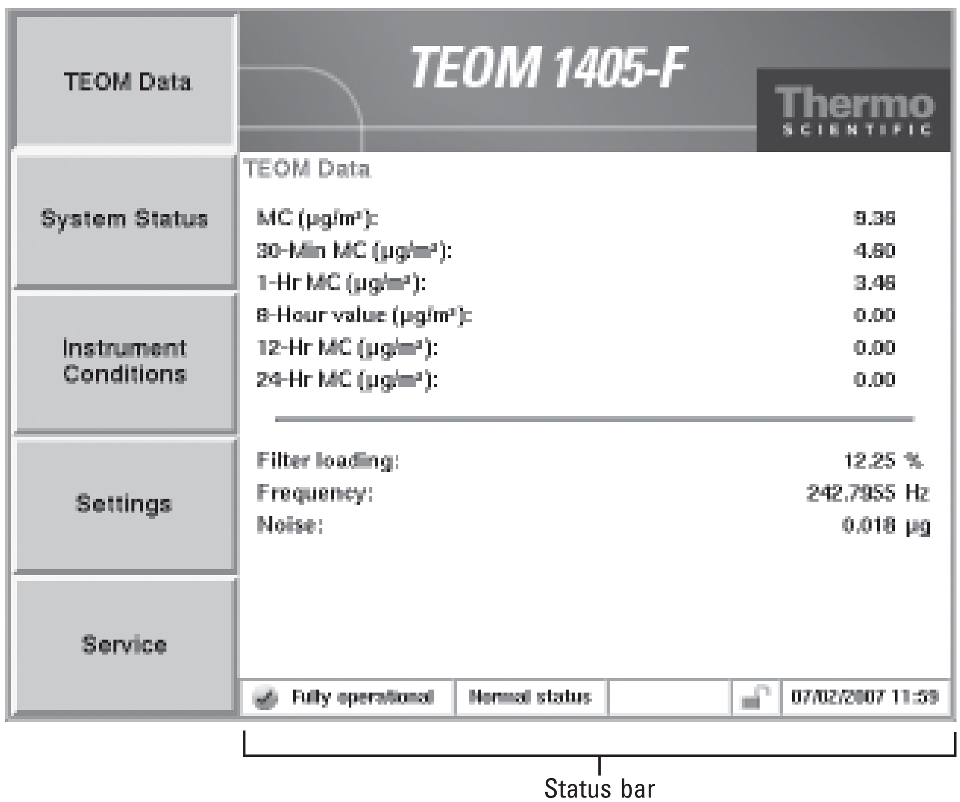


Figure 3-1.
TEOM Data screen with "Fully Operational" message.

Starting the Instrument

To program the instrument and begin collecting data:

1. Perform a leak check (refer to the following section for leak check information).

2. Install a TEOM filter into the mass transducer (Section 5).

3. Install a 47 mm filter into the FDMS tower (Section 5).

4. When in the System Status screen, ensure that the serial number listed for the instrument matches the serial number on the back of the unit.

5. When in the Instrument Conditions screen, select the **Flows** button to display the Flows screen. Select the **Flow Rates** button to select the desired flow rates for the Main and Bypass flow channels. Select the **Flow Control** button to select the desired flow control (“Active” or Passive”) and the desired standard and average temperatures and pressures. (Refer to Section 4 for more information on screens and settings.)

6. When in the Settings screen, select the **System** button, then the **Set Time** button to set the current date and time. (Refer to Section 4 for more information on screens and settings.)

7. When in the Settings screen, select the **Advanced** button, then the **Mass Transducer K0 Constant** button to confirm the current K0 setting for the TEOM. The number programmed into the unit must match the K0 constant on the label near the mass transducer. (Refer to Section 4 for more information on screens and settings.)

8. When in the Settings screen, select the **Data Storage** button to display the Data Storage screen. Confirm the desired data is selected to be logged by the instrument. (Refer to “Storing Data” later in this section for more information on selecting storage variables.)

9. If you will be setting up the unit to receive an analog input, to transmit analog outputs, or setting up the unit’s contact closure circuits, refer to Section 4 for information on the screens and settings used for these parameters.

10. If you will be using the password function to control access to the unit’s operation, refer to Section 4 for information on setting up the password function.

11. Select the TEOM Data button to display the TEOM Data screen. The instrument will begin collecting data when the mode status window displays a "Fully operational" message.

    Note. Upon initial instrument start up, the values in the mass concentration fields are the running averages that are accumulated until a 1-hour time period has passed. The values are visible to provide the user with an indication that the instrument is functioning, after instrument power up or reset. These raw values are used for internal calculations only. ▲

Performing a Leak Check

The TEOM 1405-F should be leak-checked once a month or as needed. The system comes with flow audit/leak check adapter for the 1 1/4-inch flow splitter and the 3/8-inch bypass line.

The Leak Check Wizard compares the measured difference between the units "zero" flow with the vacuum disconnected and flow through the instrument with the inlet blocked (which should also be zero). The leak check passes if the main flow is within 0.15 l/min and the bypass flow is within 0.60 l/min of their "zero" value with the vacuum disconnected.

In order to ensure proper performance of the instrument and ensure no leaks, the instrument prompts the operator to perform a leak check with the FDMS valves in both the base and reference positions.

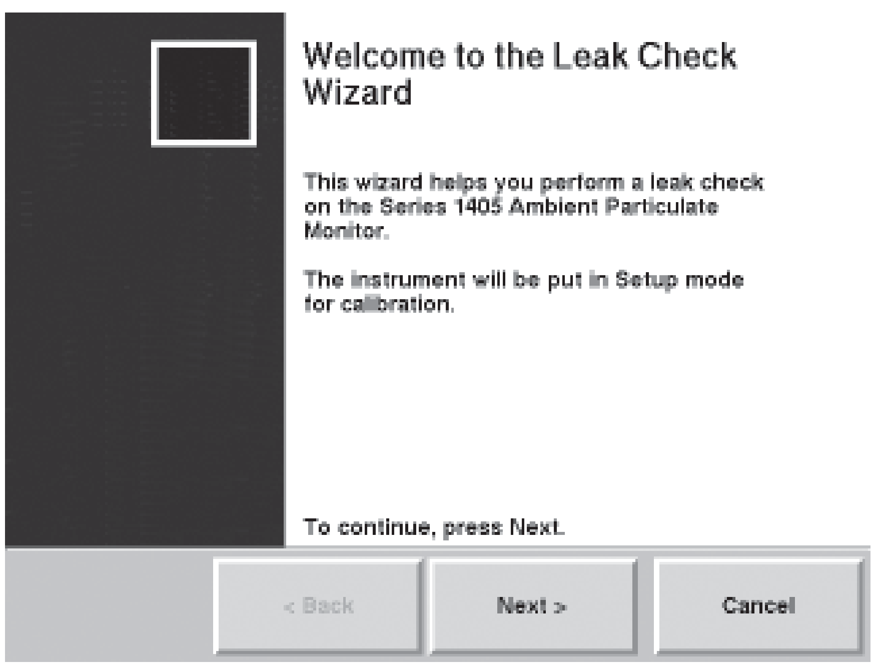
> **Note.** The Leak Check Wizard automatically disables the switching valve during a leak check. Performing a leak check without the wizard can damage the switching valve. ▲

To perform a leak check:

1. In the 1405 TEOM Data screen, select the **Service** button to display the Service screen, then select the **Verification** button to display the Verification screen.

2. Select the **Leak Check** button to display the Leak Check Wizard screen (Figure 3-2). Select the **Next >** button.

Figure 3-2. Leak Check Wizard start screen.



3. The Select Valve Position screen will display. The current valve position is displayed on the screen. To start the leak check select the current valve position leak check button (Figure 3-3). Select the **Next >** button.

   Note. If trying to isolate a leak with the valve in a specific position, select the specific valve position desired and proceed. ▲

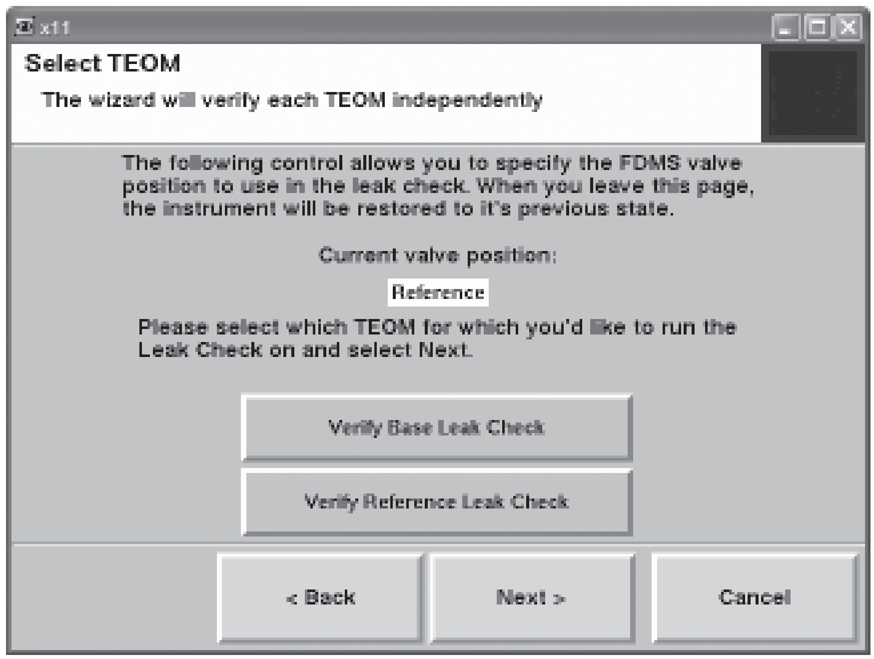
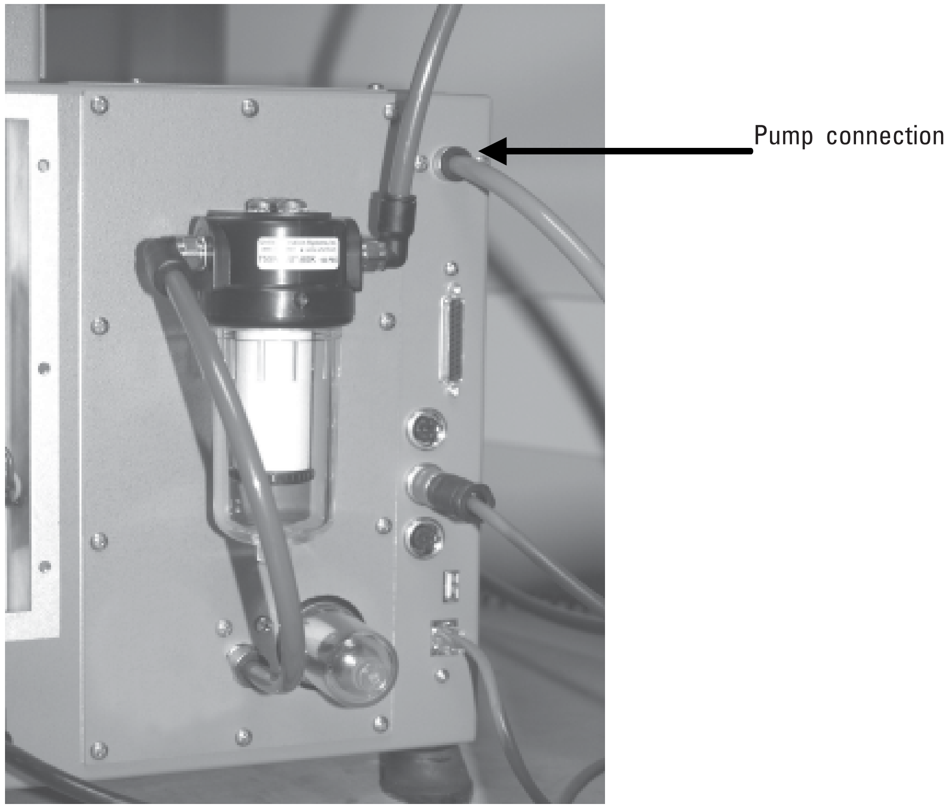


Figure 3-3. Leak Check Wizard screen with current valve position select.

4. The Remove the TEOM filter screen will display. Remove the TEOM filter from the transducer to ensure it isn't damaged during the leak check procedure. Select the **Next >** button.

5. The Disconnect Vacuum Line screen will display. Remove the main vacuum line (pump) connected to the pump from the back of the unit (Figure 3-4). Select the **Next >** button.

Figure 3-4.
Back of TEOM 1405 unit.



6. The Stabilizing screen will display. Allow 1 minute for the flows to stabilize then select the **Next >** button.

7. The Reconnect Vacuum Line screen will display. Reinstall the pump/ vacuum tubing into the back of the unit. Select the **Next >** button.

8. The Remove Inlet screen will display. Remove the inlet (Figure 3-5). Select the **Next >** button.

Figure 3-5.
Inlet assembly.

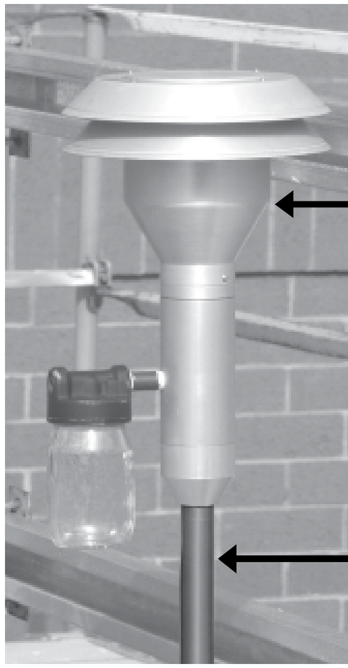
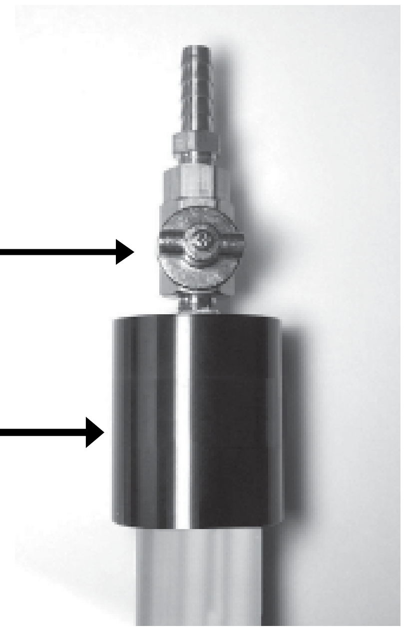


Figure 3-6.
Leak check adapter.



9. The Attach Audit Adapter screen will display. Attach the leak check/ flow audit adapter to the top of the flow splitter.

10. Slowly close the valve on the leak check adapter. Select the **Next >** button.

11. The Stabilizing screen will display. Allow 1 minute for the flows to stabilize then select the **Next >** button.

12. Slowly open the leak check adapter valve. Select the **Next >** button. Failure to release the vacuum before proceeding may damage the seals in the switching valve.

13. The Select Valve Position screen will once again display this time with the just completed valve position unavailable. Select the second valve position (Figure 3-8) and select the the **Next >** button.

Figure 3-7.
Leak Check Wizard screen with completed valve position unavailable.

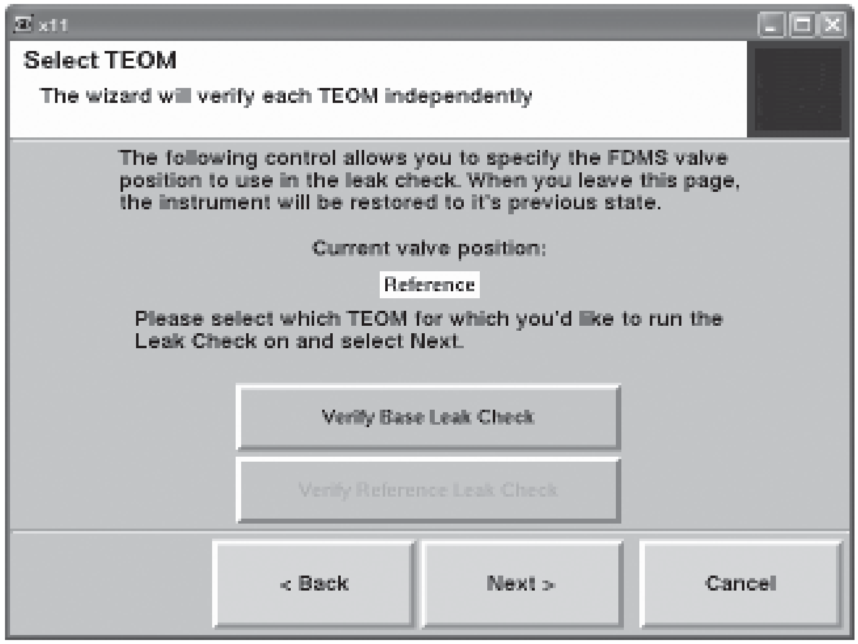
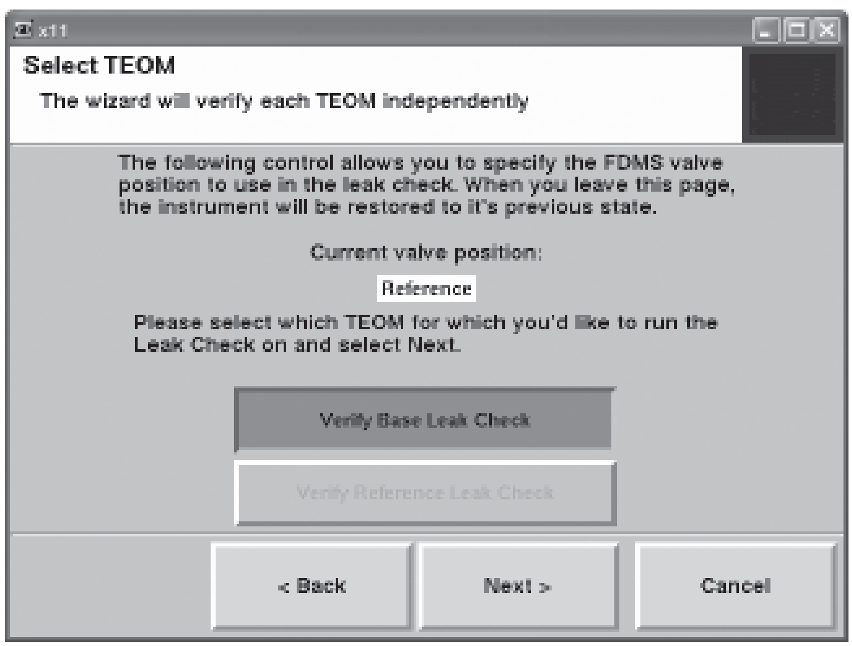


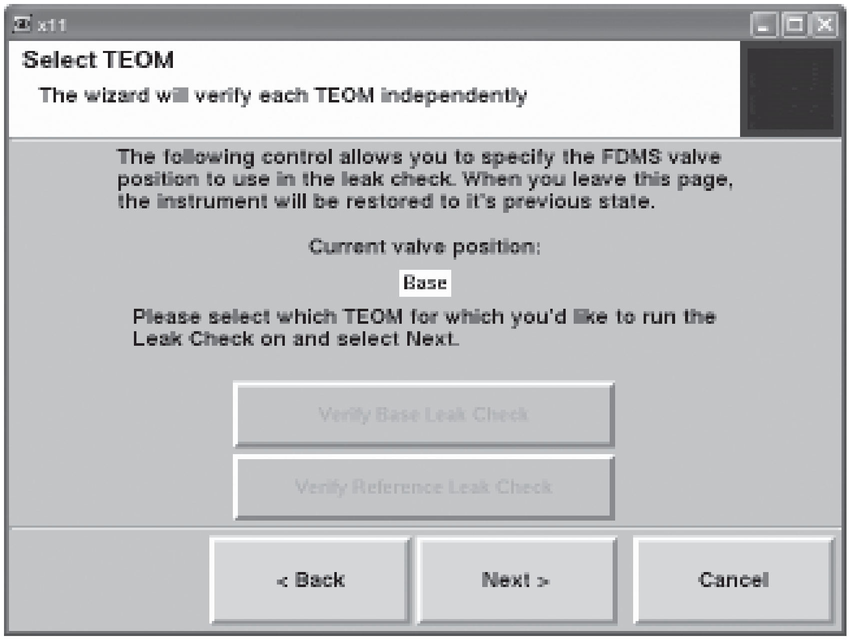
Figure 3-8.
Leak Check Wizard screen with second valve position.



14. The Replace Inlet screen will display. Slowly open the leak check valve to restore flow to the system. Remove the flow audit/leak check adapter and attach the inlet to the top of the sample inlet tube (Figure 3-5). Select the **Next >** button.

After completing the leak check with the FDMS in both the base and reference positions, the select valve position screen will again appear, but this time with both valve positions desabled. Select the **Next >** button.

Figure 3-9.
Leak Check Wizard screen with both valve positions disabled.



15. The Completing the Leak Check Wizard screen will display. If the leak check passes, a "You have successfully completed the Leak Check" message will display (Figure 3-9).

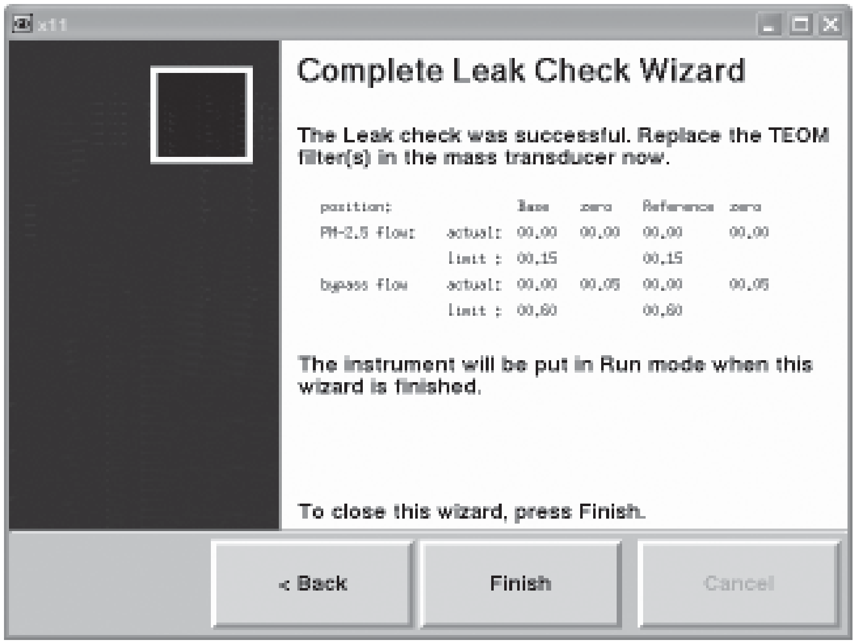


Figure 3-10. Leak Check Wizard finish screen with pass message.

Note. If a leak check fails, a fail message will display (Figure 3-7). Isolate the leak, tighten the appropriate tubing and/or other connections and attempt the leak check again. ▲

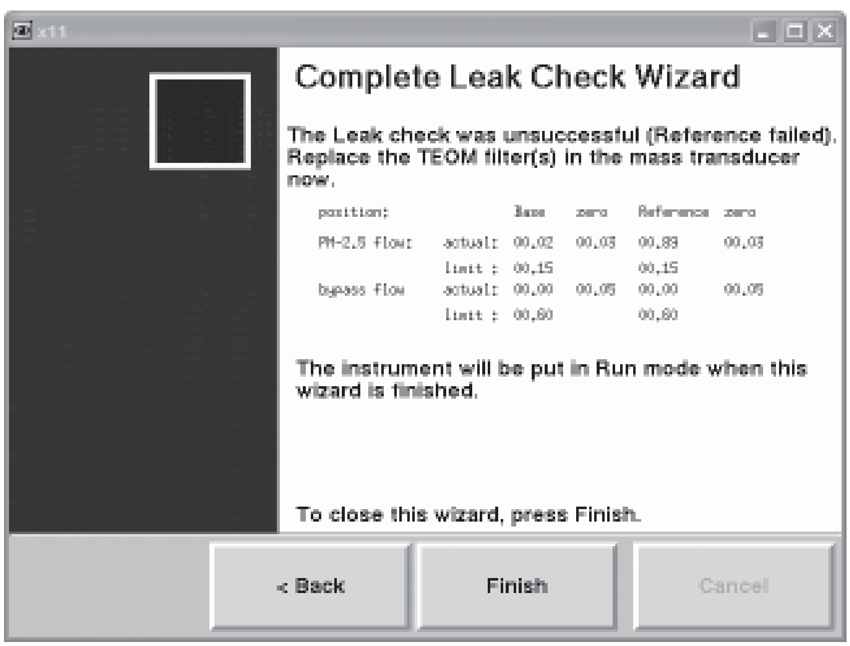


Figure 3-11. Leak Check Wizard finish screen with fail message.

15. Install a new TEOM filter in the mass transducer (Section 5).

Storing Data

The unit stores only those variables selected by the user. If instrument variables are not set up to be logged, THEY WILL NOT BE SAVED.

To select data storage variables:

1. Select the Settings menu button to display the Settings screen (Figure 3-12).

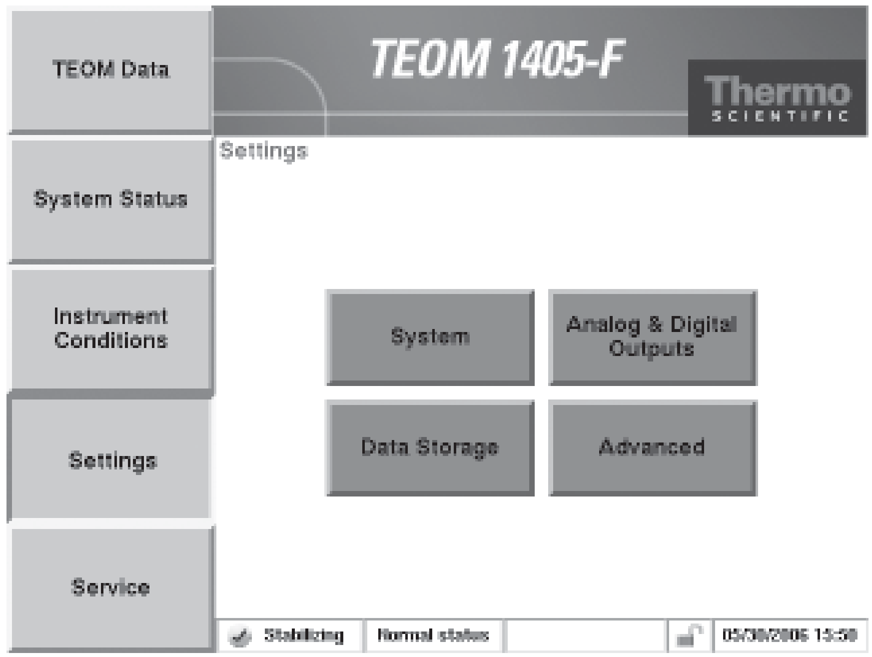


Figure 3-12. Settings screen.

2. When in the Settings screen, select the **Data Storage** button to display the Data Storage screen (Figure 3-13).

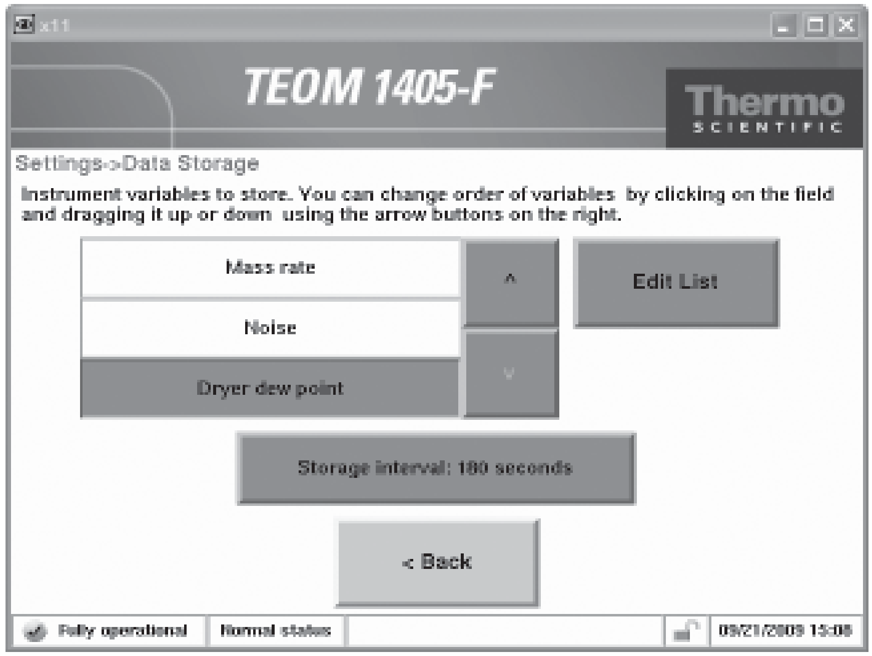


Figure 3-13.
Data Storage screen.

3. When in the Data Storage screen, select the Edit List button to display the Edit Data Storage screen. Press the names of the variables you wish to log, up to the maximum allowed of 30. Use the **Next Page >** and **< Previous Page** buttons to scroll through the entire list of variables which can be stored. Select the OK button when all the desired variables have been selected.

4. Use the **V** and **Λ** buttons to scroll through the list of selected variables to ensure that all desired variables are selected.

5. When in the Data Storage screen, select the **Storage Interval** button to select the interval for data storage. Enter the desired data storage interval into the keypad and select the **Enter** button. For example, if the storage interval is 10 seconds, every 10 seconds the instrument will log (save) the data in the selected variables.

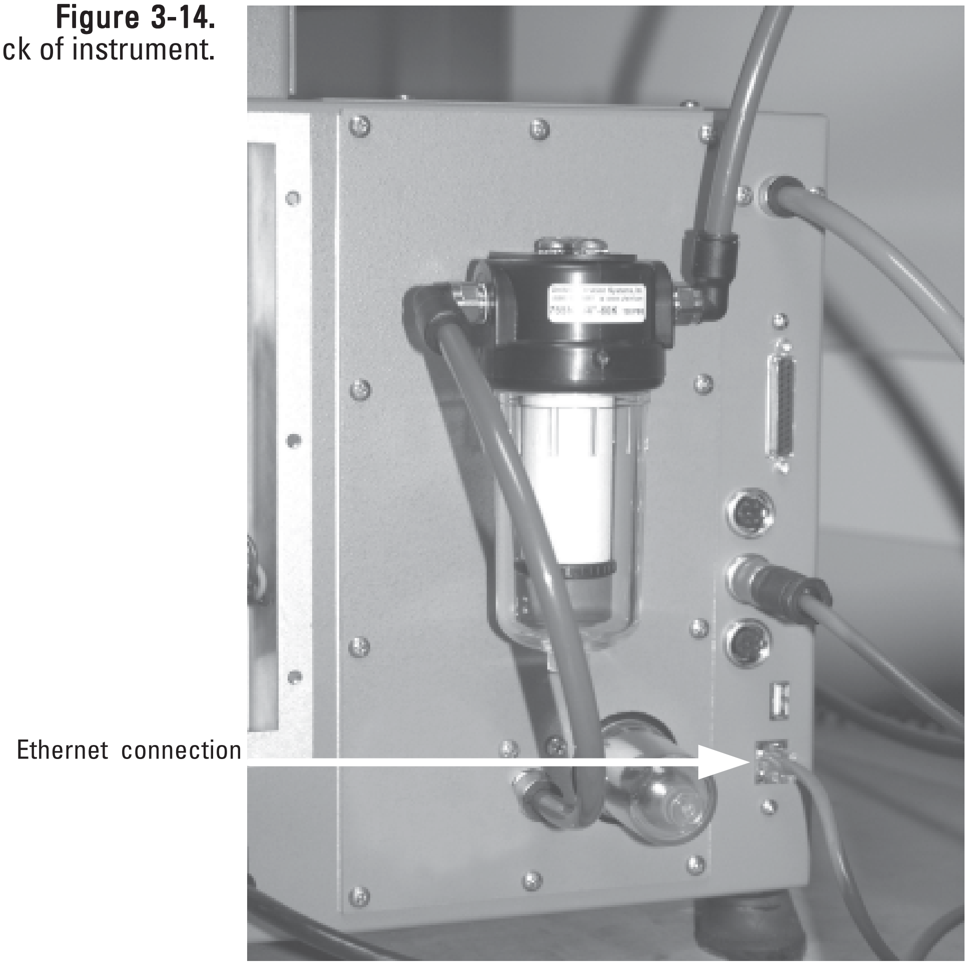
6. The storage order of the variables may be set by moving individual storage registers up or down in the list on the screen. To adjust the order, touch the desired variable and then move the position by pressing the**V** and **Λ** arrows to the right of the data variable list. For this ordering to work properly with data downloads, version 1.40 or later of ePort is required.

7. When all the desired variables are selected and the Storage Interval is set, select the **< Back** button to return to the Settings screen.

Downloading Data

The ePort software allows users to download data from the TEOM 1405-F monitor using a personal computer (PC) with the Windows XP or later operating system. The monitor must be attached to a local area network (LAN) or directly to a router using the Ethernet connection on the back of the instrument (Figure 3-14). In order to use ePort, it must have a valid IP address.

Figure 3-14.
Back of instrument.



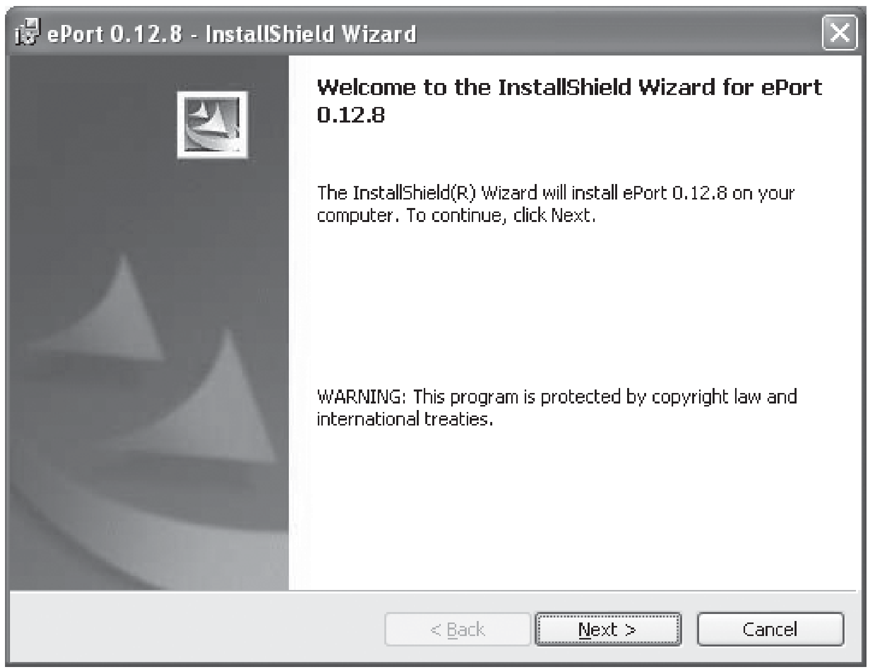
Installing ePort

Users must first install the ePort software on a personal computer (PC) connected to the same network as the TEOM 1405 that data will be downloaded from. At the same time the ePort software is installed, the installer will install Microsoft .NET Framework software if the PC does not already have an up-to-date version of .NET Framework.

To install the ePort software:

1. Locate and double-click on the "setup ePort _XX.exe" file (where "XX" is the version number) on the software CD that came with the TEOM 1405 monitor. The "Welcome to InstallShield Wizard" screen will display (Figure 3-15).

Figure 3-15.
ePort Welcome to InstallShield Wizard screen.



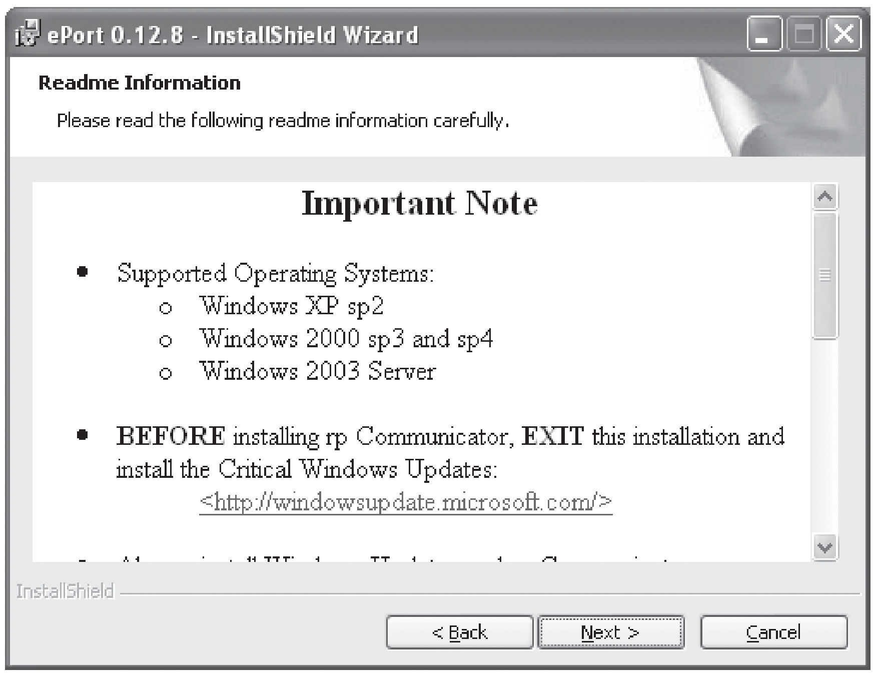
2. Select the "Install" button.

3. The wizard will display the software license agreement. Select "Yes," then select the **Next >** button.

4. The Windows update screen will display (Figure 3-16). If you have recently updated your Windows XP software, select the **Next >** button.

Note. The ePort software MUST be installed on a PC with the latest Windows XP or later updates. If you have not updated your Windows XP system, select the “Cancel” button and use the Windows Update function of the PC to update the operating system before attempting to install the ePort software. ▲

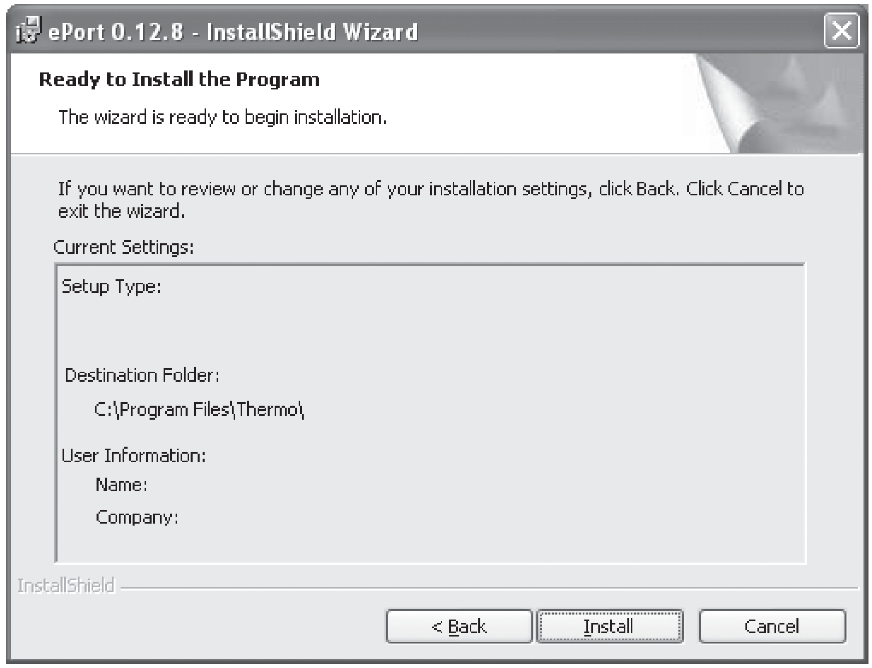
Figure 3-16.
Windows Update notice.



5. The Customer Information screen will display. Type in the information and select the **Next >** button.

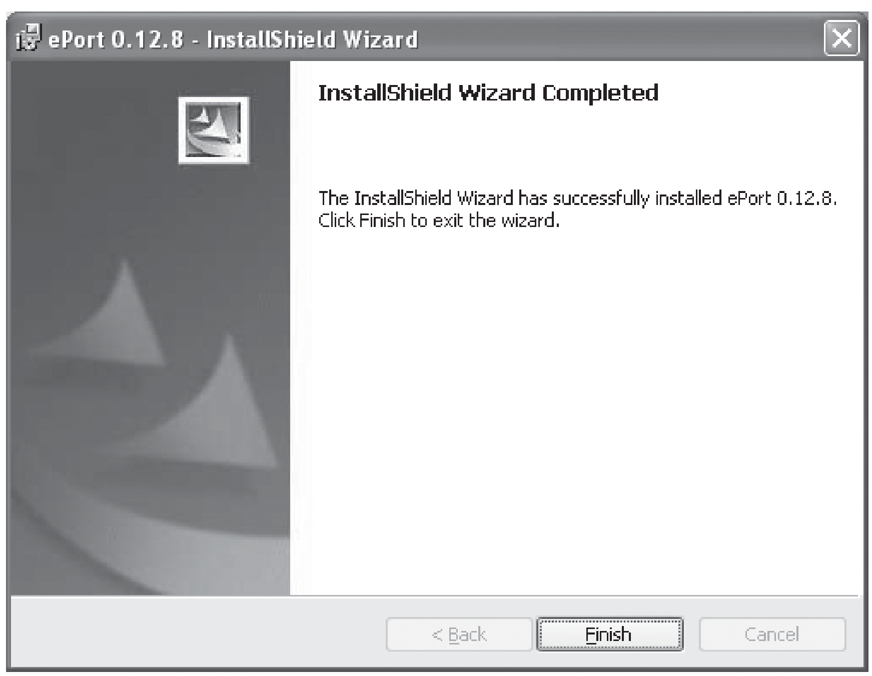
6. The Ready to Install Program screen will display (Figure 3-17). Select the **Install** button.

Figure 3-17.
Ready to Install the Program screen.



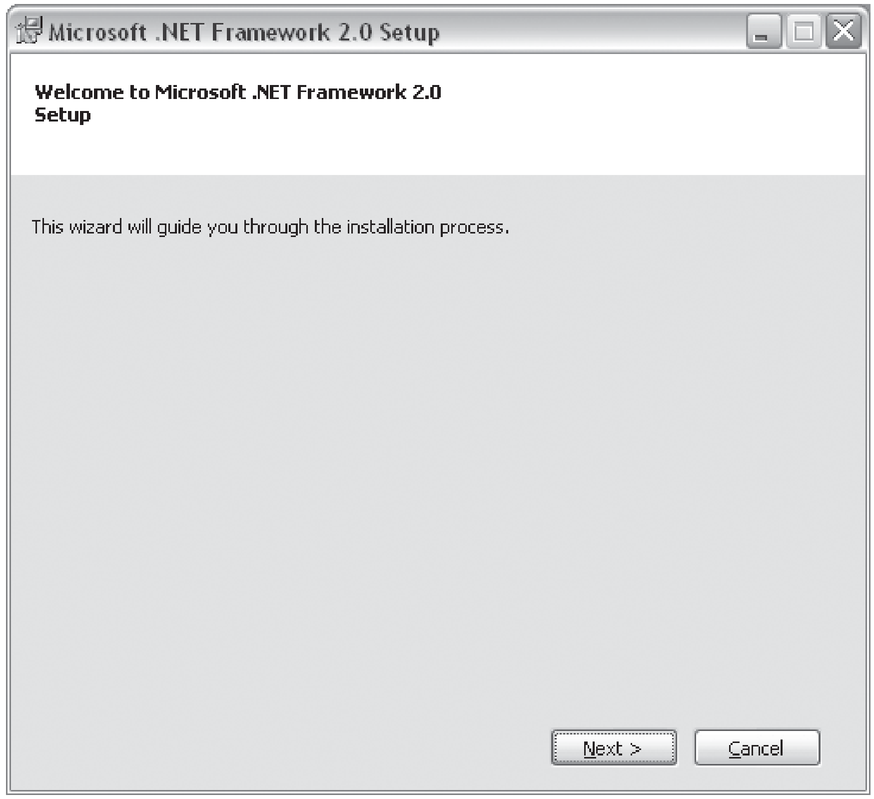
7. The wizard will post messages showing the progress of the installation. When the process is complete, the Finish screen will display (Figure 3-18). Select the **Finish** button.

Figure 3-18.
InstallShield Wizard Completed screen.



8. If the PC does not have an up-to-date version of Microsoft .NET Framework software, the system will automatically begin installing that software. The Microsoft .NET Framework Welcome screen will display (Figure 3-19). Select the **Next >** button.

Figure 3-19.
Microsoft .NET Framework Welcome screen.

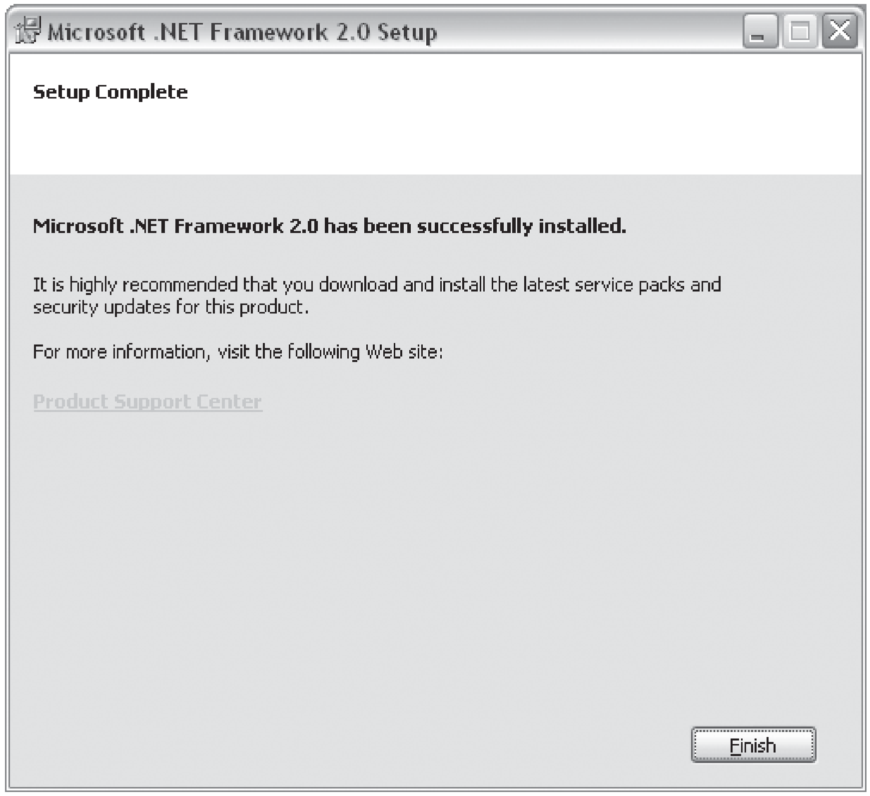


9. Select **Install**. The system will begin installing the Microsoft .NET Framework software. The wizard will post progress messages during the installation.

   Note. If the Microsoft .NET Framework software is already installed on the PC, the wizard will ask you to Repair or Remove the software. Select **Repair** to ensure the latest version is installed on the PC, or select **Cancel** to skip the Microsoft .NEW Framework installation. ▲

10. When the installation is complete, the Setup Complete screen will display (Figure 3-20). Select the **Finish** button to complete the ePort and Microsoft .NET Framework installation.

Figure 3-20. Microsoft .NET Framework Setup Complete screen.



Connecting to the Series 1405-F Unit

When the ePort software is installed, and the TEOM 1405 unit and the PC are connected to the same network, the software can connect to the instrument and download data. Additional *Technical Notes* regarding information on connecting to instruments over the network are offered in the library on our website at www.thermo.com/aqi.

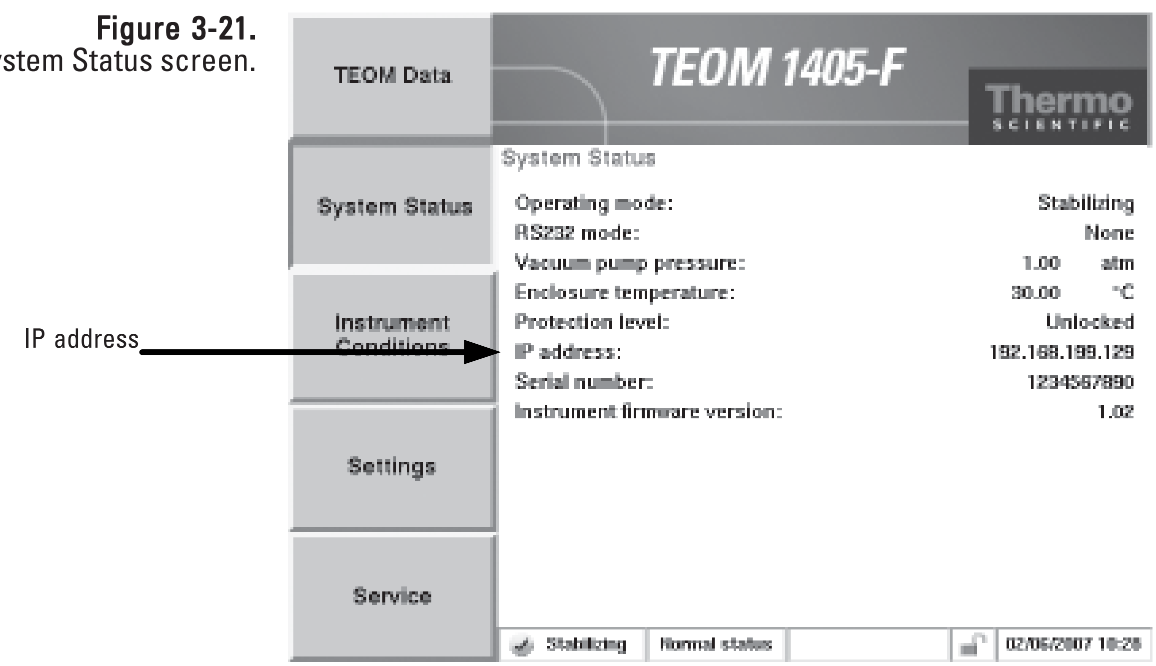
Once you have connected to an instrument (or instruments) and saved a configuration file, select **Open Saved Configuration** in the ePort Open screen to open that configuration and automatically connect to all the instruments that were saved in that configuration.

To connect to the instrument:

1. Ensure that the PC and the instrument are connected to the same network using the Ethernet connection on the back of the instrument. (Refer to the previous section for information on connecting the instrument to a network.)

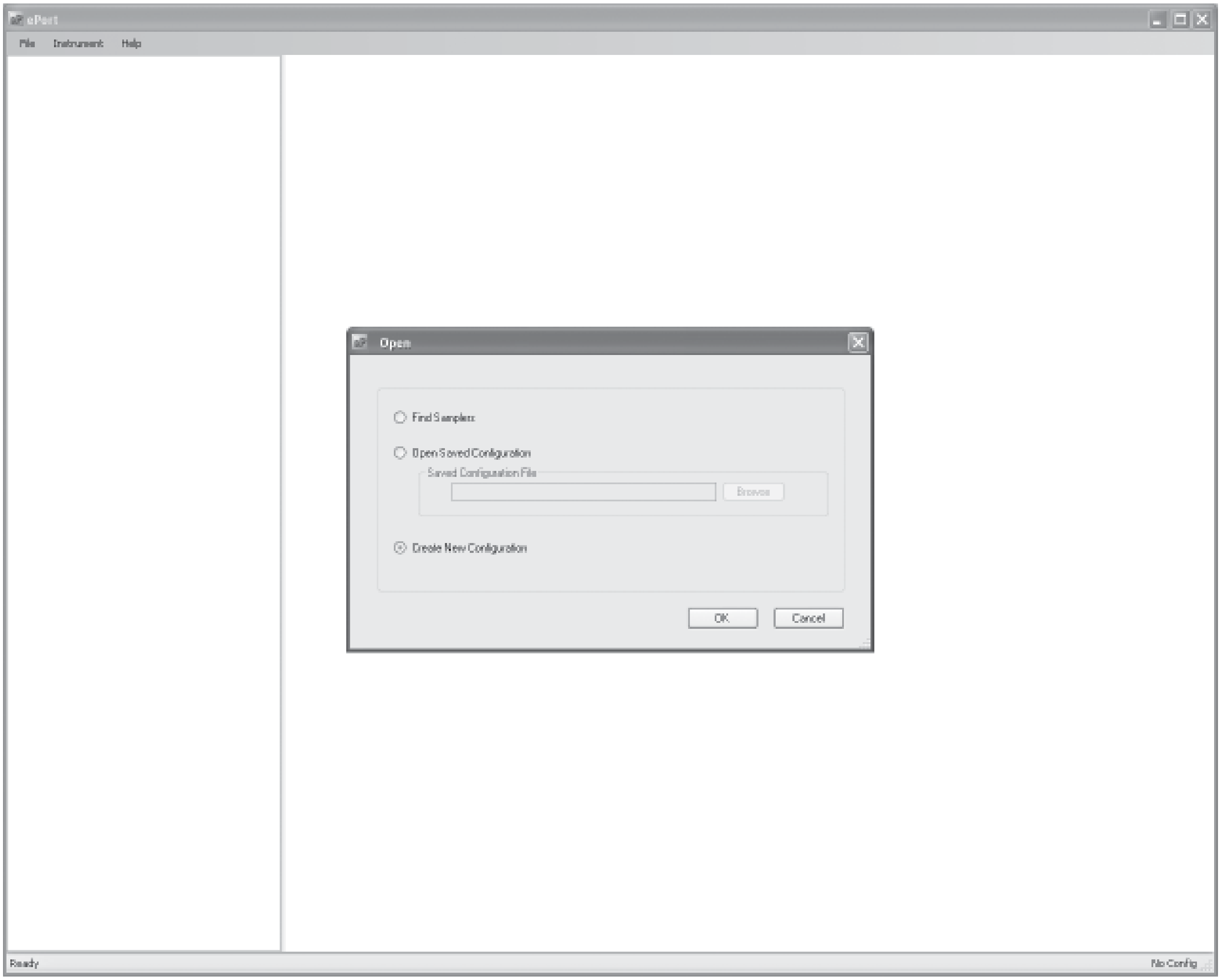
2. In the System Status screen of the machine from which you want to download data, locate and record the IP address (Figure 3-21) of that unit.

Figure 3-21.
System Status screen.



3. Start the ePort PC software, using the icon on the PC desktop or the Start menu of the PC. The ePort Main screen with the Open screen will display (Figure 3-22).

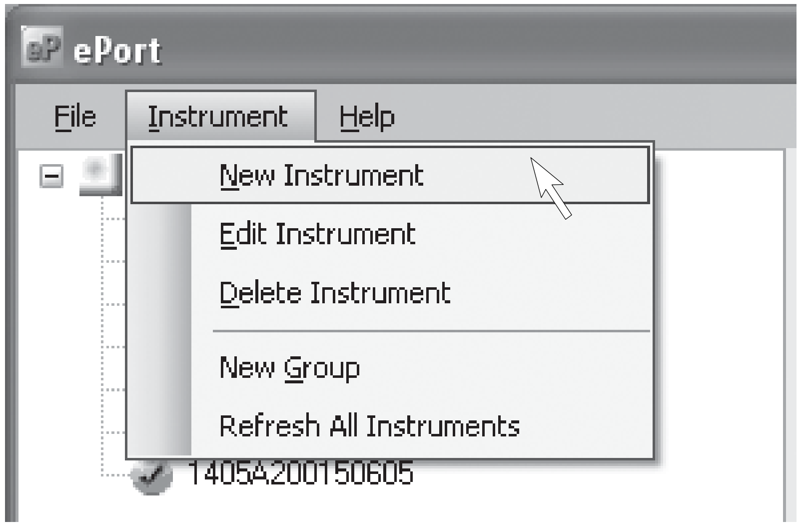
Figure 3-22.
ePort Main screen with Open screen.



4. In the ePort Open screen (Figure 3-19), select create new configuration. A blank ePort Main screen will display.

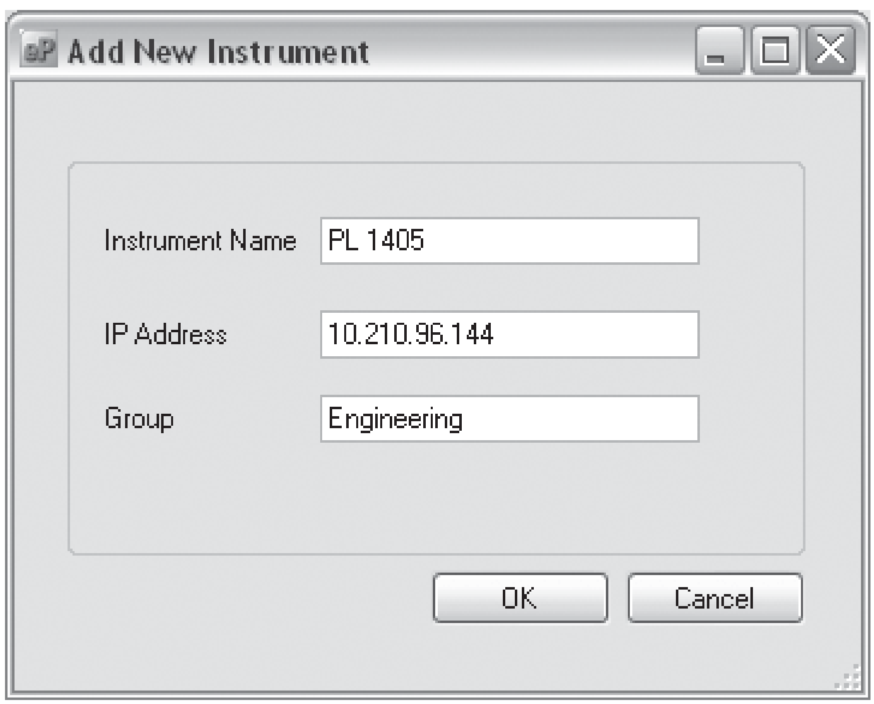
5. Select **Instrument** then **New Instrument** from the menu bar at the top of the ePort Main screen (Figure 3-23).

Figure 3-23.
Selecting New Instrument from the menu bar.



6. The Add New Instrument screen will display (Figure 3-24). Enter the IP address, the name assigned to the instrument and the group (if any) assigned to the instrument and select the **OK** button.

Figure 3-24.
Add New Instrument screen.

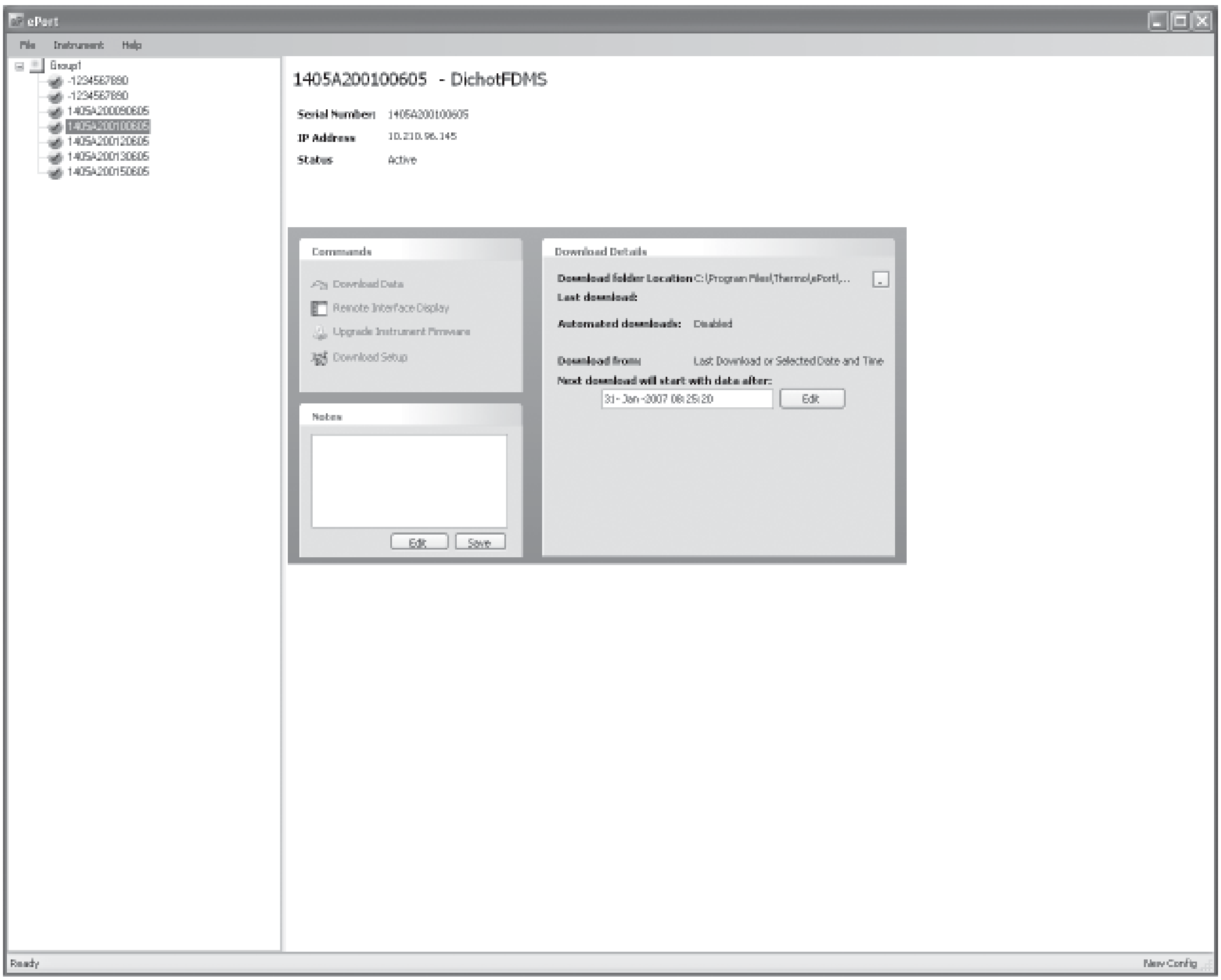


7. The ePort Main screen will display with the selected instrument displayed in the top window (Figure 3-25). Repeat the process to add additional instruments to the list.

8. To save this as a configuration, select **File** then **Save** from the menu bar at the top of the Main screen. The Save As screen will display. Type in the desired name for the configuration and select **Save**.

   Note. Once you have connected to an instrument (or instruments) and saved a configuration file, select **Open Saved Configuration** in the ePort Open screen to open that configuration and automatically connect to all the instruments that were saved in that configuration. ▲

Figure 3-25. ePort Main screen with instrument information displayed.



Finding Instruments On a Network

You may use the ePort software to search for all instruments connected to the local network.

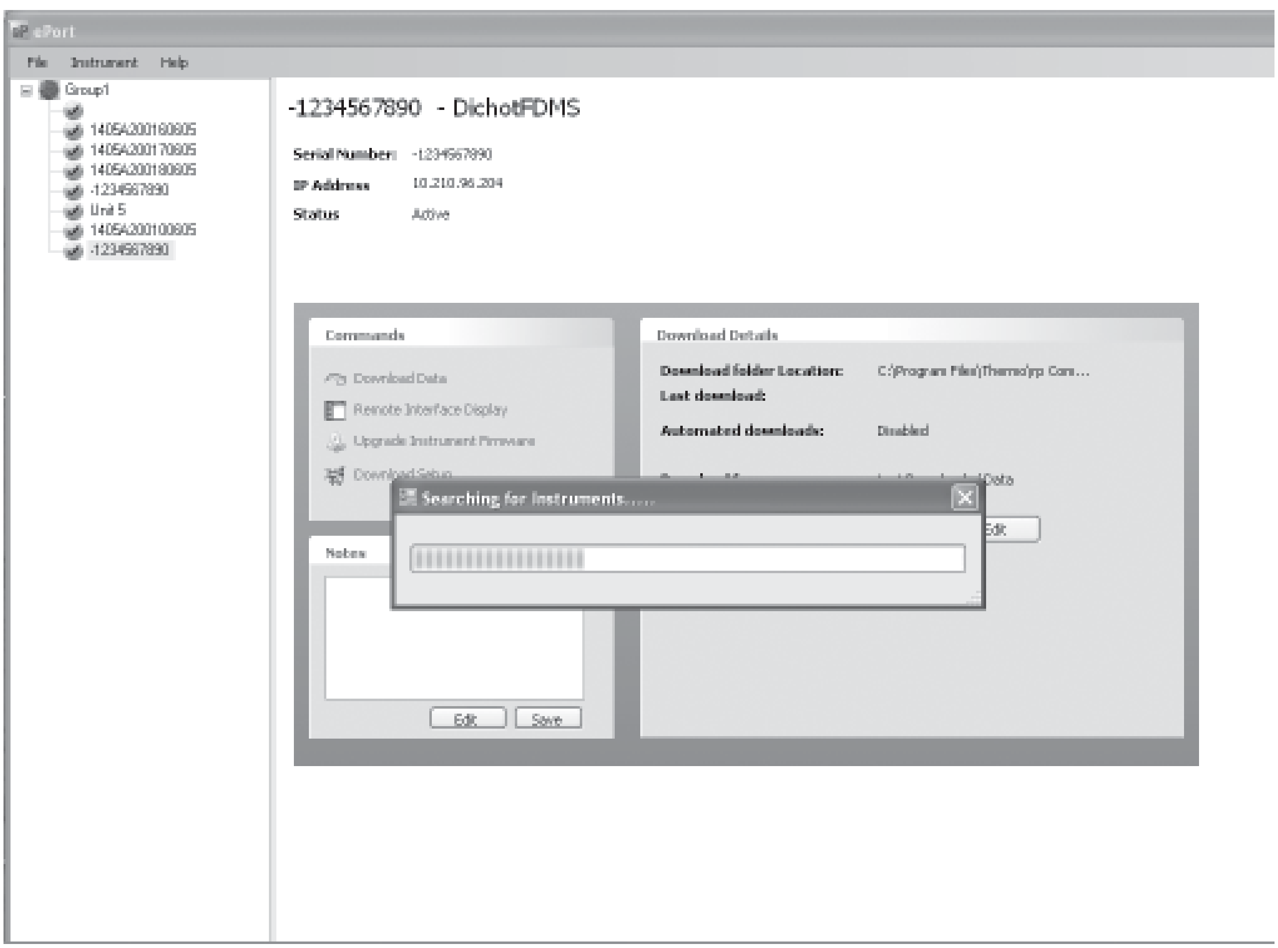
This function will only locate instruments on a local network. To connect to instruments on other connected networks, you must know the IP address of the instruments and connect to the unit manually using the **New Instrument** function of the software (Figure 3-23). Refer to the previous section for information on connecting to an instrument off the local network. Instruments on a network must have a unique IP address, or be connected through a router.

To locate all instruments on the network:

1. Open the ePort software program and select "Find Samplers" in the Open screen (Figure 3-22).

2. The ePort Main screen will display with a "Searching for Instruments..." message. As instruments are located by the software they will be added to the list in the Instrument frame on the left side of the screen (Figure 3-26).

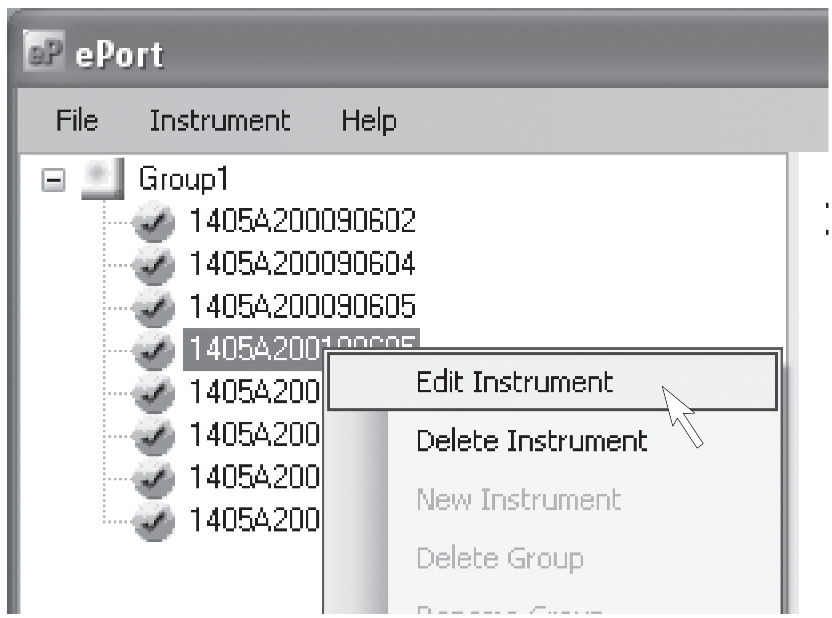
Figure 3-26.
ePort Main screen with "Searching for Instruments..." message.



3. All instruments located on the local network will be displayed in the Instrument frame on the left side of the Main screen. To edit a displayed instrument or delete an instrument from the list, right-click on the instrument and select **Edit Instrument** or **Delete Instrument** (Figure 3-27).

   Note. To add an instrument from another network connected to the local network select **Instrument** then **New Instrument** from the menu bar. Refer to the previous section for more information on manually adding an instrument to the configuration. ▲

Figure 3-27.
Adding or deleting an instrument from the list.



4. To save this list as a configuration, select **File** then **Save** from the menu bar at the top of the Main screen. The Save As screen will display. Type in the desired name for the configuration and select **Save**.

   Note. Once you have connected to an instrument (or instruments) and saved a configuration file, select **Open Saved Configuration** in the ePort Open screen to open that configuration and automatically connect to all the instruments that were saved in that configuration. ▲

Setting Up for Manual Data Downloads

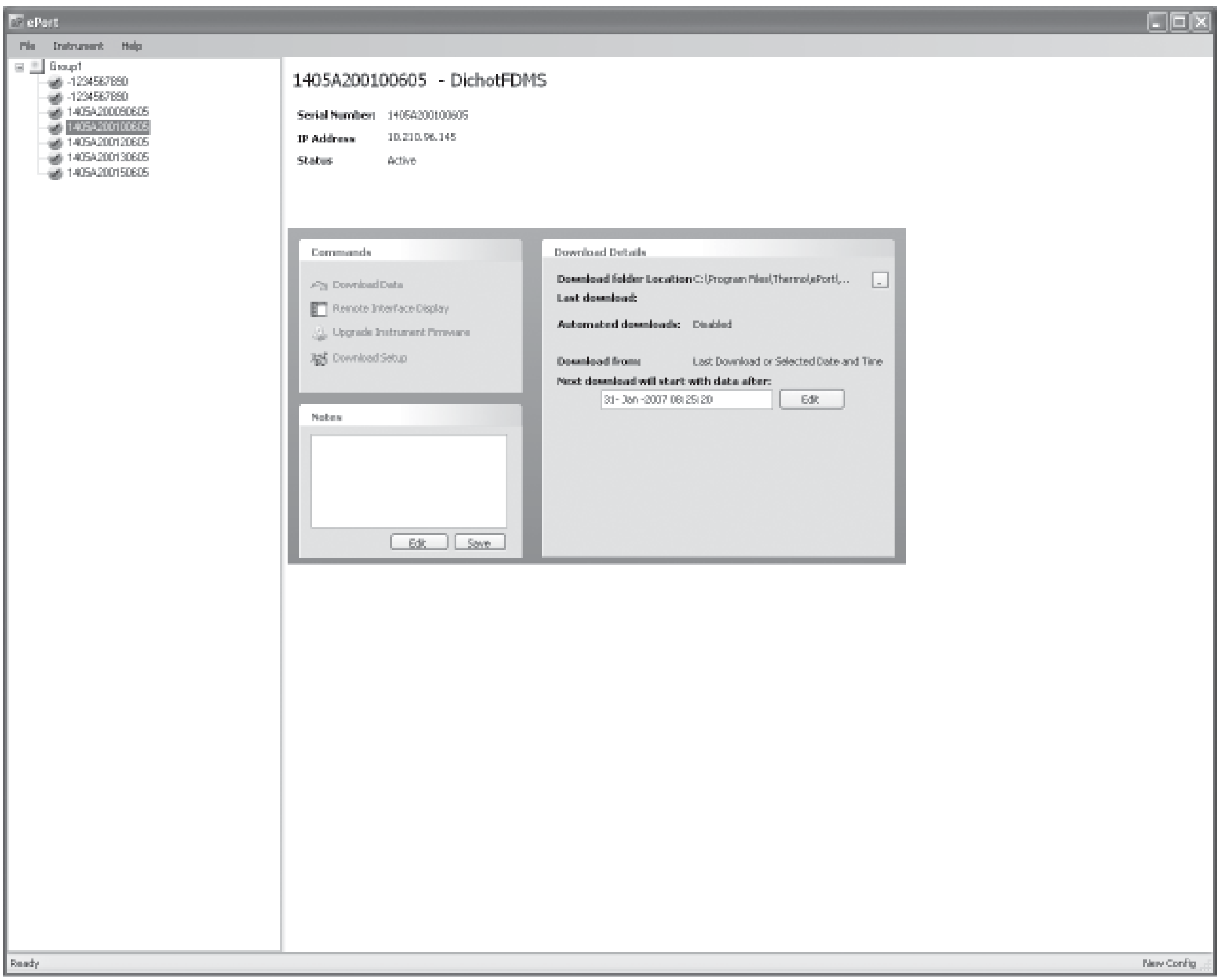
Data can be manually downloaded from the TEOM 1405 monitor through the built-in Ethernet connection using the ePort software.

To set up the software to manually download data:

1. Ensure that the PC and the instrument are connected to the same network using the Ethernet connection on the back of the instrument. (Refer to the previous section for information on connecting the instrument to a network.)

2. Use the ePort PC software to connect to the instrument and display the ePort Main screen (Figure 3-28). (Refer to the previous two sections for information on connecting to the instrument or instruments.)

Figure 3-28.
ePort Main screen.



3. Select **Download Setup** in the Commands window of the ePort Main screen. The Download Setup Wizard will display (Figure 3-29). Select the **Next >** button.

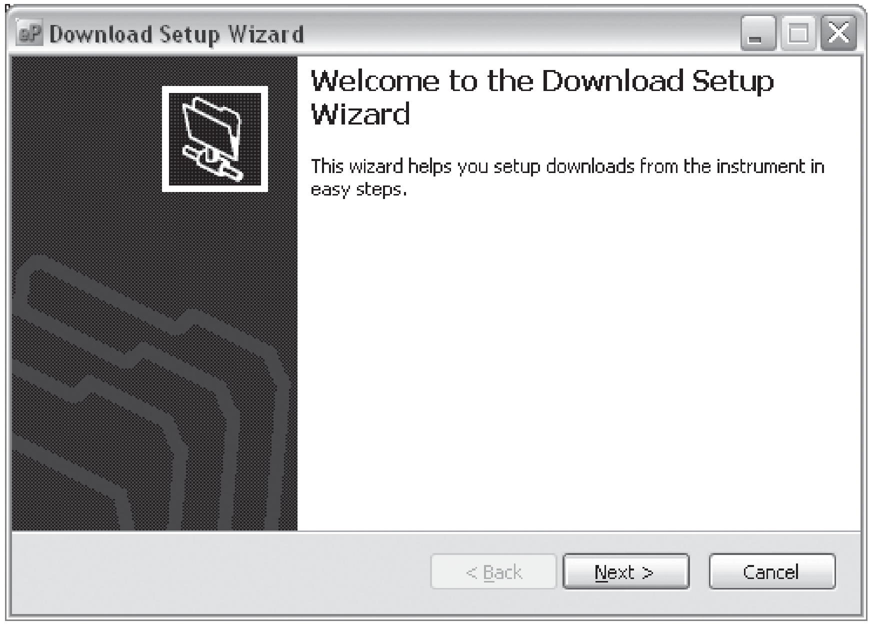


Figure 3-29.
Download Setup Wizard.

4. The Select Data screen will display. Select the data to download (either all data on the instrument or the data since the last download). Select the **Next >** button.

5. The Select Location screen will display. Use the Browse button to select a location for the data file downloaded by the software. Select the **Next >** button.

6. The Download Type screen will display. Select manual downloads. Select the **Next >** button.

7. The Completing the Download Setup Wizard screen will display. Select the **Finish** button.

Setting Up for Automatic Data Downloads

Users can set up automatic downloads for the TEOM 1405 monitor using the ePort software.

To set up the software to automatically download data:

1. Ensure that the PC and the instrument are connected to the same network using the Ethernet connection on the back of the instrument. (Refer to the previous section for information on connecting the instrument to a network.)

2. Use the ePort PC software to connect to the instrument and display the ePort Main screen (Figure 3-28). (Refer to the previous sections for information on connecting to the instrument or instruments.)

3. Select **Download Setup** in the Commands window of the ePort Main screen. The Download Setup Wizard will display (Figure 3-29). Select the **Next >** button.

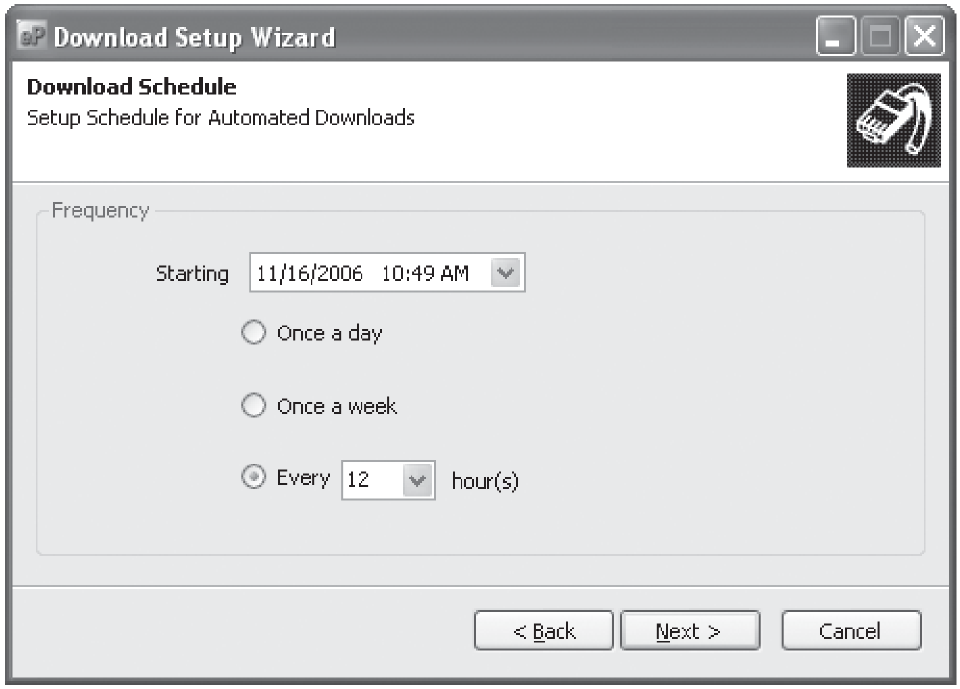
4. The Select Data screen will display. Select the data to download (either all data on the instrument or the data since the last download). Select the **Next >** button.

5. The Select Location screen will display. Use the Browse button to select a location for the data file downloaded by the software. Select the **Next >** button.

6. The Download Type screen will display. Select automatic downloads. Select the **Next >** button.

7. The Download Schedule screen will display (Figure 3-30). Select a starting date and time, and a download frequency (daily, weekly, hourly). Select the **Next >** button.

Figure 3-30.
Download Setup Wizard.



8. The Completing the Download Setup Wizard screen will display. Select the **Finish** button.

Performing a Data Download

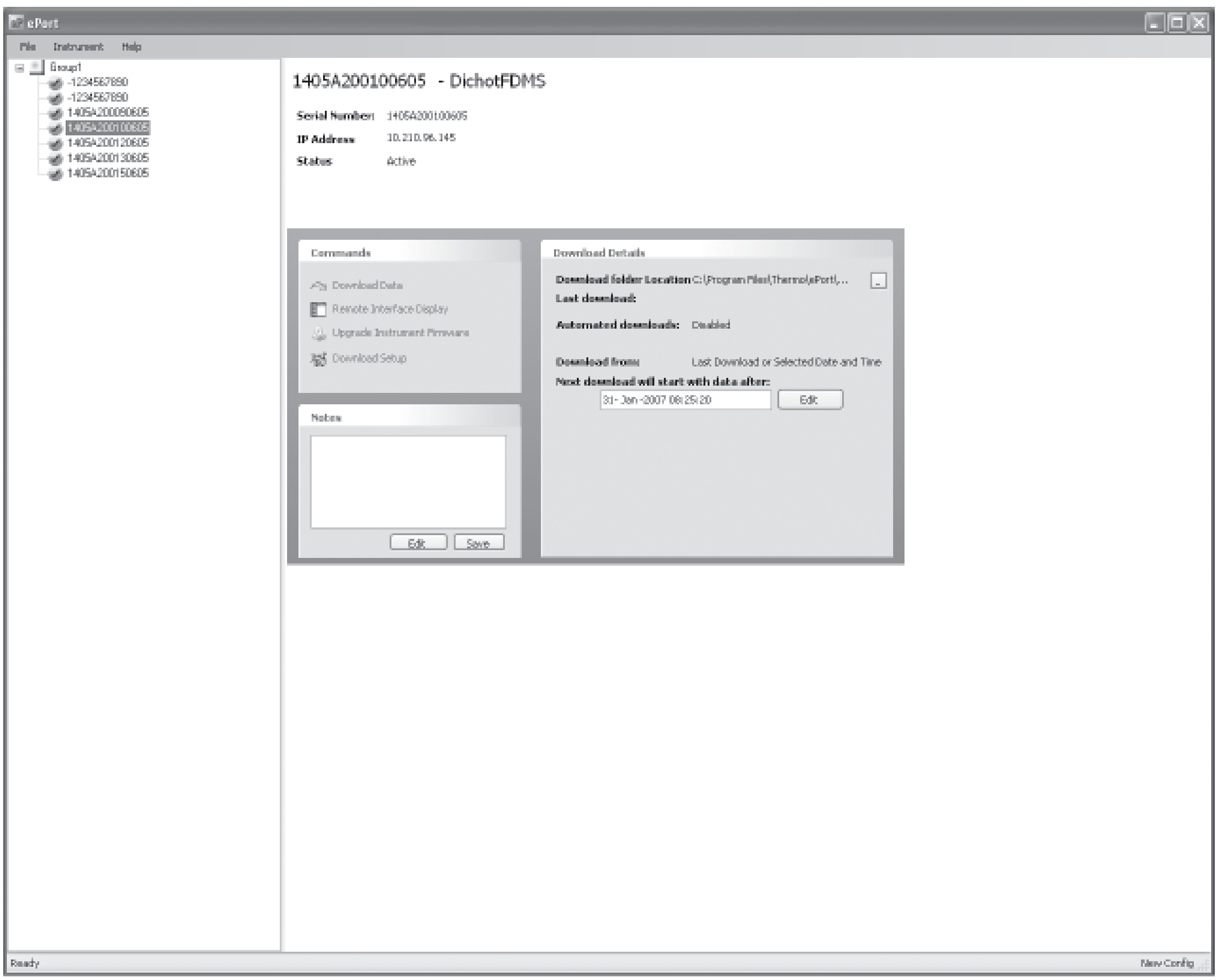
To download data:

1. Ensure that the PC and the instrument are connected to the same network using the Ethernet connection on the back of the instrument. (Refer to the Connecting to the TEOM 1405 Unit section for information on connecting the instrument to a network.)

2. Use the ePort PC software to connect to the instrument and display the ePort Main screen (Figure 3-31). (Refer to the Connecting to the TEOM 1405 Unit section for information on connecting to the instrument.)

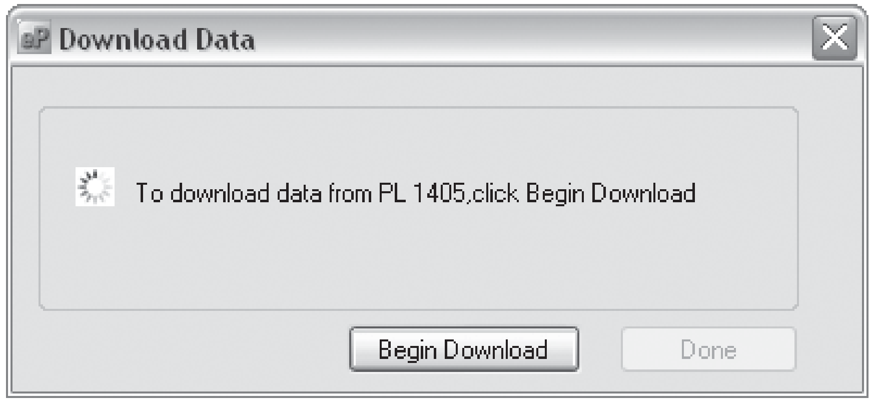
   Note. Once you have connected to an instrument (or instruments) and saved a configuration file, select **Open Saved Configuration** in the ePort Open screen to open that configuration and automatically connect to all the instruments that were saved in that configuration. ▲

Figure 3-31.
ePort Main screen.



3. Select **Download Data** in the Commands window of the ePort Main screen. The Download Data screen will display (Figure 3-32).

Figure 3-32.
Download Data screen.



4. Select the **Begin Download** button. The ePort software will download data based on the settings created in the Download Setup wizard. (Refer to the previous section for information on setting up downloads.) The message window will display a "Downloading Data" message while the software is downloading data from the instrument. When the download is complete, it will display a "Download Complete" message. Select the **Done** button to exit the Download Data screen.

Downloading Data To a Flash Drive

The TEOM 1405 also supports data downloads using the USB connection on the front of the instrument and a USB flash drive.

Note. Due to the size of the storage buffer, downloading all stored data may take 30 minutes or more. ▲

To download data using the USB connection:

1. Plug a flash drive into the USB connection on the front of the instrument. The Download Data to USB Flash Drive screen will display (Figure 3-33).

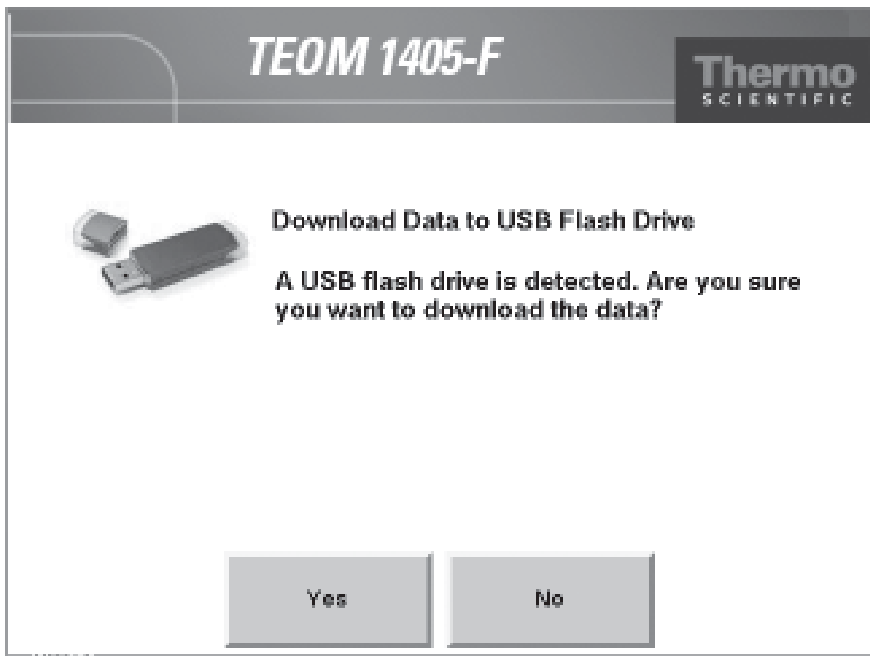


Figure 3-33. Download Data to USB Flash Drive screen.

2. To continue with the download, select the **Yes** button. To cancel select the **No** button, then remove the USB drive.

3. The Select Data screen will display (Figure 3-34). Select the **From the beginning** button to download all the data on the instrument. Select the **From last download** button to download only the data stored since the last data download. Select the **OK** button.

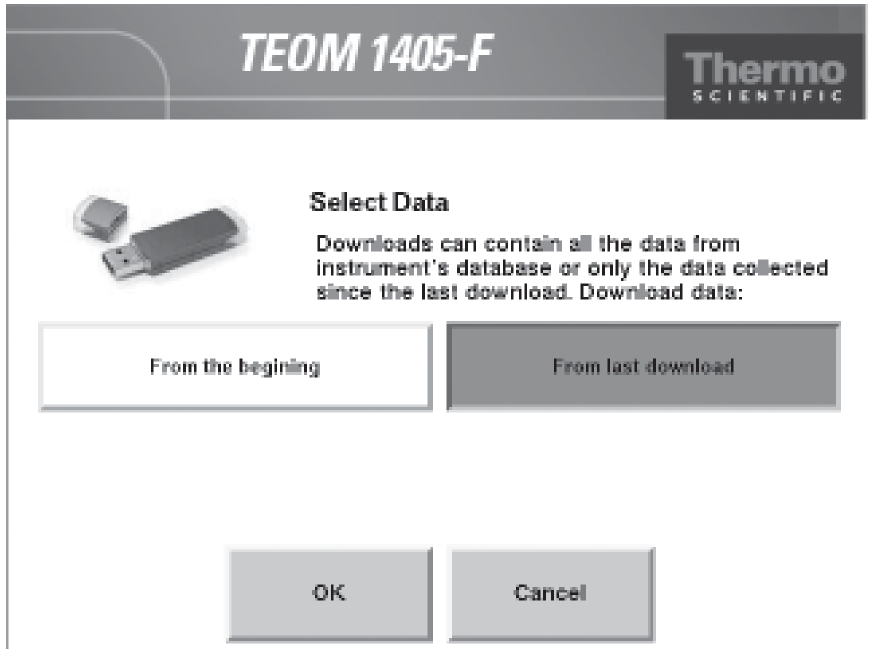


Figure 3-34. Select Data screen.

4. The instrument will display a "downloading data" message and begin transferring data to the USB drive.

   Note. Do not remove the USB drive from the instrument while the data is downloading. ▲

5. When the data download is complete, the instrument will display a "Download complete" message and display the file name as it is stored on the USB flash drive. (The file name format is the instrument serial number followed by a date/time stamp.) Remove the USB flash drive and select the **OK** button to continue.

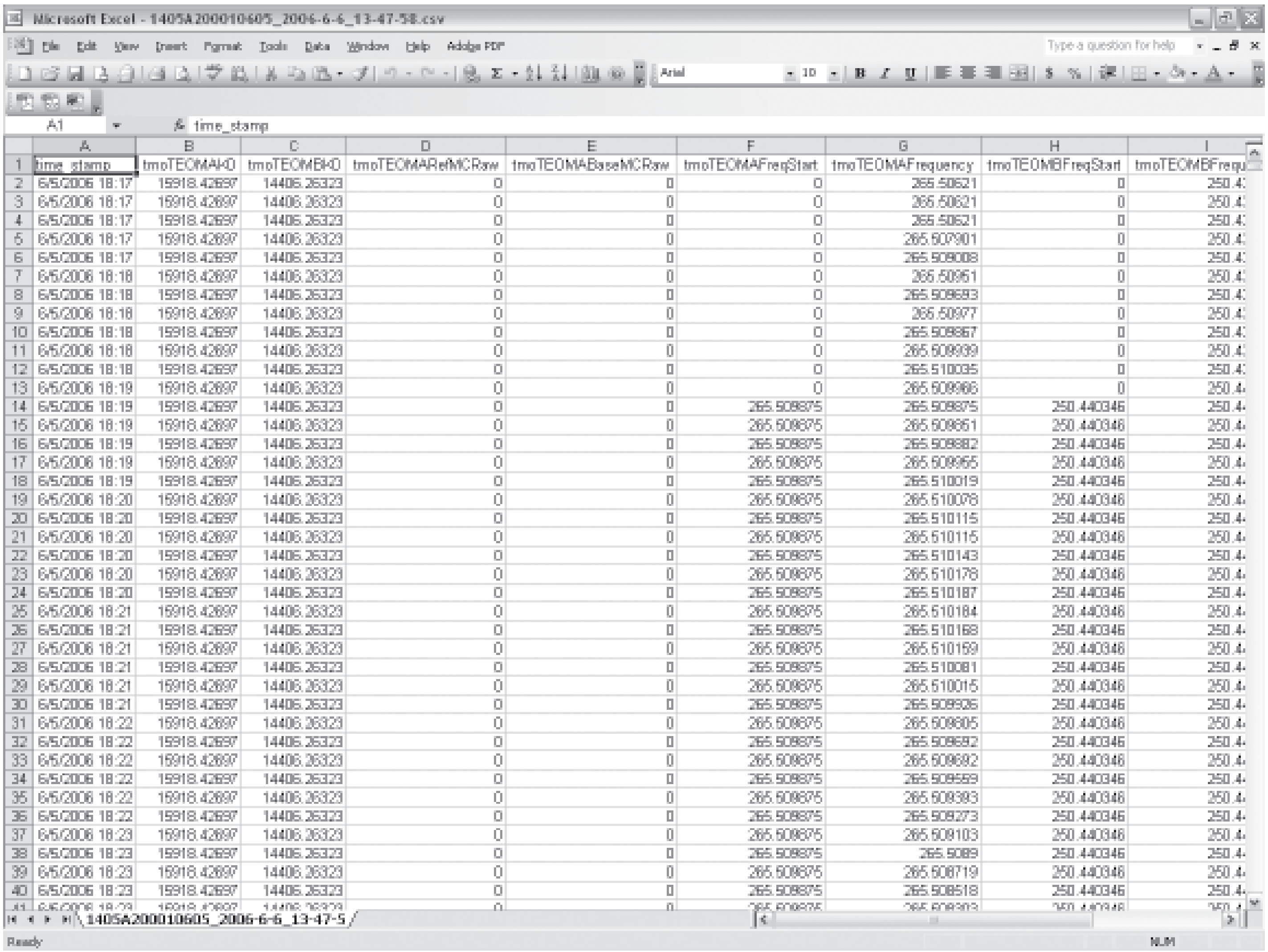
Viewing Downloaded Data

Data files are downloaded and saved as ".csv" files (.txt files through USB) that can be opened and viewed with Microsoft Excel. The file name format is the instrument serial number followed by a date/time stamp.

The data files will be saved to the folder selected using the Download Setup Wizard. Refer to the Setting Up for a Data Download section for information on setting up a data folder. The default folder location is:

C:\Program Files\Thermo\ePort\Data

Figure 3-35.
Data .csv file opened in Excel.



	A	B	C	D	E	F	G	H	I
1	time_stamp	tmoTEOMAK0	tmoTEOMBK0	tmoTEOMARefMCRaw	tmoTEOMABaseMCRaw	tmoTEOMAFreqStart	tmoTEOMAFrequency	tmoTEOMBFreqStart	tmoTEOMBFrequ
2	6/5/2006 18:17	15918.42697	14406.26323	0	0	0	265.50621	0	250.4
3	6/5/2006 18:17	15918.42697	14406.26323	0	0	0	265.50621	0	250.4
4	6/5/2006 18:17	15918.42697	14406.26323	0	0	0	265.50621	0	250.4
5	6/5/2006 18:17	15918.42697	14406.26323	0	0	0	265.507901	0	250.4
6	6/5/2006 18:17	15918.42697	14406.26323	0	0	0	265.509008	0	250.4
7	6/5/2006 18:18	15918.42697	14406.26323	0	0	0	265.50951	0	250.4
8	6/5/2006 18:18	15918.42697	14406.26323	0	0	0	265.509693	0	250.4
9	6/5/2006 18:18	15918.42697	14406.26323	0	0	0	265.50977	0	250.4
10	6/5/2006 18:18	15918.42697	14406.26323	0	0	0	265.509867	0	250.4
11	6/5/2006 18:18	15918.42697	14406.26323	0	0	0	265.509939	0	250.4
12	6/5/2006 18:18	15918.42697	14406.26323	0	0	0	265.510035	0	250.4
13	6/5/2006 18:19	15918.42697	14406.26323	0	0	0	265.509966	0	250.4
14	6/5/2006 18:19	15918.42697	14406.26323	0	0	265.509875	265.509875	250.440346	250.4
15	6/5/2006 18:19	15918.42697	14406.26323	0	0	265.509875	265.509851	250.440346	250.4
16	6/5/2006 18:19	15918.42697	14406.26323	0	0	265.509875	265.509882	250.440346	250.4
17	6/5/2006 18:19	15918.42697	14406.26323	0	0	265.509875	265.509965	250.440346	250.4
18	6/5/2006 18:19	15918.42697	14406.26323	0	0	265.509875	265.510019	250.440346	250.4
19	6/5/2006 18:20	15918.42697	14406.26323	0	0	265.509875	265.510078	250.440346	250.4
20	6/5/2006 18:20	15918.42697	14406.26323	0	0	265.509875	265.510115	250.440346	250.4
21	6/5/2006 18:20	15918.42697	14406.26323	0	0	265.509875	265.510115	250.440346	250.4
22	6/5/2006 18:20	15918.42697	14406.26323	0	0	265.509875	265.510143	250.440346	250.4
23	6/5/2006 18:20	15918.42697	14406.26323	0	0	265.509875	265.510178	250.440346	250.4
24	6/5/2006 18:20	15918.42697	14406.26323	0	0	265.509875	265.510187	250.440346	250.4
25	6/5/2006 18:21	15918.42697	14406.26323	0	0	265.509875	265.510184	250.440346	250.4
26	6/5/2006 18:21	15918.42697	14406.26323	0	0	265.509875	265.510168	250.440346	250.4
27	6/5/2006 18:21	15918.42697	14406.26323	0	0	265.509875	265.510159	250.440346	250.4
28	6/5/2006 18:21	15918.42697	14406.26323	0	0	265.509875	265.510081	250.440346	250.4
29	6/5/2006 18:21	15918.42697	14406.26323	0	0	265.509875	265.510015	250.440346	250.4
30	6/5/2006 18:21	15918.42697	14406.26323	0	0	265.509875	265.509926	250.440346	250.4
31	6/5/2006 18:22	15918.42697	14406.26323	0	0	265.509875	265.509805	250.440346	250.4
32	6/5/2006 18:22	15918.42697	14406.26323	0	0	265.509875	265.509692	250.440346	250.4
33	6/5/2006 18:22	15918.42697	14406.26323	0	0	265.509875	265.509692	250.440346	250.4
34	6/5/2006 18:22	15918.42697	14406.26323	0	0	265.509875	265.509559	250.440346	250.4
35	6/5/2006 18:22	15918.42697	14406.26323	0	0	265.509875	265.509393	250.440346	250.4
36	6/5/2006 18:22	15918.42697	14406.26323	0	0	265.509875	265.509273	250.440346	250.4
37	6/5/2006 18:23	15918.42697	14406.26323	0	0	265.509875	265.509103	250.440346	250.4
38	6/5/2006 18:23	15918.42697	14406.26323	0	0	265.509875	265.5089	250.440346	250.4
39	6/5/2006 18:23	15918.42697	14406.26323	0	0	265.509875	265.508719	250.440346	250.4
40	6/5/2006 18:23	15918.42697	14406.26323	0	0	265.509875	265.508518	250.440346	250.4

User I/O Connections

The TEOM 1405 allows users additional analog input and analog and digital output capabilities using the 25-pin "USER I/O" connector on the back of the instrument.

The female 25-pin USER I/O connector (Figures 3-36) has connections for eight analog output, four analog input and two digital output (contact closure) connections.

Figure 3-36.
USER I/O connector.

Thermo Fisher Scientific offers a 25-pin male connector manufactured by Phoenix Contact that can be wired to match to the USER I/O connector on the back of the instrument. (Figure 3-37).

Figure 3-37.
25-pin connector.

USER I/O Pin Assignments

Wire the desired analog input, analog output or digital output connections to the Phoenix Contact 25-pin male connector according to the manufacturer's instructions and the pin assignments of the TEOM 1405 (Figure 3-38and Table 3-1).

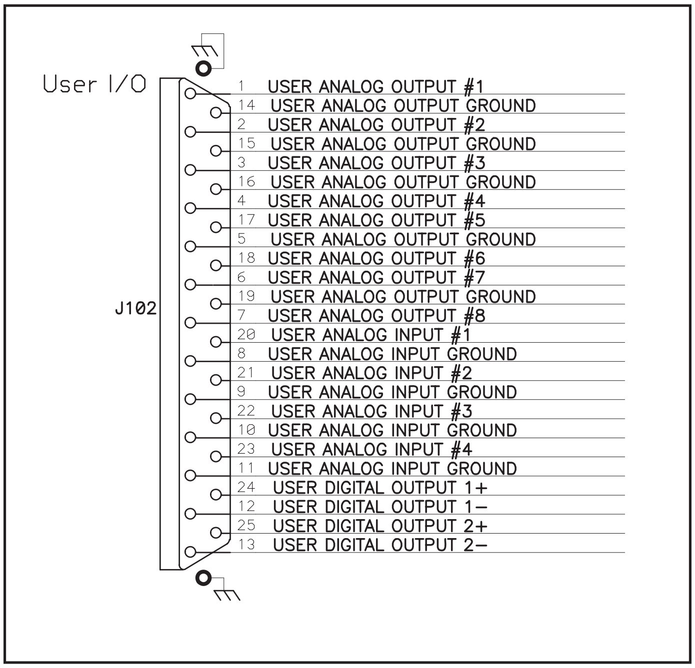


Figure 3-38. 1405 USER I/O pin assignments.

Table 3-1. 1405 USER I/O pin assignments.

Channel	Pin	Channel	Pin
Analog output 1	1	Analog output 1 ground	14
Analog output 2	2	Analog output 2 ground	15
Analog output 3	3	Analog output 3 ground	16
Analog output 4	4	Analog output 4 ground	16
Analog output 5	17	Analog output 5 ground	5
Analog output 6	18	Analog output 6 ground	5
Analog output 7	6	Analog output 7 ground	19
Analog output 8	7	Analog output 8 ground	19
Analog input 1	20	Analog input 1 ground	8
Analog input 2	21	Analog input 2 ground	9
Analog input 3	22	Analog input 3 ground	10
Analog input 4	23	Analog input 4 ground	11
Digital I/O 1+	24	Digital I/O 1-	12
Digital I/O 2+	25	Digital I/O 2-	13

When the 25-pin Phoenix Contact connector is attached to the unit with the wired digital or analog device connections, the inputs/outputs must be set up using the TEOM 1405 software screens:

When in the Instrument Conditions screen, select the **Analog Inputs** button to set up the analog inputs (1-4) and convert the incoming voltage to the desired scale. The analog inputs are self-calibrating.

When in the Settings screen, select the **Analog & Digital Outputs** screen to set up the analog outputs (1-8) and digital outputs (contact closures 1-2):

- When in the Analog & Digital Outputs screen, select the **Analog Outputs** button to set a minimum and maximum value for the output for the desired output channel. Refer to Section 5 for information on calibrating the analog outputs.

- When in the Analog & Digital Outputs screen, select the **Contact Closure** button to select a variable, operator and compare value for the desired contact closure channel (1-2).

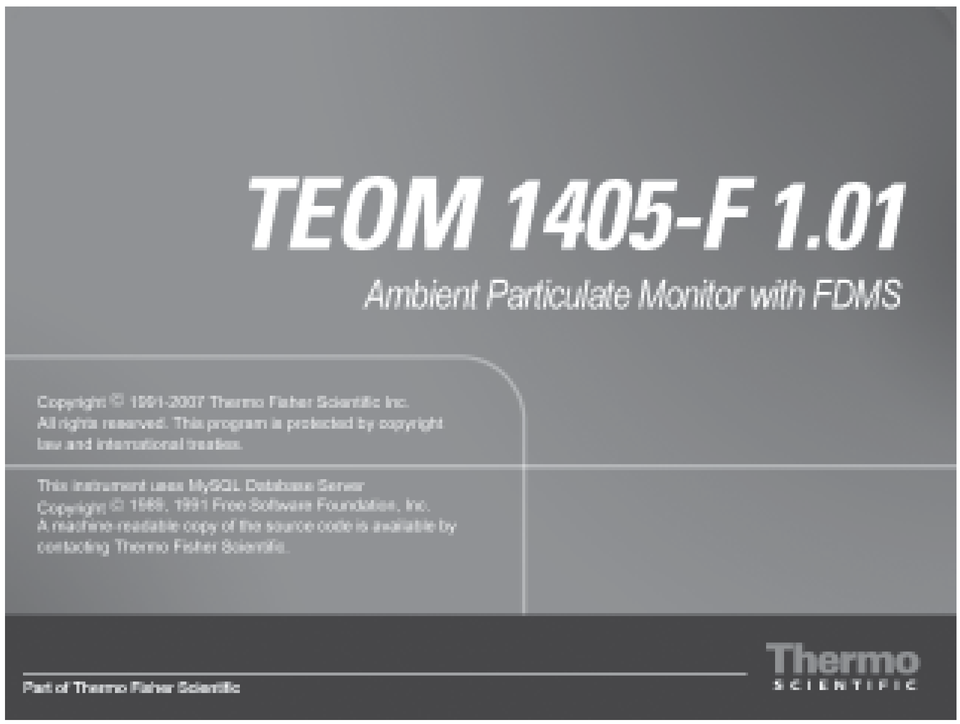
Refer to Section 4 for complete information on setting the inputs/outputs in the Analog Inputs and Analog & Digital Outputs screens.

Section 4 Screens and Settings

This section describes the screens shown in the instrument software and the system's operating modes, as well as how to change instrument settings.

When the instrument is started, it will display the Title screen for a few seconds (Figure 4-1) after the initialization process.

Figure 4-1.
Title screen.

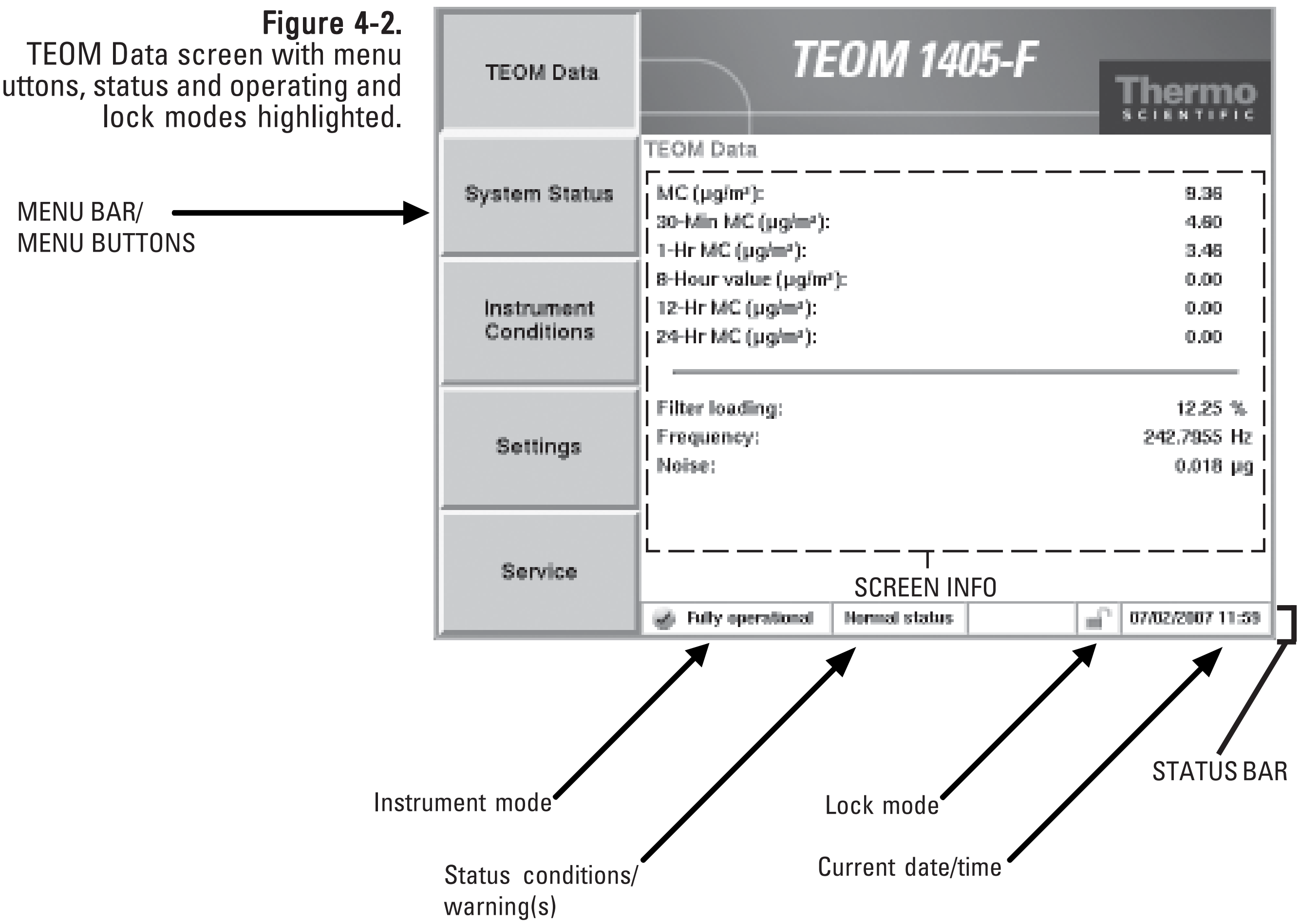


The Title screen includes the instrument model and the firmware version of the instrument.

TEOM Data Screen

After the Title screen, the TEOM Data screen will automatically display (Figure 4-2). The TEOM Data screen shows the basic operating information, as well as status conditions and the instrument operating mode. The TEOM Data screen can be displayed by selecting the TEOM Data button in any of the other four main screens (System Status, Instrument Conditions, Settings, Service).

Figure 4-2.
TEOM Data screen with menu buttons, status and operating and lock modes highlighted.



The TEOM Data screen includes menu buttons allowing users to access the other main screens. The status bar at the bottom of the screen displays operating information, including the current operating mode, lock mode and date and time, as well as the current status ("Normal" or "Warning(s)").

Note. Upon initial instrument start up, the values in the mass concentration fields are the running averages that are accumulated until a 1-hour time period has passed. The values are visible to provide the user with an indication that the instrument is functioning, after instrument power up or reset. These raw values are used for internal calculations only. ▲

The TEOM Data screen contains the following information:

- *MC (μg/m³):* This field contains the mass concentration value. The unit calculates the mass concentration (MC) value by subtracting the Ref MC from the Base MC. This is a one-hour average updated every 6 minutes. This value cannot be changed by the user.

- *01-Hr MC (μg/m³):* This field contains the 1-hour mass concentration average. This is a sliding average that is updated every 60 minutes on the hour. This value cannot be changed by the user.

- *08-Hr MC (μg/m³):* This field contains the XX-hour mass concentration average. The user may set value to any whole number greater than 1. This is a sliding average that is updated every 60 minutes on the hour. This value cannot be changed by the user.

  Note. Mass concentration averages of less than 24 hours can be averaged using data logging equipment to compute sliding 24-hour averages and 24-hour averages that do not necessarily start and end at midnight, as well as averages on other user-defined time scales. ▲

- *12-Hr MC (μg/m³):* This field contains the 12-hour mass concentration average. This is a sliding average that is updated every 60 minutes on the hour. This value cannot be changed by the user.

- *24-Hr MC (μg/m³):* This field contains the 24-hour mass concentration average. This is a sliding average that is updated every 60 minutes on the hour. This value cannot be changed by the user.

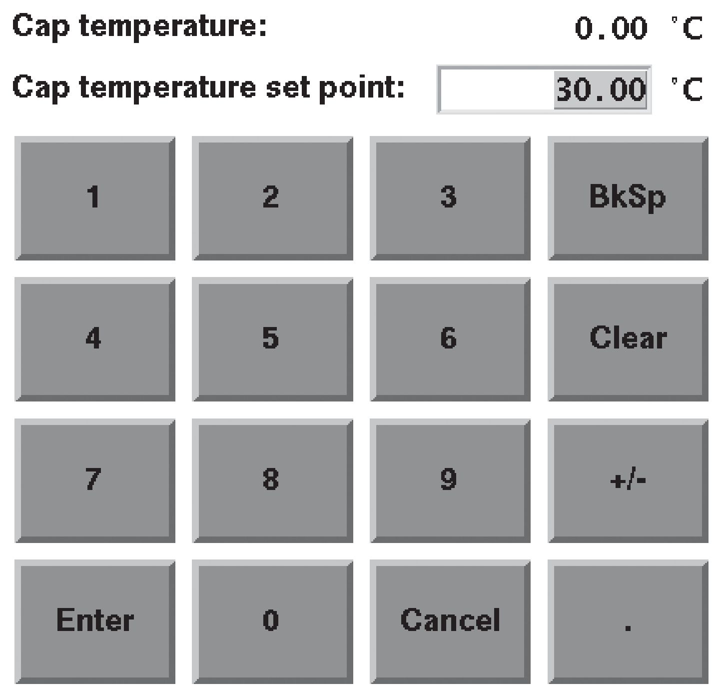
- *Frequency:* This field contains the oscillating frequency of the tapered element (TE) in the mass transducer. This value varies from one TEOM 1405 unit to another, but generally ranges between 150 and 400 Hz. This value cannot be changed by the user.

- *Noise:* This field contains the mass transducer's performance. This value should be less than "0.10" after the system has been in Operating Mode 4 for at least 30 minutes. This value cannot be changed by the user.

- *Filter loading:* This field contains the filter loading percentage (Section 5). It indicates the portion of the TEOM filter's total capacity that has been used. The instrument will always show a nonzero value even if no filter is mounted in the mass transducer. New filters generally exhibit filter loading percentages of 15% to 30% at a flow rate of 3 l/min, and less at lower flow rates. TEOM filter cartridges must be exchanged before this value reaches 100% to ensure the validity of the data generated by the instrument. At some point above 100%, the main flow drops below its set point. If the filter loading percentage is higher than 30% when a new TEOM filter is placed on the mass transducer, or if the lifetime of consecutive TEOM filter cartridges becomes noticeably shorter, inspect the in-line filter for the flow line (Section 5) and replace it, if necessary.

Users enter values into the settings screens using a number keypad (Figure 4-3). Select the button for the value that needs to be changed, such as setpoints for flow rates, temperatures or pressures, and a keypad will automatically display. The keypad will display the current setpoint and the current value (when applicable). Enter the value into the keypad, then select the **Enter** button to set the value or press the **Cancel** button to exit the keypad screen and return to the screen.

Figure 4-3.
Number entry keypad showing current value and setpoint.



Operating Mode

The TEOM 1405 Monitor displays its current operating mode in the lower left-hand corner of TEOM Data screen (Figure 4-2) and most of the other instrument screens.

The unit's operating modes (Figure 4-2) are defined as follows:

- *Stabilizing:* This operating mode indicates that the unit has not begun to compute mass values, because the monitor's temperatures and flow rates are stabilizing. The temperatures and flow rates must remain within a very narrow range of values for 30 minutes before the instrument enters the next operating mode. The monitor always starts in Stabilizing Mode when it is turned on or reset.

- *Collecting Data:* This operating mode indicates that the unit has begun to collect data records, but the monitor has not yet computed its first mass concentration value.

- *Computing Data:* This operating mode indicates that the unit has computed the first mass concentration value.

- *Fully operational:* This operating mode indicates that the unit is fully operational. The monitor normally resides in this mode. All mass values are being computed by the instrument.

- *Setup Mode:* When the unit is in this operating mode, it continues to draw a sample flow and maintain operational temperatures but it does not collect any data. Certain operating parameters such as temperatures and flow rates can be changed only in this mode, because doing so during data collection would adversely affect the quality of the data. The instrument will automatically prompt the user to enter the Setup Mode when changing a temperature, flow or other adjustable value. After the new value is entered and saved, it will automatically return to one of the four regular operating modes above. If several parameters need to be changed, the user can enter the Setup Mode manually, avoiding the warning prompts when changing each variable. To manually enter the Setup Mode, select the **Instrument Control** button in the Service screen (page 4-30). In the Instrument Control screen (page 4-32), press the **Setup** button. When the unit is in the Setup Mode, the user can change all of the system's parameters. To manually leave the Setup Mode and start data collection, when in the Instrument Control screen, select the **Run** button.

- *Stop All Mode:* Certain situations may arise in which the user may want to turn off all temperatures and flows in the instrument. To enter the Stop All Mode, select the **Instrument Control** button in the Service screen (page 4-30). In the Instrument Control screen select the **Stop** button (page 4-32). When the unit is in this operating mode, it suspends operation of the instrument. In this mode, data collection ceases, flow rates in the system drop to zero, and the output to the temperature circuits is turned off. Also, the monitor will reset its system variables to the original values that were set by the user. However, this does not set the unit to its default parameters. The instrument will remain in the Stop All Mode until you select the **Run** button in the Instrument Control screen.

System Status Screen

The current status condition is located in the status bar at the bottom of the TEOM Data screen (Figure 4-4), and most other instrument screens. If there are no status conditions, the field at the bottom of the screen will read "Normal status" (Figure 4-4). If there are status conditions present, the field at the bottom of the screen will read "Warning(s)" and a warning triangle will appear in the instrument title bar at the top of the screen (Figure 4-5).

Figure 4-4. TEOM Data screen with "Normal status" message.

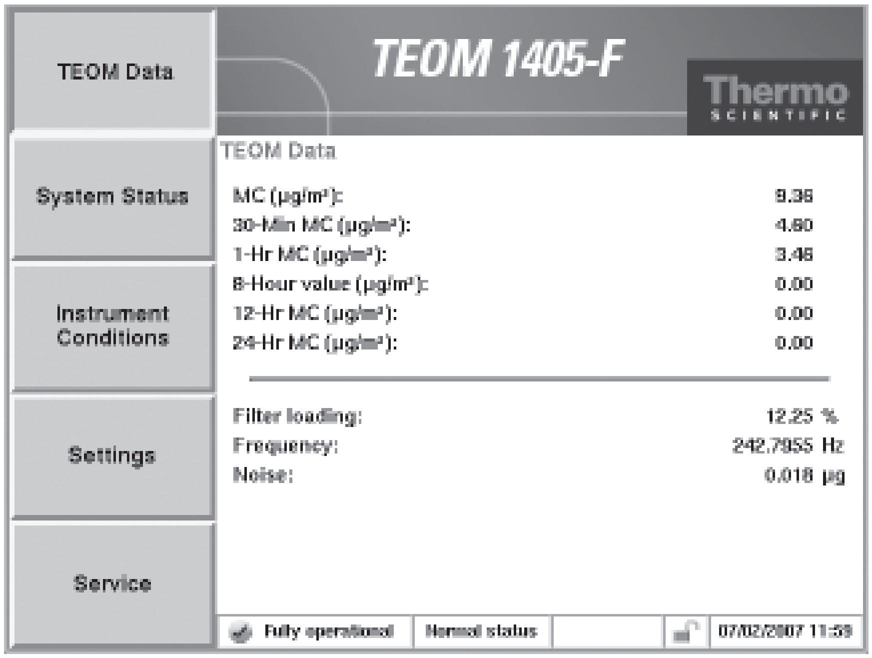
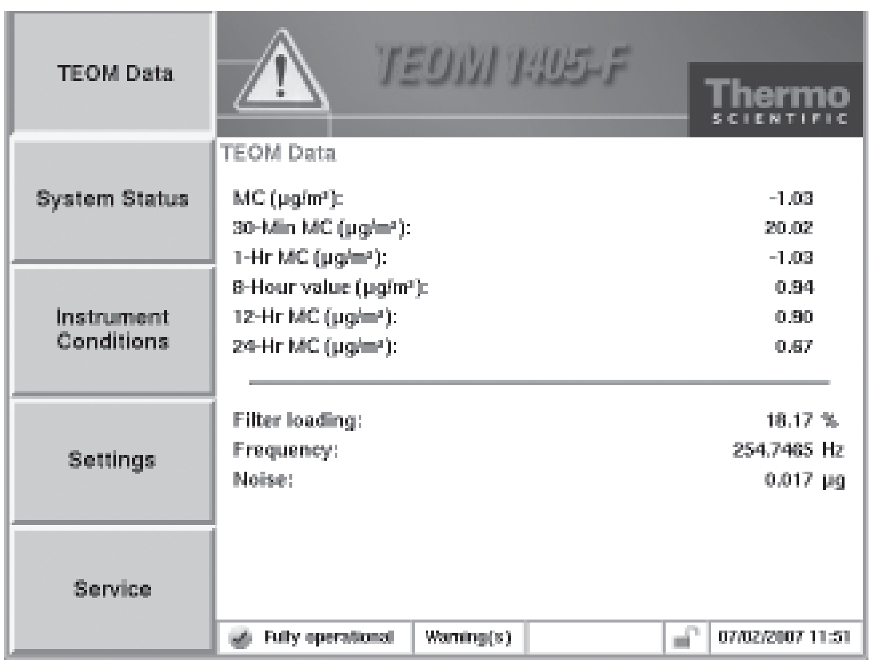
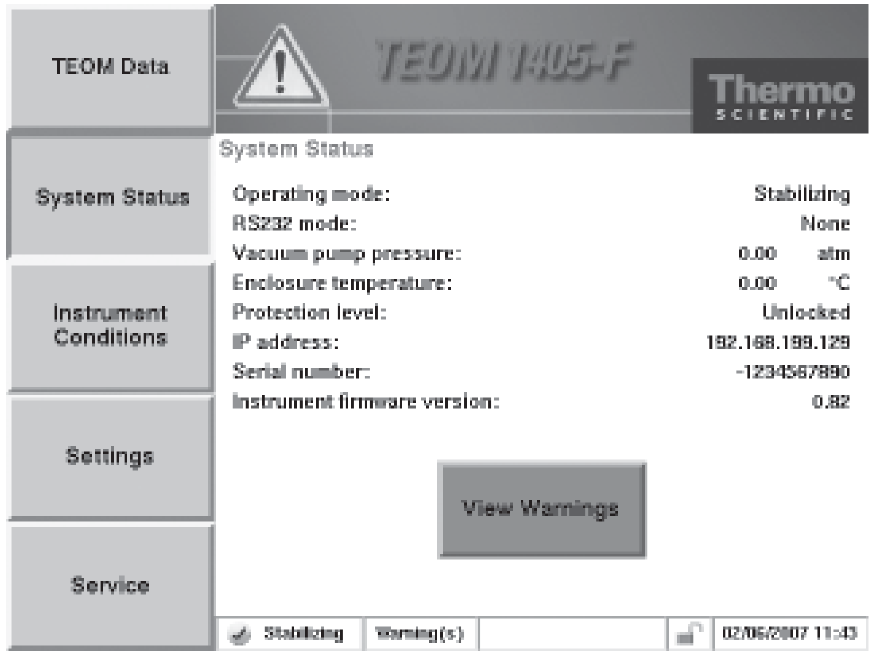


Figure 4-5. TEOM Data screen with "Warning(s)" message and warning triangle.



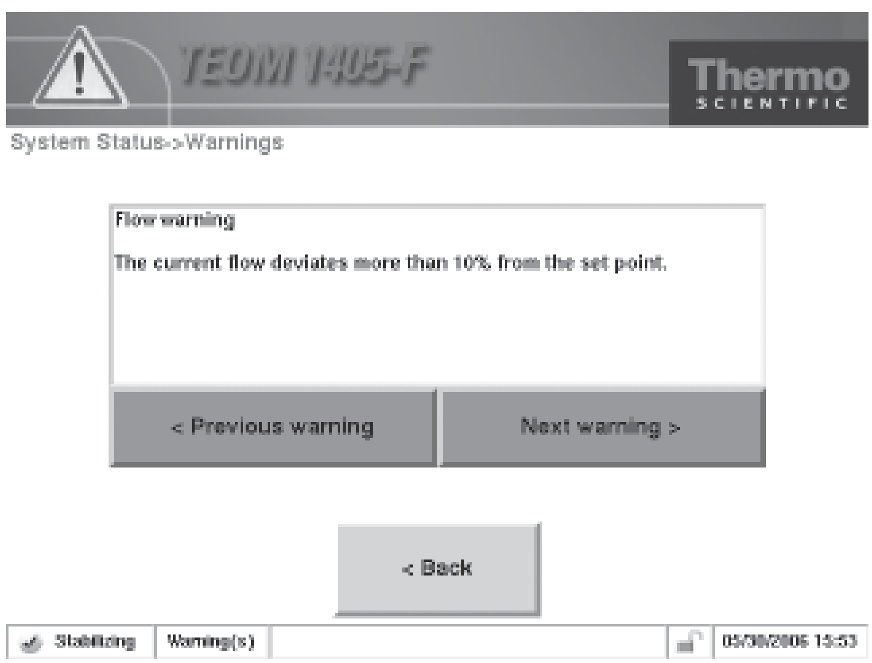
Whenever a status warning is displayed, select the **System Status** button to display the System Status screen (Figure 4-6). The System status screen provides basic operating information and access to the list of the current active status warnings.

Figure 4-6.
System Status screen.



To view the current status warnings, select the **View Warnings** button or touch the warning triangle (or the title bar) when it is visible in any screen. The Warnings screen will display (Figure 4-7). Select the **< Previous Warning** and **Next Warning >** buttons to view the status warnings.

Figure 4-7.
Warnings screen.



Instrument Conditions Screen

The Instrument Conditions button displays the Instrument Conditions screen (Figure 4-8), and provides access to several temperature and flow settings and the current ambient air conditions for the instrument.

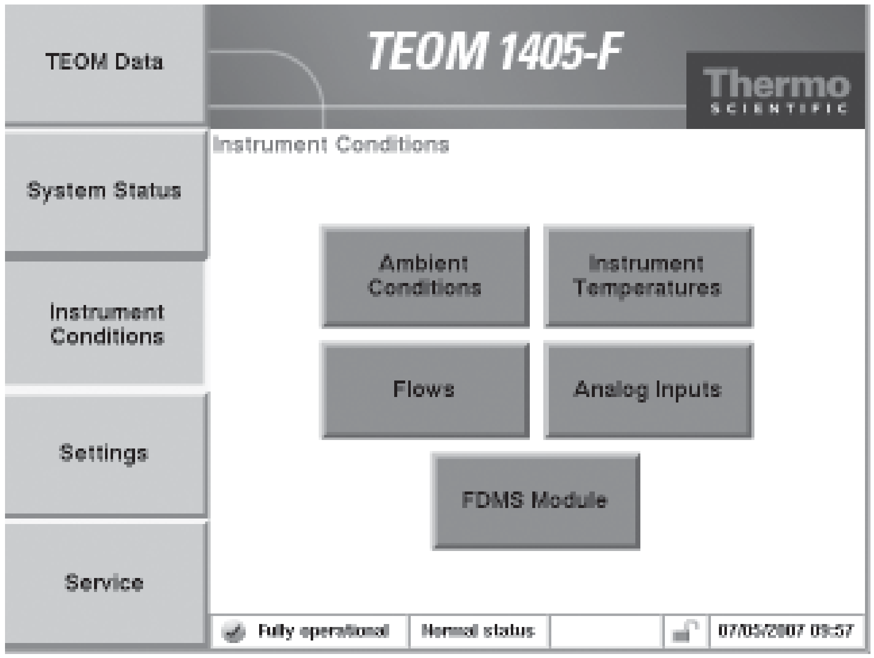
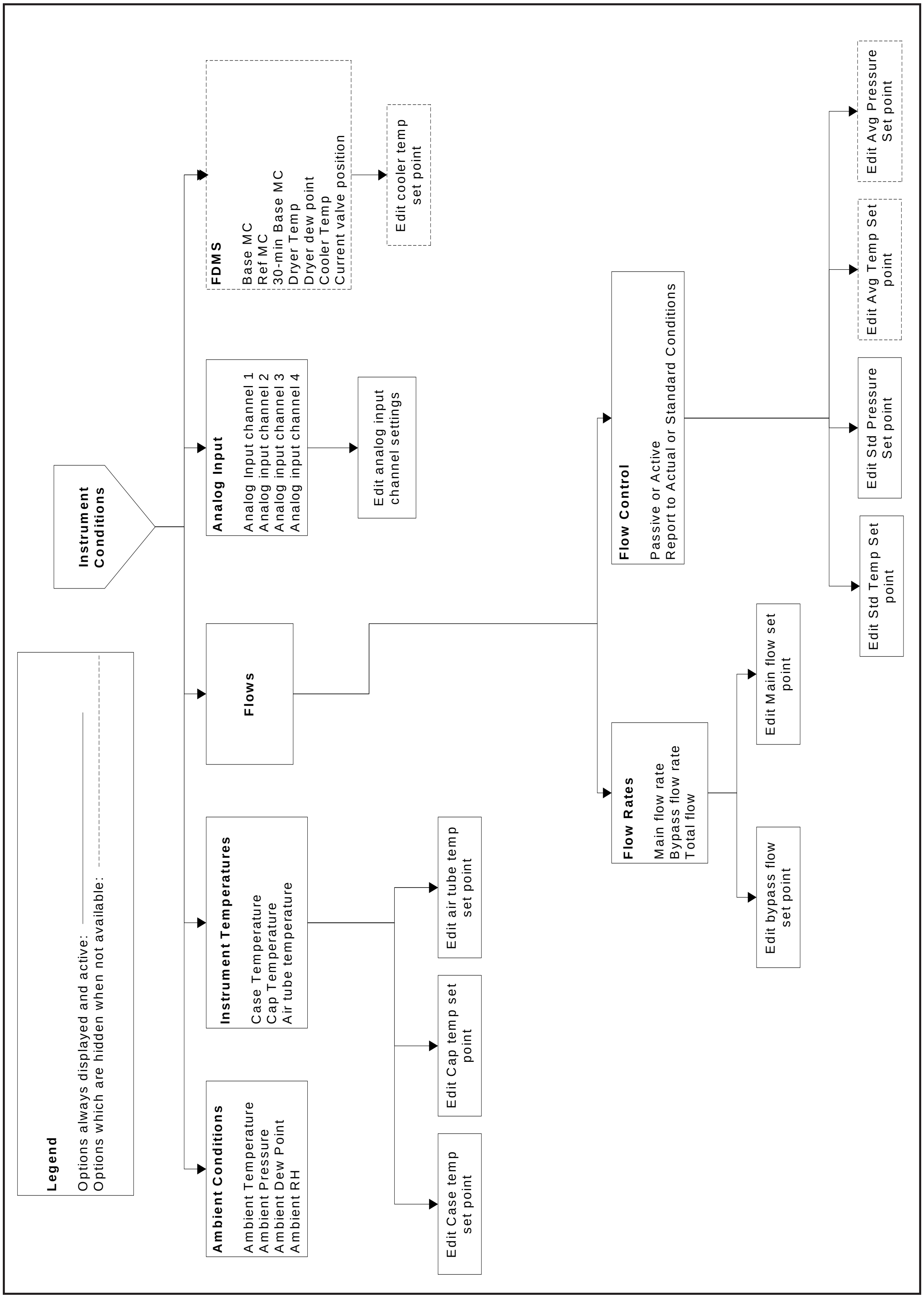


Figure 4-8.
Instrument Conditions screen.

When in the Instrument Conditions screen, select the **Ambient Conditions**, **Instrument Temperatures**, **Flows, FDMS Module**, or **Analog Inputs** buttons to reach the desired screens (Figure 4-9).

Figure 4-9.
Screens accessible through the Instrument Conditions screen.



Ambient Conditions Screen

The Ambient Conditions screen (Figure 4-10) shows the current ambient conditions for the monitor.

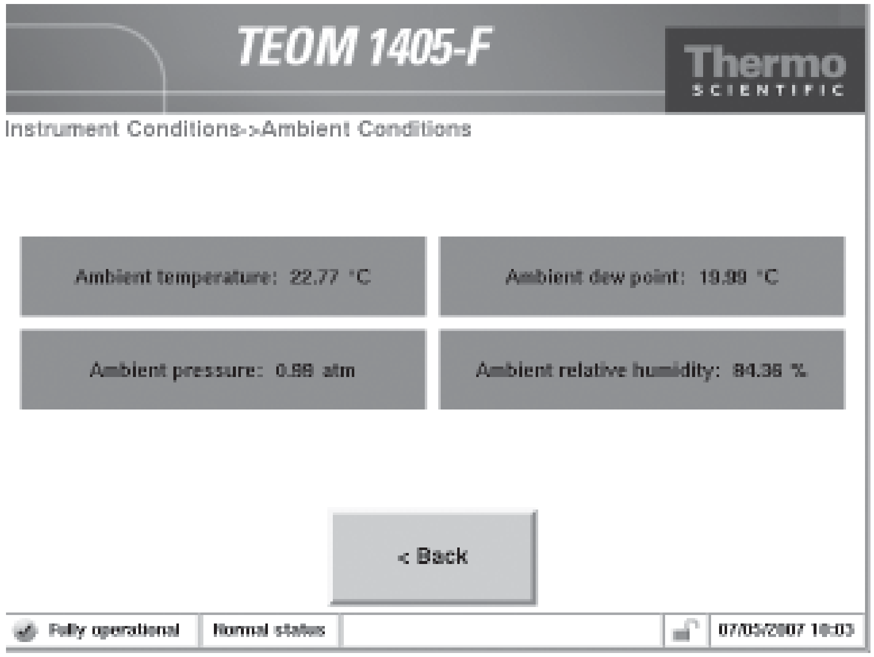


Figure 4-10.
Ambient Conditions screen.

The Ambient Conditions screen contains the following information:

- Ambient Temperature. This field contains the current ambient temperature (°C) at the site. This value cannot be edited and will be correct only when the ambient temperature/humidity sensor is properly installed.

- Ambient Pressure. This field contains the current ambient pressure (atm) at the site. This value cannot be edited.

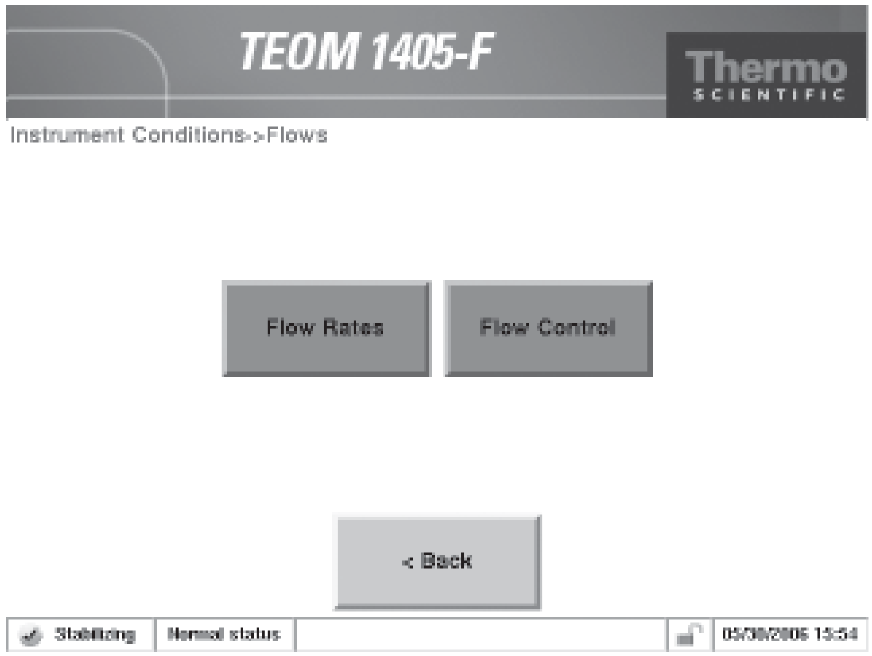
- Ambient Dew Point. This field contains the current ambient dew point (°C) at the site. This value cannot be edited and will be correct only when the ambient temperature/humidity sensor is properly installed.

- Ambient Relative Humidity. This field contains the current ambient pressure (atm) at the site. This value cannot be edited and will be correct only when the ambient temperature/humidity sensor is properly installed.

Flows Screen

The Flows screen (Figure 4-11) offers access to the flow rates and flow controls of the unit.

Figure 4-11.
Flows screen.



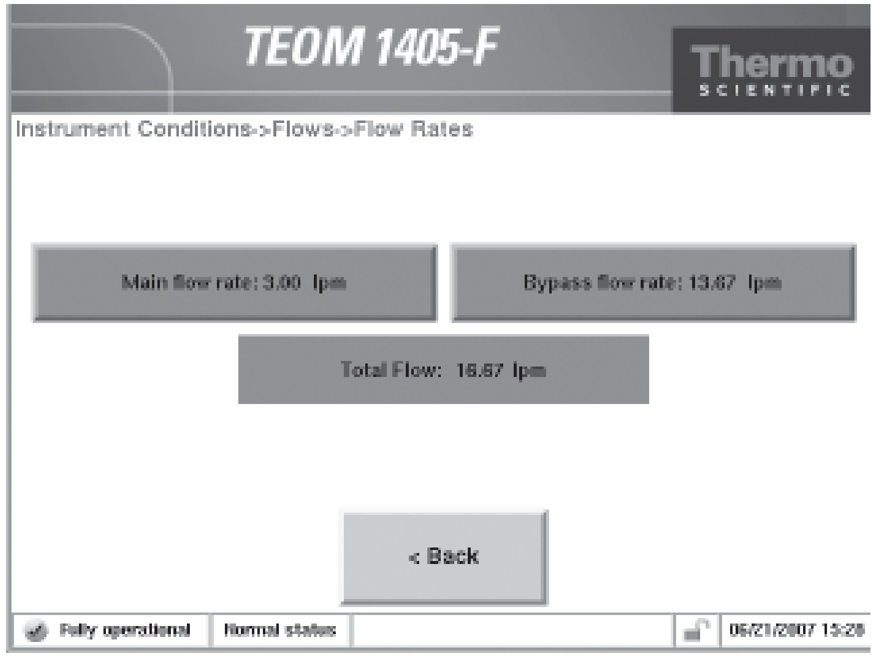
Select the **Flow Rates** button to view or adjust the instrument's flow rates. Select the **Flow Control** button to view or adjust the units standard temperature and pressure settings or select active or passive flow control.

The TEOM 1405 Monitor uses mass flow controllers to ensure a constant and precise flow through the instrument. The mass flow controllers use the actual (*active* volumetric flow control setting) or average (*passive* volumetric flow control setting) temperature and pressure values to regulate the volumetric flow through the system. The active volumetric flow control setting directs the unit to use the actual ambient temperature and pressure to regulate the volumetric flow through the system. The passive volumetric flow control setting directs the unit to use the average temperature and pressure values to regulate the volumetric flow through the system. Refer to the following sections for information on setting flow rates and flow controls.

Flow Rates Screen

Select the **Flow Rates** button in the Flows screen to display the Flow Rates screen (Figure 4-12). This screen allows users to adjust the flow rates for the main and bypass flow channels.

Figure 4-12.
Flow Rate screen.



The Flow Rates screen contains the following controls buttons:

- *Main flow rate*. This field contains the current value of the main path flow rate (l/min). The default setting is 3 l/min. To view or adjust the setpoint, select the button to display the keypad (Figure 4-3). The current value can not be edited.

- *Bypass flow rate*. This field contains the current value of the bypass flow rate. The default setting is 13.67 l/min. To view or adjust the setpoint, select the button to display the keypad (Figure 4-3). The current value can not be edited.

- *Total flow*. This field contains the current value of the total flow rate of the instrument (l/min). The current value can not be edited.

Flow Control Screen

Select the **Flow Control** button in the Flows screen to display the Flow Control screen (Figure 4-13). This screen allows users to adjust the flow control method.

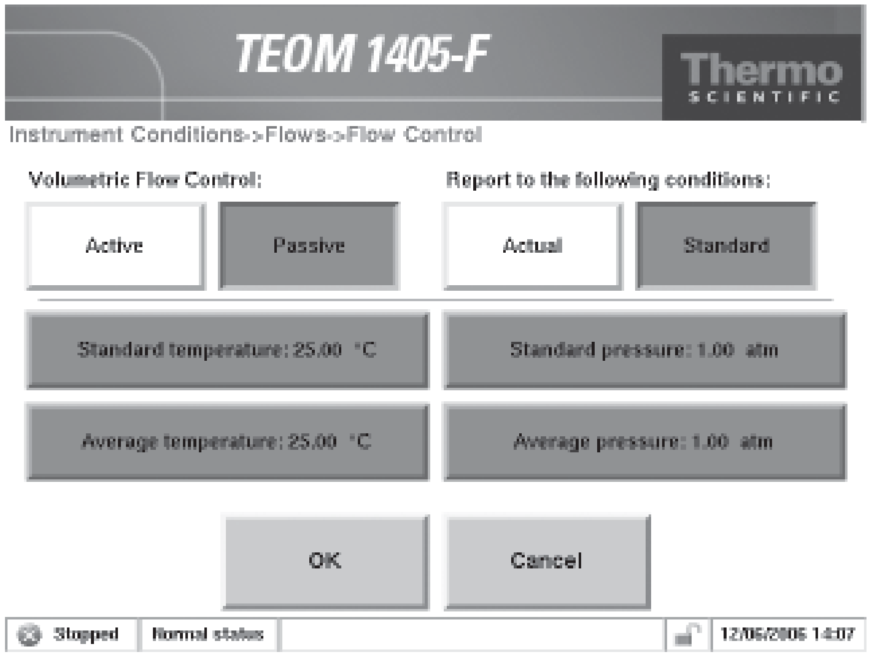


Figure 4-13. Flow Control screen.

The Flow Control screen contains the following control buttons:

- *Volumetric Flow Control (Active or Passive)*. These buttons allow the user to select "active" (using actual temperature and pressure) or "passive" (using average temperature and pressure) to adjust the flow.

- *Report to the following conditions: (Actual or Standard)*. These buttons allow the user to select "Actual" reporting (the mass concentration measured per actual volume sampled through the inlet) or "Standard" reporting (the mass concentration adjusted based on a set standard temperature and pressure).

- *Standard temperature*. This field contains the standard temperature (°C) setting. The default setting is 25° C. To adjust the setpoint, select the button to display the keypad (Figure 4-3).

- *Average temperature*. This field (visible only when passive is selected) contains the average temperature (°C) setting for passive flow control. The default setting is 25° C. To adjust the setpoint, select the button to display the keypad (Figure 4-3).

- *Standard pressure*. This field contains the standard pressure (atm) setting. The default setting is 1 atm. To adjust the setpoint, select the button to display the keypad (Figure 4-3).

- *Average pressure*. This field (visible only when passive is selected) contains the average pressure (atm) setting for passive flow control. The default setting is 1 atm. To adjust the setpoint, select the button to display the keypad (Figure 4-3).

The instrument is delivered with the following temperature and pressure settings:

Standard temperature	25° C	Standard pressure	1 atmosphere (atm)
Average temperature	25° C	Average pressure	1 atmosphere (atm)

The user must choose how they want the monitor to control the volumetric flow: actively or passively:

- **Active Flow Control** uses actual ambient pressure and ambient temperature from instrument sensors to set the flow rates

- **Passive Flow Control** uses operator input ambient temperature and ambient pressure to control flow. At their discretion, operators can input seasonal average temperature and pressure.

To select *active* flow control, select the **Active** flow control button (Figure 4-13). To use the actual temperature and pressure to control the volumetric flow, you must install the ambient temperature/humidity sensor The instrument's mass flow controllers measure flow on a mass basis. All of the size-selective inlets, including the PM-10 inlet, operate on a constant volumetric flow basis.

If the user chooses to use *passive* flow control, they must select the **Passive** flow control button (Figure 4-13). The average temperature and average pressure, used by the instrument, may vary with season and altitude. If the user wants the unit to use the average temperature and pressure to control the volumetric flow, they should manually adjust the average temperature and average pressure settings as climatic conditions change. The user usually has to adjust the average pressure only once for the average barometric pressure at the sampling site (i.e., station pressure — not adjusted to sea level). However, the user generally must adjust the average temperature periodically (often 4 times per year) in accordance with changing average ambient temperatures.

The mass concentration is reported based on the volume sampled through the TEOM inlet. It can be reported in terms of the mass collected per actual volume sampled through the inlet or reported in terms of mass collected per standard volume sampled through the inlet.

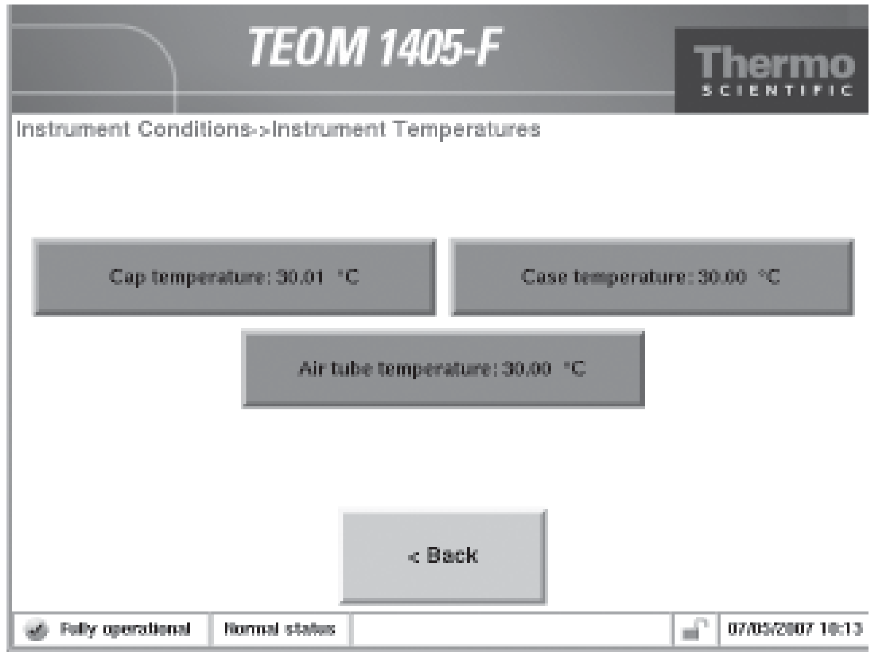
If the user chooses to set the unit to report the mass concentration levels to **Actual** conditions, they must select the **Active** flow control button (Figure 4-13). This will cause the monitor to use the actual ambient temperature and ambient pressure in its flow rate calculations.

If the user chooses to set the unit to report the mass concentration levels to **Standard** conditions, they must set the standard temperatures and pressures to the appropriate standard regulatory values.

Instrument Temperatures Screen

The Instrument Temperatures screen (Figure 4-14) shows the current temperatures of the unit.

Figure 4-14.
Instrument Temperatures screen.



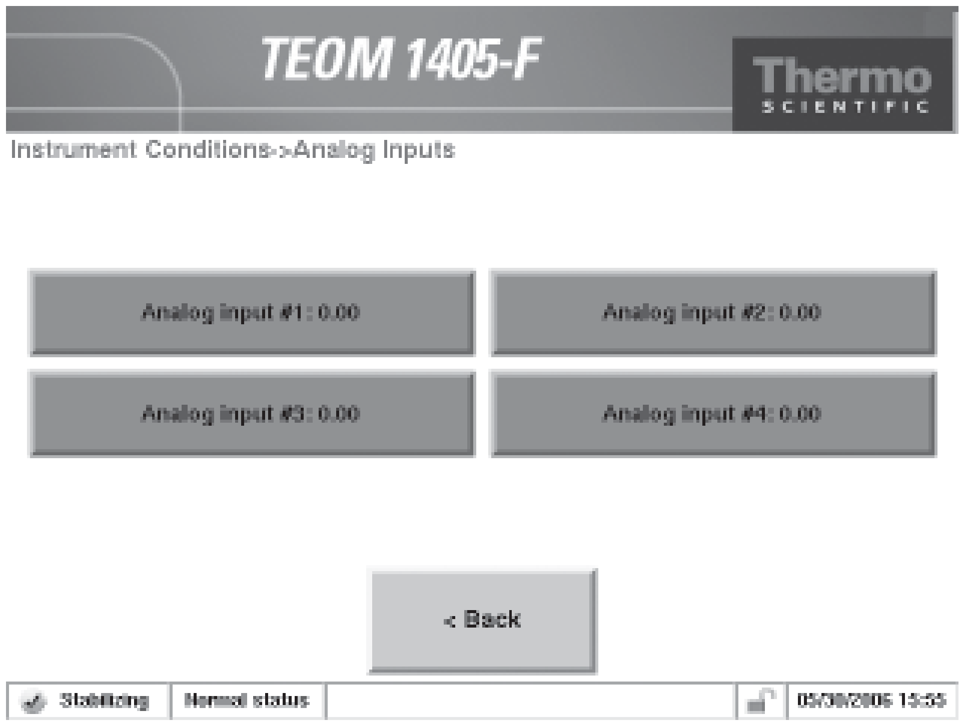
The Instrument Temperatures screen contains the following control buttons:

- *Cap temperature*. This field contains the current value of the temperature (°C) of the mass transducer's cap. The default setting is 30° C. To view or adjust the setpoint, select the button to display the keypad (Figure 4-3). DO NOT adjust this value without contacting Thermo Scientific.
- *Case temperature*. This field contains the current value of the temperature (°C) of the mass transducer case. The default setting is 30° C. To view or adjust the setpoint, select the button to display the keypad (Figure 4-3). DO NOT adjust this value without contacting Thermo Scientific.
- *Air tube temperature*. This field contains the current value of the temperature (°C) of the air stream. The default setting is 30° C. To view or adjust the setpoint, select the button to display the keypad (Figure 4-3). DO NOT adjust this value without contacting Thermo Scientific.

Analog Inputs Screen

The Analog Inputs screen (Figure 4-15) gives the current values of the units four analog input channels. The inputs accept 0-5 VDC, and can be converted to a desired scale. Select the **Analog Input #1**, **Analog Input #2**, **Analog Input #3**, or **Analog Input #4** buttons to convert the analog input to a desired scale.

Figure 4-15.
Analog Inputs screen.



FDMS Module Screen

The FDMS Module screen (Figure 4-16) allows users to access the values used by the Filter Dynamics Measurement System to generate the mass concentration measurements.

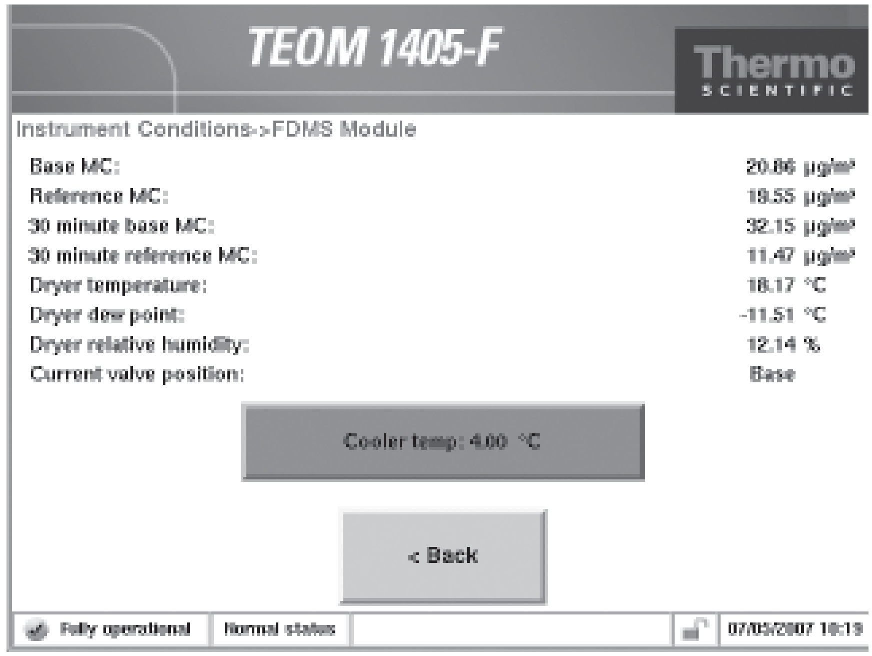


Figure 4-16.
FDMS Module Screen.

The FDMS Module screen contains the following information:

- *Base MC*. This field contains the mass concentration value recorded by the TEOM filter while the FDMS system draws dried ambient air (base flow) through the sample flow lines. This value is a rolling 1-hour average updated every 6 minutes.

- *Reference MC*. This field contains the mass concentration value recorded by the TEOM filter while the FDMS system draws dried, filtered and cooled ambient air (reference flow) through the sample flow lines. This value is a rolling 1-hour average updated every 6 minutes.

- *30-minute base MC*. This field contains the mass concentration value recorded by the TEOM filter while the FDMS system draws dried ambient air (base flow) through the sample flow lines. This value is a rolling 30-minute average updated every 6 minutes.

- *30-minute reference MC*. This field contains the mass concentration value recorded by the TEOM filter while the FDMS system draws dried, filtered and cooled ambient air (reference flow) through the sample flow lines. This value is a rolling 30-minute average updated every 6 minutes.

- *Dryer temperature*. This field contains the dryer temperature of the flow channel.
- *Dryer dew point*. This field contains the current dew point of the air stream (exiting the dryer) of the flow channel.
- *Dryer relative humidity*. This field contains the current relative humidity of the air stream (exiting the dryer) of the flow channel.
- *Current valve position*. This field contains the current valve position, base or reference.

Select the **Cooler temp** button to change the temperature (°C) of the FDMS cooler.

FDMS Cooler Temperature Setting

The default settings for the FDMS cooler temperatures are 4° C. If the dewpoint of the sample gases are greater then 2° C, a status warning will occur. Under this condition, check and verify the performance of the sample dryers.

Under certain ambient conditions, the capability of the dryers to remove moisture from the sample gases is insufficient resulting is a high sample dewpoint. High ambient temperature, humidity, or both, may cause this condition to occur. If the high ambient temperature or humidity exists such that the dewpoint of the sample gases may exceed 0° C, Thermo Fisher Scientific recommends the cooler temperatures be adjusted to a 10° C set point for the operating period where the high ambient temperature or humidity exists. This is accomplished by setting the cooler temperature to 10° C at the beginning of the typical calendar period when these conditions exist and resetting the cooler temperature to 4° C at the end of the calendar period.

When changing the cooler temperature from 4° C to 10° C, follow these steps:

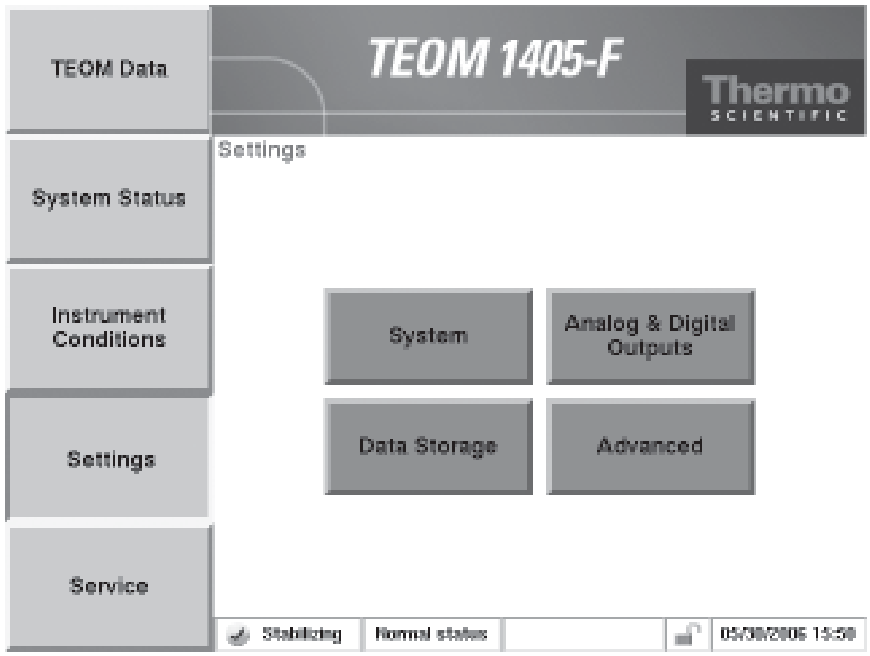
1. Remove the TEOM sample filters.
2. Perform the Cooler Cleaning as instructed in Secion 5.
3. Change the Cooler temperature from 4° C to 10° C.
4. Install new TEOM Sample filters.

The instrument is now ready to sample at the new FDMS cooler temperature. When changing the cooler temperature setting from 10° C to 4° C, these steps are not necessary.

Settings Screen

The **Settings** button displays the Settings screen (Figure 4-17), and provides access to system, data and advanced settings for the instrument.

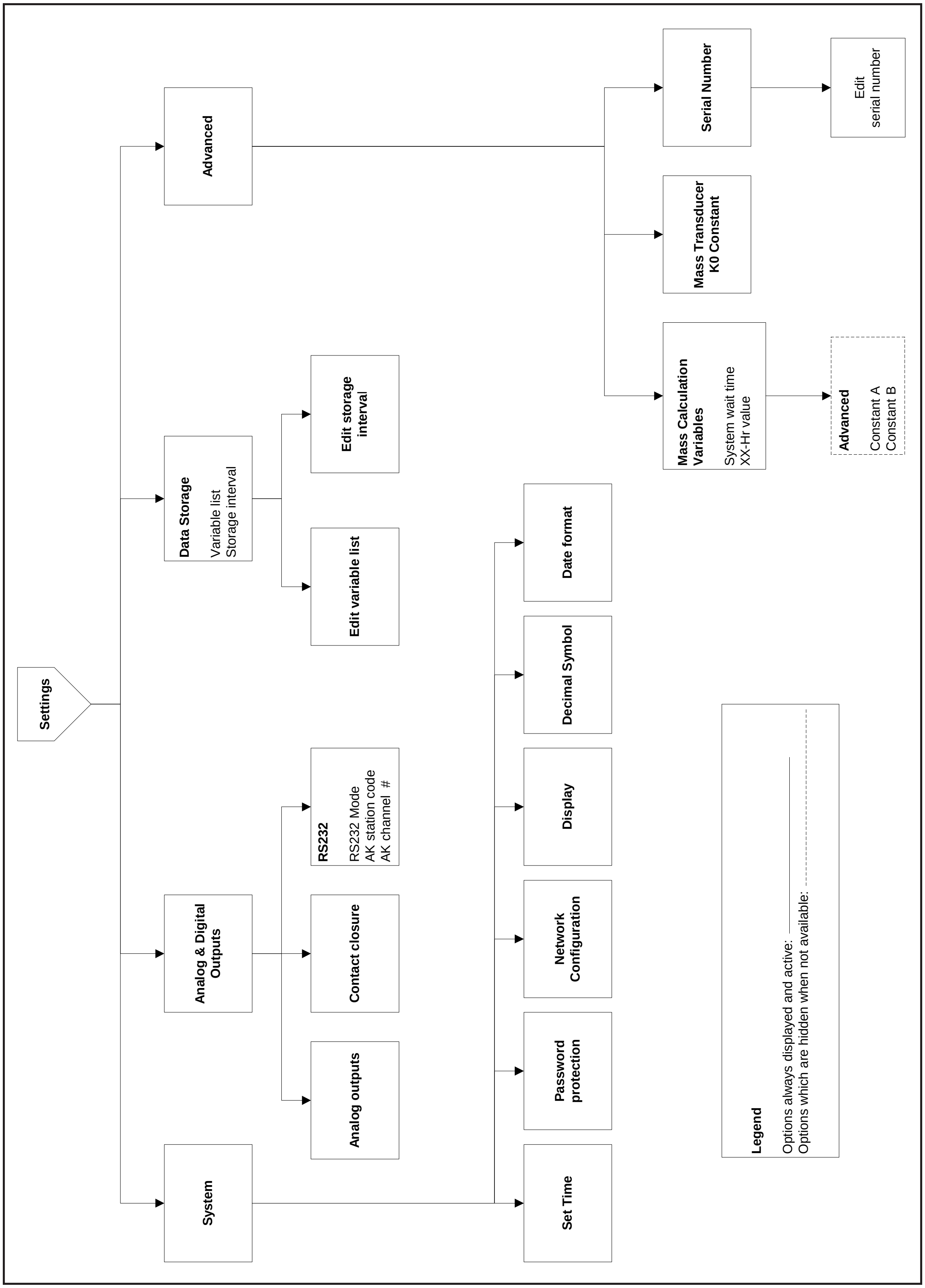
Figure 4-17.
Settings screen.



When in the Settings screen, select the **System**, **Analog & Digital Outputs**, **Data Storage** and **Advanced** buttons to reach the desired screens (Figure 4-18).

Note. Refer to Section 3 for information on using the Data Storage button to select variables for data storage. ▲

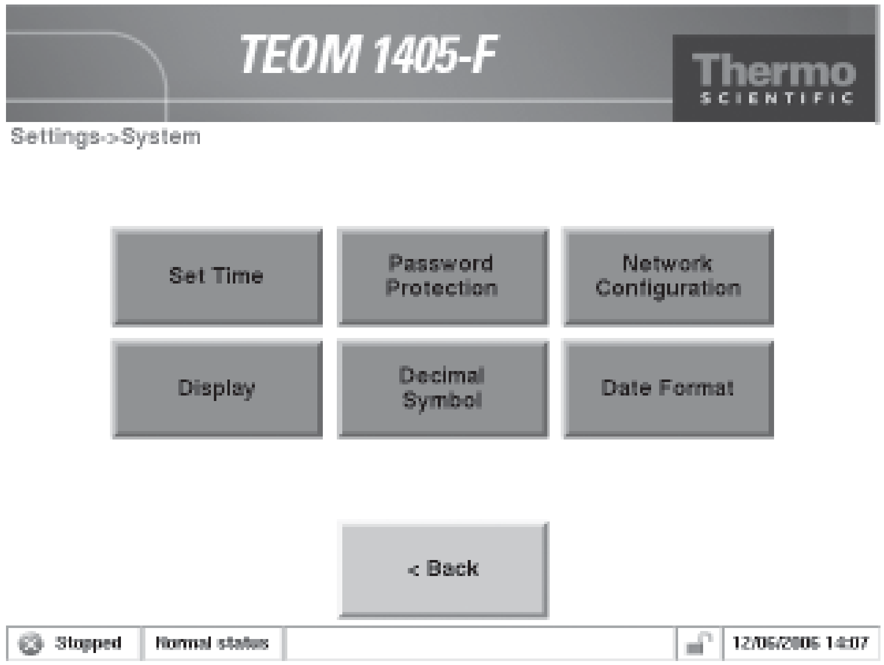
Figure 4-18.
Screens accessible through the Settings button.



System Screen

The System screen (Figure 4-19) allows users to set the basic configuration of the unit.

Figure 4-19.
System screen.



When in the System screen:

- *Set Time*. Select the **Set Time** button to enter the current time and date.
- *Password Protection*. Select the **Password Protection** button to initiate High Lock or Low Lock mode. In Low Lock mode, the user can view all instrument screens and can change the operating mode to perform filter changes. High Lock mode means the user cannot view any screens other than the TEOM Data screen. The user can also set the password using this button.
- *Network Configuration*. Select the **Network Configuration** button to determine whether the unit's Internet Protocol (IP) address will be selected automatically or entered manually. If the user wishes to specify an IP address, the user must enter both the correct IP address and the Subnet mask for the system.
- *Display*. Select the **Display** button to choose the preferred viewing mode of the instrument screen: white background with black text or black background with white text.

- *Decimal Symbol*. Select the **Decimal Symbol** button to choose whether to separate decimal numbers with a period (".") or a comma (","). The unit must be restarted for this change to take effect.

- *Date Format*. Select the **Date Format** button to choose whether to display the date in the "Month/Day/Year" or the "Day/Month/Year" format. The unit must be restarted for this change to take effect.

Analog & Digital Outputs Screen

The Analog & Digital Outputs screen (Figure 4-20) allows users to set the basic parameters of the unit.

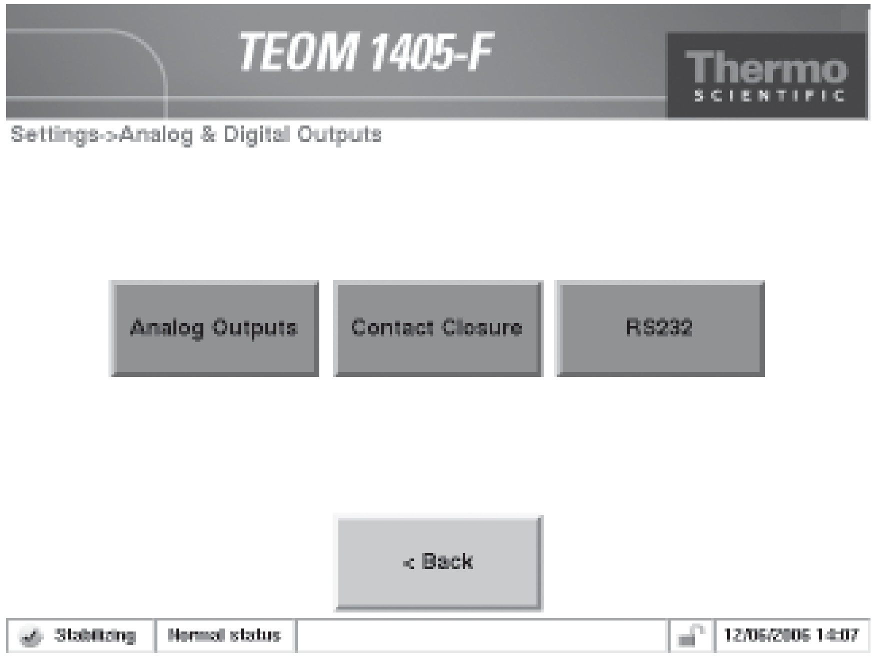


Figure 4-20.
Analog & Digital Outputs screen.

When in the Analog & Digital Outputs screen, select the **Analog Outputs** or **Contact Closure** buttons to set up the analog output and contact closure functions. Select the **RS232** button to set up the unit for serial connections using RPComm or other programs using AK protocol.

Analog Outputs Screen

Select the **Analog Outputs** button to display the Analog Outputs screen (Figure 4-21). In the Analog Outputs screen, use the buttons to select a variable, and set a minimum and maximum value for the output for the desired output channel (1-8). Refer to Section 5 for information on calibrating the analog outputs.

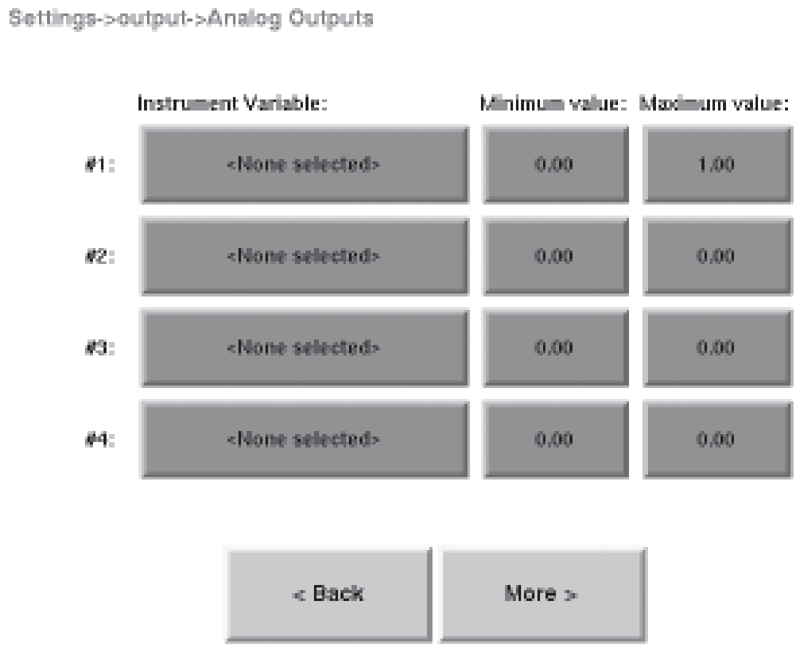


Figure 4-21. Analog Outputs screen.

Contact Closure Screen

Select the **Contact Closure** button to display the Contact Closure screen (Figure 4-22). When in the Contact Closure screen, use the buttons to select a variable, operator and compare value for the desired contact closure channel (1-2).

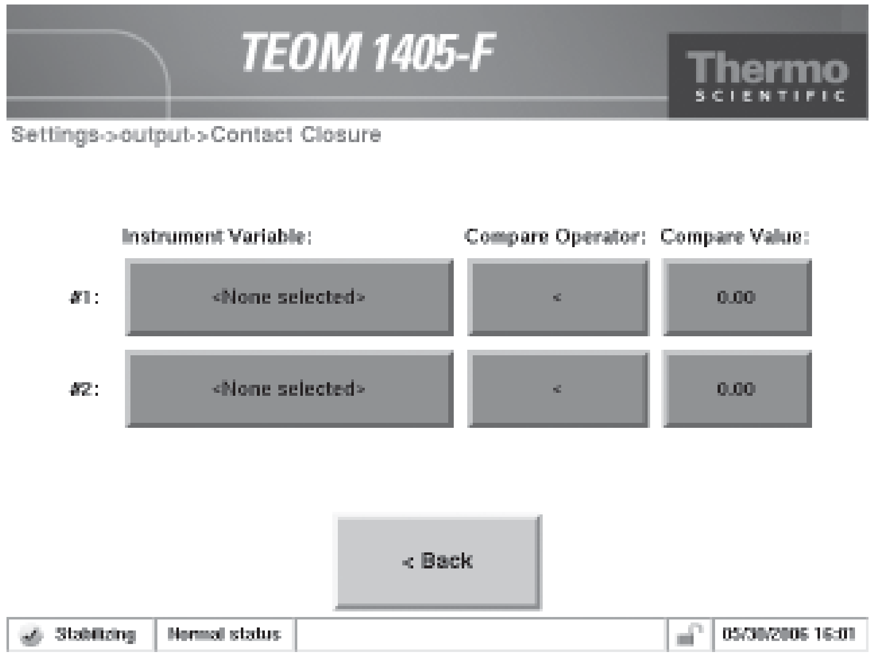
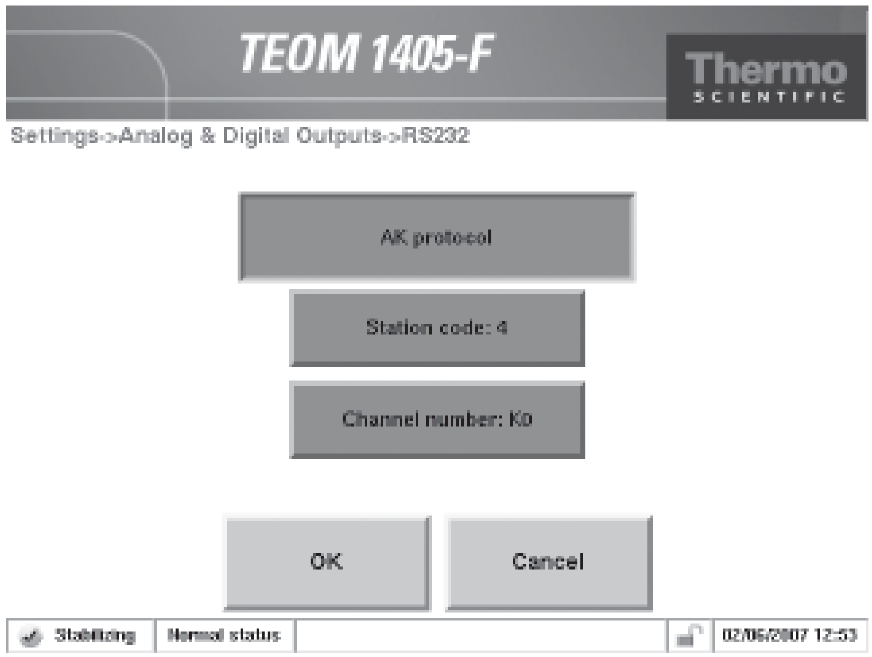


Figure 4-22.
Contact Closure screen.

RS232 Screen

Select the **RS232** button to display the RS232 screen (Figure 4-23). The RS232 screen allows users to set up the serial port for communication with the RP Comm software, or AK protocol.

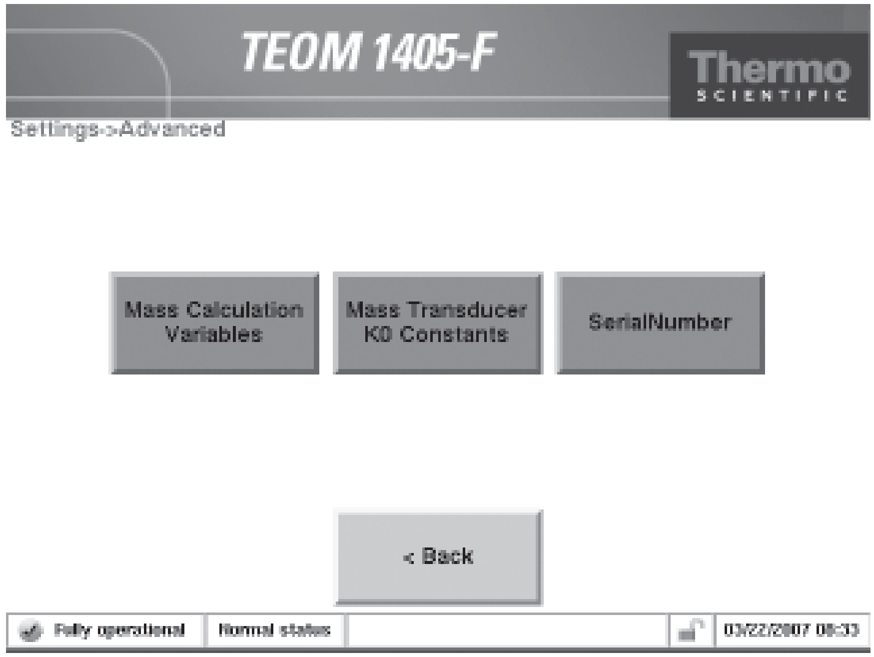
Figure 4-23.
RS232 screen.



Settings Advanced Screen

Select the **Advanced** button to display the Advanced screen (Figure 4-24), which allows users to adjust the advanced settings of the unit.

Figure 4-24.
Advanced Screen



When in the Advanced screen, select the **Mass Calculation Variables**, **Mass Transducer** or **Serial Number** buttons to set advanced frequency parameters and check the K0 constant and serial number.

Select the **Serial Number** button to display the Serial Number screen. The screen shows the instrument's serial number. DO NOT adjust this value.

Select the **Mass Calculation Variables** button to display the Mass Calculation Variables screen.

The Mass Calculation Variables screen contains the following control buttons:

- *System wait time.* This field contains the length of time (sec) in which the temperatures and flow rates must remain (within a range around their setpoints) before the instrument changes from Stabilizing Mode to Collecting Data Mode. The default setting is "1800" seconds. To adjust the setpoint, select the button to display the keypad.

  Note. Thermo Scientific recommends that the user set the "Wait Time" to "1000" or higher to avoid damaging the instrument, and to maintain accurate data reporting. ▲

- *Frequency gate time*. The basis of mass change is raw frequency. Raw frequency is calculated by comparing cycle counts of a highly stable 10 megahertz (Mhz) clock to the cycle counts of the oscillating tapered element (TE). The gate time controls how often the comparisons are made. To adjust the setpoint, select the button to display the keypad. DO NOT adjust this value without contacting Thermo Scientific.

- *Frequency wait time*. This field contains the time interval (sec) after a valve position change before the instrument begins collecting frequency data. The default setting is 90 seconds. To adjust the setpoint, select the button to display the keypad. DO NOT adjust this value without contacting Thermo Scientific.

- *Equivalency Designation*. Equivalency Designation is reserved for future use.

- *XX-Hr MC*. This field contains the XX-Hr MC parameter. This value gives the user a choice of averaging times (hours) shown on the Main screen, following the 1-hour mass concentration average. The default value for this parameter is "8," which causes the monitor to compute 8-hour averages. The user can set an averaging time of any whole hour greater than 1 hour for this parameter. To adjust the setpoint, select the button to display the keypad.

Select the **Mass Transducer K0 Constants** button to display the Mass Transducer K0 Constants screen.

The Mass Transducer K0 Constants screen contains the following information:

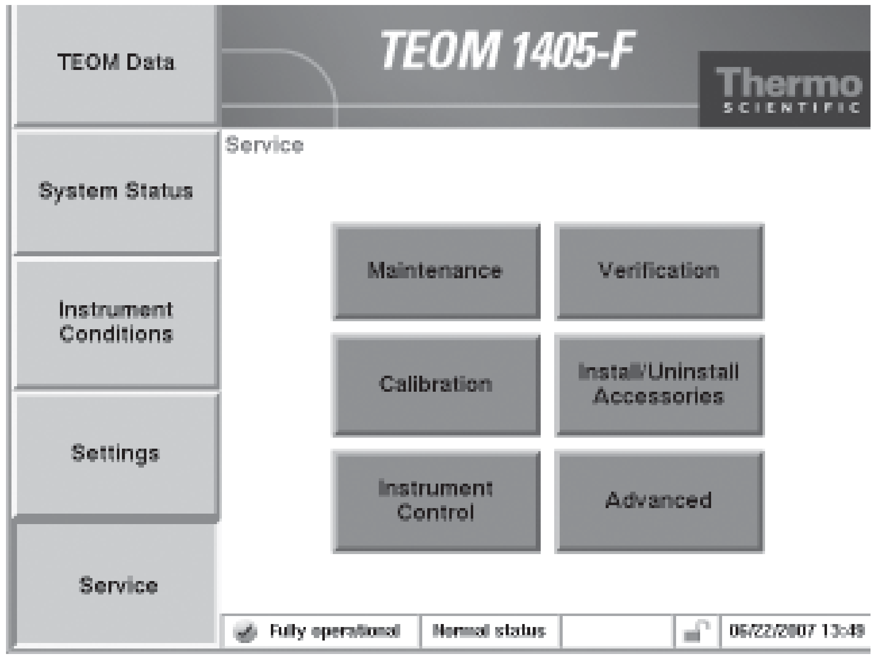
- *TEOM K0*. This field contains the calibration constant, K_0 (K0) (Section 1), for the TEOM.

Note. You can find your monitor's K0 number on the label located near the mass transducer. Each TEOM 1405 monitor has a unique K0 for the TEOM in the unit. The constant listed in the Mass Transducer K0 Constants screen must match the value shown on the label near the mass transducer, or the mass concentration data will be incorrect. To adjust the value, select the button to display the keypad. ▲

Service Screen

The **Service** button displays the Service screen (Figure 4-25) and provides access to maintenance and verification wizards and procedures, as well as advanced troubleshooting and service tools.

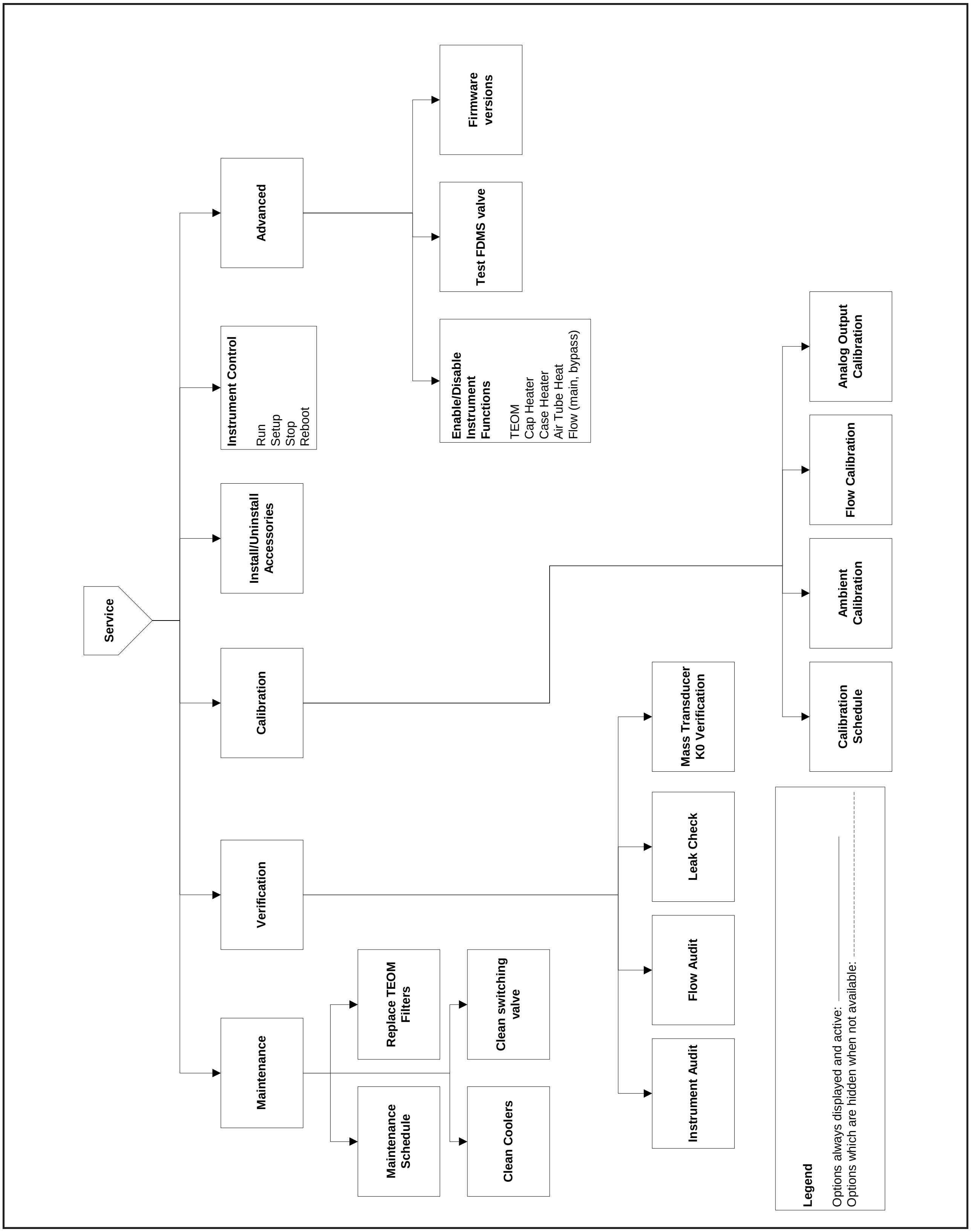
Figure 4-25.
Service screen.



When in the Service screen, select the **Maintenance**, **Verification, Calibration**, **Install/Uninstall Accessories, Advanced** and **Instrument Control** buttons to reach the desired screens (Figure 4-26).

Note. Refer to Section 5 for information on the Maintenance, Verification, Calibration, Install/Uninstall Accessories screens and other screens accessible through those buttons. ▲

Figure 4-26.
Screens accessible through the Service screen.



Instrument Control Screen

Select the **Instrument Control** button to display the Instrument Control screen (Figure 4-27). The Instrument Control screen allows users to change the unit operating mode and restart or shut down the instrument..

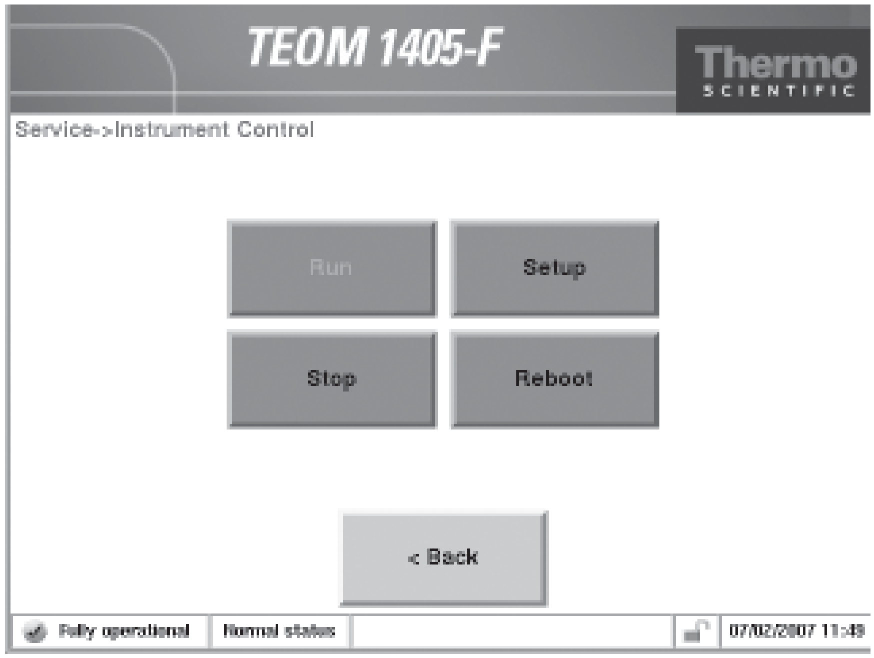


Figure 4-27.
Instrument Control screen.

When in the Instrument Control screen, select the **Run**, **Setup**, **Stop**, or **Reboot** buttons to change the instrument operating mode.

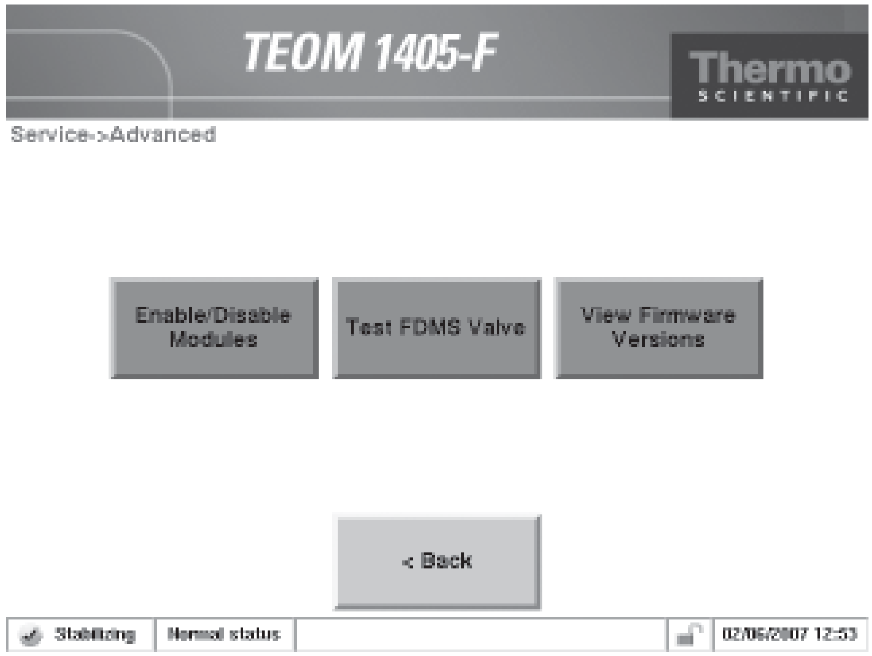
The Instrument Control screen contains the following control buttons:

- *Run*. This button returns the instrument to normal operating mode (Fully Operational). Refer to the beginning of this section for more information on operating modes.
- *Setup*. This button manually puts the instrument in Setup Mode. Refer to the beginning of this section for more information on operating modes.
- *Stop*. This button manually puts the instrument in Stop All Mode. Refer to the beginning of this section for more information on operating modes.
- *Reboot*. This button IMMEDIATELY restarts the instrument. Pressing the button returns the unit to Stabilizing Mode and will require the full warm-up period before restarting data collection

Service Advanced Screen

Select the **Advanced** button to display the Advanced screen (Figure 4-28). The Advanced screen allows users to manually adjust the status, temperatures or flows of several instrument components.

Figure 4-28.
Advanced screen.



Only qualified service personnel should attempt to adjust these settings. Contact Thermo Scientific before adjusting any of these settings.

Installing New Firmware

If the instrument needs new firmware, there are two methods that can be used to update the instrument; using the ePort software or by using a USB flash drive. Refer to Section 3 for information on installing and starting the ePort software. New versions of the TEOM 1405 instrument software are periodically made available either on computer CD or in the online library on the company website at www.thermo.com/aqi.

The next section provides instructions on installing new firmware via ePort. Refer to the following section for installing software via USB.

To install new firmware using ePort:

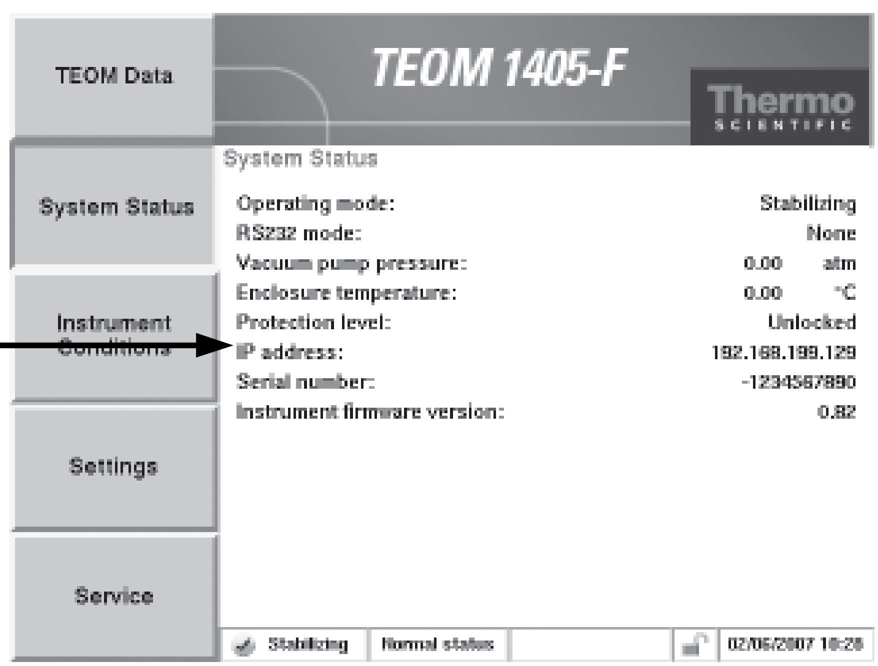
1. Download the new firmware file onto a personal computer (PC) from the company website or locate the updated version on the software CD. Note the file name.

2. Ensure that the PC and the instrument are connected to the same network using the Ethernet connection on the back of the instrument. (Refer to Section 3 for information on connecting the instrument to a network.)

3. In the System Status screen of the machine you want to update, locate and record the IP address (Figure 4-29).

Figure 4-29.
System Status screen.

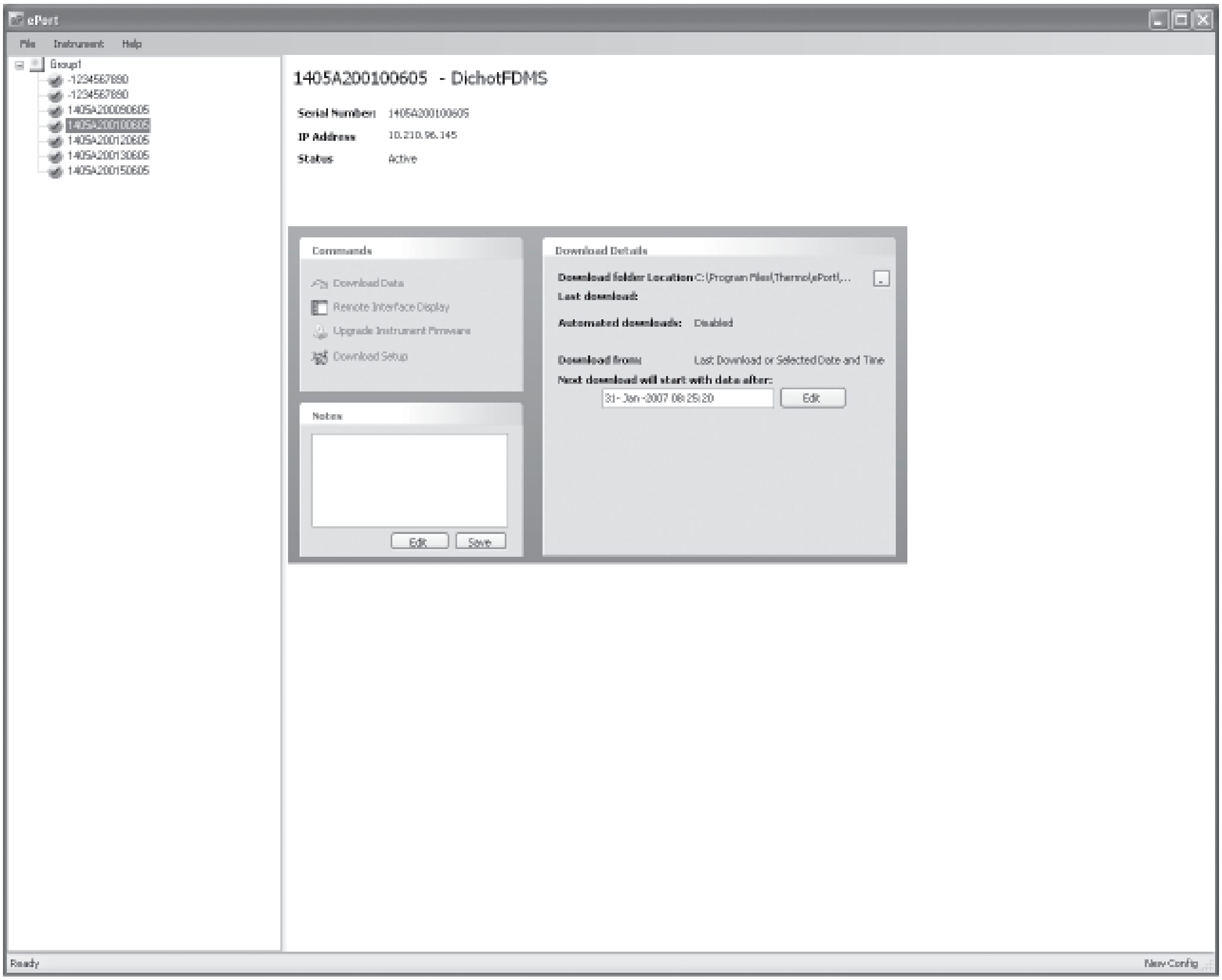
IP address



4. Use the ePort PC software to connect to the instrument (refer to Section 3 for information on connection to the instrument.)

5. In the ePort Main screen (Figure 4-30), select Upgrade Instrument Software.

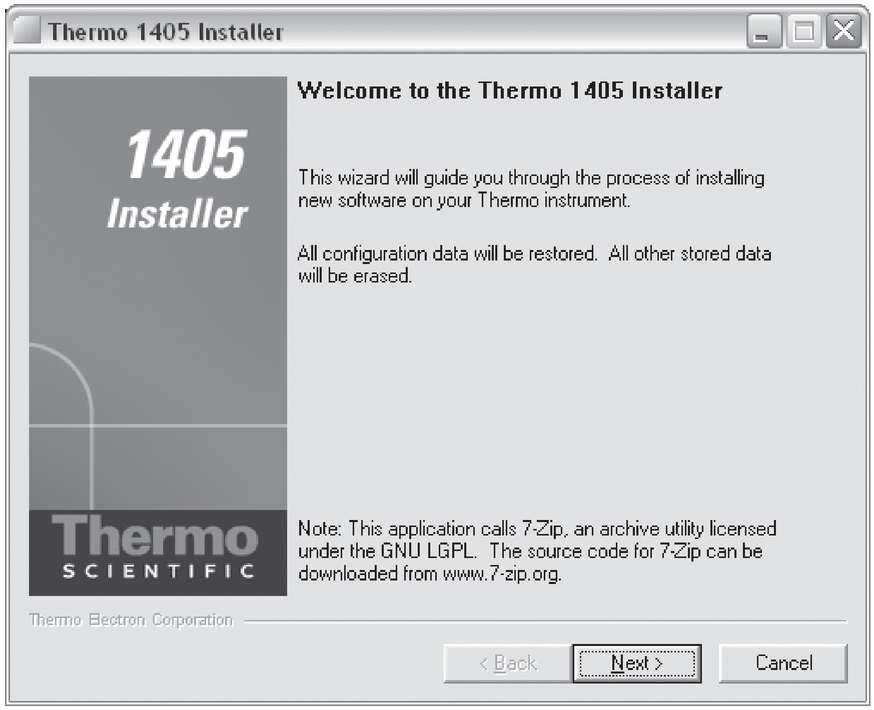
Figure 4-30.
ePort Main screen.



Note. Data will not be collected during the upload procedure and the instrument will be restarted. ▲

6. The Thermo 1405 Installer Wizard screen will display (Figure 4-31). Select the **Next >** button.

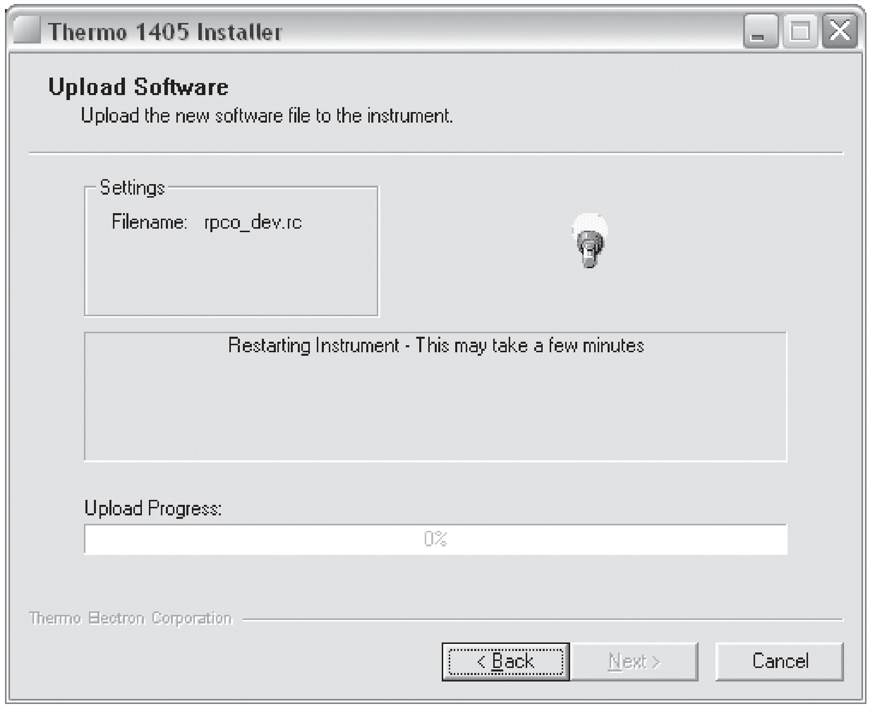
Figure 4-31.
Thermo 1405 Installer screen.



7. The Software File screen will display. Select the Browse button to locate and select the file from the CD or the file that was downloaded from the company website. For firmware updates using ePort, the file is named etx.dichotFDMS_ePort.rc. When the file is selected, it will display in the window below "Choose the File to Upload." Select the **Next >** button.

8. The Upload Software screen will display (Figure 4-32). The software will restart the instrument then install the firmware. The "Upload Progress" bar will show the status of the upload. When the process is complete, select the **Next >** button.

Figure 4-32.
Upload Software screen.



Note. It may take several minutes to upload the new firmware, depending on the speed of the uploading PC and the speed of the network. During the upload, the TEOM 1405 instrument touch screen will display a text message, then a scrolling cursor to indicate progress. ▲

9. The Software Upload Completed screen will display (Figure 4-33). Select the Finish button. Close ePort and return to normal operation.

Figure 4-33.
Software Upload Completed screen.

Note. The instrument will restart automatically after the firmware is uploaded. ▲

To install new firmware using a USB Flash Drive:

> **Note**. In order to update the instrument firmware via the USB port, current instrument firmware version 1.51 or later is required to be installed on the monitor. Contact Thermo Fisher Scientific for further information if an earlier version is installed. If updating the firmware using ePort, this limitation does not apply. ▲

To perform a firmware upgrade using the USB port, first copy the firmware upgrade files to the root folder of a standard USB flash drive. The required files are:

etx_singleFDMS.tar
etx_singleFDMS.kernel
etx_singleFDMS_USB.rc

1. Record all important configuration information from the instrument. This includes K0 values, instrument serial number, data storage settings, etc.

2. Turn off the instrument.

3. Open the front panel that contains the instrument display.

4. Compare the inside of the instrument to the following figure. If the instrument interface board matches the figure, proceed to step 4. If the unit is an updated version, close the front panel and continue with step 6. An updated interface board includes the text "Thermo Fisher Scientific" along the front edge of the board.

5. Locate the Module power Jumper on the interface board as indicated in Figure 4-34 and install a jumper across the pins. (One of the analog input jumpers may be temporarily used for this purpose.)

6. Insert the USB Flash Drive and turn on the instrument power.

7. The instrument will automatically locate and install the necessary files from the USB flash drive and update the instrument firmware.

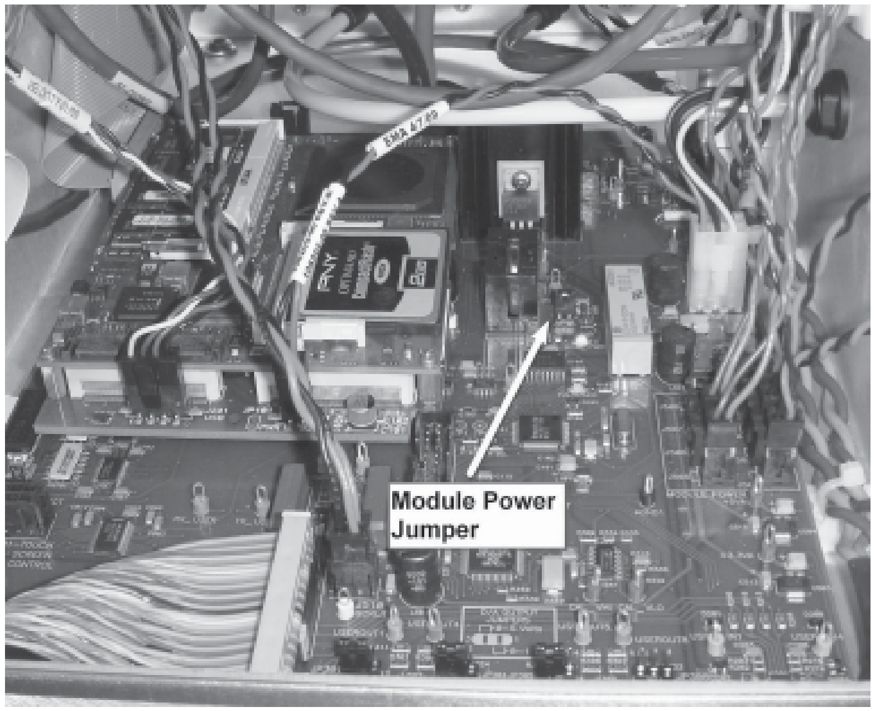
8. At the end of the update process, the instrument will pause for 20 seconds before a blank/white screen appears. Remove the USB Flash Drive. The instrument will reboot automatically to complete the installation of the firmware.

9. If you installed a jumper in step 4 above, turn off the instrument power and remove the jumper. If one of the analog input jumpers was used, replace it in the original location. Close the instrument front panel and turn on the instrument power.

10. Verify the instrument settings were retained, including serial number and K0. Re-enter these values if necessary.

11. Thermo Fisher Scientific recommends performing a calibration of the instrument temperatures, pressure and flows after a firmware update. Refer to Section 5 for calibration instructions.

Figure 4-34.
Interface Board.



Section 5 Maintenance and Calibration Procedures

Periodic Maintenance

Thermo Fisher Scientific recommends the following regular maintenance procedures for the TEOM 1405-F:

Replace/Refurbish the dryer	Replace/Refurbish the FDMS dryer once a year, or as necessary. See page 5-3.
Replace the TEOM filter	Replace the TEOM filter when the filter loading percentage (displayed in the Main screen) nears 100% or every 30 days.
Replace the 47 mm filter	Replace the 47 mm filter every time you replace the TEOM filter (every 30 days).
Clean the sample inlet	Clean the sample inlet that is mounted on the tripod each time that you replace a TEOM filter (every 30 days).
Replace the in-line filters	Replace the main flow in-line filter and the bypass in-line filter every 6 months, or as necessary.
Clean the cooler	Clean the cooler once a year, or as necessary.
Clean the switching valve	Clean the switching valve once a year, or as necessary.
Clean the air inlet system	Clean the air inlet system inside the mass transducer once a year, or as necessary.
Rebuild the sample pump	Rebuild the sample pump once every 18 months, or as necessary. The pump rebuild kit (59-008630) contains instructions for rebuilding the pump.

These maintenance intervals are guidelines. Requirements for routine maintenance are site-specific, and may vary from one location to another.

Maintenance Wizards

The TEOM 1405 software allows users to step through the periodic maintenance procedures. Select the **Service** button to display the Service screen. When in the Service screen, select the **Maintenance** button to display the Maintenance screen.

Figure 5-1.
TEOM Data screen.

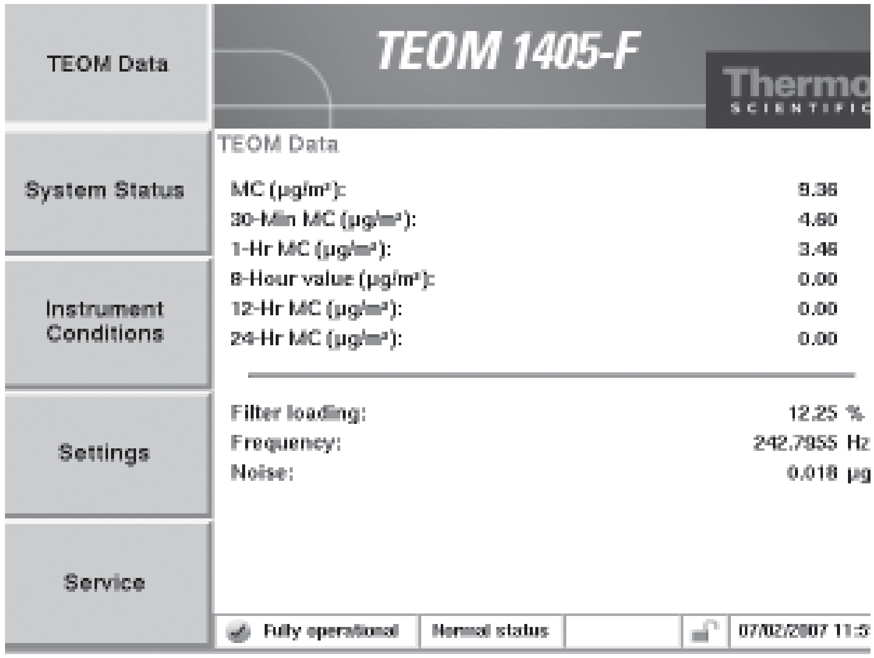


Figure 5-2.
1405 Service screen.

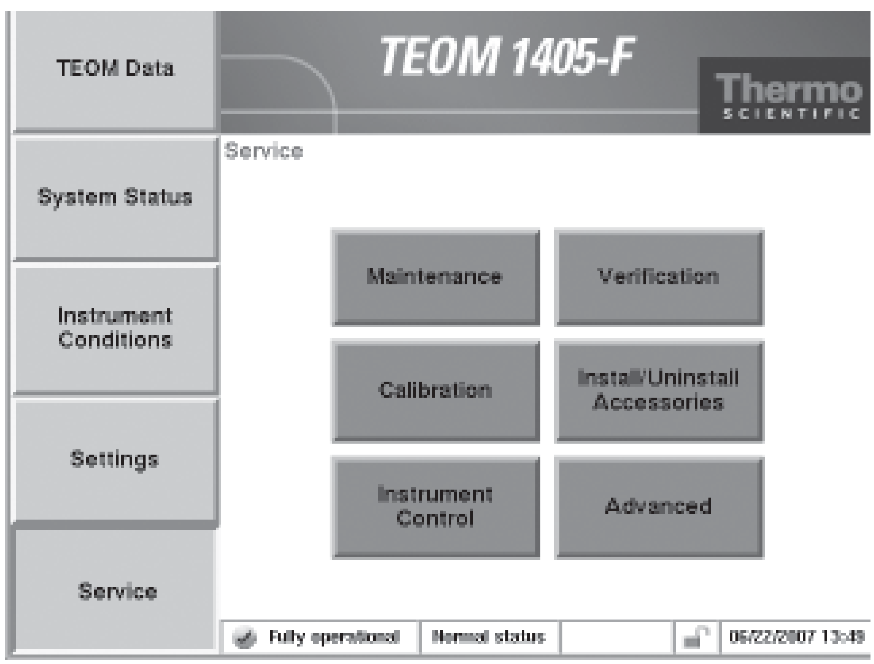
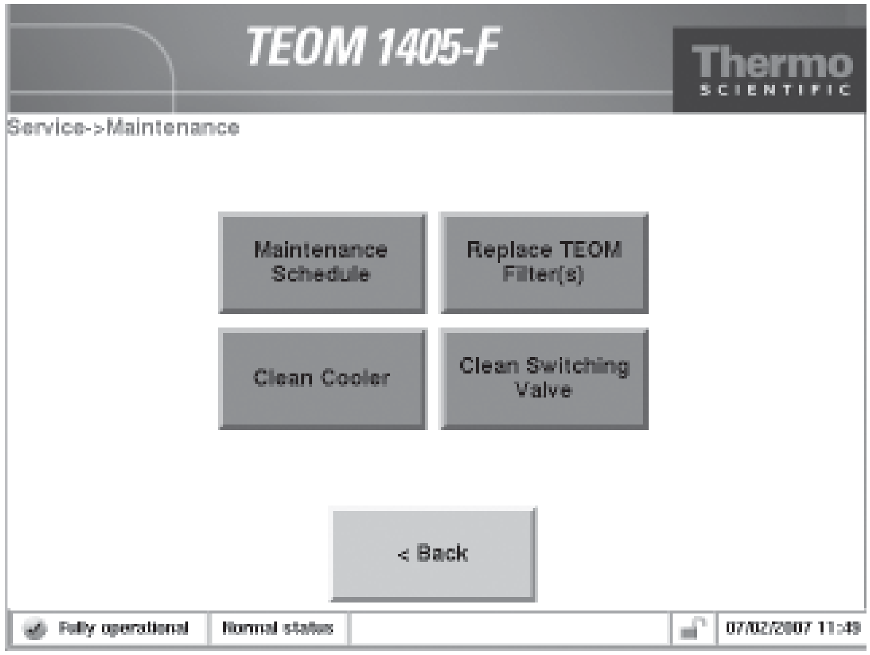


Figure 5-3.
1405 Maintenance screen.



FDMS Dryer Replacement/ Refurbishment

Thermo Fisher Scientific recommends an annual dryer replacement/ refurbishment for the FDMS dryers installed in the 1405-F TEOM Series. This refurbishment (75-010965) is to minimize sampling artifacts that could effect the measurement of total mass concentration over time. The refurbishment consists of cleaning and any necessary replacement of parts. Contact Thermo Fisher Scientific's Service Department.

TEOM Filter Replacement

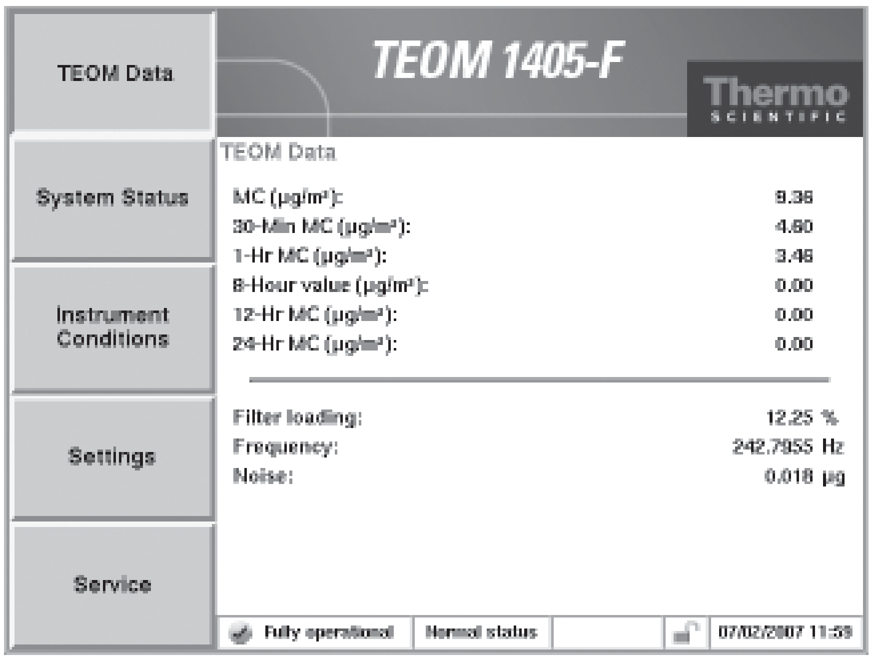
The Series 1405 TEOM filter needs to be changed periodically before filter loading can affect the flow, or at least every 30 days.

Note. Change the filter at least every 30 days. ▲

Filter Loading

The filter loading percentage value indicates the percentage of the TEOM filter's total capacity that has been used. You can check the TEOM filter loading percentage on the monitor's TEOM Data screen (Figure 5-4). Because this value is determined by the pressure drop of the main sample flow line, the instrument always shows a non-zero value even if no TEOM filter is mounted in the mass transducer. New TEOM filters generally exhibit filter loading percentages of 15% to 30% at a main flow rate of 3 l/min, and less at lower flow rates.

Figure 5-4.
TEOM Data screen.



TEOM filters must be replaced before the filter loading percentage reaches 100% to ensure the quality of the data generated by the instrument. At some point above 100%, the main flow drops below its set point.

If the filter loading percentage is higher than 30% (at a main flow rate of 3 l/min) when a new TEOM filter is placed on the mass transducer, or if the lifetime of consecutive TEOM filters becomes noticeably shorter, you may need to replace the in-line filter. Refer to "Exchanging the In-Line Filters" later in this section.

Filters should be stored inside the unit for easy access and to keep them dry and warm.

TEOM filter life depends upon the nature and concentration of the particulate matter sampled, as well as the flow rate settings. TEOM filters must be replaced when the filter loading value approaches 100%. This generally corresponds to a total mass accumulation on the filter of approximately 3-5 mg. TEOM filter life at a main flow rate of 3 l/min is generally 21 days at an average PM-10 concentration of 50 μg/m^3. TEOM filter life is longer at lower flow rates because the particulate matter accumulation on the TEOM filter is slower.

TEOM filters must be replaced before the filter loading percentage on the status line of the Main screen reaches 100%. When the filter loading percentage is greater than 90%, the unit will trigger a status condition. You must replace the 47 mm filter every time that you replace a TEOM filter.

Note. Do not handle new TEOM filters with your fingers. Use the filter exchange tool provided with the instrument to replace filters. ▲

Changing the TEOM Filters

To install a TEOM filter:

1. Ensure that the filter exchange tool is clean and free of any contamination that might be transferred to the TEOM filter.

2. In the 1405 TEOM Data screen, select the **Service** button to display the Service screen, then select the **Maintenance** button to display the Maintenance screen (Figure 5-3).

3. Select the **Replace TEOM Filter** button to start the TEOM Filter Replacement Wizard (Figure 5-5). Select the **Next >** button to begin the procedure.

   Note. If you are an experienced user and comfortable with changing TEOM filters, select the **Advanced User Mode** button to stop the movement of the mass transducer and proceed with a quick exchange procedure. Refer to the next section for a complete explanation of the Advanced User Mode for filter changes. ▲

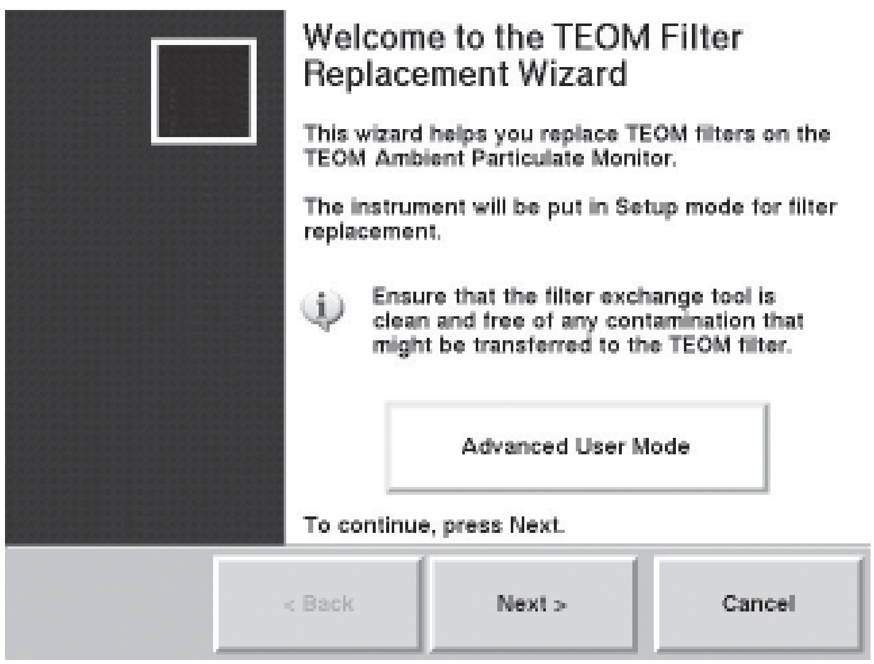


Figure 5-5. TEOM Filter Replacement Wizard starting screen.

4. The Open Mass Transducer screen will display. Open the door of the sampler.

5. Pull the TEOM latch toward you to open the transducer latch.

6. With the mass transducer unlatched, swing the bottom of the mass transducer downward, exposing the tapered element (TE) (Figure 5-6). Select the **Next >** button.

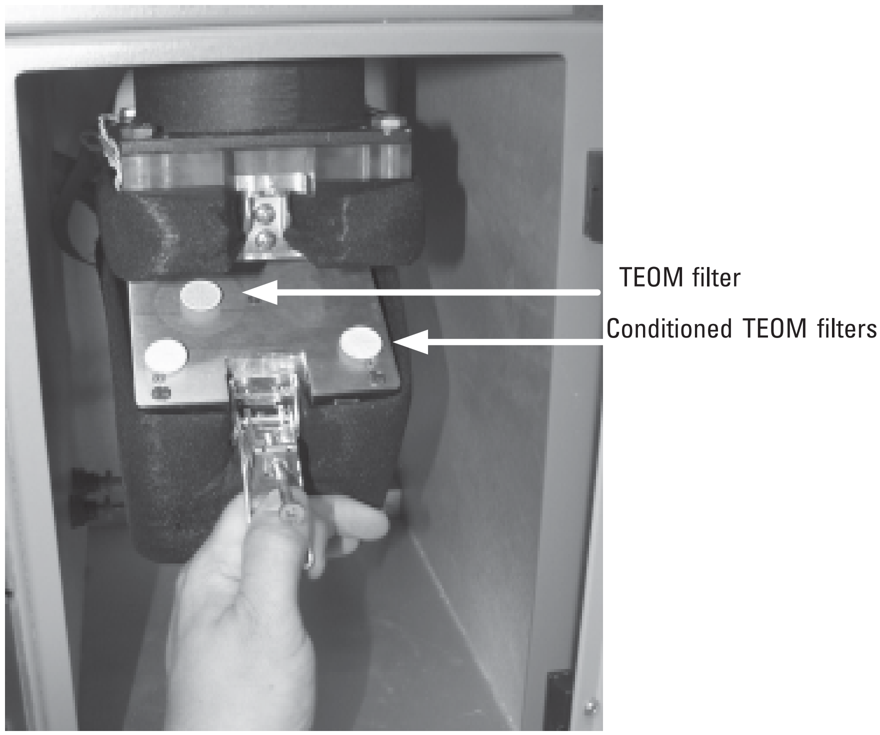


Figure 5-6.
Opening the mass transducer.

7. The Remove Old Filter screen will display. Carefully insert the lower fork of the filter exchange tool under the used TEOM filter so that the filter disk is between the fork and the upper tab of the filter exchange tool (Figure 5-7). The tines of the fork should straddle the hub of the filter base.

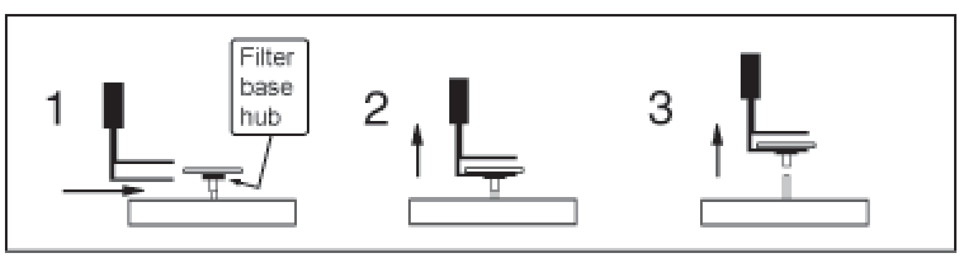


Figure 5-7.
Opening the mass transducer.

8. Gently pull straight up, lifting the TEOM filter from the tapered element (TE). Do not twist or tilt the filter exchange tool from side-to-side while removing the filter from the TE. This will damage the TE.

9. The Replace Filter screen will display. Pick up a new, conditioned TEOM filter from one of the filter holders with the filter exchange tool so that the filter disk lies between the fork and the upper tab of the tool and the hub of the filter lies between the tines of the fork (Figures 5-8 and 5-9).

   Note. TEOM filters must be preconditioned to avoid excessive moisture buildup prior to their use in the system. Refer to the next section. ▲

   Note. Do not touch the filter with your fingers while picking it up with the filter exchange tool. ▲

10. Hold the filter exchange tool in line with the tapered element (Figures 5-8 and 5-9) and lightly place the hub of the filter onto the tip of the tapered element. Select the **Next >** button.

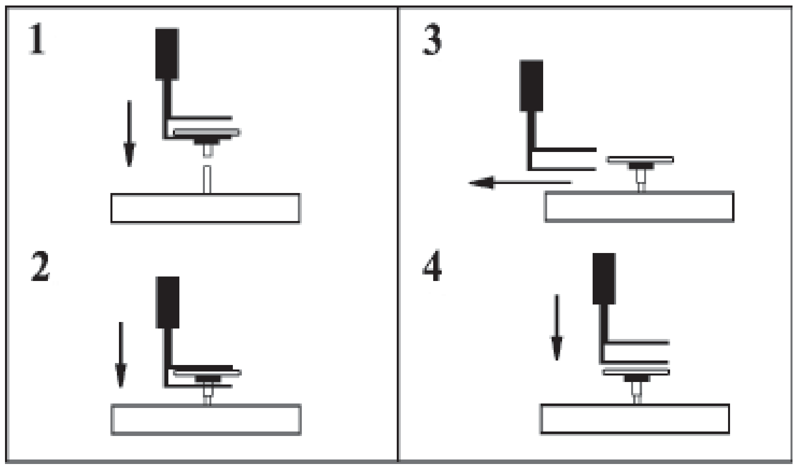
Figure 5-8.
Placing the filter on the tapered element.

11. The Seat Filter screen will display. Gently press down on the TEOM filter to ensure that it is seated properly (Figure 5-9).

12. Remove the filter exchange tool by slowly retracting it until it clears the filter (Figure 5-9). Do not disturb the filter.

13. Place the bottom of the filter exchange tool on top of the TEOM filter (Figures 5-9) and apply downward pressure (approximately 0.5 kg or 1 lb) to seat the filter firmly in place.

Figure 5-9.
Placing the filter on the tapered element.



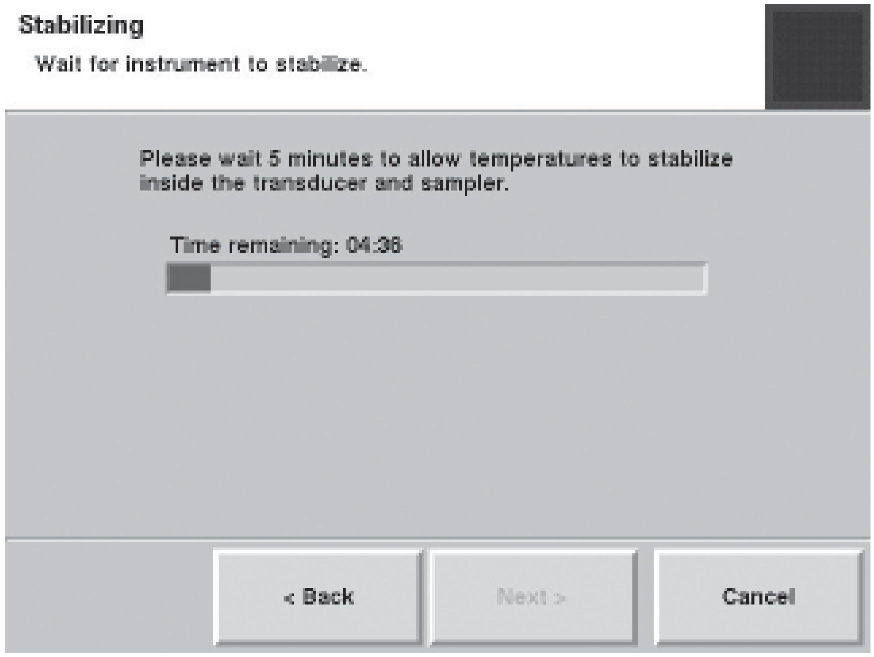
14. The Precondition Filter screen will display. Place a new TEOM filter on the empty conditioning post on the mass transducer. (Refer to the next section for more information on conditioning filters.) Select the **Next >** button.

15. The Close Instrument screen will display. Raise the mass transducer to the closed position and fasten the holding rod onto the latch plate.

16. Close and latch the door to the sensor unit. Keep the door open for as short a time as possible to minimize the temperature change in the system. Select the **Next >** button.

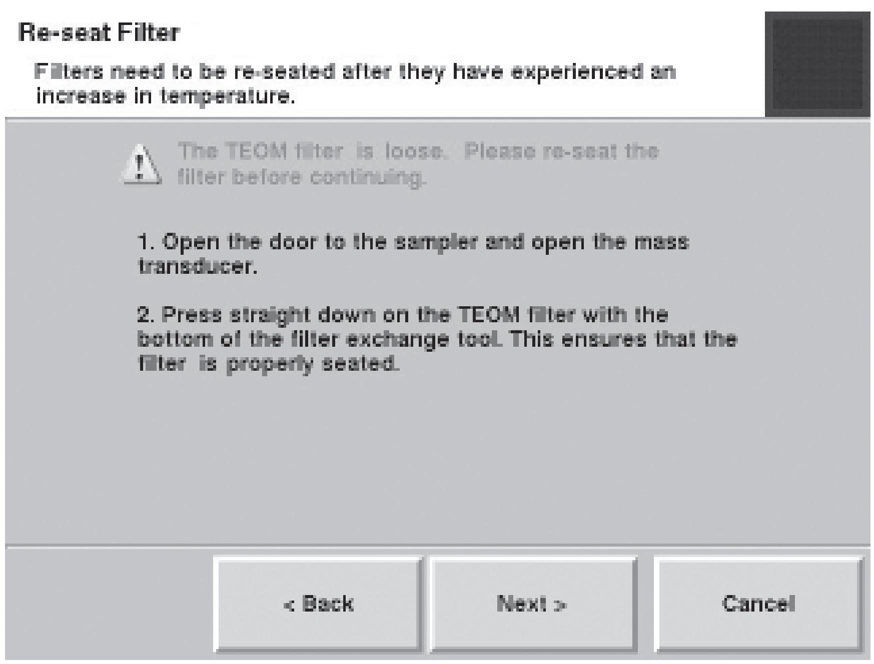
17. The system will automatically test the newly installed TEOM filter to ensure it is firmly seated. The system will display a screen with the wait time (Figure 5-10).

Figure 5-10. Stabilizing screen.



18. If the system is unable to obtain a stable frequency for the filter, it will display a screen stating the filter needs to be re-seated (Figure 5-11). Otherwise, the filter change is complete (go to step 21).

Figure 5-11. Re-seat Filters screen.

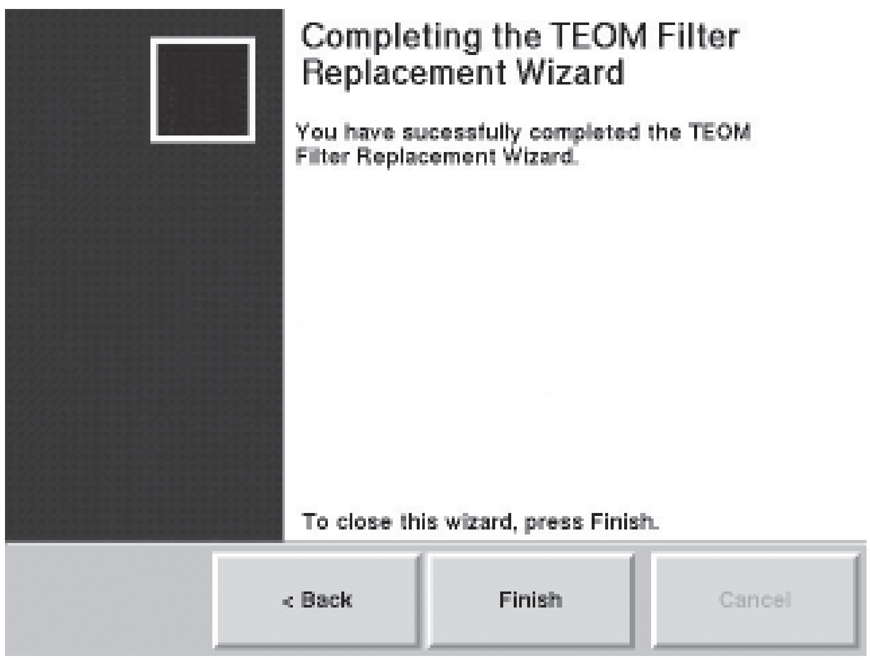


19. If the filter needs to be re-seated, open the door to the sampler and the mass transducer and press straight down on the TEOM filter with the bottom of the filter exchange tool (Figure 5-9). This ensures that the filter is properly seated. Close the mass transducer and sensor unit door. Select the **Next >** button

20. The system will again display the waiting screen while it is testing for a stable frequency. If it still cannot obtain a frequency for the filter, it will prompt the user to re-seat the filter a second time. If it still cannot obtain a stable frequency, the procedure will prompt to replace the filter or post a fail message (Figures 5-13and 14)

21. When the frequency stable, the system will display the Completing the TEOM Filter Replacement Wizard screen (Figure 5-12). Select the **Finish >** button.

Figure 5-12.
Finish screen with successfully completed message.



Note. If the system still cannot detect a stable frequency for the filter, it will display a "filter could be damaged" message, and prompt for replacement of the filter (Figure 5-13). If the system fails to establish the frequency again, the filter change procedure will fail completely and recommend appropriate service (Figure 5-14). ▲

Figure 5-13.
Try Another Filter screen.

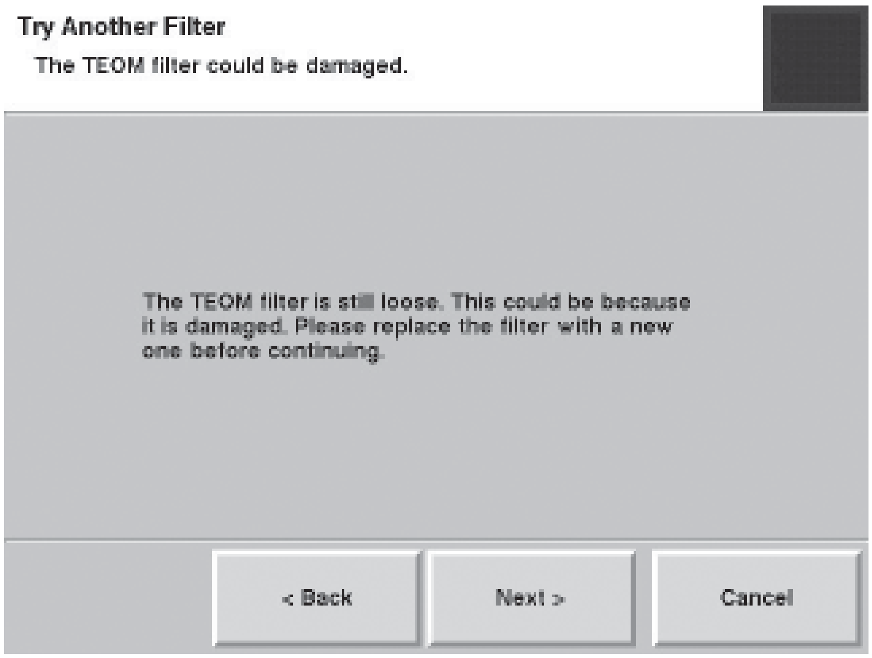
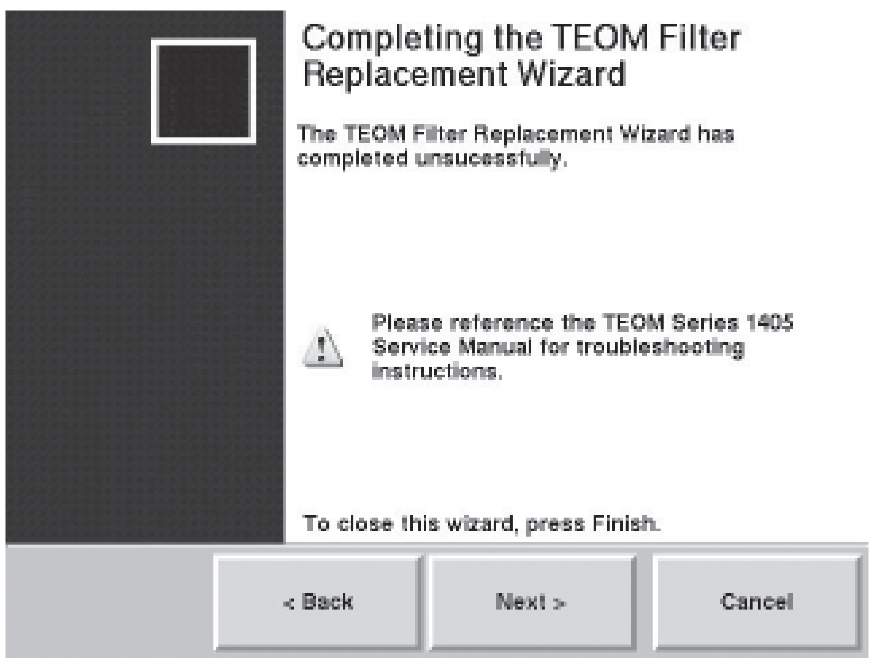


Figure 5-14.
Fail/service message.



Advanced Filter Change

For experienced users who are comfortable with the filter change operation, the monitor offers an advanced filter change mode. When the users selects the advanced mode in the TEOM Filter Replacement starting screen, (Figure 5-5), the system automatically stops the TEOM filter and displays a screen to prompt the filter change operation (Figure 5-15).

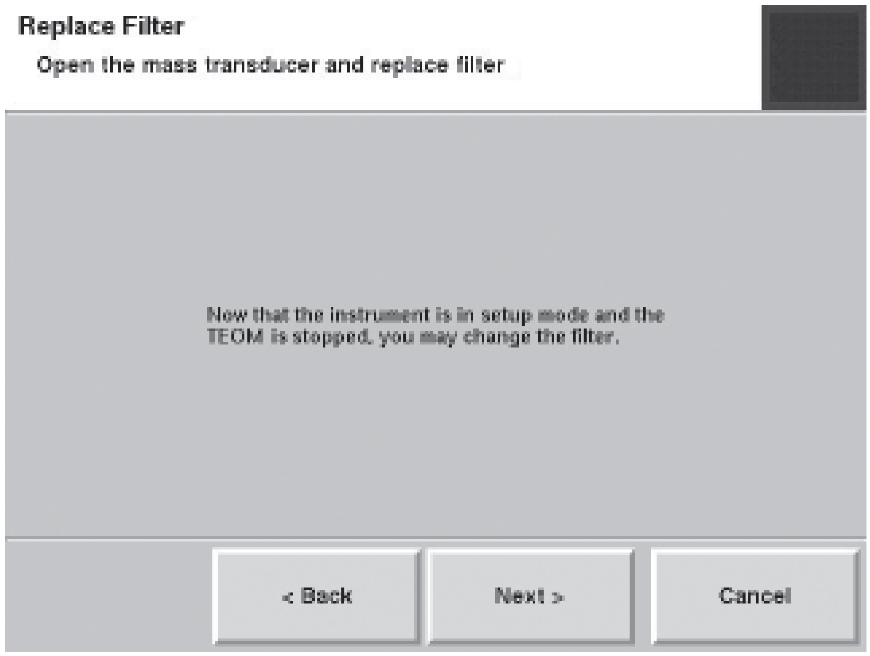


Figure 5-15. Advanced filter change screen.

When the screen displays, change the filters and select the **Next >** button. The finished screen will display (Figure 5-16).

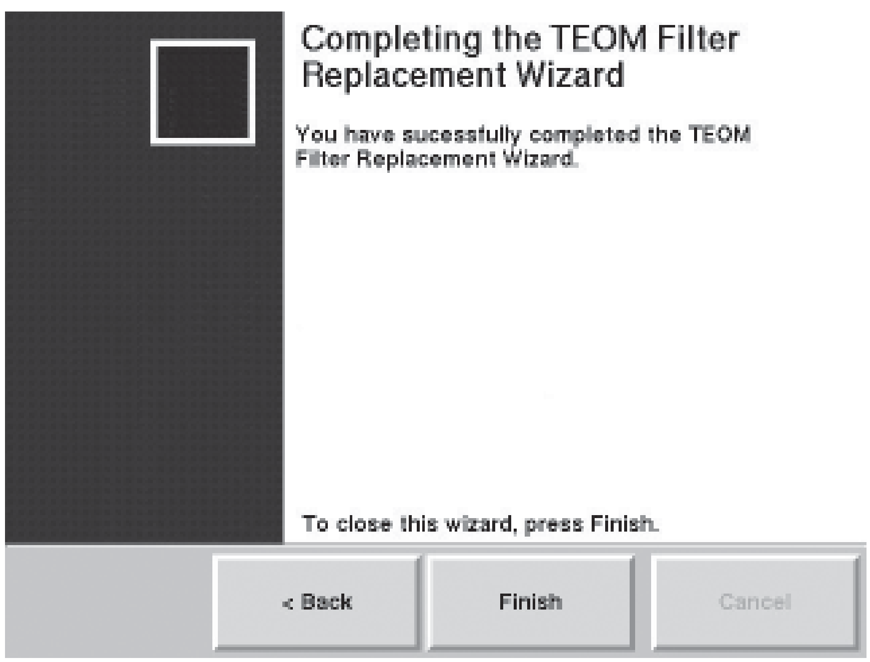


Figure 5-16. Wizard complete message.

Note. The advanced filter wizard DOES NOT automatically check the frequency. Users MUST ensure that the frequency is stable in order to ensure valid test data. Look at the change in the TE's oscillating frequency on the TEOM Data screen (Figure 5-17). The last two digits of the reading will fluctuate (due to noise) and the rest will remain steady. If more than the last two digits fluctuate in this reading, this indicates that the TEOM filter is loose. Re-seat the filter and check the frequency again.

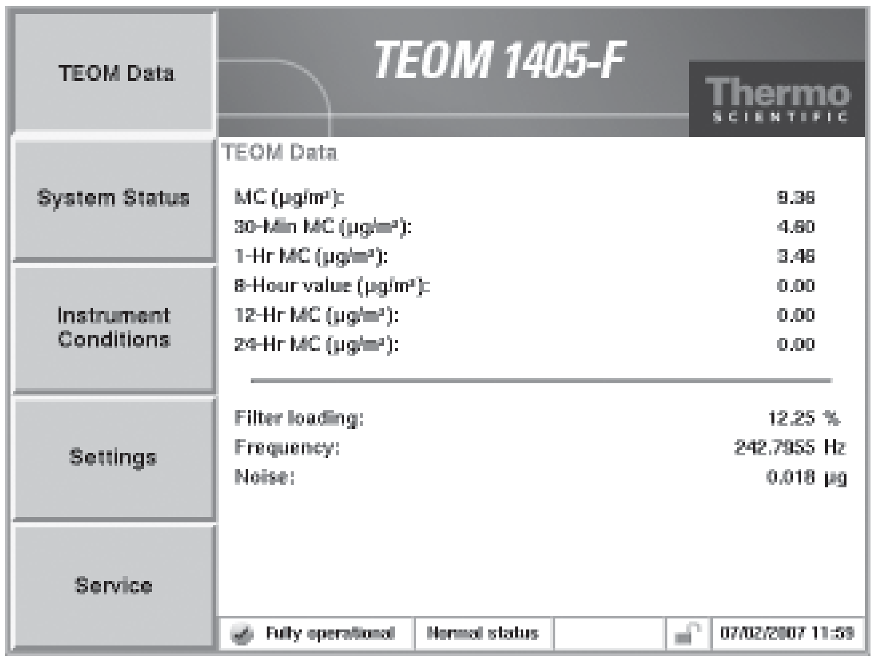


Figure 5-17.
TEOM Data screen.

Conditioning the TEOM Filters

TEOM filters must be preconditioned to avoid excessive moisture buildup prior to their use in the system. The TEOM 1405 has two posts for preconditioning filters.

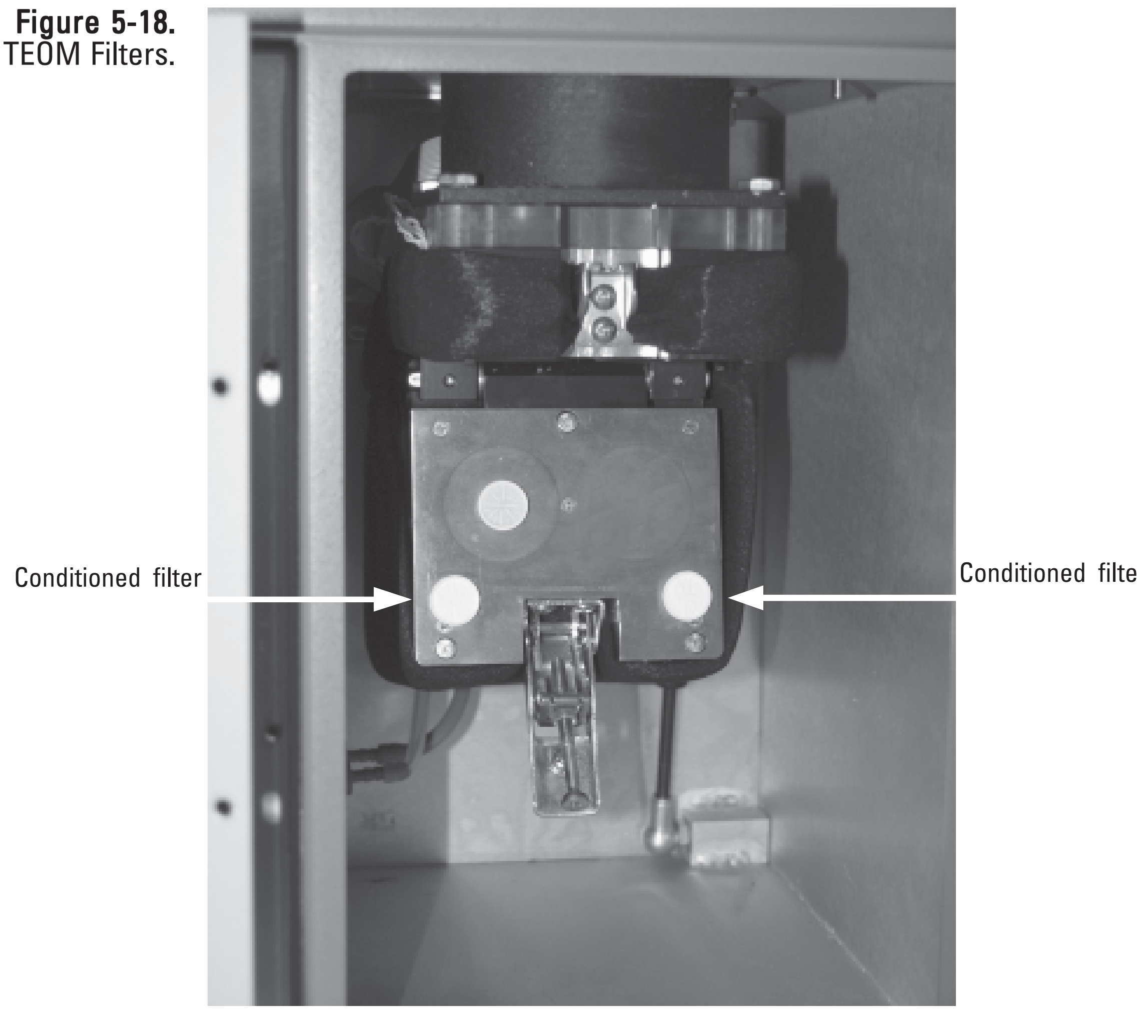
To precondition a TEOM filter:

1. Place two TEOM filters on the TEOM filter holders of the mass transducer (Figure 5-18) to condition the filters.

2. When it is time to install a new TEOM filter, use a conditioned filter from one of the filter holders.

3. Replace the conditioned TEOM filter that was on the filter holder with a new filter.

Figure 5-18.
Conditioned TEOM Filters.



Note. Extra filters should be stored inside the carrier box, in the interior of the unit near the mass transducer to ensure they are at or near the appropriate temperature and humidity level for sampling. ▲

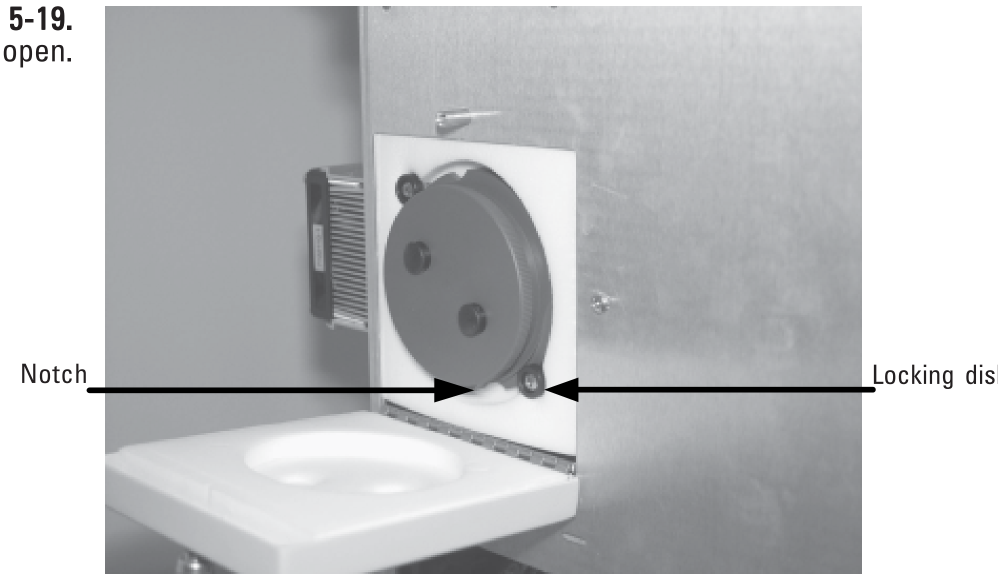
Replacing the 47 mm Filter

Install a new 47 mm filter into the TEOM 1405-F unit before running the first sample run, and every time that you install a new TEOM filter into the unit.

To install the 47 mm filter:

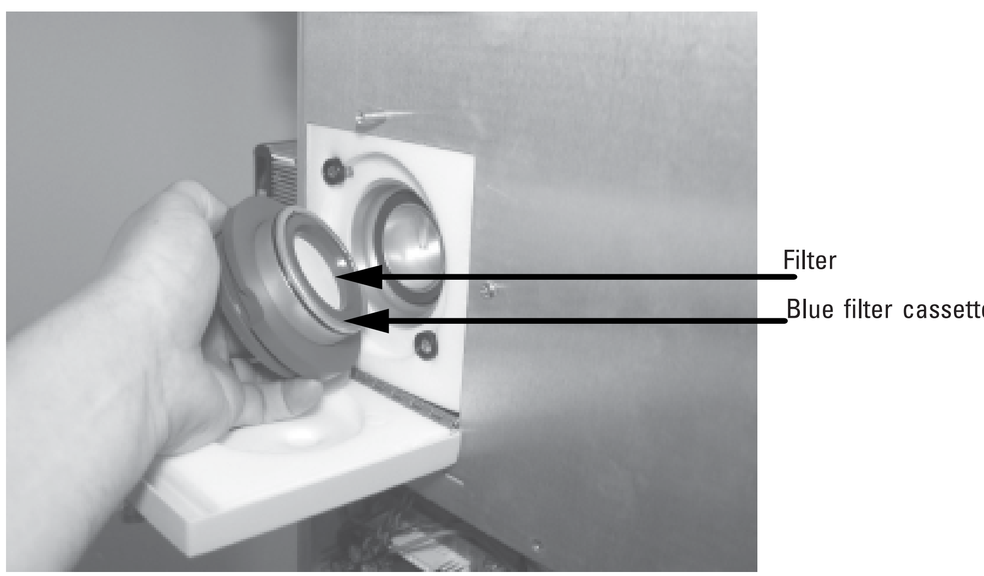
1. Locate the small door on the left side of the TEOM 1405-F unit. Open the small filter door (Figures 5-19).

Figure 5-19. Filter door open.



2. Turn the filter holder counterclockwise until the notches line up with the locking disk (Figure 5-20) and then pull outward to remove the holder from the unit.

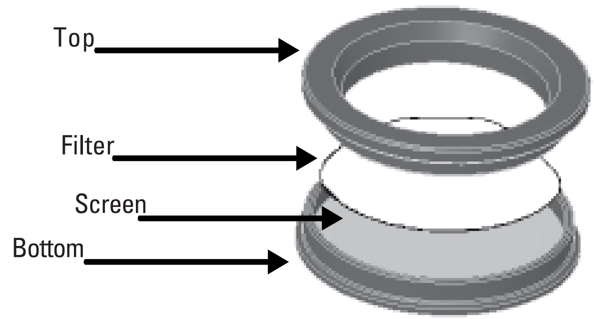
Figure 5-20. Removing the 47 mm filter.



3. Locate blue filter cassette and remove the used 47 mm filter.

4. Insert a new 47 mm filter into the cassette. Be sure to install the 47 mm filter into the cassette with the face of the filter paper facing the "top" of the cassette. The "top" of the cassette fits *into* the "bottom" of the cassette (Figure 5-21).

Figure 5-21.
47 mm filter cassette with filter and screen.



5. Close the filter cassette (Figure 5-22).

Figure 5-22.
Closing the filter cassette.

6. Install the filter into the filter holder with the "top" of the cassette and filter surface facing out.

7. Line up the notches with the locking disks and install the filter holder into unit. Turn the holder clockwise to lock it in place.

   Note. Do not overtighten the filter holder. The O-ring creates the seal, not the force of the turn. ▲

8. Close the small filter door.

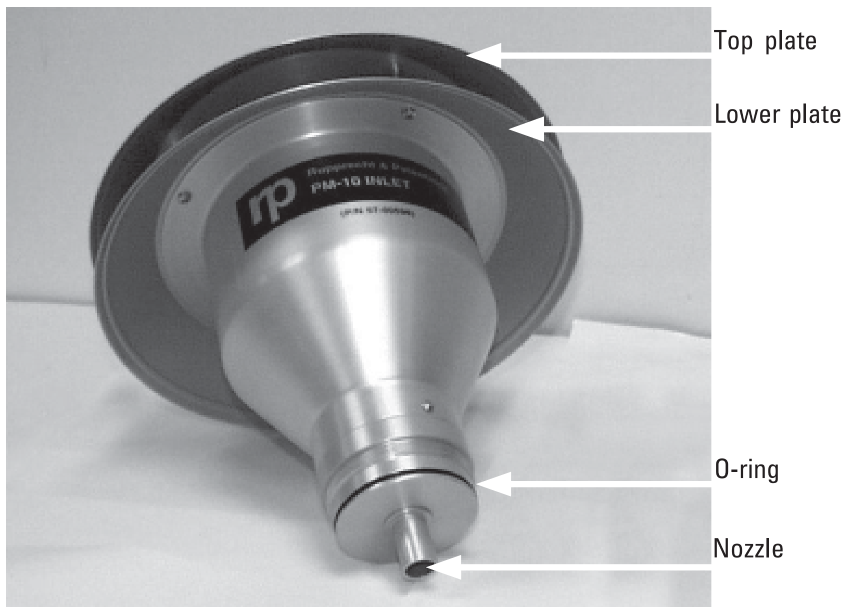
Cleaning the PM-10 Inlet

The PM-10 inlet should be cleaned every time the TEOM filter is changed, or as necessary. To clean the unit you will need an ammonia-based general-purpose cleaner, cotton swabs, a small soft-bristle brush, paper towels, distilled water, silicone-based stopcock grease, a small screwdriver, a small adjustable wrench and a pocket knife

To clean/maintain the PM-10 inlet:

1. Remove rain jar from the inlet and the inlet from the sample tube. Unscrew the top acceleration assembly from the lower collector assembly (Figure 5-23).

Figure 5-23.
Top of inlet assembly.



2. Mark the top plate deflector cone and lower plate with a pencil to facilitate proper orientation when reassembling, then use a Phillips screwdriver to remove the four pan head screws from the top of the top plate (Figure 5-23). Lift the top plate off the four threaded, spacer standoffs and set aside.

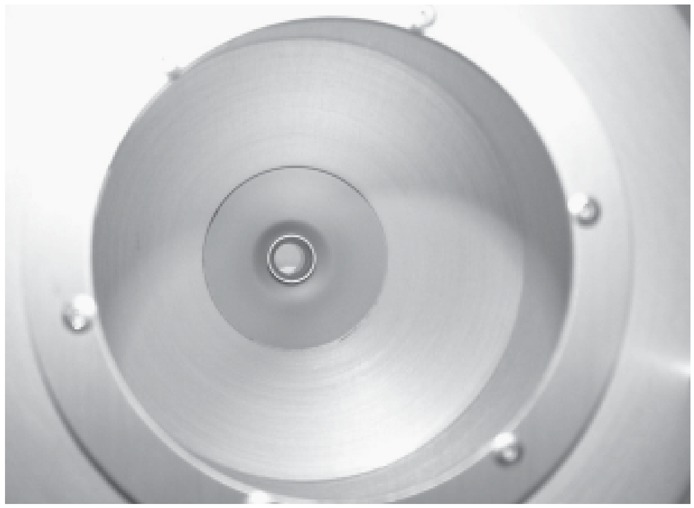
3. Clean the insect screen (with brush or water) then dry.

4. Using a general-purpose cleaner and paper towel, clean the deflector cone on the inside of the top plate.

5. Clean the internal wall surface of the acceleration assembly (Figure 5-24).

   Note. Ensure the acceleration nozzle is clean. If not, use a cotton swab and cleaner to remove any contamination. ▲

Figure 5-24.
Interior wall of inlet.

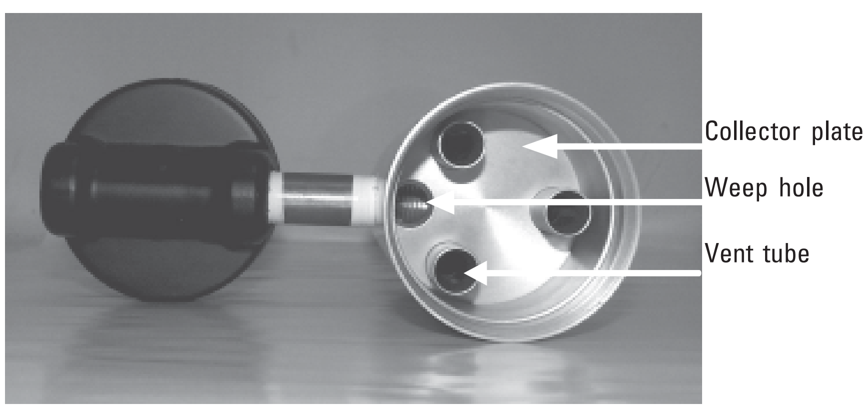


6. Inspect the large diameter, impactor nozzle O-ring for damage or wear (Figure 5-20). Replace it, if necessary. Apply a thin film of silicone grease to the O-ring. Also, apply a light coating of silicone grease to the aluminum threads of the upper acceleration assembly.

7. Using a general-purpose cleaner with a paper towel, clean the collector assembly walls and plate (Figure 5-25).

   Note. Most of the contamination in the inlet is usually found on the collector plate. ▲

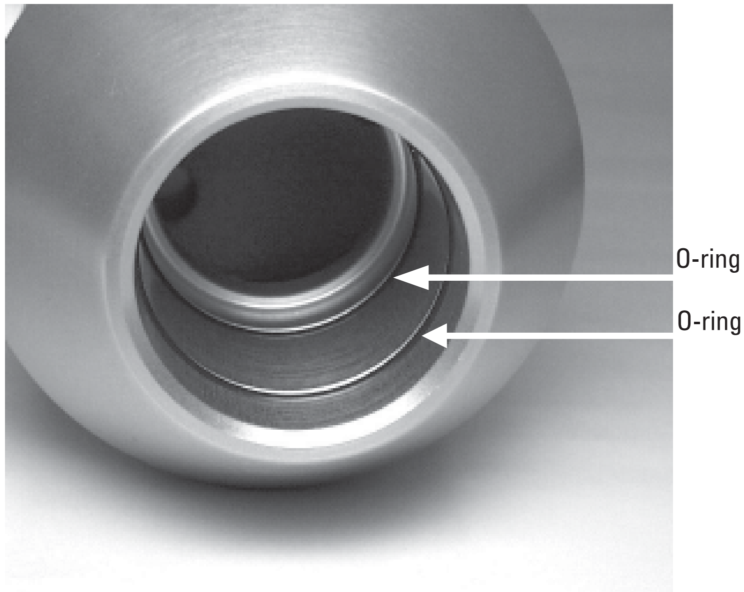
Figure 5-25.
Inside of inlet collector assembly.



8. Clean the three vent tubes (Figure 5-25). You may need to use a cotton swab to clean these vent tubes.

9. Clean the bottom side of the collector assembly (Figure 5-26). Inspect the two inlet tube-sealing O-rings for damage or wear. If necessary, replace the O-rings.

Figure 5-26.
Bottom of collector assembly with O-rings.



10. Clean the weep hole in the collector plate where the moisture runs out to the moisture trap (Figure 5-25).

11. Clean the rain jar. Inspect the rain jar cover's brass nipple fitting to ensure that it is secure and free from blockages (Figure 5-27).

Figure 5-27.
Rain jar cover.

12. Apply a light coating of silicone grease to the O-rings (Figure 5-26) to ensure that a seal is made when they are reinstalled on the flow splitter.

13. Clean the lower collector assembly's threads to ensure a tight seal when the two halves are reassembled.

14. Reassemble the top and bottom inlet assemblies until the threads tighten. Hand-tighten only.

15. Reinstall the insect screen and align the top plate markings with the lower plate markings. Install the top plate onto the lower plate and tighten the four pan-head screws.

16. Place a light coating of silicone grease on the gasket inside the cap of the rain jar. This will ensure a leak-free fit. Reinstall the rain jar.

17. Place the inlet on the flow splitter. Take care not to damage the internal O-rings.

For information on cleaning the cyclone, refer to the supplemental cyclone operating manual.

Exchanging In-Line Filters

The main flow in-line filter (57-010745) and the large bypass flow filter (57-010755) should be changed every 6 months or as necessary. They are located on the back of the unit (Figure 5-28). These filters prevent contamination from reaching the flow controller. For convenience, replace the large in-line filters immediately following one of the regularly-scheduled TEOM filter exchanges. This allows you to exchange the in-line filters during the 30-minute flow and temperature stabilization period.

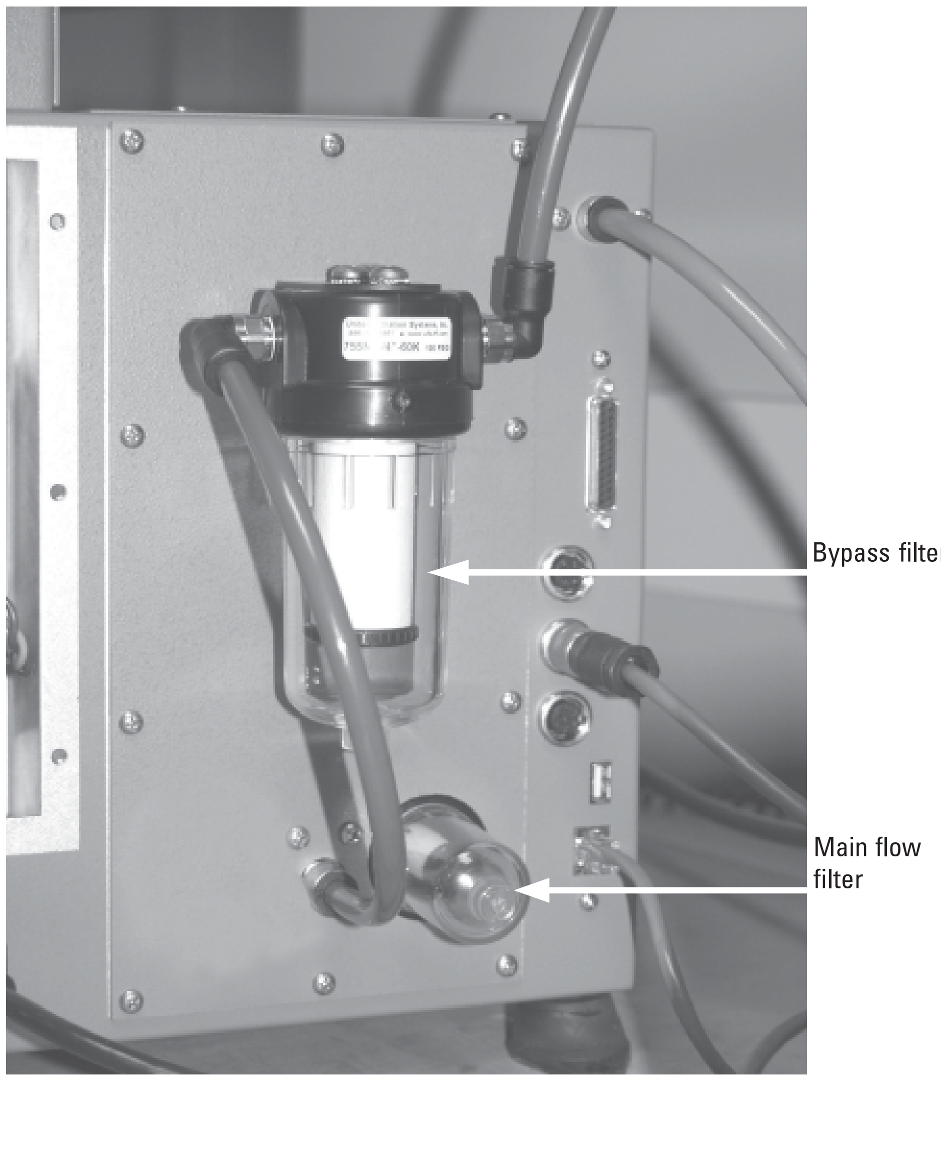


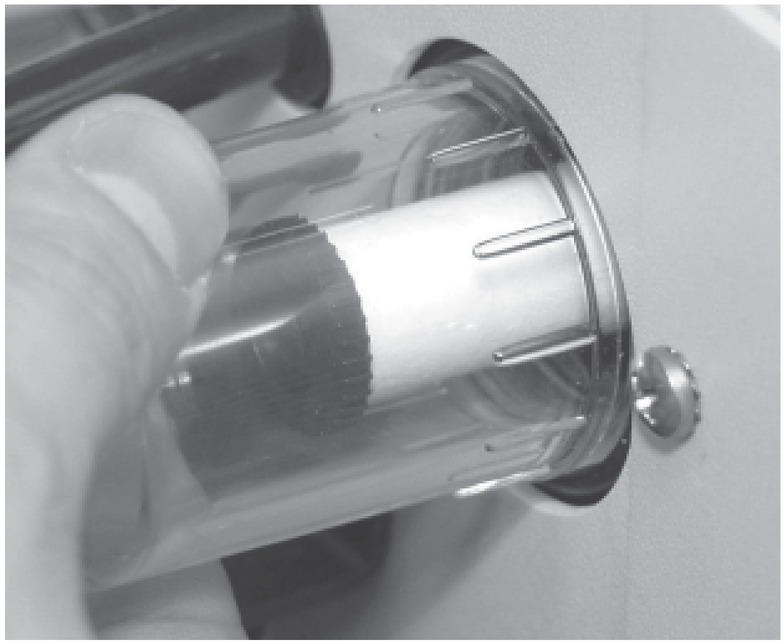
Figure 5-28. Back of 1405 unit.

To exchange the in-line filters:

1. Unplug the sample pump.

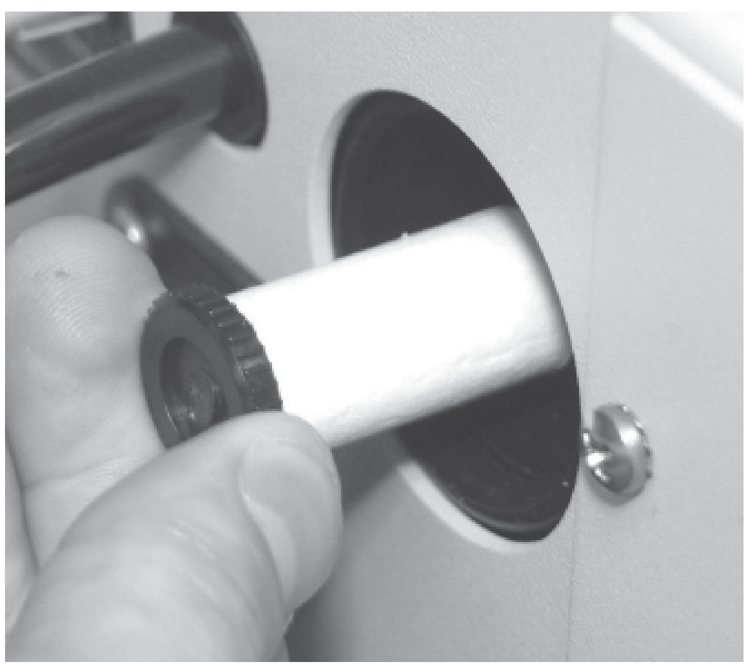
2. Unscrew and remove the small filter cover for the main flow channel on the back of the unit (Figure 5-29).

Figure 5-29.
Removing the filter cover.



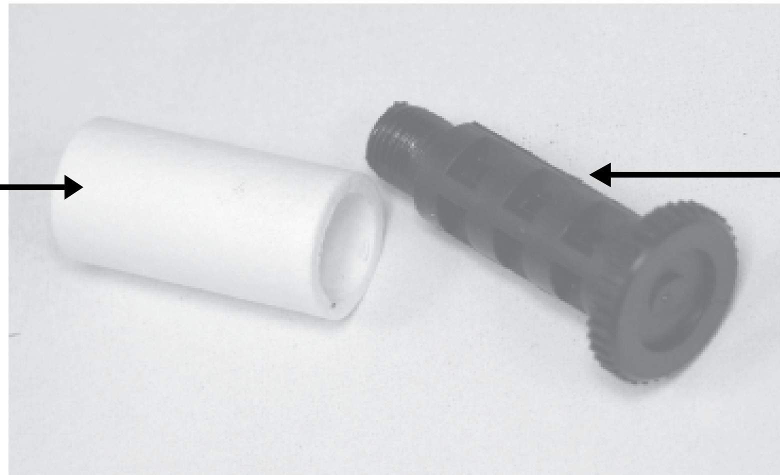
3. Unscrew the filter mount for main flow channel (Figure 5-30).

Figure 5-30.
Removing the filter mount.



4. Slide the filter cartridges off the mount and install a new cartridge onto the mount (Figure 5-31).

Figure 5-31.
Filter cartridge and mount.



5. Install the mount into the unit, then install the cover.

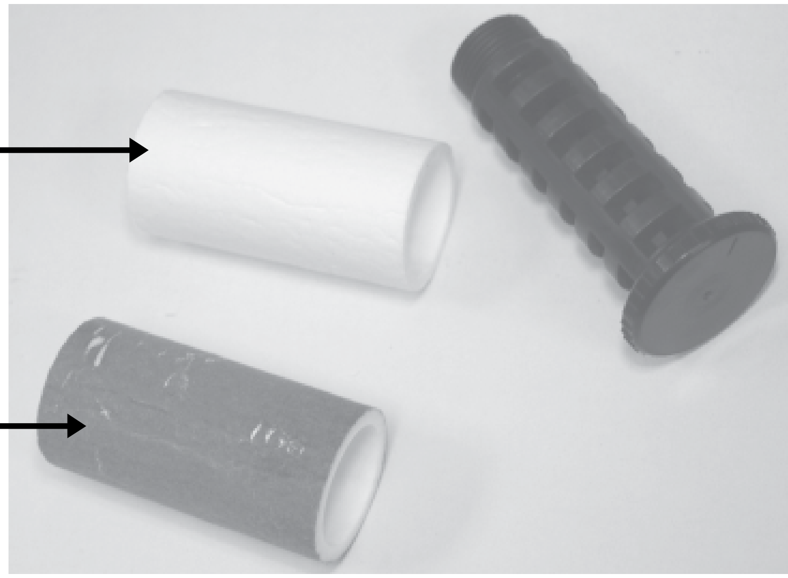
6. Unscrew and remove the large filter cover from the bypass flow channel on the back of the unit (Figure 5-32).

Figure 5-32.
Bypass in-line filter.

7. Unscrew the filter mount for the bypass flow channel.

8. Slide the large filter cartridge off the mount and install a new cartridge onto the mount (Figure 5-33).

Figure 5-33.
Bypass filter mount with clean and dirty filter cartridges.



9. Install the mount into the unit, then install the cover for the bypass flow.

10. Plug in the sample pump and return to normal operation.

Cleaning the Air Inlet

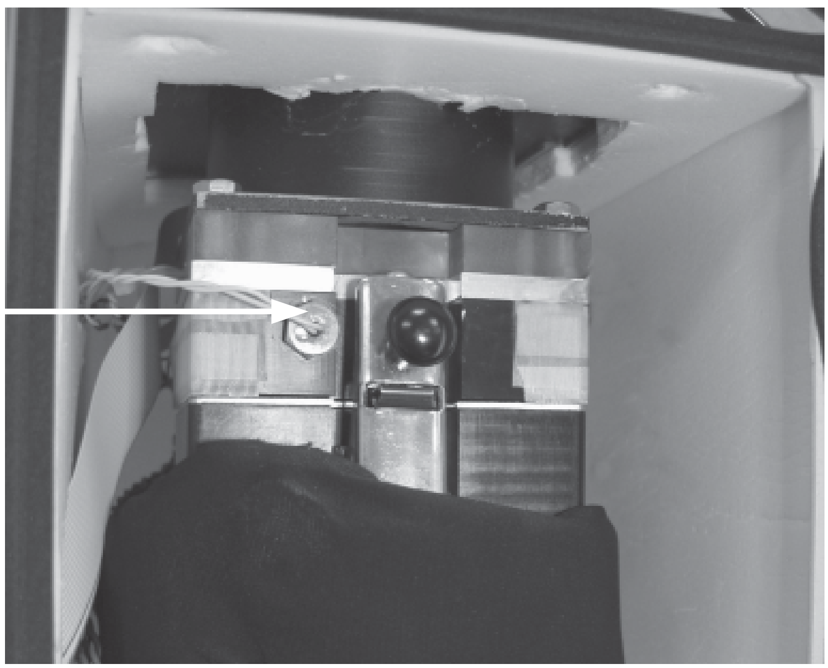
You must clean the heated air inlet in the TEOM 1405 once a year to remove the buildup of particulate matter on its inner walls. You can order a tapered bristle brush that is appropriate for cleaning the air inlet system from Thermo Scientific. You will need a piece of plastic or another protective material; soapy water, alcohol or freon solution; a 1/2-inch (or adjustable) wrench and a soft brush to clean the air inlet.

Follow these steps to clean the air inlet system:

1. Turn off the TEOM 1405 unit.

2. Open the door of the unit (Figure5-34) and locate the thermistor in the top of the mass transducer assembly.

Figure 5-34. Thermistor on top of mass transducer.



3. Using the 1/2-inch wrench, remove the thermistor from the top of the mass transducer assembly.

   Note. The thermistor has a short thread depth. Installation/removal should take 1 1/2 to 2 1/2 turns. ▲

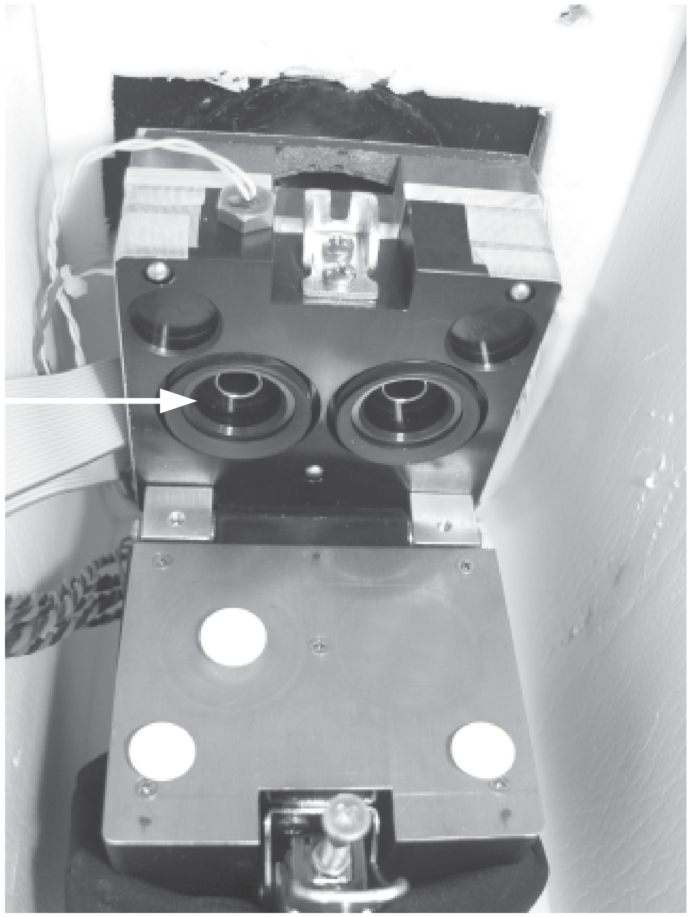
4. Open the mass transducer (refer to the Replacing the TEOM Filter section earlier in this chapter for instructions on opening the mass transducer).

5. Place a piece of plastic or another protective material over the exposed TEOM filters.

6. Using a soapy water, alcohol or freon solution, clean the left side of the air inlet (Figure 5-35). A soft brush may be used to remove particulate matter on the insides of the walls.

Figure 5-35.
Air inlets.

Nozzle



7. Allow the air inlet to dry.

8. Remove the protective material from the exposed TEOM filters.

9. Close the mass transducer and latch the latch.

10. Install the air thermistors into the cap of the mass transducer assembly and tighten lightly with the wrench.

11. Close and latch the door to the unit. Keep the door open for as short a time as possible to minimize the temperature change in the system.

12. Turn on the TEOM 1405 unit.

Cleaning the Coolers

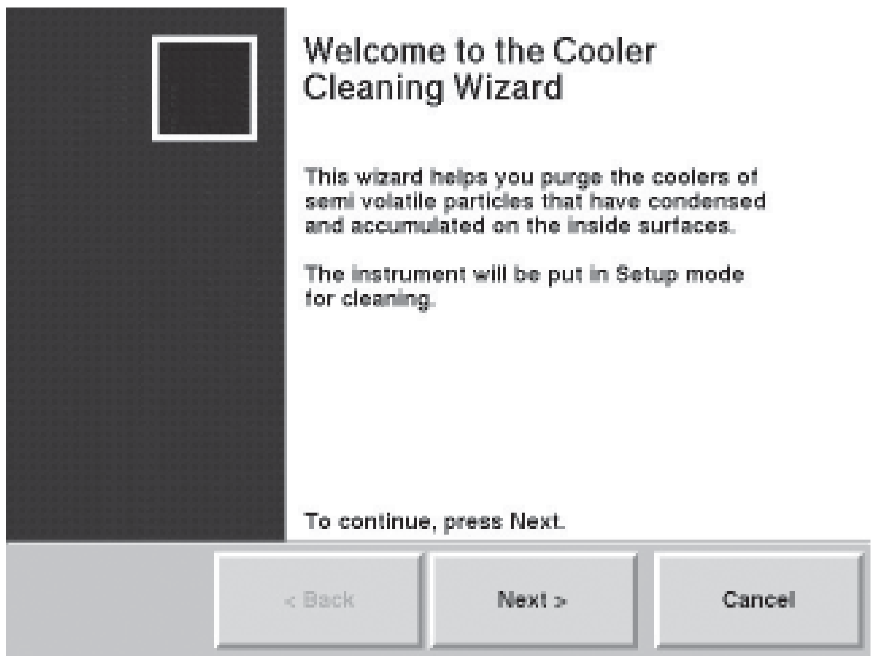
The cooler should be cleaned once per year, or as necessary. The Cooler Cleaning Wizard describes all the steps necessary to clean the cooler. Some additional information is included below.

Follow these steps to clean the coolers:

1. In the 1405 TEOM Data screen, select the **Service** button to display the Service screen, then select the **Maintenance** button to display the Maintenance screen (Figure 5-3).

2. Select the **Clean Coolers** button to start the Cooler Cleaning Wizard (Figure 5-36). Select the **Next >** button to begin the procedure.

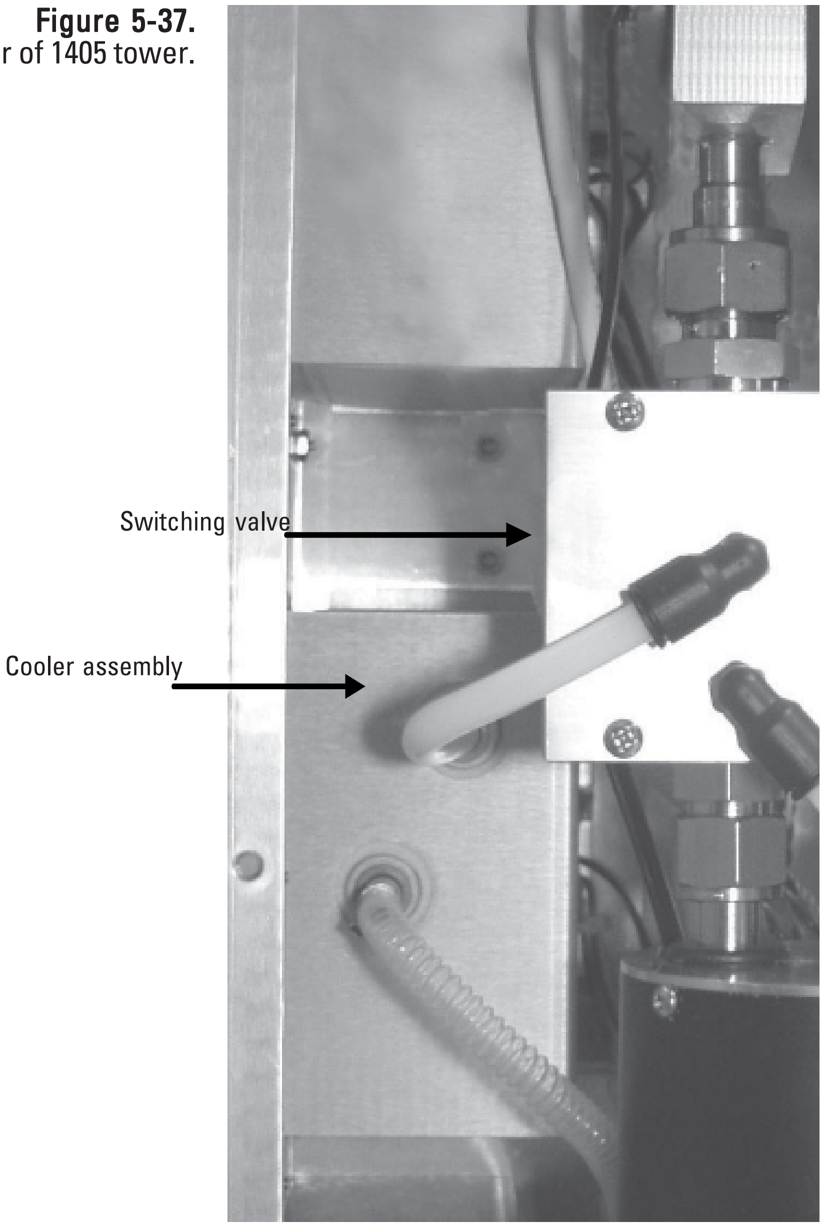
Figure 5-36. Cooler Cleaning Wizard Welcome screen.



3. The Remove Filter Cassettes screen will display. Open the compartment door on the side of the unit and remove the 47 mm filter cassette and filter. (Refer to the "Replacing the 47 mm Filters" section earlier in this chapter for more information on removing the filter cassettes. Select the **Next >** button.

4. The Open Unit screen will display. Remove the front cover from the unit tower and locate the cooler assembly, the switching valve and the dryer vacuum connection (Figure 5-37).

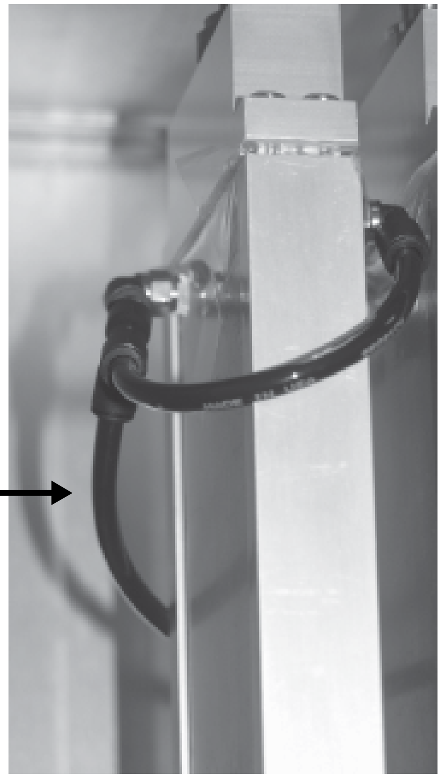
Figure 5-37.
Interior of 1405 tower.



5. Remove the tubing from both the top and bottom quick-connect fittings on the cooler (Figure 5-37). Select the **Next >** button.

6. The Disconnect Vacuum Line screen will display. Remove the main line from the bottom of the T-connection of the dryer vacuum line (Figures 5-38 and 5-39). Select the **Next >** button.

Figure 5-38.
Main dryer vacuum line T-fitting.

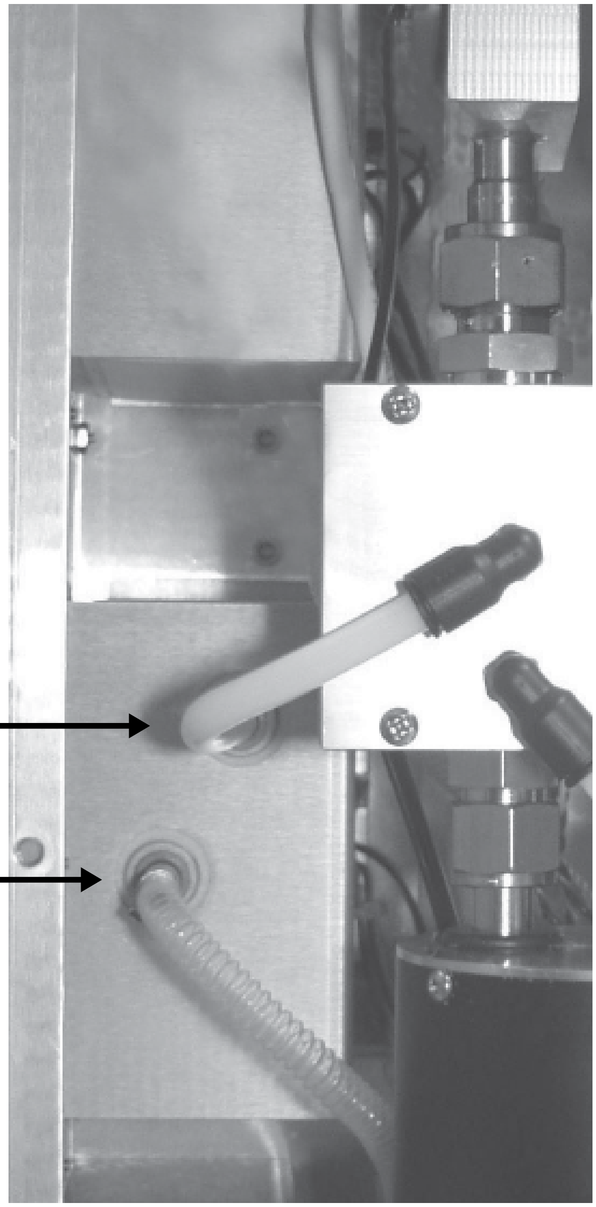


Main dryer vacuum line

Figure 5-39.
Main dryer vacuum line removed from T-fitting.

7. The Connect the Vacuum Line screen will display. Install the piece of tubing with the orifice fitting provided in the instrument package into the top quick-connect fitting of the cooler assembly (Figure 5-40).

Figure 5-40.
Y-adapters installed.

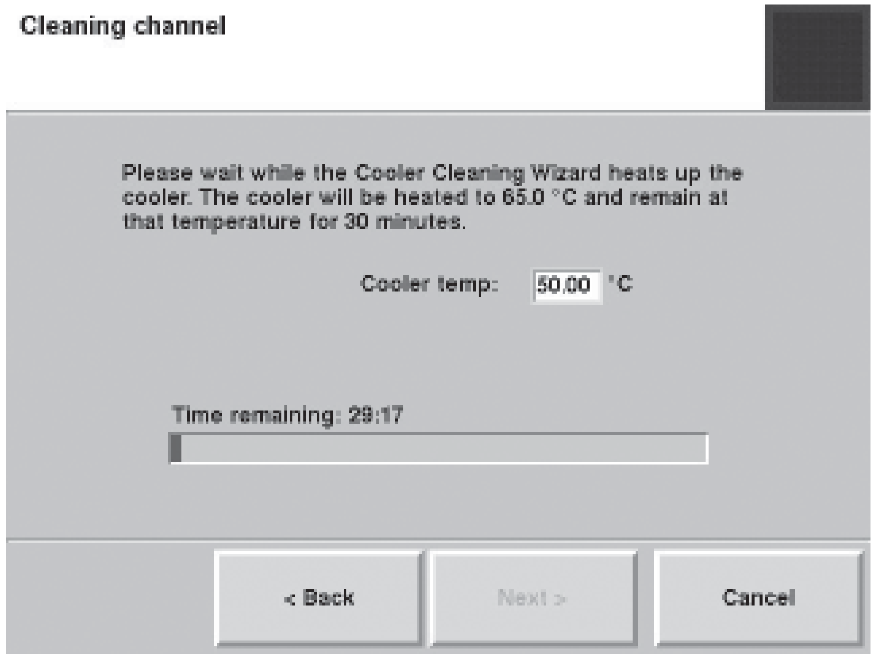


8. Install the main dryer vacuum line removed in step 6 into the bottom of the other adapter (Figure 5-40), and install the piece of tubing into the bottom quick-connect fitting of the cooler assemby. Select the **Next >** button.

Note. Ensure that you use the adapter with the orifice provided with the unit. It restricts the flow through the cooler to the proper rate. ▲

9. The system will automatically begin heating the cooler to 50° C to clean the cooler. The wizard will display a timer screen to show how much time is left to complete the cleaning (Figure 5-41).

Figure 5-41.
Cleaning channels screen.



10. When the procedure is finished, select the **Next >** button.

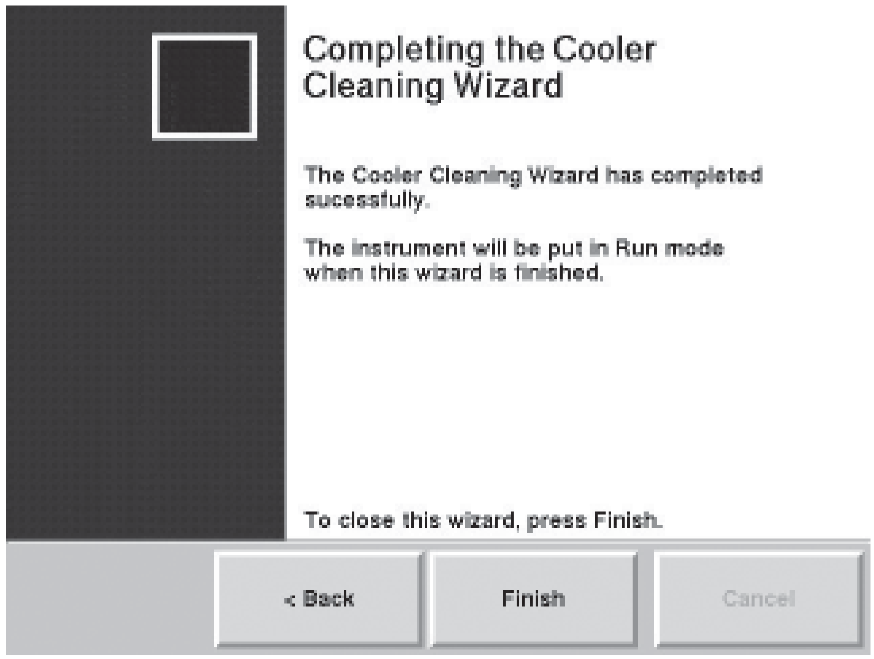
11. The Close Unit screen will display. Disconnect the adapters and reinstall the tubing into the cooler assembly as described by the wizard.

12. Reinstall the 47 mm filter cassette (with new filter installed) into the unit. (Refer to the “Replacing the 47 mm Filters” section earlier in this chapter for more information on removing the filter cassettes.)

13. Reinstall the tower cover.

14. Select the **Next >** button. The wizard will display a message showing the procedure is complete (Figure 5-42). Select the **Finish** button to exit the wizard and return to the Maintenance screen, or select the **< Back** button to move backward one step in the procedure.

Figure 5-42.
Complete screen.



Cleaning the Switching Valve

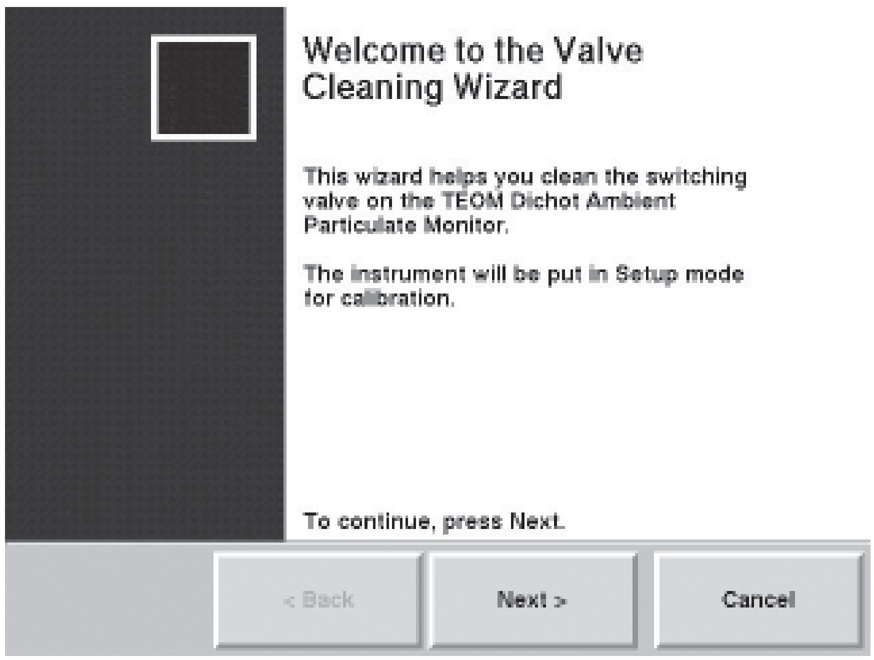
The switching valve should be cleaned once a year or as necessary.

Follow these steps to clean the switching valve:

1. In the 1405 TEOM Data screen, select the **Service** button to display the Service screen, then select the **Maintenance** button to display the Maintenance screen (Figure 5-3).

2. Select the **Clean the Switching Valve** button to start the Valve Cleaning Wizard (Figure 5-43). Select the **Next >** button to begin the procedure.

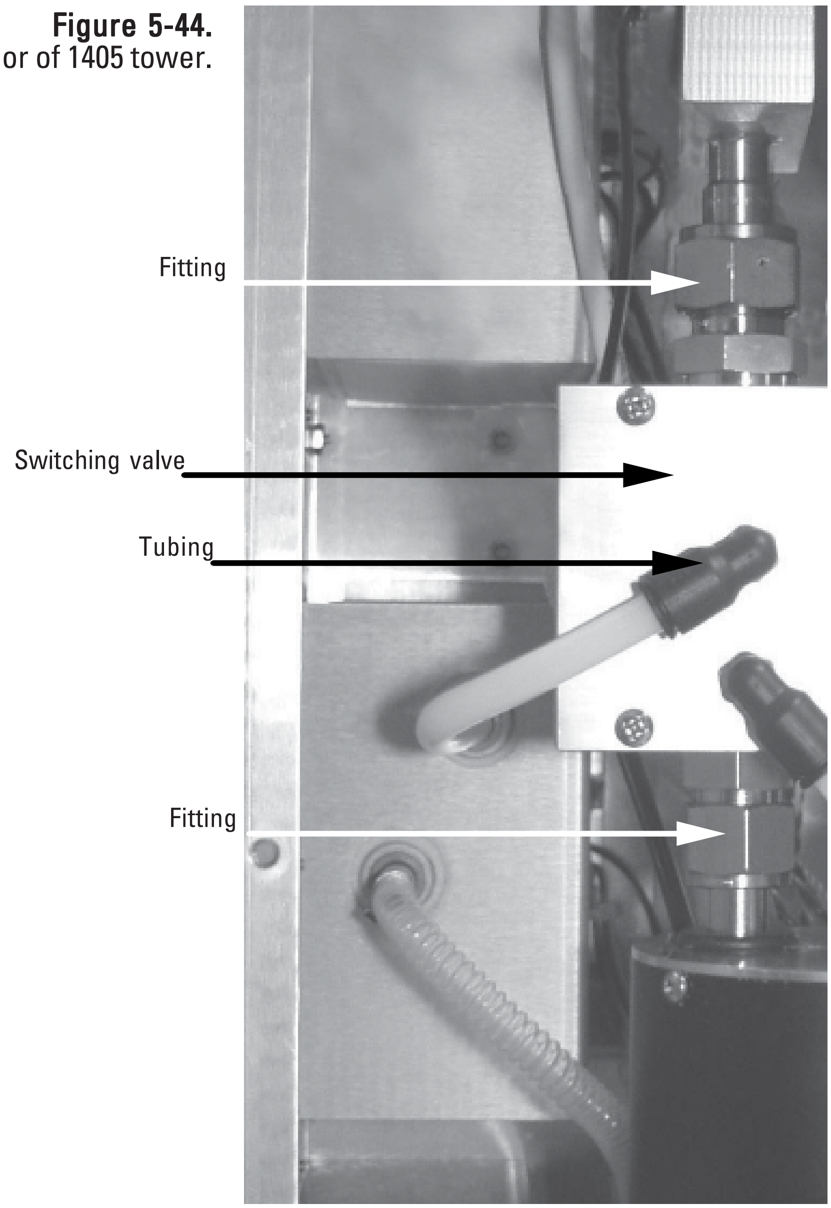
Figure 5-43. Valve Cleaning Wizard Welcome screen.



3. The Remove Front Cover screen will display. Remove the front cover from the unit and locate the switching valve, fittings and tubing connections (Figure 5-44).

4. Remove the tubing from the top quick-connect fitting on the switching valve. Select the **Next >** button.

Figure 5-44.
Interior of 1405 tower.



5. The Remove Valve screen will display. Using a 1-inch wrench (or an adjustable wrench), completely loosen the Swagelok fitting on the top of the switching valve and the Swagelok fitting on the bottom of the switching valve (Figures 5-44 and 5-45).

Figure 5-45.
Removing a valve Swagelok fitting.

6. Loosen the sample tube fitting on the top plate of the 1405-F tower, then push the dryer back while lifting the switching valve slightly then partially remove it from the tower. It will still be connected by the tubes leading to the cooler. Select the **Next >** button.

7. The Clean Valve screen will display. Clean the chamber of the switching valve with the cleaning brush (do not use a cleaning solution) provided with the system (Figure 5-46). Select the **Next >** button.

Figure 5-46.
Cleaning the valve with the valve brush.

8. The Reinstall screen will display. Set the switching valve back into the system, ensuring that the empty quick-connect fitting is located on the top of the switching valve.

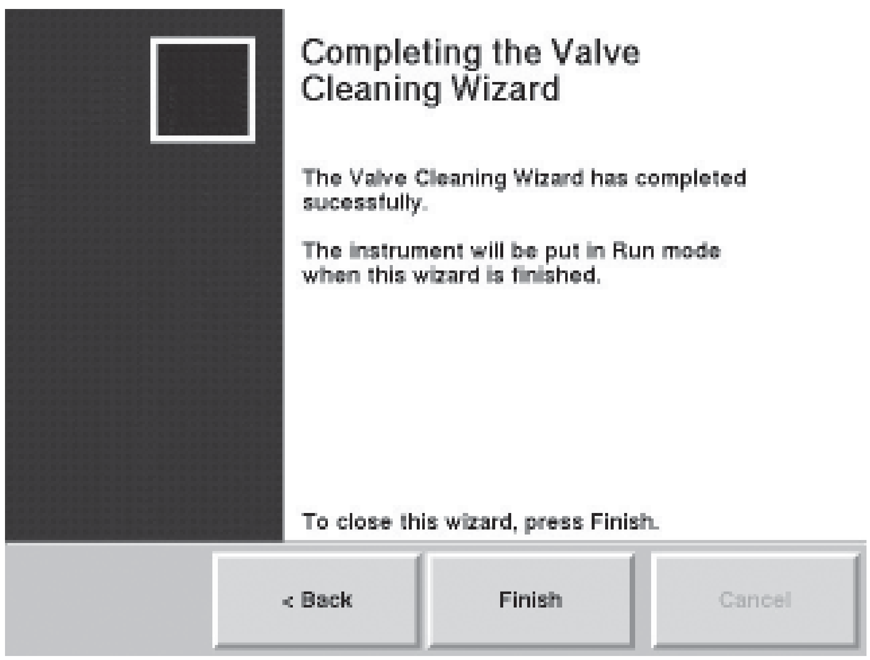
9. Tighten the two Swagelok connections. Tighten them finger-tight at first, then turn them 1-1/4 turns with the wrench.

10. Reinstall the tubing into the quick-connect fitting on the top of the switching valve.

11. Reinstall the cover of the unit, and tighten the sample tube fitting at the top of the unit. Select the **Next >** button.

12. The wizard will display a message showing the procedure is complete (Figure 5-47). Select the **Finish** button to exit the wizard and return to the Maintenance screen, or select the **< Back** button to move backward one step in the procedure.

Figure 5-47. Completing the Valve Cleaning Wizard screen.



Audit/Calibration Procedures

Thermo Fisher Scientific recommends the following regular maintenance procedures for the TEOM 1405-F:

Ambient temperature	Audit/calibrate the ambient air temperature measurement once per month. The temperature must be calibrated before a flow calibration.
Ambient pressure	Audit/calibrate the ambient pressure measurement once per month. The pressure must be calibrated before a flow calibration.
Flow	Audit/calibrate the main and bypass flows once a month.
Leak check	Perform a leak check once a month or as necessary (refer to Section 3 for leak check instructions).
Analog outputs	Calibrate the analog output channels once a year or as necessary, for example any time the voltage range setting is changed.
Mass transducer	Audit the calibration of the mass transducer once a year.

The TEOM 1405 software allows users to step through the standard calibration and audit procedures. Select the Service button to display the **Service** screen. When in the Service screen, select the **Verification** or **Calibration** buttons to display the Verification and Calibration screens (Figure 5-48 and 5-49).

Figure 5-48.
Calibration screen.

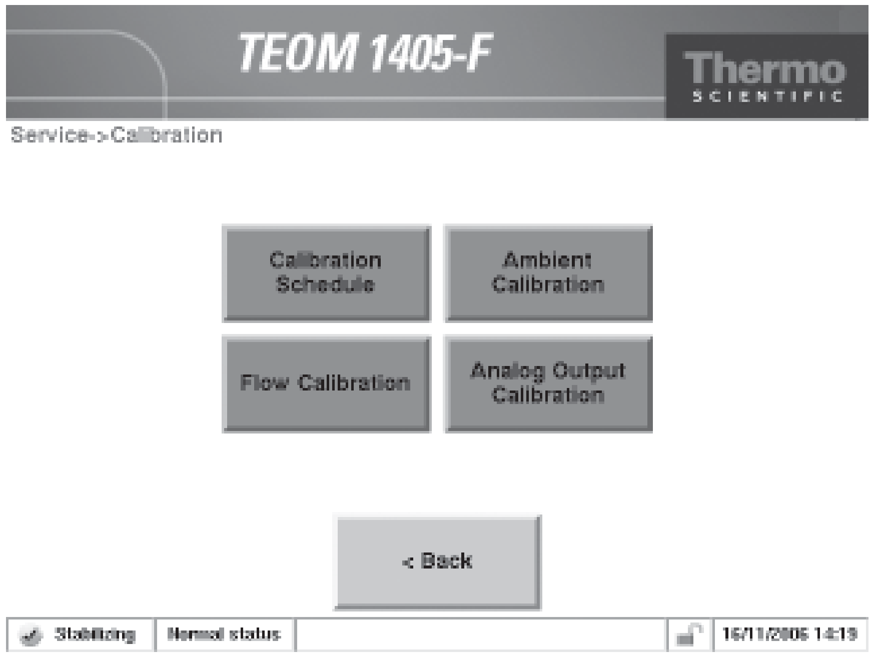
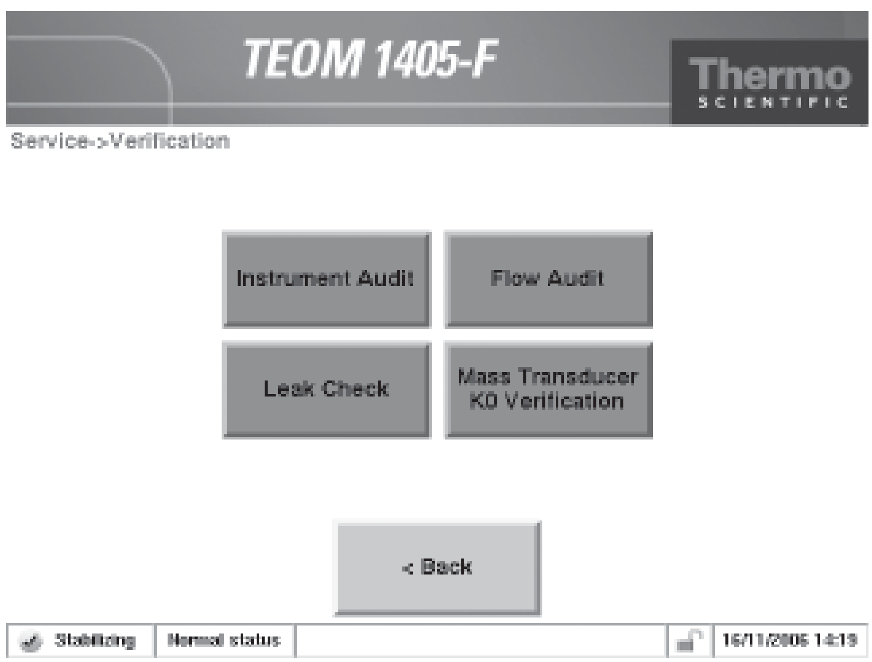
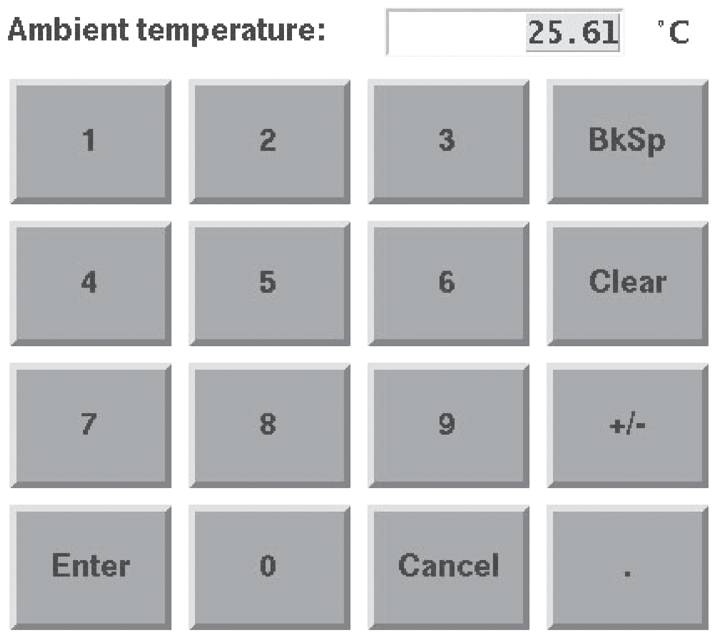


Figure 5-49.
Verification screen.



Users enter values into the calibration screens using a number keypad (Figure 5-50). Whenever the user is prompted to enter a value, such as an externally measured temperature, pressure or flow rate, the calibration wizard will automatically display a keypad. Enter the value into the keypad as instructed by the wizard, then select the **Enter** button to set the value or press the **Cancel** button to exit the keypad screen and return to the wizard.

Figure 5-50.
Number entry keypad.

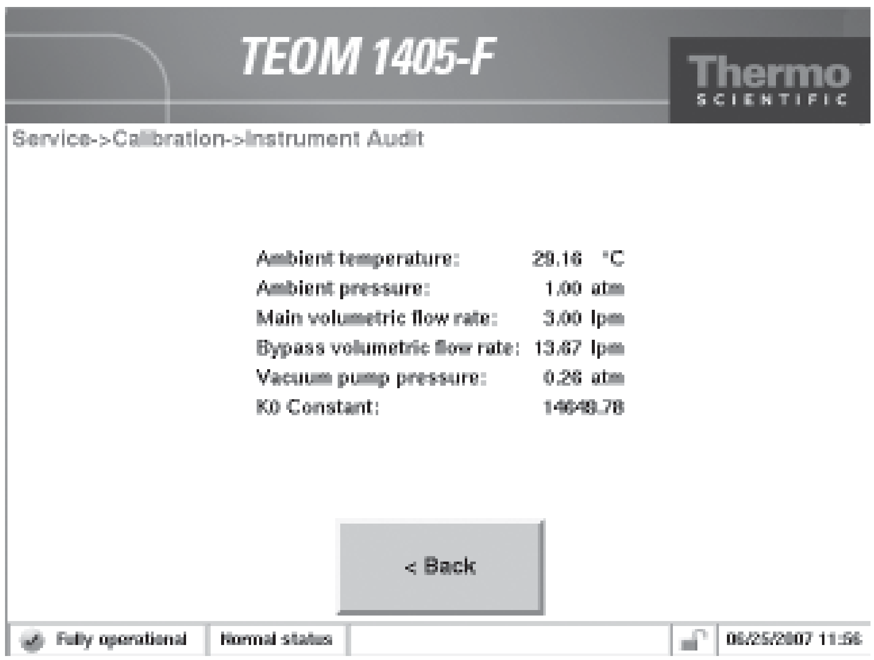


Auditing the System

Users can instantly audit all of the instruments functions through a single software screen. When in the Verification screen, select the **Instrument Audit** button to display the Instrument Audit screen (Figure 5-51).

The Instrument Audit screen shows the temperature, flow and other values that can be audited by the user. Placing a temperature or barometer in the desired location, allows users to audit those values compared to an external measurement device. Flows can be individually audited for accuracy using the flow audit wizard. For changing or "calibrating" the values, refer to the following sections. Refer to the flow, temperature and pressure calibration section for information on how to attach external measurement devices to the TEOM 1405 unit.

Figure 5-51.
Instrument Audit screen.



Calibrating the Ambient Temperature

Perform the ambient air temperature calibration, pressure calibration and leak check (Section 3) before executing the flow calibration procedure.

To calibrate the ambient air temperature:

1. In the TEOM Data screen, select the **Service** button to display the Service screen, then select the **Calibration** button to display the Calibration screen (Figure 5-32).

2. Select the **Ambient Calibration** button to display the Ambient Calibration screen (Figure 5-36).

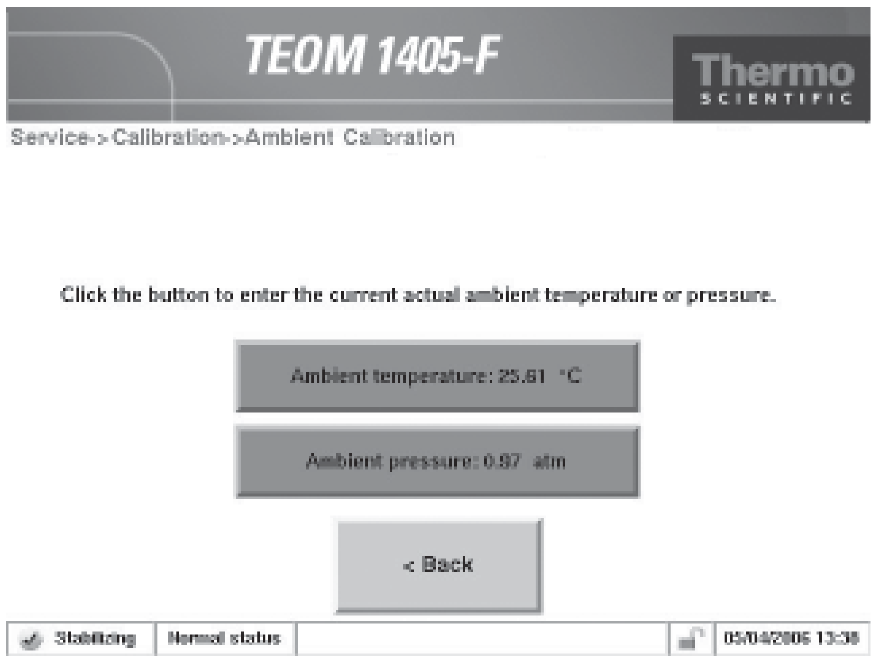


Figure 5-52.
Ambient Calibration screen.

3. Determine the current temperature (°C) at the ambient temperature sensor using an external thermometer, [°C = 5/9 x (°F - 32)].

4. If the measured value is within ± 2° C of the temperature displayed in the **Ambient Temperature:** field of the button, no further action is necessary. Select the **< Back** button to return to the Calibration screen. If the value is not within ± 2° C of the temperature displayed in the **Ambient Temperature:** field of the button, select the Ambient Temperature: button. A keypad will display. Enter the actual temperature as measured by the external thermometer and press the **Enter** button. The Ambient Temperature Calibration screen will display with the new entered value. Select the **< Back** button to return to the Calibration screen.

Calibrating the Ambient Pressure

Perform the ambient air temperature calibration, pressure calibration and leak check (Section 3) before executing the flow calibration procedure.

To calibrate the ambient pressure:

1. In the TEOM Data screen, select the **Service** button to display the Service screen, then select the **Calibration** button to display the Calibration screen (Figure 5-48).

2. Select the **Ambient Calibration** button to display the Ambient Calibration screen (Figure 5-53).

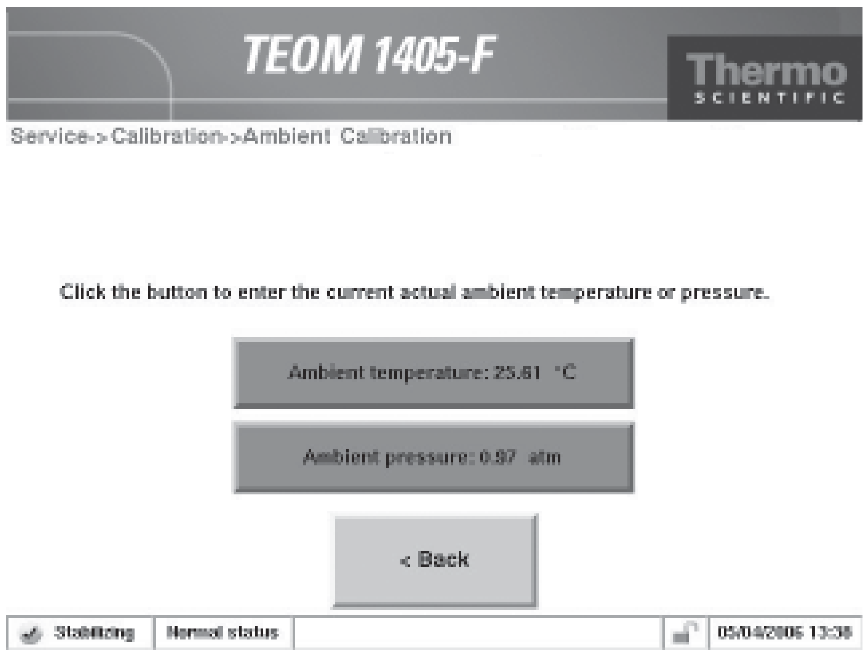


Figure 5-53.
Ambient Calibration screen.

3. Determine the current ambient pressure in atmospheres (absolute pressure, not corrected to sea level).

4. If the measured value is within ± 0.01 atm of the pressure displayed in the **Ambient Pressure:** field of the button, no further action is necessary. Select the **< Back** button to return to the Calibration screen. If the value is not within ± 0.01 atm of the pressure displayed in the **Ambient Pressure:** field of the button, select the **Ambient Pressure:** button. A keypad will display. Enter the actual pressure as measured by the external device and press the **Enter** button. The Ambient Pressure Calibration screen will display with the new entered value. Select the **< Back** button to return to the Calibration screen.

Auditing the Flow Rates

To audit the main or bypass flow:

1. In the TEOM Data screen, select the **Service** button to display the Service screen, then select the **Verification** button to display the Verification screen (Figure 5-49).

2. Select the **Flow Audit** button to begin the Flow Audit Wizard (Figure 5-54). Select the **Next >** button.

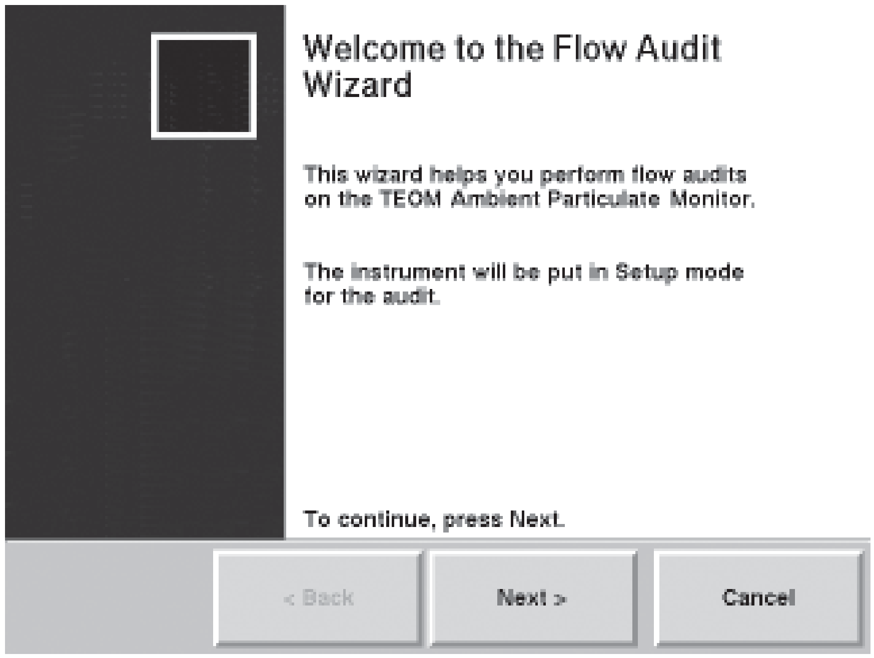


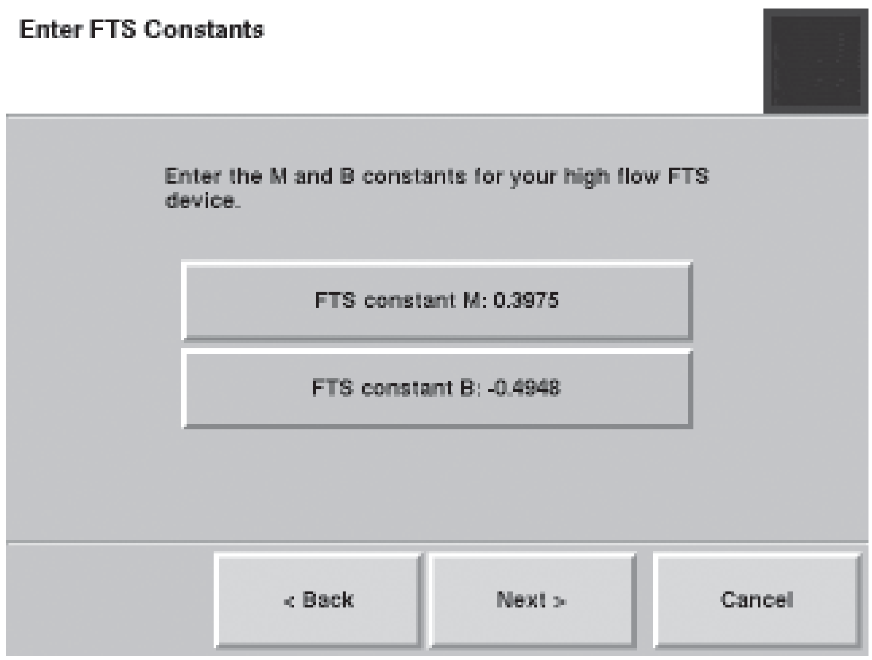
Figure 5-54. Flow Audit Wizard.

3. The Select a Flow Audit Device screen will display. Select a flow audit device. Select “Direct Flow Device” to audit the flow using a direct flow measuring device (reading “l/min” adjusted for temperature and pressure) such as the Streamline Pro. Select “FTS” to audit the flow using the FTS system. FTS users will enter the device calibration constant and the change in pressure from the FTS. Select the “Next >” button.

4. The Select Flow to Audit screen will display. Select which flow to audit. Press the “Next > “ button.

Note. If you selected the FTS option in the previous screen, you will be prompted to enter the correct calibration constants before proceeding with the audit (Figure 5-55). ▲

Figure 5-55.
Enter FTS Constants screen.



5. The Connect Flow Audit Device screen will display. Attach a flow meter to the appropriate flow channel:

    a. To audit the **main flow channel**, remove the inlet and attach the 1 1/4-inch flow adapter/meter to the top of the flow splitter (Figure 5-56). Disconnect the bypass line from the side of the flow splitter (don't let it fall to the ground) and cap the bypass fitting with the 3/8-inch Swagelok cap provided with the system (Figure 5-57).

Figure 5-56. Flow adapter/meter attached to the flow splitter.

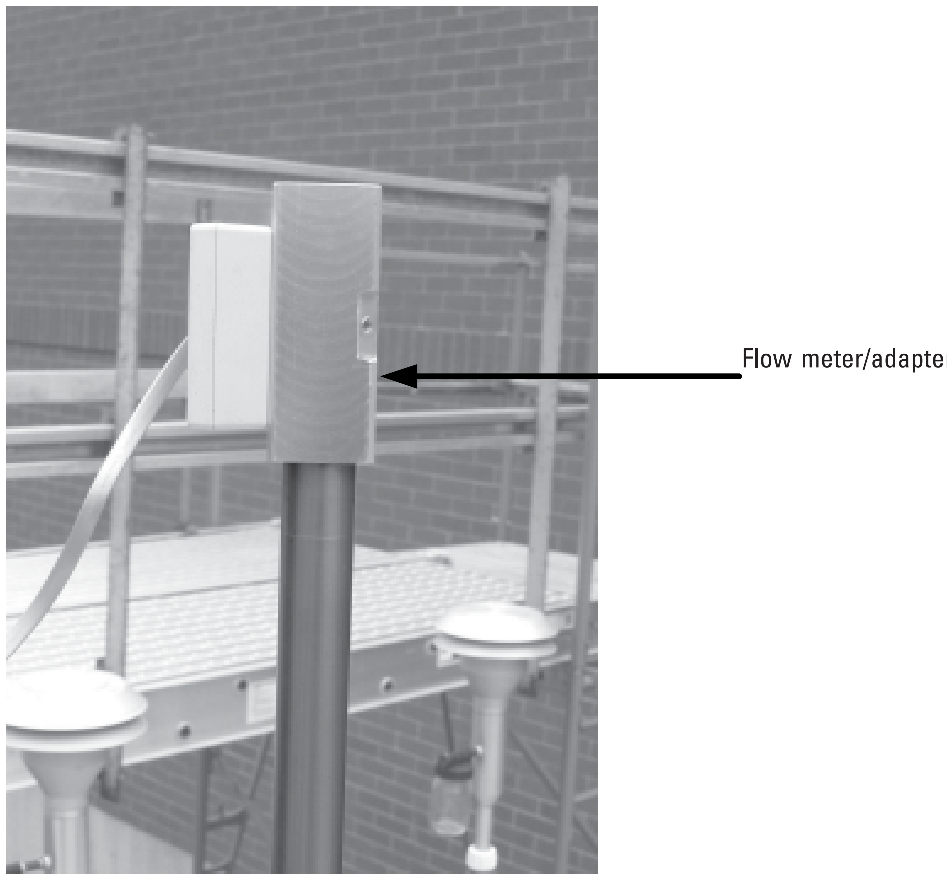
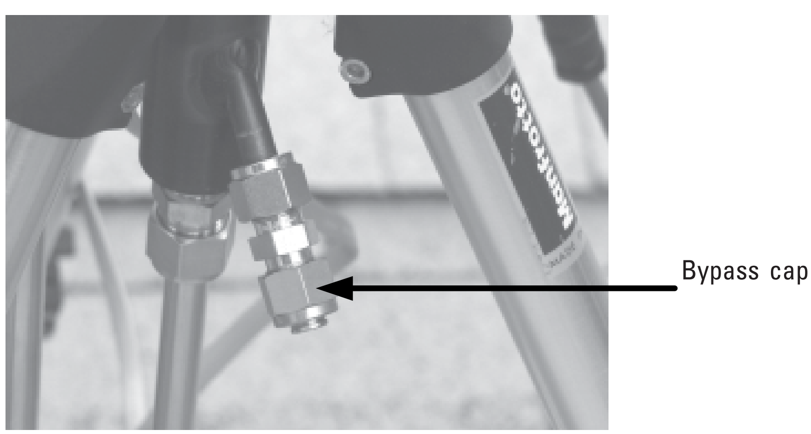


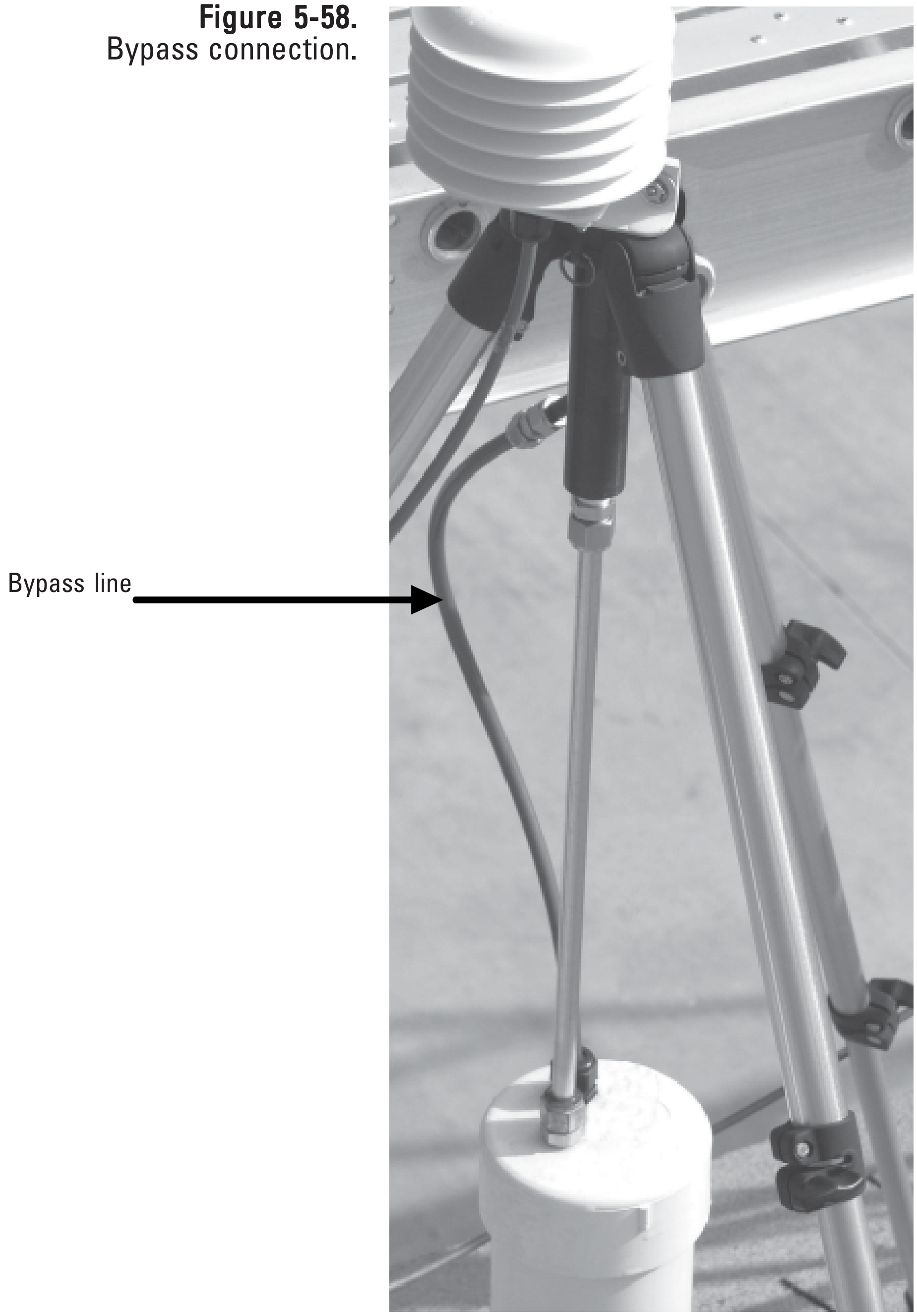
Figure 5-57. Bypass line capped.



b. To audit the **bypass flow channel**, remove the bypass line from the flow splitter and connect the 3/8-inch flow adapter to the green tubing of the bypass line (Figure 5-58). Connect the flow meter/ adapter to the flow audit adapter.

When the flow meter is attached, select the **Next >** button.

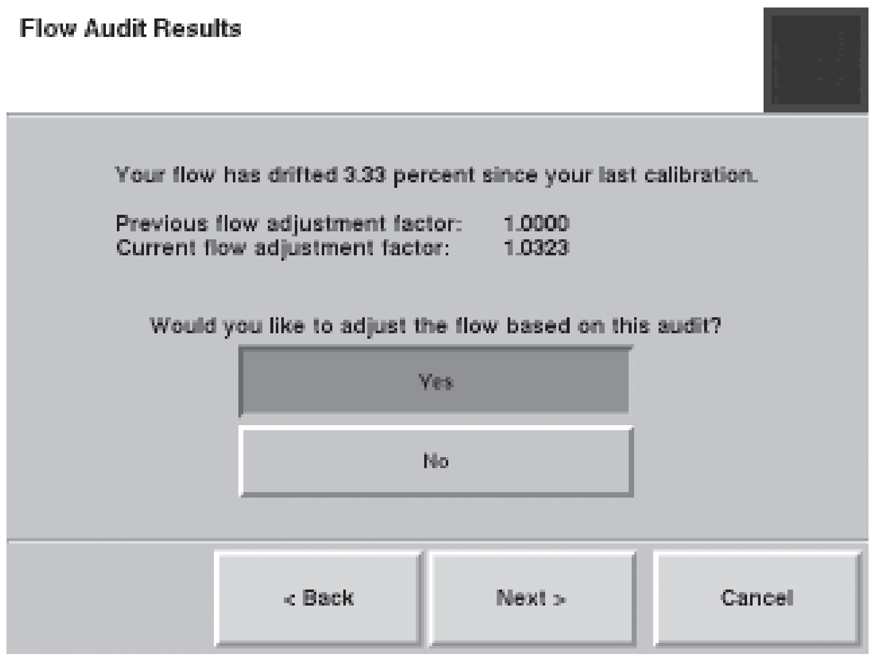
Figure 5-58.
Bypass connection.



6. The Measure Flow screen will display. *Allow the flow to stabilize*. When the flow is stable, press the flow button and enter the reading from the flow device. Select the **Next >** button.

7. The Flow Audit Results screen will display the difference between the flow rate of the instrument and the flow rate on the measurement device (Figure 5-59). If the difference is less than 10 percent, you may adjust the flow rate to reflect the value on the audit device. Select the **Yes** button to adjust the flow based on the results of the flow audit. Select the **No** button to leave the original flow settings in place. Select the **Next >** button to return to the Select Flow screen and audit another flow channel.

Figure 5-59.
Flow Audit Results screen.



8. The Select Flow to Audit screen will display again. The flow channel that was just audited will be “grayed out” on the screen to show it was audited during this session. If you want to audit another flow channel, select another channel and follow steps 3 - 8 (and the wizard) to complete additional flow channels. Otherwise, ensure that no flow channel buttons are selected, and select the **Next >** button.

Note. If the difference is more than 10 percent, the flow will fail the audit and the unit requires a leak check/flow calibration (Figure 5-61). ▲

9. The Completing the Flow Audit Wizard screen will display (Figure 5-60). Remove the flow meter and flow adapter(s) and install the inlet. Ensure all lines, including the bypass, are reconnected. Select the **Finish** button to exit the wizard and return to the Verification screen, or select the **< Back** button to move backward one step in the procedure.

Figure 5-60.
Finish screen with flow audit results.

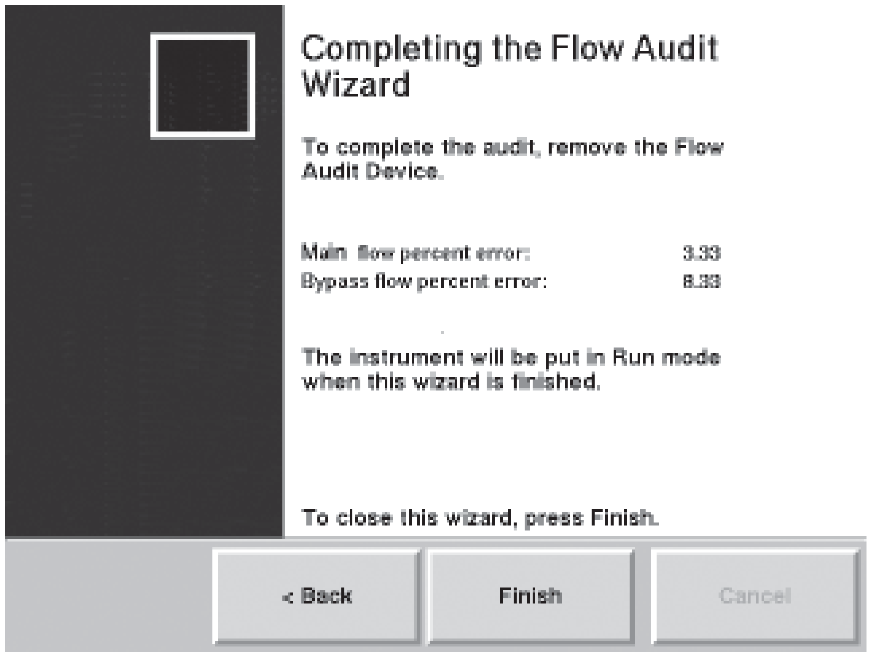
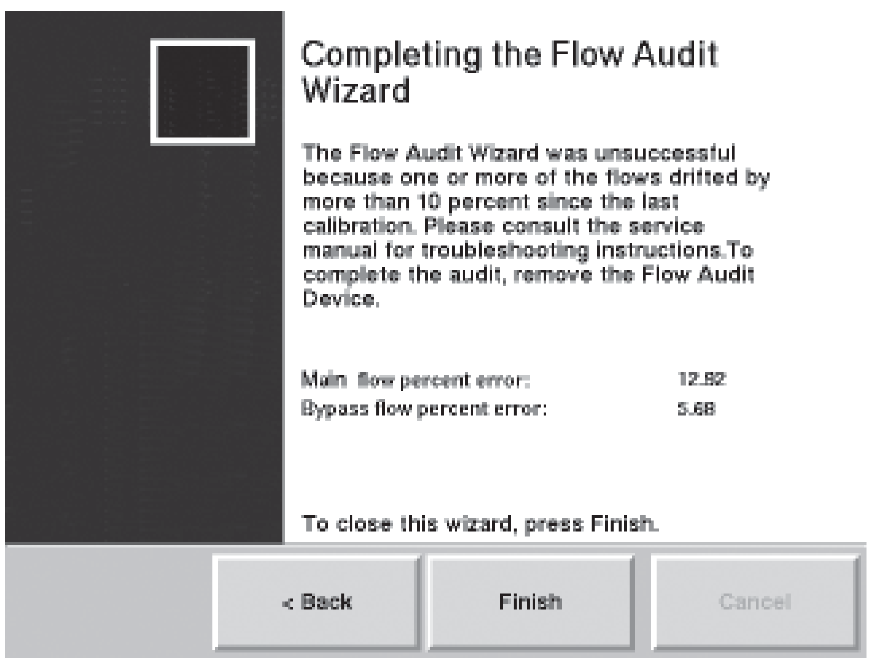


Figure 5-61.
Finish screen with a failed audit.



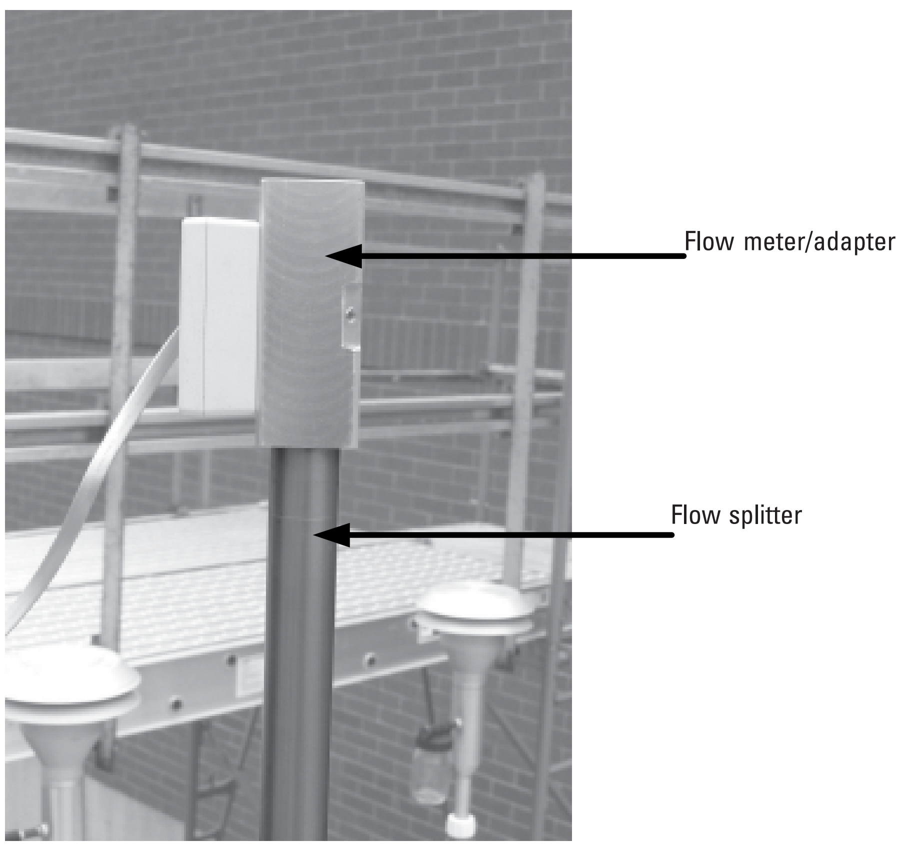
Calibrating the Flow Rates

Perform the ambient air temperature calibration, pressure calibration and leak check (Section 3) before executing the flow calibration procedure. To calibrate (or audit) the main and bypass flows, you will need a 1 1/4-inch flow adapter, a 3/8-inch Swagelok flow adapter and a flow measurement device.

The reference flow meter, such as a bubble meter, dry gas meter, or mass flow meter should have been recently calibrated to a primary standard, and should have an accuracy of ±1% at 3 l/min and 16.67 l/min, and a pressure drop of less than 0.07 bar (1 psi). If you are using a mass flow meter, you must make any necessary corrections to translate this reading to volumetric l/min at the current ambient temperature and barometric pressure. No adjustment is necessary in the case of a volumetric flow meter. Thermo Scientific offers the Streamline Pro Multi-Cal system (57-008887) to measure volumetric flow measurements.

Note. To audit the total flow, you will need a 1 1/4-inch flow adapter. Remove the inlet and attach the flow adapter and meter to the top of the inlet tube (Figure 5-62). ▲

Figure 5-62. Flow meter/adapter attached to top of inlet tube for total flow audit.



To calibrate the main or bypass flow:

1. In the TEOM Data screen, select the **Service** button to display the Service screen, then select the **Calibration** button to display the Calibration screen (Figure 5-48).

2. Select the **Flow Calibration** button to start the Flow Calibration Wizard (Figure 5-63). Select the **Next >** button to begin the procedure.

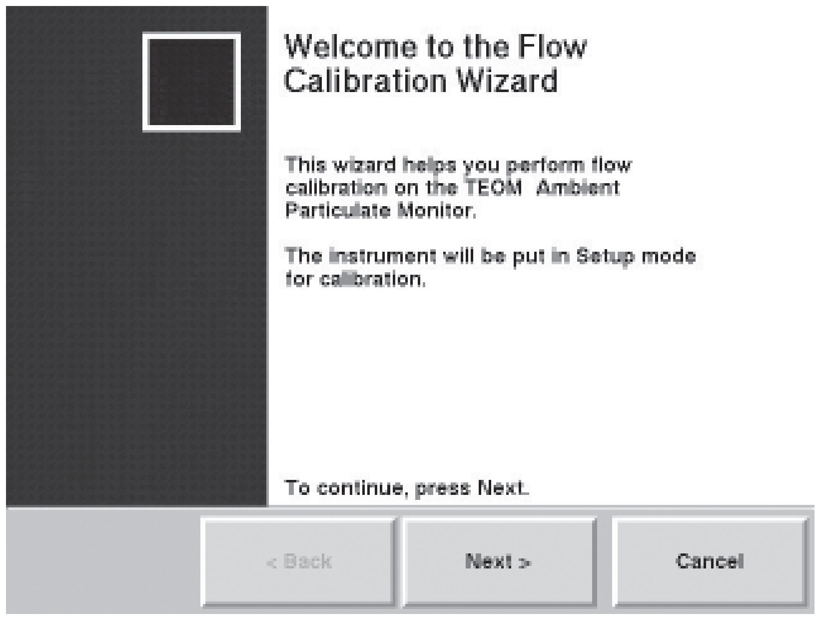


Figure 5-63. Welcome to the Flow Calibration Wizard screen.

3. The Select a Flow Audit Device screen will display. Select a flow audit device. Select "Direct Flow Device" to audit the flow using a direct flow measuring device (reading "l/min" adjusted for temperature and pressure) such as the Streamline Pro. Select "FTS" to audit the flow using the FTS system. FTS users will enter the device calibration constant and the change in pressure from the FTS. Select the "Next >" button.

4. The Select Flow to Calibrate screen will display. Select the **Calibrate Main Flow** or **Calibrate Bypass Flow** button to calibrate the selected flow. Select the **Next >** button.

5. The wizard will prompt you to attach a flow meter to the appropriate flow channel:

   a. To calibrate the **main flow channel**, remove the inlet and attach the 1 1/4-inch flow adapter/meter to the top of the flow splitter (Figure 5-64). Disconnect the bypass line from the side of the flow splitter (don't let it fall to the ground) and cap the bypass fitting with the 3/8-inch Swagelok cap provided with the system (Figure 5-65).

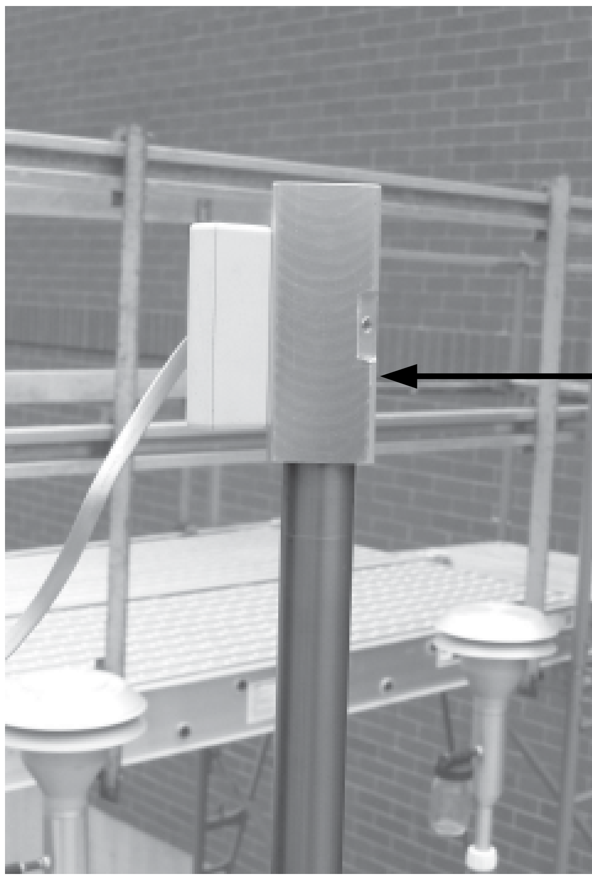


Figure 5-64.
Flow adapter/meter attached to the flow splitter.

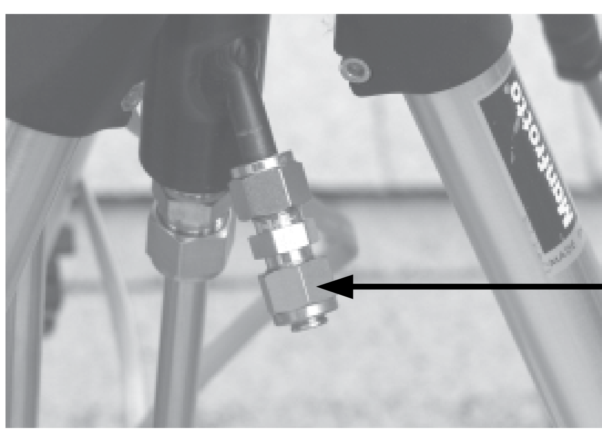
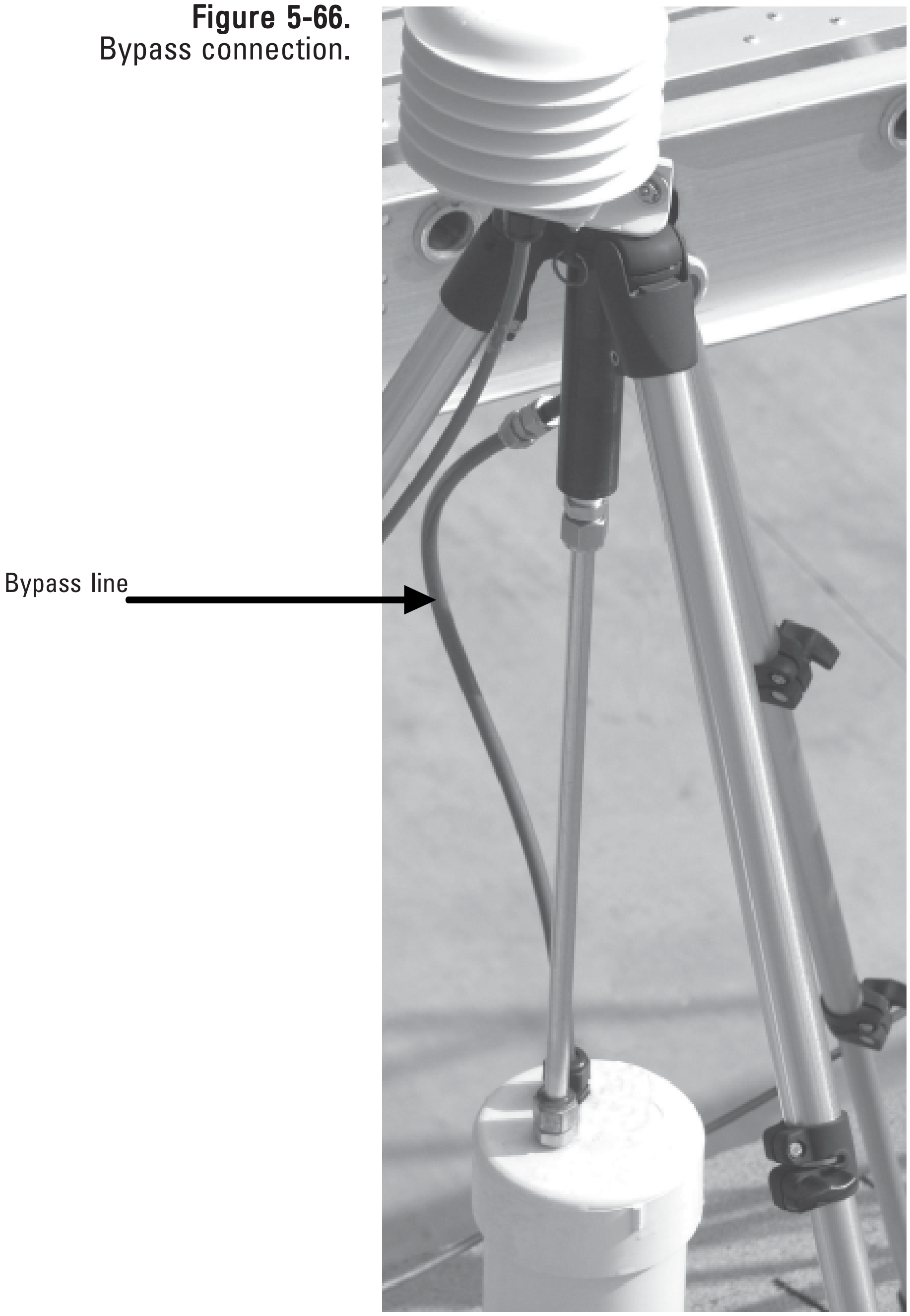


Figure 5-65.
Bypass line capped.

b. To calibrate the **bypass flow channel**, remove the bypass line from the flow splitter and connect the 3/8-inch flow adapter to the green tubing of the bypass line (Figure 5-66). Connect the flow meter/adapter to the flow audit adapter.

When the flow audit device is attached to the correct channel, select the **Next >** button.

Figure 5-66.
Bypass connection.



6. The wizard will display a screen that shows the current low-setpoint flow rate (as measured by the instrument) in the **TEOM flow rate:** button (Figure 5-67). *Allow the flow to stabilize.* Select the **TEOM flow rate:** button and enter the current flow rate (to two decimal places) as measured by the flow meter into the number pad and select the **Enter** button. The newly entered flow rate will display in the **TEOM flow rate:** button. Select the **Next >** button.

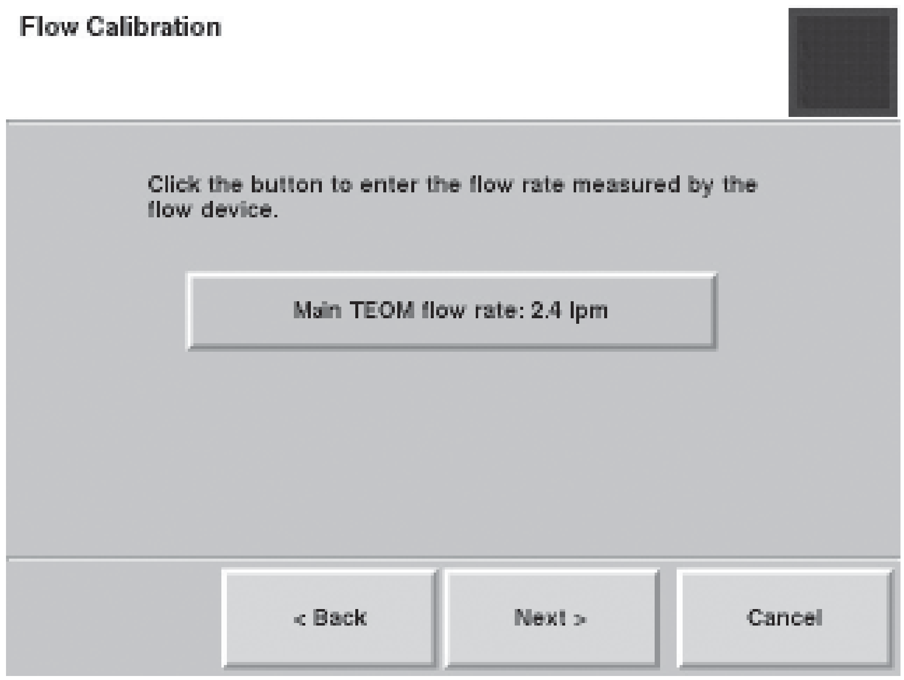


Figure 5-67.
Flow Calibration screen.

7. The wizard will display a screen that shows the current high-setpoint flow rate (as measured by the instrument) in the **TEOM flow rate:** button. *Allow the flow to stabilize.* Select the **TEOM flow rate:** button and enter the current flow rate (to two decimal places) as measured by the flow meter into the number pad and select the **Enter** button. The newly entered flow rate will display in the **TEOM flow rate:** button. Select the **Next >** button.

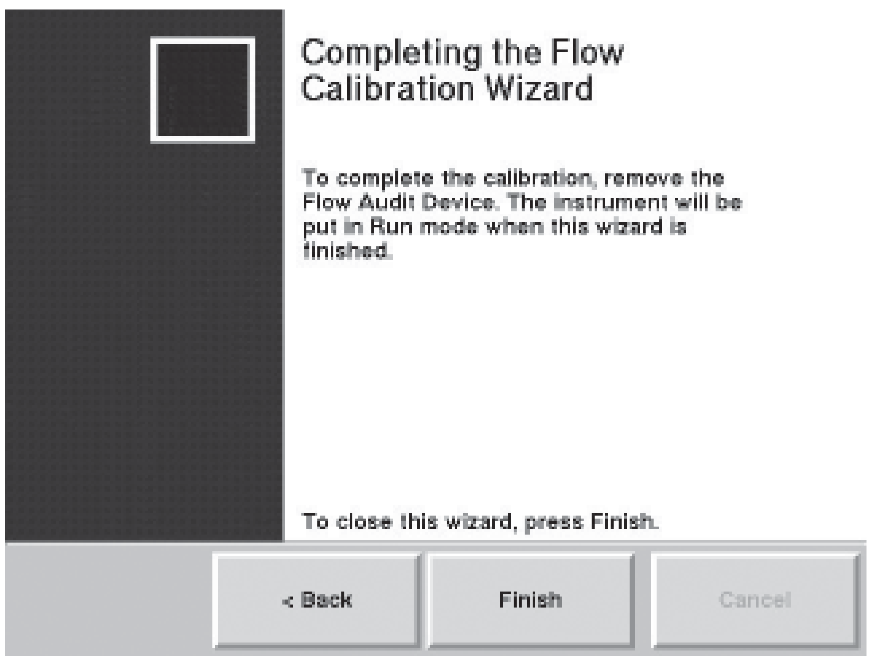
8. The wizard will display a screen that shows the current setpoint flow rate (as measured by the instrument) in the **TEOM flow rate:** button. *Allow the flow to stabilize.* Select the **TEOM flow rate:** button and enter the current flow rate (to two decimal places) as measured by the flow meter into the number pad and select the **Enter** button. The newly entered flow rate will display in the **TEOM flow rate:** button. Select the **Next >** button.

9. After the third flow value has been entered, the Select Flow to Calibrate screen will display again. The flow channel that was just calibrated will be "grayed out" on the screen to show it was calibrated during this calibration session. If you want to calibrate another flow channel, select another channel and follow steps 4 - 9 (and the wizard) to complete additional flow channels. Otherwise, ensure that no flow channel buttons are selected, and select the **Next >** button.

10. The Completing the Flow Calibration Wizard screen will display Figure 5-68). Remove the flow meter and flow adapter(s) and install the inlet. Ensure all lines, including the bypass, are reconnected. Select the **Finish** button to exit the wizard and return to the Calibration screen, or select the **< Back** button to move backward one step in the procedure.

    Note. If you want to audit the total flow rate following the calibration procedure, see Figure 5-62. ▲

Figure 5-68. Completing the Flow Calibration Wizard screen.



Calibrating the Analog Outputs

The Analog Output Calibration Wizard allows users to calibrate the eight analog output channels to either 0-1 VDC or 0-5 VDC.

Note. Always wear appropriate anti-static devices when working with the system electronics. ▲

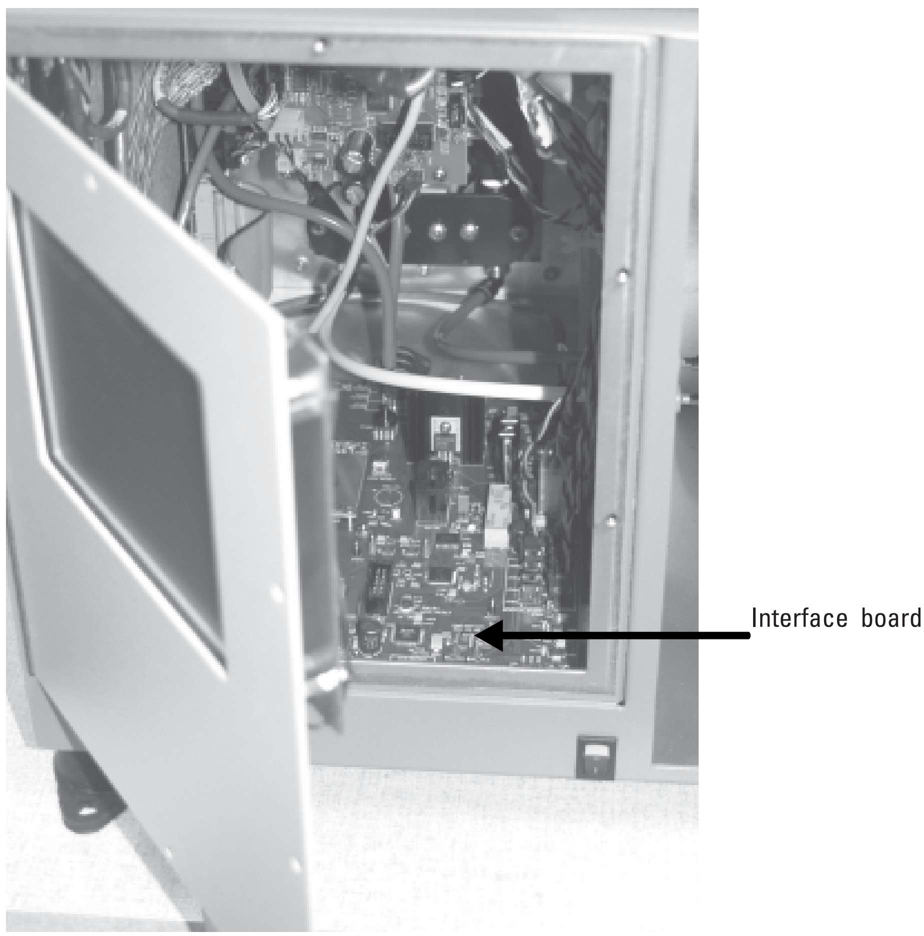
To calibrate the analog outputs:

1. Attach an antistatic wrist strap to your wrist. Attach the other end of the wrist strap to the chassis of the control unit to discharge any static electricity while working on the unit.

   Note. Always wear appropriate anti-static devices when working with the system electronics. ▲

2. Open the door to the unit (Figure 5-69) and locate the interface board mounted to the bottom of the unit.

Figure 5-69. 1405-DF unit with left door open.



3. Locate the analog outputs jumpers and test points located at the front of the board and ensure that the jumper for the channel you are calibrating is set to the correct voltage limit (Figures 5-70 and 5-71).

Note. Set the jumper on the right and middle posts (pictured) for 0-1 VDC and over the middle and left posts for 0-5 VDC. ▲

Figure 5-70.
Front of interface board with jumpers and testpoints highlighted.

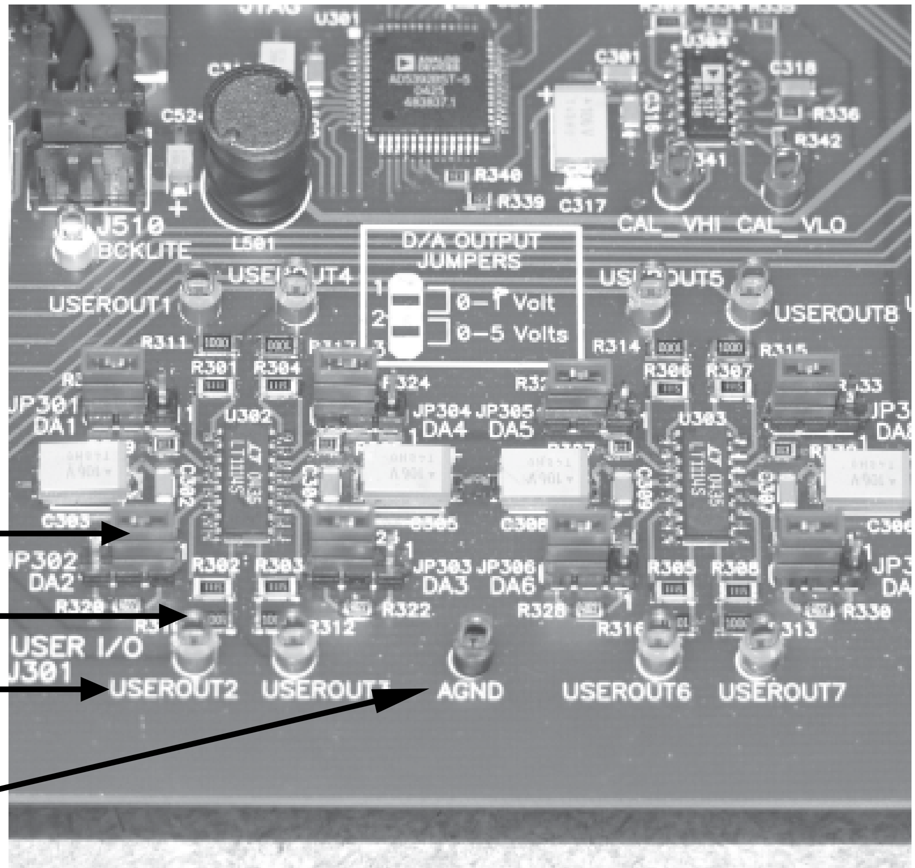
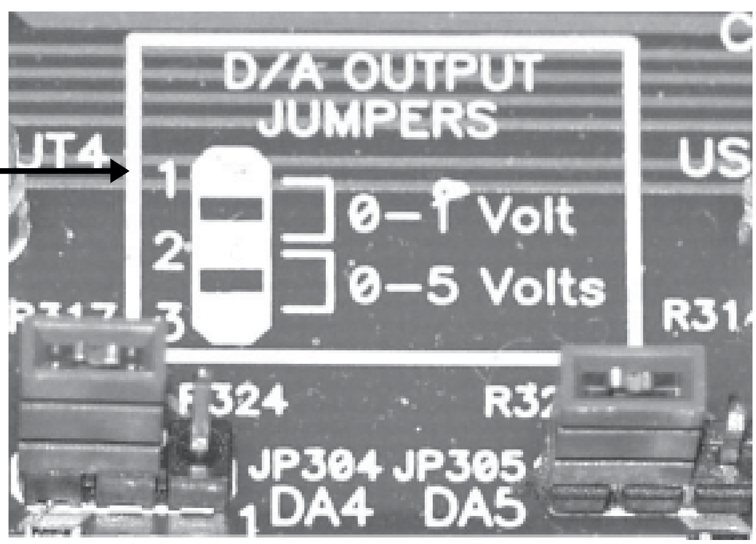


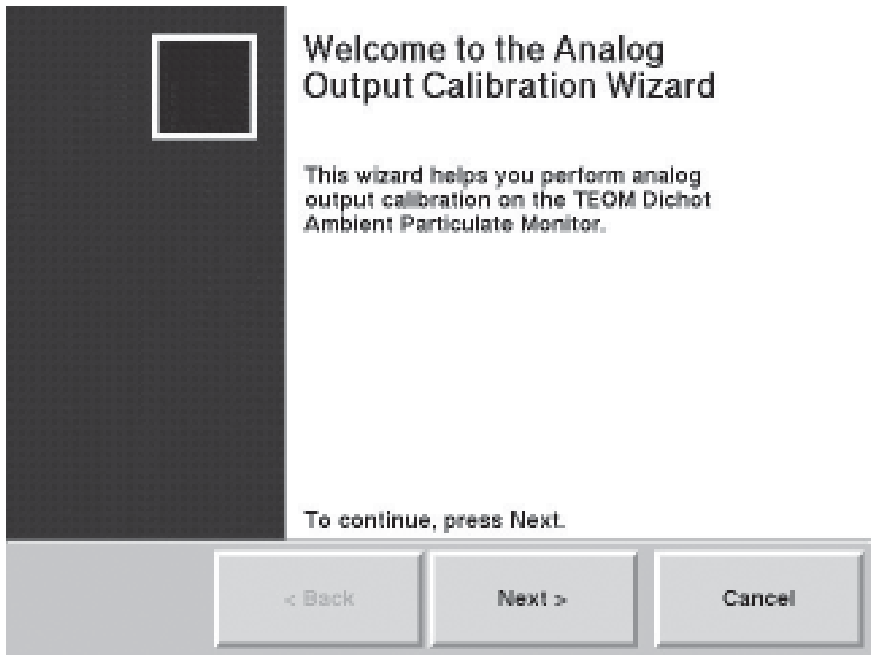
Figure 5-71.
Close-up of setting guide.



4. In the 1405 Data screen, select the **Service** button to display the Service screen, then select the **Calibration** button to display the Calibration screen (Figure 5-48).

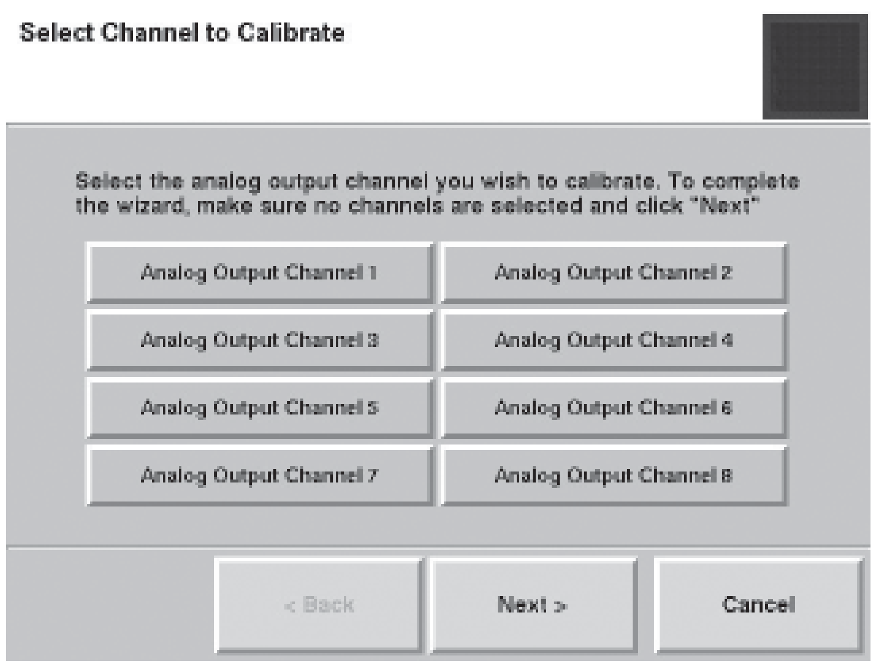
5. Select the **Analog Output Calibration** button to start the Analog Output Calibration Wizard (Figure 5-72). Select the **Next >** button to begin the procedure.

Figure 5-72.
Welcome to the Analog Output Calibration Wizard screen.



6. The Select Channel to Calibrate screen will display (Figure 5-73). Select which analog output channel you want to calibrate. Select the **Next >** button.

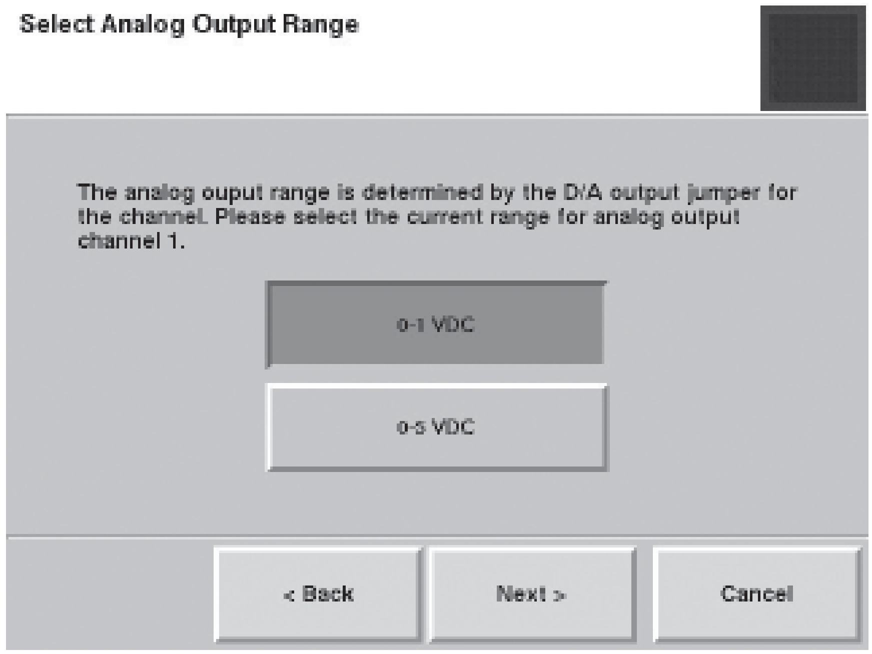
Figure 5-73.
Select Channel to Calibrate screen.



7. The Select Analog Output Range screen will display (Figure 5-74). Set the voltage range for the analog output. Select the **Next >** button.

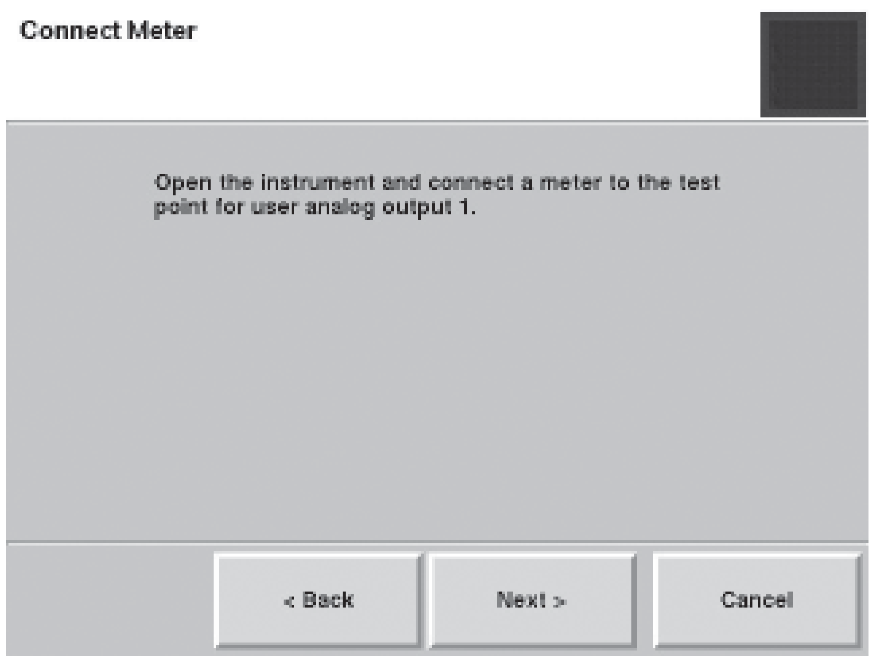
   Note. Ensure that the voltage range selected for the analog output channel matches the jumper voltage setting for the analog output channel (step 3). ▲

Figure 5-74. Select Analog Output Range screen



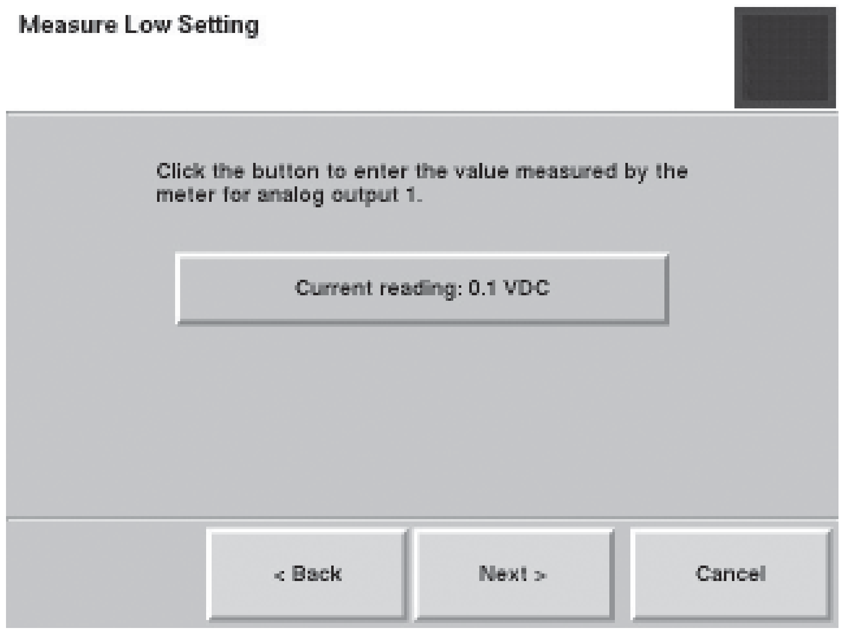
8. The Connect Meter screen will display (Figure 5-75). Locate the test point (Figure 5-70) for the analog output being calibrated and attach a voltmeter set to VDC to the test point and to the ground test point on the board. Select the **Next >** button.

Figure 5-75. Connect Meter screen.



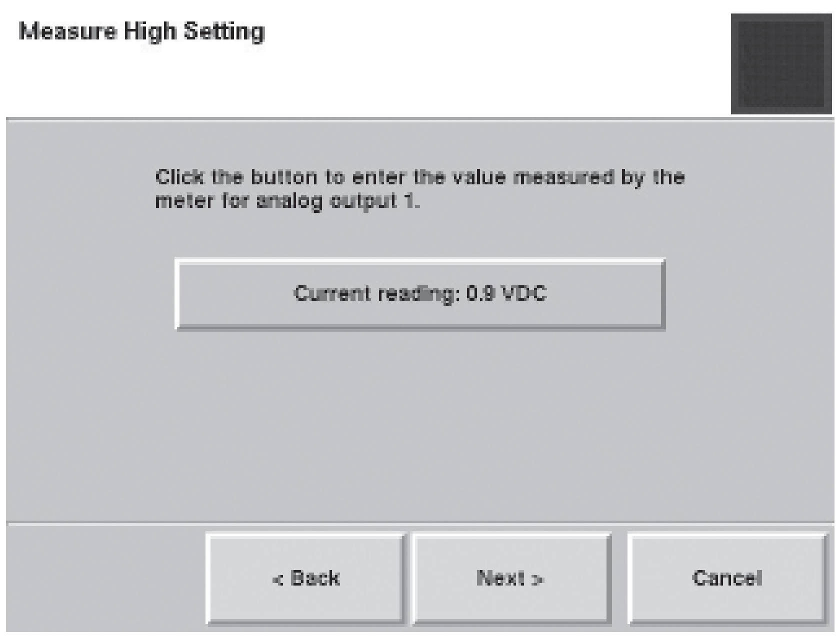
9. The Measure Low Setting screen will display (Figure 5-76). Compare the reading on the volt meter to the reading on the screen. If the readings are different, select the **Current reading:** button to display the number keypad and enter the current reading, and press the **Enter** button. Select the **Next >** button.

Figure 5-76.
Measure Low Setting screen.



10. The Measure High Setting screen will display (Figure 5-77). Compare the reading on the volt meter to the reading on the screen. If the readings are different, select the **Current reading:** button to display the number keypad and enter the current reading, and press the **Enter** button. Select the **Next >** button.

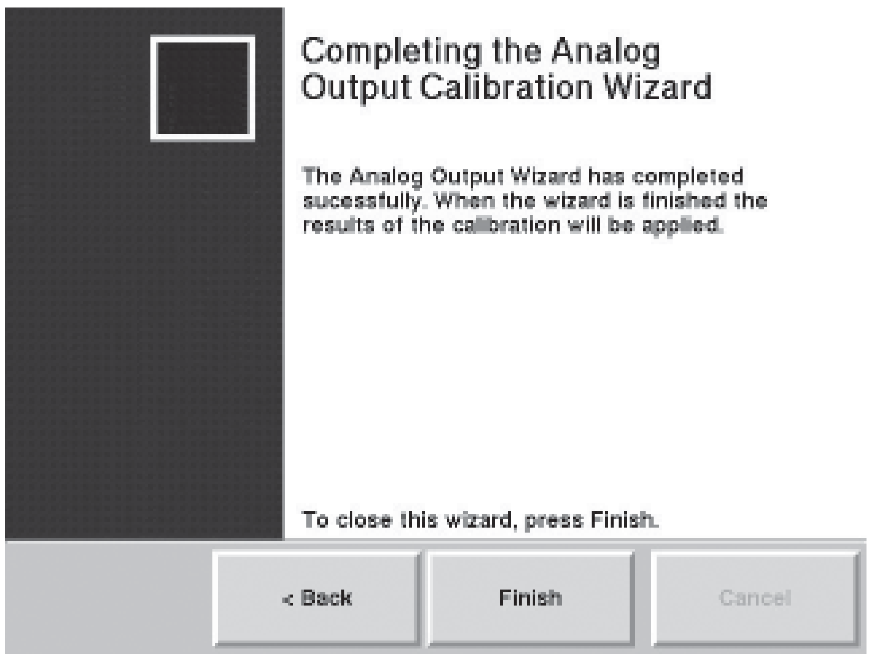
Figure 5-77.
Measure High Setting screen.



11. The Select Channel to Calibrate screen will display again. The channel that was just calibrated will be "grayed out" on the screen to show it was calibrated during this calibration session. If you want to calibrate another analog output channel, select another channel then the **Next >** button and follow steps 1 - 9 (and the wizard) to complete additional channels. Otherwise, ensure that no Analog Output Channel buttons are selected, and select the **Next >** button.

12. The Completing the Analog Output Calibration Wizard screen will display (Figure 5-78). Select the **Finish** button to exit the wizard and return to the Verification & Calibration screen, or select the **< Back** button to move backward one step in the procedure.

Figure 5-78.
Completing the Analog Output Calibration Wizard screen.



Verifying the Calibration Constant

The calibration of the mass transducer in the TEOM 1405 Monitor is determined by the mass transducer's physical mechanical properties. Under normal circumstances, the calibration does not change materially over the life of the instrument. Contact Thermo Scientific if the results of the verification procedure fails. You can locate the original calibration constant on the "Instrument Checkout Record" or the "Final Test Record" documents that are shipped from the factory with the instrument.

Before the TEOM 1405 is shipped to the customer, it is calibrated with a new, pre-weighed TEOM filter installed in its mass transducer as a calibration weight. Because the mass of the filter cartridge with particulate matter differs from the mass of a new filter cartridge by only a small fraction, calibrating the system with a calibration mass equivalent to the filter mass allows all measurements to be made at essentially the same operating point as the original calibration. Refer to Section 1 for a detailed explanation of how the calibration constant, K_0, is derived.

To audit/verify the K0 number requires a mass calibration verification kit (59-002107), which includes a pre-weighed filter, a filter exchange tool, desiccant and a humidity indicator) and the pre-filter with a half-inch quick-connect fitting supplied with the instrument.

Note. Refill kits for the mass calibration verification kit are available from Thermo Scientific (59-002019). ▲

To confirm the system's K_0 calibration:

1. Confirm that the K0 number entered into the instrument and the K0 number on the plate near the mass transducer are the same. The K0 number entered into the unit can be found in the Audit screen (Figure 5-51)

2. Ensure the instrument is at the normal operating temperature and condition.

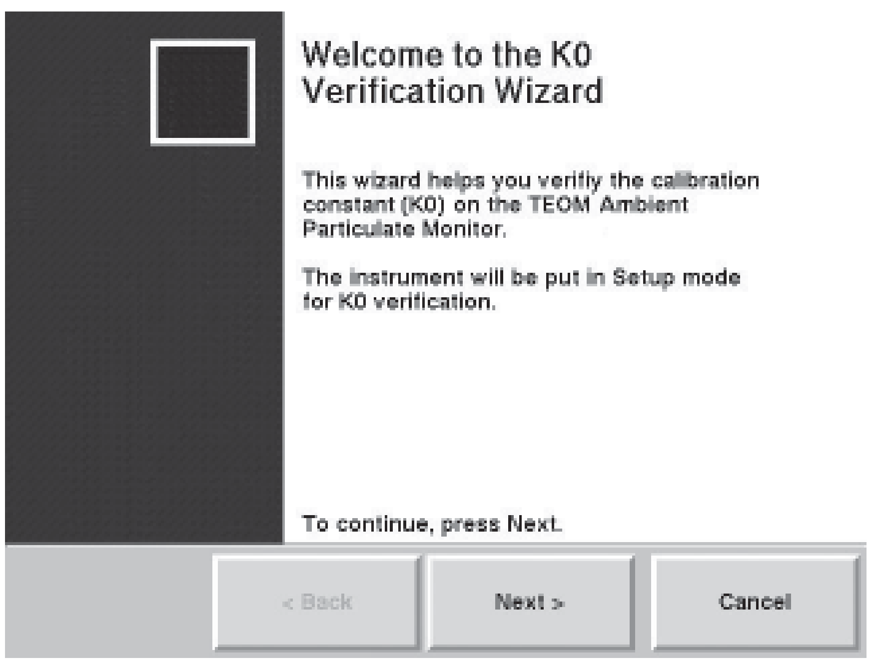
3. Ensure that the pre-weighed filter in the kit matches the humidity conditions for the test, as shown on the card provided with the kit.

   Note. If the filter does not match the conditions listed on the humidity indicator, follow the instructions provided with the kit to dry the filter to an acceptable level. ▲

4. In the TEOM Data screen, select the **Service** button to display the Service screen, then select the **Calibration** button to display the Calibration screen (Figure 5-48).

5. Select the **Mass Transducer K0 Verification** button to start the K0 Verification Wizard (Figure 5-79). Select the **Next >** button to begin the procedure.

Figure 5-79.
Welcome to K0 Verification Wizard screen.



6. The Install Pre-Filter screen will display (Figure 5-80). Remove the inlet and install the flow audit adapter onto the flow splitter, then install the pre-filter assembly (the filter and short length of silicone tubing) onto the flow audit adapter (Figure 5-81). Select the **Next >** button.

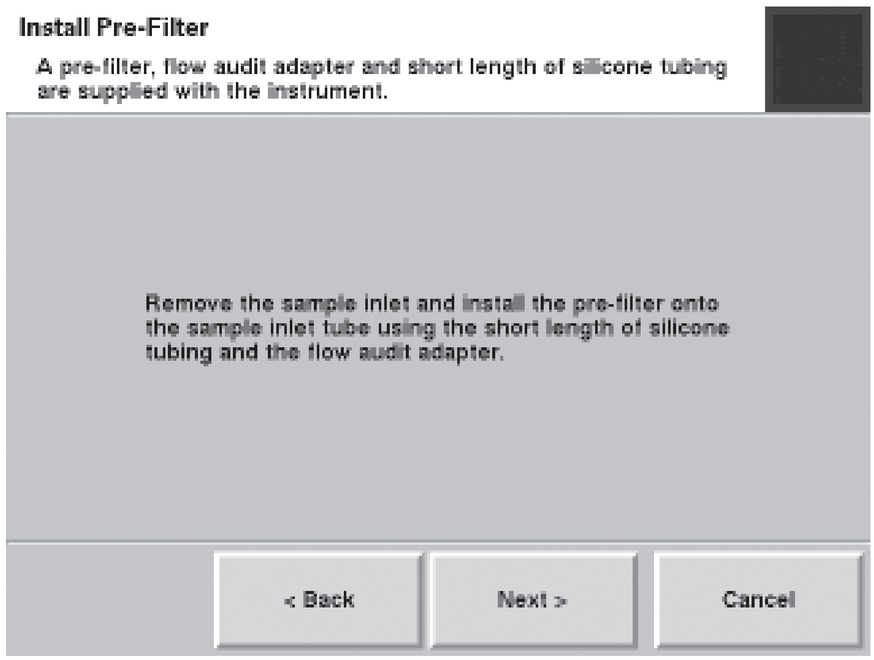
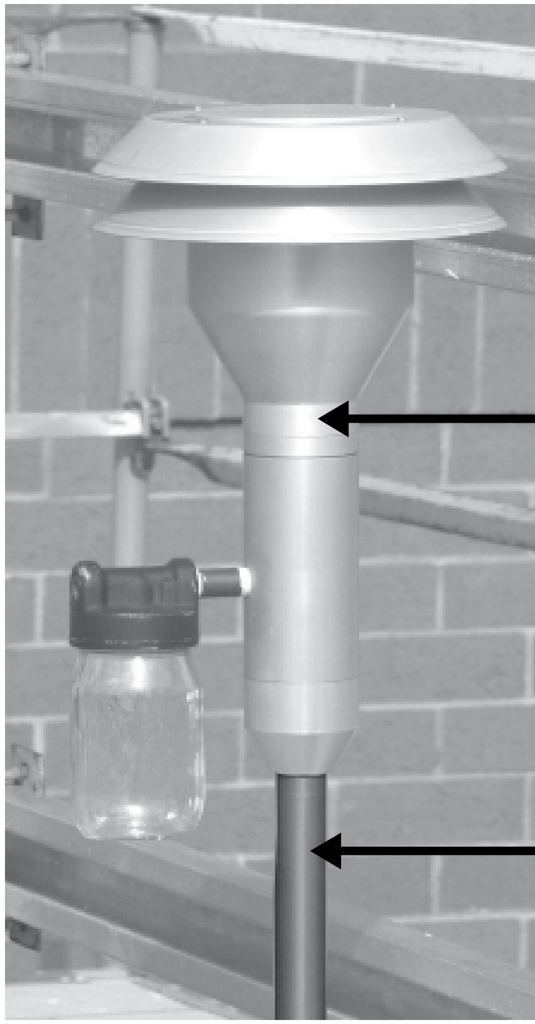


Figure 5-80. Install Pre-Filter screen.

Figure 5-81.
Series 1405 inlet assembly.



Inlet

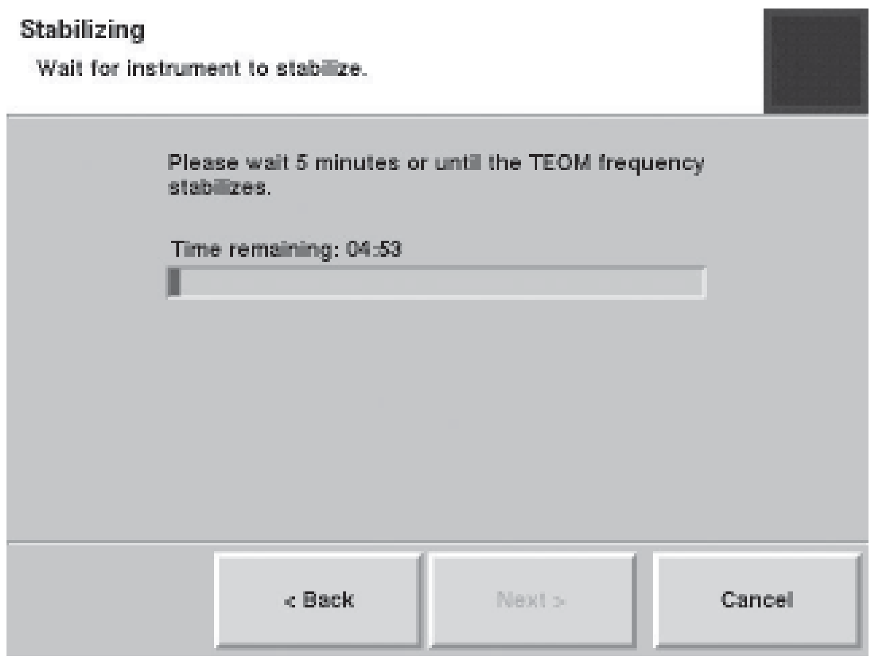
Flow splitter

7. The Remove Sample Filter screen will display. Open the mass transducer and remove the standard TEOM filter from the mass transducer. (Refer to the section on installing/removing TEOM filter for assistance on removing the filter.) Close the mass transducer (without installing another filter). Select the **Next >** button.

   Note. DO NOT use the calibration filter exchange tool for installing or removing ANY filter other than the pre-weighed calibration filter. ▲

8. The Stabilizing screen will display (Figure 5-82). While the instrument waits to mesaure the frequency of the system with no TEOM filter installed, a countdown timer on the screen will show the progress of the stabilization step. When the stabilization “Complete” message displays, select the **Next >** button.

Figure 5-82.
Stabilizing screen.



9. The Enter Filter Weight screen will display (Figure 5-83). Select the **Filter Weight:** button. The keypad will display. Enter the weight of the pre-weighed filter into the system and press the **Enter** button to save the value and exit the keypad. Select the **Next >** button.

Figure 5-83.
Enter Filter Weight screen.

10. The Install Calibration Filter screen will display (Figure 5-84). Correctly install and properly seat the pre-weighed calibration/verification filter onto the mass transducer using the calibration filter exchange tool. (Follow the instructions for changing a filter earlier in this section.) Select the **Next >** button.

    Note. DO NOT use the calibration filter exchange tool for installing or removing ANY filter other than the pre-weighed calibration filter. ▲

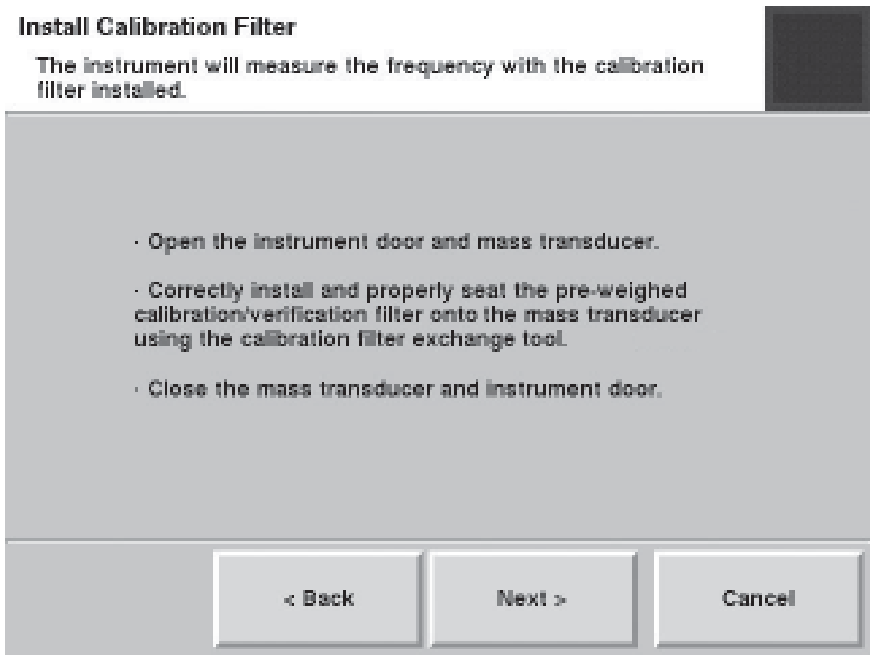


Figure 5-84.
Install Calibration Filter screen.

11. The Stabilizing screen will display while the instrument waits for the frequency of the TEOM calibration filter. A countdown timer on the screen will show the progress of the stabilization step (Figure 5-82). When the stabilization "Complete" message displays, select the **Next >** button.

    Note. If the frequency doesn't stabilize, the wizard will display a screen with instructions to re-seat the filter. Re-seat the filter and select the **Next >** button. The Stabilizing screen will display. If the unit is unable find a stable frequency the second time, the unit will fail the K0 audit (Figure 5-87). ▲

12. The Replace Sample Filter screen will display (Figure 5-85). Remove the calibration filter with the calibration filter removal tool. Correctly install and properly seat a new TEOM filter onto the mass transducer using the regular filter exchange tool. (Follow the instructions for changing a filter earlier in this section.) Select the **Next >** button.

    Note. DO NOT use the calibration filter exchange tool for installing or removing ANY filter other than the pre-weighed calibration filter. ▲

    Note. If the frequency doesn't stabilize, the wizard will display a screen with instructions to re-seat the filter. Re-seat the filter and select the **Next >** button. The Stabilizing screen will display. If the unit is unable find a stable frequency the second time, the unit will fail the K0 audit (Figure 5-87). ▲

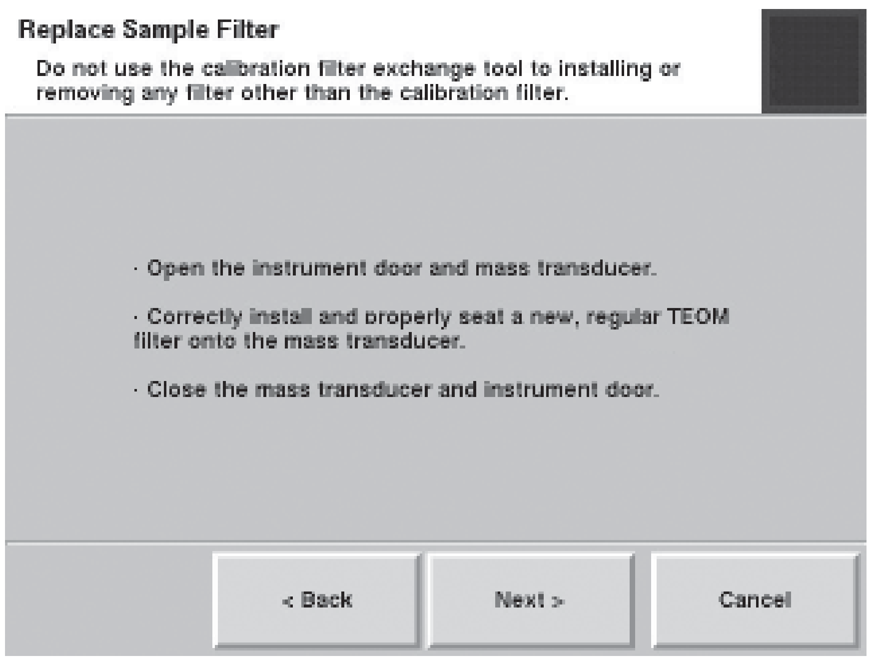


Figure 5-85.
Replace Sample Filter screen.

13. When the final verification has been performed, the Completing the K0 Verification Wizard screen will display. The screen will display either a pass (Figure 5-86) or a fail (Figure 5-87) message for each K0 number. Select the **Finish** button.

Note. If one or both of the K0 verifications fail, repeat the procedure for that K0 number. If the verification fails again, contact Thermo Scientific. ▲

Figure 5-86. Completing to K0 Verification Wizard screen with a pass message.

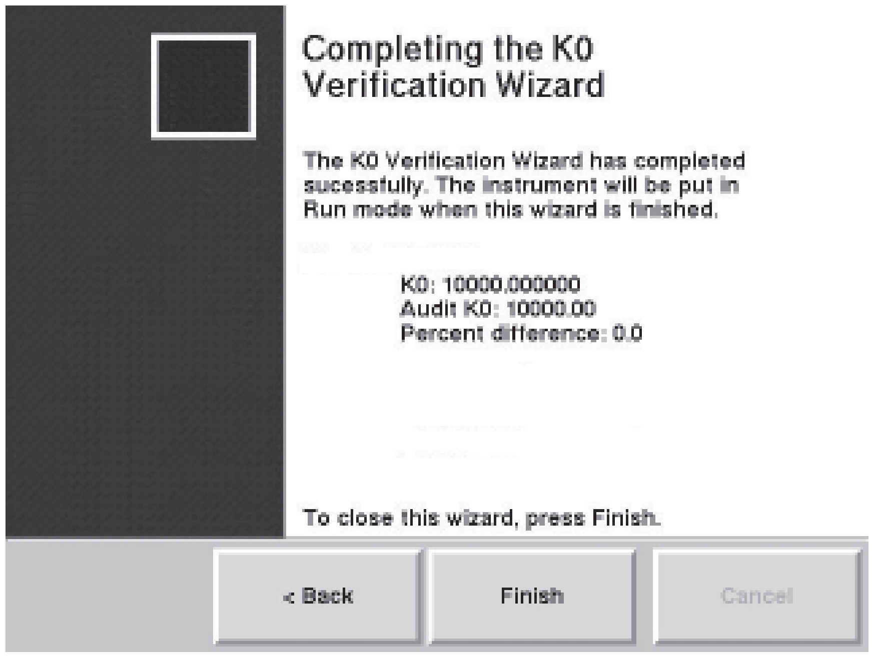
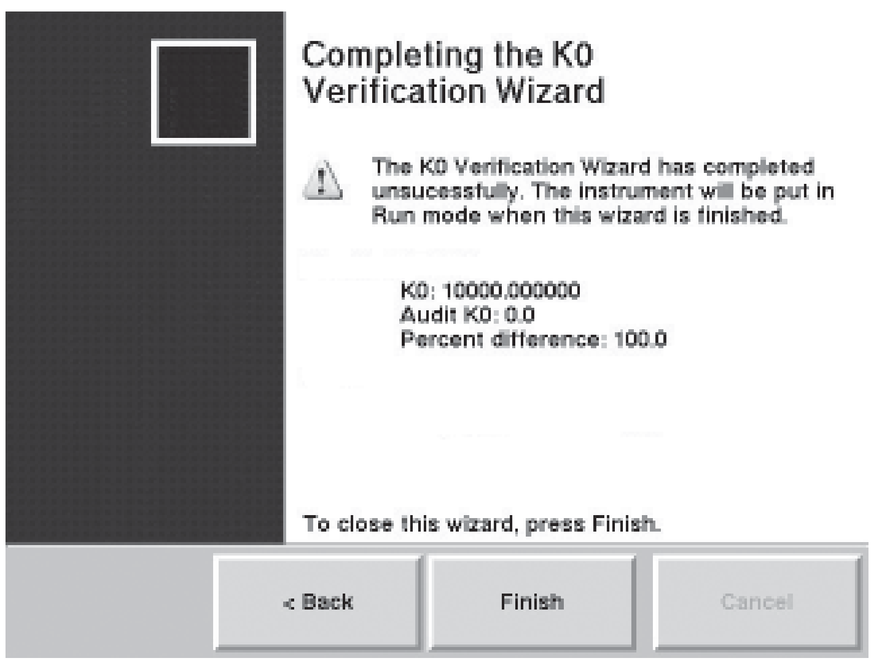


Figure 5-87. Completing the K0 Verification Wizard screen with a fail message.



Appendix A Troubleshooting

The current status condition is located in the status bar at the bottom of the TEOM Data screen (Section 4), and most other instrument screens. In data files, however, status codes are reported as decimal/hexadecimal numbers). The decimal number reported by the unit must be compared to the list of status codes (Table A-1). If the exact decimal code does not appear in the list, multiple status codes are present, and the decimal must be converted to hexadecimal number in order to determine which codes are being reported by the unit.

Note. The status code list in this section (Table A-1) shows codes for both single and dual 1405 systems, as well as those equipped with the FDMS system. ▲

Table A–1. 1405-DF Status Codes

Code	Warning	Decimal	Reason for warning
0x40000000	%RH High Side A	1,073,741,824	>= 98%
0x20000000	Dryer A	536,870,912	> 2
0x10000000	Cooler A	268,435,456	> 0.5 C deviation
0x08000000	Exchange Filter A	134,217,728	> 90
0x04000000	Flow A	67,108,864	> 10% deviation
0x02000000	Heaters Side A	33,554,432	> 2% deviation
0x01000000	Mass Transducer A	16,777,216	frequency < 10 Hz
0x00400000	%RH High Side B	4,194,304	>= 98%
0x00200000	Dryer B	2,097,152	> 2
0x00100000	Cooler B	1,048,576	> 0.5 C deviation
0x00080000	Exchange Filter B	524,288	> 90
0x00040000	Flow B	262,144	> 10% deviation
0x00020000	Heaters Side B	131,072	> 2% deviation
0x00010000	Mass Transducer B	65,536	frequency < 10 Hz
0x00004000	User I/O Device	16,384	
0x00002000	FDMS Device	8,192	
0x00001000	Head 1	4,096	
0x00000800	Head 0	2,048	
0x00000400	MFC 1 Device	1,024	
0x00000200	MFC 0 Device	512	
0x00000100	System Bus	256	
0x00000080	Vacuum Pressure	128	(Ambient -Vac) < 0.1 atm
0x00000040	Case or Cap Heater	64	> 2% deviation
0x00000020	FDMS Valve	32	
0x00000010	Bypass Flow	16	> 10% deviation
0x00000008	Ambient %RH & Temp Sensor	8	Ambient %RH & temp sensor disconnected
0x00000004	Database	4	Unable to log to the database
0x00000002	Enclosure Temp	2	temperature exceeds 60 C
0x00000001	Power Failure	1	

Converting Decimal/Hexadecimal Numbers

The easiest way to convert the decimal numbers reported by the unit is to use the calculator on a Windows-based PC.

To convert a decimal status code to a hexadecimal number:

1) Open the Windows calculator (it's located in **Accessories** under **All Programs** in the Start menu.

2) Select **View,** then **Scientific** to open the scientific-style calculator.

3) Select **Dec** to choose the decimal calculator option, and then enter the decimal status number into the calculator

4) Select **Hex** to choose the hexadecimal calculator option. The new number displayed in the calculator is the hexadecimal number you will use to decipher the status code list.

Note. To convert a hexadecimal to a decimal number, select **Hex**, type in the hexadecimal number then select **Dec.** ▲

To properly use the hexadecimal numbers converted from the decimal data download, separate the converted number and the status codes on the table into place holders: the "one's," "ten's," "100's," "1,000's," "10,000's," and "100,000's" and the "1,000,000's" place. Each "place" in the converted code will have a hexadecimal digit. Each hexadecimal digit (0 -F) in each place will have a unique status code (or set of status codes) that go with it.

Table A-2.
Hex digits and status codes.

Decimal Number	Hex Number	Code (Sum of Codes)
0	0	0
1	1	H(1)
2	2	H(2)
3	3	H(1), (H)2
4	4	H(4)
5	5	H(1), H(4)
6	6	H(2), H(4)
7	7	H(1), H(2), H(4)
8	8	H(8)
9	9	H(1), H(8)
10	A	H(2), H(8)
11	B	H(1), H(2), H(8)
12	C	H(4), H(8)
13	D	H(1), H(4), H(8)
14	E	H(2), H(4), H(8)
15	F	H(1), H(2), H(4), H(8)

Deciphering Status Codes

When the unit shows more than one status code, it adds the codes together and displays them as a decimal sum. For example, if the unit displays a Memory status code (listed as hexadecimal number "(H)1" on the instrument's specific status code table) and a Valve A status code (listed as hexadecimal number "(H)4" on the instrument's specific status code table) at the same time, the two status codes (when downloaded) would be displayed as the decimal number "5."

The decimal number "5" must then be converted back to hexadecimal (in this case also "5") to match the status code table. Only two status codes would add up to a value of 5 (Table A-2). By looking at instrument's specific table and breaking down the downloaded status codes, you will be able to decipher which status codes the unit has displayed. Repeat the operation for each place in the hexadecimal code (10's, 100's, etc.).

Example

For example, decipher the following decimal status code (8433666) for an instrument with the given example status code table (Table A-3).

First convert the decimal status code downloaded from the monitor to a hexadecimal number using the Windows (or another scientific) calculator: 8433666= (H)80B002

Table A-3. Example status code table

Code	Warning	Code	Warning
&H1	Flash Memory	&H4000	Leak on Loop A
&H2	Power Switch (TPIC)	&H8000	Leak on Loop B
&H4	Valve A	&H10000	Audit Failure
&H8	Valve B	&H20000	System Reset
&H10	Filter A Temperature	&H40000	Power Failure
&H20	Filter B Temperature	&H80000	Sample volume low
&H40	Heater A Temperature	&H100000	Meter Out of Range (>98%)
&H80	Heater B Temperature	&H400000	AC Voltage Out of Bounds
&H800	External Sample Tube Temperature	&H800000	Sensor Comm Problem
&H1000	Serial Port Problem	&H10000000	Pinch Valve
&H2000	Line Printer Problem		

- In the "one's" place of the status code, a status code of "2" is displayed. In the "one's" place of the status code table, the "2" status code matches the (H)2 "Power Switch (TPIC)" status code. This is one of the status codes that the unit is displaying in its status code.

- In the "ten's" place of the status code, there are no (0) status codes displayed.

- In the "100's" place of the status code, there are no (0) status codes displayed.

- In the "1,000's" place of the status code, a status code of "B" is displayed. Because there are no status codes in the status code table that match this number, the numbers needs to be broken down further. Convert "B" to a decimal number using Table A-2 — which converts B to "11." Next, look at the status code table to decipher the status code. In the "1,000's" place of the table, there are three status codes that, when added together, will total 11: (H)1000 "Serial Port Problem," (H)2000 "Line Printer Problem" and (H)8000 "Leak on Loop B." These are three more of the status codes that the unit is displaying in its status code.

- In the "10,000's" place of the status code, there are no (0) status codes displayed.

- In the "100,000's" place of the status code (800000), a status code of "800000" is displayed, which matches: (H)800000: "Sensor Comm Problem."

- In the "1,000,000's" place of the status code, there are no (0) status codes displayed.

Therefore, the downloaded status code "8433666" ((H)80B002) breaks down into the following status codes, according to the example status code table:

(H)2 "Power Switch (TPIC)"
(H)1000 "Serial Port Problem"
(H)2000 "Line Printer Problem"
(H)8000 "Leak on Loop B"
(H)800000: "Sensor Comm Problem."

Notes

Appendix B Serial Communication

The TEOM 1405 Monitor supports AK Protocol. This protocol permits a locally or remotely located computer to obtain information electronically from the unit. These protocols are described in this appendix.

AK Protocol

The AK Protocol allows the user to query the present value of any system variable remotely, and allows the user to change those system variable values. The user also can download information from the internal data logger. The RPComm software program uses this protocol for two-way communication directly to a personal computer or through a modem.

The following AK Protocol commands are presented in detail on the following pages:

- **AREG (Ask Register Command).** The user can query the TEOM 1405 Monitor for the current value of any system variable.

- **EREG (Enter Register Command).** The user can assign a new value to any system variable. Great care must be taken when using this command, as the value of variables should only be changed when the monitor is in the appropriate operating mode.

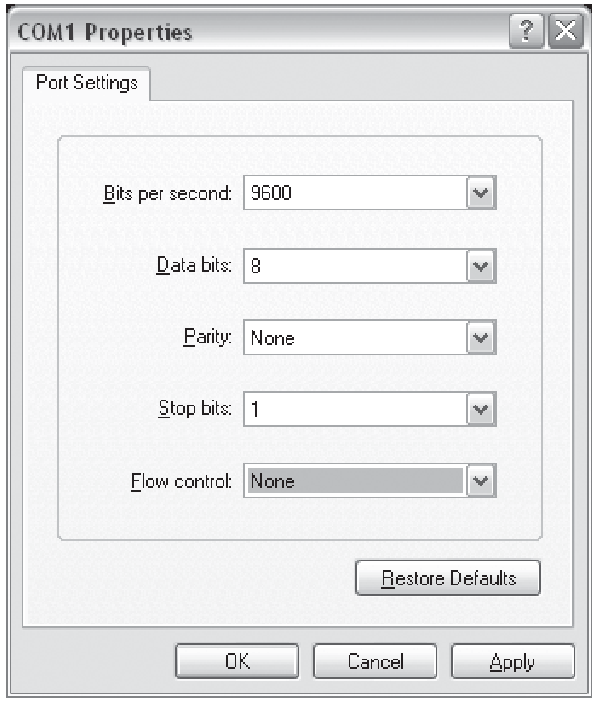
- **SFxx (Set Function xx Command).** The user can send commands using the <RUN> key and the <DATA STOP> key to the instrument. Each command is designated by a two-digit code, xx.

- **ASTO (Ask Storage Command).** The user can download a specified number of records from the internal data logger from the current position of the data storage pointer. The location of this storage pointer may be defined by the SSTO command. The values on each line of output are delimited by commas.

- **SSTO (Set Storage Command).** The user can change the location of the data storage pointer in the internal data logger, and is used in conjunction with the ASTO command described above. The data storage pointer is always located immediately after the last record transmitted through the RS232 port via the AK Protocol. If the circular buffer overwrites this location or if the ASTO or SSTO commands have not been used, the data storage pointer is positioned at the oldest record in the internal data logger.

For AK communication, the COM port settings are:

Figure B-1.
AL COM Port Settings.



The following pages list the common PRC codes and show how RS-Para 1 through RS-Para 4 are defined in the AK Protocol, and also detail the format of the transmission and response messages of the commands listed on the previous page.

Table B-1. 1405-F Main PRC Codes

PRC Code	Description	PRC Code	Description
001	Serial Number	282	TEOM Cooler Temperature
007	Operating Mode	284	TEOM Base MC
008	Status Condition	285	TEOM Reference MC
047	Current Case Temperature		
058	Current Cap Temperature		
061	Current Ambient Temperature		
063	Current Ambient Relative Humidity		
064	Ambient Dew Point		
066	Current Ambient Pressure		
090	Bypass Flow		
096	Vacuum Pump Pressure		
217	TEOM Flow		
231	TEOM Current Air Temperature		
237	TEOM Filter Loading Percentage		
240	TEOM Mass Concentration		
244	TEOM 1-Hour Average Mass Concentration		
245	TEOM XX-Hour Average Mass Concentration		
246	TEOM 12-Hour Average Mass Concentration		
247	TEOM 24-Hour Average Mass Concentration		
248	TEOM Mass Rate		
252	TEOM Frequency		
253	TEOM Noise		
267	TEOM Dryer Dew Point		

AK Protocol

Ask Register Command (AREG)

COM 2-WAY SETTINGS

RS-Para 1	52	ASCII code for the 1-digit Station Number (for example "4": 052). The Station Number is always 1 digit in length.
RS-Para 2	75048	ASCII code representation of the 2-digit Channel Number (for example: "K0": 075, 048). The Channel Number is always 2 digits in length.
RS-Para 3	13010	Optional: Up to 3 ASCII codes can be added to response from the instrument. In this case, <CR> and <LF> (ASCII codes 013 and 010) are appended to the response. Enter 0 if nothing is to be appended.
RS-Para 4	0	Not used.

Transmission to Instrument			Response from Instrument			
Byte	**Example**	**Description**	**B**	**No Err**	**Error**	**Description**
1	<STX>	ASCII code 002.	1	<STX>	<STX>	ASCII code 002.
2	4	1-digit Station Number, RS-Para 1.	2	4	4	1-digit Station Number, RS-Para 1.
3	A	Ask Register command.	3	A	A	4-digit Ask Register command.
4	R		4	R	R	
5	E		5	E	E	
6	G		6	G	G	
7	<space>	Space.	7	<space>	<space>	Space.
8	K	2-digit Channel Number as defined by RS Para 2.	8	0	0	Number of current status conditions.
9	0		9	<space>	<space>	Space.
10	<space>	Space.	10	9	S	Program Register Code of the variable whose value is being requested. The PRC may be up to 3 digits long and is not right-filled in the response.
11	9	Program Register Code of the variable whose value is being requested. The PRC may be up to 3 digits long. Do not right-fill if the PRC is less than 3 characters long.	11		E	
12			12		<ETX>	
13			13	<space>	<CR>	Space.
14	<ETX>	ASCII code 003.	14	9	<LF>	Current value of the variable referenced by the Ask Register command. NOTE: This value can be of varying length.
15			15	7		
16			16	4		
17			17	.		
18			18	3		
19			19	8		

AK Protocol

Ask Register Command (AREG) (continued)

Transmission to Instrument			Response from Instrument			
Byte	**Example**	**Description**	**B**	**No Err**	**Error**	**Description**
20			20	<ETX>		ASCII code 003.
21			21	<CR>		Up to 3 digits appended to the end of the response transmission, according to the entry for RS-Para 3.
22			22	<LF>		
23	Description of Status Codes (PRC 008) 1 Mass Transducer 2 Temperature 4 Flow Rate 8 Filter Exchange 16 Voltage		23			
24			24			
25			25			
26			26			
27			27			
28			28			
29			29			
30			30			
31			31			
32			32			
33			33			
34			34			
35			35			
36			36			
37			37			
38			38			
39			39			
40			40			
41			41			
42			42			
43			43			
44			44			
45			45			
46			46			

AK Protocol

Enter Register Command (EREG)

COM 2-WAY SETTINGS

RS-Para 1	52	ASCII code for the 1-digit Station Number (for example "4": 052). The Station Number is always 1 digit in length.
RS-Para 2	75048	ASCII code representation of the 2-digit Channel Number (for example: "K0": 075, 048). The Channel Number is always 2 digits in length.
RS-Para 3	13010	Optional: Up to 3 ASCII codes can be added to response from the instrument. In this case, <CR> and <LF> (ASCII codes 013 and 010) are appended to the response. Enter 0 if nothing is to be appended.
RS-Para 4	0	Not used.

Transmission to Instrument			Response from Instrument			
Byte	**Example**	**Description**	**B**	**No Err**	**Error**	**Description**
1	<STX>	ASCII code 002.	1	<STX>	<STX>	ASCII code 002.
2	4	1-digit Station Number, RS-Para 1.	2	4	4	1-digit Station Number, RS-Para 1.
3	E	Enter Register command.	3	E	E	4-digit Enter Register command.
4	R		4	R	R	
5	E		5	E	E	
6	G		6	G	G	
7	<space>	Space.	7	<space>	<space>	Space.
8	K	2-digit Channel Number, as defined by RS Para 2.	8	0	0	Number of current status conditions.
9	0		9	<space>	<space>	Space.
10	<space>	Space.	10	6	S	Program Register Code of the variable whose value was entered. The PRC may be 1 to 3 digits long and is not right-filled in the response.
11	6	Program Register Code of the variable whose value is being requested. The PRC may be up to 3 digits long. Do not right-fill if the PRC is less than 3 characters long.	11	3	E	
12	3		12		<ETX>	
13			13	<ETX>	<CR>	ASCII code 003.
14	<space>	Space.	14	<CR>	<LF>	Up to 3 digits appended to the end of the response transmission, according to the entry for RS-Para 3.
15	2	New value to be entered for variable referenced by Program Register Code in bytes 11 to 13 above. NOTE: The value entered may be of varying length, and is not restricted to 4 bytes.	15	<LF>		
16	3		16			
17	8		17			
18	0		18			
19	<ETX>	ASCII code 003.	19			

AK Protocol

Set Function Command (SFxx)

RS-Para 1	52	ASCII code for the 1-digit Station Number (for example "4": 052). The Station Number is always 1 digit in length.
RS-Para 2	75048	ASCII code representation of the 2-digit Channel Number (for example: "K0": 075, 048). The Channel Number is always 2 digits in length.
RS-Para 3	13010	Optional: Up to 3 ASCII codes can be added to response from the instrument. In this case, <CR> and <LF> (ASCII codes 013 and 010) are appended to the response. Enter 0 if nothing is to be appended.
RS-Para 4	0	Not used.

Transmission to Instrument

Byte	Example	Description
1	<STX>	ASCII code 002.
2	4	1-digit Station Number, RS-Para 1.
3	S	Set Function command, where xx represents a 2-digit code between 00 and 32. These codes are defined below.
4	F	
5	x	
6	x	
7	<space>	Space.
8	K	2-digit Channel Number, as defined by RS Para 2.
9	0	
10	<ETX>	ASCII code 003.

LISTING OF FUNCTION CODES (xx):

03 <Run>
06 <Data Stop>
09 <F1>
17 <F5>
25 <Stop All>
26 Set Time

Response from Instrument

B	No Err	Error	Description
1	<STX>	<STX>	ASCII code 002.
2	4	4	1-digit Station Number, RS-Para 1.
3	S	S	4-digit Set Function command, with the 2-digit xx code corresponding to the function that was set.
4	F	F	
5	x	x	
6	x	x	
7	<space>	<space>	Space.
8	0	0	Number of current status conditions.
9	<ETX>	<space>	Space.
10	<CR>	S	Upto 3 digits appended to the end of the response transmission, according to the entry for RS-Para 3.
11	<LF>	E	
12		<ETX>	
13		<CR>	
14		<LF>	
15			
16			
17			
18			
19			

To Set Time Remotely:

1) Ensure that the instrument is in the Stop Mode.
2) Transmit the proper values in PRCs 2 through 6.
3) Execute the SF26 command.

AK Protocol

Ask Storage Command (ASTO)

COM 2-WAY SETTINGS

RS-Para 1	52	ASCII code for the 1-digit Station Number (for example "4": 052). The Station Number is always 1 digit in length.
RS-Para 2	75048	ASCII code representation of the 2-digit Channel Number (for example: "K0": 075, 048). The Channel Number is always 2 digits in length.
RS-Para 3	13010	Optional: Up to 3 ASCII codes can be added to response from the instrument. In this case, <CR> and <LF> (ASCII codes 013 and 010) are appended to the response. Enter 0 if nothing is to be appended.
RS-Para 4	0	Not used.

Transmission to Instrument			Response from Instrument			
Byte	**Example**	**Description**	**B**	**No Err**	**Error**	**Description**
1	<STX>	ASCII code 002.	1	<STX>	<STX>	ASCII code 002.
2	4	1-digit Station Number, RS-Para 1.	2	4	4	1-digit Station Number, RS-Para 1.
3	A	Ask Storage command.	3	A	A	4-digit Ask Storage command.
4	S		4	S	S	
5	T		5	T	T	
6	O		6	O	O	
7	<space>	Space.	7	<space>	<space>	Space.
8	K	2-digit Channel Number, as defined by RS Para 2.	8	0	0	Number of current status conditions.
9	0		9	<space>	<space>	Space.
10	<space>	Space.	10	3	S	Records to be downloaded from storage. This can be smaller than requested number due to end of file. Storage Marker moved to after last record transmitted. Not right-filled.
11	5	The number of records to be downloaded from the instrument's storage. Downloading begins at the storage marker, which can be set using the SSTO command.	11	1	E	
12	0		12		<ETX>	
13			13	<ETX>	<CR>	ASCII code 003.
14	<ETX>	ASCII code 003.	14	<CR>	<LF>	Up to 3 digits appended to the end of the response transmission, according to the entry for RS-Para 3.
15			15	<LF>		
16			16			
17			17	The instrument then transmits the number of storage records shown in response bytes10 through 12 above. Each record is followed by <CR><LF>.		
18			18			
19			19			

AK Protocol

Set Storage Marker Command (SSTO)

COM 2-WAY SETTINGS

RS-Para 1	52	ASCII code for the 1-digit Station Number (for example "4": 052). The Station Number is always 1 digit in length.
RS-Para 2	75048	ASCII code representation of the 2-digit Channel Number (for example: "K0": 075, 048). The Channel Number is always 2 digits in length.
RS-Para 3	13010	Optional: Up to 3 ASCII codes can be added to response from the instrument. In this case, <CR> and <LF> (ASCII codes 013 and 010) are appended to the response. Enter 0 if nothing is to be appended.
RS-Para 4	0	Not used.

Transmission to Instrument			Response from Instrument			
Byte	**Example**	**Description**	**B**	**No Err**	**Error**	**Description**
1	<STX>	ASCII code 002.	1	<STX>	<STX>	ASCII code 002.
2	4	1-digit Station Number, RS-Para 1.	2	4	4	1-digit Station Number, RS-Para 1.
3	S	Set Storage Marker command.	3	S	S	4-digit Set Storage Marker command.
4	S		4	S	S	
5	T		5	T	T	
6	O		6	O	O	
7	<space>	Space.	7	<space>	<space>	Space.
8	K	2-digit Channel Number, as defined by RS Para 2.	8	0	0	Number of current status conditions.
9	0		9	<ETX>	<space>	ASCII code 003.
10	<space>	Space.	10	<CR>	S	Up to 3 digits appended to the end of the response transmission, according to the entry for RS-Para 3.
11	B	New location of the Storage Marker. B:move to beginning of storage buffer. E: move to end of storage buffer. Enter positive numbers, such as 250, to move forward by 250 records, and negative numbers, such as -1000, to move backwards by 1000 records. Do not right fill.	11	<LF>	E	
12			12		<ETX>	
13			13		<CR>	
14			14		<LF>	
15			15			
16	<ETX>	ASCII code 003.	16			
17			17			
18			18			
19			19			

AK Protocol

Response if Command Addressed to Instrument is Unrecognizable

COM 2-WAY SETTINGS

RS-Para 1	52	ASCII code for the 1-digit Station Number (for example "4": 052). The Station Number is always 1 digit in length.
RS-Para 2	75048	ASCII code representation of the 2-digit Channel Number (for example: "K0": 075, 048). The Channel Number is always 2 digits in length.
RS-Para 3	13010	Optional: Up to 3 ASCII codes can be added to response from the instrument. In this case, <CR> and <LF> (ASCII codes 013 and 010) are appended to the response. Enter 0 if nothing is to be appended.
RS-Para 4	0	Not used.

Transmission to Instrument			Response from Instrument			
Byte	Example	Description	B	No Err	Error	Description
1			1		<STX>	ASCII code 002.
2			2		4	1-digit Station Number, RS-Para 1.
3			3		?	Question marks inserted in place of unrecognizable command.
4			4		?	
5			5		?	
6			6		?	
7			7		<space>	Space.
8			8		0	Number of current status conditions.
9			9		<space>	Space.
10			10		S	Syntax error.
11			11		E	
12			12		<ETX>	ASCII code 003.
13			13		<CR>	Up to 3 digits appended to the end of the response transmission, according to the entry for RS-Para 3.
14			14		<LF>	
15			15			
16			16			
17			17			
18			18			
19			19			