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ENERGIE UND UMWELT GMBH

Deutsche Akkreditierungsstelle D-PL-11120-02-00

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}

TÜV-Report: 936/21209885/B
Cologne, November 25, 2011

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TÜV Rheinland Energie und Umwelt GmbH

is accredited for the following work areas:

- Determination of emissions and ambient airs of air pollution and odor 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

according to EN ISO/IEC 17025.
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DAkkS Deutsche Akkreditierungsstelle D-PL-11120-02-00

Report on the suitability test of the ambient air quality measuring system TEOM 1405-F Ambient Particulate Monitor with PM10 pre-separator of the company Thermo Fisher Scientific for the component PM10

Device tested:	TEOM 1405-F Ambient Particulate Monitor with PM10 pre-separator
Manufacturer:	Thermo Fisher Scientific 27 Forge Parkway Franklin, Ma 02038 USA
Test period:	December 2009 to October 2011
Date of report:	November 25, 2011
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1. Summary and proposal for declaration of suitability

1.1 Summary

According to Directive 2008/50/EC of 21 May 2008 on “Air quality and cleaner air for Europe” (replaces Council Directive of 27 September 1996 on ambient air quality assessment and management including its daughter directives 1999/30/EC, 2000/69/EC, 2002/3/EC and the Council Decision 97/101/EC), the methods described in Standard EN12341 „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“ and Standard EN14907 „Ambient air quality - Standard gravimetric measurement method for the determination of the $PM_{2.5}$ mass fraction of suspended particulate matter“ serve as reference methods for suspended particle measurement of the respective mass fraction. However, EC member states are free to use any other method in the case of particulate matter for which the Member State concerned can demonstrate displays a consistent relationship to the reference method. In that event the results achieved by that method must be corrected to produce results equivalent to those that would have been achieved by using the reference method.“ (2008/50/EC, Annex VI, B).

The Guidance “Demonstration of Equivalence of Ambient Air Monitoring Methods” [5] (which was developed by an ad hoc EC task group (Source:

http://ec.europa.eu/environment/air/quality/legislation/pdf/equivalence.pdf, Version January 2010)
describes an equivalence check method for non-standard measurement methods.

The specifications of the Guide for the equivalence testing were included in the last revision of the VDI Standards VDI 4202, Part 1 as well as VDI 4203, Part 3.

The following limits were applied during suitability testing:

	PM_{10}
Daily limit value (24 h)	50 µg/m³
Annual limit value (1 a)	40 µg/m³

as well as for the calculations according to the Guide [4]

	PM_{10}
Limit value	50 µg/m³

Standard VDI 4202, Part 1 of June 2002 describes all „Minimum requirements for suitability tests of automatic ambient air measuring systems". General parameters for the related tests are given in Standard VDI 4203, Part 1 „Testing of automatic measuring systems - General concepts" of October 2001 and furthermore specified in VDI 4203, Part 3 „Testing of automatic measuring systems - Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants" of August 2004. The fulfilment of the requirements from VDI standards is mandatory in Germany.

Standard VDI 4202, Part 1 and VDI 4203, Part 3 were republished after an extensive revision with latest update September 2010. Unfortunately, after this revision uncertainties and contradictions remain regarding the concrete minimum requirements on the one hand and the general relevance of the test points on the other hand while testing particulate ambient air measuring devices. The following test points require clarification:

6.1 5.3.2 Repeated standard deviation at zero point
no minimum requirement defined

6.1 5.3.3 Repeated standard deviation at reference point
not relevant for particulate devices

6.1 5.3.4 Linearity (Lack of fit)
not relevant for particulate devices

6.1 5.3.7 Sensitivity coefficient of the surrounding temperature
no minimum requirement defined

6.1 5.3.8 Sensitivity coefficient of the electric voltage
no minimum requirement defined

6.1 5.3.11 Standard deviation from paired measurements
no minimum requirement defined

6.1 5.3.12 Long-term drift
no minimum requirement defined

6.1 5.3.13 Short-time drift
not relevant for particulate devices

6.1 5.3.18 Overall uncertainty
→ not relevant for particulate devices

For this reason an official request to the competent German body was made, to define a co-ordinated procedure for dealing with inconsistencies in the Standard.

The following procedure was suggested:

The test points 5.3.2, 5.3.7, 5.3.8, 5.3.11 and 5.3.12 are evaluated as before based on the minimum requirements stated in VDI 4202 Part 1 from 2002 (i.e. using the reference values B_0, B_1 and B_2).

The testing of the test points 5.3.3, 5.3.4, 5.3.13 and 5.3.18 is waived, as they are not relevant for particulate measuring devices.

The competent German body agreed with the proposed procedure by decision of 27 June 2011 respectively 07 October 2011.

According to the applied standards the following reference values have been agreed upon:

	PM_{10}
B_0	2 µg/m³
B_1	40 µg/m³
B_2	200 µg/m³

Thermo Fisher Scientific has commissioned TÜV Rheinland Energie und Umwelt GmbH with the performance of a suitability testing of TEOM 1405-F Ambient Particulate Monitor for the component PM10. The suitability testing of the measuring system was carried out applying the following standards and requirements:

- Standard VDI 4202 Part 1, „Minimum requirements for suitability tests of automatic ambient air measuring systems – Point-related measurement methods of gaseous and particulate pollutants“, September 2010 or June 2002
- Standard VDI 4203 Part 3, „Testing of automatic measuring systems - Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants“, September 2010 or August 2004
- Standard EN 12341, „Ambient 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“, German version EN 12341: 1998
- Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods”, English version of January 2010

The measuring system TEOM 1405-F Ambient Particulate Monitor determines the particulate concentration by an oscillating microbalance measuring principle (TEOM = Tapered Element Oscillating Microbalance). With the aid of a pump, ambient air is sucked at 16.7 l/min via a PM_{10} sampling inlet. The dust-laden sampling air is collected and quantified on a TEOM-filter. By securing a constant flow rate of 3 l/min and by a continuous determination of the collected mass on the TEOM-filter, the PM_{10}-concentration can nearly be determined in real time. The measuring system TEOM 1405-F Ambient Particulate Monitor is equipped with a so called FDMS-system (= Filter Dynamics Measurement System). By using a FDMS-system non-volatile as well as the volatile particulate matter is taken into account while determining the concentration of the particulate matter.

The tests took place in the laboratory and for several months in the field.

The following test sites were chosen for the field test according to Table 1:

Table 1: Description of the test sites

	Teddington (UK), winter	Teddington (UK), summer	Cologne, parking lot, winter	Bornheim, motorway parking lot, summer
Time period	12/2009 – 03/2010	04/2010 – 07/2010	01/2011 – 05/2011	07/2011 – 10/2011
No. of paired values: Candidates	46	49	88	68
Characteristics	Urban background	Urban background	Urban background	Rural structure + motorway
Rank of pollution	Average	Average	Average to high	Low to average

The complete test was performed within the scope of the test program „Combined MCERTS and TÜV PM Equivalence Testing Programme“. In the context of European harmonization, the test program was developed by British and German test institutes (Bureau Veritas UK Limited, National Physical Laboratory (NPL) and TÜV Rheinland) and comprises the testing of the latest series of suspended particle measuring systems by different manufacturers in the laboratory and at field test sites in the UK and in Germany.

The minimum requirements were fulfilled during suitability testing.

TÜV Rheinland Energie und Umwelt GmbH therefore suggests publication as a suitability-tested measuring system for continuous monitoring of suspended particulate matter PM_{10} in ambient air.

1.2 Proposal of declaration of suitability

On the basis of the positive results that have been achieved, the following recommendation is made for the notification as a suitability-tested measuring system:

Measuring system:

TEOM 1405-F Ambient Particulate Monitor with PM10 pre-separator for PM10

Manufacturer:

Thermo Fisher Scientific, Franklin, USA

Suitability:

For continuous monitoring of suspended particulate matter of the PM_{10}-fraction in ambient air (stationary operation).

Measuring ranges during the suitability test:

Component	Certification range	Unit
PM_{10}	0 – 1000	µg/m³

Software version:

1.55

Restrictions:

The allowed range of ambient temperature at the installation test site is 8 °C to 25 °C.

Notes:

1. The requirements to the variation coefficient R^2 according standard EN 12341 were not kept for the test sites Teddington (Summer) and Bornheim (Summer).
2. The requirements according to guide “Demonstration of Equivalence of Ambient Air Monitoring Methods” are fulfilled for the measured components PM_{10}.
3. The measuring system is to be calibrated on test site in regular intervals by application of the gravimetric PM_{10} reference method according to EN 12341.
4. The test report on the suitability test is visible in the internet under www.qal1.de.

Test report:

TÜV Rheinland Energie und Umwelt GmbH, Cologne, Germany

Report-No.: 936/21209885/B of November 25, 2011

1.3 Summary of test results

Minimum requirement		Specification	Test result	Fulfilled	Page
4	Requirements on the instrument design				
4.1	General requirements				
4.1.1	Measured value display	Shall be available.	The measuring device comprises a measured value display.	yes	61
4.1.2	Easy maintenance	Necessary maintenance of the measuring systems should be possible without larger effort, if possible from outside.	Maintenance works can be carried out with commonly available tools taking reasonable time and effort.	yes	63
4.1.3	Functional test	If the operation or the functional check of the measuring system require particular instruments, they shall be considered as part of the measuring system and be applied in the corresponding sub-tests and included in the assessment. Test gas units included in the measuring system shall indicate their operational readiness to the measuring system by a status signal and shall provide direct as well as remote control via the measuring system.	All system functions listed in the manual are available, activatable and functioning. The current system status in continuously monitored and displayed by a set of different status messages (operation, warning and error messages).	yes	65
4.1.4	Set-up times and warm-up times	The set-up times and warm-up-times shall be specified in the instruction manual.	The setup- and warm-up times were determined.	yes	67
4.1.5	Instrument design	The instruction manual shall include specifications of the manufacturer regarding the design of the measuring system.	The instrument design specifications listed in the operating manual are complete and correct.	yes	69
4.1.6	Unintended adjustment	It shall be possible to secure the adjustment of the measuring system against illicit or unintended adjustment during operation.	The AMS is protected against unauthorized and unintended adjustment. In addition, the AMS shall be locked in a measuring cabinet.	yes	70
4.1.7	Data output	The output signals shall be provided digitally and/or as analogue signals	Measured signals are offered analogue (0-1 or. 5 V) and digital (via Ethernet, RS 232, UBS).	yes	71

Minimum requirement	Specification	Test result	Fulfilled	Page
5. Performance requirements				
5.1 General	The manufacturer's specifications in the instruction manual shall be by no means better than the results of the performance test. Deviating specifications shall be corrected in the instruction manual by the manufacturer before declaration of suitability.	Differences between the instrument design and the descriptions given in the manual could not be detected.	yes	73
5.2 General requirements on measuring systems				
5.2.1 Certification ranges	Have to comply with the requirements of Table 1 of the Standard VDI 4202 Part 1.	The assessment of the measuring device in the range of the relevant limit values is possible.	yes	74
5.2.2 Measuring range	The upper limit of measurement of the measuring systems shall be greater or equal to the upper limit of the certification range.	A measuring range of 0 – 1.000 µg/m³ is set by default. Other measuring ranges up to a maximum of 0 – 1.000.000 µg/m³ are possible. The measuring range value of the measuring device is higher than the respective upper limit of the certification range.	yes	75
5.2.3 Negative output signals	Negative output signals or measured values may not be suppressed (life zero).	Negative measuring signals are displayed directly and are output correctly via the respective measured value outputs by the measuring system.	yes	76
5.2.4 Failure in the mains voltage	Uncontrolled emission of operation and calibration gas shall be avoided. The instrument parameters shall be secured by buffering against loss caused by failure in the mains voltage. When mains voltage returns, the instrument shall automatically reach the operation mode and start the measurement according to the operating instructions.	All instrument parameters are protected against loss through buffering. After the power supply has returned, the measuring device goes back into a failure-free operational condition and continues independently the measuring operation after achieving the instrument status "fully operational".	yes	77
5.2.5 Operating states	The measuring system shall allow the control of important operating states by telemetrically transmitted status signals.	The measuring devices can be extensively monitored and controlled by an external PC via modem or router.	yes	78
5.2.6 Switch-over	Switch-over between measurement and functional check and/or calibration shall be possible telemetrically by computer control or manual intervention.	Generally all necessary operations for functional check can be monitored directly at the device or via telemetric remote control.	yes	79
5.2.7 Maintenance interval	If possible 3 months, minimum 2 weeks.	The maintenance interval is defined by necessary maintenance procedures and is 1 month.	yes	80

Minimum requirement	Specification	Test result	Ful-filled	Page
5.2.8 Availability	Minimum 95 %.	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 d) for SN 20006 caused by the leak switching valve cannot be fully shuffled off onto the AMS itself, since a prompt repair was not possible due to communication problems.	yes	81
5.2.9 Instrument software	The version of the instrument software to be tested shall be displayed during switch-on of the measuring system. The test institute shall be informed on changes in the instrument software, which have influence on the performance of the measuring system.	The version of the instrument software is shown on the display. The test institute is informed on changes in the instrument software.	yes	83
5.3 Requirements on measuring systems for gaseous air pollutants				
5.3.1 General	Minimum requirement according VDI 4202 Part 1.	The test was done based on the minimum requirements stated in Standard VDI 4202 Part 1 (September 2010). The test points 5.3.2, 5.3.7, 5.3.8, 5.3.11 and 5.3.12 are evaluated as before based on the minimum requirements stated in Standard VDI 4202 Part 1 from 2002 (i.e. using the reference values B0, B1 and B2). The testing of the test points 5.3.3, 5.3.4, 5.3.13 and 5.3.18 is waived, as they are not relevant for particulate measuring devices.	yes	85
5.3.2 Repeated standard deviation at zero point	The repeatability standard deviation at zero point shall not exceed the requirements of Table 2 in the certification range according to Table 1 of Standard VDI 4202 Part 1 (September 2010). For PM: Maximal B_0.	The detection limit was determined from investigations on 0.82 µg/m³ for device 1 (SN 20006) and 0.82 µg/m³ for device 2 (SN 20107).	yes	87
5.3.3 Repeated standard deviation at reference point	The repeatability standard deviation at reference point shall not exceed the requirements of Table 2 in the certification range according to Table 1 of Standard VDI 4202 Part 1 (September 2010).	Not applicable.	-	89

Minimum requirement	Specification	Test result	Fulfilled	Page
5.3.4 Linearity (Lack of fit)	The analytical function describing the relationship between the output signal and the value of the air quality characteristic shall be linear.	For particulate measuring devices for PM10 this test shall be performed according to minimum requirement 5.4.2 „ Equivalency of the sampling system“.	-	90
5.3.5 Sensitivity coefficient of the sample gas pressure	The Sensitivity coefficient of the sample gas pressure at reference point shall not exceed the specifications of Table 2 of Standard VDI 4202 Part 1 (September 2010).	Not applicable.	-	91
5.3.6 Sensitivity coefficient of the sample gas temperature	The Sensitivity coefficient of the sample gas temperature at reference point shall not exceed the specifications of Table 2 of Standard VDI 4202 Part 1 (September 2010).	Not applicable.	-	92
5.3.7 Sensitivity coefficient of the surrounding temperature	The sensitivity coefficient of the surrounding temperature at zero and reference point shall not exceed the specifications of Table 2 of Standard VDI 4202 Part 1 (September 2010). For PM: Zero point value for ΔTu of 15 K between +5 °C and +20 °C or 20 K between +20 °C and +40 °C shall not exceed B_0. The measurement value in the range of B_1 shall not exceed ± 5 % for ΔTu of 15 K between +5 °C and +20 °C or for 20 K between +20 °C and +40 °C.	The permitted surrounding temperature at the test site of the measuring device pursuant to the manufacturer is 8 °C to 25 °C. When observing the values output by the device, a maximum influence of the surrounding temperature on the zero-point of -2.3 µg/m³ in the range 8 °C to 25 °C could be detected. At reference point no deviation > 0.4 % to the default value at 20 °C could be observed.	yes	93
5.3.8 Sensitivity coefficient of the electric voltage	The sensitivity coefficient of the electric voltage at reference point shall not exceed the specifications made in Table 2 of Standard VDI 4202 Part 1 (September 2010). For PM: Change in measured value at B_1 maximum B_0 within the voltage interval (230 +15/-20) V	Due to voltage changes no deviation > 0.4 % could be detected for PM10, referring to the standard value of 230 V.	yes	96

Minimum requirement	Specification	Test result	Ful-filled	Page
5.3.9 Cross sensitivity	The change in the measured value caused by interfering components in the sample gas shall not exceed the requirements of Table 2 of Standard VDI 4202 Part 1 (September 2010) at zero and reference point.	Not applicable.	-	98
5.3.10 Averaging effect	For gaseous components the measuring system shall allow the formation of hourly averages. The averaging effect shall not exceed the requirements of Table 2 of Standard VDI 4202 Part 1 (September 2010).	Not applicable.	-	99
5.3.11 Standard deviation from paired measurements	The standard deviation from parallel determinations shall be done with two identical measuring devices during field test. It shall not exceed the specifications stated in Table 2 of Standard VDI 4202 Part 1 (September 2010). For PM: RD ≥ 10 referring to B_1.	The reproducibility RD for PM10 was 23 during field test for the complete data set.	yes	100
5.3.12 Long-term drift	The long-term drift at zero point and reference point shall not exceed the requirements of Table 2 in the field test. A value ct at 70% to 80% of the upper limit of the certification range shall be used as reference point. For PM: Zero point: within 24 h and within the maintenance interval a maximum of B0. As reference point: within 24 h and within the maintenance interval a maximum 5 % of B1.	The maximum deviation found at zero-point was 1.5 µg/m³ with reference to the previous value and 1.6 µg/m³ with reference to the start value and are thus within the allowed range of B0 = 2 µg/m³. The values for the drift of the sensitivity, referring to the respective previous values, determined within the scope of the test, have been at maximum 1.3 % for PM10.	yes	102
5.3.13 Short-time drift	The short-term drift at zero point and reference point shall not exceed the requirements of Table 2 of Standard VDI 4202 Part 1 (September 2010) within 12 h (for benzene 24 h) in the laboratory test and within 24 h in the field test. A value *c*t at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.	Not applicable.	-	108

Minimum requirement	Specification	Test result	Fulfilled	Page
5.3.14 Response time	The response time (rise) of the measuring system shall not exceed 180 s. The response time (fall) of the measuring system shall not exceed 180 s. The difference between the response time (rise) and response time (fall) of the measuring system shall not exceed 10% of response time (rise) or 10 s, whatever value is larger.	Not applicable.	-	109
5.3.15 Difference between sample- and calibration port	The difference between the measured values obtained by feeding gas at the sample and calibration port shall not exceed the requirements of Table 2 of Standard VDI 4202 Part 1 (September 2010).	Not applicable.	-	110
5.3.16 Converter efficiency	In the case of measuring systems with a converter, the efficiency of the converter shall be at least 98 %.	Not applicable.	-	111
5.3.17 Increase of NO2 concentration due to residence in the measuring system	In case of NO_x measuring systems, the increase of NO_2 concentration due to residence in the measuring system shall not exceed the requirements of Table 2 of Standard VDI 4202 Part 1 (September 2010).	Not applicable.	-	112
5.3.18 Overall uncertainty	The expanded uncertainty of the measuring system shall be determined. The value determined shall not exceed the corresponding data quality objectives in the applicable EU Directives on air quality listed in Annex A, Table A1 of Standard VDI 4202 Part 1 (September 2010).	According to the decision of the competent German body (see module 5.3.1 this test point is not relevant for particulate measuring devices. Reference is made to module 5.4.10.	-	113

Minimum requirement	Specification	Test result	Fulfilled	Page
5.4 Requirements on measuring systems for particulate air pollutants				
5.4.1 General	Test according to the minimum requirement stated in Table 5 of Standard VDI 4202, Part 1. Furthermore, the particle mass concentration shall be related to a defined volume. The relation to volume with respect to pressure and temperature shall be comprehensively described.	The test took place according to the minimum requirement stated in Table 5 of Standard VDI 4202, Part 1 (September 2010). The measuring unit TEOM 1405-F Ambient Particle Monitor is a gravimetric measuring device, which determines the mass depotest sited on a filter via oscillating micro weighing. The determined mass is related to a defined and actively regulated sampling volume and thereby the particulate concentration is determined.	yes	114
5.4.2 Equivalency of the sampling system	The equivalency between the PM10 sampling system and the reference method according to EN 12341 shall be demonstrated.	The reference-equivalence functions lay within the limits of the respective acceptance range. Furthermore, the variation coefficient R^2 of the calculated reference-equivalence functions in the relevant concentration range for the data sets „All data set“, „Teddington (Winter)“ and „Cologne (Winter)“ is ≥ 0.95. For the data sets “Teddington (Summer)” and Bornheim (Summer) the variation coefficient is < 0.95. Both test sites are characterized by a low variation of the particulate concentrations. The equivalence test according to 6.1 5.4.10 Calculation *of the expanded uncertainty* of the instruments is fulfilled nevertheless for all test sites.	no	115
5.4.3 Reproducibility of the sampling systems	The PM_{10} sampling systems of two identical systems under test shall be reproducible among themselves according to EN 12341. This shall be demonstrated in the field test.	The two-sided confidence interval CI95 is with a maximum of 2.57 µg/m³ beneath the demanded value of 5 µg/m³ for all test sites.	yes	122
5.4.4 Calibration	The systems under test shall be calibrated in the field test by comparison measurements with the reference method according to EN 12341. Here, the relationship between the output signal and the gravimetrically determined reference concentration shall the determined as a steady function.	A statistically secured relation between the reference measuring procedure and the instrument display could be demonstrated.	yes	127

Minimum requirement	Specification	Test result	Fulfilled	Page
5.4.5 Cross-sensitivity	The interference caused by moisture in the sample may not exceed 10 % of the limit value in the range of the limit value.	No interference caused by moisture in the sample > 1.9 µg/m³ deviation from nominal value for PM10 could be observed. During the field test, no negative influence on the measured values could be noted at changing relative humidities. The comparability of the candidates with the reference method according to Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods" [4] also is given for the days with a relative humidity > 70 %.	yes yes	129
5.4.6 Averaging effect	The measuring system shall allow for formation of 24 h averages. The time of the sum of all filter changes within 24 h may not exceed 1 % of this averaging time.	The formation of valid daily averages is possible.	yes	132
5.4.7 Constancy of sample volumetric flow	The sample volumetric flow averaged over the sampling time shall be constant within ± 3 % of the rated value. All instantaneous values of the sample volumetric flow shall be within a range of ± 5 % of the rated value during sampling.	All determined daily averages deviate less than ± 3 %, all instantaneous values less than ± 5 % from the nominal value.	yes	133
5.4.8 Tightness of the measuring system	The complete measuring system shall be checked for tightness. Leakage shall not exceed 1 % of the sample volume sucked.	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 PM10-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 damages of the instrument.	yes	139

Minimum requirement	Specification	Test result	Fulfilled	Page
5.4.9 Determination of uncertainty between systems under test ubs	For the test of PM2,5 measuring systems the uncertainty between the systems under test shall be determined according to chapter 9.5.2.1 of the guidance document „Demonstration of Equivalence of Ambient Air Monitoring Methods“ in the field test at least at four sampling test sites representative of the future application.	The in-between-uncertainty between the candidates ubs is with a maximum of 1.35 µg/m³ for PM10 below the required value of 2.5 µg/m³.	yes	142
5.4.10 Calculation of the expanded uncertainty of *the instruments*	For the test of PM2,5 measuring systems the equivalency with the reference method shall be demonstrated according to chapter 9.5.2.2 to chapter 9.5.4 of the guidance document „Demonstration of Equivalence of Ambient Air Monitoring Methods“ in the field test at least at four sampling test sites representative of the future application.	The determined uncertainties WCM without application of correction factors lay for all observed data sets beneath the defined expanded relative uncertainty Wdqo of 25 % for particulate.	yes	148
5.4.11 Application of correction factors and terms	If the maximum expanded uncertainty of the systems under test exceeds the data quality objectives according to Annex A of Standard VDI 4202 Part 1 for the test of $PM_{2.5}$ measuring systems, the application of correction factors and terms is allowed. Values corrected shall meet the requirements of chapter 9.5.2.2 ff. of the guidance document „Demonstration of Equivalence of Ambient Air Monitoring Methods”.	The candidate systems fulfil the requirements on the data quality of ambient air quality measurements during the test already without application of correction factors.	yes	161
5.5 Requirements on multiple-component measuring systems	Multiple-component measuring systems shall comply with the requirements set for each component, also in the case of simultaneous operation of all measuring channels.	Not applicable.	-	166

2. Task definition

2.1 Type of test

Thermo Fisher Scientific has commissioned TÜV Rheinland Energie und Umwelt GmbH with the performance of a suitability test of TEOM 1405-F Ambient Particulate Monitor with PM_{10} pre-separator. The test was conducted as a complete suitability testing.

2.2 Objective

The AMS shall determine the content of $PM_{2.5}$ suspended particulate matter in ambient air within the concentration range of 0 to 1000 µg/m^3.

The suitability test was carried out based on the current standards for suitability tests while taking into account the latest developments.
The test was performed in consideration of the following standards:

- Standard VDI 4202 Part 1, „Minimum requirements for suitability tests of automatic ambient air measuring systems – Point-related measurement methods of gaseous and particulate pollutants“, September 2010 or June 2002 [1]
- Standard VDI 4203 Part 3, „Testing of automatic measuring systems - Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants“, September 2010 or August 2004 [2]
- Standard EN 12341, „Ambient 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“, German version EN 12341: 1998 [3]
- Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods”, English version of January 2010 [4]

3. Description of the tested measuring system

3.1 Measuring principle

The ambient air measuring system TEOM 1405-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.

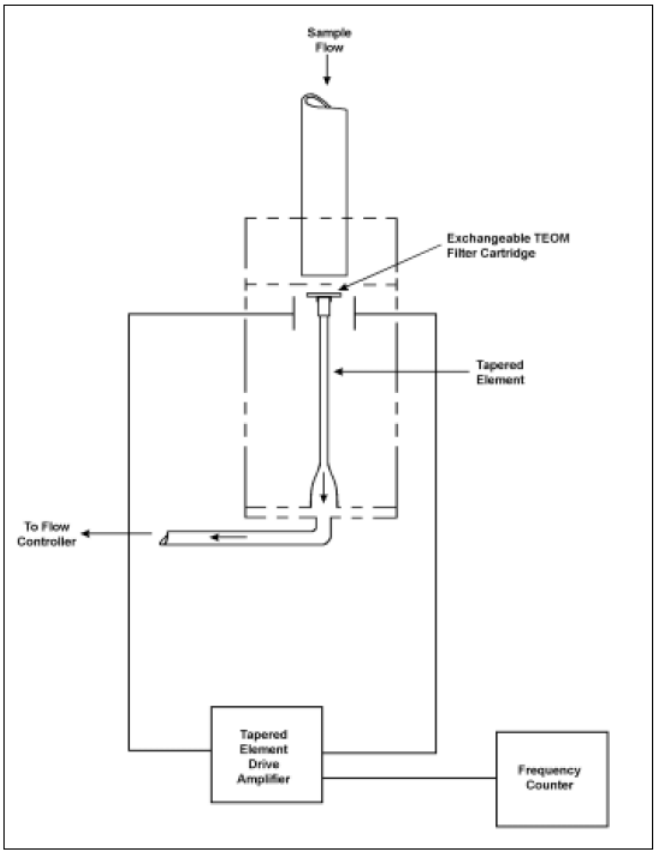

Figure 1: Schematic set-up of the mass transducer

The tapered element oscillates precisely at its natural frequency, 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 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).

3.2 Functionality of the measuring system

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 °C) and the secreted mass of particles is quantified.

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 compensated automatically the part of the semi-volatile particulate using a switching valve and two operation modi – 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 mass measuring. 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°C.

Based on the mass concentration measuring during the base- and reference-modi, 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“.

3.3 AMS scope and layout

The particulate ambient air measuring device TEOM 1405-F Ambient Particulate Monitor is based on the measuring principle of oscillating micro weighing.

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 incl. FDMS-tower, the vacuum pump with its respective power supply cord and cables as well as adapters, the roof lead-through incl. a flange and a manual in German/English.

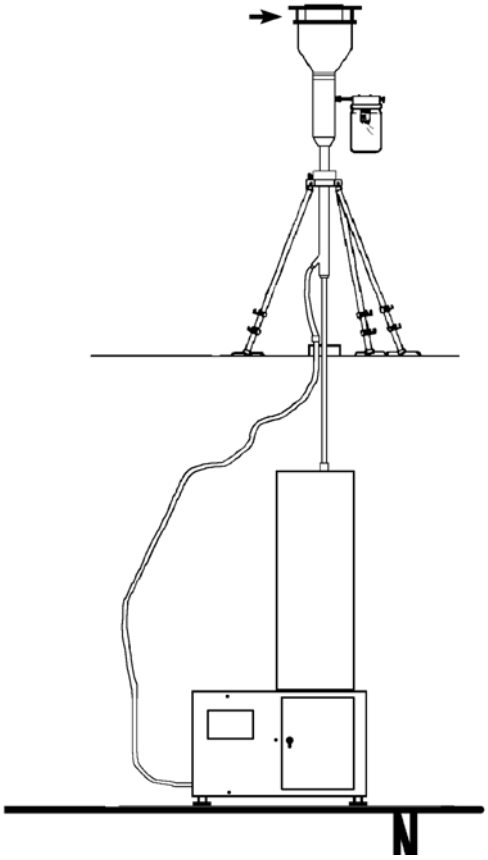

Figure 2: Overview of complete system TEOM 1405-F Ambient Particulate Monitor

Figure 3: American PM_{10}-sampling inlet (Original style, p/n 57-000596-0001) for TEOM 1405-F Ambient Particulate Monitor

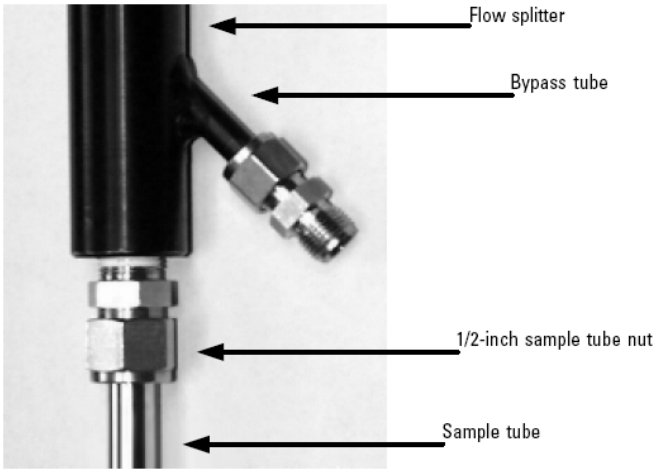

Figure 4: Flow-splitter

Figure 5: Measuring device TEOM 1405-F Ambient Particulate Monitor

Figure 6: Measuring device TEOM 1405-F Ambient Particulate Monitor (1st system from left) in measuring station

Figure 7: Vacuum pump (p/n 10-011413)

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.

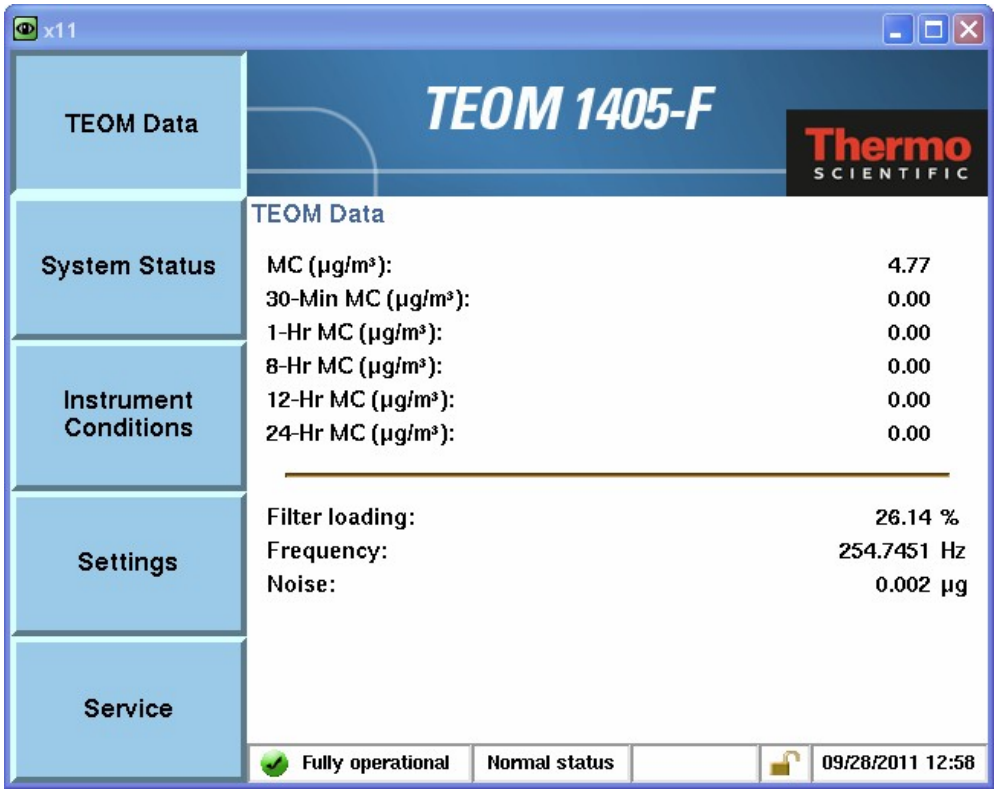

Figure 8: Main window of the user display

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.

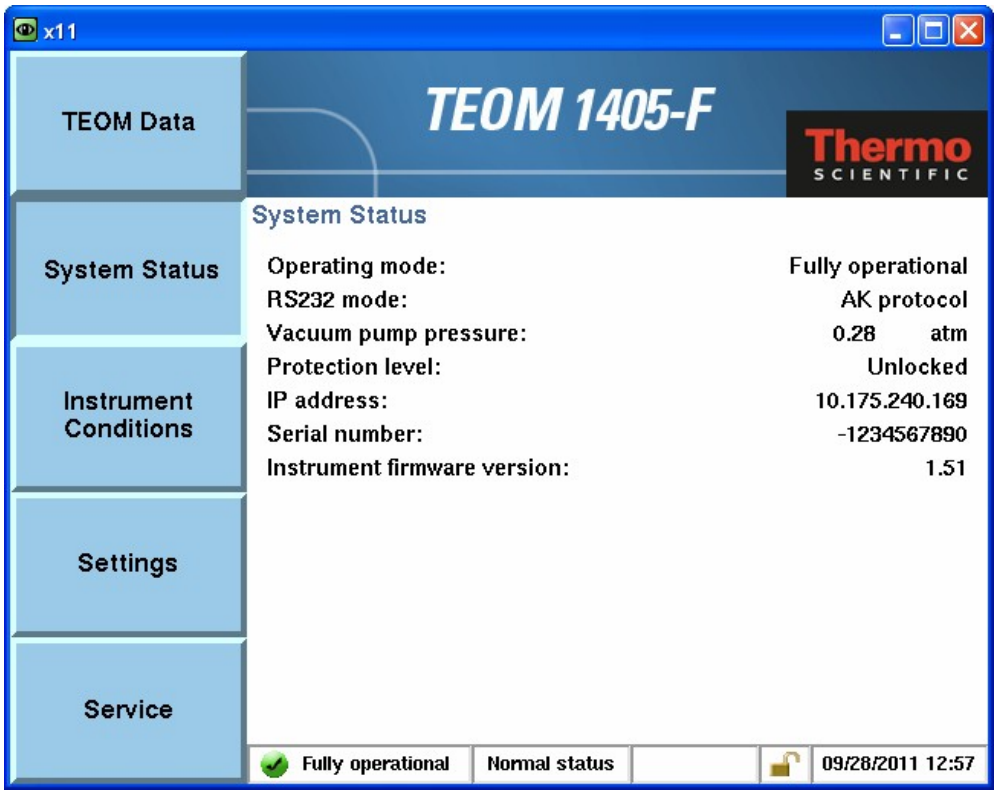

Figure 9: Menu: System status (here software version 1.51)

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.

Note:

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.

No influence on the instrument performance is to be expected due to the realised changes up to the version 1.55.

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.

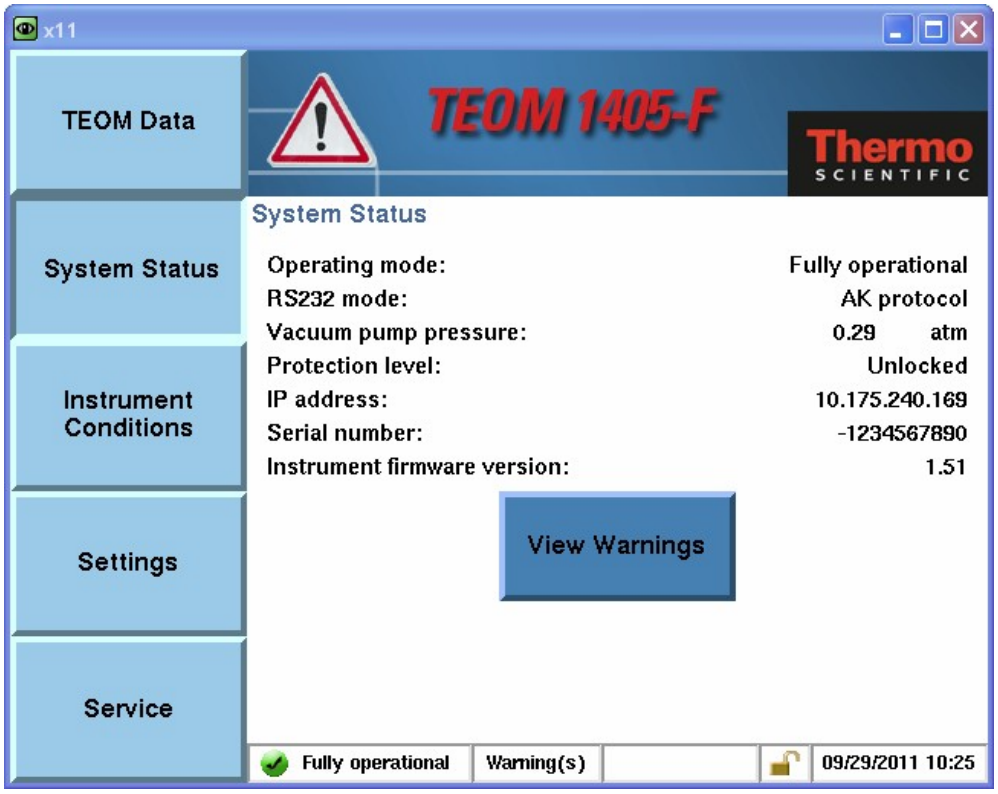

Figure 10: Warning messages display (triangular warning symbol + button „View Warnings“)

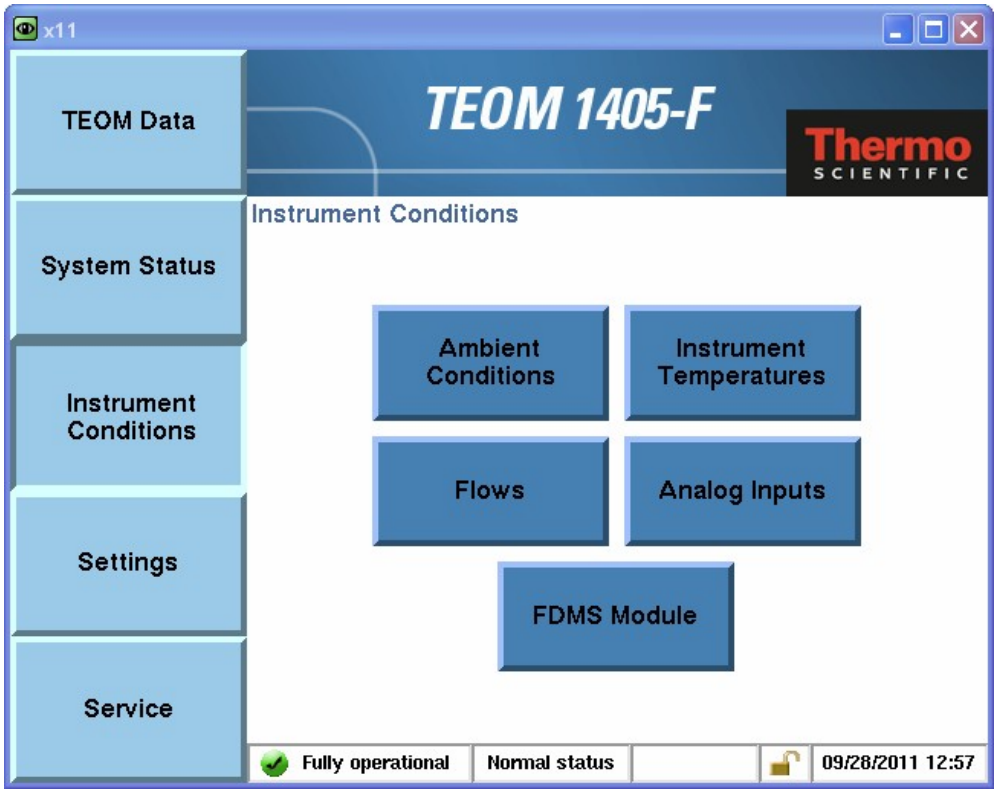

Figure 11: Menu: Instrument conditions

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.

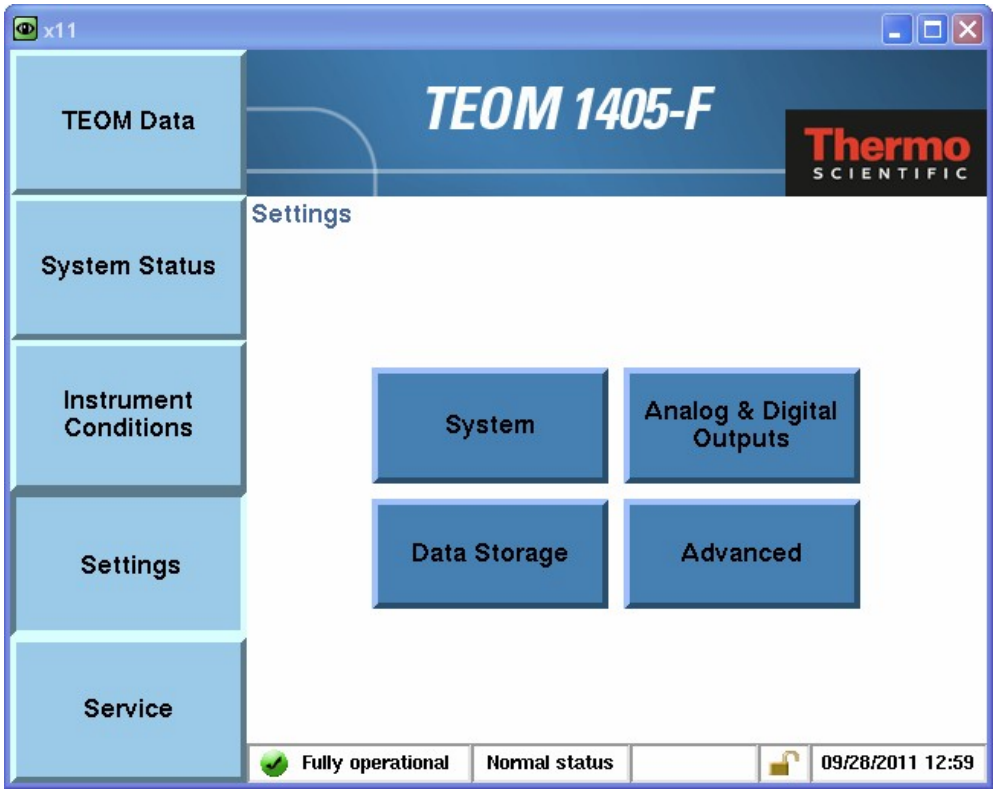

Figure 12: Menu: Settings

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.

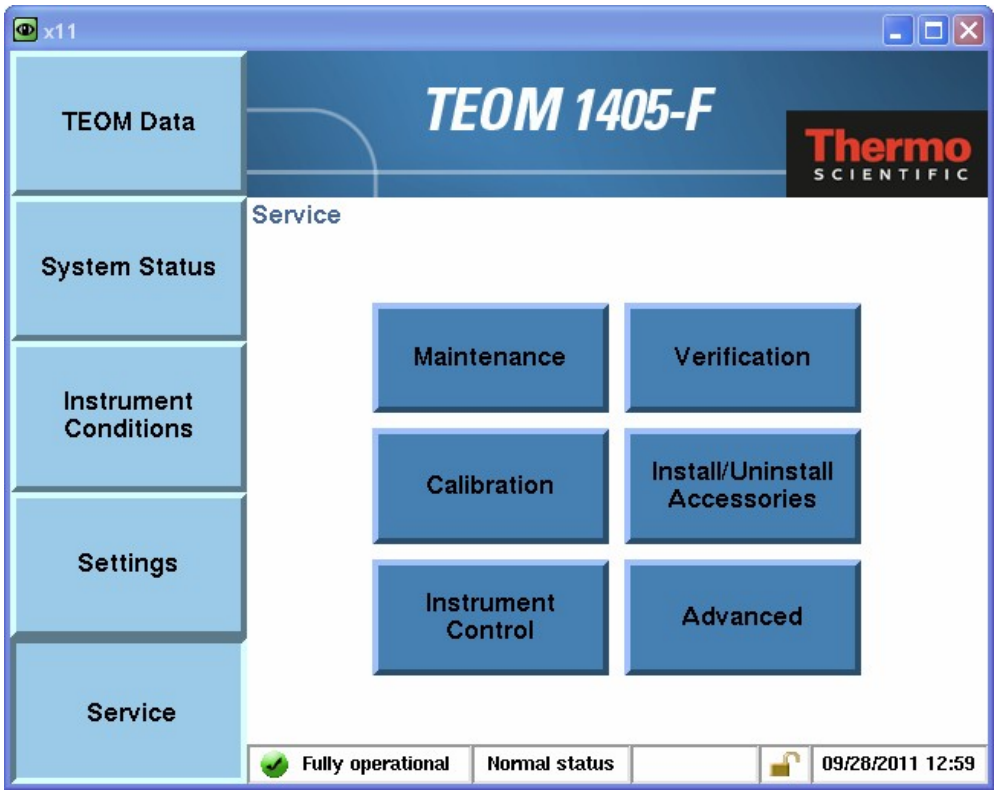

Figure 13: Menu: Service

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 14: 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.

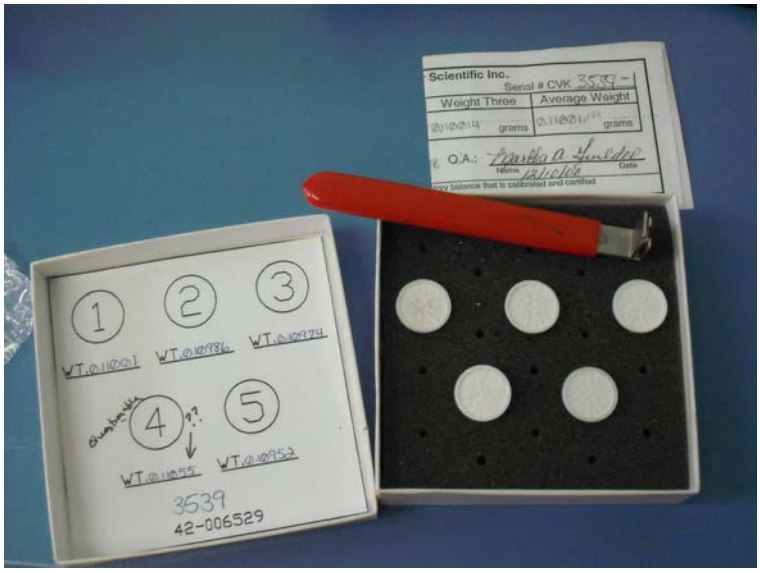

Figure 15: Set of filters for the check of the calibration constant K_0

Within the scope of the testing, after the test site “Teddington (Summer)” a modification of the measuring system from configuration C to D was made. In doing so the following components were changed:

Table 2: 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.

The change was made after the performance of the two field test sites in England. 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 contains a list of the most important device-related characteristics of the particulate ambient air measuring device TEOM 1405-F Ambient Particulate Monitor.

Table 3: 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 °C
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	30 °C
Mass transducer case	30 °C
PM_{10} air tube	30 °C
Parameter FDMS	
Dryer type	NAFION-Dryer, Type C
Temperature dryer (normal conditions):	4 °C
Dew point of the air flows (normal conditions):	at >2 °C Warning message
Pump vacuum:	> 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
Status signals / error messages	Available, overview see annex A of the instruction manual

4. Test program

4.1 General

The suitability test has been performed with two identical devices with the serial numbers SN 20006 und SN 20107.

The test was performed with firmware version 1.51.

The software has been constantly developed and optimized up to version 1.55 during the test program. 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.

No influences on the system performance are expected from the changes which were made on the firmware up to version 1.55.

The laboratory tests for the determination of system characteristics were followed by a field test of several months at different test sites.

All concentrations, determined under operational conditions, are presented in µg/m³ (operational conditions). Additionally, according to Standard EN 12341, the PM_{10}-concentrations are presented in normal conditions in µg/m³ (273 K, 101.3 kPa) for the evaluation.

The following report comprises a description of each minimum requirement according to standards [1, 2, 3, 4] in number and wording.

4.2 Laboratory test

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 und SN 20107. According to the Standards [1, 2], the following test program was specified for the laboratory test:

- Description of system functions
- Determination of detection limits
- Determination of the dependence of zero point / sensitivity on ambient temperature
- Determination of the dependence of zero point / sensitivity on the mains voltage
- Sampling flow stability check

The following devices were used to determine the system characteristics during laboratory test:

- Climate chamber (temperature range from –20 °C to +50 °C, accuracy better than 1 °C)
- Adjustable isolating transformer
- Zero-filter for external zero point check.
- K_0-check kit

The measured values were recorded in the devices. The stored measured values were read out *via* Data download via USB.

Section 6 describes the laboratory tests and the results.

4.3 Field test

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

Device 1: SN 20006

Device 2: SN 20107

The following test program was specified for the field test:

- Determination of the comparability of the candidates according to the Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods”
- Determination of the comparability of the candidates and the reference methods according to the Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods”
- Sampling flow stability check
- Determination of the calibration ability and set-up of analysis function
- Determination of field reproducibility
- Determination of drift behaviour of zero point and sensitivity
- Investigation on the tightness of the sampling system
- Investigation of the dependency of the measured values on humidity
- Determination of the maintenance interval
- Determination of availability
- Determination of the total uncertainty of the candidates.

The following devices were used for the field test:

- Measurement cabinet of TÜV Rheinland, air-conditioned to approx. 20 °C
- Weather station (WS 500 of the company ELV Elektronik AG) 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} according to point 5
- Gas meter, dry
- 1 mass flow rate measuring device Type 4043 (Manufacturer: TSI)
- Measuring device Metratester 5 (Manufacturer: company Gossen Metrawatt) for the determination of power consumption
- Zero-filter for external zero point check
- K_0-check kit.

Two TEOM 1405-F Ambient Particulate Monitor-systems and two reference devices for PM_{10} were simultaneously operated for 24 h each during the field test. The reference equipment operates discontinuously, i.e. the filters must be changed manually after each sample.

The impaction plates of the PM_{10} sampling inlets of the reference devices were cleaned approx. every 2 weeks and lubricated with silicone-grease, in order to guarantee a safe separation and secretion of the particulate. The PM_{10} sampling inlets of the candidates were cleaned approx. every 4 weeks. 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 candidate and each reference device prior to and after each change of location with a dry gas meter respectively a mass flow meter, which could be connected to the air inlet of the systems *via* a hose assembly.

Measurement test sites and test site of the measuring devices

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 candidate systems as well as the central units of the reference systems LVS3 were installed inside the climate-controlled measurement cabinet.

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

Table 4: Field test sites

No.	Measuring test site	Period	Characterization
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 16 to Figure 19 show the course of time of the PM_{10}-concentrations at the field test sites, which were recorded with the reference measuring device.

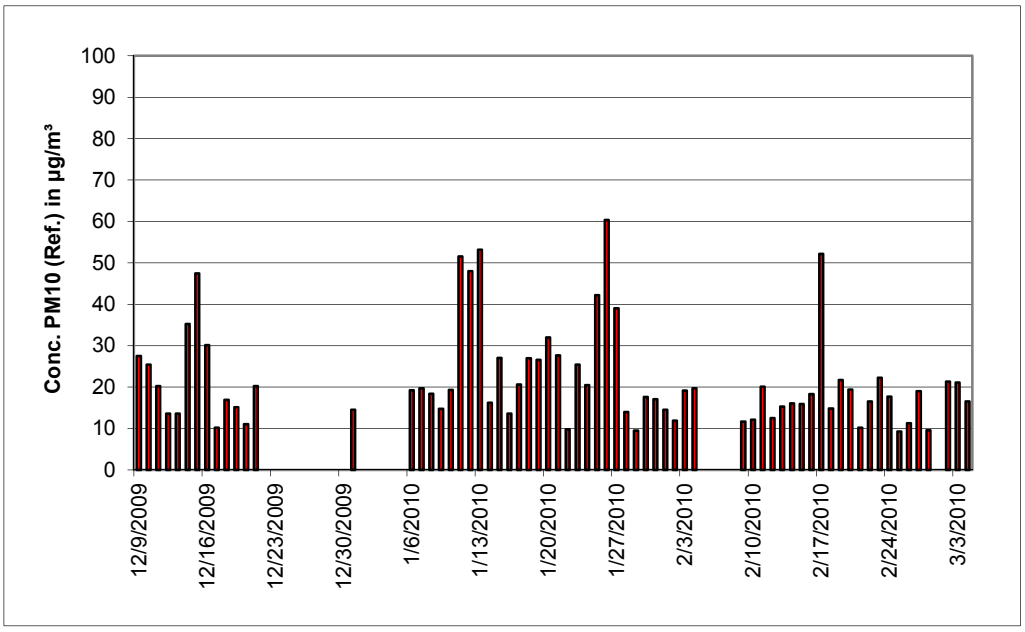

Figure 16: Course of time of the PM_{10}-concentrations (Reference) at the test site „Teddington, winter“

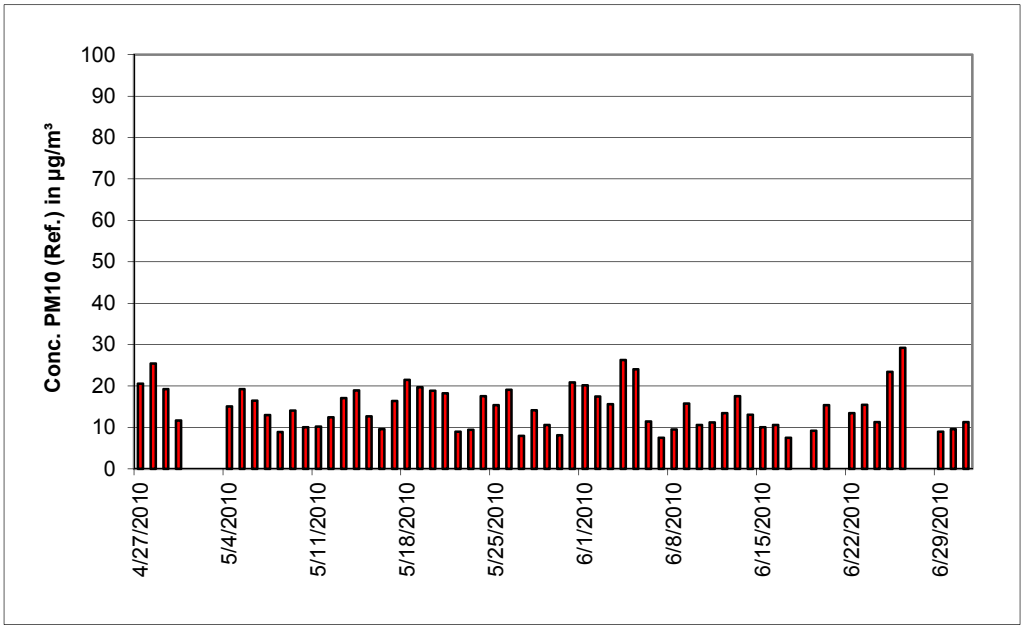

Figure 17: Course of time of the PM_{10}-concentrations (Reference) at the test site „Teddington, summer“

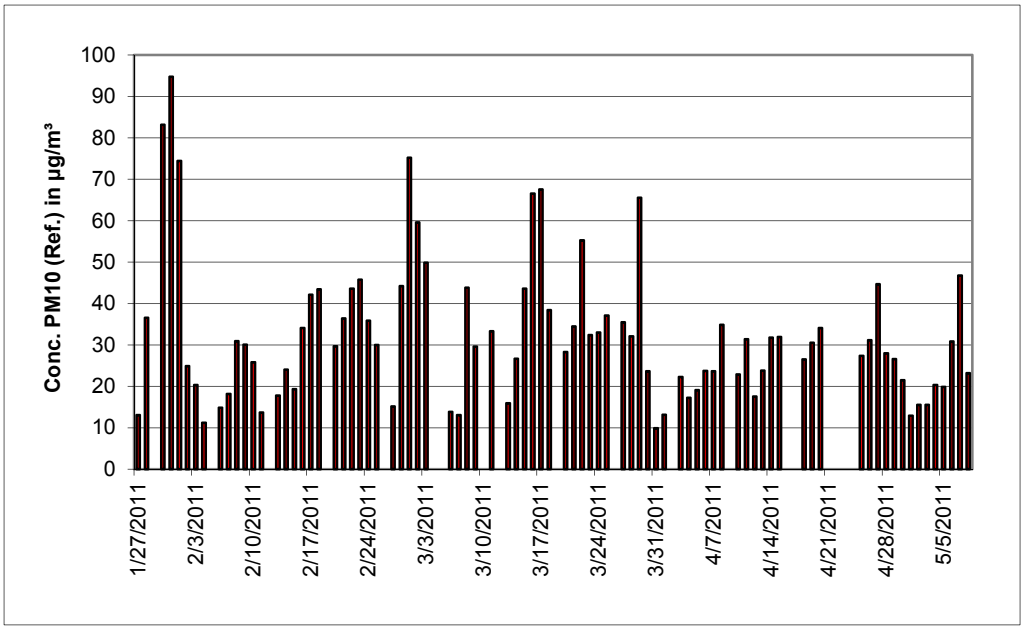

Figure 18: Course of time of the PM_{10}-concentrations (Reference) at the test site „Cologne, parking lot, winter“

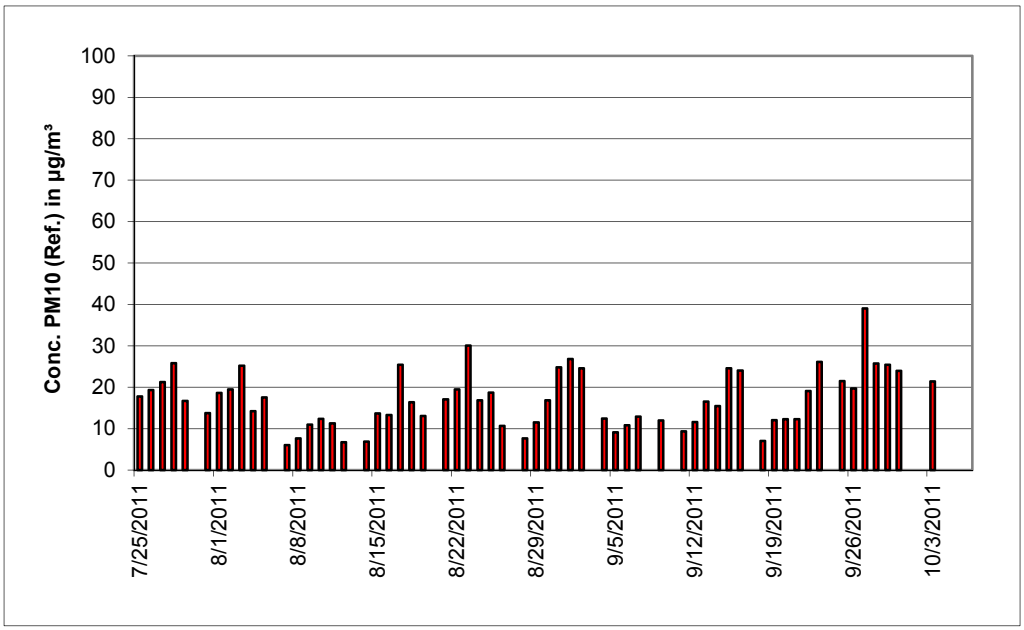

Figure 19: Course of time of the PM_{10}-concentrations (Reference) at the test site „Bornheim, mo torway parking lot, summer”

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

Figure 20: Field test site Teddington

Figure 21: Field test site Cologne, parking lot

Figure 22: 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 min. averages were recorded.

The installation of the cabinet itself 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 / 0.51 m above the cabinet roof
- Reference device 3.61 / 3.01 m above ground
- Height of the wind vane: 4.5 m above ground

The following Table 5 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. Refer to section 5 and 6 for detailed results.

Table 5: 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 [°C]				
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

Sampling period

EN 12341 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 (Bornheim).

Data handling

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 [4] 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.

Within the scope of the „Combined MCERTS and TÜV PM Equivalence Testing“ program we agreed with our British partners not to discard any measured value for the candidates, unless the implausibility is caused due to technical reasons. During the entire testing period, no measured value of the candidates was discarded.

Table 6 shows an overview on the amount of paired values (reference) which were recognized and removed as significant outliers at each test site.

Table 6: 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 following data pairs were removed:

Table 7: 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

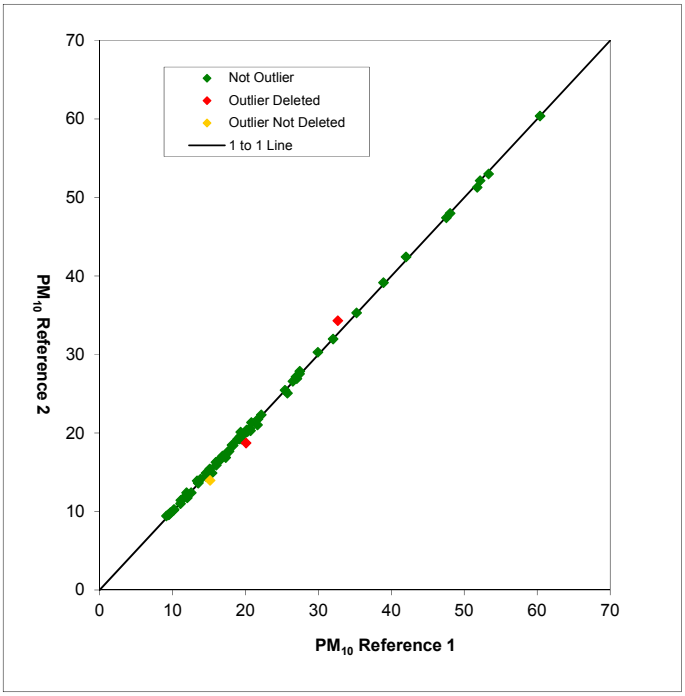

Figure 23: Grubbs test results for the PM_{10} reference method, Teddington (Winter)

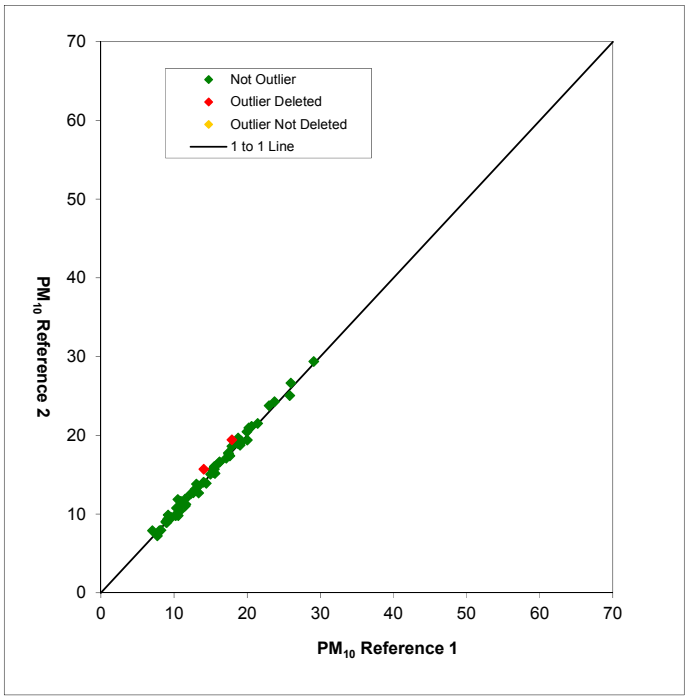

Figure 24: Grubbs test results for the PM_{10} reference method, Teddington (Summer)

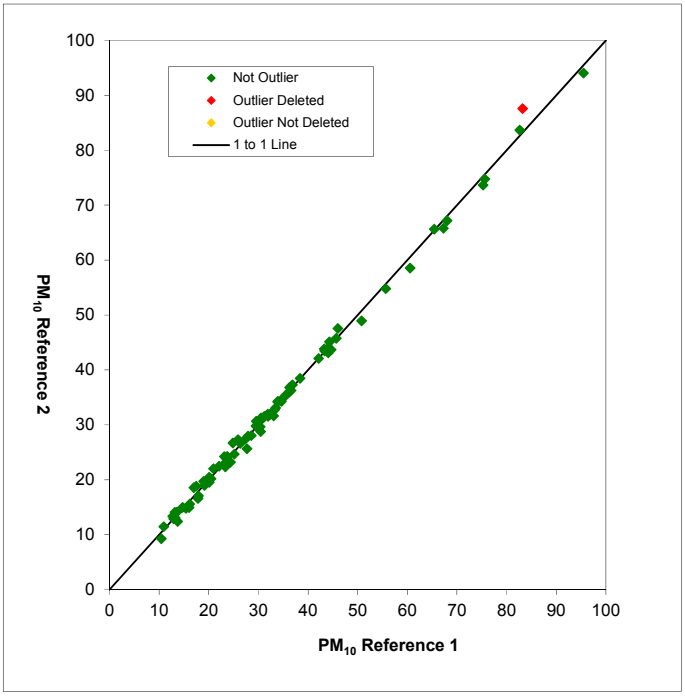

Figure 25: Grubbs test results for the PM_{10} reference method, Cologne (Winter)

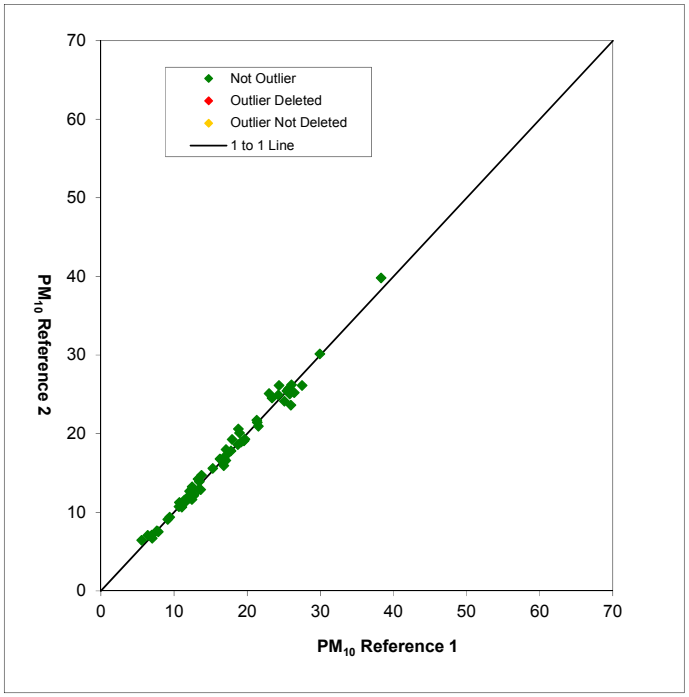

Figure 26: Grubbs test results for the PM_{10} reference method, Bornheim (Summer)

Filter handling – Mass determination

The following filters were used for the suitability testing:

Table 8: Used filter materials

Measuring device	Filter material, type	Manufacturer
Reference value LVS3	Emfab™, ∅ 47 mm	Pall

The filter material EMFAB™ (Teflon-coated glass fibre filters) was used in the scope of the „Combined MCERTS and TÜV PM Equivalence Testing“ program by special request of our British partners, because according to [8], they consider it most appropriate for the test purpose.

The filter handling is according to the requirements of EN 14907.

The procedures of filter handling and weighing are described in detail in Appendix 2 of this report.

5. Reference measurement procedures

The following devices were used during the field test in accordance with EN 12341.

1. Reference equipment for PM_{10}

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 each for PM_{10} and $PM_{2.5}$ 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.

The sampling air is sucked in *via* the rotary vane vacuum pump through the sampling inlet for the small filter device LVS3. The sampling air volume flow is measured with a measuring orifice which is installed between filter and vacuum pump. In order to collect any dust created by the abrasion of the vanes, the incoming air passes a separator before flowing to the air outlet.

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 (or standard-m³ according to EN 12341).

6. Test results

6.1 4.1.1 Measured value display

The measuring system shall be fitted with a measured value display.

6.2 Equipment

No additional devices are needed.

6.3 Performance of test

It was checked whether the measuring device has a display for measured values.

6.4 Evaluation

The measuring device has a display for measured values. The following values are displayed:

MC	Mass concentration, moving 1h-average, updated every 6 minutes.
30-Min-MC	not working at the moment
1-Hr-MC	moving 1h-average, updated every 60 minutes every full hour.
8-Hr-MC	moving 8h-average, updated every 60 minutes every full hour.
12-Hr-MC	moving 12h-average, updated every 60 minutes every full hour.
24-Hr-MC	moving 24h-average, updated every 60 minutes every full hour.

6.5 Assessment

The measuring device comprises a measured value display.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Figure 27 shows the user's display with the current measured concentration values.

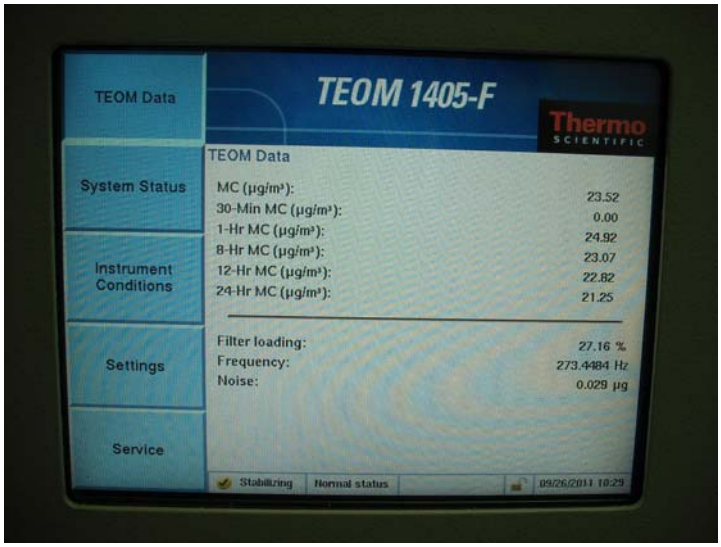

Figure 27: Display of the measured concentration value

6.1 4.1.2 Easy maintenance

Necessary maintenance for the measuring systems should be possible without larger effort, if possible from outside.

6.2 Equipment

No additional equipment required.

6.3 Performance of test

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

6.4 Evaluation

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 °C at 4 °C 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.

6.5 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.

Minimum requirement fulfilled? yes

6.6 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.

6.1 4.1.3 Functional test

If the operation or the functional check of the measuring system requires particular instruments, they shall be considered as part of the measuring system and be applied in the corresponding sub-tests and included in the assessment.
Test gas units included in the measuring system shall indicate their operational readiness to the measuring system by a status signal and shall provide direct as well as remote control via the measuring system.

6.2 Equipment

Manual, zero-filter, K_0-check kit

6.3 Performance of test

The device status is constantly monitored and problems are indicated by a series of different warning messages. Important parameters for a proper performance (e.g. noise of the mass measurement, flow rates, pump vacuum, dew point of the air sample) moreover can be looked up at the device itself or while recording the data.

Furthermore there is also the possibility to check the zero point of the measuring device externally. For this a zero-filter is installed at the device inlet. The use of this filter allows the provision of particle-free air.

Within the scope of the test work, a determination of the zero point by using the zero-filter was also performed approx. every 4 weeks.

Moreover, there is the possibility to check the calibration constant of the mass measurement externally. For this the calibration constant is determined using the K_0-check kit and afterwards compared with the nominal value stored within the device.

Within the scope of the check the calibration constant was determined at the beginning and the end of each test site.

6.4 Evaluation

All instrument functions, which are listed in the manual, are available and can be activated. The current status of the system is monitored continuously and problems are indicated by a series of different warning messages.

An external check of the zero point by using the zero-filter is possible at any time. An external check of the mass measured value transducer using the K_0-check kit also is possible at any time.

6.5 Assessment

All system functions listed in the manual are available, activatable and functioning. The current system status in continuously monitored and displayed by a set of different status messages (operation, warning and error messages).

The results of the external checks of the zero point with a zero-filter during the field test period as well as periodically performed checks of the calibration constant K_0 are described in chapter 6.1 5.3.12 Long-term drift of this report.

Minimum requirement fulfilled? yes

Detailed representation of the test results

Refer to chapter 6.1 5.3.12 Long-term drift.

6.1 4.1.4 Set-up times and warm-up times

The set-up times and warm-up times shall be specified in the instruction manual.

6.2 Equipment

A clock was required for this test.

6.3 Performance of test

The AMS were started up according to the description given by the manufacturer. Necessary setup- and warm-up times were recorded separately.

Necessary constructional works prior to the measurement, such as the installation of an inlet through the cabinet roof, were not included in this test.

6.4 Evaluation

The setup time comprises the time needed for all necessary works from system installation to start-up.

The measuring system must be protected from weather inconsistencies e.g. in an acclimated measuring cabinet. Extensive construction work is required in order to lead the sample tube through the roof of a measuring cabinet. A non-stationary application is therefore only assumed together with the belonging peripheral devices.

The following steps are generally necessary for the installation of the measuring device:

- Unpacking and installation of the measuring system (in a rack or on a table)
- Connection of the sampling tube, flow splitter, tripod and PM_{10}-sampling inlet
- Connection of the pump
- Mounting of ambient air sensor (nearby the sampling inlet)
- Connection of all connecting and control lines
- Connection of power supply
- Switch-on of the measuring system
- Performance of the leak test
- Installation of the TEOM-filter as well as the two 47 mm-filter
- Check of the instrument setting regarding die regulation of the flow rate (here: Active/Actual), date and time and the parameterization of the proper calibration constant K_0
- Check of the sensors for ambient temperature and pressure and the flow rate.
- Optional connection of peripheral recording and control systems (data logger, PC with ePort, RPComm and HyperTerminal) to the respective interfaces

The performance of these actions and therewith the set-up time takes approx. 2 hours.

The warm-up time contains the time need between the start of operation of the measuring system and the readiness for measurement.

After switching on the system, the system is in the stabilizing phase (“stabilizing”) until reaching the stabilized condition regarding the instrument temperature. The duration of the stabilizing phase is dependent of the ambient temperature at the installation place and of the thermic instrument condition when switched on. In the scope of the suitability test, the stabilizing times where between 30 min and 90 min. After reaching a stabilized condition, the instrument starts collecting first data (“Collecting Data“). This data is not yet used to determine mass concentration. The collecting of first data is followed by first data computation (“Computing Data“). Afterwards the instrument is fully operational („Fully operational“). The intermediate steps „Collecting Data“ and „Computing Data“ take one hour. After that, the instrument delivers the moving 1h-average values of the mass concentration, which are updated every 6 minutes.

If required, possible changes of the basic parameterization of the measuring system can likewise be performed within few minutes by personal, familiar with the devices. However, the measuring operation is for this purpose interrupted and the instrument switched in setup-mode.

6.5 Assessment

The setup- and warm-up times were determined.

The measuring system can be operated at different measurement test sites with manageable effort. The set-up time is approximately 2 hours and the warm-up time is, depending on the necessary stabilizing time, 1.5 to 2.5 hours.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Not required for this test.

6.1 4.1.5 Instrument design

The instruction manual shall include specifications of the manufacturer regarding the design of the measuring system. The main elements are:

- *Instrument shape (e.g. bench mounting, rack mounting, free mounting)*
- *Mounting position (e.g. horizontal or vertical mounting)*
- *Safety requirements*
- *Dimensions*
- *Weight*
- *Power consumption*

6.2 Equipment

A measuring device for power consumption measurement and a scale were used for this test.

6.3 Performance of test

The installation of the delivered instruments was compared with the description given in the manuals. The specified power consumption was continuously tested for 24 h under standard operation conditions during field test.

6.4 Evaluation

The measuring system has to be installed in horizontal mounting position (e.g. on a table or a rack), independent from atmospheric conditions. The temperature at the installation test site shall be within the range of 8 °C to 25 °C with a relatively low amount of temperature fluctuation (maximum 2 °C per hour/ no direct sun, no direct exposure to heater or air conditioner).

The dimensions and the weights of the measuring system are in compliance with the specifications in the manual.

The power consumption of the measuring system with the used pump is specified by the manufacturer with at maximum 100-130 W for the measuring device and approximately 550-600 W for the pump. During a 24 h-test, these specifications were checked. At no time the mentioned value was exceeded during these investigations.

6.5 Assessment

The instrument design specifications listed in the operating manual are complete and correct.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Not required for this minimum requirement.

6.1 4.1.6 Unintended adjustment

It shall be possible to secure the adjustment of the measuring system against illicit or unintended adjustment during operation.

6.2 Equipment

No additional equipment required.

6.3 Performance of test

The operation of the measuring device is carried out *via* a touch screen-display at the front panel or *via* the RS232- or Ethernet interfaces from an external computer.

A change of the parameters or the adjustment of sensors is only possible via several key sequences.

The measuring device has the following level of password protection.

Low Lock Mode:

In this mode the user can see all instrument views and can change the operation mode in order to perform a filter change.

High Lock Mode:

In this mode the user can only see the „TEOM-Data".

Because an installation of the measuring device outdoors is not possible, an additional protection is granted by installing it at test sites where no unauthorised people can go to (e.g. locked measuring cabinet).

6.4 Evaluation

Unintended adjustment of instrument parameters is avoided by the password protection. The adjustment of sensors and a change of the parameters can only be done via several key sequences. Moreover there is an additional protection against unauthorized intervention by the installation in a locked measurement cabinet.

6.5 Assessment

The AMS is protected against unauthorized and unintended adjustment. In addition, the AMS shall be locked in a measuring cabinet.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Not required for this minimum requirement.

6.1 4.1.7 Data output

The output signals shall be provided digitally (e.g. RS 232) and/or as analogue signals (e.g. 4 mA to 20 mA).

6.2 Equipment

PC with software „ePort“

6.3 Performance of test

The test was carried out using a PC with the software „ePort“(via Ethernet).

The AMS was connected to a PC via Ethernet and the data were downloaded. As usual, the data was in parallel downloaded to an USB-stick via USB interface. The test was performed by comparing both data.

The AMS has the possibility to offer analogue signals (maximum 8 analogue exits) as well as to offer measuring signals/ communication via serial interface RS 232 (AK protocol, software e.g. RPComm or HyperTerminal).

6.4 Evaluation

The measured signals are offered at the rear side of the instrument in the following way:

Analogue:	0-1 resp. 5 V	concentration range selectable
Digital:	Ethernet with Software „ePort“	
	RS 232-interface, AK protocol	
	USB	

The transmitted measured values via Ethernet comply with the data downloaded via USB-interface.

6.5 Assessment

Measured signals are offered analogue (0-1 or. 5 V) and digital (via Ethernet, RS 232, UBS).

The connection of additional measuring and peripheral devices to the respective ports of the devices is possible (e.g. analogue entrances).

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Figure 28 shows a view of the rear side of the instrument with the respective measured value outputs.

Figure 28: View on rear of the device TEOM 1405-F Ambient Particulate Monitor

6.1 5.1 General

The manufacturer's specifications in the instruction manual shall be by no means better than the results of the performance test. Deviating specifications shall be corrected in the instruction manual by the manufacturer before declaration of suitability.

6.2 Equipment

Not necessary for this minimum requirement.

6.3 Performance of test

The test results are compared with the specifications given in the manual.

6.4 Evaluation

Found deviations between the first draft of the manual and the actual design were resolved.

6.5 Assessment

Differences between the instrument design and the descriptions given in the manual could not be detected.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Refer to point 6.4 of this module.

6.1 5.2.1 Certification ranges

The certification range for the testing must be determined.

6.2 Equipment

No additional equipment required.

6.3 Performance of test

The certification range for the testing must be determined.

6.4 Evaluation

Standard VDI 4202, Part 1 contains the following minimum requirements for the certification ranges for particulate ambient air measuring devices:

Table 9: Certification ranges (CR)

Measured component	Lower limit of CR	Upper limit of CR	Limit value	Evaluation period
	in µg/m³	in µg/m³	in µg/m³	
PM_{10}	0	100	50	24h

The certification range is oriented at the limit value of the smallest assessment period of the measuring device in the range of the limit value. This assessment of the measuring device in the range of the limit value is made within the scope of the determination of the advanced uncertainty of the candidates according to the Guide [5]. For this purpose, according to the Guide the following values are used as reference values:

PM_{10}: 50 µg/m³

Reference is made to test point 6.1 5.4.10 Calculation of the expanded uncertainty of the instruments in this report.

6.5 Assessment

The assessment of the measuring device in the range of the relevant limit values is possible.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

See test point 6.1 5.4.10 Calculation of the expanded uncertainty of the instruments in this report.

6.1 5.2.2 Measuring range

The upper limit of the measuring range shall be greater or equal to the upper limit of the certification range.

6.2 Equipment

No additional equipment required.

6.3 Performance of test

It was tested, whether the upper limit of measuring range of the measuring system is greater or equal to the upper limit of the certification range.

6.4 Evaluation

At the measuring devices, measuring ranges up to a maximum of 0 – 1.000.000 µg/m³ can be set theoretically.

As appropriate default setting of the analogue output for European conditions a measuring range of 0 – 1.000 µg/m³ is recommended.

Measuring range:	0 – 1.000 µg/m³ (Standard)
Upper limit of the certification range:	PM_{10}: 100 µg/m³

6.5 Assessment

A measuring range of 0 – 1.000 µg/m³ is set by default. Other measuring ranges up to a maximum of 0 – 1.000.000 µg/m³ are possible.

The measuring range value of the measuring device is higher than the respective upper limit of the certification range.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Not required for this minimum requirement.

6.1 5.2.3 Negative output signals

Negative output signals or measured values may not be suppressed (life zero).

6.2 Equipment

No additional equipment required.

6.3 Performance of test

The AMS was tested on its ability to display negative output signals in the laboratory and in the field.

6.4 Evaluation

The AMS was tested on its ability to display negative output signals in the laboratory and in the field.

6.5 Assessment

Negative measuring signals are displayed directly and are output correctly via the respective measured value outputs by the measuring system.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Not required for this minimum requirement.

6.1 5.2.4 Failure in the mains voltage

In case of malfunction of the measuring system or failure in the mains voltage for a period of up to 72 h, uncontrolled emission of operation and calibration gas shall be avoided. The instrument parameters shall be secured by buffering against loss caused by failure in the mains voltage. When mains voltage returns, the instrument shall automatically reach the operation mode and start the measurement according to the operating instructions.

6.2 Equipment

Not required for this minimum requirement.

6.3 Performance of test

A failure in the mains voltage was simulated and it was tested, if the instrument remains undamaged and ready for measurement after restart of the power supply.

6.4 Evaluation

Since the measuring devices need neither operational nor calibration gases for operating, an uncontrolled escape of gases is not possible.

In the case of a failure in the mains voltage the measuring device remains in a stabilizing phase (“Stabilizing”) after the return of the power supply until reaching a stabilized condition regarding the instrument temperatures. The duration of the stabilizing phase depends on the ambient conditions at the sampling test site and on the thermic instrument condition when switching on.

In the scope of the suitability test the stabilizing times were between 30 min and 90 min. After reaching of the stable condition, the device starts to collect first data (“Collecting Data”). This data are not used yet for the determination of the mass concentrations. The collecting of the first data is followed by first computing of data (“Computing Data”). Afterwards the device is ready to operate (“Fully operational”). The intermediate steps „Collecting Data“ and „Computing Data“ take one hour. Afterwards the device delivers moving 1h-average values of the mass concentrations, which are updated every 6 minutes (refer to point 6.1 4.1.4 Set-up times and warm-up times).

6.5 Assessment

All instrument parameters are protected against loss through buffering. After the power supply has returned, the measuring device goes back into a failure-free operational condition and continues independently the measuring operation after achieving the instrument status “fully operational”.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Not required for this minimum requirement.

6.1 5.2.5 Operating states

The measuring system shall allow the control of important operating states by telemetrically transmitted status signals.

6.2 Equipment

PC for data acquisition.

6.3 Performance of test

A PC was connected locally via Ethernet to the AMS and data transfer incl. instrument status tested.

Furthermore, it is possible to control the instrument via serial interface (AK Protocol).

With a respective router or modem, the remote control is possible.

6.4 Evaluation

The measuring device enables a complete telemetric control of the AMS through a choice of different possibilities (Ethernet, RS232).

6.5 Assessment

The measuring devices can be extensively monitored and controlled by an external PC via modem or router.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Not necessary for this minimum requirement.

6.1 5.2.6 Switch-over

Switch-over between measurement and functional check and/or calibration shall be possible telemetrically by computer control or manual intervention.

6.2 Equipment

Not required for this minimum requirement.

6.3 Performance of test

The AMS can be monitored and partly controlled by a user directly at the instrument or via telemetric remote control. Some functions, as for example the performance of the K_0-test , can only be done directly at the instrument.

6.4 Evaluation

All operating procedures that do not require practical work on test site, can be monitored by a user directly at the instrument as well as by telemetric remote control.

6.5 Assessment

Generally all necessary operations for functional check can be monitored directly at the device or via telemetric remote control.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Not required for this minimum requirement.

6.1 5.2.7 Maintenance interval

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.

6.2 Equipment

Not required for this minimum requirement.

6.3 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 point 6.1 5.3.12 Long-term drift were included into the determination of the maintenance interval.

6.4 Evaluation

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

Therefore, the maintenance interval is determined by scheduled maintenance procedures (refer to module 4.1.2).

During operation, the maintenance works can be limited to checks on contamination, plausibility and status / error message.

6.5 Assessment

The maintenance interval is defined by necessary maintenance procedures and is 1 month.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Necessary maintenance works can be found in module 4.1.2 of this report and in chapter 5 of the operating manual

6.1 5.2.8 Availability

The availability of the measuring system shall be determined during the field test and shall be at least 95 %.

6.2 Equipment

Not required for this minimum requirement.

6.3 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.

6.4 Evaluation

Table 10 and Table 11 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 (refer to Annex 5).

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 (approx. every 4 weeks) and the regular check of the flow rates respectively of the tightness can lead to outages of more than 2 h per device, especially when all is done on one day. The affected daily averages in this case have been rejected.

6.5 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 d) for SN 20006 caused by the leak switching valve cannot be fully shuffled off onto the AMS itself, since a prompt repair was not possible due to communication problems.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Table 10: 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 11: 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

6.1 5.2.9 Instrument software

The version of the instrument software to be tested shall be displayed during switch-on of the measuring system. The test institute shall be informed on changes in the instrument software, which have influence on the performance of the measuring system.

6.2 Equipment

Not required for this minimum requirement.

6.3 Performance of test

It was tested, if the instrument software can be displayed at the instrument. The manufacturer of the instrument was told that any change to the instrument software shall be reported to the test body.

6.4 Evaluation

The present software is shown in the display when turning on the device. At any time it can be looked at in the menu “system status”.

The suitability test was performed with the software version 1.51 (2009).

During the test the software was developed and optimized constantly up to the version 1.55. Appearing problems with the touch screen display were resolved during the development. E.g. there have been problems with the availability of the button „reboot“ during a possible system crash.

Due to the changes up to the version 1.55 no influence on the instrument performance is to be expected.

6.5 Assessment

The version of the instrument software is shown on the display. The test institute is informed on changes in the instrument software.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

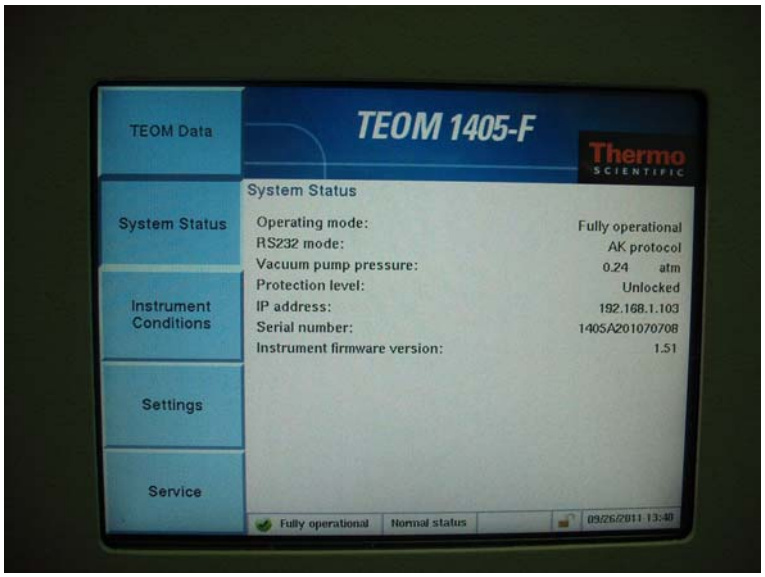

Figure 29: Display of the software version (here 1.51) in the menu „System Status“

6.1 5.3.1 General

The testing is done based on the minimum requirement according to Standard VDI 4202 Part 1 (September 2010).

6.2 Equipment

Not required for this minimum requirement.

6.3 Performance of test

The test is made on the basis of the minimum requirements of Standard VDI 4202, Part 1 (September 2010).

6.4 Evaluation

Standard VDI 4202, Part 1 and VDI 4203, Part 3 have been republished after a detailed revision in September 2010. Unfortunately, after this revision uncertainties and contradictions remain regarding the concrete minimum requirements on the one hand and the general relevance of the test points on the other hand while testing particulate ambient air measuring devices. The following test points require clarification:

6.1 5.3.2 Repeated standard deviation at zero point
no minimum requirement defined

6.1 5.3.3 Repeated standard deviation at reference point
not relevant for particulate devices

6.1 5.3.4 Linearity (Lack of fit)
not relevant for particulate devices

6.1 5.3.7 Sensitivity coefficient of the surrounding temperature
no minimum requirement defined

6.1 5.3.8 Sensitivity coefficient of the electric voltage
no minimum requirement defined

6.1 5.3.11 Standard deviation from paired measurements
no minimum requirement defined

6.1 5.3.12 Long-term drift
no minimum requirement defined

6.1 5.3.13 Short-time drift
not relevant for particulate devices

6.1 5.3.18 Overall uncertainty
→ not relevant for particulate devices

For this reason an official request to the competent German body was made, to define a coordinated procedure for dealing with inconsistencies in the Standard.

The following procedure was suggested:

The test points 5.3.2, 5.3.7, 5.3.8, 5.3.11 and 5.3.12 are evaluated as before based on the minimum requirements stated in Standard VDI 4202 Part 1 from 2002 (i.e. using the reference values B_0, B_1 and B_2).

The testing of the test points 5.3.3, 5.3.4, 5.3.13 and 5.3.18 is waived, as they are not relevant for particulate measuring devices.

The competent German body agreed with the proposed procedure by decision of 27 June 2011 respectively 07 October 2011.

6.5 Assessment

The test was done based on the minimum requirements stated in Standard VDI 4202 Part 1 (September 2010). The test points 5.3.2, 5.3.7, 5.3.8, 5.3.11 and 5.3.12 are evaluated as before based on the minimum requirements stated in Standard VDI 4202 Part 1 from 2002 (i.e. using the reference values B_0, B_1 and B_2). The testing of the test points 5.3.3, 5.3.4, 5.3.13 and 5.3.18 is waived, as they are not relevant for particulate measuring devices.

Minimum requirement fulfilled? yes

Detailed representation of the test results

Not required for this minimum requirement.

6.1 5.3.2 Repeated standard deviation at zero point

The repeatability standard deviation at zero point shall not exceed the requirements of Table 2 in the certification range according to Table 1 of Standard VDI 4202 Part 1 (September 2010).
In case of deviating certification ranges, the repeatability standard deviation at zero point shall not exceed 2% of the upper limit of this certification range.

Note:

This test point is not evaluable for particulate measuring devices on the basis of the currently valid version of Standard VDI 4202 Part 1 (September 2010) and VDI 4203 Part 3 (September 2010) due no non-defined minimum requirements. According to the decision of the competent German body (see module 5.3.1), reference is made alternatively to the following previous version of Standard VDI 4202 Part 1 (June 2002).

The detection limit of the measuring device shall not exceed the reference value B_0. The detection limit shall be determined during field test.

6.2 Equipment

Zero-filter for zero point check.

6.3 Performance of test

The determination of the detection limit is done for the candidates SN 20006 and SN 20107 by operating the devices with the respective zero-filters which are installed at both measuring device inlets.

The offering of particulate-free sampling air is done for a time period of 15 days for 24 h each.

The determination of the detection limit is done in the laboratory, because under field conditions a provision of particulate-free air for such a long time period was not possible.

6.4 Evaluation

The detection limit X is determined from the standard deviation s_{x0} of the measured values at the intake of particulate-free sampling air by both candidates.

It corresponds with the standard deviation of the average x_0 of the measured values x_{0i} multiplied with the student factor for the respective candidate.

$$X = t_{n-1;0.95} \cdot s_{x0} \qquad \text{where} \cdot s_{x0} = \sqrt{\frac{1}{n-1} \cdot \sum_{i=1,n} (x_{0i} - \overline{x_0})^2}$$

Reference value: $B_0 = 2\ \mu g/m^3$

6.5 Assessment

The detection limit was determined from investigations on 0.82 µg/m³ for device 1 (SN 20006) and 0.82 µg/m³ for device 2 (SN 20107).

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Table 12: Detection limit PM_{10}

		Device SN 20006	Device SN 20107
Amount of values n		15	15
Average of the zero values $\overline{x_0}$	µg/m³	0.96	1.28
Standard deviation of the values s_{x0}	µg/m³	0.38	0.38
Student-Factor $t_{n-1;0,95}$		2.14	2.14
Detection limit X	µg/m³	**0.82**	**0.82**

Single values from the determination of the detection limit can be looked up in annex 1 in the annex.

6.1 5.3.3 Repeated standard deviation at reference point

The repeatability standard deviation at reference point shall not exceed the requirements of Table 2 in the certification range according to Table 1 of Standard VDI 4202 Part 1 (September 2010). The limit value or the alert threshold shall be used as reference point.
In case of deviating certification ranges, the repeatability standard deviation at reference point shall not exceed 2% of the upper limit of this certification range. In this case a value ct at 70% to 80% of the upper limit of this certification range shall be used as reference point.

Note:

According to the decision of the competent German body (see module 5.3.1) this test point is not relevant for particulate measuring devices.

6.2 Equipment

Not applicable.

6.3 Performance of test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Minimum requirement fulfilled? -

6.6 Detailed representation of the test results

Not applicable.

6.1 5.3.4 Linearity (Lack of fit)

The analytical function describing the relationship between the output signal and the value of the air quality characteristic shall be linear.

The linearity is considered as secured when the deviation of the group averages of the measured values of the calibration function in the certification range meet the specifications stated in Table 2 of Standard VDI 4202 Part 1 (September 2010).

For other certification ranges the deviation of the group average of the measured values of the calibration function shall not exceed 5 % of the upper limit of the respective certification range.

Note:

According to the decision of the competent German body (see module 5.3.1) this test point is not relevant for particulate measuring devices.

For particulate measuring devices for PM_{10} this test shall be performed according to minimum requirement 5.4.2 „ Equivalency of the sampling system".

6.2 Equipment

See module 5.4.2. (PM_{10}).

6.3 Performance of test

For particulate measuring devices for PM_{10} this test shall be performed according to minimum requirement 5.4.2 „ Equivalency of the sampling system".

6.4 Evaluation

See module 5.4.2. (PM_{10}).

6.5 Assessment

For particulate measuring devices for PM_{10} this test shall be performed according to minimum requirement 5.4.2 „ Equivalency of the sampling system".

Minimum requirement fulfilled? -

6.6 Detailed representation of the test results

See module 5.4.2. (PM_{10}).

6.1 5.3.5 Sensitivity coefficient of the sample gas pressure

The sensitivity coefficient of sample gas pressure at reference point shall not exceed the requirements of Table 2 of Standard VDI 4202 Part 1 (September 2010). A value ct at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

Note:

This point is not relevant for particulate measuring devices.

6.2 Equipment

Not applicable.

6.3 Performance of test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Minimum requirement fulfilled? -

6.6 Detailed representation of the test results

Not applicable.

6.1 5.3.6 Sensitivity coefficient of the sample gas temperature

The sensitivity coefficient of sample gas temperature at reference point shall not exceed the requirements of Table 2. A value ct at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

Note:

This point is not relevant for particulate measuring devices.

6.2 Equipment

Not applicable.

6.3 Performance of test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Minimum requirement fulfilled? -

6.6 Detailed representation of the test results

Not applicable.

6.1 5.3.7 Sensitivity coefficient of the surrounding temperature

The sensitivity coefficient of surrounding temperature at zero and reference point shall not exceed the requirements of Table 2. A value ct at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

Note:
This test point is not evaluable for particulate measuring devices on the basis of the currently valid version of Standard VDI 4202 Part 1 (September 2010) and VDI 4203 Part 3 (September 2010) due no non-defined minimum requirements. According to the decision of the competent German body (see module 5.3.1), reference is made alternatively to the following previous version of Standard VDI 4202 Part 1 (June 2002).

The temperature dependence of the zero-point measured value shall not exceed the reference value B_0 when changing the surrounding temperature by 15 K in the range between +5 °C and +20 °C or respectively by 20 K in the range between +20 °C and +40 °C.

The temperature dependence of the measured value in the range of the reference value B_1 shall not exceed ± 5 % of the measured value when changing the surrounding temperature by 15 K in the range between +5 °C and +20 °C or respectively by 20 K in the range between +20 °C and +40 °C.

6.2 Equipment

Climate chamber for the temperature range +8 to +25 °C, zero-filter for zero-point check, K_0-test kit for reference point check.

6.3 Performance of test

The permitted surrounding temperature at the test site of the measuring device pursuant to the manufacturer is 8 °C to 25 °C. For this reason the test was limited to this surrounding temperature.

For the investigation of the dependence of the zero-point and the measured values on the surrounding temperature, the complete measuring devices were run in the climatic chamber.

For the zero-point check the two candidates SN 20006 and SN 20107 by installation of zero-filters were fed at both device inlets each with particulate-free sampling air.

For the reference point check at the two candidates SN 20006 and SN 20107 the calibration constant K_0 was tested to check the stability of the sensitivity.

The surrounding temperatures in the climatic chamber were varied in this order: 20 °C – 8 °C – 20 °C – 25 °C – 20 °C. After an equilibration time of approx. 24 h per temperature step, the recording of the measured values at zero-point (per temperature step 3 X 24 h each) as well as the measured values at reference point (per temperature step 3X each) started

6.4 Evaluation

Zero-point:

The measured values for the concentration of the respective 24 h-single measurements were read out and evaluated. The absolute deviation in µg/m³ per temperature step is observed in relation to the default point of 20 °C.

Reference value: B_0 = 2 µg/m³

Reference point:

The deviation as a percentage of the determined measured values for the calibration constant K_0 was observed for each temperature step in relation to the default point at 20 °C.

As note it should be mentioned that by using the check of the calibration constant K_0 no concentration values could be simulated, an assessment in the range B_1 was not possible for this reason.

6.5 Assessment

The permitted surrounding temperature at the test site of the measuring device pursuant to the manufacturer is 8 °C to 25 °C. When observing the values output by the device, a maximum influence of the surrounding temperature on the zero-point of -2.3 µg/m³ in the range 8 °C to 25 °C could be detected.

At reference point no deviation > 0.4 % to the default value at 20 °C could be observed.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Table 13: Dependence of the zero-point on the surrounding temperature, deviation in µg/m³, average for 3 measurements

Temperature		Deviation	
Start temperature	End temperature	SN 20006	SN 20107
°C	°C	µg/m³	µg/m³
20	8	-2.3	-0.6
8	20	-0.4	-0.3
20	25	0.8	1.0
25	20	-0.5	0.0

Table 14: Dependence of sensitivity (calibration constant K_0) on the surrounding temperature, deviation in %, average for 3 measurements

Temperature		Deviations	
		SN 20006	SN 20107
Start temperature	End temperature	K_0	K_0
°C	°C	%	%
20	8	-0.1	-0.1
8	20	0.0	-0.1
20	25	0.2	0.1
25	20	0.0	0.2

The respective results of the 3 single measurements can be taken from annex 2 and 3 in the appendix.

6.1 5.3.8 Sensitivity coefficient of the electric voltage

The sensitivity coefficient of supply voltage shall not exceed the requirements of Table 2. A value ct at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

Note:

This test point is not evaluable for particulate measuring devices on the basis of the currently valid version of Standard VDI 4202 Part 1 (September 2010) and VDI 4203 Part 3 (September 2010) due no non-defined minimum requirements. According to the decision of the competent German body (see module 5.3.1), reference is made alternatively to following previous version of Standard VDI 4202 Part 1 (June 2002).

The changes of the measured value for the reference value B_1 caused by the voltage changes typical for an electrical grid within the interval (230 +15/-20) V, shall not exceed B_0.

6.2 Equipment

Adjustable isolating transformer, K_0-test kit for reference point check.

6.3 Performance of test

To check the dependence of the measuring signals on the mains voltage, the voltage was reduced from 230 V to 210 V and afterward increased with an intermediate step of 230 V to 245 V.

For the reference point check at both candidates SN 20006 and SN 20107 the calibration constant K_0 was tested to check the stability of the sensitivity.

Since the mobile use of the AMS is not planned, an additional check of the dependence of the measuring signal on the mains frequency was waived.

6.4 Evaluation

At reference point the change as a percentage of the determined measured value for the calibration constant K_0 is observed for each test step in relation to the default point at 230 V.

As note it should be mentioned that by using the check of the calibration constant K_0 no concentration values could be simulated, an assessment in the range B_1 was not possible for this reason.

6.5 Assessment

Due to voltage changes no deviation > 0.4 % could be detected for PM_{10}, referring to the standard value of 230 V.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Table 15 shows the summarized representation of the test results

Table 15: Dependence of the measured value of the mains voltage, deviation in %

Mains voltage		Deviation	
		SN 20006	SN 20107
Start voltage	End voltage	K_0	K_0
V	V	%	%
230	210	0.3	0.0
210	230	0.0	-0.1
230	245	0.4	0.2
245	230	0.0	-0.1

The single values can be taken from annex 4 of the appendix.

6.1 5.3.9 Cross sensitivity

The change in the measured value caused by interfering components in the sample gas shall not exceed the requirements of Table 2 of Standard VDI 4202 Part 1 (September 2010) at zero and reference point.

Note:

This point is not relevant for particulate measuring devices. The minimum requirement 5.4.5 is valid. Therefore, the results of this test can be found in module 5.4.5.

6.2 Equipment

Not applicable.

6.3 Performance of test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Minimum requirement fulfilled? -

6.6 Detailed representation of the test results

Not applicable.

6.1 5.3.10 Averaging effect

For gaseous components the measuring system shall allow the formation of hourly averages. The averaging effect shall not exceed the requirements of Table 2 of Standard VDI 4202 Part 1 (September 2010).

Note:

This point is not relevant for particulate measurements.

6.2 Equipment

Not applicable.

6.3 Performance of test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Minimum requirement fulfilled? -

6.6 Detailed representation of the test results

Not applicable.

6.1 5.3.11 Standard deviation from paired measurements

The standard deviation from paired measurements under field conditions shall be determined with two identical measuring systems by paired measurements in the field test. It shall not exceed the requirements of Table 2 of Standard VDI 4202 Part 1 (September 2010).

Note:

This test point is not evaluable for particulate measuring devices on the basis of currently valid Standard versions of the Standard VDI 4202 Part 1 (September 2010) and VDI 4203 Part 3 (September 2010) due to a lack of defined minimum requirements. According to the decision of the competent authorities in Germany (see Module 5.3.1), alternatively the following specifications of the previous version of Standard VDI 4202 Part 1 (June 2002) are referred to.

The reproducibility R_D of the measuring device shall be determined with repeat determinations of two identical measuring devices and shall not fall below the value 10. The reference value B_1 shall be used.

6.2 Equipment

Additional measuring devices as stated in Chapter 5 were used when determining the reproducibility.

6.3 Performance of test

Reproducibility R_D is defined as the maximum deviation of two randomly chosen single values which were obtained under equal conditions in relation to each other. This test has been carried out with two identical devices which were simultaneously operated during the field test. The measured data from all four field tests was used for this test.

6.4 Evaluation

The reproducibility R_D is calculated as follows:

$$R = \frac{B_1}{U} \geq 10 \qquad \text{where} \qquad U = \pm s_D \cdot t_{(n;0,95)} \quad \text{and} \quad s_D = \sqrt{\frac{1}{2n} \cdot \sum_{i=1}^{n} (x_{1i} - x_{2i})^2}$$

- R = Reproducibility R_D at B_1
- U = Uncertainty
- B_1 = 40 µg/m³ for PM_{10}
- s_D = Standard deviation from repeat determinations
- n = No. of parallel measurements
- $t_{(n;0,95)}$ = Student factor for 95% certainty
- x_{1i} = Measuring signal of device 1 (e.g. SN 20006) at i^{th} concentration.
- x_{2i} = Measuring signal of device 2 (e.g. SN 20107) at i^{th} concentration.

6.5 Assessment

The reproducibility R_D for PM_{10} was 23 during field test for the complete data set.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

The test results are summarized in Table 16. The graphical representation for PM_{10} is shown from Figure 55 to Figure 59.

Note: The determined uncertainties are applied to the reference value B_1 for each test site.

Table 16: Concentration averages, standard deviation, uncertainty range and reproducibility in the field, measured component PM_{10}

Test site	Amount	$\overline{c}$ (SN 20006)	$\overline{c}$ (SN 20107)	$\overline{c}_{ges}$	s_D	t	U	R
		µg/m³	µg/m³	µg/m³	µg/m³		µg/m³	
Teddington (Winter)	46	18.8	20.0	19.4	0.26	2.013	0.53	75
Teddington (Summer)	49	16.4	16.4	16.4	0.49	2.010	0.98	41
Cologne (Winter)	88	31.2	32.0	31.6	1.00	1.987	1.99	20
Bornheim (Summer)	68	16.7	17.5	17.1	1.10	1.996	2.19	18
All test sites	251	22.1	22.8	22.5	0.89	1.969	1.76	23

- $\overline{c}$ (SN 20006): Concentration averages, device SN 20006
- $\overline{c}$ (SN 20107): Concentration averages, device SN 20107
- $\overline{c}_{ges}$: Concentration averages of the devices SN 20006 & SN 20107

Single values can be taken from the annex 5 of the appendix.

6.1 5.3.12 Long-term drift

The long-term drift at zero point and reference point shall not exceed the requirements of Table 2 in the field test. A value ct at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

Note:

This test point is not evaluable for particulate measuring devices on the basis of currently valid Standard versions of the Standard VDI 4202 Part 1 (September 2010) and VDI 4203 Part 3 (September 2010) due to a lack of defined minimum requirements. According to the decision of the competent authorities in Germany (see Module 5.3.1), alternatively the following specifications of the previous version of Standard VDI 4202 Part 1 (June 2002) are referred to.

The temporal change of the zero point measured value shall not exceed the reference value B_0 within 24 h and the maintenance interval.
The temporal change of the measured values in the range of the reference value B_1 shall not exceed ± 5 % of B_1 within 24 h and the maintenance interval.

6.2 Equipment

Zero-filter for zero-point check, K_0-test kit for reference-point check.

6.3 Performance of test

The test was performed within the scope of the field test with a total time period of 22 months.

Within the scope of a regular check approx. once a month (incl. at the beginning and the end of every test site), the measuring device was run for a time period of at least 24 h each with zero-filters at the device-inlets; the measured zero-valued were evaluated. The zero-measurements were performed as planned with a monthly change of the TEOM-filter and the 47 mm-filter.

Furthermore, the stability of the calibration constant was tested and evaluated for the reference point check at the beginning and end auf each test site.

6.4 Evaluation

An evaluation of the drift at zero-point and the measured value within 24 h is not possible.

The evaluation at zero-point is done on the basis of the measuring results of the regular external zero-point measurements by comparing the respective values with the „measured values“ of the previous test and the „measured values“ of the first test.

The evaluation at reference-point is done on the basis of the measuring results for the calibration constant K_0 by comparing the respective values with the „measured values“ of the previous test and the „measured values“ of the first test.

It should be noted that using the test of the calibration constant K_0 no concentration values can be simulated. Therefore, an assessment in the range of B_1 was not possible.

6.5 Assessment

The maximum deviation found at zero-point was 1.5 µg/m³ with reference to the previous value and 1.6 µg/m³ with reference to the start value and are thus within the allowed range of B_0 = 2 µg/m³. The values for the drift of the sensitivity, referring to the respective previous values, determined within the scope of the test, have been at maximum 1.3 % for PM_{10}.

The found deviations on 07.03.2010 (SN 20006) and on 06.02.2010 and 07.02.2010 (SN 20107) could be ascribed to not correctly installed TEOM-filters and therefore cannot be evaluated for the drift test. On 26.05.2010, a measured value of SN 20006 could not be evaluated, because the measuring signal produced a strong noise due to a leak of the switching valve. The switching valve was changed on 11.06.2010.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Table 17 contains the determined values for the zero-point and the calculated deviation referring to the previous value and the start value in µg/m³. Figure 30 to Figure 31 show the graphical representation of the zero-point drift over the test period.

In Table 18 the deviations of the measured values are shown in % of the respective previous value. Figure 32 and Figure 33 show the graphical representation of the drift of the measured values (referring to the previous value).

Table 17: Zero-point drift SN 20006 & SN 20107, with zero-filter

	SN 20006			SN 20107		
Date	Measured value	Deviation from previous value	Deviation from start value	Measured value	Deviation from previous value	Deviation from start value
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
06.12.2009	0.0	-	-	Not yet operating	-	-
07.12.2009	-1.4	-1.4	-1.4	Not yet operating	-	-
04.01.2010	-1.6	-0.2	-1.6	0.6*	-	-
06.02.2010	-0.7	0.9	-0.7	3.5**	-	-
07.02.2010	-0.7	0.1	-0.6	4.9**	-	-
07.03.2010	-4.7**	-	-	1.8	1.2	1.2
26.04.2010	-0.1	0.6	-0.1	1.1	-0.7	0.5
26.05.2010	Rejected due to noise***	-	-	0.9	-0.2	0.3
02.07.2010	0.5	0.6	0.6	1.1	0.2	0.5
29.01.2011	1.5	1.0	1.5	1.7	0.6	1.2
30.01.2011	1.4	-0.1	1.4	1.8	0.1	1.3
31.01.2011	0.9	-0.5	0.9	1.2	-0.6	0.6
05.03.2011	-0.4	-1.3	-0.4	0.2	-1.0	-0.4
06.03.2011	-0.4	0.0	-0.3	0.4	0.2	-0.2
07.03.2011	0.5	0.9	0.6	0.0	-0.4	-0.6
09.04.2011	1.0	0.5	1.1	1.5	1.5	0.9
10.04.2011	1.1	0.1	1.2	2.1	0.6	1.6
22.07.2011	-0.5	-1.7	-0.5	0.8	-1.3	0.3
23.07.2011	-0.2	0.4	-0.1	1.3	0.5	0.8
24.07.2011	-0.5	-0.3	-0.4	0.1	-1.2	-0.4
17.09.2011	0.0	0.5	0.1	0.4	0.3	-0.1
18.09.2011	0.1	0.1	0.1	0.6	0.2	0.0

* measured on 11.01.2010

** SN 20006 on 07.03.2010 and SN 20107 on 06.02.2010 and 07.02.2010 – TEOM-filter not installed correctly – strong noise, not possible to evaluate.

*** SN 20006 on 26.05.2010 – strong noise due to a leak at the switching valve - measured value rejected.

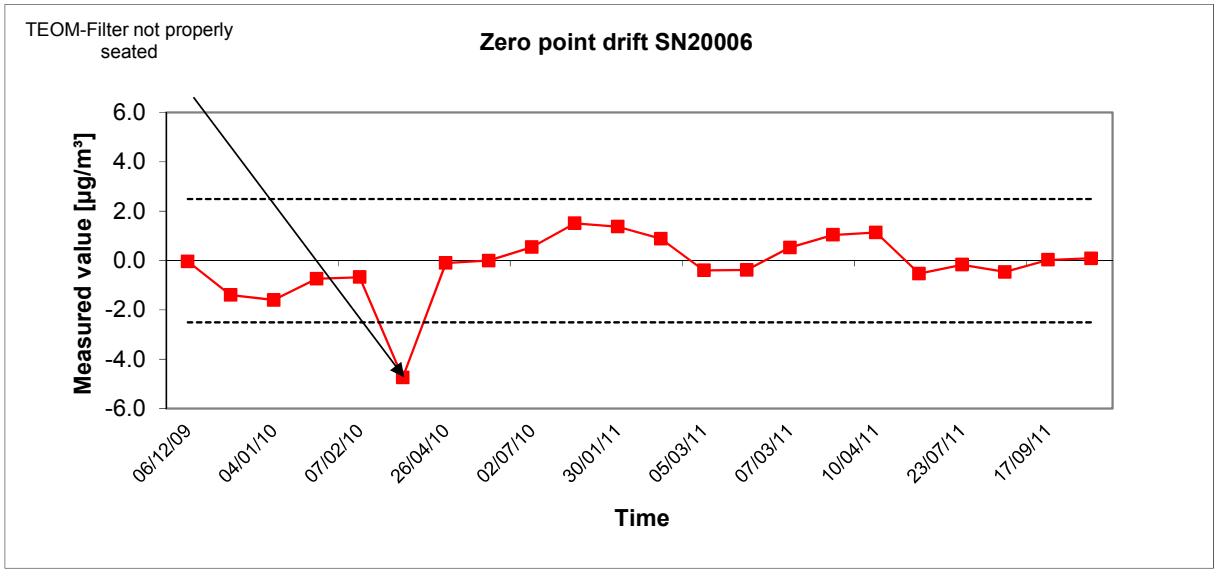

Figure 30: Zero-point drift SN 20006, measured component PM_{10}

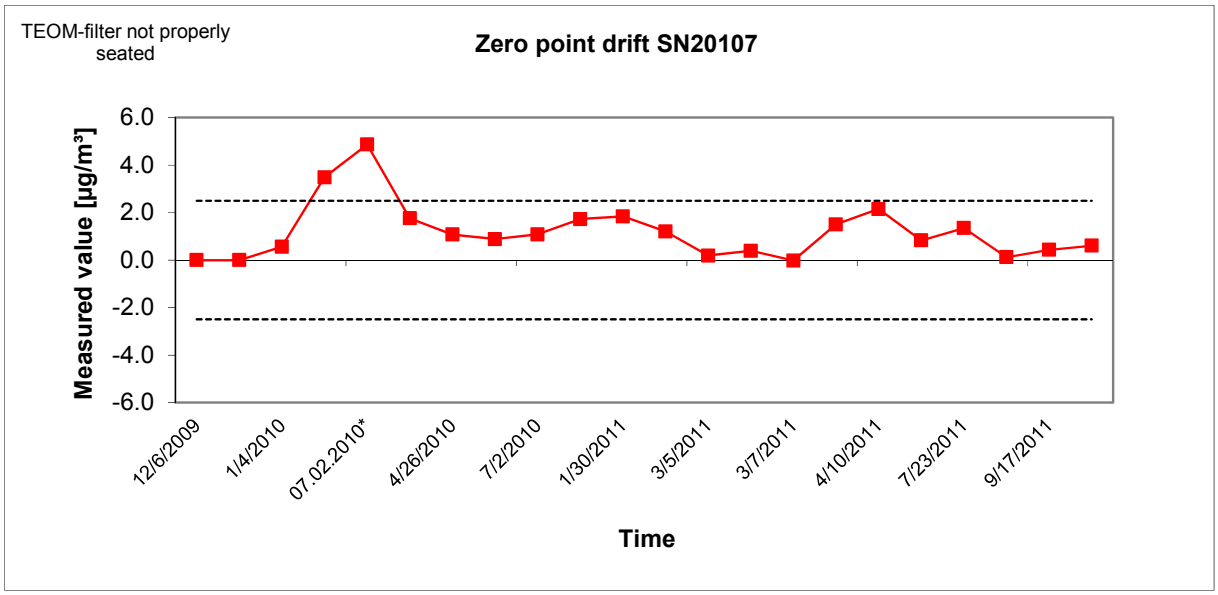

Figure 31: Zero-point drift SN 20107, measured component PM_{10}

Table 18: Sensitivity drift SN 20006 & SN 20107

Date	SN 20006			SN 20107		
	Measured value K_0	Deviation form previ-ous value %	Deviation form start value %	Measured value K_0	Deviation form previ-ous value %	Deviation form start value %
06.12.2009	15034.0	-	-	17256.0*	-	-
05.03.2010	14929.2	-0.7	-0.7	17098.0	-0.9	-0.9
19.04.2010	14952.0	0.2	-0.5	17312.0	1.3	0.3
07.07.2010	15001.0	0.3	-0.2	17270.0	-0.2	0.1
27.01.2011	14984.8	-0.1	-0.3	17412.9	0.8	0.9
12.05.2011	14912.6	-0.5	-0.8	17201.7	-1.2	-0.3
19.07.2011	15106.5	1.3	0.5	17406.6	1.2	0.9
26.09.2011	14981.4	-0.8	-0.3	17330.8	-0.4	0.4

* measured on 05.02.2010

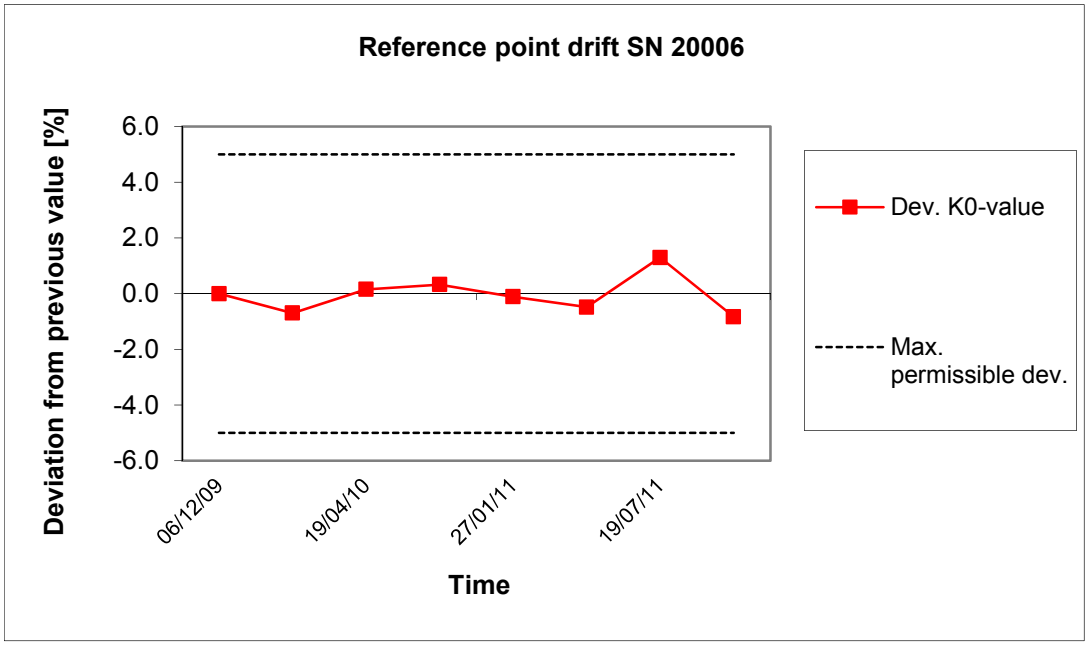

Figure 32: Drift of the measured value SN 20006, measured component PM_{10}

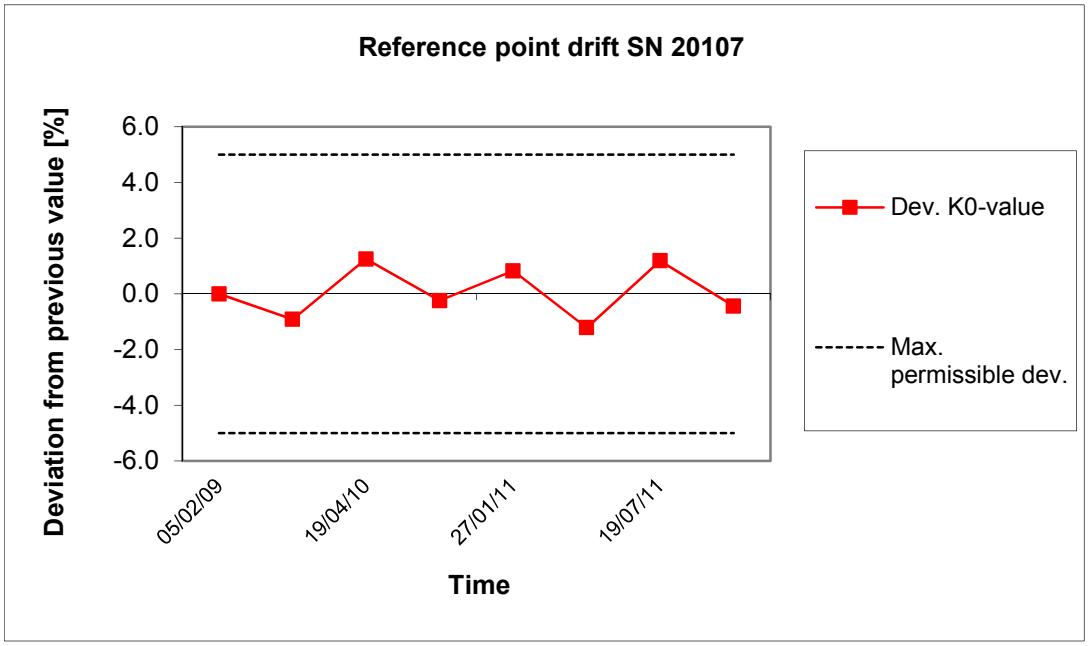

Figure 33: Drift of the measured value SN 20107, measured component PM_{10}

6.1 5.3.13 Short-time drift

The short-term drift at zero point and reference point shall not exceed the requirements of Table 2 of Standard VDI 4202 Part 1 (September 2010) within 12 h (for benzene 24 h) in the laboratory test and within 24 h in the field test. A value ct at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

Note:
According to the decision of the competent German body (see module 5.3.1) this test point is not relevant for particulate measuring devices.

6.2 Equipment

Not applicable.

6.3 Performance of test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Minimum requirement fulfilled? -

6.6 Detailed representation of the test results

Not applicable.

6.1 5.3.14 Response time

The response time (rise) of the measuring system shall not exceed 180 s.

The response time (fall) of the measuring system shall not exceed 180 s.

The difference between the response time (rise) and response time (fall) of the measuring system shall not exceed 10% of response time (rise) or 10 s, whatever value is larger.

Note:

This point is not relevant for particulate measuring devices.

6.2 Equipment

Not applicable.

6.3 Performance of test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Minimum requirement fulfilled? -

6.6 Detailed representation of the test results

Not applicable.

6.1 5.3.15 Difference between sample- and calibration port

The difference between the measured values obtained by feeding gas at the sample and calibration port shall not exceed the requirements of Table 2 of Standard VDI 4202 Part 1 (September 2010). A value ct at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

Note:

This point is not relevant for particulate measuring devices.

6.2 Equipment

Not applicable.

6.3 Performance of test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Minimum requirement fulfilled? -

6.6 Detailed representation of the test results

Not applicable.

6.1 5.3.16 Converter efficiency

In the case of measuring systems with a converter, the efficiency of the converter shall be at least 98 %.

Note:

This point is not relevant for particulate measuring devices.

6.2 Equipment

Not applicable.

6.3 Performance of test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Minimum requirement fulfilled? -

6.6 Detailed representation of the test results

Not applicable.

6.1 5.3.17 Increase of NO_2 concentration due to residence in the measuring system

In case of NO_x measuring systems the increase of NO_2 concentration due to residence in the measuring system shall not exceed the requirements of Table 2 of Standard VDI 4202 Part 1 (September 2010).
The requirements of Table 2 Standard VDI 4202 Part 1 (September 2010) apply to certification ranges according to Table 1 of Standard VDI 4202 Part 1 (September 2010). For deviating certification ranges the requirements shall be proportionally converted.

Note:

This point is not relevant for particulate measuring devices.

6.2 Equipment

Not applicable.

6.3 Performance of test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Minimum requirement fulfilled? -

6.6 Detailed representation of the test results

Not applicable.

6.1 5.3.18 Overall uncertainty

The expanded uncertainty of the measuring system shall be determined. The value determined shall not exceed the corresponding data quality objectives in the applicable EU Directives on air quality listed in Annex A, Table A1 of Standard VDI 4202 Part 1 (September 2010).

Note:

According to the decision of the competent German body (see module 5.3.1 this test point is not relevant for particulate measuring devices. Reference is made to module 5.4.10.

6.2 Equipment

According to the decision of the competent German body (see module 5.3.1 this test point is not relevant for particulate measuring devices. Reference is made to module 5.4.10.

6.3 Performance of test

According to the decision of the competent German body (see module 5.3.1 this test point is not relevant for particulate measuring devices. Reference is made to module 5.4.10.

6.4 Evaluation

According to the decision of the competent German body (see module 5.3.1 this test point is not relevant for particulate measuring devices. Reference is made to module 5.4.10.

Assessment

According to the decision of the competent German body (see module 5.3.1 this test point is not relevant for particulate measuring devices. Reference is made to module 5.4.10.

Minimum requirement fulfilled? -

6.6 Detailed representation of the test results

According to the decision of the competent German body (see module 5.3.1), this test point is not relevant for particulate measuring devices. Reference is made to module 5.4.10.

6.1 5.4.1 General

Test for particulate measuring units according to the minimum requirement stated in Table 5 of Standard VDI 4202, Part 1.
Furthermore, the particle mass concentration shall be related to a defined volume. The relation to volume with respect to pressure and temperature shall be comprehensively described.

6.2 Equipment

Not necessary for this minimum requirement.

6.3 Performance of test

The test took place according to the minimum requirement stated in Table 5 of Standard VDI 4202, Part 1.

It was tested, if the measured particulate mass concentrations are referred to a defined volume.

6.4 Evaluation

The test took place according to the minimum requirement stated in Table 5 of Standard VDI 4202, Part 1 (September 2010).

The measuring unit TEOM 1405-F Ambient Particle Monitor is a gravimetric measuring device, which determines the mass depotest sited on a filter via oscillating micro weighing. The determined mass is related to a defined and actively regulated sampling volume and thereby the particulate concentration is determined.

6.5 Assessment

The test took place according to the minimum requirement stated in Table 5 of Standard VDI 4202, Part 1 (September 2010).

The measuring unit TEOM 1405-F Ambient Particle Monitor is a gravimetric measuring device, which determines the mass depotest sited on a filter via oscillating micro weighing. The determined mass is related to a defined and actively regulated sampling volume and thereby the particulate concentration is determined.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Not necessary for this minimum requirement.

6.1 5.4.2 Equivalency of the sampling system

The equivalency between the PM_{10} sampling system and the reference method according to EN 12341 [T5] shall be demonstrated.

6.2 Equipment

For this test point additional equipment was used according to point 5 of this report.

6.3 Performance of test

The test was performed at different test sites during field test according to point 4 of this report. In doing so, the different seasons and different levels of concentrations were taken into account.

At each test site at least 15 valid data pairs were determined.

6.4 Evaluation

Requirement from EN 12341:

The calculated functional relationship y = f(x) between concentration values measured with the candidate sampler (y) and concentration values measured with the reference sampler (x) has to be limited by a two-sided acceptance range. This acceptance range is given by:

$y = (x \pm 10)$ µg/m³ for concentration averages $\leq$ 100 µg/m³ and

$y = 0.9x$ µg/m³ respectively $1.1x$ µg/m³ for concentration averages > 100 µg/m³

Moreover, the variance coefficient R^2 of the calculated reference-equivalence-function shall be at least 0.95.

The test procedure focuses on the functional relationship between the concentration values which were determined through double measurements with candidate and reference sampler. Ideally both instruments sample the same fraction of suspended particulate matter which leads to the relation y = x. The evaluation process is as follows:

A linear regression analysis based on the measured values was done for every single test site and, after merging the overall measured data, for all four test sites together.

One receives for every measurement value y_i of the candidate sampler i and the concentration x, measured with the reference sampler – both in µg/m³ - a reference-equivalence-function according to the general relation:

$$y_i = m \cdot x + b \qquad \text{with i = candidate 1405-F}$$

6.5 Assessment

The reference-equivalence functions lay within the limits of the respective acceptance range. Furthermore, the variation coefficient R^2 of the calculated reference-equivalence functions in the relevant concentration range for the data sets „All data set“, „Teddington (Winter)“ and „Cologne (Winter)” is ≥ 0.95. For the data sets “Teddington (Summer)” and Bornheim (Summer) the variation coefficient is < 0.95. Both test sites are characterized by a low variation of

the particulate concentrations. The equivalence test according to 6.1 5.4.10 Calculation of the expanded uncertainty of the instruments is fulfilled nevertheless for all test sites.

Minimum requirement fulfilled? no

Detailed representation of the test results

The results of the regression analysis are summarized from Table 19 to Table 20. The graphical representations are shown from Figure 34 to Figure 43. Next to the regression line, the diagrams show an image of the ideal curve y=x and the two-sided acceptance range. All single values for the candidates and the reference device – separated according to test site – can be taken from annex 5 of the appendix.

Table 19: Results of the linear regression analysis of the measurements with both candidates SN 20006 and SN 20107 at the four test sites

SN 20006	No. of paired values N	Slope m	Ordinate intercept b	R^2
Teddington, W	66	0.954	-1.401	0.99
Teddington, S	42	1.057	0.952	0.90
Cologne, W	74	0.984	0.598	0.99
Bornheim, S	55	1.095	-1.504	0.93
SN 20107	**No. of paired values N**	**Slope m**	**Ordinate intercept b**	**R^2**
Teddington, W	45	0.928	0.299	0.98
Teddington, S	57	1.034	1.398	0.93
Cologne, W	74	0.997	1.127	0.98
Bornheim, S	54	1.060	0.032	0.91

Table 20: Results of the linear regression analysis of the measurements with both candidates SN 20006 and SN 20107 (total)

Device	No. of paired values N	Slope m	Ordinate intercept b	R^2
SN 20006	237	0.981	0.160	0.97
SN 20107	230	0.986	1.148	0.97

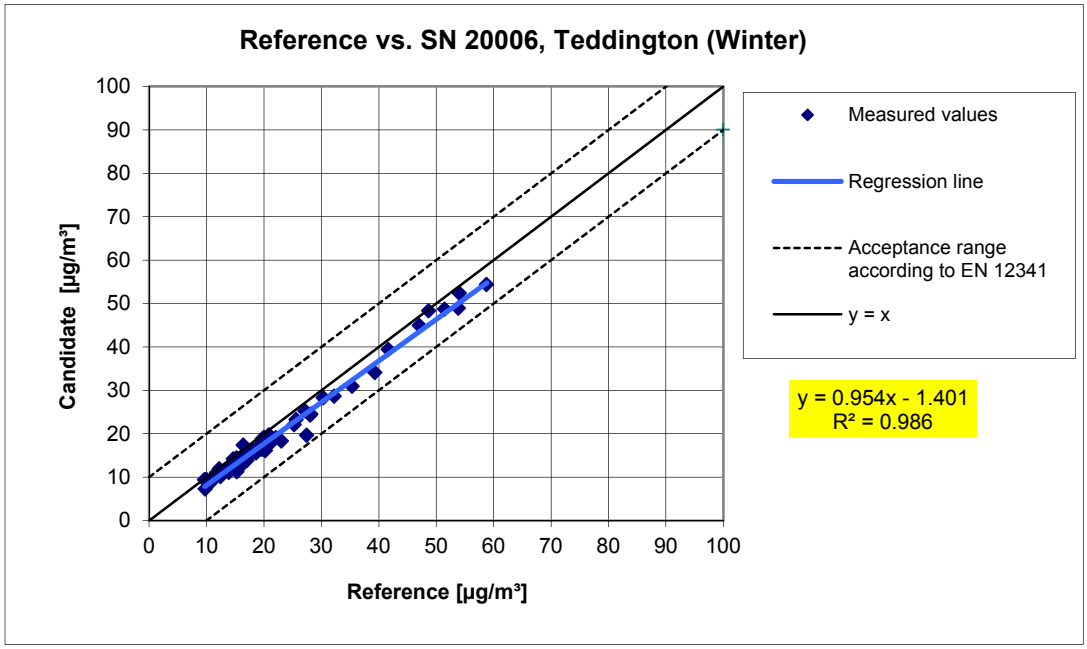

Figure 34: Reference-equivalence function SN 20006, test site Teddington (Winter)

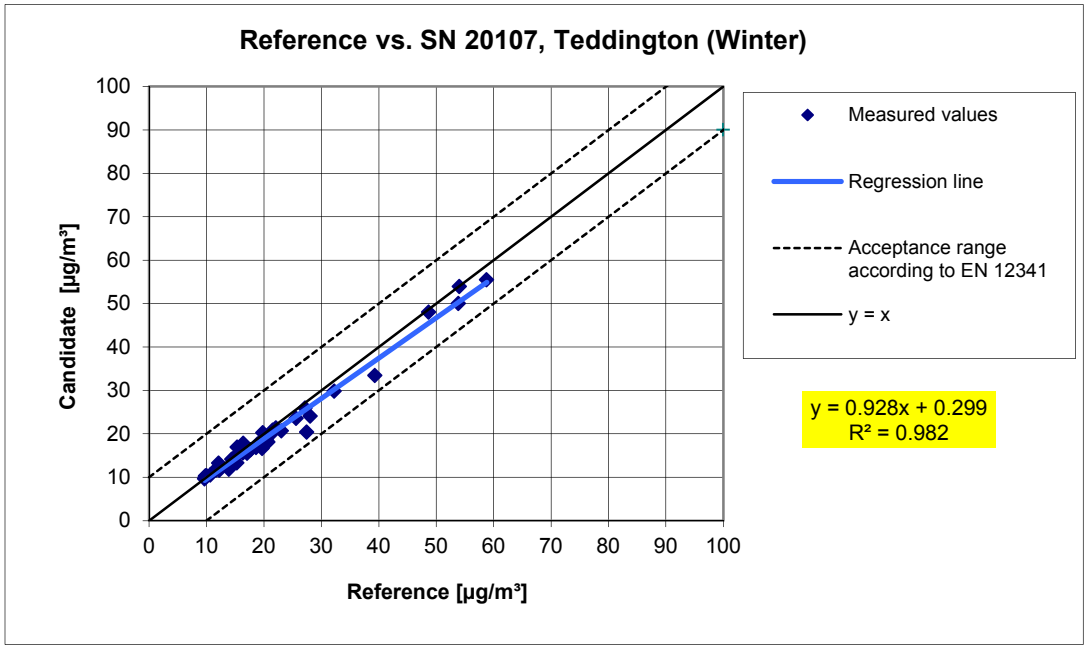

Figure 35: Reference-equivalence function SN 20107, test site Teddington (Winter)

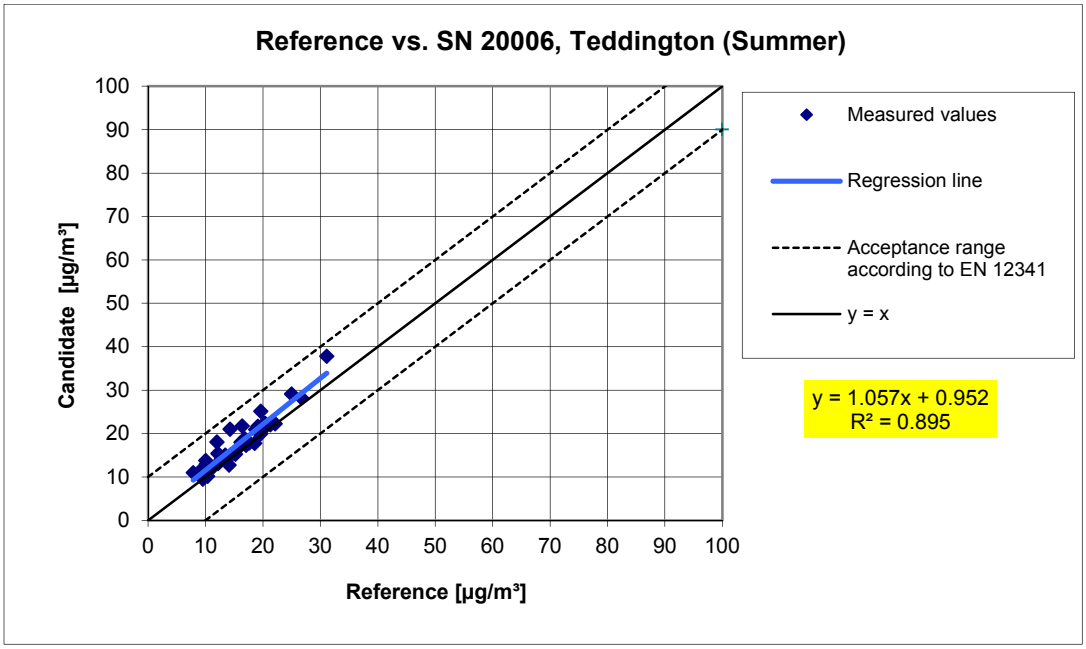

Figure 36: Reference-equivalence function SN 20006, test site Teddington (Summer)

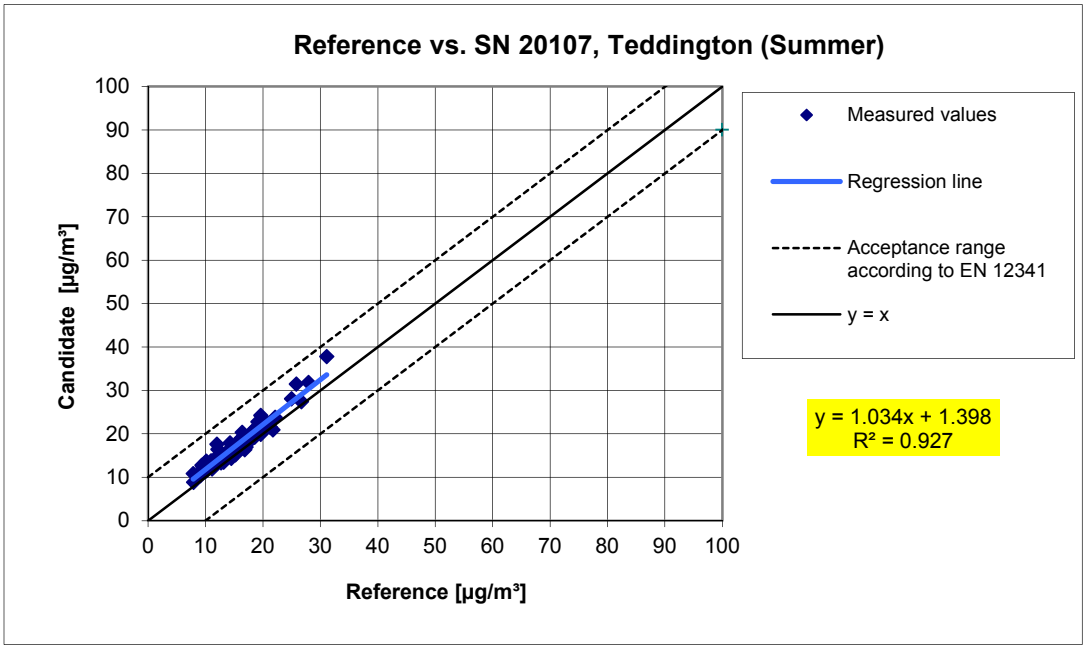

Figure 37: Reference-equivalence function SN 20107, test site Teddington (Summer)

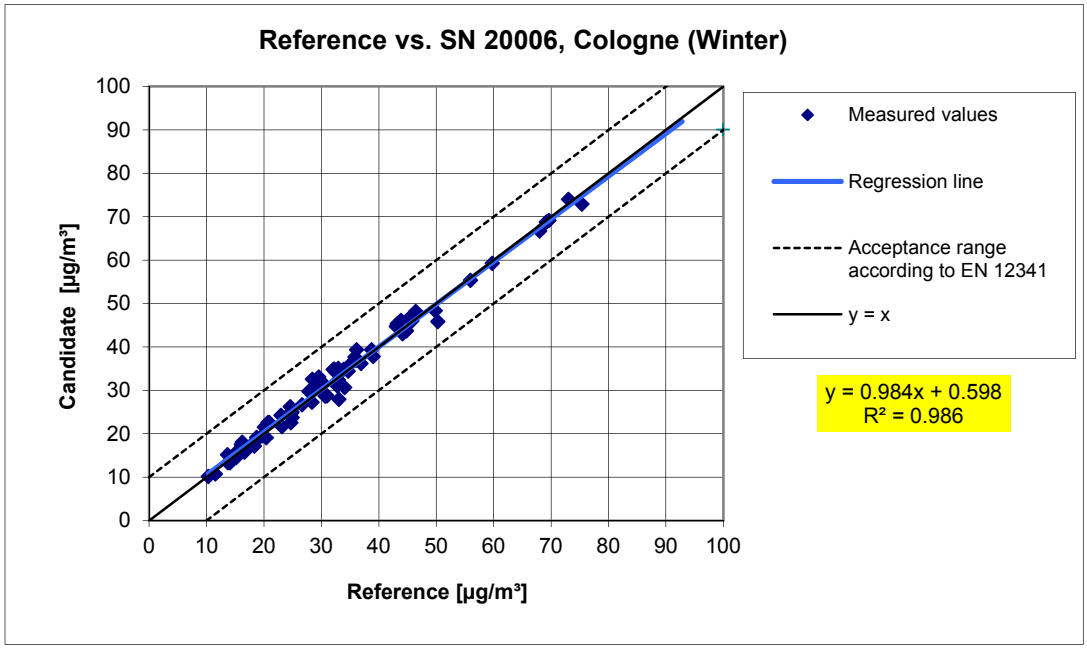

Figure 38: Reference-equivalence function SN 20006, test site Cologne, parking lot

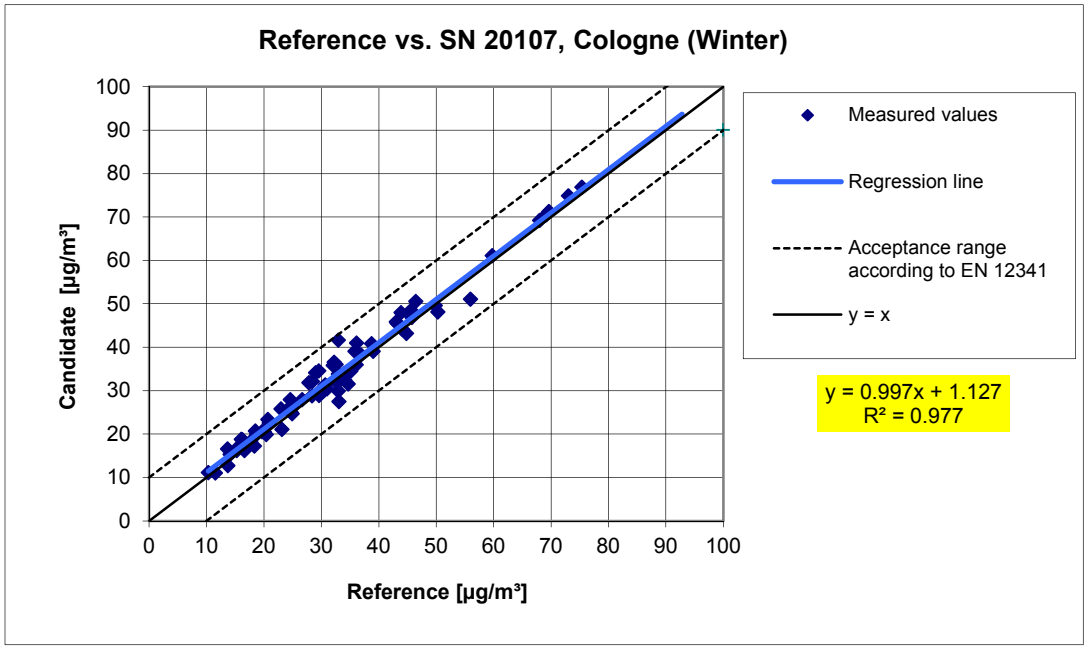

Figure 39: Reference-equivalence function SN 20107, test site Cologne, parking lot

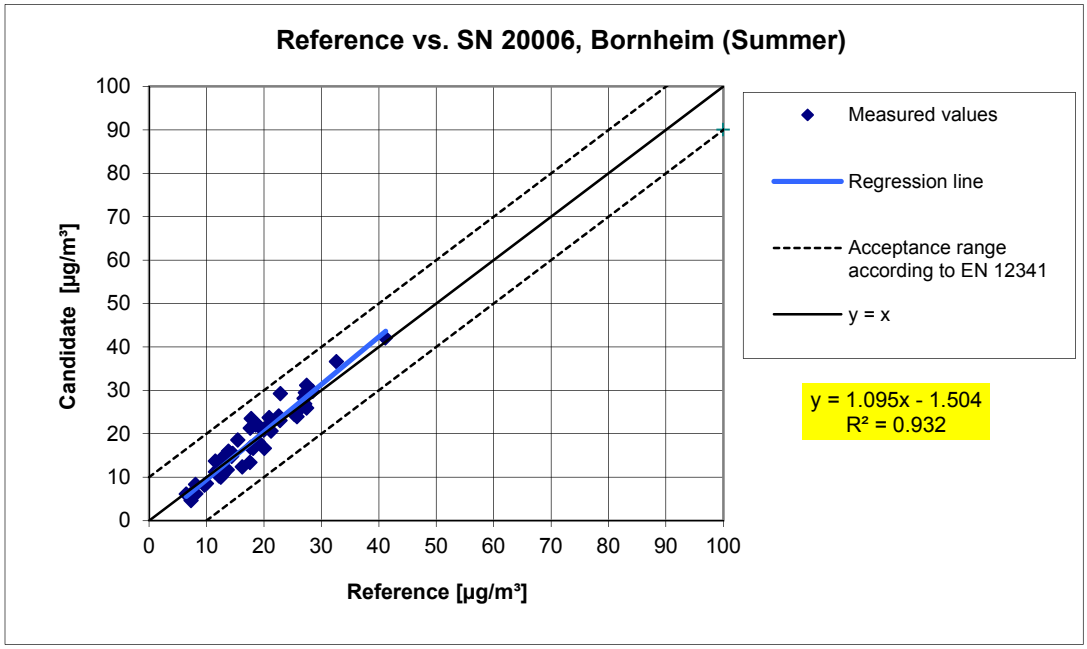

Figure 40: Reference-equivalence function SN 20006, test site Bornheim (Summer)

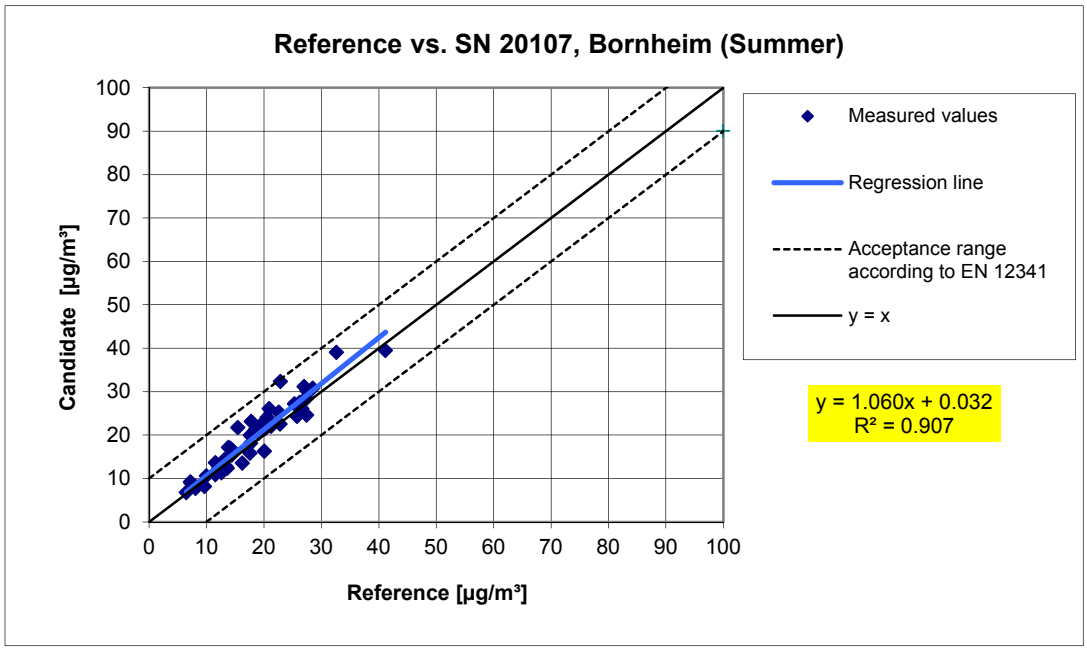

Figure 41: Reference-equivalence function SN 20107, test site Bornheim (Summer)

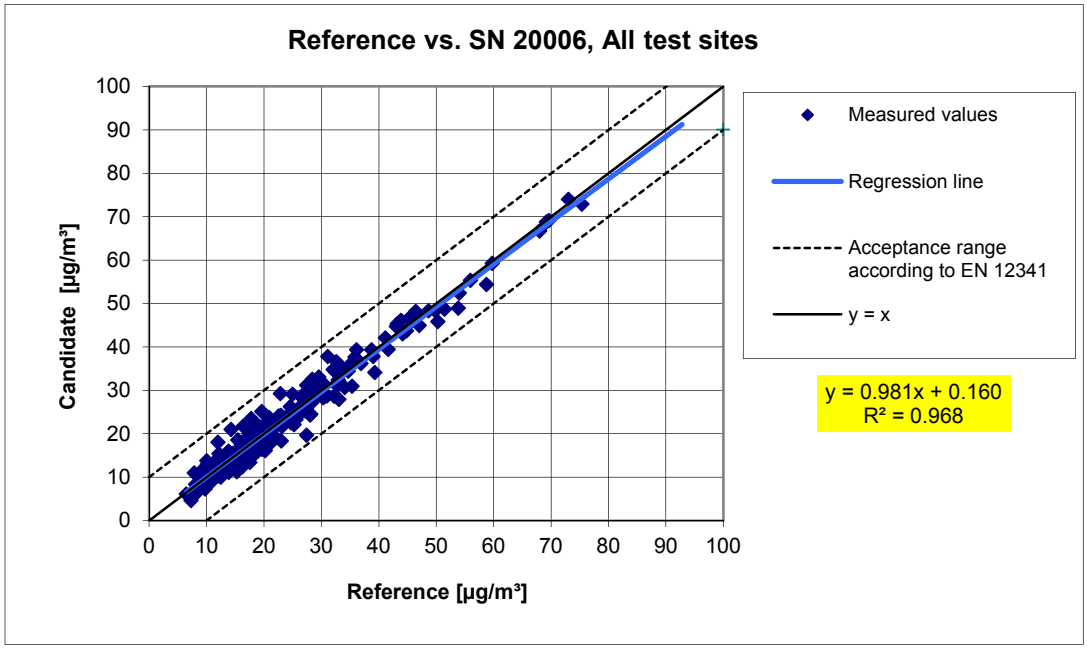

Figure 42: Reference-equivalence function SN 20006, all test sites

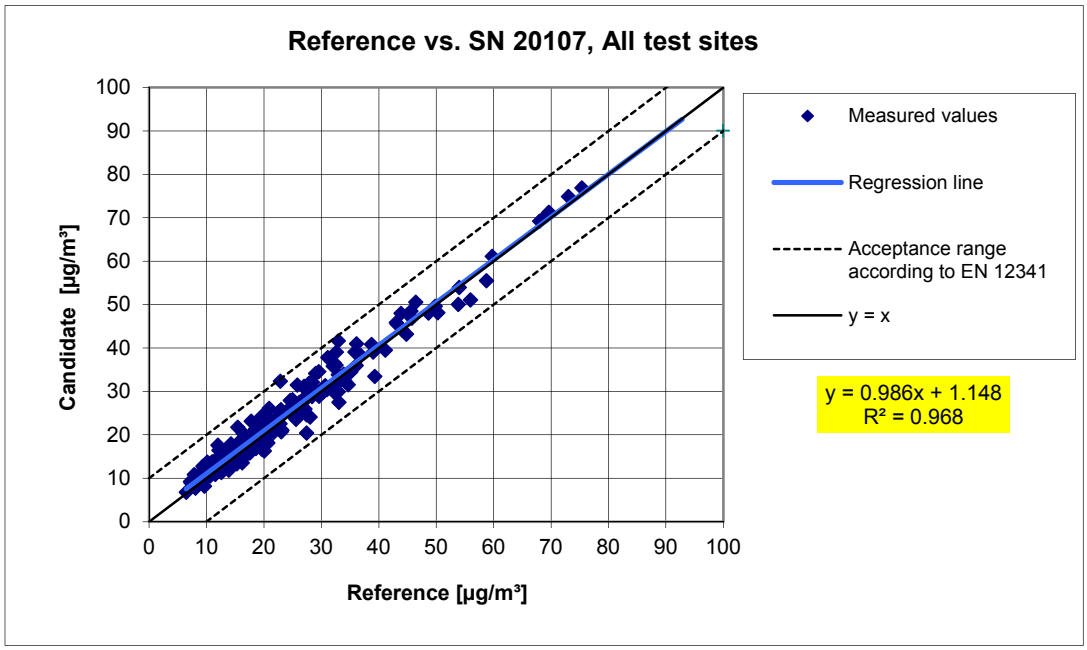

Figure 43: Reference-equivalence function SN 20107, all test sites

6.1 5.4.3 Reproducibility of the sampling systems

The PM_{10} sampling systems of two identical systems under test shall be reproducible among themselves according to EN 12341. This shall be demonstrated in the field test.

6.2 Equipment

Not necessary for this minimum requirement.

6.3 Performance of test

The test was performed at different test sites during field test. In doing so, the different seasons and different levels of PM_{10}-concentrations were taken into account.

At each test site at least 15 valid data pairs were determined.

6.4 Evaluation

The two-sided confidence interval CI_{95}, calculated from the concentration averages measured with the candidates, shall not exceed a value of 5 µg/m³ for concentration averages of 100 µg/m³ or less, and of 0.05 for concentration averages of more than 100 µg/m³.

The demonstration of comparability of the candidates is focused on the differences D_i of the concentration values Y_i. Ideally both candidates are equal and thus sample the same suspended particulate matter fraction, implying $D_i = 0$. The procedure is as follows:

The average concentrations Y_i of the i-th parallel measurement of the candidate samplers are calculated, followed by dividing the average concentrations Y_i into two separated data sets:

a) Data set with $Y_i \leq 100$ µg/m³ with number of paired values $n_{\leq}$ and
b) Data set with $Y_i > 100$ µg/m³ with number of paired values $n_{>}$

Re a):

The absolute standard deviation s_a is calculated from the paired values of the data set with $Y_i \leq 100$ µg/m³:

$$s_a = \sqrt{(\sum D_i^2 / 2n_{\leq})}$$

The corresponding Student factor $t_{f_{\leq};0,975}$ is used, defined as the 0.975 quintile of the two-sided 95 % confidence interval of the Student t-distribution with $f_{\leq} = n_{\leq} - 2$ degrees of freedom.

The two-sided confidence interval CI_{95} for the average concentration values ≤ 100 µg/m³ is then calculated as follows:

$$CI_{95} = s_a \cdot t_{f_{\leq};0,975}$$

Re b):

The relative standard deviation s_r is calculated from the paired values of the data set with Y_i > 100 µg/m³ as follows:

$$s_r = \sqrt{(\sum (D_i / Y_i)^2 / 2n_>)}$$

Once again the corresponding Student factor $t_{f_\leq;0,975}$, defined as the 0.975 quintile of the two-sided 95 % confidence interval of the Student t-distribution with $f_\leq = n_\leq - 2$ degrees of freedom, is used.

The two-sided confidence interval CI_{95} for the average concentration values > 100 µg/m³ is then calculated as follows:

$$CI_{95} = s_r \cdot t_{f_>;0,975}$$

During the field tests no concentration values > 100 µg/m³ were measured. A statistical evaluation of these concentration ranges is for this reason not possible. Therefore the assessment according to b) is not applicable.

6.5 Assessment

The two-sided confidence interval CI_{95} is with a maximum of 2.57 µg/m³ beneath the demanded value of 5 µg/m³ for all test sites.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Table 21 shows the calculated values for the standard deviation s_a and the two-sided confidence interval CI_{95}. The graphical representation follows in Figure 44 to Figure 48. The diagrams contain, besides the regression line of both candidates (determined via linear regression analysis), the curve y = x, which is seen as the ideal case and the two-sided acceptance range. All single values for the candidate can be looked up in annex 5.

Table 21: Two-sided 95%-confidence-interval CI_{95} for the candidates SN 20006 and SN 20107

Candidate	Test site	No. of values	Standard deviation s_a	Student factor t_f	Confidence interval CI_{95}
SN			µg/m³		µg/m³
20006/20107	Teddington, W	46	1.14	2.015	2.29
20006/20107	Teddington, S	49	0.82	2.012	1.66
20006/20107	Cologne, W	88	1.23	1.988	2.45
20006/20107	Bornheim, S	68	1.29	1.997	2.57
20006/20107	Total	251	1.16	1.970	2.29

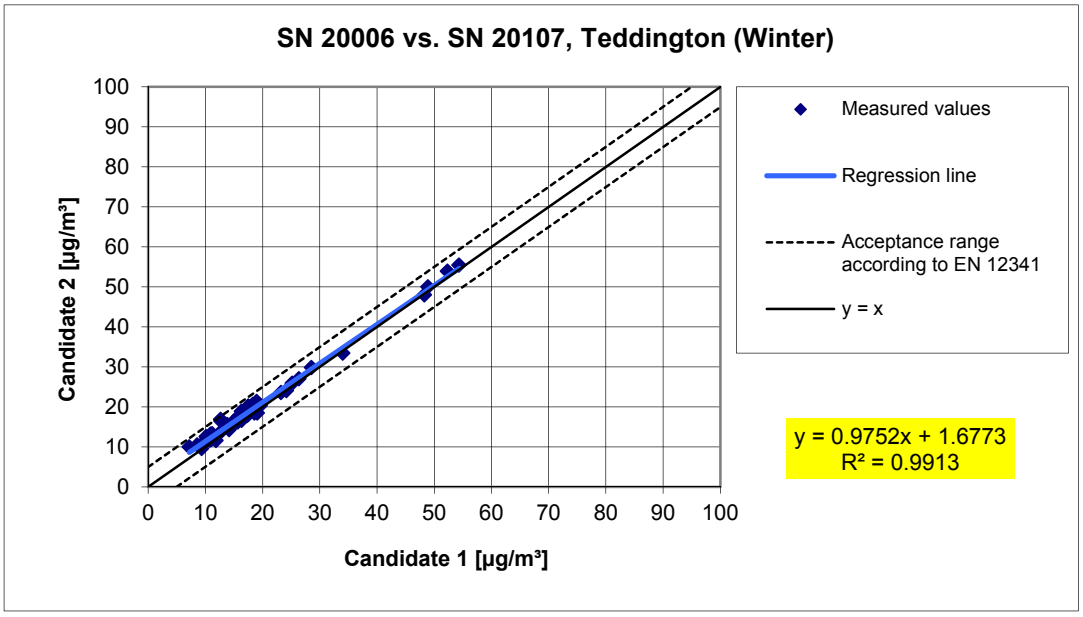

Figure 44: Result of the parallel measurements with the candidates SN 20006 / SN 20107, test site Teddington (Winter)

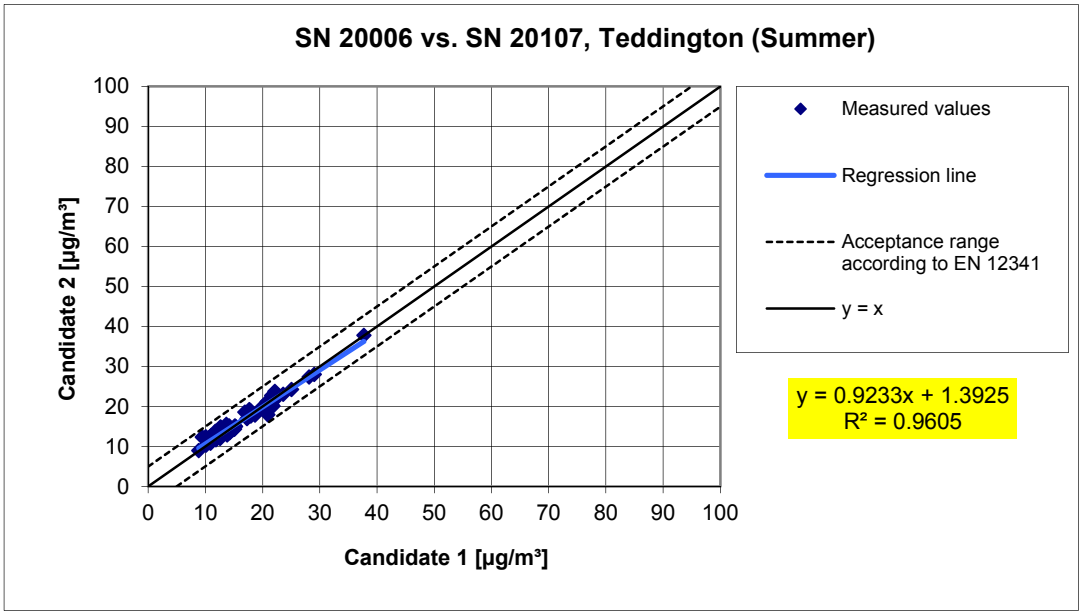

Figure 45: Result of the parallel measurements with the candidates SN 20006 / SN 20107, test site Teddington (Summer)

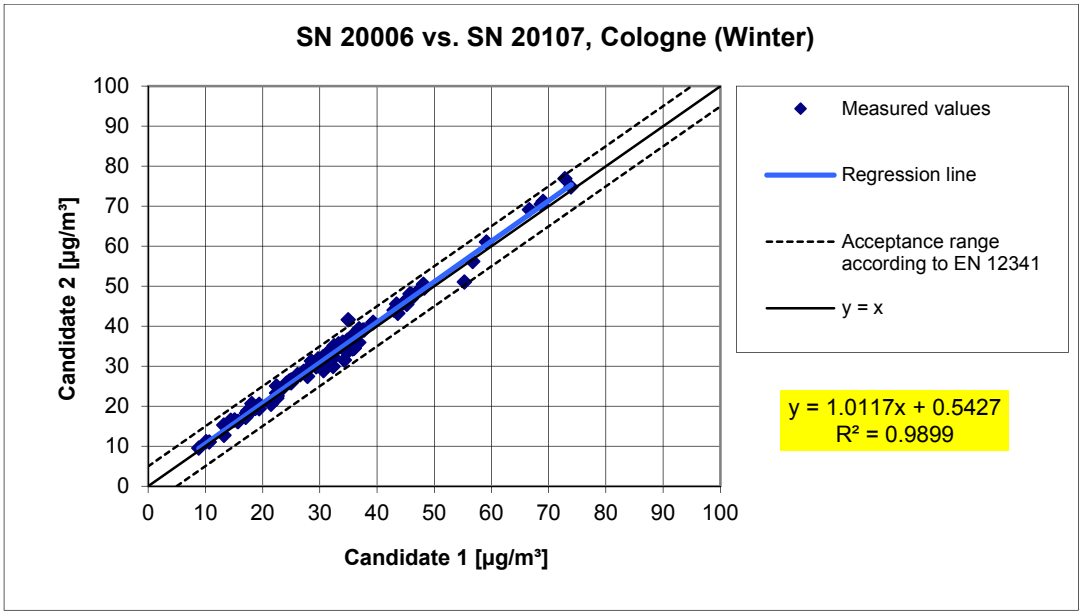

Figure 46: Result of the parallel measurements with the candidates SN 20006 / SN 20107, test site Cologne, parking lot

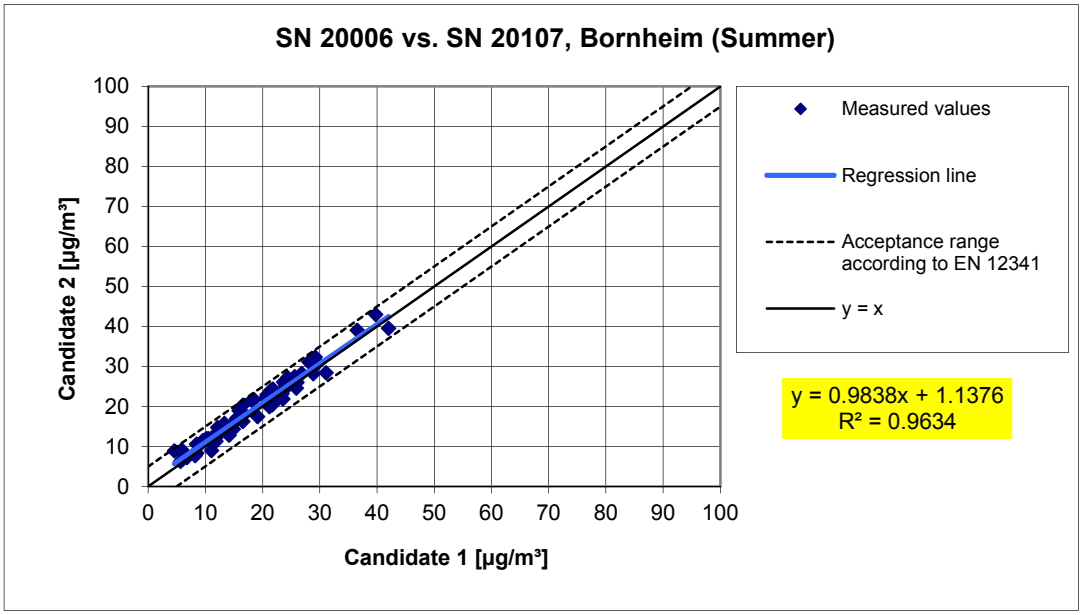

Figure 47: Result of the parallel measurements with the candidates SN 20006 / SN 20107, test site Bornheim

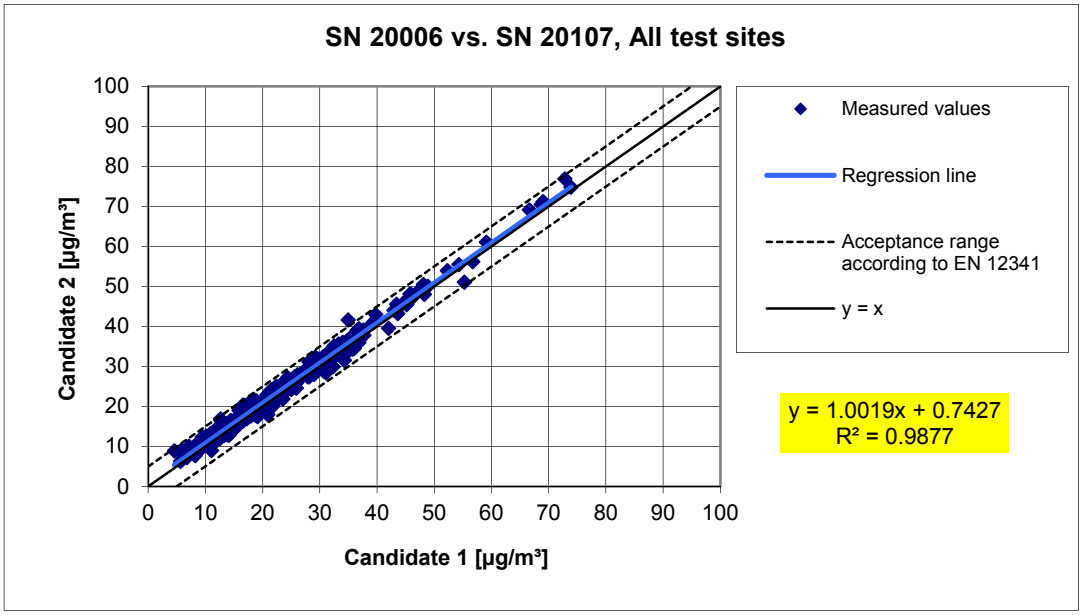

Figure 48: Result of the parallel measurements with the candidates SN 20006 / SN 20107, all test sites

6.1 5.4.4 Calibration

The systems under test shall be calibrated in the field test by comparison measurements with the reference method according to EN 12341. Here, the relationship between the output signal and the gravimetrically determined reference concentration shall the determined as a steady function.

6.2 Equipment

See module 5.4.2.

6.3 Performance of test

For PM_{10}:

The comparability of the measuring systems was demonstrated within the scope of the testing (see module 5.4.2).

For the determination of the calibration and the analysis function, the complete data set is used (237 valid measured value pairs for SN 20006, 230 valid measured value pairs for SN 20107).

The parameters of the calibration function

$$y = m * x + b$$

were determined by linear regression. The analysis function is the reversal of the calibration function. It reads

$$x = 1/m * y - b/m$$

The slope m of the regression line characterized the sensitivity of the measuring device; the ordinate intercept b characterized the zero-point.

The values result as shown in Table 22.

Table 22: Results of the calibration and analysis function, measured component PM_{10}

Device-Nr.	Calibration function		Analysis function	
	Y = m * x + b		x = 1/m * y - b/m	
	m	b	1/m	b/m
	µg/m³ / µg/m³	µg/m³	µg/m³ / µg/m³	µg/m³
Device 1 (SN 20006)	0.981	0.160	1.019	0.163
Device 2 (SN 20107)	0.986	1.148	1.014	1.164

6.5 Assessment

A statistically secured relation between the reference measuring procedure and the instrument display could be demonstrated.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

See module 5.4.2.

6.1 5.4.5 Cross-sensitivity

The interference caused by moisture in the sample may not exceed 10% of the limit value in the range of the limit value.

6.2 Equipment

Not necessary for this minimum requirement.

6.3 Performance of test

The determination of the interference caused by moisture in the sample has been carried out under field conditions.

Instead, the differences between the determined reference value (= nominal value) and the measured value of the respective candidate system were calculated for days of more than 70 % relative humidity during field test, and the average difference was set as a conservative estimation of the interfering effect of humidity contained in the measured medium.

In addition, the reference-equivalence-functions were determined from the field investigations for days of more than 70 % relative humidity for both candidate systems.

6.4 Evaluation

The average difference between the determined reference value (= nominal value) and the measured value of the respective candidate system was calculated for days of more than 70 % relative humidity during field test, and the relative deviation of the average concentration was determined.

Annual limit value PM_{10} = 40 µg/m³ 10 % of ALV = 4 µg/m

Further investigations were made to determine whether the comparability of the candidate systems with the reference method according to Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods” [4] is also given at days of more than 70 % relative humidity.

6.5 Assessment

No interference caused by moisture in the sample > 1.9 µg/m³ deviation from nominal value for PM_{10} could be observed.

During the field test, no negative influence on the measured values could be noted at changing relative humidities. The comparability of the candidates with the reference method according to Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods" [4] also is given for the days with a relative humidity > 70 %.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Table 23 shows a summarizing presentation.

Table 23: Deviation between reference measurement and candidates at the days with a relative humidity > 70 %, measured component PM_{10}

Field test, days with a relative humidity >70 %				
		Reference	SN 20006	SN 20107
Average	µg/m³	21.8	19.9	20.8
Deviation to average reference in µg/m³	µg/m³	-	1.9	1.0
Deviation in % of average reference	%	-	8.7	4.6
Deviation in % of ALV	%	-	4.8	2.5

Single values can be taken from annex 5 and 6 in the appendix.

The presentation and the assessment of the measuring uncertainties W_{CM} at the days with a relative humidity > 70 % is made in Table 24 and in Table 25. Single values can be taken from annex 5 and 6 in the appendix.

Table 24: Comparison candidate 20006 with reference device, rel. humidity > 70 %, all test sites, measured component PM_{10}

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010				
Candidate	1405-F	SN	SN 20006	
Test site	All test sites, rH>70%	Limit value	50	µg/m³
Status of measured values	Raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.01**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**-0.90**	**significant**		
Uncertainty of a	**0.41**			
Results of the equivalence test				
Deviation at limit value	**-0.53**	**µg/m³**		
Uncertainty $u_{c\_s \text{ at limit value}}$	**2.26**	**µg/m³**		
Combined measurement uncertainty w_{CM}	**4.52**	**%**		
Expanded measurement uncertainty W_{CM}	**9.03**	**%**		
Status equivalence test	**pass**			

Table 25: Comparison candidate 20107 with reference device, rel. humidity > 70 %, all test sites, measured component PM_{10}

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010				
Candidate	1405-F	SN	SN 20107	
Test site	All test sites, rH>70%	Limit value	50	µg/m³
Status of measured values	Raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.00**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**0.15**	**not significant**		
Uncertainty of a	**0.39**			
Results of the equivalence test				
Deviation at limit value	**0.27**	**µg/m³**		
Uncertainty $u_{c\_s \text{ at limit value}}$	**2.13**	**µg/m³**		
Combined measurement uncertainty w_{CM}	**4.26**	**%**		
Expanded measurement uncertainty W_{CM}	**8.52**	**%**		
Status equivalence test	**pass**			

6.1 5.4.6 Averaging effect

The measuring system shall allow for formation of 24 h averages.
The time of the sum of all filter changes within 24 h may not exceed 1 % of this averaging time.

6.2 Equipment

For the test a clock was provided.

6.3 Performance of test

It was tested, if the AMS allows the formation of daily averages.

6.4 Evaluation

The FDMS-unit of the AMS switches alternately every 6 minutes between the operating modi “base mode” and “reference mode” to take into account the amount of semi-volatile particle matter (see as well point 3.2)

On the basis of the determined mass concentration in the “base mode” and the respective following “reference mode” the expended mass concentration is determined.

Example:

The device collects for 6 minutes in the „base mode“ and determines a base mass concentration of 5 µg/m³. Afterwards the device collects for 6 minutes in the “reference mode” and determines a reference mass concentration of -1 µg/m³. The expended mass concentration amounts therefore to 5 µg/m³ - (-1 µg/m³) = 6 µg/m³.

The actual available sampling time (= base mode) per measuring cycle therefore is exactly 50 % of the total cycle. The results of the field tests according to 6.1 5.4.10 Calculation of the expanded uncertainty of the instruments in this report show, that for this instrument configuration a comparability of the candidates could be demonstrated securely with the reference method and the formation of daily averages therefore is possible securely.

6.5 Assessment

The formation of valid daily averages is possible.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Not required.

6.1 5.4.7 Constancy of sample volumetric flow

The sample volumetric flow averaged over the sampling time shall be constant within ± 3 % of the rated value. All instantaneous values of the sample volumetric flow shall be within a range of ± 5 % of the rated value during sampling.

6.2 Equipment

For the test additionally a flow meter according to point 4 was provided.

6.3 Performance of test

The sample volumetric flow was calibrated before the first field sampling test site and tested for its correctness 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.

6.4 Evaluation

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

6.5 Assessment

The results from the performed flow rate checks before each field test site are represented in Table 26

Table 26: Results control flow rate

Flow rate check before Test site		SN 20006		SN 20107	
		[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

The graphical representation of the flow rates for PM_{10} (Nominal: 3 l/min) and the total flow rate (Nominal: 16.67 l/min) show that all values determined during sampling deviate less than ±5 % from the respective nominal value. The deviation of the 24h-average for the total flow rate of 16.67 l/min are as well significantly smaller than the demanded ±3 % of the nominal value.

All determined daily averages deviate less than ± 3 %, all instantaneous values less than ± 5 % from the nominal value.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

In Table 27 and Table 28 the determined parameter for the flow are shown. Figure 49 to Figure 54 show the graphical representation of the flow measurements at both candidates SN 20006 and SN 20107.

Table 27: 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 28: 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

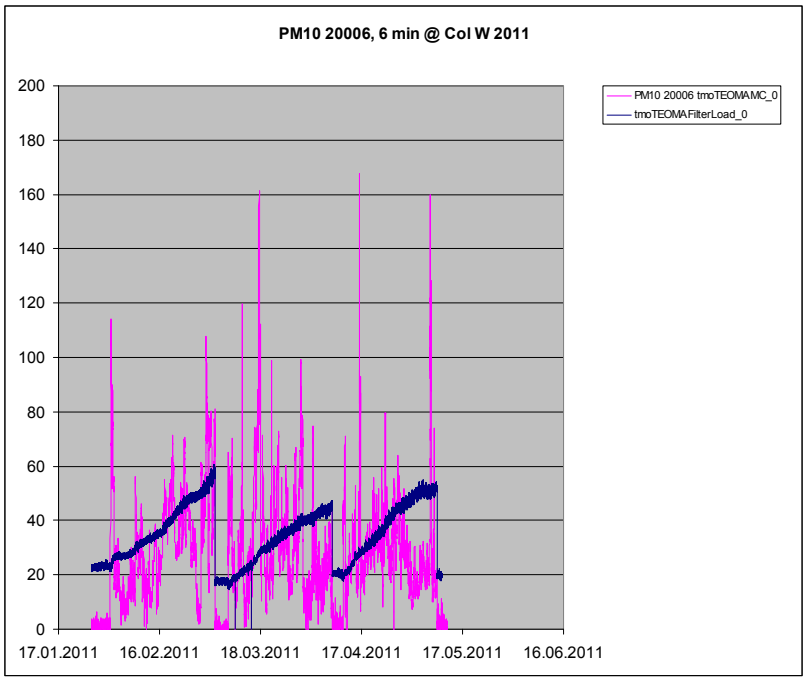

Figure 49: Course of time of the PM-concentration [µg/m³] and the filter load [%], Candidate SN 20006, Cologne (Winter)

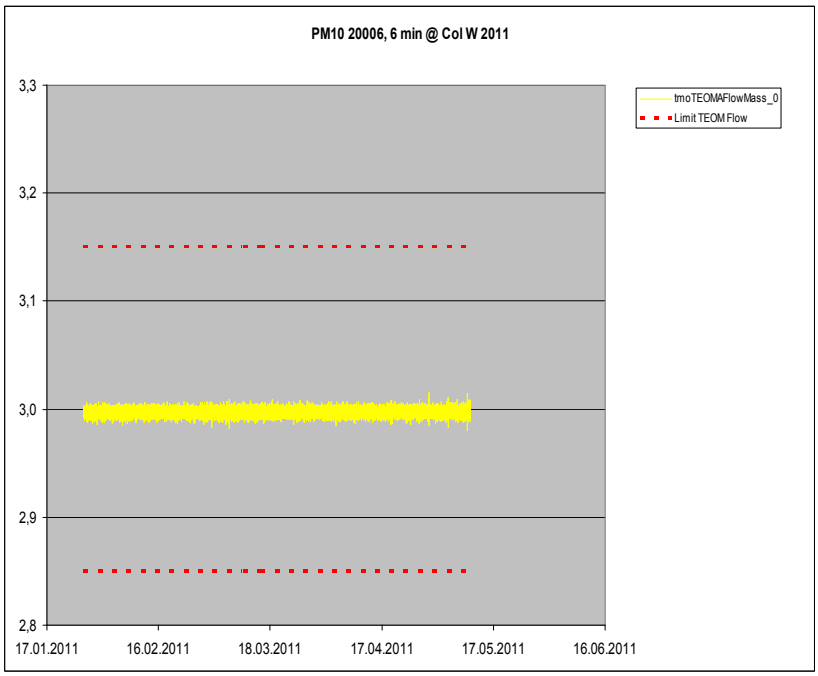

Figure 50: PM_{10}-flow rate at candidate SN 20006, Cologne (Winter)

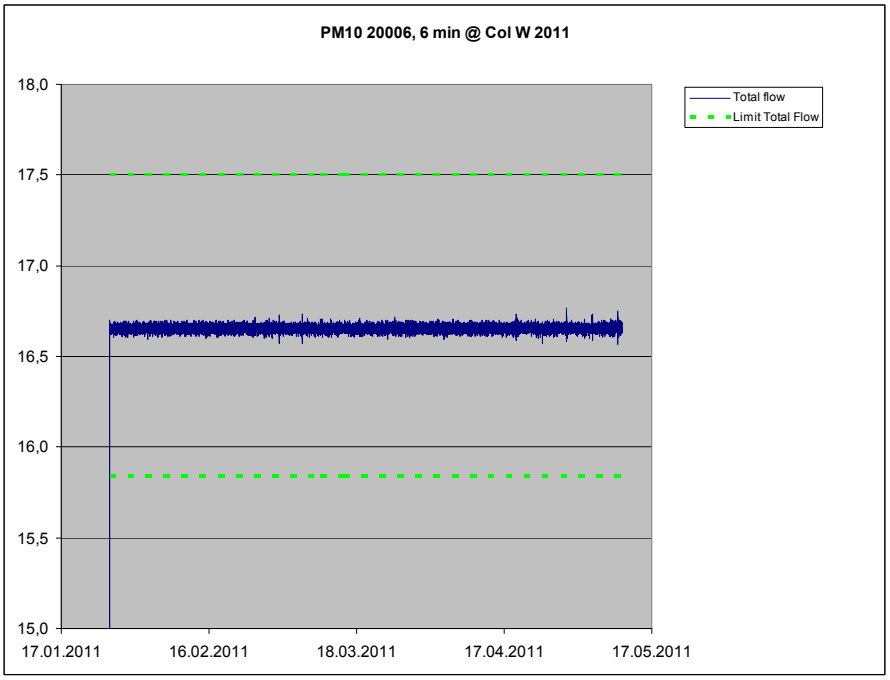

Figure 51: Total flow rate at candidate SN 20006, Cologne (Winter)

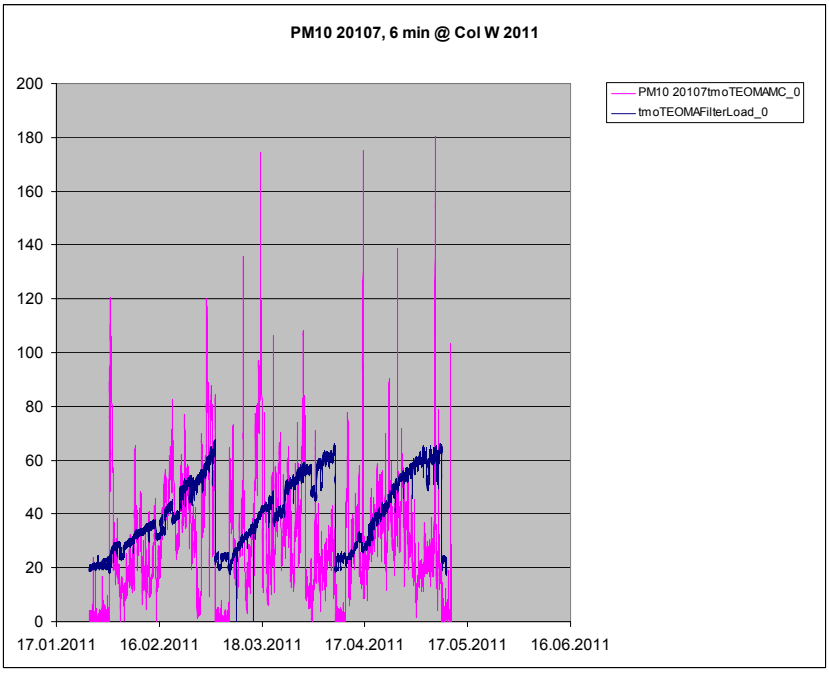

Figure 52: Course of time of the PM-concentration [µg/m³] and the filter load [%], Candidate SN 20107, Cologne (Winter)

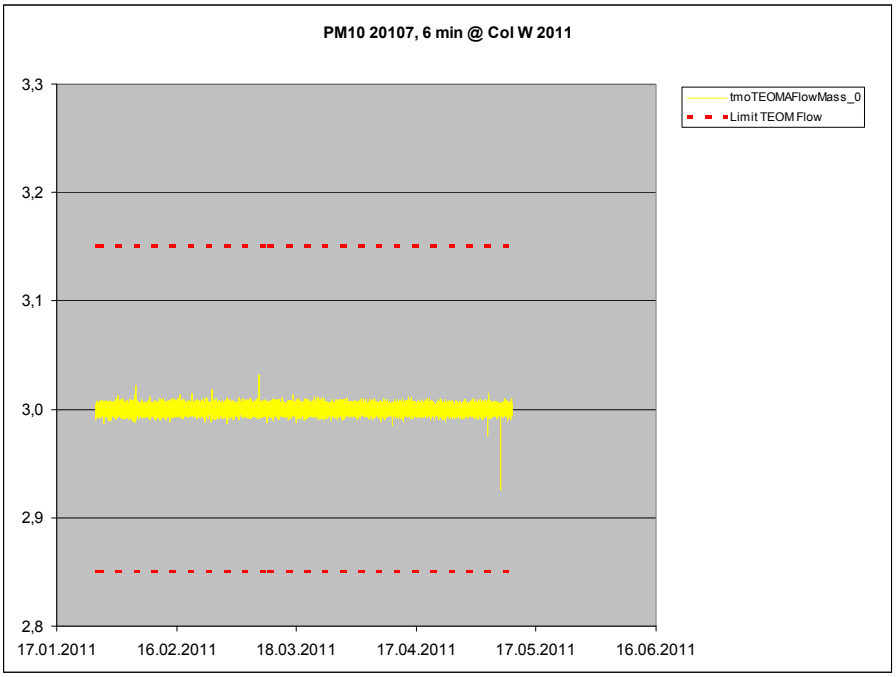

Figure 53: PM_{10}-flow rate at candidate SN 20107, Cologne (Winter)

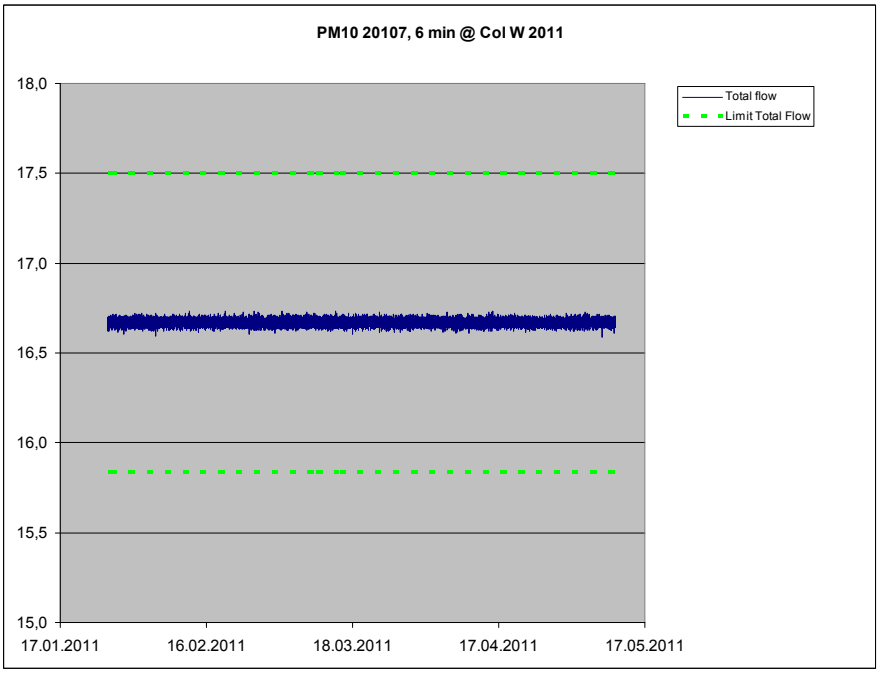

Figure 54: Total flow rate at candidate SN 20107, Cologne (Winter)

6.1 5.4.8 Tightness of the measuring system

The complete measuring system shall be checked for tightness. Leakage shall not exceed 1 % of the sample volume sucked.

6.2 Equipment

Adapter for flow rate check/ tightness check

6.3 Performance of test

The AMS TEOM 1405-F Ambient Particulate Monitor can perform a tightness check using a device internal implemented tightness check assistant.

The tightness check assistant compares the different measured values between zero flow (with turned off vacuum) 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 during 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 AMS once a month using the described procedure.

6.4 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 damages of the instrument.

6.5 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 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 damages of the instrument.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Table 29 contains the determined values from the tightness check

Table 29: Results of the tightness check during field test

		SN 20006			SN 20107		
		Limit [l/min]	Basis [l/min]	Refer-ence [l/min]	Limit [l/min]	Basis [l/min]	Refer-ence [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

6.1 Methodology of the equivalence check (modules 5.4.9 – 5.4.11)

According to the version of the Guide from January 2010 [4] the following 5 criteria must be fulfilled to proof the 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: $|b-1| \le 2 \cdot u(b)$, 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 fulfillment of the 5 criteria is checked in the following chapters:

In chapter 6.1 5.4.9 Determination of uncertainty between systems under test u_{bs} criteria 1 and 2 will be checked.

In chapter 6.1 5.4.10 Calculation of the expanded uncertainty of the instruments criteria 3, 4 and 5 will be checked.

In chapter 6.1 5.4.11 Application of correction factors and terms, there is an exemplary evaluation for the case, that criterio 5 cannot be fulfilled without the application of correction factors or terms.

6.1 5.4.9 Determination of uncertainty between systems under test u_{bs}

For the test of PM2,5 measuring systems the uncertainty between the systems under test shall be determined according to chapter 9.5.2.1 of the guidance document „Demonstration of Equivalence of Ambient Air Monitoring Methods“ in the field test at least at four sampling test sites representative of the future application.

The tests are performed as well for the component PM_{10}

6.2 Equipment

Not required for this minimum requirement.

6.3 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 [7]. 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.

6.4 Evaluation

According to **Point 9.5.2.1** of the Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods“ applies:

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 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 = No. of 24h-values

6.5 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.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Table 30 shows the calculated values for the uncertainty between systems under test u_{bs}. The graphical representation is done in Figure 55 to Figure 61.

Table 30: 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

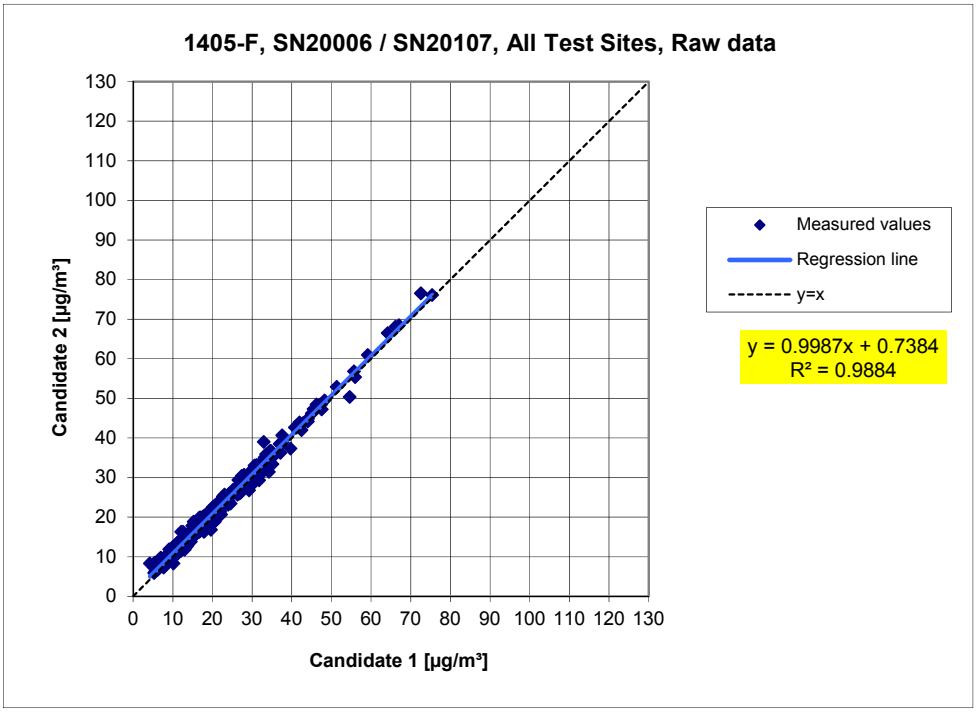

Figure 55: Results of the parallel measurements with the candidates SN 20006 / SN 20107, measured component PM_{10}, all test sites

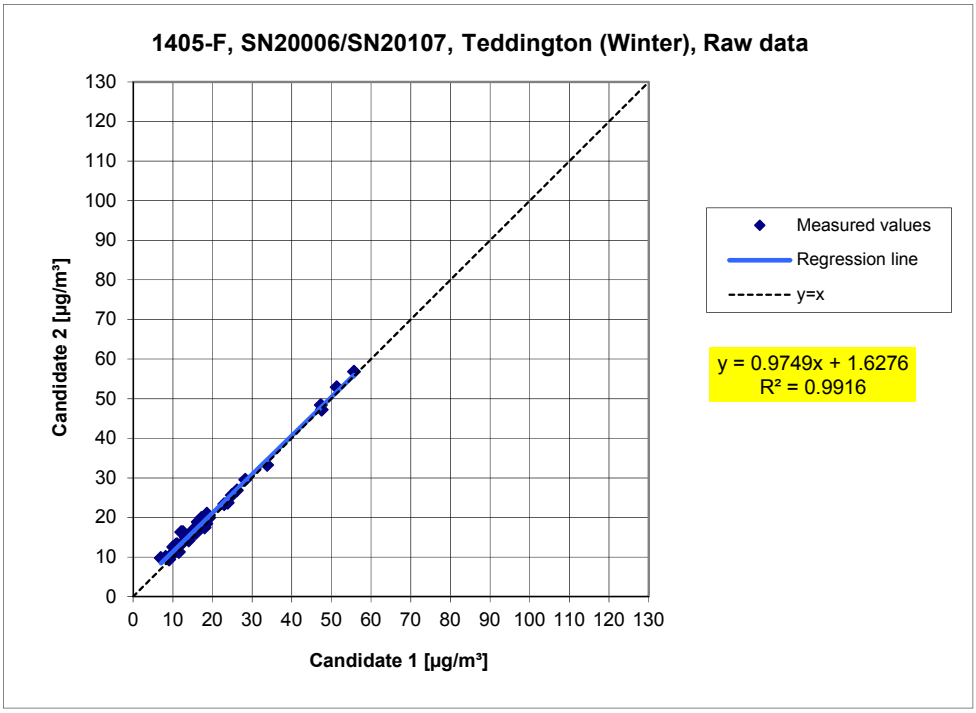

Figure 56: Results of the parallel measurements with the candidates SN 20006 / SN 20107, measured component PM_{10}, test site Teddington (Winter)

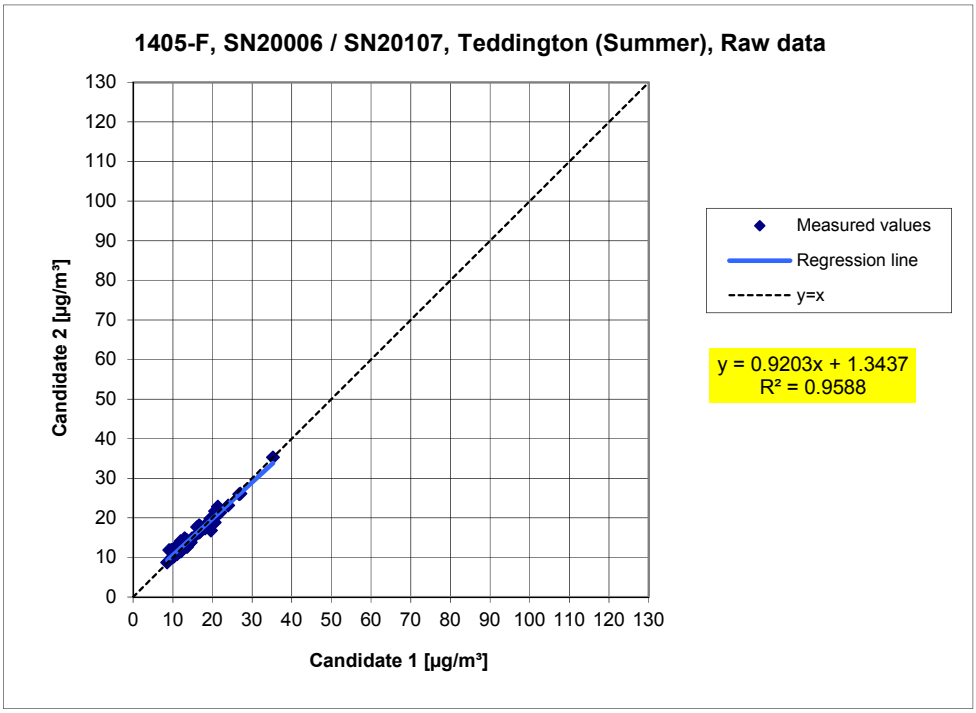

Figure 57: Results of the parallel measurements with the candidates SN 20006 / SN 20107, measured component PM_{10}, test site Teddington (Summer)

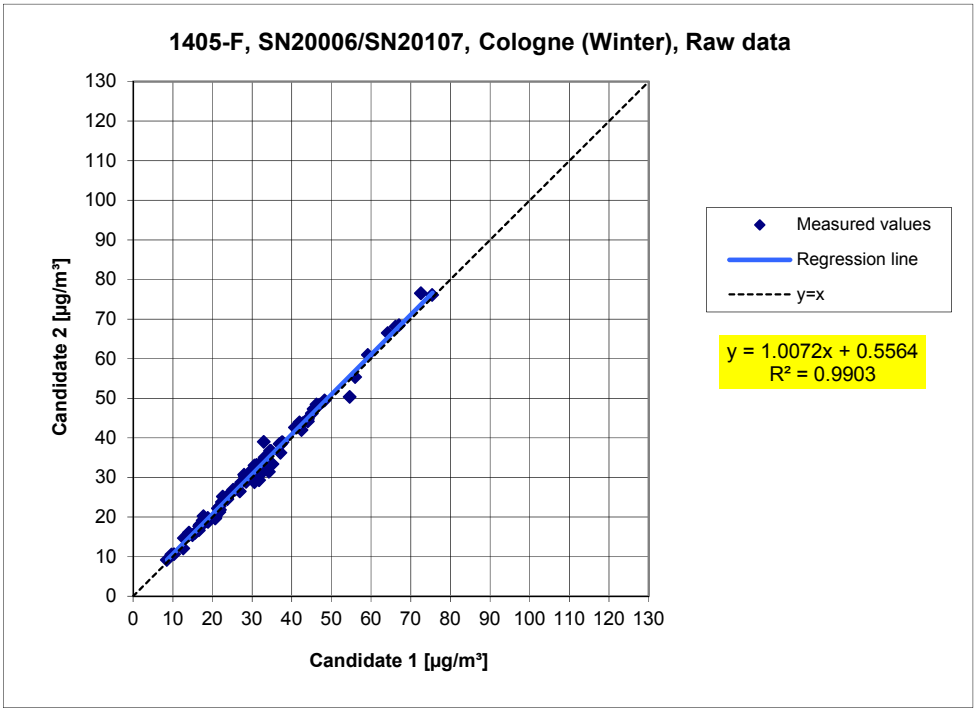

Figure 58: Results of the parallel measurements with the candidates SN 20006 / SN 20107 measured component PM_{10}, test site Cologne (Winter)

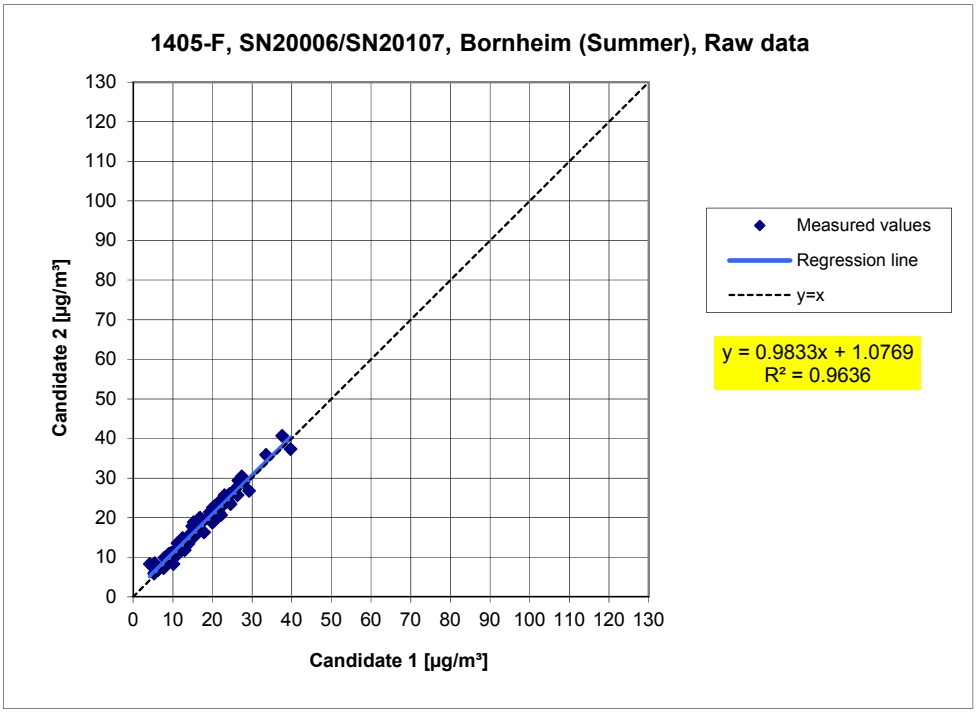

Figure 59: Results of the parallel measurements with the candidates SN 20006 / SN 20107, measured component PM_{10}, test site Bornheim (Summer)

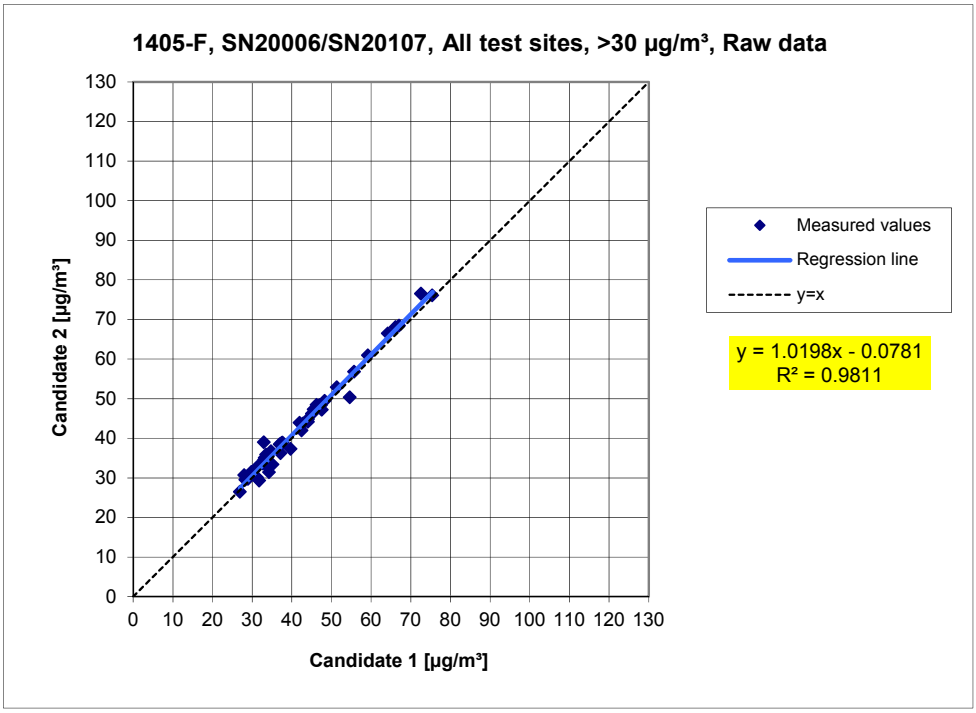

Figure 60: Results of the parallel measurements with the candidates SN 20006 / SN 20107, measured component PM_{10}, all test sites, values ≥ 30 µg/m³

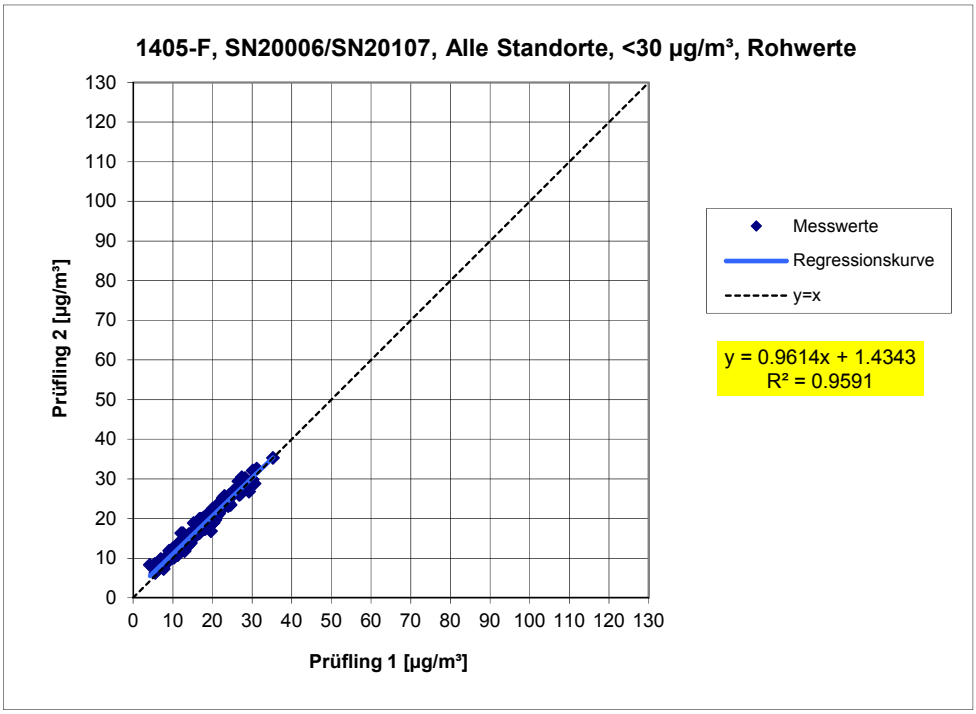

Figure 61: Results of the parallel measurements with the candidates SN 20006 / SN 20107, measured component PM_{10}, all test sites, values < 30 µg/m³

6.1 5.4.10 Calculation of the expanded uncertainty of the instruments

For the test of $PM_{2,5}$ measuring systems the equivalency with the reference method shall be demonstrated according to chapter 9.5.2.2 to chapter 9.5.4 of the guidance document „Demonstration of Equivalence of Ambient Air Monitoring Methods" in the field test at least at four sampling test sites representative of the future application. The maximum expanded uncertainty of the systems under test shall be compared with data quality objectives according to Annex A of Standard VDI 4202 Part 1 (September 2010)

The tests are performed as well for the components PM_{10}.

6.2 Equipment

For this test point additionally the devices according to chapter 5 of this report were used.

6.3 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 [7]. 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.

6.4 Evaluation

[Point 9.5.2.2] 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.

Section 6.6 of this test point shows the evaluated results.

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} ≥ 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 (refer to point 6.1 5.4.9 Determination of uncertainty between systems under test u_{bs})

Algorithm for the calculation of ordinate intercept a as well as slope b and its variances by orthogonal regression are described in detail in annex B of [4].

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 significantly different from 1: $|b-1| \le 2 \cdot u(b)$

and

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

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 point 9.7 of the Guide (refer to 6.1 5.4.11 Application of correction factors and terms). The calibration shall only be applied to the full dataset.

[Point 9.5.3] The combined uncertainty of the candidates $w_{c,CM}$ is calculated for each data set by combining the contributions from 9.5.2.1 and 9.5.2.2 according to the following equation:

$$w^2_{c,CM}(y_i) = \frac{u^2_{CR}(y_i)}{y^2_i}$$

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

[Point 9.5.4] 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 large n

[Point 9.6] The highest resulting uncertainty W_{CM} is compared and assessed with the requirements on data quality of ambient air measurements according to EU Standard [7]. 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 % [7].

6.5 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.

Minimum requirement fulfilled? yes

The following Table 31 shows an overview of the results of the equivalence check for the candidate 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 chapter 6.1 Methodology of the equivalence check are taken into account, the related cells are highlighted in colour.

Table 31: 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 chapter 6.1 Methodology of the equivalence check 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 Mr. 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 31.

The 2006 UK Equivalence Report [8] highlighted that this 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 accurate (Appendix E Section 4.2 therein). This same flaw is copied in the July 2009 version. It is the opinion of TŰV Rheinland and their UK partners that the TEOM 1405-F Ambient Particulate Monitor for PM_{10} is indeed being penalised by the mathematics for being accurate. 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 lays at 0.395. Therefore, under point 6.1
5.4.11 Application of correction factors and terms an additional evaluation, using the respective calibration factor for the data sets, is done.

The reworked version of the Guide 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 their UK partners recommend, that the expanded uncertainty for the full data set is refered to for this, namely 8.4 %, which again would require an annual test at 2 measurement sites (Guide [4], chapter 9.9.2, table 6).

Detailed representation of the test results

Table 32 shows an overview on the uncertainties between the reference devices $u_{ref\ from}$ the field tests. In Table 33 a summarized representation of the results of the equivalence test incl. the determined expanded measuring uncertainties W_{CM} from the field test is shown.

Table 32: 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

The uncertainty between the reference devices u_{ref} is for all test sites < 2 µg/m³.

Table 33: Summary of the results of the equivalence test, SN 20006 & SN 20107, measured component PM_{10}, raw data

PM10 1405F FDMS	23.3% > 28 µg m-3	Orthogonal Regression				Between Instrument Uncertainties	
	W_{CM} / %	n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	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	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 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	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 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

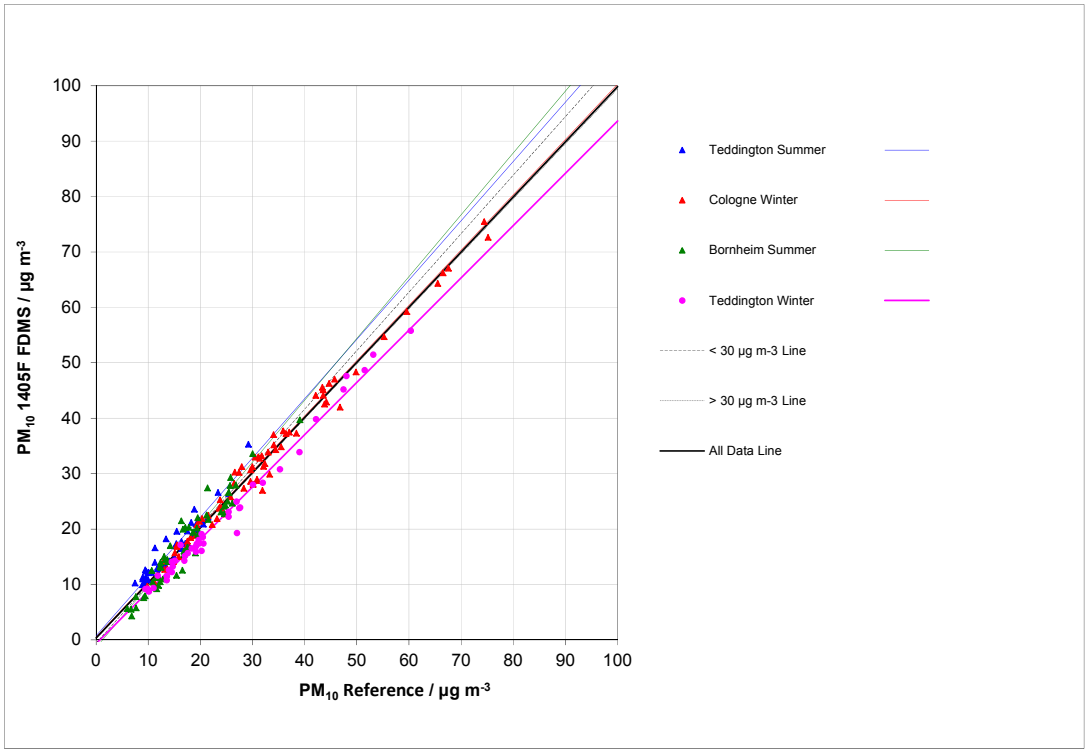

Figure 62: Reference vs. candidate, SN 20006 & SN 20107, measured component PM_{10}, all test sites

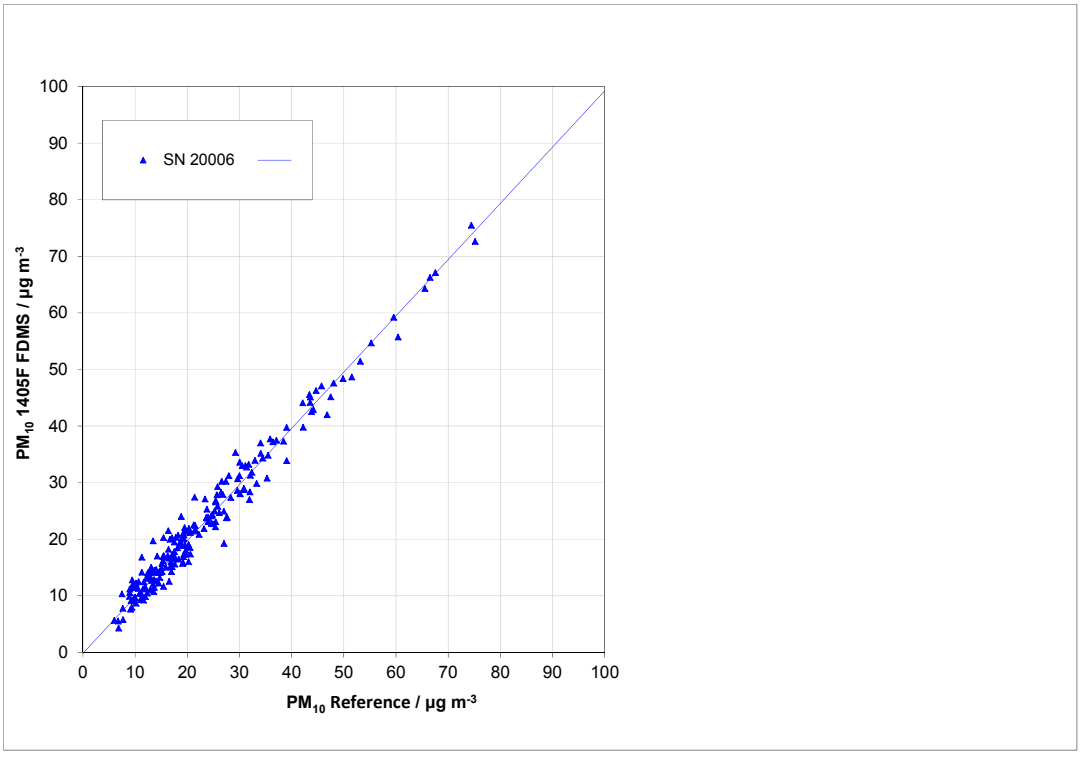

Figure 63: Reference vs. candidate, SN 20006, measured component PM_{10}, all test sites

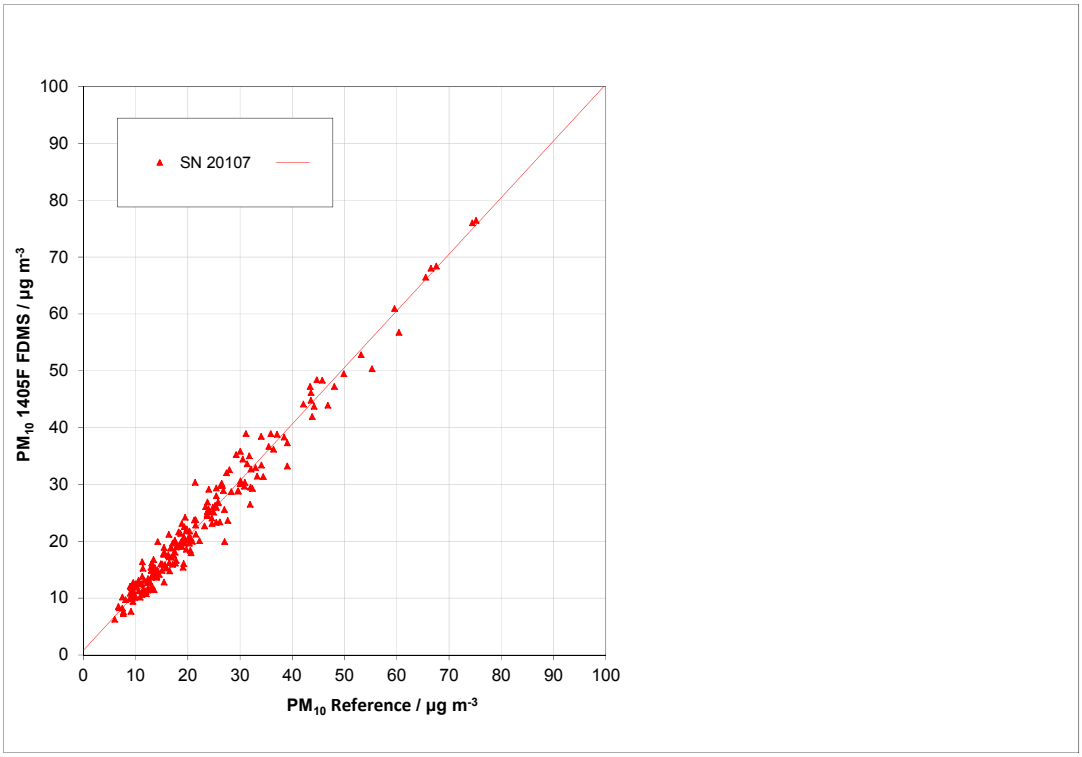

Figure 64: Reference vs. candidate, SN 20107, measured component PM_{10}, all test sites

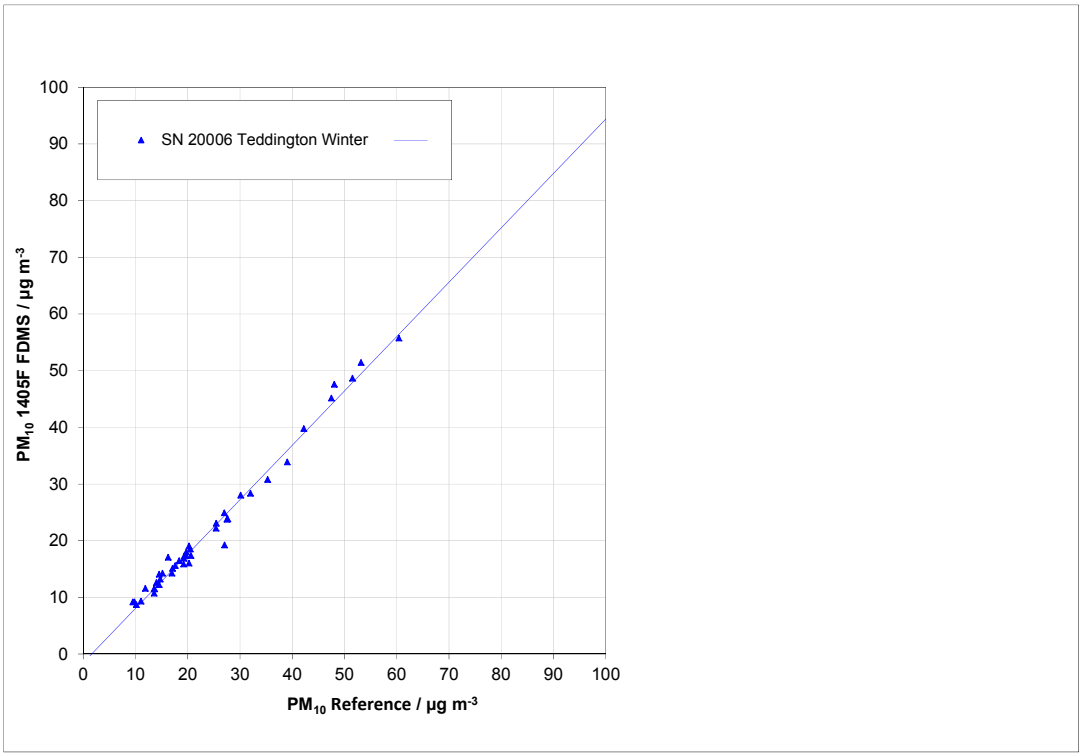

Figure 65: Reference vs. candidate, SN 20006, measured component PM_{10}, Teddington (Winter)

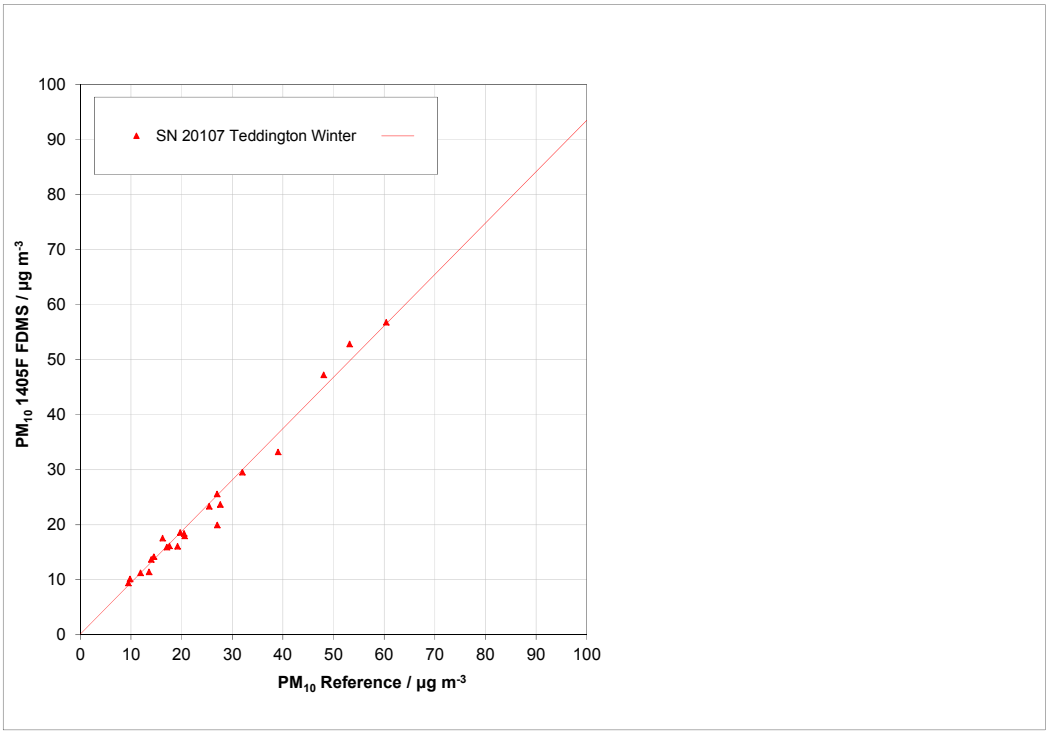

Figure 66: Reference vs. candidate, SN 20107, measured component PM_{10}, Teddington (Winter)

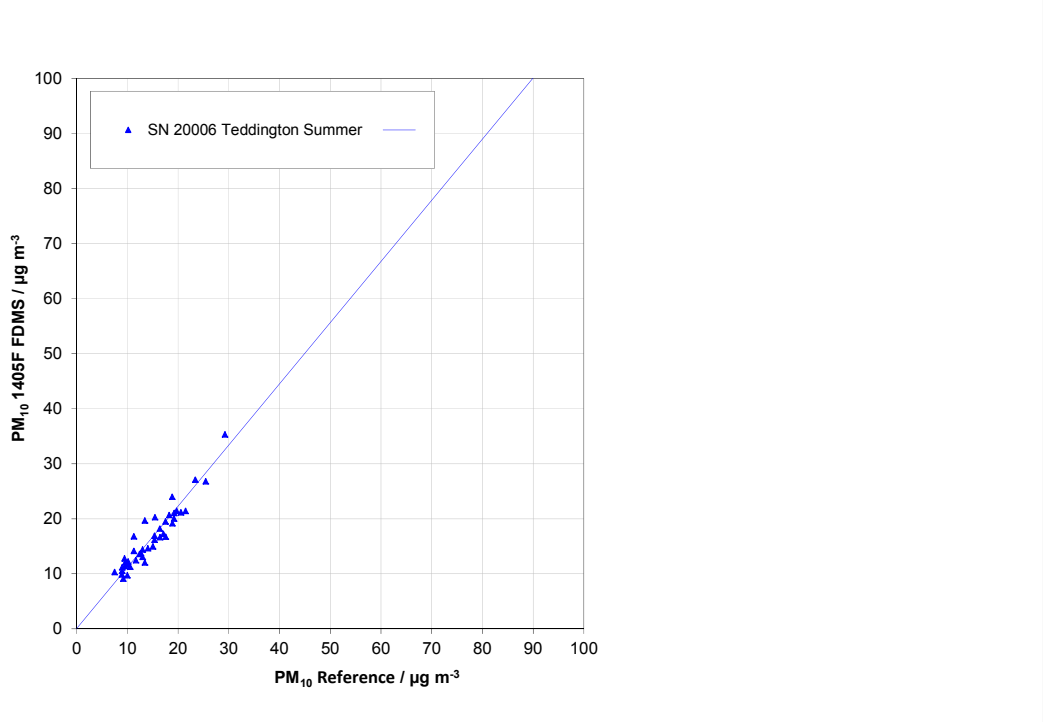

Figure 67: Reference vs. candidate, SN 20006, measured component PM_{10}, Teddington (Summer)

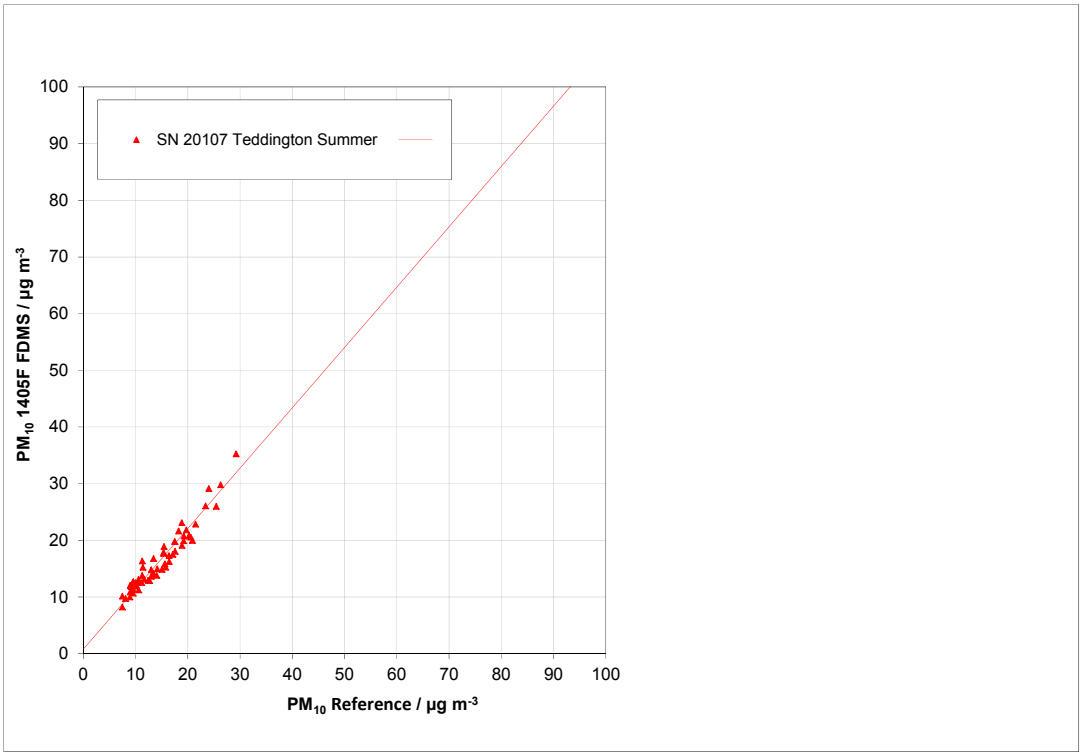

Figure 68: Reference vs. candidate, SN 20107, measured component PM_{10}, Teddington (Summer)

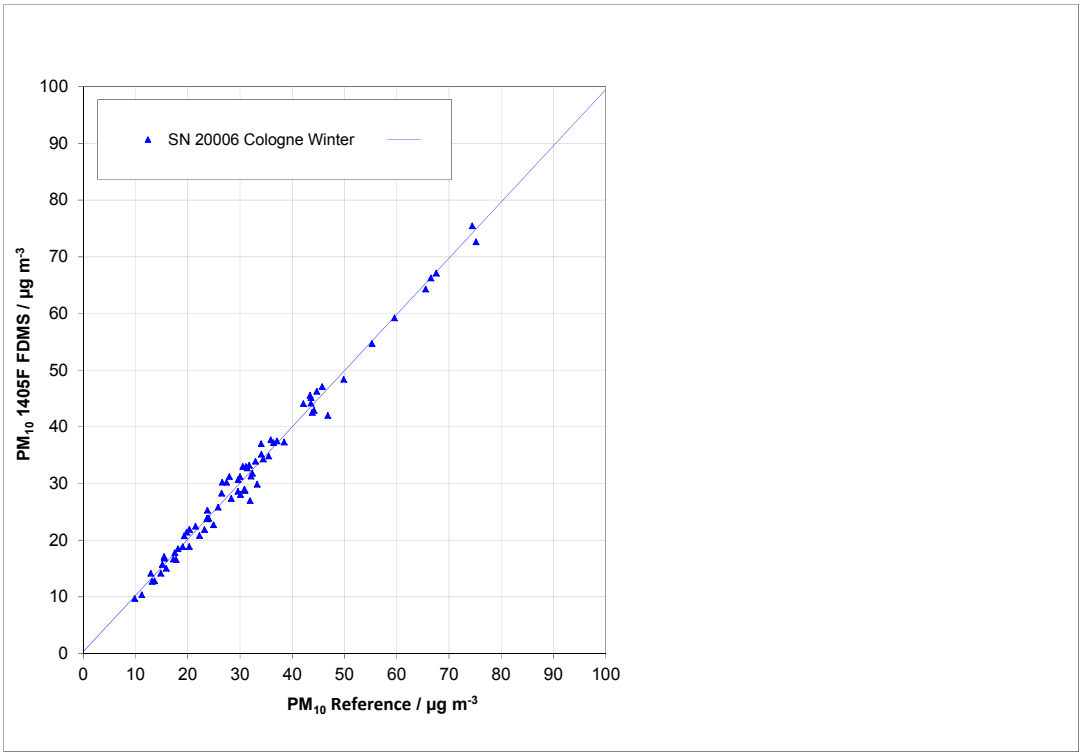

Figure 69: Reference vs. candidate, SN 20006, measured component PM_{10}, Cologne (Winter)

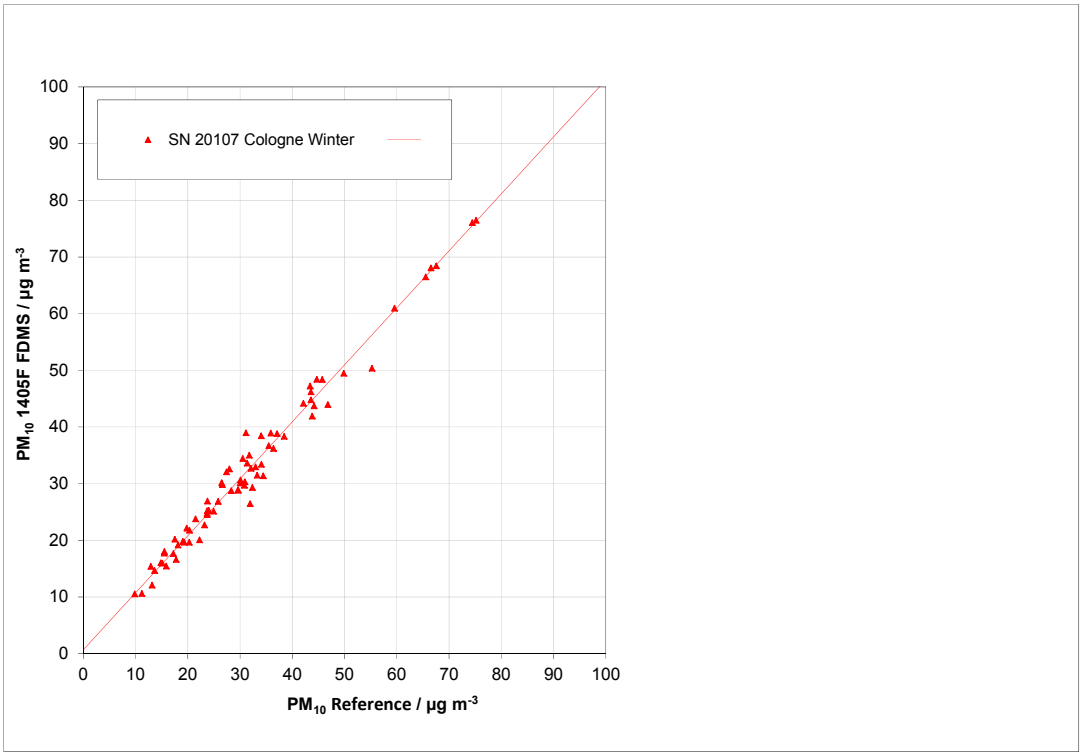

Figure 70: Reference vs. candidate, SN 20107, measured component PM_{10}, Cologne (Winter)

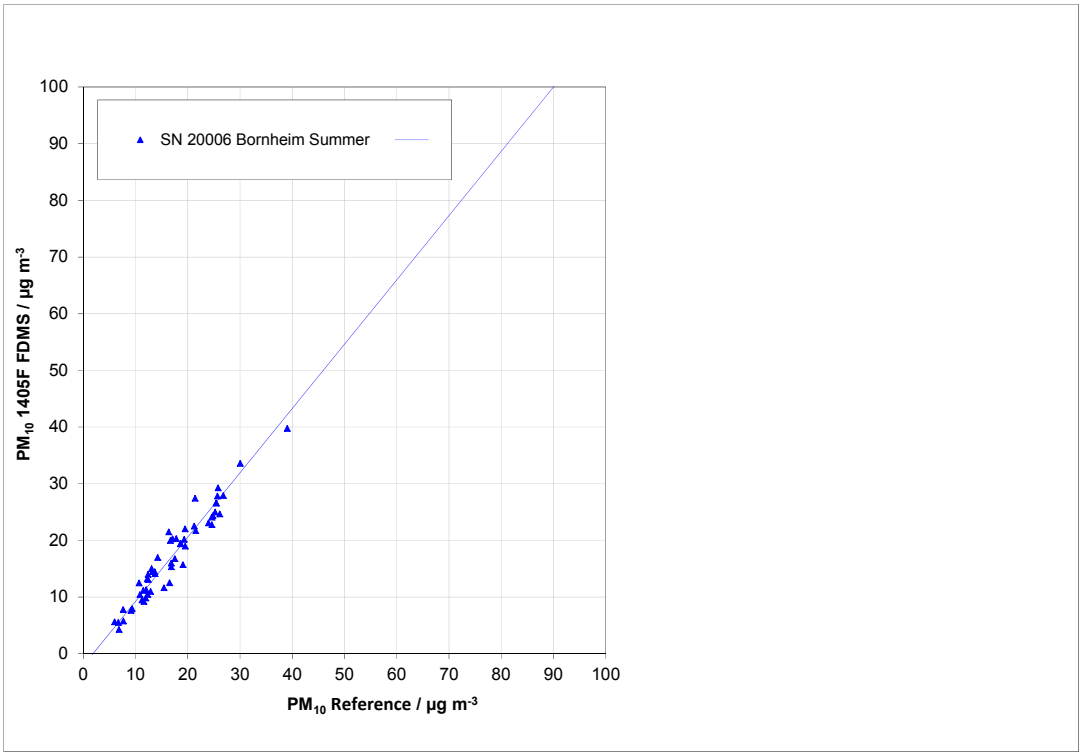

Figure 71: Reference vs. candidate, SN 20006, measured component PM_{10}, Bornheim (Summer)

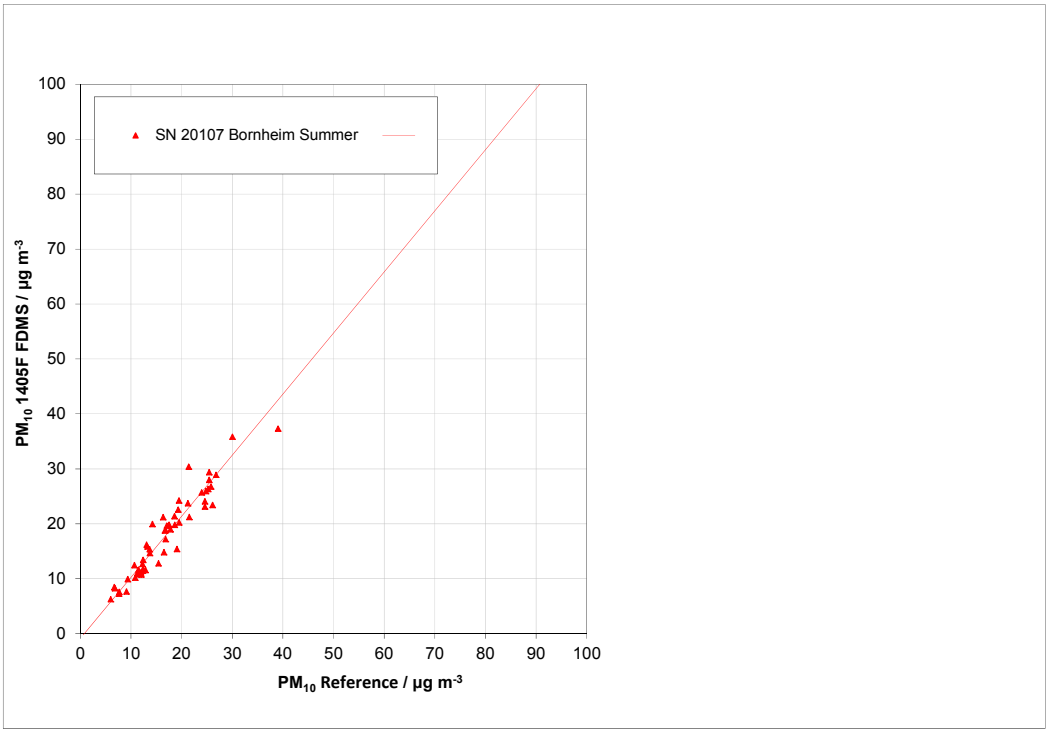

Figure 72: Reference vs. candidate, SN 20107, measured component PM_{10}, Bornheim (Summer)

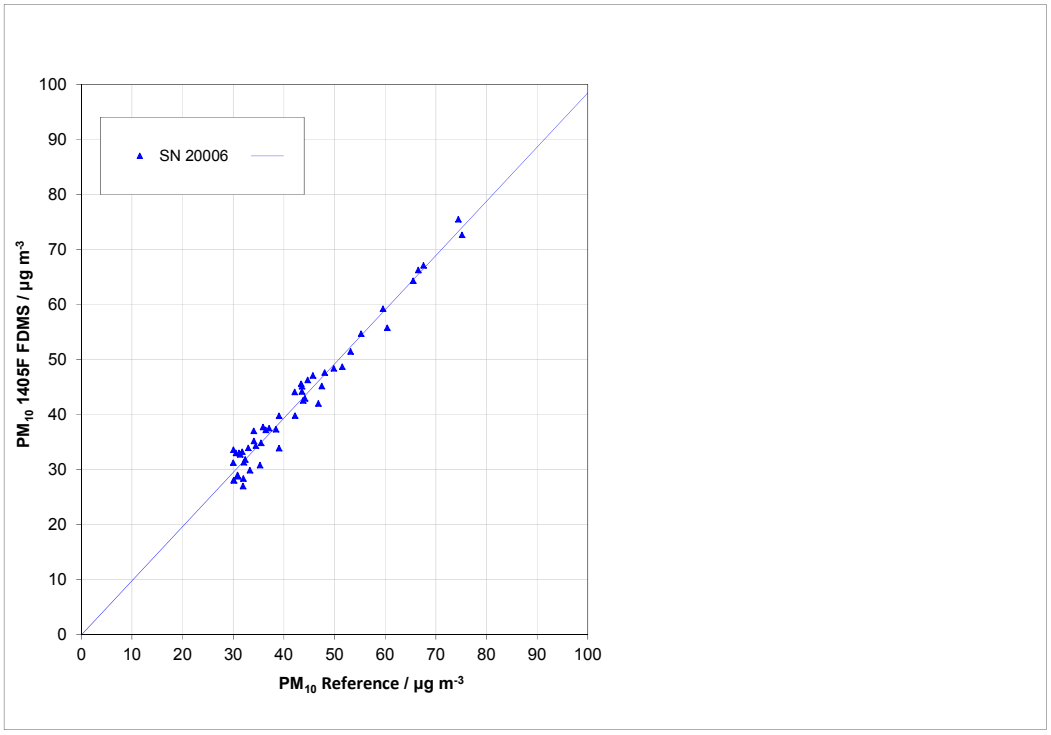

Figure 73: Reference vs. candidate, SN 20006, measured component PM_{10}, values ≥ 30 µg/m³

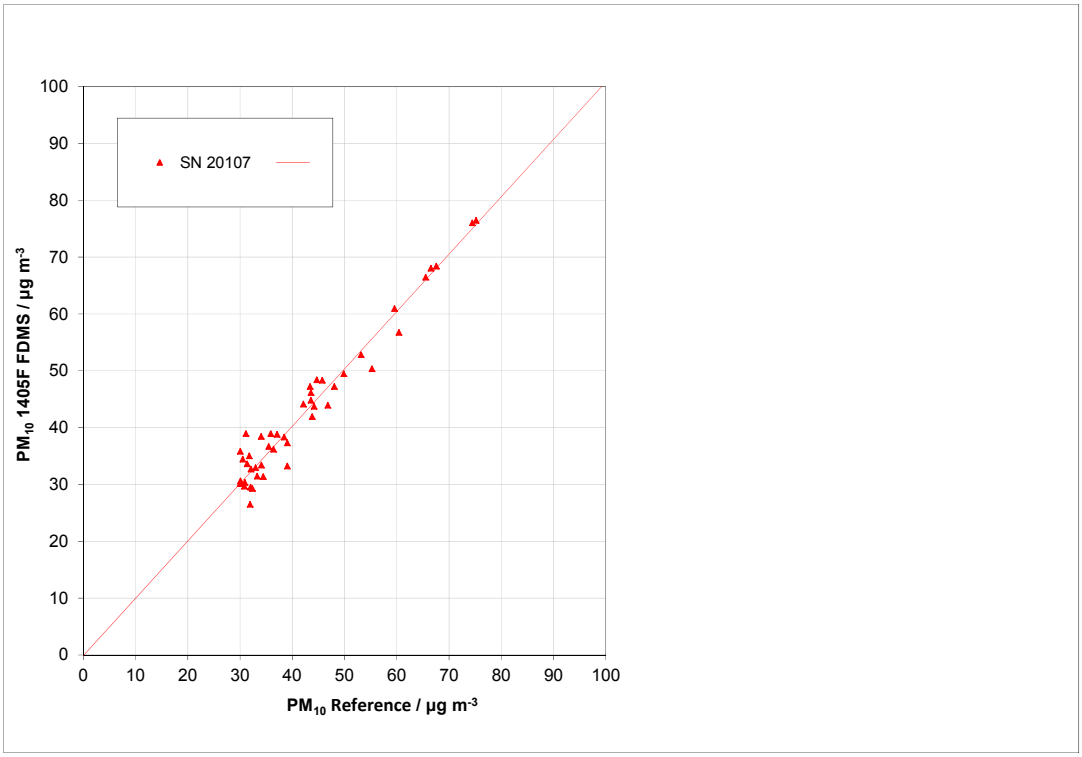

Figure 74: Reference vs. candidate, SN 20107, measured component PM_{10}, values ≥ 30 µg/m³

6.1 5.4.11 Application of correction factors and terms

If the highest resulting expanded uncertainty of the candidate method is larger than the expanded relative uncertainty, which is defined in the requirements on the data quality of ambient air measurements according to EU-Guideline [7], the application of correction factors or terms is permitted. The corrected values have to fulfill the requirements according to point 9.5.2.2 et seqq. of the Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods".

The tests are performed as well for the component PM_{10}.

6.2 Equipment

Not required for this minimum requirement.

6.3 Performance of test

Refer to module 9.5.2.2 – 9.5.6.

6.4 Evaluation

If evaluation of the raw data according to module 9.5.2.2 – 9.5.6 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 (refer to module 9.5.2.2 – 9.5.6). 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

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

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 annex B of [6]. RSS is determined analogue to the calculation in module 9.5.2.2 – 9.5.6.

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

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

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 annex B of [4]. RSS is determined analogue to the calculation in module 9.5.2.2 – 9.5.6.

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

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

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 annex B of [4]. RSS is determined analogue to the calculation in module 9.5.2.2 – 9.5.6.

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 EU Standard [7]. 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 % [7]

6.5 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.

Minimum requirement fulfilled? yes

The evaluation of the “All data” comparison for both candidate nevertheless delivers a significant intercept for SN 20107 (see Table 31). 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.

The version of the Guide of January 2010 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 (Guide [4], 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 ongoing QA/QC in networks is the responsibility of the network operator or of the responsible authority of the member state. However TÜV Rheinland and their UK partners 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.

6.6 Detailed representation of the test results

Table 34 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 34: 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	
	W_{CM} / %	n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	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	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 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	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 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

6.1 5.5 Requirements on multiple-component measuring systems

Multiple-component measuring systems shall comply with the requirements set for each component, also in the case of simultaneous operation of all measuring channels.

6.2 Equipment

Not applicable.

6.3 Performance of test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Minimum requirement fulfilled? -

6.6 Detailed representation of the test results

Not applicable.

7. Recommendations for practical use

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°C at 4°C cooler temperature) 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.

Department of Environmental Protection

Karsten Pletscher

Dr. Peter Wilbring

Cologne, November 25, 2011
936/21209885/B

8. Literature

[1] Standard VDI 4202, Part 1, „Minimum requirements for suitability tests of automated ambient air quality measuring systems – Point-related measurement methods of gaseous and particulate pollutants “, June 2002 & September 2010

[2] Standard VDI 4203, Part 3, „Testing of automated measuring systems – Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants “, August 2004 & September 2010

[3] Standard EN 12341, „ Ambient 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“, German version EN 12341: 1998

[4] Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods”, English version of January 2010)

[5] Operating manual 42-0109785 Revision A.000, Sep 22 2009

[6] Operating manual LVS3, Status 2000

[7] Directive 2008/50/EC of the European Parliament and of the Council of May 21 2008 on ambient air quality and cleaner air for Europe

[8] Report „UK Equivalence Programme for Monitoring of Particulate Matter“, Report No.: BV/AQ/AD202209/DH/2396 of June 5th, 2006

9. Appendix

Appendix 1 **Measured and calculated values**

Annex 1: Detection limit
Annex 2: Temperature dependency of zero-point
Annex 3: Temperature dependency of the sensibility
Annex 4: Dependency on supply voltage
Annex 5: Measured values at the field test sites
Annex 6: Surrounding conditions at the field test sites

Appendix 2 **Filter weighing procedure**

Appendix 3 **Manuals**

Annex 1 **Detection limit** **Page 1 of 1**

Manufacturer Thermo Fisher Scientific

Type 1405F

Serial-No. SN 20006 / SN 20107

Standards ZP Measured value with zero filter

No.	Date	Measured values [µg/m³] SN 20006	Date	Measured values [µg/m³] SN 20107
1	6/7/2011	1.0	10/25/2010	1.3
2	6/8/2011	1.3	10/26/2010	1.6
3	6/9/2011	0.9	10/27/2010	1.8
4	6/9/2011	0.9	10/28/2010	2.1
5	6/10/2011	0.7	10/29/2010	1.4
6	6/11/2011	0.2	10/30/2010	1.6
7	6/12/2011	0.3	10/31/2010	1.0
8	6/13/2011	1.2	11/1/2010	1.3
9	6/14/2011	1.5	11/2/2010	1.4
10	6/15/2011	1.3	11/3/2010	0.8
11	6/16/2011	1.5	11/4/2010	0.8
12	6/17/2011	1.2	11/5/2010	1.2
13	6/18/2011	0.6	11/6/2010	1.4
14	6/19/2011	1.0	11/7/2010	1.2
15	6/20/2011	0.8	11/8/2010	0.6
	No. of values	15	No. of values	15
	Mean	0.96	Mean	1.28
	Standard deviation s_{x0}	0.38	Standard deviation s_{x0}	0.38
	Detection limit x	0.82	Detection limit x	0.82

$$s_{xo} = \sqrt{\left(\frac{1}{n-1}\right) \cdot \sum_{i=1,n} (x_{0i} - \overline{x_0})^2}$$

Annex 2 Dependence of zero point on ambient temperature

Manufacturer Thermo Fisher Scientific

Standards ZP Measured value with zero filter

Type 1405F

Serial-No. SN 20006 / SN 20107

			Cycle 1		Cycle 2		Cycle 3			
SN 20006	No.	Temperature [°C]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]		
RP	1	20	2.5	-	2.7	-	2.8	-		
	2	8	0.3	-2.2	0.1	-2.6	0.6	-2.2		
	3	20	2.0	-0.5	2.4	-0.3	2.3	-0.5		
	4	25	3.5	1.0	3.7	1.0	3.2	0.4		
	5	20	2.2	-0.3	1.8	-0.9	2.4	-0.4		
SN 20107	No.	Temperature [°C]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]		
RP	1	20	1.1	-	1.1	-	1.3	-		
	2	8	2.0	0.9	-0.4	-1.5	0.0	-1.3		
	3	20	-0.1	-1.2	1.9	0.8	0.7	-0.6		
	4	25	1.9	0.8	2.4	1.3	2.1	0.8		
	5	20	0.9	-0.2	1.4	0.3	1.3	0.0		

Annex 3 Dependence of measured value on ambient temperature

Manufacturer Thermo Fisher Scientific

Standards RP K_0-Test

Type 1405F

Serial-No. SN 20006 / SN 20107

			Cycle 1		Cycle 2		Cycle 3			
SN 20006	No.	Temperature [°C]	Measured value K_0	Dev. [%]	Measured value K_0	Dev. [%]	Measured value K_0	Dev. [%]		
RP	1	20	15066.2	-	15068.0	-	15087.4	-		
	2	8	15057.7	-0.1	15058.9	-0.1	15074.0	-0.1		
	3	20	15062.0	0.0	15088.2	0.1	15066.5	-0.1		
	4	25	15088.8	0.2	15106.4	0.3	15101.9	0.1		
	5	20	15102.6	0.2	15086.2	0.1	15045.7	-0.3		
SN 20107	No.	Temperature [°C]	Measured value K_0	Dev. [%]	Measured value K_0	Dev. [%]	Measured value K_0	Dev. [%]		
RP	1	20	17345.5	-	17417.1	-	17383.4	-		
	2	8	17363.4	0.1	17409.0	0.0	17341.2	-0.2		
	3	20	17352.6	0.0	17421.3	0.0	17334.9	-0.3		
	4	25	17388.7	0.2	17436.6	0.1	17381.3	0.0		
	5	20	17397.2	0.3	17442.3	0.1	17404.7	0.1		

Annex 4 Dependence of measured value on mains voltage

Manufacturer Thermo Fisher Scientific

Standards RP K_0-Test

Type 1405F

Serial-No. SN 20006 / SN 20107

			Cycle 1		Cycle 2		Cycle 3			
SN 20006	No.	Voltage [V]	Measured value K_0	Dev. [%]	Measured value K_0	Dev. [%]	Measured value K_0	Dev. [%]		
RP	1	230	14869.8	-	14875.9	-	14918.9	-		
	2	190	14932.1	0.4	14927.6	0.3	14928.8	0.1		
	3	230	14937.7	0.5	14875.3	0.0	14832.3	-0.6		
	4	245	14957.5	0.6	14943.2	0.5	14921.6	0.0		
	5	230	14938.1	0.5	14900.0	0.2	14843.6	-0.5		
SN 20107	No.	Voltage [V]	Measured value K_0	Dev. [%]	Measured value K_0	Dev. [%]	Measured value K_0	Dev. [%]		
RP	1	230	17213.3	-	17270.2	-	17268.4	-		
	2	190	17283.1	0.4	17247.2	-0.1	17246.2	-0.1		
	3	230	17265.2	0.3	17221.8	-0.3	17226.0	-0.2		
	4	245	17274.6	0.4	17283.3	0.1	17296.0	0.2		
	5	230	17256.4	0.3	17239.3	-0.2	17220.3	-0.3		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 1 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/m³]	SN 20107 PM10 [µg/m³]	Remark	Test site
1	12/9/2009	11.3	11.6	27.5	27.5	41.6	23.8			Teddington
2	12/10/2009	16.4	16.2	25.4	25.4	64.2	22.2			(Winter)
3	12/11/2009	11.8	11.7	20.3	20.2	57.9	16.0			
4	12/12/2009	6.4	6.5	13.5	13.6	47.6	11.5			
5	12/13/2009	8.6	9.1	13.4	13.9	65.1	11.5			
6	12/14/2009	27.9	28.3	35.3	35.3	79.6	30.8			
7	12/15/2009	39.8	38.8	47.6	47.4	82.8	45.2			
8	12/16/2009	24.9	24.5	30.0	30.3	82.0	28.0			
9	12/17/2009	5.7	5.6	10.2	10.1	55.7	8.7			
10	12/18/2009	11.6	11.9	16.9	17.0	69.3	14.2			
11	12/19/2009	10.3	11.0	15.4	14.9	70.4	14.3			
12	12/20/2009	6.2	6.4	11.1	11.0	56.9	9.3			
13	12/21/2009	17.7	17.7	20.2	20.4	87.2	19.0			
14	12/22/2009	29.4	28.9				32.9		PM10 Grubbs outlier	
15	12/23/2009						17.8	Device not yet in operation		
16	12/24/2009						18.3			
17	12/25/2009						12.2			
18	12/26/2009						8.0			
19	12/27/2009						7.2			
20	12/28/2009						23.3			
21	12/29/2009						10.8			
22	12/30/2009						11.3			
23	12/31/2009	6.0	6.5	15.2	13.9	42.9	12.2			
24	1/1/2010						16.1			
25	1/2/2010						15.0			
26	1/3/2010						20.9			
27	1/4/2010								Zero filter	
28	1/5/2010	15.6	15.5				18.4		PM10 Grubbs outlier	
29	1/6/2010			19.2	19.3		16.9		PM2.5 Grubbs outlier	
30	1/7/2010	15.3	15.7	19.4	20.1	78.4	17.4			

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 2 of 22**

Manufacturer: Thermo Fisher Scientific

Type of instrument: TEOM 1405-F

Serial-No.: SN 20006 & SN 20107

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/m³]	SN 20107 PM10 [µg/m³]	Remark	Test site
31	1/8/2010	14.6	14.9	18.3	18.4	80.3	16.5	Device not yet in operation		Teddington (Winter)
32	1/9/2010	7.1	6.9	14.6	14.9	47.4	13.2			
33	1/10/2010	16.0	16.1	19.5	19.2	82.9	17.3			
34	1/11/2010	45.7	46.2	51.8	51.3	89.1	48.7		SN 20107 Zero filter	
35	1/12/2010	43.2	43.6	48.1	48.0	90.4	47.6	47.2		
36	1/13/2010	48.0	48.3	53.4	53.0	90.6	51.4	52.8		
37	1/14/2010	14.1	14.4	16.2	16.3	87.5	17.1	17.5		
38	1/15/2010	14.6	14.4	26.9	27.1	53.6	19.2	19.9		
39	1/16/2010	6.5	6.1	13.5	13.6	46.1	10.7	11.4		
40	1/17/2010	11.0	10.5	20.6	20.6	52.3	17.3	17.9		
41	1/18/2010	21.0	20.4	27.1	26.9	76.7	24.9	25.6		
42	1/19/2010	20.4	20.2	26.5	26.6	76.4			Power supply interrupted	
43	1/20/2010	26.6	27.0	32.0	31.9	83.8	28.3	29.5		
44	1/21/2010	20.5	20.9	27.5	27.9	75.0	23.9	23.7		
45	1/22/2010	7.8	7.6	9.7	9.8	78.5	9.2	10.1		
46	1/23/2010	21.0	20.9	25.8	25.1	82.3	23.1	23.3		
47	1/24/2010	16.2	15.9	20.7	20.3	78.4	18.5	18.4		
48	1/25/2010	36.1	35.8	42.0	42.4	85.1	39.8			
49	1/26/2010	50.7	51.1	60.4	60.4	84.2	55.7	56.7		
50	1/27/2010	27.1	27.3	38.9	39.1	69.7	33.9	33.2		
51	1/28/2010	8.3	8.0	13.9	14.1	58.3	12.6	13.7		
52	1/29/2010	5.7	6.0	9.4	9.6	61.5	9.2	9.4		
53	1/30/2010	12.4	12.5	17.6	17.6	70.7	15.6	16.2		
54	1/31/2010	12.2	13.0	17.3	16.9	73.5	15.1	15.9		
55	2/1/2010	8.4	8.3	14.7	14.4	57.5	14.1	14.2		
56	2/2/2010	8.3	8.3	12.0	11.7	70.0	11.6	11.2		
57	2/3/2010	9.4	9.3	19.2	19.2	48.6	15.9	16.1		
58	2/4/2010	12.0	12.4	19.7	19.8	61.7	18.0	18.6		
59	2/5/2010								Inlet -> Zero filter	
60	2/6/2010								Zero filter	

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 3 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/m³]	SN 20107 PM10 [µg/m³]	Remark	Test site
61	2/7/2010								Zero filter	Teddington
62	2/8/2010							19.9	SN 20006 Zero filter->Inlet	(Winter)
63	2/9/2010	6.3	6.3	11.6	11.8	53.8	10.8	11.8		
64	2/10/2010	5.8	5.6	12.0	12.4	46.6	10.9	13.2		
65	2/11/2010	12.4	12.0	20.2	20.1	60.5	16.3	18.8		
66	2/12/2010	6.7	6.5	12.6	12.4	52.7	10.1	12.5		
67	2/13/2010	8.8	8.8	15.1	15.4	57.6	11.2	13.2		
68	2/14/2010	13.9	13.4	16.0	16.3	84.8	12.6	16.3		
69	2/15/2010	12.5	12.8	16.0	15.9	79.2	13.5	15.2		
70	2/16/2010	14.9	15.9	18.2	18.5	83.9	15.4	17.0		
71	2/17/2010	44.8	45.2	52.2	52.1	86.3	47.4	48.4		
72	2/18/2010	13.1	12.3	14.8	14.8	85.9	12.2	16.2		
73	2/19/2010	18.3	18.5	21.7	21.7	84.6	18.7	20.9		
74	2/20/2010	16.5	16.6	19.3	19.5	85.2	17.3	19.8		
75	2/21/2010	7.4	7.3	10.2	10.2	71.7	8.2	10.0		
76	2/22/2010	9.9	10.3	16.6	16.5	61.1	13.4	14.9		
77	2/23/2010	14.5	14.4	22.2	22.3	64.9	17.6	19.8		
78	2/24/2010	9.2	9.1	17.8	17.7	51.6	14.7	15.9		
79	2/25/2010	5.9	4.8	9.2	9.4	57.2	8.6	9.7		
80	2/26/2010	4.4	4.3	11.2	11.4	38.8	10.4	11.2		
81	2/27/2010	11.8	11.7	18.9	19.2	61.6	18.1	17.5		
82	2/28/2010	5.0	5.2	9.6	9.6	53.5	7.0	9.7		
83	3/1/2010						26.2	26.8		
84	3/2/2010	12.7	13.1	21.7	21.0	60.4	18.6	20.5		
85	3/3/2010	7.9	8.7	20.9	21.3	39.3	17.8	19.7		
86	3/4/2010	9.3	8.7	16.5	16.6	54.2	15.2	16.6		
87	4/27/2010	12.1	11.2	20.2	20.9	56.7	21.2	20.6		Teddington
88	4/28/2010	16.0	16.7	25.8	25.0	64.3	26.8	26.0		(Summer)
89	4/29/2010	11.3	11.4	19.2	19.3	58.9	21.1	20.7		
90	4/30/2010	5.4	5.4	11.5	11.9	45.9	12.4	13.1		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 4 of 22**

Manufacturer: Thermo Fisher Scientific

Type of instrument: TEOM 1405-F

Serial-No.: SN 20006 & SN 20107

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/m³]	SN 20107 PM10 [µg/m³]	Remark	Test site
91	5/1/2010						12.1	11.5		Teddington
92	5/2/2010						8.6	8.7		(Summer)
93	5/3/2010						13.6	12.7		
94	5/4/2010	8.5	8.6	15.0	15.1	56.7	15.0	14.8		
95	5/5/2010	14.0	13.9	18.8	19.7	72.5	20.0	19.9		
96	5/6/2010	9.8	9.2	16.2	16.6	58.0	16.6	16.2		
97	5/7/2010	7.8	7.7	12.9	13.1	59.8	14.4	13.6		
98	5/8/2010	4.5	4.2	8.9	8.9	48.5	9.9	10.0		
99	5/9/2010	6.5	7.6	14.1	14.0	50.4	14.6	13.8		
100	5/10/2010	4.9	5.1	10.2	9.8	49.7	11.8	12.5		
101	5/11/2010	6.2	6.0	10.6	9.8	60.1	12.2	12.0		
102	5/12/2010	8.4	8.3	12.3	12.5	67.5	13.6	12.9		
103	5/13/2010	13.4	13.2	17.2	17.1	77.7	17.3	17.5		
104	5/14/2010	12.7	13.7	19.1	18.7	69.9	19.2	19.1		
105	5/15/2010	7.0	6.7	12.7	12.7	54.0	13.8	12.9		
106	5/16/2010	5.6	5.2	9.5	9.6	56.4	11.4	11.3		
107	5/17/2010	10.2	10.3	16.2	16.6	62.5	18.2	17.3		
108	5/18/2010	12.7	13.4	21.5	21.5	60.8	21.4	22.8		
109	5/19/2010	14.0	15.2	20.0	19.4	74.2	21.5	21.8		
110	5/20/2010	13.9	14.7	18.7	19.0	75.9	24.0	23.1		
111	5/21/2010	14.3	15.5	17.9	18.6	81.7	20.7	21.6		
112	5/22/2010	6.4	6.2	9.0	8.9	70.3	10.5	12.1		
113	5/23/2010	5.6	5.7	9.3	9.6	60.0	12.8	12.5		
114	5/24/2010	12.0	12.4	17.5	17.6	69.7	19.5	19.7		
115	5/25/2010	6.1	6.9	15.6	15.2	42.4	16.9	17.8		
116	5/26/2010	9.7	9.2	19.1	19.0	49.8			Zero filter	
117	5/27/2010	7.3	7.3	8.0	7.9	92.3			Zero filter-> Inlet	
118	5/28/2010	8.2	8.2	14.4	13.9	57.7		15.0	SN 20006 noisy signal	
119	5/29/2010	5.0	4.9	10.5	10.7	46.1		11.2	SN 20006 noisy signal	
120	5/30/2010	4.0	3.9	8.2	7.9	48.9		9.7	SN 20006 noisy signal	

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 5 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/m³]	SN 20107 PM10 [µg/m³]	Remark	Test site
121	5/31/2010	13.2	13.0	20.6	21.1	62.8		20.0	SN 20006 noisy signal	Teddington
122	6/1/2010	15.2	15.5	20.0	20.5	76.0		20.7	SN 20006 noisy signal	(Summer)
123	6/2/2010	12.4	11.9	17.7	17.4	69.5		19.7	SN 20006 noisy signal	
124	6/3/2010	9.0	8.8	15.5	15.7	57.1		15.8	SN 20006 noisy signal	
125	6/4/2010	17.8	17.9	26.0	26.6	67.9		29.8	SN 20006 noisy signal	
126	6/5/2010	17.3	16.4	23.8	24.3	70.1		29.1	SN 20006 noisy signal	
127	6/6/2010	7.3	6.4	11.6	11.2	59.8		15.2	SN 20006 noisy signal	
128	6/7/2010	4.0	3.7	7.8	7.2	51.9		8.2	SN 20006 noisy signal	
129	6/8/2010	4.5	4.4	9.2	9.9	46.5		10.7	SN 20006 noisy signal	
130	6/9/2010	11.3	9.8	15.5	16.0	66.9		15.3	SN 20006 noisy signal	
131	6/10/2010	7.8	7.6	10.4	10.8	73.1		12.6	SN 20006 noisy signal	
132	6/11/2010			10.5	11.8			12.5	No ref.measurement PM2.5, Repair (leaking switching valve)	
133	6/12/2010	6.6	6.6	13.4	13.5	48.8	12.1	14.1		
134	6/13/2010	9.7	9.9	17.4	17.7	55.8	16.7	18.1		
135	6/14/2010	7.2	6.2	13.4	12.7	51.4	13.1	14.8		
136	6/15/2010	2.9	3.1	10.2	9.8	30.2	9.7	11.9		
137	6/16/2010	5.0	4.6	10.8	10.3	45.4	11.3	13.1		
138	6/17/2010	4.1	4.5	7.1	7.9	57.6	10.3	10.1		
139	6/18/2010						13.6	14.4		
140	6/19/2010	3.7	3.4	9.1	9.3	38.1	9.1	11.8		
141	6/20/2010	9.1	8.9	15.5	15.3	58.4	16.2	17.7		
142	6/21/2010	7.5	7.3				20.6	18.8	PM10 Grubbs outlier	
143	6/22/2010	4.9	6.3	13.1	13.8	41.9	19.7	16.8		
144	6/23/2010	8.1	8.0	15.3	15.7	52.0	20.3	18.9		
145	6/24/2010	6.9	6.3	11.5	11.0	58.5	16.8	16.4		
146	6/25/2010	14.6	15.4	23.0	23.8	64.0	27.1	26.1		
147	6/26/2010	20.9	20.1	29.1	29.4	70.1	35.3	35.2		
148	6/27/2010						19.8	18.2		
149	6/28/2010	10.4	9.3				22.0	21.4	PM10 Grubbs outlier	
150	6/29/2010	4.9	4.7	8.9	9.0	53.3	11.1	10.9		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 6 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/m³]	SN 20107 PM10 [µg/m³]	Remark	Test site
151	6/30/2010	4.4	5.5	9.6	9.5	51.7	12.0	12.7		Teddington
152	7/1/2010	6.9	6.1	11.0	11.6	57.7	14.2	13.8		(Summer)
153	1/27/2011	8.9	8.8	12.8	13.3	67.8			Audits	Cologne
154	1/28/2011	28.3	28.5	36.3	36.8	77.8			Audits	(Winter)
155	1/29/2011								Zero filter	
156	1/30/2011	62.0	62.1	82.7	83.7	74.6			Zero filter	
157	1/31/2011	81.6	81.8	95.5	94.0	86.2			Zero filter	
158	2/1/2011	61.9	62.0	75.3	73.6	83.2	75.5	76.0		
159	2/2/2011	20.6	20.1	25.2	24.7	81.8	22.7	25.1		
160	2/3/2011	14.1	13.4	20.1	20.4	67.7	18.9	19.6		
161	2/4/2011	6.1	6.2	11.0	11.4	54.6	10.4	10.6		
162	2/5/2011						8.6	9.1		
163	2/6/2011	8.4	8.5	14.8	15.0	57.0	14.1	16.0		
164	2/7/2011	9.7	10.0	17.5	18.8	54.2	18.5	19.2		
165	2/8/2011	18.0	17.3	30.6	31.3	57.2	28.7	30.3		
166	2/9/2011	21.2	21.9	29.6	30.6	71.5	28.1	30.6		
167	2/10/2011	19.4	20.8	24.9	26.7	77.9	25.8	26.9		
168	2/11/2011	10.5	11.3	13.2	14.1	80.0	12.8	14.7		
169	2/12/2011						18.3	18.9		
170	2/13/2011	11.5	12.5	17.0	18.5	67.5	16.6	16.6		
171	2/14/2011	21.1	19.5	23.8	24.2	84.6	23.9	25.3		
172	2/15/2011	16.4	16.0	19.0	19.7	83.7	20.8	19.6		
173	2/16/2011	24.5	24.0	34.0	34.2	71.1	35.2	33.4		
174	2/17/2011	36.0	35.5	42.2	42.1	84.8	44.1	44.1		
175	2/18/2011	36.5	36.7	43.4	43.5	84.3	45.6	47.2		
176	2/19/2011						56.1	55.3		
177	2/20/2011	27.6	27.8	29.5	29.8	93.5	30.7	28.8		
178	2/21/2011	31.3	31.8	36.6	36.2	86.6	37.2	36.2		
179	2/22/2011	36.5	37.9	43.3	43.8	85.4	45.1	46.2		
180	2/23/2011	38.0	37.9	45.7	45.7	83.0	47.1	48.3		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 7 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/m³]	SN 20107 PM10 [µg/m³]	Remark	Test site
181	2/24/2011	30.3	31.4	36.0	35.8	85.9	37.7	38.9		Cologne
182	2/25/2011	26.4	26.7	30.4	29.6	88.6	31.2	30.1		(Winter)
183	2/26/2011						18.9	18.8		
184	2/27/2011	13.5	13.3	15.4	14.8	88.5	15.7	16.0		
185	2/28/2011	36.7	36.0	44.7	43.7	82.3	42.9	43.7		
186	3/1/2011	66.6	66.0	75.6	74.7	88.2	72.6	76.5		
187	3/2/2011	49.4	49.7	60.6	58.5	83.1	59.2	60.9		
188	3/3/2011	39.4	37.5	50.8	48.9	77.1	48.3	49.5		
189	3/4/2011	76.3	76.5						PM10 Grubbs outlier; Inlet -> Zero filter	
190	3/5/2011								Zero filter	
191	3/6/2011	8.9	9.2	13.6	14.1	65.1			Zero filter	
192	3/7/2011	8.3	9.0	13.8	12.4	66.2			Zero filter	
193	3/8/2011	31.1	31.8	43.9	43.8	71.7	42.5	41.9		
194	3/9/2011	19.1	18.8	30.5	28.7	63.9	28.6	28.9		
195	3/10/2011								Power cut (complete)	
196	3/11/2011	16.7	16.1	33.5	33.1	49.2	29.9	31.5		
197	3/12/2011						30.6	33.0		
198	3/13/2011	13.3	13.1	16.2	15.6	83.0	15.0	15.4		
199	3/14/2011	18.2	20.0	27.7	25.6	71.5			Power cut (only Thermo)	
200	3/15/2011	37.4	37.8	44.1	43.1	86.3	44.1	44.8		
201	3/16/2011			67.3	65.8		66.2	68.1	PM2.5 Grubbs outlier	
202	3/17/2011	50.7	49.6	68.0	67.1	74.1	67.1	68.4		
203	3/18/2011	28.4	28.1	38.4	38.4	73.5	37.3	38.3		
204	3/19/2011						18.4	19.1		
205	3/20/2011	20.4	20.3	28.6	28.0	72.0	27.3	28.7		
206	3/21/2011	22.4	22.3	34.7	34.3	64.8	34.3	31.4		
207	3/22/2011	41.7	41.6	55.7	54.8	75.4	54.7	50.3		
208	3/23/2011	20.3	20.4	33.1	31.6	63.0	31.8	29.3		
209	3/24/2011	18.6	20.2	33.3	32.7	58.7	33.9	32.9		
210	3/25/2011	27.6	27.5	36.9	37.2	74.2	37.5	38.8		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 8 of 22**

Manufacturer: Thermo Fisher Scientific

Type of instrument: TEOM 1405-F

Serial-No.: SN 20006 & SN 20107

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/m³]	SN 20107 PM10 [µg/m³]	Remark	Test site
211	3/26/2011						17.6	19.1		Cologne
212	3/27/2011	24.6	24.8	35.6	35.4	69.5	34.8	36.7		(Winter)
213	3/28/2011	20.5	20.7	32.4	31.9	64.2	31.3	32.7		
214	3/29/2011	44.7	44.2	65.4	65.6	67.8	64.3	66.5		
215	3/30/2011	15.6	15.6	24.0	23.4	65.8	23.8	24.5		
216	3/31/2011	6.0	5.1	10.5	9.3	56.2	9.7	10.6		
217	4/1/2011	8.5	7.7	13.3	13.0	61.7	12.7	12.1		
218	4/2/2011						32.5	31.1		
219	4/3/2011	14.6	13.7	22.1	22.4	63.6	20.8	20.1		
220	4/4/2011	8.8	9.0	17.9	16.6	51.6	16.7	17.6		
221	4/5/2011	11.0	11.4	19.2	19.0	58.7	18.8	19.8		
222	4/6/2011	13.0	12.9	23.6	23.8	54.6	23.9	25.2		
223	4/7/2011	13.7	13.1	23.2	24.2	56.7	23.7	24.8		
224	4/8/2011	19.0	19.8	34.9	34.8	55.7			Inlet -> Zero filter	
225	4/9/2011								Zero filter	
226	4/10/2011	11.1	11.8	23.4	22.3	50.1			Zero filter	
227	4/11/2011	15.2	15.1	31.3	31.5	48.2	32.7	33.6		
228	4/12/2011	9.0	8.2	18.0	17.1	49.0	17.8	20.2		
229	4/13/2011	12.5	12.2	24.4	23.2	51.9	25.3	26.9		
230	4/14/2011	19.6	19.4	32.0	31.5	61.5	33.2	35.0		
231	4/15/2011	13.3	11.4	31.9	31.9	38.8	27.0	26.5		
232	4/16/2011						34.3	32.8		
233	4/17/2011						21.8	21.2		
234	4/18/2011	17.0	17.2	26.4	26.6	64.6	28.3	30.2		
235	4/19/2011	17.5	17.9	30.3	30.7	58.0	33.0	34.4		
236	4/20/2011	20.0	20.8	33.9	34.2	59.8	37.0	38.4		
237	4/21/2011						34.5	36.7		
238	4/22/2011						30.2	31.1		
239	4/23/2011						40.8	42.6		
240	4/24/2011						31.1	33.1		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 9 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/m³]	SN 20107 PM10 [µg/m³]	Remark	Test site
241	4/25/2011	19.6	20.7	27.4	27.4	73.6	30.2	32.1		Cologne
242	4/26/2011	17.0	17.6	31.0	31.3	55.7	33.0	38.9		(Winter)
243	4/27/2011			44.3	45.1		46.3	48.4	No ref.measurement PM2.5	
244	4/28/2011	16.2	17.8	28.0	28.0	60.8	31.2	32.6		
245	4/29/2011	19.0	19.3	25.9	27.3	72.0	30.2	29.8		
246	4/30/2011	12.9	13.3	21.0	22.0	61.0	22.4	23.8		
247	5/1/2011	6.7	7.0	13.0	12.9	52.9	14.1	15.4		
248	5/2/2011	9.3	9.2	16.1	14.9	59.8	17.1	17.7		
249	5/3/2011	9.0	9.3	15.9	15.1	59.2	16.8	18.0		
250	5/4/2011	11.4	11.5	20.5	20.2	56.1	21.9	21.8		
251	5/5/2011			20.1	19.5		21.4	22.1	PM2.5 Grubbs outlier	
252	5/6/2011	13.7	13.6	30.7	31.1	44.2	29.0	29.7		
253	5/7/2011	19.1	17.6	46.1	47.5	39.2	42.0	43.9		
254	5/8/2011	12.3	12.2	23.4	23.0	53.0	21.8	22.7		
255	7/25/2011	12.1	11.2	17.8	17.8	65.4	20.3	19.0		Bornheim
256	7/26/2011	11.8	11.8	19.6	19.1	61.2	20.2	22.5		(Summer)
257	7/27/2011	14.3	13.7	21.5	20.9	65.9	22.5	23.7		
258	7/28/2011	17.5	19.0	26.5	25.2	70.6	29.3	26.7		
259	7/29/2011	10.2	7.9	16.8	16.6	54.2	20.0	18.8		
260	7/30/2011						11.2	11.4		
261	7/31/2011	9.8	9.5	13.3	14.2	70.4	14.1	14.7		
262	8/1/2011	12.7	11.4	18.0	19.2	64.8	19.4	21.4		
263	8/2/2011	10.3	10.1	19.0	20.1	52.1	19.0	20.2		
264	8/3/2011	17.0	16.6	24.4	26.1	66.5	25.0	26.3		
265	8/4/2011	8.7	8.4	13.8	14.7	60.2	17.0	19.9		
266	8/5/2011	8.6	10.6	17.1	18.0	54.7	16.8	19.8		
267	8/6/2011						11.2	13.5		
268	8/7/2011	2.8	3.1	5.6	6.4	49.5	5.6	6.3		
269	8/8/2011	2.8	4.0	7.9	7.5	44.1	5.8	7.6		
270	8/9/2011	2.7	3.2	10.8	11.2	27.1			Audit flow rate	

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 10 of 22**

Manufacturer: Thermo Fisher Scientific

Type of instrument: TEOM 1405-F

Serial-No.: SN 20006 & SN 20107

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/m³]	SN 20107 PM10 [µg/m³]	Remark	Test site
271	8/10/2011	5.3	6.4	12.1	12.7	47.0	14.0	13.4		Bornheim
272	8/11/2011	5.5	5.2	11.4	11.1	47.3	9.5	11.0		(Summer)
273	8/12/2011	3.0	3.8	6.4	7.0	50.2	5.5	8.5		
274	8/13/2011						10.2	8.3		
275	8/14/2011	2.6	3.6	7.0	6.7	45.5	4.3	8.3		
276	8/15/2011	6.0	5.4	13.5	13.9	41.7	14.5	15.3		
277	8/16/2011	6.0	6.0	13.7	12.9	45.1	14.5	15.9		
278	8/17/2011	14.7	14.0	25.8	25.0	56.3	26.6	28.0		
279	8/18/2011	9.0	8.7	16.8	15.9	54.1	21.5	21.2		
280	8/19/2011	6.6	6.2	13.3	12.8	48.8	15.0	16.2		
281	8/20/2011						17.9	16.2		
282	8/21/2011	10.4	10.3	17.1	17.2	60.4	20.3	19.6		
283	8/22/2011	10.9	10.8	19.7	19.3	55.8	22.0	24.2		
284	8/23/2011	19.2	19.1	29.9	30.1	63.7	33.6	35.8		
285	8/24/2011	6.7	7.4	16.9	16.7	41.9	15.3	18.8		
286	8/25/2011	11.5	12.1	18.8	18.6	63.4	19.5	19.8		
287	8/26/2011	4.9	5.5	10.7	10.7	48.8	12.5	12.4		
288	8/27/2011						5.3	5.9		
289	8/28/2011	1.8	1.8	7.7	7.6	24.1	7.8	7.3		
290	8/29/2011	5.9	6.2	11.4	11.5	53.0	11.2	11.6		
291	8/30/2011	9.1	8.1	17.1	16.6	51.1	16.0	17.2		
292	8/31/2011	14.5	13.9	26.0	23.6	57.2	24.3	26.0		
293	9/1/2011	17.7	18.2	27.5	26.1	66.9	27.9	28.9		
294	9/2/2011	14.9	15.0	25.1	24.1	60.6	24.1	24.0		
295	9/3/2011						26.4	25.7		
296	9/4/2011	8.2	8.0	12.7	12.1	65.3	13.1	11.8		
297	9/5/2011	4.8	5.0	9.2	9.1	53.8	7.6	7.6		
298	9/6/2011	5.2	5.6	11.1	10.6	49.8	10.4	10.2		
299	9/7/2011	6.1	5.8	12.5	13.2	46.1	11.0	11.6		
300	9/8/2011						8.0	7.8		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 11 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/m³]	SN 20107 PM10 [µg/m³]	Remark	Test site
301	9/9/2011	6.8	7.1	12.1	11.8	57.9	9.8	11.1		Bornheim
302	9/10/2011						12.9	13.1		(Summer)
303	9/11/2011	5.7	5.5	9.4	9.3	59.5	7.9	9.9		
304	9/12/2011	5.2	6.1	11.6	11.6	48.5	9.2	10.8		
305	9/13/2011	6.3	7.2	16.3	16.8	40.6	12.5	14.8		
306	9/14/2011	6.7	7.2	15.3	15.6	44.9	11.6	12.8		
307	9/15/2011	11.1	12.2	24.3	24.9	47.4	22.8	23.1		
308	9/16/2011	13.0	13.7	23.0	25.1	55.4			Inlet -> Zero filter	
309	9/17/2011								Zero filter	
310	9/18/2011	3.2	3.9	7.0	7.1	50.4			Zero filter	
311	9/19/2011	7.8	8.2	12.5	11.6	66.2	11.3	10.7		
312	9/20/2011	6.2	6.2	12.3	12.3	50.8	13.3	12.7		
313	9/21/2011	6.6	6.6	12.4	12.3	53.6	10.5	11.4		
314	9/22/2011	6.4	7.8	19.2	18.9	37.3	15.7	15.4		
315	9/23/2011	12.2	13.4	26.1	26.2	49.1	24.7	23.4		
316	9/24/2011						22.3	20.6		
317	9/25/2011	15.7	14.5	21.3	21.7	70.0	21.7	21.2		
318	9/26/2011	12.0	12.0	18.8	20.6	60.8			Audits	
319	9/27/2011	21.9	21.9	38.3	39.8	56.0	39.7	37.3		
320	9/28/2011	15.5	15.5	25.7	25.7	60.2	27.8		SN 20107 leak repairs	
321	9/29/2011	17.1	16.0	25.4	25.4	65.1	26.6	29.4		
322	9/30/2011	12.4	11.8	23.4	24.5	50.6	23.1	25.7		
323	10/1/2011						20.7	23.0		
324	10/2/2011						37.6	40.6		
325	10/3/2011	13.5	14.8	21.4	21.4	66.2	27.4	30.4		
326	10/4/2011						15.0	17.8		
327	10/5/2011						6.4	6.7		
328	10/6/2011						9.1	10.8		

Annex 5 **PM10 measured values from field test sites, related to standard conditions [EN 12431]** **Page 12 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10, Außenluft
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/Nm³]	SN 20107 PM10 [µg/Nm³]	Remark	Test site
1	12/9/2009	-	-	28.0	28.3	-	24.5			Teddington (Winter)
2	12/10/2009	-	-	25.1	25.4	-	22.0			
3	12/11/2009	-	-	20.2	20.3	-	16.1			
4	12/12/2009	-	-	13.5	13.7	-	11.6			
5	12/13/2009	-	-	13.4	14.0	-	11.5			
6	12/14/2009	-	-	35.2	35.6	-	30.9			
7	12/15/2009	-	-	46.9	47.2	-	44.9			
8	12/16/2009	-	-	30.1	30.7	-	28.2			
9	12/17/2009	-	-	10.2	10.3	-	8.8			
10	12/18/2009	-	-	16.7	17.0	-	14.2			
11	12/19/2009	-	-	15.5	15.1	-	14.4			
12	12/20/2009	-	-	11.2	11.2	-	9.5			
13	12/21/2009	-	-	20.7	21.1	-	19.7			
14	12/22/2009	-	-			-	33.3		PM10 Grubbs outlier	
15	12/23/2009	-	-			-	18.3	Device not yet in operation		
16	12/24/2009	-	-			-	19.0			
17	12/25/2009	-	-			-	12.5			
18	12/26/2009	-	-			-	8.2			
19	12/27/2009	-	-			-	7.3			
20	12/28/2009	-	-			-	23.9			
21	12/29/2009	-	-			-	11.2			
22	12/30/2009	-	-			-	11.7			
23	12/31/2009	-	-	15.4	14.3	-	12.5			
24	1/1/2010	-	-			-	16.1			
25	1/2/2010	-	-			-	15.0			
26	1/3/2010	-	-			-	20.6			
27	1/4/2010	-	-			-			Zero filter	
28	1/5/2010	-	-			-	18.7		PM10 Grubbs outlier	
29	1/6/2010	-	-	19.0	19.3	-	16.9		PM2.5 Grubbs outlier	
30	1/7/2010	-	-	19.1	20.1	-	17.3			

Annex 5 **PM10 measured values from field test sites, related to standard conditions [EN 12431]** **Page 13 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10,
Außenluft
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/Nm³]	SN 20107 PM10 [µg/Nm³]	Remark	Test site
31	1/8/2010	-	-	17.9	18.2	-	16.2	Device not yet in operation		Teddington (Winter)
32	1/9/2010	-	-	14.5	14.8	-	13.2			
33	1/10/2010	-	-	19.4	19.3	-	17.3			
34	1/11/2010	-	-	51.5	51.5	-	48.7		SN 20107 Zero filter	
35	1/12/2010	-	-	48.5	48.9	-	48.3	48.0		
36	1/13/2010	-	-	54.0	54.1	-	52.3	53.9		
37	1/14/2010	-	-	16.2	16.6	-	17.3	17.8		
38	1/15/2010	-	-	27.2	27.7	-	19.6	20.3		
39	1/16/2010	-	-	13.8	14.0	-	11.0	11.8		
40	1/17/2010	-	-	20.6	20.8	-	17.5	18.1		
41	1/18/2010	-	-	27.1	27.3	-	25.2	25.9		
42	1/19/2010	-	-	26.9	27.2	-			Power supply interrupted	
43	1/20/2010	-	-	32.1	32.4	-	28.6	29.8		
44	1/21/2010	-	-	27.7	28.4	-	24.2	24.1		
45	1/22/2010	-	-	9.9	10.1	-	9.4	10.3		
46	1/23/2010	-	-	25.8	25.3	-	23.2	23.6		
47	1/24/2010	-	-	20.6	20.4	-	18.6	18.5		
48	1/25/2010	-	-	41.3	42.1	-	39.3			
49	1/26/2010	-	-	58.5	59.1	-	54.4	55.4		
50	1/27/2010	-	-	39.0	39.6	-	34.1	33.4		
51	1/28/2010	-	-	14.2	14.6	-	13.0	14.1		
52	1/29/2010	-	-	9.6	9.8	-	9.4	9.6		
53	1/30/2010	-	-	17.6	17.8	-	15.7	16.3		
54	1/31/2010	-	-	17.3	17.0	-	15.2	16.0		
55	2/1/2010	-	-	14.7	14.6	-	14.2	14.3		
56	2/2/2010	-	-	12.3	12.1	-	11.9	11.6		
57	2/3/2010	-	-	19.6	19.8	-	16.4	16.6		
58	2/4/2010	-	-	20.3	20.6	-	18.7	19.3		
59	2/5/2010	-	-			-			Inlet -> Zero filter	
60	2/6/2010	-	-			-			Zero filter	

Annex 5 **PM10 measured values from field test sites, related to standard conditions [EN 12431]** **Page 14 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10,
Außenluft
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/Nm³]	SN 20107 PM10 [µg/Nm³]	Remark	Test site
61	2/7/2010	-	-			-			Zero filter	Teddington
62	2/8/2010	-	-			-		20.1	SN 20006 Zero filter->Inlet	(Winter)
63	2/9/2010	-	-	11.7	11.9	-	11.0	12.0		
64	2/10/2010	-	-	11.8	12.4	-	10.9	13.2		
65	2/11/2010	-	-	20.0	20.2	-	16.3	18.9		
66	2/12/2010	-	-	12.5	12.4	-	10.1	12.6		
67	2/13/2010	-	-	15.1	15.5	-	11.2	13.2		
68	2/14/2010	-	-	16.0	16.5	-	12.7	16.5		
69	2/15/2010	-	-	16.3	16.4	-	13.8	15.6		
70	2/16/2010	-	-	18.7	19.2	-	15.9	17.6		
71	2/17/2010	-	-	53.6	54.1	-	48.9	50.0		
72	2/18/2010	-	-	15.2	15.5	-	12.7	16.9		
73	2/19/2010	-	-	22.0	22.3	-	19.0	21.3		
74	2/20/2010	-	-	19.6	20.0	-	17.6	20.2		
75	2/21/2010	-	-	10.6	10.7	-	8.6	10.5		
76	2/22/2010	-	-	17.0	17.2	-	13.8	15.5		
77	2/23/2010	-	-	22.9	23.3	-	18.3	20.6		
78	2/24/2010	-	-	18.6	18.7	-	15.5	16.8		
79	2/25/2010	-	-	9.7	10.0	-	9.2	10.3		
80	2/26/2010	-	-	11.5	11.9	-	10.8	11.6		
81	2/27/2010	-	-	19.8	20.3	-	19.1	18.5		
82	2/28/2010	-	-	9.7	9.9	-	7.2	10.0		
83	3/1/2010	-	-			-	26.4	27.0		
84	3/2/2010	-	-	21.8	21.3	-	18.8	20.8		
85	3/3/2010	-	-	20.9	21.6	-	18.0	19.9		
86	3/4/2010	-	-	16.3	16.6	-	15.0	16.4		
87	4/27/2010	-	-	20.9	21.8	-	22.0	21.4		Teddington
88	4/28/2010	-	-	27.0	26.4	-	28.1	27.3		(Summer)
89	4/29/2010	-	-	20.2	20.4	-	22.3	22.0		
90	4/30/2010	-	-	12.0	12.5	-	13.0	13.8		

Annex 5 **PM10 measured values from field test sites, related to standard conditions [EN 12431]** **Page 15 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10,
Außenluft
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/Nm³]	SN 20107 PM10 [µg/Nm³]	Remark	Test site
91	5/1/2010	-	-			-	12.6	12.0		Teddington
92	5/2/2010	-	-			-	8.8	9.0		(Summer)
93	5/3/2010	-	-			-	13.8	12.9		
94	5/4/2010	-	-	15.2	15.3	-	15.2	15.1		
95	5/5/2010	-	-	19.4	20.5	-	20.8	20.7		
96	5/6/2010	-	-	16.8	17.4	-	17.3	16.9		
97	5/7/2010	-	-	13.3	13.7	-	15.0	14.2		
98	5/8/2010	-	-	9.1	9.3	-	10.2	10.3		
99	5/9/2010	-	-	14.5	14.6	-	15.1	14.3		
100	5/10/2010	-	-	10.5	10.1	-	12.2	13.0		
101	5/11/2010	-	-	10.8	10.0	-	12.5	12.3		
102	5/12/2010	-	-	12.5	12.9	-	13.9	13.2		
103	5/13/2010	-	-	17.6	17.7	-	17.8	18.1		
104	5/14/2010	-	-	19.7	19.6	-	19.9	19.9		
105	5/15/2010	-	-	13.1	13.3	-	14.3	13.4		
106	5/16/2010	-	-	9.8	9.9	-	11.9	11.8		
107	5/17/2010	-	-	16.6	17.1	-	18.7	17.8		
108	5/18/2010	-	-	22.0	22.3	-	22.2	23.7		
109	5/19/2010	-	-	20.7	20.2	-	22.3	22.7		
110	5/20/2010	-	-	19.5	19.9	-	25.1	24.2		
111	5/21/2010	-	-	18.7	19.5	-	21.6	22.7		
112	5/22/2010	-	-	9.4	9.4	-	11.1	12.7		
113	5/23/2010	-	-	9.9	10.2	-	13.7	13.3		
114	5/24/2010	-	-	18.7	18.9	-	20.8	21.2		
115	5/25/2010	-	-	16.4	16.0	-	17.9	18.9		
116	5/26/2010	-	-	20.0	20.0	-			Zero filter	
117	5/27/2010	-	-	8.4	8.3	-			Zero filter-> Inlet	
118	5/28/2010	-	-	15.1	14.6	-		15.7	SN 20006 noisy signal	
119	5/29/2010	-	-	11.1	11.4	-		11.9	SN 20006 noisy signal	
120	5/30/2010	-	-	8.6	8.4	-		10.2	SN 20006 noisy signal	

Annex 5 **PM10 measured values from field test sites, related to standard conditions [EN 12431]** **Page 16 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10, Außenluft
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/Nm³]	SN 20107 PM10 [µg/Nm³]	Remark	Test site
121	5/31/2010	-	-	21.4	22.1	-		20.9	SN 20006 noisy signal	Teddington (Summer)
122	6/1/2010	-	-	20.7	21.4	-		21.6	SN 20006 noisy signal	
123	6/2/2010	-	-	18.5	18.3	-		20.8	SN 20006 noisy signal	
124	6/3/2010	-	-	16.3	16.6	-		16.7	SN 20006 noisy signal	
125	6/4/2010	-	-	27.6	28.4	-		31.8	SN 20006 noisy signal	
126	6/5/2010	-	-	25.5	26.2	-		31.4	SN 20006 noisy signal	
127	6/6/2010	-	-	12.3	12.0	-		16.3	SN 20006 noisy signal	
128	6/7/2010	-	-	8.2	7.7	-		8.8	SN 20006 noisy signal	
129	6/8/2010	-	-	9.8	10.6	-		11.4	SN 20006 noisy signal	
130	6/9/2010	-	-	16.6	17.2	-		16.3	SN 20006 noisy signal	
131	6/10/2010	-	-	10.9	11.4	-		13.5	SN 20006 noisy signal	
132	6/11/2010	-	-	11.1	12.5	-		13.3	No ref.measurement PM2.5, Repair (leaking switching valve)	
133	6/12/2010	-	-	14.0	14.2	-	12.7	14.9		
134	6/13/2010	-	-	18.4	18.8	-	17.7	19.2		
135	6/14/2010	-	-	13.9	13.2	-	13.7	15.5		
136	6/15/2010	-	-	10.5	10.2	-	10.1	12.4		
137	6/16/2010	-	-	11.2	10.8	-	11.8	13.7		
138	6/17/2010	-	-	7.4	8.3	-	10.9	10.8		
139	6/18/2010	-	-			-	14.2	15.1		
140	6/19/2010	-	-	9.4	9.7	-	9.5	12.3		
141	6/20/2010	-	-	16.1	16.0	-	16.9	18.5		
142	6/21/2010	-	-			-	21.8	20.0	PM10 Grubbs outlier	
143	6/22/2010	-	-	13.9	14.7	-	21.0	17.9		
144	6/23/2010	-	-	16.2	16.6	-	21.7	20.3		
145	6/24/2010	-	-	12.3	11.8	-	18.0	17.6		
146	6/25/2010	-	-	24.6	25.4	-	29.0	28.0		
147	6/26/2010	-	-	31.0	31.2	-	37.7	37.8		
148	6/27/2010	-	-			-	21.4	19.7		
149	6/28/2010	-	-			-	23.6	23.0	PM10 Grubbs outlier	
150	6/29/2010	-	-	9.5	9.7	-	11.9	11.6		

Annex 5 **PM10 measured values from field test sites, related to standard conditions [EN 12431]** **Page 17 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10,
Außenluft
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/Nm³]	SN 20107 PM10 [µg/Nm³]	Remark	Test site
151	6/30/2010	-	-	10.2	10.1	-	12.9	13.6		Teddington
152	7/1/2010	-	-	11.8	12.5	-	15.3	14.9		(Summer)
153	1/27/2011	-	-	12.7	13.3	-			Audits	Cologne
154	1/28/2011	-	-	35.7	36.4	-			Audits	(Winter)
155	1/29/2011	-	-			-			Zero filter	
156	1/30/2011	-	-	80.9	82.5	-			Zero filter	
157	1/31/2011	-	-	93.1	92.6	-			Zero filter	
158	2/1/2011	-	-	73.4	72.7	-	73.9	74.8		
159	2/2/2011	-	-	24.8	24.6	-	22.5	25.0		
160	2/3/2011	-	-	20.2	20.7	-	19.0	19.8		
161	2/4/2011	-	-	11.3	11.8	-	10.7	11.0		
162	2/5/2011	-	-			-	8.9	9.5		
163	2/6/2011	-	-	15.0	15.3	-	14.4	16.4		
164	2/7/2011	-	-	18.0	19.5	-	19.1	19.9		
165	2/8/2011	-	-	30.5	31.5	-	28.7	30.4		
166	2/9/2011	-	-	30.0	31.3	-	28.6	31.3		
167	2/10/2011	-	-	25.7	27.7	-	26.6	27.8		
168	2/11/2011	-	-	13.6	14.6	-	13.2	15.2		
169	2/12/2011	-	-			-	18.8	19.4		
170	2/13/2011	-	-	17.6	19.0	-	17.1	17.2		
171	2/14/2011	-	-	24.5	25.2	-	24.7	26.3		
172	2/15/2011	-	-	19.7	20.5	-	21.5	20.4		
173	2/16/2011	-	-	34.8	35.4	-	36.1	34.4		
174	2/17/2011	-	-	43.1	43.3	-	45.2	45.4		
175	2/18/2011	-	-	43.6	44.2	-	46.1	47.9		
176	2/19/2011	-	-			-	56.7	56.2		
177	2/20/2011	-	-	29.3	29.9	-	30.7	28.9		
178	2/21/2011	-	-	36.1	36.1	-	36.8	35.9		
179	2/22/2011	-	-	42.6	43.6	-	44.7	45.8		
180	2/23/2011	-	-	45.4	45.9	-	47.0	48.4		

Annex 5 **PM10 measured values from field test sites, related to standard conditions [EN 12431]** **Page 18 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10, Außenluft
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/Nm³]	SN 20107 PM10 [µg/Nm³]	Remark	Test site
181	2/24/2011	-	-	35.8	35.9	-	37.6	39.0		Cologne
182	2/25/2011	-	-	30.6	30.1	-	31.5	30.6		(Winter)
183	2/26/2011	-	-			-	19.5	19.4		
184	2/27/2011	-	-	15.6	15.1	-	15.8	16.1		
185	2/28/2011	-	-	44.3	44.0	-	43.0	44.0		
186	3/1/2011	-	-	75.5	75.3	-	72.9	76.9		
187	3/2/2011	-	-	60.6	59.0	-	59.2	61.0		
188	3/3/2011	-	-	50.6	49.1	-	48.3	49.5		
189	3/4/2011	-	-			-			PM10 Grubbs outlier; Inlet -> Zero filter	
190	3/5/2011	-	-			-			Zero filter	
191	3/6/2011	-	-	13.5	14.1	-			Zero filter	
192	3/7/2011	-	-	13.7	12.5	-			Zero filter	
193	3/8/2011	-	-	44.7	45.0	-	43.7	43.2		
194	3/9/2011	-	-	31.2	29.6	-	29.4	29.8		
195	3/10/2011	-	-			-			Power cut (complete)	
196	3/11/2011	-	-	34.2	34.0	-	30.6	32.4		
197	3/12/2011	-	-			-	32.5	35.1		
198	3/13/2011	-	-	16.9	16.4	-	15.7	16.2		
199	3/14/2011	-	-	28.6	26.6	-			Power cut (only Thermo)	
200	3/15/2011	-	-	46.1	45.5	-	46.0	46.8		
201	3/16/2011	-	-	70.2	69.1	-	69.1	71.2	PM2.5 Grubbs outlier	
202	3/17/2011	-	-	69.4	69.1	-	68.7	70.5		
203	3/18/2011	-	-	38.9	39.2	-	37.8	39.0		
204	3/19/2011	-	-			-	18.3	19.1		
205	3/20/2011	-	-	28.5	28.3	-	27.2	28.7		
206	3/21/2011	-	-	34.7	34.6	-	34.3	31.5		
207	3/22/2011	-	-	56.3	55.8	-	55.3	51.1		
208	3/23/2011	-	-	33.6	32.4	-	32.4	29.9		
209	3/24/2011	-	-	34.1	33.8	-	34.8	33.9		
210	3/25/2011	-	-	38.5	39.1	-	39.3	40.8		

Annex 5 **PM10 measured values from field test sites, related to standard conditions [EN 12431]** **Page 19 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10,
Außenluft
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/Nm³]	SN 20107 PM10 [µg/Nm³]	Remark	Test site
211	3/26/2011	-	-			-	18.1	19.8		Cologne
212	3/27/2011	-	-	36.8	37.0	-	36.1	38.2		(Winter)
213	3/28/2011	-	-	33.1	32.9	-	32.2	33.8		
214	3/29/2011	-	-	67.7	68.4	-	66.6	69.1		
215	3/30/2011	-	-	25.1	24.6	-	25.0	25.8		
216	3/31/2011	-	-	10.9	9.7	-	10.1	11.1		
217	4/1/2011	-	-	13.8	13.7	-	13.3	12.7		
218	4/2/2011	-	-			-	34.8	33.4		
219	4/3/2011	-	-	22.9	23.4	-	21.6	21.0		
220	4/4/2011	-	-	18.3	17.1	-	17.2	18.2		
221	4/5/2011	-	-	19.7	19.7	-	19.4	20.5		
222	4/6/2011	-	-	24.7	25.1	-	25.0	26.6		
223	4/7/2011	-	-	24.1	25.3	-	24.8	25.9		
224	4/8/2011	-	-	36.2	36.3	-			Inlet -> Zero filter	
225	4/9/2011	-	-			-			Zero filter	
226	4/10/2011	-	-	24.3	23.5	-			Zero filter	
227	4/11/2011	-	-	31.8	32.3	-	34.8	35.8		
228	4/12/2011	-	-	18.9	18.1	-	18.2	20.7		
229	4/13/2011	-	-	25.1	24.1	-	26.1	27.9		
230	4/14/2011	-	-	32.7	32.5	-	34.0	36.0		
231	4/15/2011	-	-	32.9	33.2	-	27.9	27.4		
232	4/16/2011	-	-			-	35.8	34.3		
233	4/17/2011	-	-			-	22.5	22.0		
234	4/18/2011	-	-	27.6	28.1	-	29.7	31.8		
235	4/19/2011	-	-	31.9	32.6	-	34.8	36.5		
236	4/20/2011	-	-	35.8	36.4	-	39.3	40.9		
237	4/21/2011	-	-			-	36.9	39.3		
238	4/22/2011	-	-			-	32.6	33.7		
239	4/23/2011	-	-			-	43.5	45.5		
240	4/24/2011	-	-			-	33.3	35.6		

Annex 5 **PM10 measured values from field test sites, related to standard conditions [EN 12431]** **Page 20 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10, Außenluft
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/Nm³]	SN 20107 PM10 [µg/Nm³]	Remark	Test site
241	4/25/2011	-	-	28.9	29.1	-	31.9	34.0		Cologne (Winter)
242	4/26/2011	-	-	32.7	33.3	-	35.0	41.6		
243	4/27/2011	-	-	45.9	47.1	-	48.1	50.5	No ref.measurement PM2.5	
244	4/28/2011	-	-	29.4	29.7	-	33.0	34.5		
245	4/29/2011	-	-	27.6	29.3	-	32.5	32.1		
246	4/30/2011	-	-	22.4	23.6	-	24.2	25.7		
247	5/1/2011	-	-	13.7	13.7	-	15.1	16.6		
248	5/2/2011	-	-	16.8	15.7	-	18.0	18.7		
249	5/3/2011	-	-	16.4	15.8	-	17.5	18.7		
250	5/4/2011	-	-	21.0	20.9	-	22.5	22.5		
251	5/5/2011	-	-	20.9	20.5	-	22.5	23.3	PM2.5 Grubbs outlier	
252	5/6/2011	-	-	32.5	33.2	-	31.0	31.8		
253	5/7/2011	-	-	49.3	51.3	-	45.8	48.1		
254	5/8/2011	-	-	25.0	24.8	-	23.6	24.6		
255	7/25/2011	-	-	19.0	19.2	-	21.7	20.3		Bornheim (Summer)
256	7/26/2011	-	-	20.8	20.4	-	21.5	24.1		
257	7/27/2011	-	-	22.8	22.4	-	24.0	25.2		
258	7/28/2011	-	-	28.0	26.9	-	31.1	28.4		
259	7/29/2011	-	-	17.7	17.7	-	21.2	19.9		
260	7/30/2011	-	-			-	11.8	12.0		
261	7/31/2011	-	-	13.9	15.0	-	14.8	15.4		
262	8/1/2011	-	-	19.2	20.8	-	20.8	22.9		
263	8/2/2011	-	-	20.6	22.0	-	20.6	22.0		
264	8/3/2011	-	-	26.1	28.2	-	26.9	28.3		
265	8/4/2011	-	-	14.9	16.1	-	18.5	21.7		
266	8/5/2011	-	-	18.4	19.5	-	18.2	21.5		
267	8/6/2011	-	-			-	12.2	14.7		
268	8/7/2011	-	-	6.0	6.9	-	6.0	6.7		
269	8/8/2011	-	-	8.3	8.0	-	6.1	8.1		
270	8/9/2011	-	-	11.2	11.8	-			Audit flow rate	

Annex 5 **PM10 measured values from field test sites, related to standard conditions [EN 12431]** **Page 21 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10,
Außenluft
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/Nm³]	SN 20107 PM10 [µg/Nm³]	Remark	Test site
271	8/10/2011	-	-	12.8	13.6	-	14.9	14.3		Bornheim
272	8/11/2011	-	-	12.2	12.1	-	10.3	11.9		(Summer)
273	8/12/2011	-	-	6.9	7.6	-	5.9	9.1		
274	8/13/2011	-	-			-	11.1	9.0		
275	8/14/2011	-	-	7.5	7.2	-	4.6	8.8		
276	8/15/2011	-	-	14.3	14.9	-	15.4	16.4		
277	8/16/2011	-	-	14.5	13.8	-	15.4	16.9		
278	8/17/2011	-	-	27.8	27.2	-	28.8	30.2		
279	8/18/2011	-	-	18.2	17.4	-	23.4	23.1		
280	8/19/2011	-	-	14.1	13.6	-	15.9	17.1		
281	8/20/2011	-	-			-	19.2	17.4		
282	8/21/2011	-	-	18.4	18.7	-	21.9	21.3		
283	8/22/2011	-	-	21.1	20.8	-	23.7	26.0		
284	8/23/2011	-	-	32.4	32.9	-	36.6	39.0		
285	8/24/2011	-	-	18.1	18.1	-	16.6	20.3		
286	8/25/2011	-	-	20.2	20.2	-	21.1	21.4		
287	8/26/2011	-	-	11.5	11.6	-	13.7	13.6		
288	8/27/2011	-	-			-	5.7	6.2		
289	8/28/2011	-	-	8.1	8.1	-	8.2	7.7		
290	8/29/2011	-	-	12.0	12.2	-	11.8	12.2		
291	8/30/2011	-	-	17.9	17.5	-	16.8	18.1		
292	8/31/2011	-	-	27.3	25.1	-	25.7	27.4		
293	9/1/2011	-	-	29.1	27.9	-	29.7	30.8		
294	9/2/2011	-	-	27.0	26.2	-	26.1	26.0		
295	9/3/2011	-	-			-	28.9	28.1		
296	9/4/2011	-	-	13.7	13.1	-	14.2	12.8		
297	9/5/2011	-	-	9.7	9.7	-	8.1	8.1		
298	9/6/2011	-	-	11.8	11.4	-	11.2	10.9		
299	9/7/2011	-	-	13.2	14.1	-	11.7	12.3		
300	9/8/2011	-	-			-	8.5	8.3		

Annex 5 **PM10 measured values from field test sites, related to standard conditions [EN 12431]** **Page 22 of 22**

Manufacturer Thermo Fisher Scientific

Type of instrument TEOM 1405-F

Serial-No. SN 20006 & SN 20107

Suspended particulate matter PM10,
Außenluft
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2.5 [µg/m³]	Ref. 2 PM2.5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2.5/PM10 [%]	SN 20006 PM10 [µg/Nm³]	SN 20107 PM10 [µg/Nm³]	Remark	Test site
301	9/9/2011	-	-	13.0	12.7	-	10.5	11.9		Bornheim
302	9/10/2011	-	-			-	14.1	14.3		(Summer)
303	9/11/2011	-	-	10.0	10.0	-	8.5	10.5		
304	9/12/2011	-	-	12.4	12.6	-	9.9	11.6		
305	9/13/2011	-	-	17.3	17.9	-	13.4	15.8		
306	9/14/2011	-	-	16.0	16.5	-	12.3	13.5		
307	9/15/2011	-	-	25.3	26.2	-	23.9	24.2		
308	9/16/2011	-	-	24.4	26.9	-			Inlet -> Zero filter	
309	9/17/2011	-	-			-			Zero filter	
310	9/18/2011	-	-	7.4	7.5	-			Zero filter	
311	9/19/2011	-	-	13.0	12.3	-	11.9	11.3		
312	9/20/2011	-	-	13.0	13.0	-	13.9	13.3		
313	9/21/2011	-	-	13.0	13.1	-	11.1	12.1		
314	9/22/2011	-	-	20.1	20.0	-	16.6	16.2		
315	9/23/2011	-	-	27.3	27.6	-	25.9	24.6		
316	9/24/2011	-	-			-	23.6	21.8		
317	9/25/2011	-	-	22.5	23.1	-	23.0	22.5		
318	9/26/2011	-	-	19.9	22.0	-			Audits	
319	9/27/2011	-	-	40.2	42.2	-	42.0	39.5		
320	9/28/2011	-	-	27.2	27.2	-	29.5		SN 20107 leak repairs	
321	9/29/2011	-	-	27.0	27.0	-	28.1	31.1		
322	9/30/2011	-	-	24.6	26.0	-	24.4	27.2		
323	10/1/2011	-	-			-	21.8	24.3		
324	10/2/2011	-	-			-	39.8	42.9		
325	10/3/2011	-	-	22.9	22.9	-	29.2	32.3		
326	10/4/2011	-	-			-	15.9	18.9		
327	10/5/2011	-	-			-	6.8	7.2		
328	10/6/2011	-	-			-	9.6	11.4		
						-				

Annex 6 — Ambient conditions at the field test sites — Page 1 of 11

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
1	12/9/2009	Teddington	9.8	12.6	1017	94.1	0.1	221	0.3
2	12/10/2009	(Winter)	3.9	11.3	1028	90.9	0.2	244	0.3
3	12/11/2009		5.7	7.8	1029	93.8	0.4	231	0.0
4	12/12/2009		5.8	9.4	1026	83.9	0.8	200	0.0
5	12/13/2009		4.2	7.2	1022	87.7	0.5	234	0.3
6	12/14/2009		3.4	5.6	1017	88.8	0.2	201	0.0
7	12/15/2009		-0.6	3.3	1015	87.5	0.2	196	0.3
8	12/16/2009		1.5	3.9	1006	96.9	0.2	245	2.8
9	12/17/2009		1.3	4.6	1008	85.2	2.4	225	1.3
10	12/18/2009		-0.8	2.3	1013	86.6	0.9	281	0.0
11	12/19/2009		-0.1	1.7	1002	85.9	0.2	240	1.8
12	12/20/2009		-0.9	2.7	995	87.3	0.1	206	0.0
13	12/21/2009		1.1	3.3	984	97.3	0.3	187	8.6
14	12/22/2009		-2.1	2.7	988	98.3	0.0	218	0.3
15	12/23/2009		2.8	5.4	987	95.9	0.4	173	7.1
16	12/24/2009		4.1	6.6	986	94.1	0.3	217	0.5
17	12/25/2009		4.1	7.3	998	94.5	0.2	210	2.5
18	12/26/2009		5.9	9.4	995	90.2	0.3	200	0.8
19	12/27/2009		2.4	7.8	1000	86.2	0.3	240	0.0
20	12/28/2009		3.7	6.1	998	88.6	1.2	80	1.8
21	12/29/2009		4.8	5.6	988	95.9	1.7	94	11.7
22	12/30/2009		4.3	5.6	992	93.1	1.9	101	5.6
23	12/31/2009		2.3	4.5	998	81.8	1.1	207	0.0
24	1/1/2010		-0.1	3.9	1008	88.3	0.2	243	0.0
25	1/2/2010		1.6	5.0	1016	87.2	0.1	245	0.0
26	1/3/2010		-1.6	3.5	1021	88.3	0.3	205	0.0
27	1/4/2010		-3.7	0.6	1012	97.2	0.0	232	0.0
28	1/5/2010		0.8	2.2	998	89.9	0.7	129	4.8
29	1/6/2010		-2.3	1.1	1005	94.3	0.7	215	1.8
30	1/7/2010		-1.2	0.0	1013	91.1	0.5	240	0.0

Annex 6 **Ambient conditions at the field test sites** **Page 2 of 11**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
31	1/8/2010	Teddington	-1.6	1.6	1022	91.1	0.8	225	0.3
32	1/9/2010	(Winter)	0.9	2.2	1018	79.3	1.8	161	0.0
33	1/10/2010		1.4	2.8	1015	90.5	0.7	92	1.3
34	1/11/2010		1.5	2.4	1015	86.0	0.3	137	0.3
35	1/12/2010		1.4	2.8	1000	85.9	1.5	103	0.0
36	1/13/2010		1.5	3.0	998	94.8	0.1	151	8.6
37	1/14/2010		2.5	4.4	1008	97.0	0.1	229	0.3
38	1/15/2010		5.6	6.7	1011	90.0	1.8	151	1.8
39	1/16/2010		5.7	7.8	1003	96.3	0.4	202	9.1
40	1/17/2010		4.1	9.4	1019	93.9	0.1	219	0.0
41	1/18/2010		6.2	7.8	1021	97.8	0.1	199	0.0
42	1/19/2010		6.4	8.7	1012	83.7	1.4	111	1.0
43	1/20/2010		3.0	3.9	1012	92.1	0.2	227	3.8
44	1/21/2010		6.1	8.3	1015	85.2	1.1	154	0.3
45	1/22/2010		7.6	8.6	1014	95.0	0.5	209	7.4
46	1/23/2010		4.8	6.7	1018	87.0	0.2	262	0.0
47	1/24/2010		4.4	6.7	1022	91.1	0.1	241	1.3
48	1/25/2010		3.2	5.0	1033	80.0	0.9	161	0.5
49	1/26/2010		0.0	3.3	1037	83.2	0.5	167	0.0
50	1/27/2010		4.4	7.2	1018	85.5	0.3	247	1.0
51	1/28/2010		5.5	7.6	1000	86.4	0.5	247	8.1
52	1/29/2010		1.3	6.2	992	76.9	0.9	279	0.3
53	1/30/2010		-0.9	4.5	1001	84.4	0.2	240	0.0
54	1/31/2010		0.0	4.0	1005	91.2	0.1	241	0.0
55	2/1/2010		3.1	7.1	1010	83.9	0.4	222	0.3
56	2/2/2010		5.9	8.4	1002	89.6	0.3	229	1.0
57	2/3/2010		6.7	8.9	1004	91.0	0.2	180	2.0
58	2/4/2010		7.6	8.9	997	86.1	1.3	153	2.3
59	2/5/2010		7.2	12.8	1000	84.9	0.6	143	0.3
60	2/6/2010		5.1	7.8	1017	89.7	0.6	227	0.0

Annex 6 **Ambient conditions at the field test sites** **Page 3 of 11**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
61	2/7/2010	Teddington	3.8	5.6	1015	85.1	0.8	201	0.0
62	2/8/2010	(Winter)	1.4	3.3	1008	82.1	2.0	137	0.5
63	2/9/2010		3.2	5.8	1010	77.7	1.3	233	0.0
64	2/10/2010		1.1	3.9	1016	70.1	1.8	215	0.0
65	2/11/2010		2.3	3.9	1019	74.1	1.1	233	1.0
66	2/12/2010		3.0	5.0	1020	76.5	1.1	167	0.5
67	2/13/2010		2.4	4.0	1017	82.4	0.5	254	0.0
68	2/14/2010		2.2	5.0	1010	91.8	0.1	241	0.3
69	2/15/2010		3.3	5.0	997	89.7	0.1	203	7.9
70	2/16/2010		3.7	5.6	988	94.6	0.1	186	23.1
71	2/17/2010		3.4	9.4	988	78.8	0.3	139	1.0
72	2/18/2010		3.7	6.6	986	92.6	0.7	216	4.6
73	2/19/2010		0.8	6.7	993	87.5	0.2	238	0.3
74	2/20/2010		1.7	7.2	994	87.9	0.2	216	3.3
75	2/21/2010		5.3	7.5	986	92.2	0.5	150	14.7
76	2/22/2010		3.1	4.0	985	88.2	1.4	140	2.8
77	2/23/2010		4.8	7.9	988	92.2	0.8	127	3.6
78	2/24/2010		8.4	11.1	985	91.6	0.5	188	2.8
79	2/25/2010		7.7	10.0	979	88.1	1.0	174	8.6
80	2/26/2010		6.4	9.4	991	77.0	0.7	208	1.3
81	2/27/2010		7.8	11.2	983	88.4	0.7	181	17.5
82	2/28/2010		3.4	6.7	997	88.5	0.5	258	4.3
83	3/1/2010		4.1	11.7	1013	78.0	0.2	236	0.0
84	3/2/2010		6.4	12.0	1020	62.9	0.9	101	0.0
85	3/3/2010		4.7	7.2	1016	71.6	2.5	85	0.0
86	3/4/2010		2.1	8.3	1026	72.0	1.0	196	0.0
87	4/27/2010	Teddington	14.8	22.7	1020	64.1	0.3	187	0.0
88	4/28/2010	(Summer)	15.6	21.7	1011	61.9	0.5	192	0.0
89	4/29/2010		14.2	20.0	1003	76.8	0.2	238	2.5
90	4/30/2010		12.6	16.1	1004	76.4	0.4	227	2.0

Annex 6 **Ambient conditions at the field test sites** **Page 4 of 11**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
91	5/1/2010	Teddington	12.4	18.2	1004	75.3	0.5	184	9.4
92	5/2/2010	(Summer)	7.4	9.5	1012	76.5	1.8	233	4.8
93	5/3/2010		7.7	12.2	1021	60.1	1.7	240	0.5
94	5/4/2010		7.9	13.4	1021	66.2	0.8	226	0.0
95	5/5/2010		12.1	16.7	1012	64.2	0.8	209	0.0
96	5/6/2010		10.9	17.3	1007	59.1	1.2	175	0.0
97	5/7/2010		9.9	14.2	1007	64.5	1.4	181	0.8
98	5/8/2010		8.6	10.5	1009	78.3	1.1	213	0.0
99	5/9/2010		9.2	12.2	1008	69.6	1.0	153	0.0
100	5/10/2010		9.5	14.3	1008	56.5	1.4	173	0.0
101	5/11/2010		6.7	11.1	1009	66.1	0.6	196	0.0
102	5/12/2010		8.1	13.4	1011	61.1	0.6	220	0.0
103	5/13/2010		9.7	15.0	1009	59.8	0.3	212	0.0
104	5/14/2010		12.0	16.3	1008	58.0	0.4	213	0.0
105	5/15/2010		12.5	19.2	1011	60.3	0.4	260	0.0
106	5/16/2010		11.3	17.2	1014	82.3	0.2	219	4.8
107	5/17/2010		12.8	19.8	1021	63.0	0.4	266	0.0
108	5/18/2010		14.1	20.5	1024	62.0	0.4	189	0.0
109	5/19/2010		16.0	23.3	1025	68.8	0.1	235	0.0
110	5/20/2010		18.1	24.4	1026	72.3	0.1	247	0.0
111	5/21/2010		18.9	25.5	1024	62.4	1.2	111	0.0
112	5/22/2010		18.2	24.6	1022	60.0	1.2	131	0.0
113	5/23/2010		21.7	31.1	1014	51.3	0.3	213	0.0
114	5/24/2010		20.5	30.8	1007	54.6	1.4	158	0.0
115	5/25/2010		15.0	20.2	1006	54.5	2.3	91	0.0
116	5/26/2010		13.2	18.2	1005	66.0	1.0	140	1.5
117	5/27/2010		13.3	19.4	1006	58.9	0.4	241	0.3
118	5/28/2010		15.2	21.8	1010	59.6	0.6	209	0.0
119	5/29/2010		14.1	16.7	1003	82.5	1.0	209	1.0
120	5/30/2010		14.6	21.0	1010	52.9	1.6	263	0.0

Annex 6 **Ambient conditions at the field test sites** **Page 5 of 11**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
121	5/31/2010	Teddington	14.3	16.7	1014	72.1	0.6	203	0.0
122	6/1/2010	(Summer)	13.0	16.7	1013	86.7	0.4	176	2.8
123	6/2/2010		17.4	24.5	1017	55.2	0.7	152	0.0
124	6/3/2010		17.5	22.7	1016	51.8	1.6	91	0.0
125	6/4/2010		20.3	29.6	1014	55.5	0.5	179	0.0
126	6/5/2010		22.1	28.4	1008	60.2	0.4	185	0.0
127	6/6/2010		18.2	24.7	1006	68.1	0.6	262	0.0
128	6/7/2010		15.8	22.7	1002	73.9	0.5	154	7.9
129	6/8/2010		15.7	20.9	997	81.3	0.5	193	2.3
130	6/9/2010		17.8	22.2	1000	72.1	1.1	154	0.0
131	6/10/2010		15.2	19.4	1002	83.2	1.8	211	0.3
132	6/11/2010		15.5	21.7	1006	68.2	0.5	243	0.0
133	6/12/2010		15.6	21.5	1012	63.0	0.7	201	0.0
134	6/13/2010		16.9	21.7	1007	65.8	0.7	192	0.3
135	6/14/2010		14.6	20.6	1017	70.4	1.5	163	1.8
136	6/15/2010		14.4	19.3	1022	56.1	1.8	171	0.0
137	6/16/2010		15.2	21.0	1018	57.8	1.9	164	0.0
138	6/17/2010		17.6	24.3	1015	58.5	1.6	142	0.0
139	6/18/2010		14.5	21.1	1014	69.7	1.1	216	0.8
140	6/19/2010		12.5	16.2	1014	55.8	1.5	253	0.0
141	6/20/2010		15.6	22.1	1017	55.8	0.7	240	0.0
142	6/21/2010		19.8	27.5	1017	55.1	0.4	194	0.0
143	6/22/2010		21.5	29.5	1017	50.1	0.3	238	0.0
144	6/23/2010		21.8	30.0	1014	52.4	0.3	226	0.0
145	6/24/2010		21.3	27.7	1012	54.7	0.4	261	0.0
146	6/25/2010		21.9	28.3	1011	56.1	1.0	130	0.0
147	6/26/2010		21.1	27.1	1011	63.2	0.9	146	0.0
148	6/27/2010		22.8	30.8	1013	50.3	0.3	203	0.0
149	6/28/2010		23.2	31.0	1013	43.9	0.3	218	2.8
150	6/29/2010		21.5	30.0	1013	70.2	0.2	210	0.0

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No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
151	6/30/2010	Teddington	20.1	28.7	1011	63.2	0.3	197	0.0
152	7/1/2010	(Summer)	21.9	26.4	1005	58.8	0.6	173	0.0
153	1/27/2011	Cologne	-0.2	3.2	1015	72.1	1.6	49	0.0
154	1/28/2011	(Winter)	-1.8	3.4	1015	77.0	1.3	98	0.0
155	1/29/2011		-2.1	4.7	1013	77.0	0.9	157	0.0
156	1/30/2011		-3.4	1.8	1015	83.9	0.7	168	0.0
157	1/31/2011		-3.8	-2.2	1020	86.9	1.3	127	0.0
158	2/1/2011		-2.3	-0.4	1022	88.2	2.1	172	0.0
159	2/2/2011		0.8	2.5	1021	88.6	3.1	144	8.7
160	2/3/2011		4.3	7.6	1018	83.0	2.9	193	0.3
161	2/4/2011		9.9	10.7	1014	72.4	6.9	239	0.3
162	2/5/2011		11.0	12.0	1017	71.2	7.1	241	0.0
163	2/6/2011		8.2	10.6	1018	69.5	3.9	224	0.0
164	2/7/2011		9.8	15.5	1011	60.9	3.6	212	0.6
165	2/8/2011		3.2	10.3	1017	77.0	1.1	166	0.0
166	2/9/2011		6.1	10.9	1014	67.6	3.2	120	0.0
167	2/10/2011		8.7	11.0	1007	84.2	3.2	185	14.0
168	2/11/2011		8.9	11.2	1007	93.5	2.0	193	33.0
169	2/12/2011		6.0	7.8	1007	89.8	2.7	130	3.0
170	2/13/2011		6.3	9.1	1002	81.1	4.2	106	0.0
171	2/14/2011		6.0	8.7	998	87.5	2.5	143	5.1
172	2/15/2011		5.4	8.2	992	86.9	3.5	110	1.8
173	2/16/2011		4.0	9.8	994	86.7	1.4	125	0.0
174	2/17/2011		4.1	10.2	1002	76.8	1.7	124	0.0
175	2/18/2011		2.7	3.6	1009	78.4	1.5	104	0.0
176	2/19/2011		2.7	5.3	1010	73.6	4.5	95	0.0
177	2/20/2011		-0.5	2.9	1011	67.1	4.1	77	0.0
178	2/21/2011		-2.7	0.9	1011	65.5	3.1	94	0.0
179	2/22/2011		-1.6	4.2	1015	56.2	3.0	124	0.0
180	2/23/2011		1.2	3.6	1016	59.6	5.0	132	0.0

Annex 6 **Ambient conditions at the field test sites** **Page 7 of 11**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
181	2/24/2011	Cologne	2.2	3.8	1019	94.2	2.6	102	5.7
182	2/25/2011	(Winter)	5.3	7.2	1018	87.1	3.4	111	0.0
183	2/26/2011		6.3	8.5	1005	86.0	4.3	196	10.5
184	2/27/2011		4.2	6.4	1010	86.0	3.9	251	1.5
185	2/28/2011		3.8	6.6	1022	83.3	0.9	202	0.0
186	3/1/2011		5.2	10.3	1026	69.9	2.1	139	0.3
187	3/2/2011		4.8	13.6	1024	54.7	2.2	137	0.0
188	3/3/2011		3.7	10.6	1024	50.4	1.4	90	0.0
189	3/4/2011		3.4	10.8	1021	67.8	1.2	222	0.0
190	3/5/2011		2.7	7.0	1021	73.4	2.2	206	0.0
191	3/6/2011		3.0	8.2	1024	52.4	1.9	84	0.0
192	3/7/2011		4.0	9.3	1023	34.2	5.1	101	0.0
193	3/8/2011		7.9	14.4	1013	54.0	2.3	147	0.0
194	3/9/2011		7.1	10.6	1010	75.8	3.5	232	0.9
195	3/10/2011		9.2	10.1	1008	68.9	5.3	231	0.0
196	3/11/2011		8.1	11.4	1008	69.5	3.8	197	0.3
197	3/12/2011		12.1	16.4	998	61.6	3.3	147	0.3
198	3/13/2011		11.2	14.1	1001	77.3	2.0	156	1.5
199	3/14/2011		9.8	13.8	1010	81.2	0.3	114	0.0
200	3/15/2011		12.3	19.6	1006	66.2	2.2	96	0.0
201	3/16/2011		9.5	16.9	1000	71.9	2.5	126	0.0
202	3/17/2011		5.7	7.2	1009	86.9	4.7	267	0.0
203	3/18/2011		6.0	7.6	1018	89.1	1.1	135	11.1
204	3/19/2011		5.0	12.1	1027	59.5	1.2	123	0.0
205	3/20/2011		5.3	13.2	1027	57.7	0.9	150	0.0
206	3/21/2011		6.9	16.1	1029	56.5	1.0	166	0.0
207	3/22/2011		9.4	17.2	1031	62.7	1.1	184	0.0
208	3/23/2011		10.7	18.6	1030	66.8	1.2	161	0.0
209	3/24/2011		10.9	18.6	1021	67.2	1.0	174	0.0
210	3/25/2011		11.8	18.0	1010	59.4	1.6	183	0.0

Annex 6 **Ambient conditions at the field test sites** **Page 8 of 11**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
211	3/26/2011	Cologne	7.7	11.6	1010	64.8	1.5	105	0.0
212	3/27/2011	(Winter)	9.3	16.3	1006	60.9	1.1	196	0.0
213	3/28/2011		7.2	13.7	1009	60.2	1.9	172	0.0
214	3/29/2011		9.6	18.5	1007	62.1	1.1	168	0.0
215	3/30/2011		12.6	15.9	1008	66.7	2.4	170	0.0
216	3/31/2011		13.8	15.6	1011	78.2	3.7	230	6.5
217	4/1/2011		13.9	18.8	1014	78.1	2.3	175	0.0
218	4/2/2011		17.6	24.3	1006	62.2	2.6	159	0.0
219	4/3/2011		10.9	15.8	1009	85.3	2.0	251	8.7
220	4/4/2011		10.0	15.0	1017	65.3	2.7	214	0.0
221	4/5/2011		11.8	15.1	1020	71.9	2.1	173	0.9
222	4/6/2011		16.2	23.0	1019	73.9	1.8	196	0.0
223	4/7/2011		13.8	21.6	1019	67.2	3.0	245	0.0
224	4/8/2011		12.9	18.2	1018	64.7	2.9	255	0.0
225	4/9/2011		11.3	18.9	1018	59.8	1.3	183	0.0
226	4/10/2011		14.0	23.1	1016	60.2	1.1	191	0.0
227	4/11/2011		16.0	25.0	1012	58.8	3.9	244	2.7
228	4/12/2011		7.7	12.4	1018	66.7	4.1	257	0.9
229	4/13/2011		10.1	14.3	1013	57.1	2.0	203	0.0
230	4/14/2011		8.0	14.2	1013	65.4	0.6	159	0.0
231	4/15/2011		10.4	17.0	1014	53.6	1.2	169	0.0
232	4/16/2011		11.9	16.9	1017	51.7	0.9	166	0.0
233	4/17/2011		11.4	19.2	1017	53.7	1.2	139	0.0
234	4/18/2011		14.3	21.2	1011	48.6	1.9	149	0.0
235	4/19/2011		15.5	25.5	1009	52.4	1.2	146	0.0
236	4/20/2011		16.6	25.7	1008	51.3	1.1	154	0.0
237	4/21/2011		17.8	26.3	1006	54.1	0.7	180	0.0
238	4/22/2011		20.0	27.8	1003	51.8	1.3	146	8.3
239	4/23/2011		18.0	28.9	1005	58.0	0.7	152	0.0
240	4/24/2011		18.1	28.0	1011	51.7	1.0	172	0.0

Annex 6 **Ambient conditions at the field test sites** **Page 9 of 11**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
241	4/25/2011	Cologne	16.8	26.0	1013	50.3	1.2	153	0.0
242	4/26/2011	(Winter)	16.7	23.4	1011	51.5	1.8	166	2.1
243	4/27/2011		10.8	12.5	1010	90.4	0.7	213	8.9
244	4/28/2011		14.2	20.5	1005	77.6	0.7	176	0.3
245	4/29/2011		17.2	24.9	1002	56.8	1.7	112	3.0
246	4/30/2011		16.9	24.2	1002	47.4	1.7	141	0.0
247	5/1/2011		14.8	22.4	1002	44.5	1.6	111	0.0
248	5/2/2011		11.0	17.8	1004	53.3	2.0	116	0.0
249	5/3/2011		10.0	17.2	1011	49.4	1.0	164	0.0
250	5/4/2011		9.7	16.2	1016	61.5	1.3	168	0.0
251	5/5/2011		14.1	19.8	1015	46.9	2.2	119	0.0
252	5/6/2011		18.6	24.8	1012	41.1	2.5	110	0.0
253	5/7/2011		21.9	28.3	1011	37.0	3.4	109	0.0
254	5/8/2011		22.1	28.6	1013	34.7	4.1	97	0.0
255	7/25/2011	Bornheim	17.2	22.8	1001	73.8	0.8	193	1.2
256	7/26/2011	(Summer)	17.0	20.6	1006	78.4	1.1	259	0.0
257	7/27/2011		17.3	24.3	1010	84.8	0.7	229	51.7
258	7/28/2011		17.7	24.5	1011	85.6	0.6	228	5.9
259	7/29/2011		16.9	20.2	1011	76.2	2.9	299	0.0
260	7/30/2011		14.5	16.1	1010	80.4	2.3	288	0.0
261	7/31/2011		13.4	16.6	1009	76.2	0.9	244	0.0
262	8/1/2011		19.1	26.1	1008	68.1	0.9	177	0.0
263	8/2/2011		23.2	30.0	1007	60.8	1.5	143	0.0
264	8/3/2011		19.7	24.1	1006	82.9	1.1	195	5.4
265	8/4/2011		22.3	29.2	1005	71.6	0.8	204	3.6
266	8/5/2011		20.6	25.0	1004	75.8	1.1	221	0.6
267	8/6/2011		19.3	25.4	996	85.0	1.4	171	7.7
268	8/7/2011		17.8	22.4	998	64.0	1.5	209	1.8
269	8/8/2011		15.5	18.4	1000	74.7	2.5	219	6.2
270	8/9/2011		13.8	17.8	1012	76.8	2.7	265	14.8

Annex 6 **Ambient conditions at the field test sites** **Page 10 of 11**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
271	8/10/2011	Bornheim	18.0	22.4	1013	57.5	1.3	224	0.0
272	8/11/2011	(Summer)	20.9	25.5	1004	53.8	1.2	220	0.3
273	8/12/2011		18.5	21.7	1003	78.9	1.1	228	2.1
274	8/13/2011		20.1	23.7	1001	77.0	0.7	185	0.0
275	8/14/2011		17.4	19.9	1000	86.2	1.1	219	17.4
276	8/15/2011		17.9	22.4	1009	71.8	1.2	230	0.0
277	8/16/2011		19.1	23.9	1010	69.0	0.7	190	0.6
278	8/17/2011		21.1	27.8	1007	73.8	0.7	206	4.7
279	8/18/2011		22.5	31.3	1004	76.6	1.2	174	20.9
280	8/19/2011		16.8	21.2	1011	80.0	1.5	235	3.3
281	8/20/2011		20.7	28.1	1011	66.6	0.8	157	0.0
282	8/21/2011		23.2	31.4	1007	74.8	1.0	184	0.3
283	8/22/2011		20.4	24.4	1009	76.5	1.2	253	0.0
284	8/23/2011		22.6	27.8	1005	78.4	0.9	206	0.0
285	8/24/2011		20.1	27.2	1007	76.6	0.7	192	0.6
286	8/25/2011		20.8	27.6	1003	83.4	1.0	176	2.1
287	8/26/2011		19.4	30.2	999	83.7	1.5	195	29.1
288	8/27/2011		15.3	20.0	1007	77.0	1.1	207	0.3
289	8/28/2011		15.6	19.7	1009	69.2	1.3	212	0.0
290	8/29/2011		14.5	18.4	1008	66.7	2.0	243	0.0
291	8/30/2011		13.6	18.4	1008	73.6	0.8	236	0.0
292	8/31/2011		14.8	21.4	1007	72.0	0.7	225	0.0
293	9/1/2011		16.4	23.4	1006	71.6	0.6	182	0.0
294	9/2/2011		21.2	29.4	1004	72.2	0.8	160	0.0
295	9/3/2011		24.5	30.9	1002	67.0	1.3	132	3.6
296	9/4/2011		20.2	27.4	1002	79.5	1.1	223	0.6
297	9/5/2011		16.6	21.4	1009	62.9	1.9	217	0.0
298	9/6/2011		17.4	20.6	1005	66.8	2.6	219	4.8
299	9/7/2011		14.9	18.1	1004	73.1	2.2	246	5.7
300	9/8/2011		14.7	16.2	1003	84.7	1.1	209	3.3

Annex 6 — Ambient conditions at the field test sites — Page 11 of 11

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
301	9/9/2011	Bornheim	19.0	21.6	1004	86.9	0.4	167	0.0
302	9/10/2011	(Summer)	23.8	29.7	1001	73.0	1.5	155	0.0
303	9/11/2011		16.2	22.1	1003	86.0	0.7	165	16.2
304	9/12/2011		19.4	24.6	1004	71.1	1.7	204	0.0
305	9/13/2011		16.7	20.8	1006	67.3	1.6	219	0.0
306	9/14/2011		15.2	19.6	1011	65.1	1.5	224	0.0
307	9/15/2011		14.1	20.4	1013	75.3	0.6	207	0.0
308	9/16/2011		17.1	21.9	1006	72.6	1.4	145	0.0
309	9/17/2011		16.8	21.4	1001	70.6	1.0	207	3.6
310	9/18/2011		13.3	16.5	998	76.4	1.0	200	4.5
311	9/19/2011		13.6	18.1	1008	75.8	1.4	231	0.9
312	9/20/2011		15.6	18.5	1014	78.0	0.5	196	0.0
313	9/21/2011		16.9	20.5	1011	69.5	0.8	204	0.0
314	9/22/2011		15.2	18.7	1011	72.2	1.2	231	0.0
315	9/23/2011								
316	9/24/2011								
317	9/25/2011								
318	9/26/2011				Outage of weather station				
319	9/27/2011								
320	9/28/2011								
321	9/29/2011								
322	9/30/2011		18.4	26.8	1017	68.3	1.2	155	0.0
323	10/1/2011		18.1	28.0	1018	70.6	0.5	176	0.0
324	10/2/2011		17.8	26.8	1016	75.4	0.3	213	0.0
325	10/3/2011		18.8	26.5	1013	65.9	0.8	168	0.0
326	10/4/2011		17.8	20.5	1013	72.4	1.6	214	0.0
327	10/5/2011		17.5	20.0	1011	70.8	1.2	199	0.0
328	10/6/2011		13.2	19.3	1001	71.2	2.3	213	0.3

Appendix 2

Filter weighing procedure

A) German test sites (Cologne and Bornheim)

A.1 Carrying out the weighing

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

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.

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 75). 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 76 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 °C or less. The filters are stored at 7 °C in a refrigerator.

A2 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:

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

$MKon_{pre}$ = 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 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.

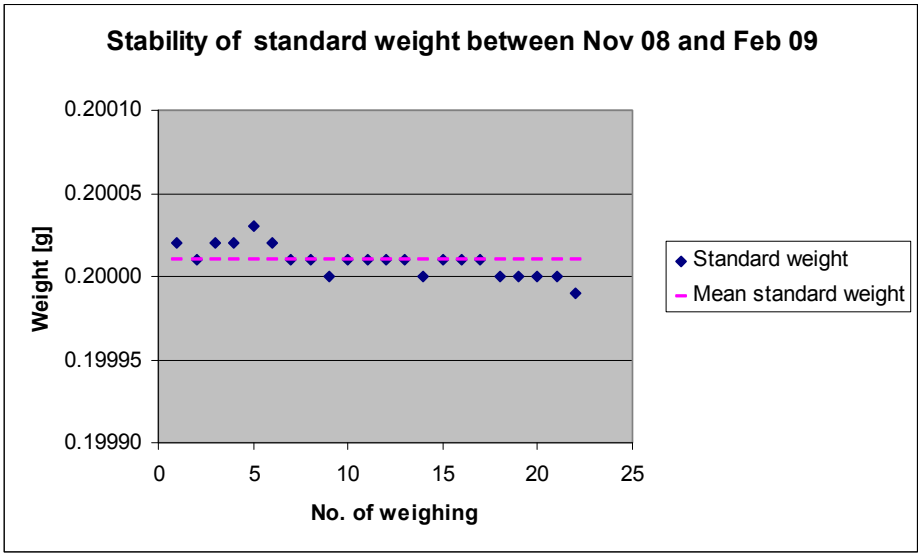


Figure 75: Stability of standard weight

Table 35: Stability standard weight

Date	Weighing No.	Standard weight	Difference to the previous weighing
		g	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

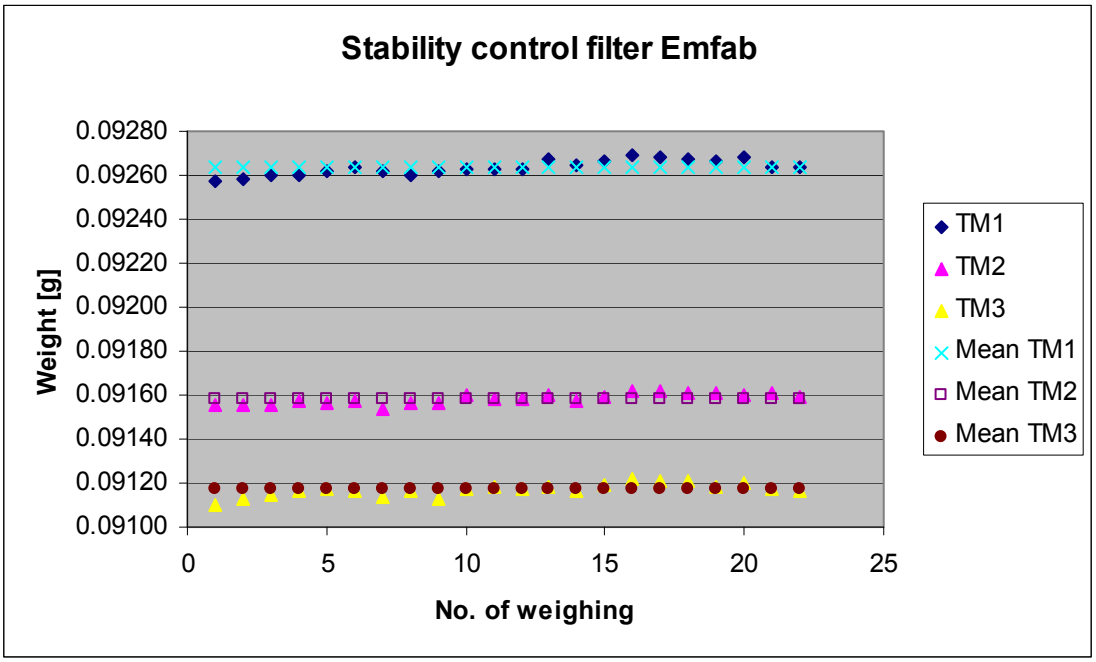


Figure 76: Stability of the control filters

Table 36: 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
rel. 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) UK test site (Teddington)

B.1 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) °C and (50 ± 5) %; and filters were weighed twice before and after sampling. Table 37 summarizes the conditioning and weighing timescales utilised:

Table 37: 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, 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 A.1** below:

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

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 A.2** below:

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

Where:

m_{filter} = Mass of sample filter

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

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

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:

$$S_{Pre} = RM_{Anf1} - RM_{Anf2} \qquad \textbf{E A.4}$$

$$S_{Post} = RM_{End1} - RM_{End2} \qquad \textbf{E A.5}$$

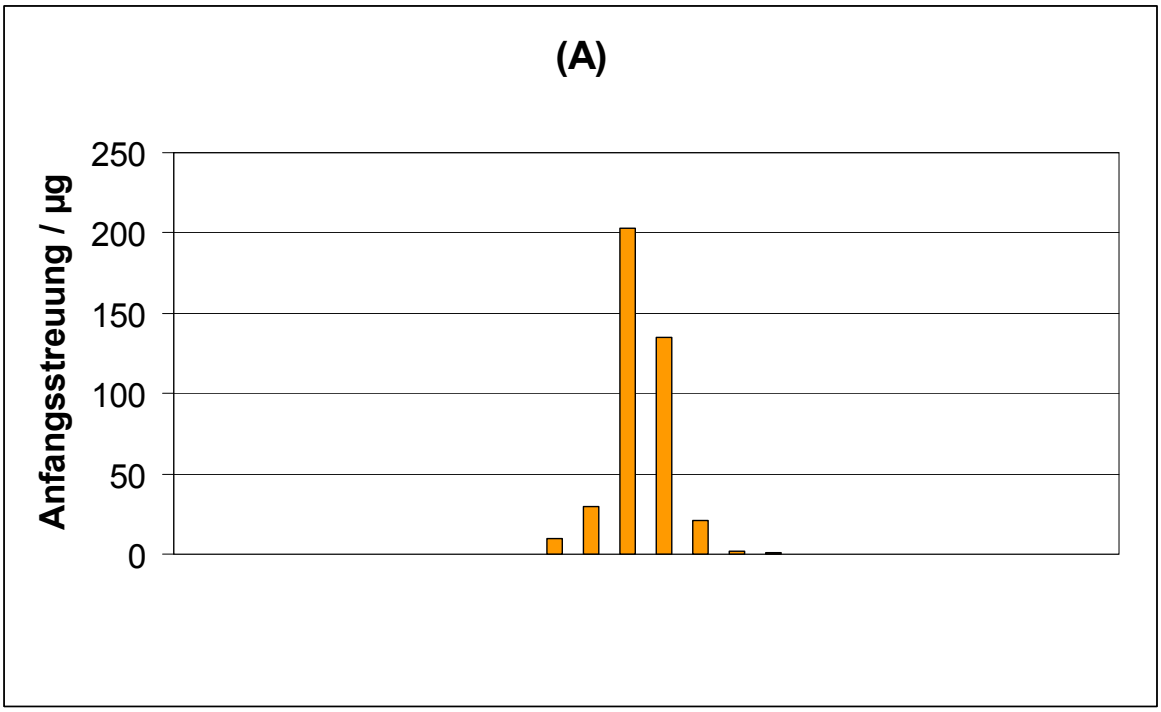
$$S_{Blank} = \left(\frac{CM_{End2} + CM_{End1}}{2}\right) - \left(\frac{CM_{Anf2} + CM_{Anf1}}{2}\right) \qquad \textbf{E A.6}$$

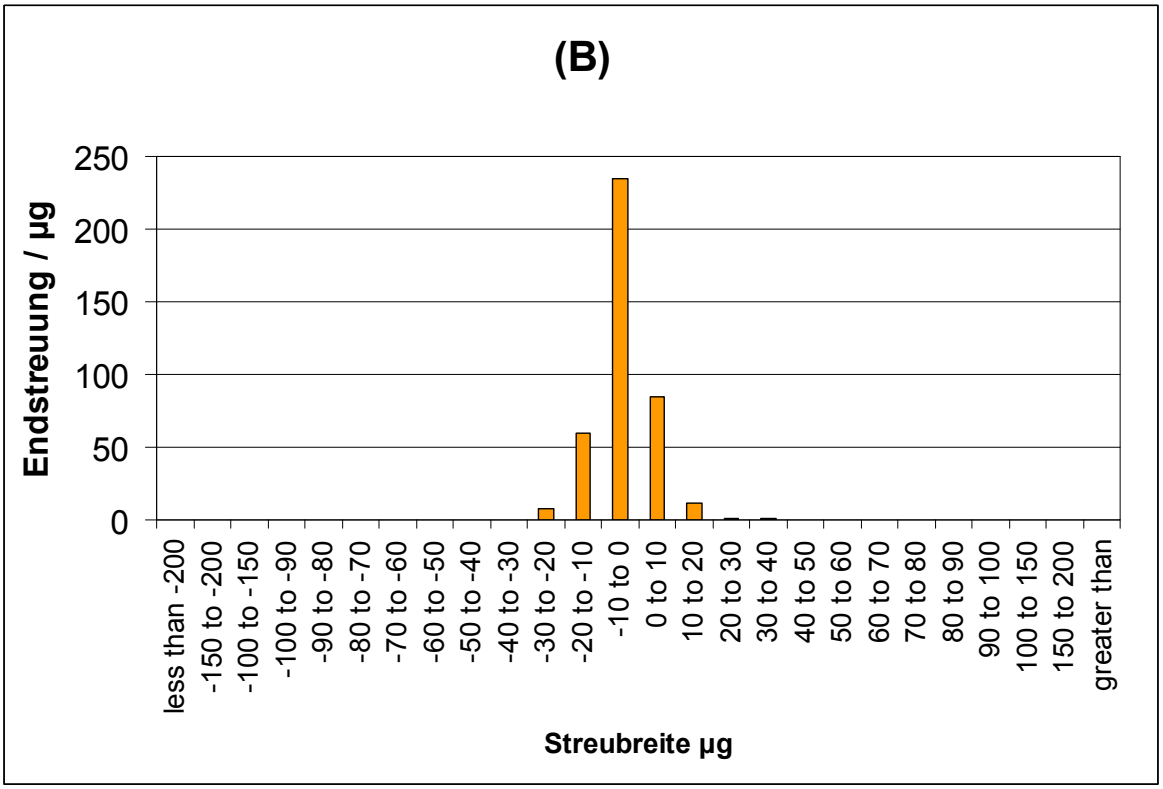
As with the UK PM Equivalence Report [11], it was not possible to weigh all filters within the 15 day timeframe suggested in EN14907. However, as filters were removed immediately from the reference samplers and placed in the refrigerator, it was not necessary to determine if $T_{Ambient}$ exceeded 23 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.

A.2 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 77. 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 77: Distribution for Emfab filters of (**A**) Pre spread weighed relative to the check weight and (**B**) Post spread weighed relative to the check weight.





Appendix 3

Manuals

TEOM® 1405-F

Ambient Particulate Monitor

with FDMS® Option

42-010978 Revision A.000 22Sep2009

Thermo SCIENTIFIC

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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

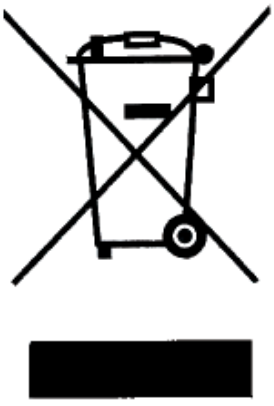
The product has been tested and has been documented to be in compliance with the following U.S. and Canadian safety standards:

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.



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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

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Section 1 Introduction

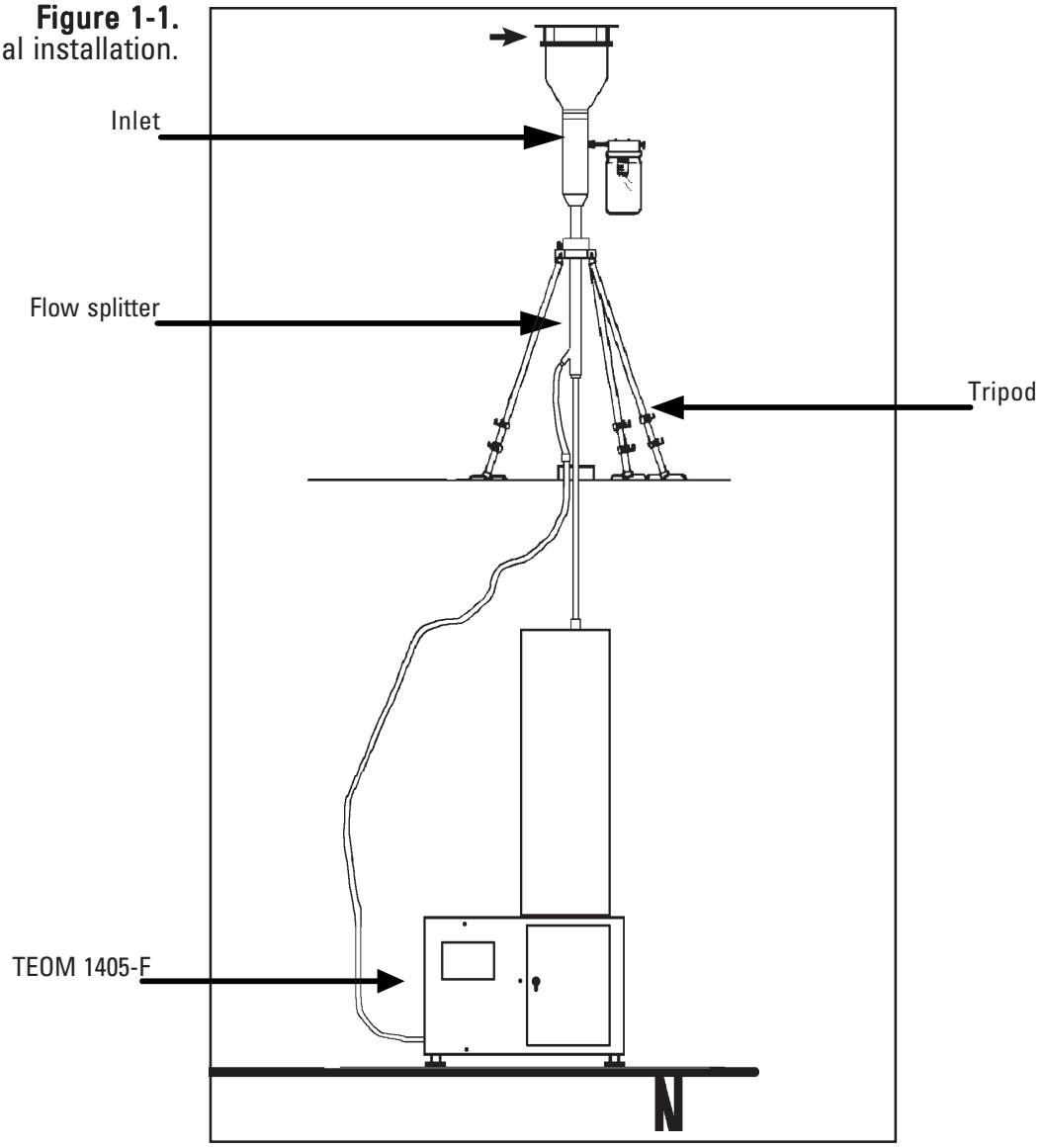
The TEOM® 1405-F Ambient Particulate Monitor with FDMS is a mass measurement monitor that incorporates the patented Tapered Element Oscillating Microbalance (TEOM) to measure particulate matter mass concentrations continuously. The TEOM 1405-F Monitor is a true "gravimetric" instrument that draws ambient 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 $\mu g/m^3$ 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 ($\mu g/m^3$) 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:

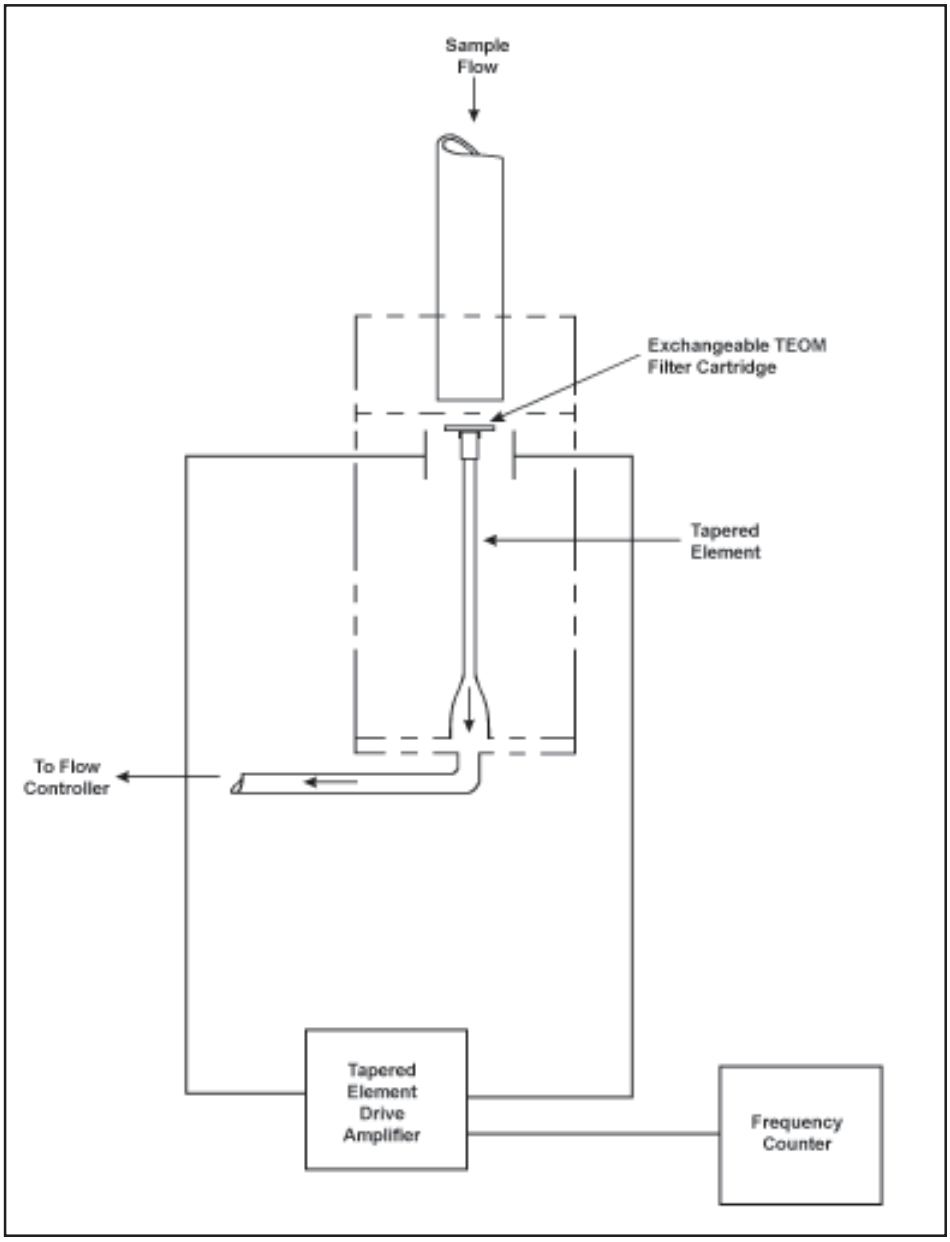
- Base mass concentration (Base MC) = PM concentration of the particle-laden sample stream.
- Reference mass concentration (Ref MC) = PM concentration of the particle-free sample stream, after passing through the chilled filter.
- Mass concentration (MC) = Base mass concentration (Base MC) adjusted by 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 $\mu g/m^3$ (Base MC = 5). Then the unit draws a reference flow for six minutes and measures a mass concentration of -1 $\mu g/m^3$ (Ref MC = -1). Therefore, the mass concentration is 6 $\mu g/m^3$

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:

$$FlowSP_{Passive} = FlowSP_{Vol} \times \frac{P_{AVG}}{P_{STD}} \times \frac{Temp_{STD} + 273.15}{Temp_{AVG} + 273.15}$$

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.

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

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

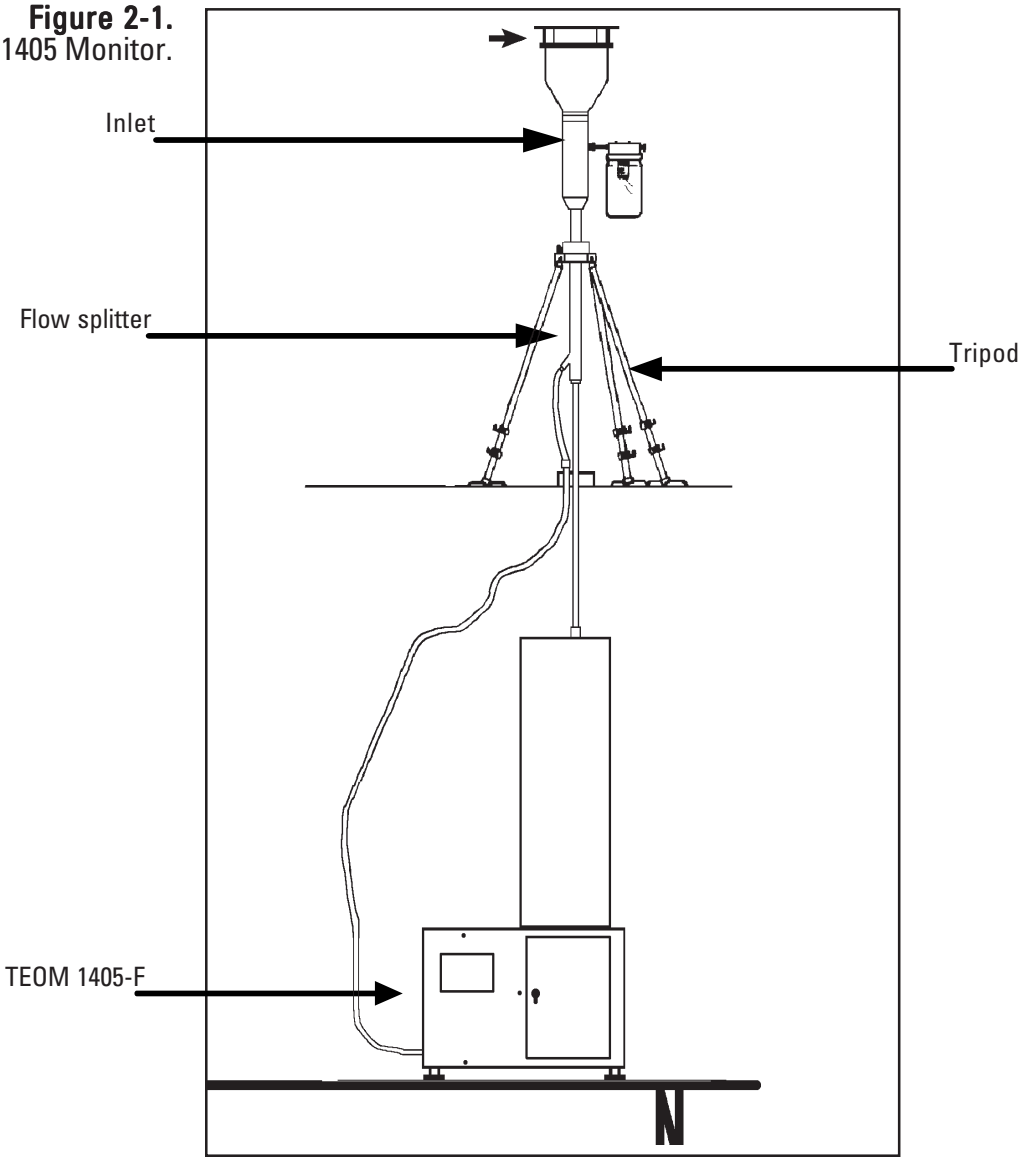
Note. When reporting concentrations to actual conditions, the system must be set for "Active" flow control (Section 4). This will ensure that the monitor uses the current actual values for temperature and pressure in the equation above. ▲

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

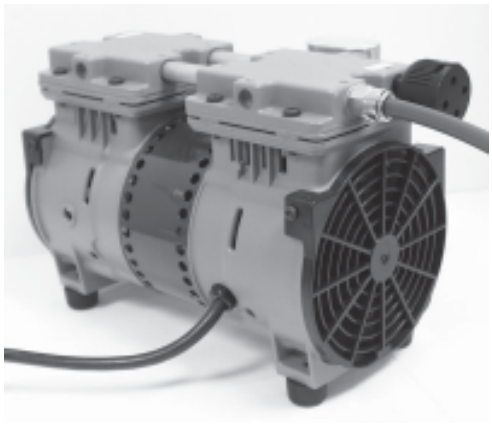
Pump Connections

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.)

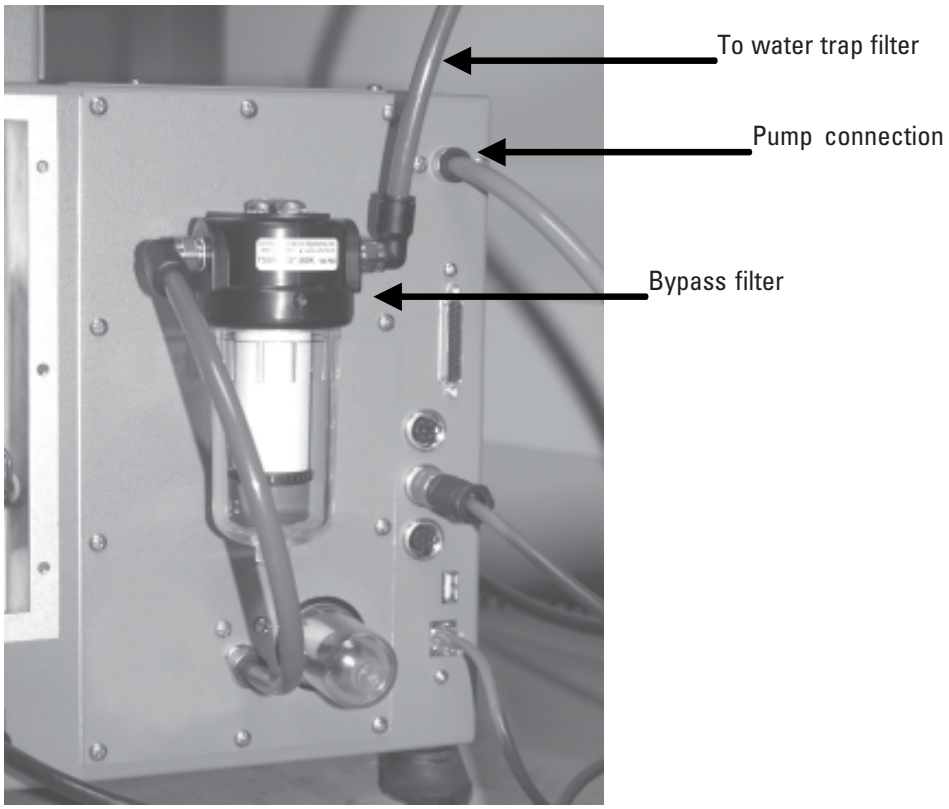
2. Locate the sample pump in a location to minimize vibrations effecting the instrument. Push the one end of the 5m pump tubing into the fitting on the vacuum pump (Figure 2-2).

Figure 2-2.
Vacuum pump.



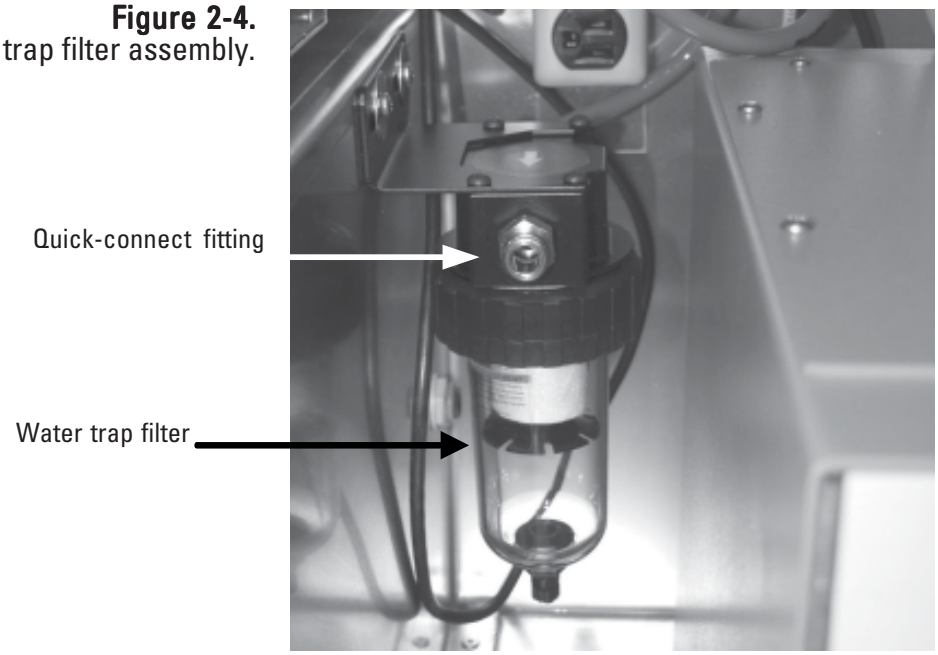
3. Push the other end of the 5m length of pump tubing into the pump connection on the back of the TEOM 1405 unit (Figure 2-3).

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.

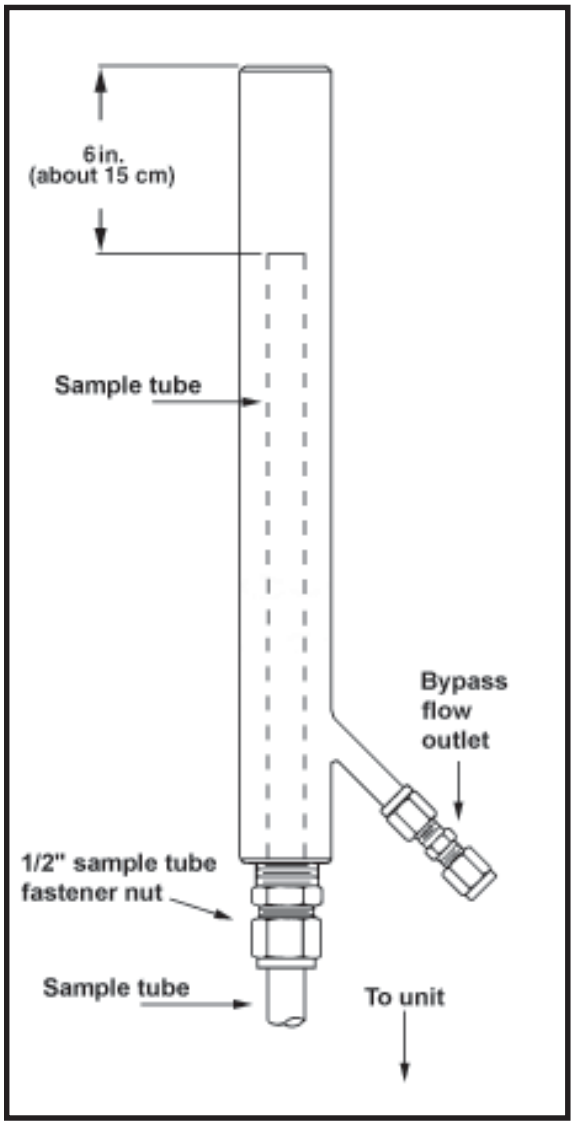
Note. The other end of the bypass tubing will be connected to the bypass connection on the flow splitter when you assemble and install the sample inlet (following section). ▲

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.

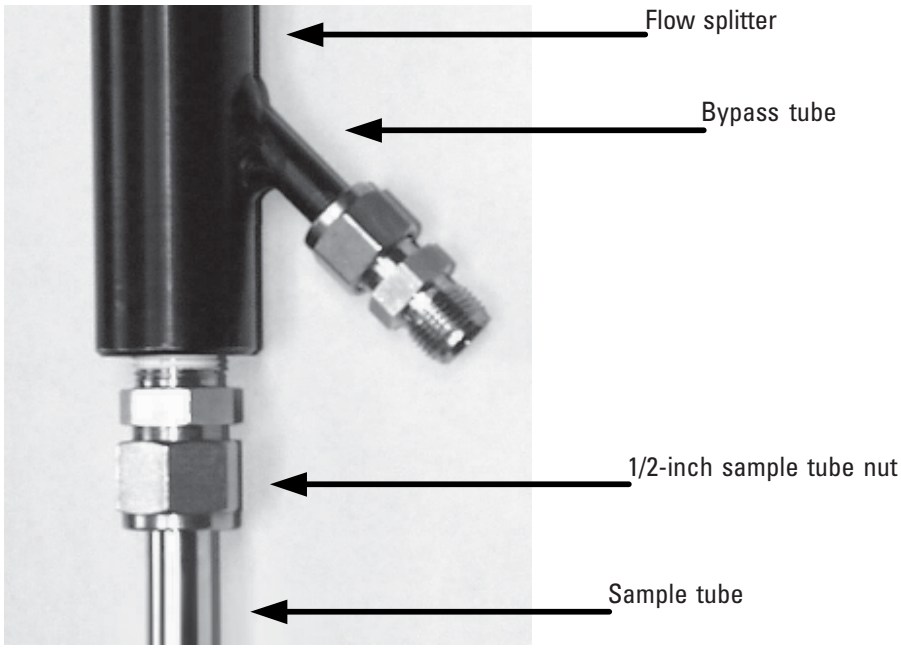
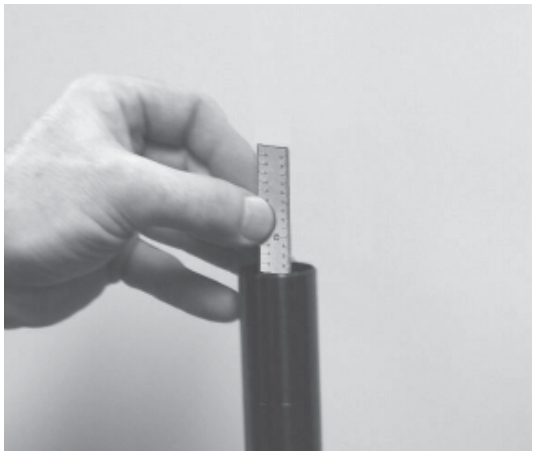


Figure 2-7.
Measuring the distance from the top of the sample tube to the top of the flow splitter.



Assembling the Tripod

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

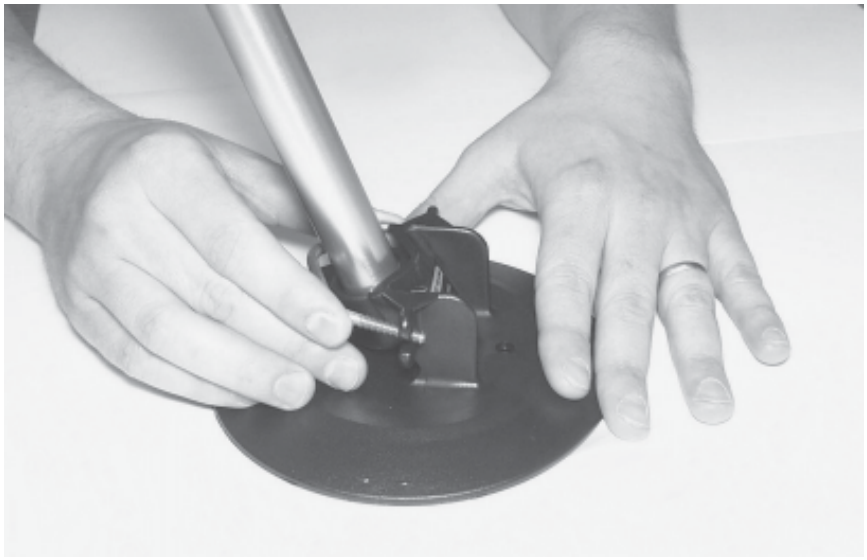
To assemble the tripod:

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.

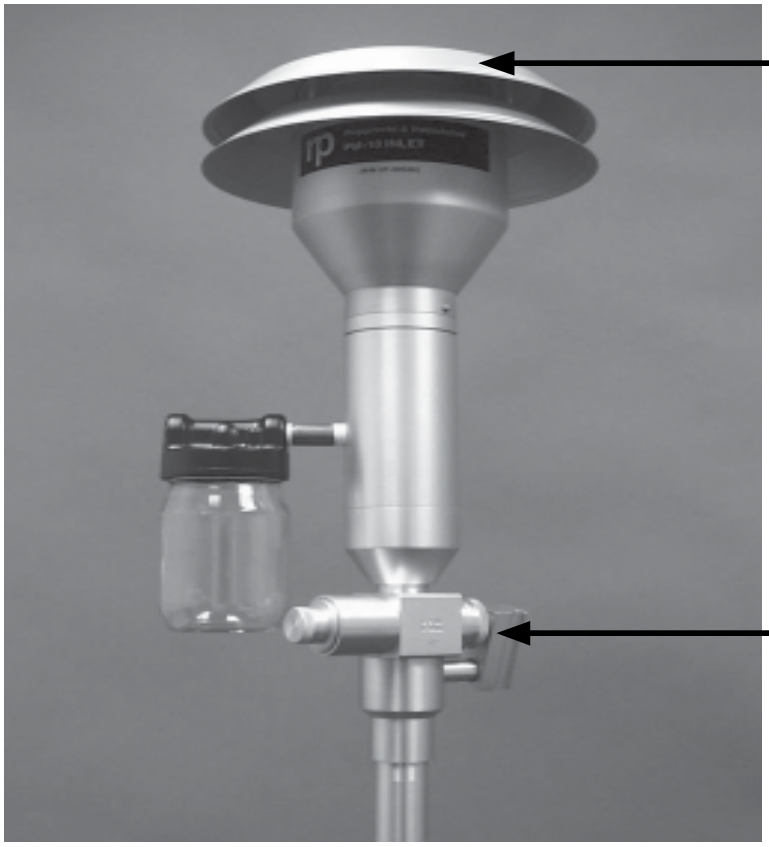
   Note. Hand-tighten both nuts on the bracket before tightening them with the wrench to ensure that the bracket is positioned properly on the tripod leg and tripod foot. ▲

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.



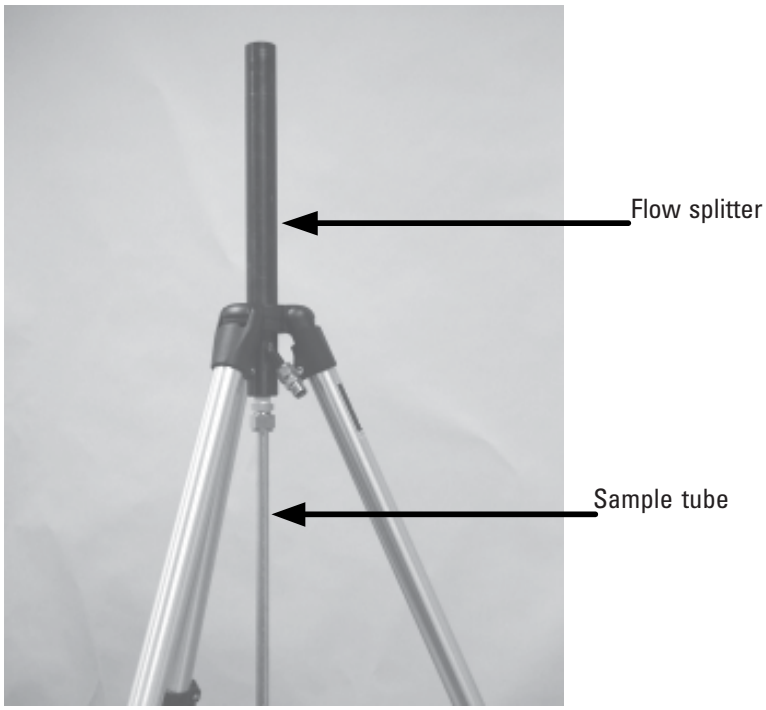
To install the inlet :

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.



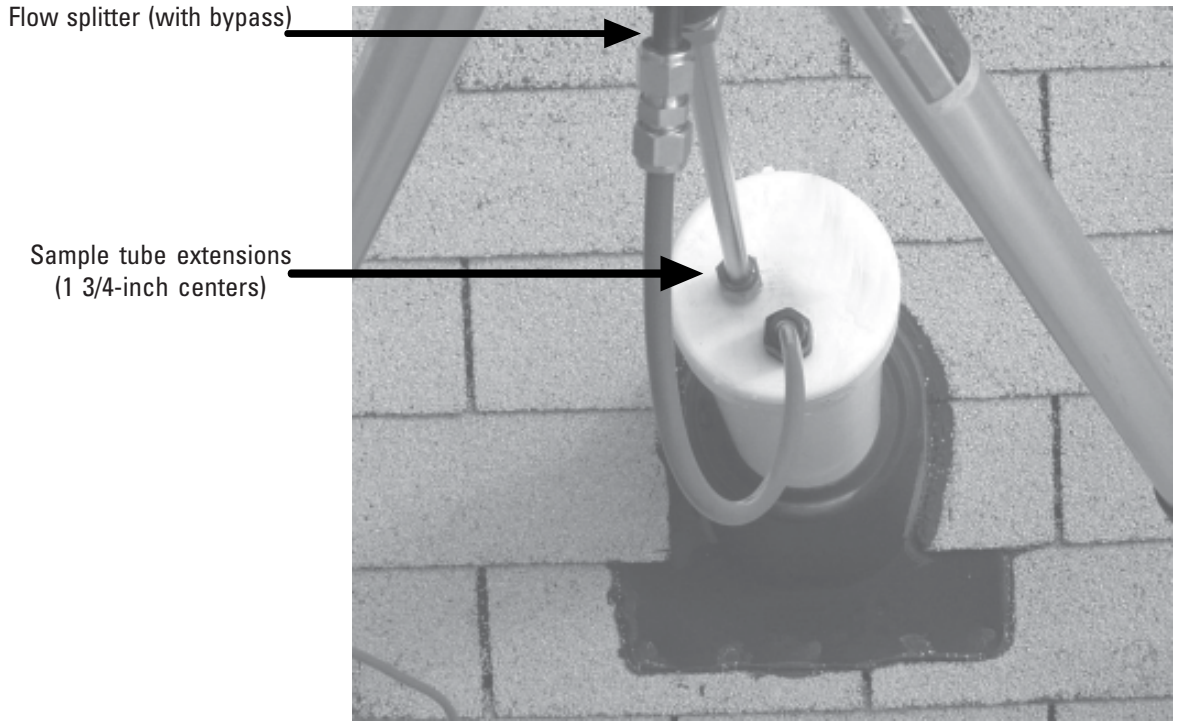
3. Measure and mark a spot in the roof directly above the 1/2-inch sample line on the top of the instrument.

   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.

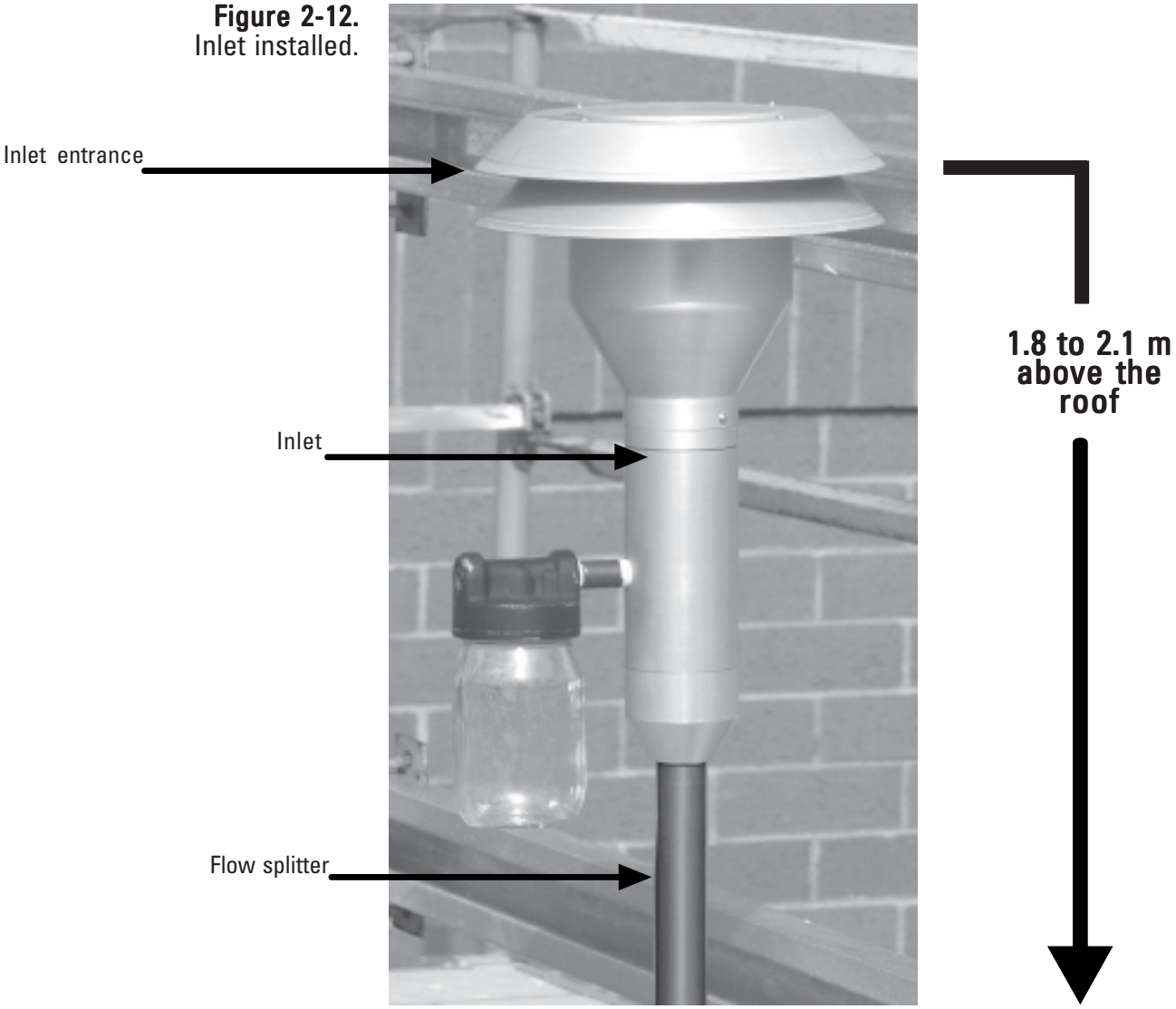
Figure 2-11.
Installing the sample tubes and bypass line through the roof.



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.

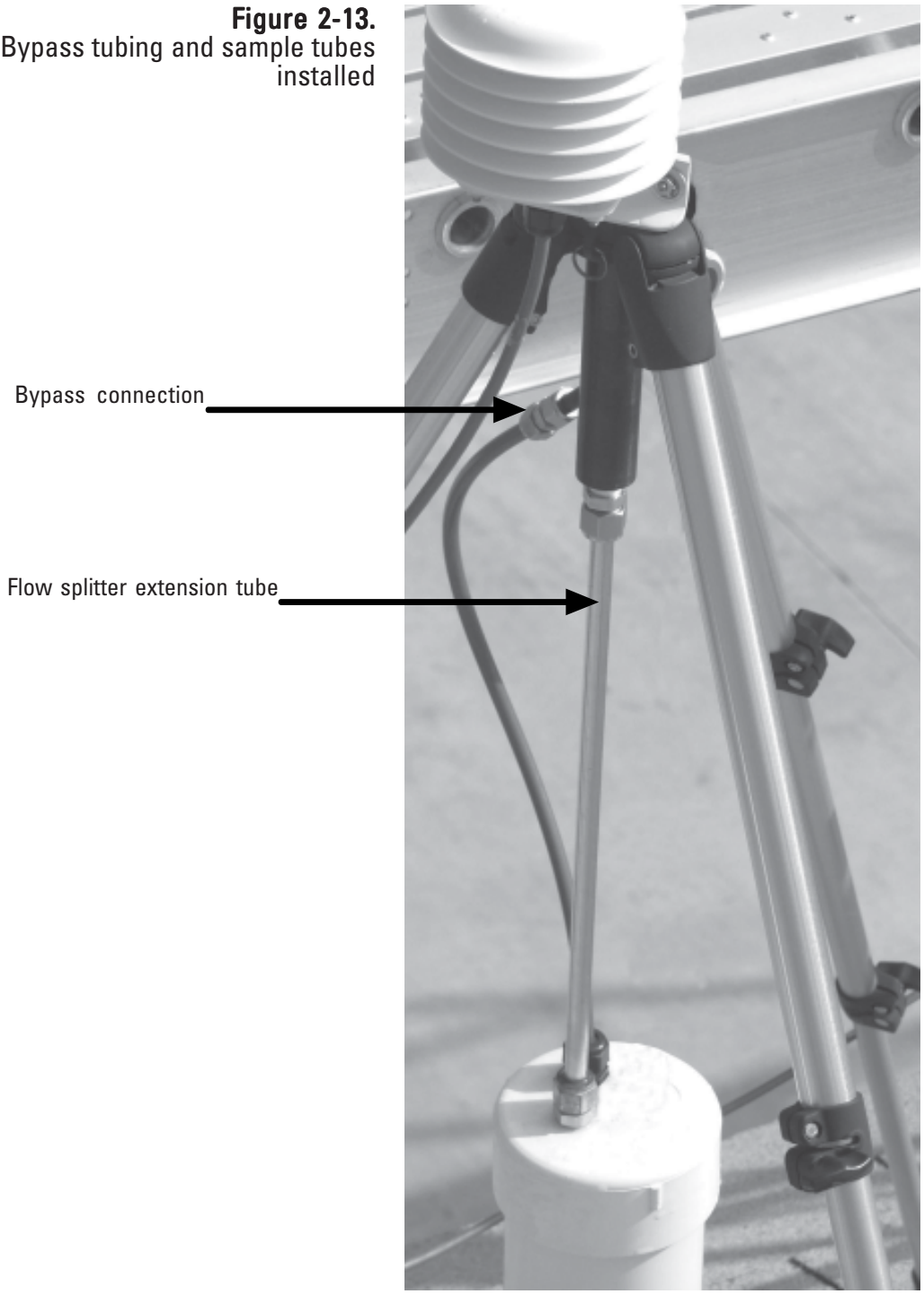


7. Center the tripod over the roof hole. Measure and cut the sample tube extensions from the top of the instrument, through the roof and connect to the flow splitter sample tube. Make sure to clean and deburr the cut ends of the sample tube extensions.

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.

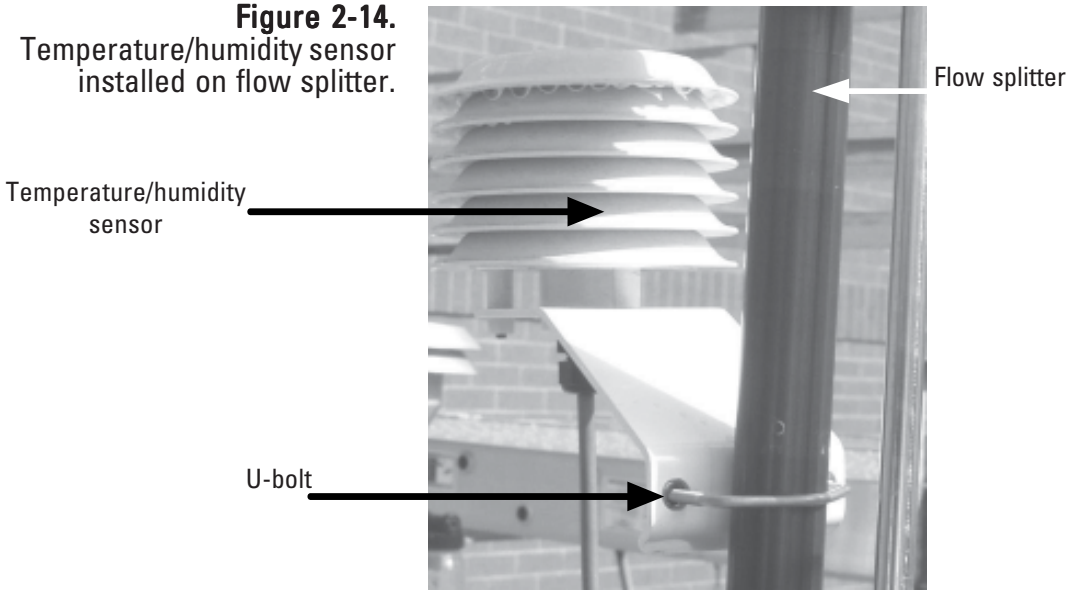
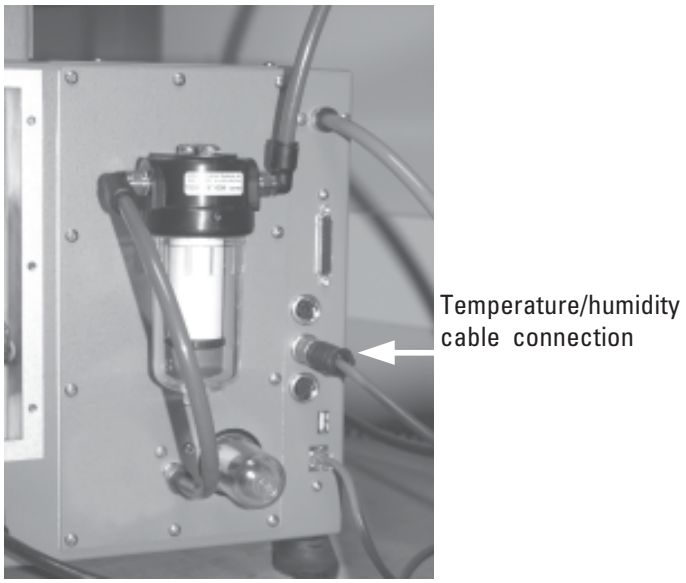


Figure 2-15. Temperature/humidity sensor connection of the back of the Series 1405 unit.



Applying Power to the Instrument

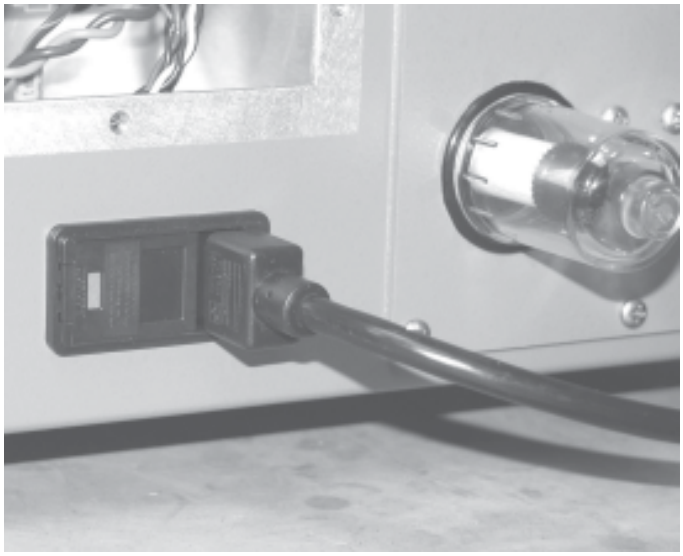
The TEOM 1405-F unit accepts all voltage inputs between 85 and 240 volts AC. The unit should be connected to an appropriate, code-approved electrical outlet for the sampler location. Contact a qualified electrician if there is doubt as to whether the power service for the instrument is adequate.

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.

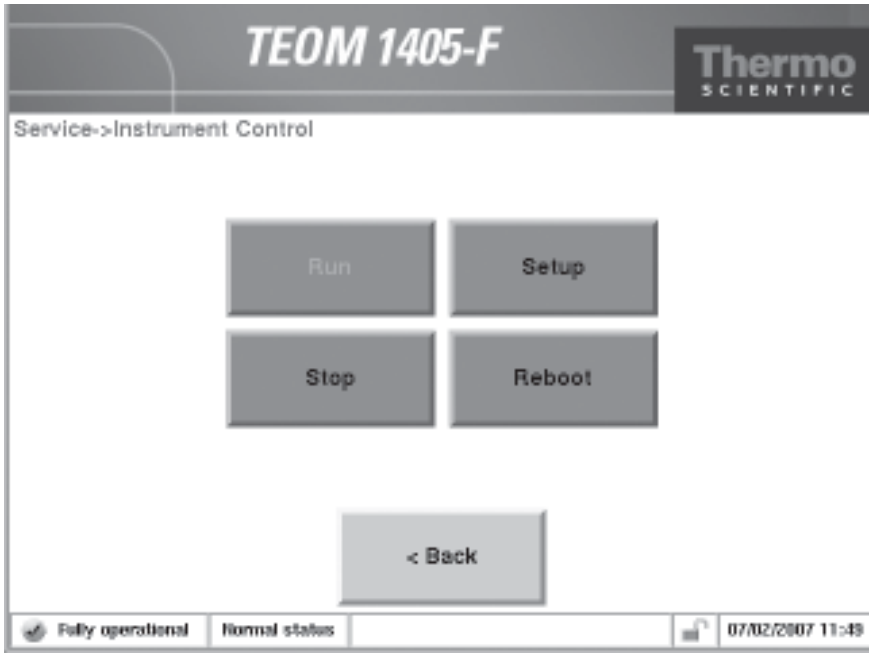
Restarting the Instrument

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.

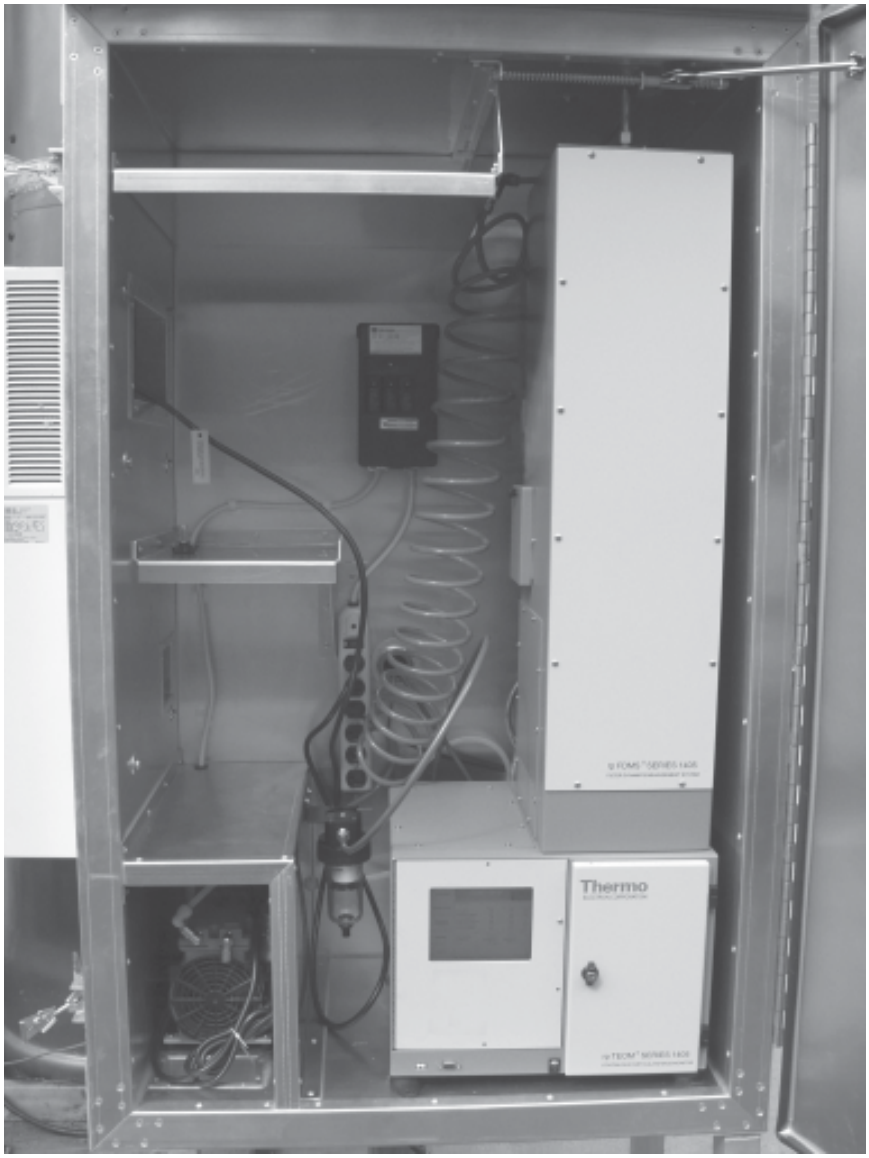
Figure 2-18. Instrument Control screen.



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.

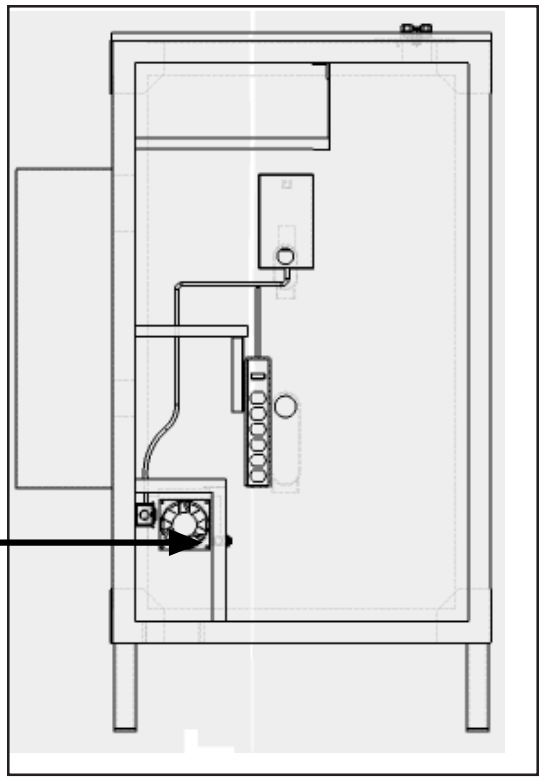
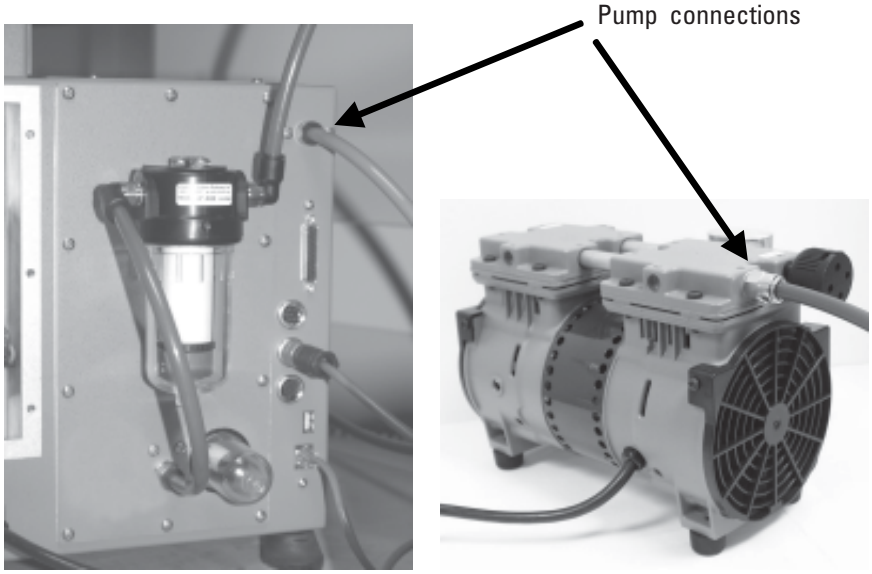


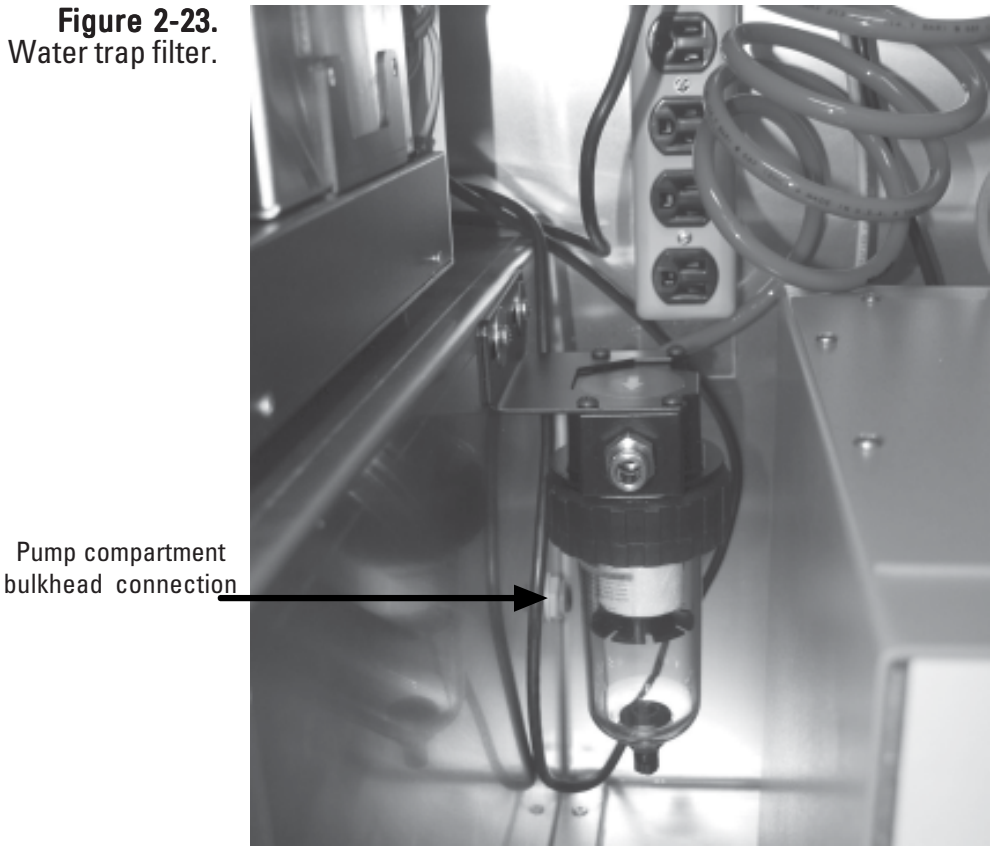
Figure 2-21 (left). Back of the 1405 unit.

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. ▲

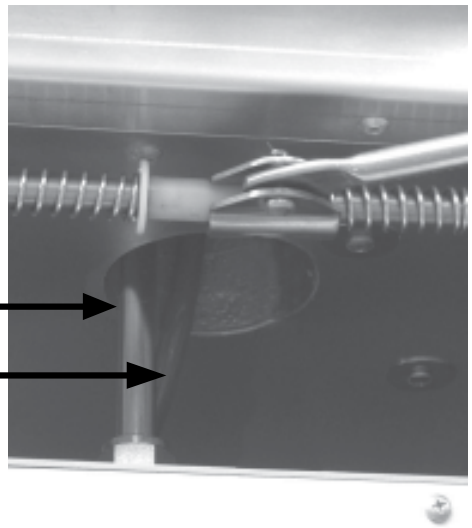
9. Ensure that the sample tube is properly installed in the flow splitter (refer to "Adjusting the Flow Splitter" earlier in this section).

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. ▲

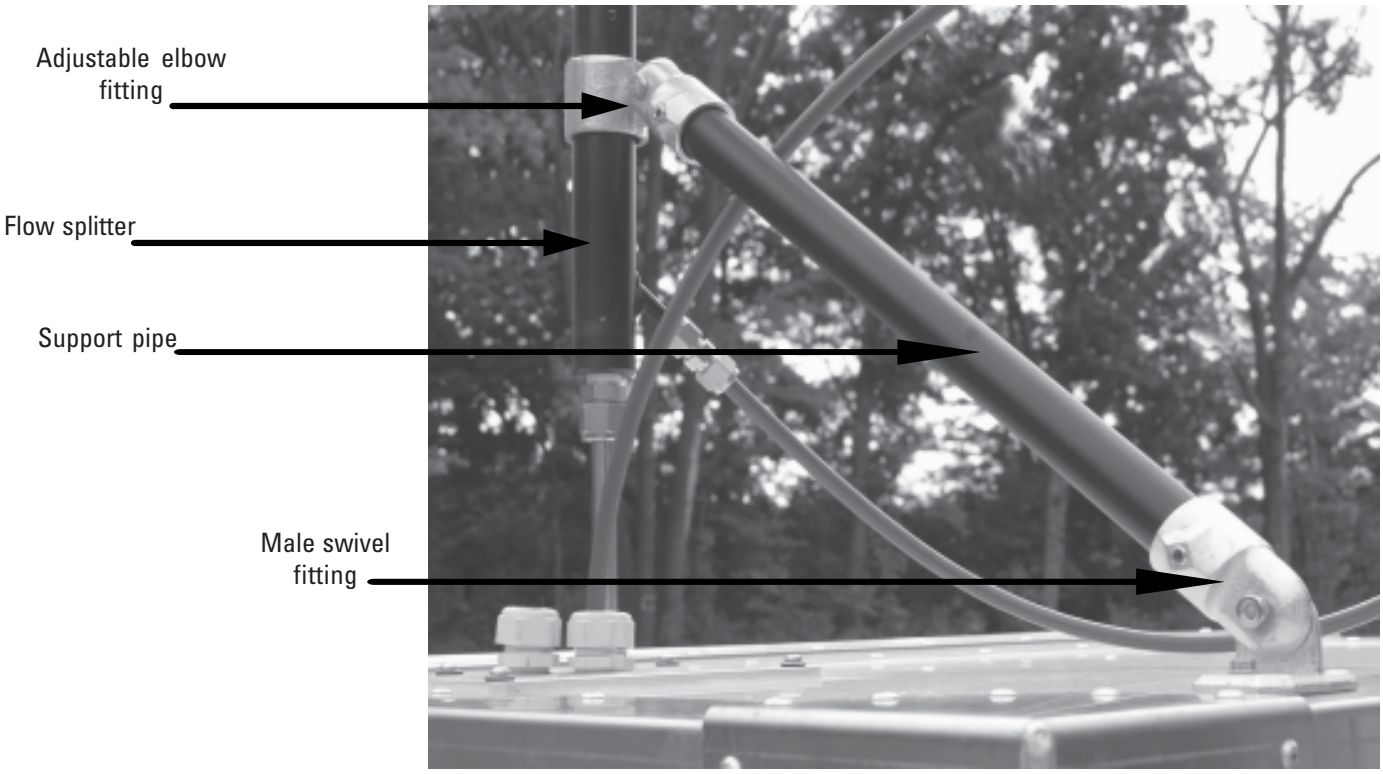
Figure 2-24 (left). Sample connections inside enclosure.

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



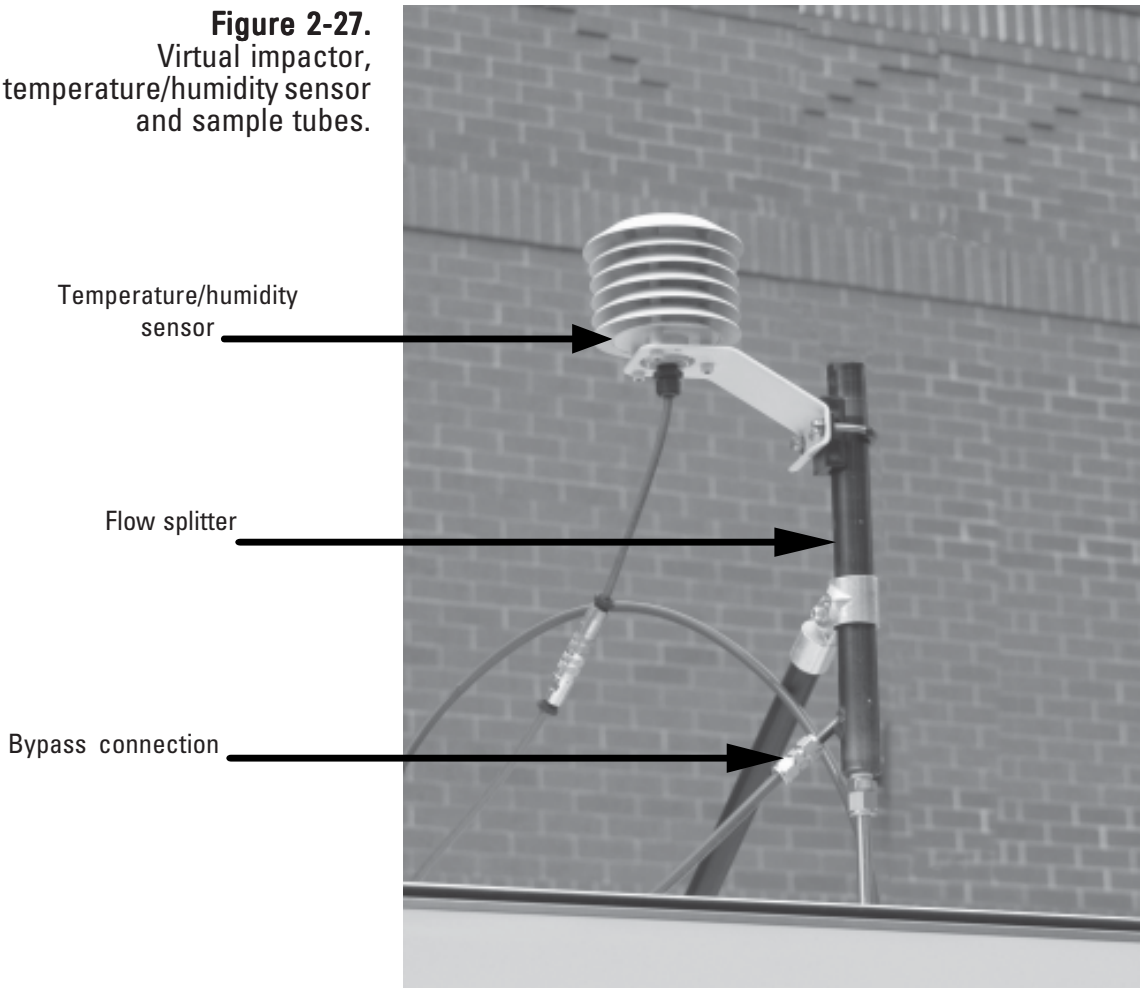
11. Install the adjustable elbow fitting and male swivel fitting from the enclosure package onto the piece of 19-inch section of pipe that came with the enclosure. Lightly tighten the screws. Install the elbow fitting and support pipe onto the flow splitter and enclosure top (Figure 2-26). Slide the 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.

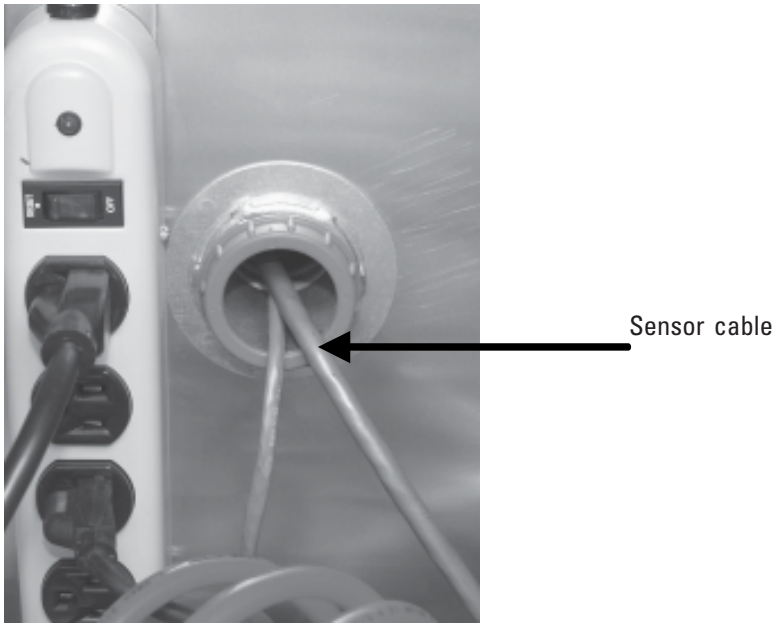
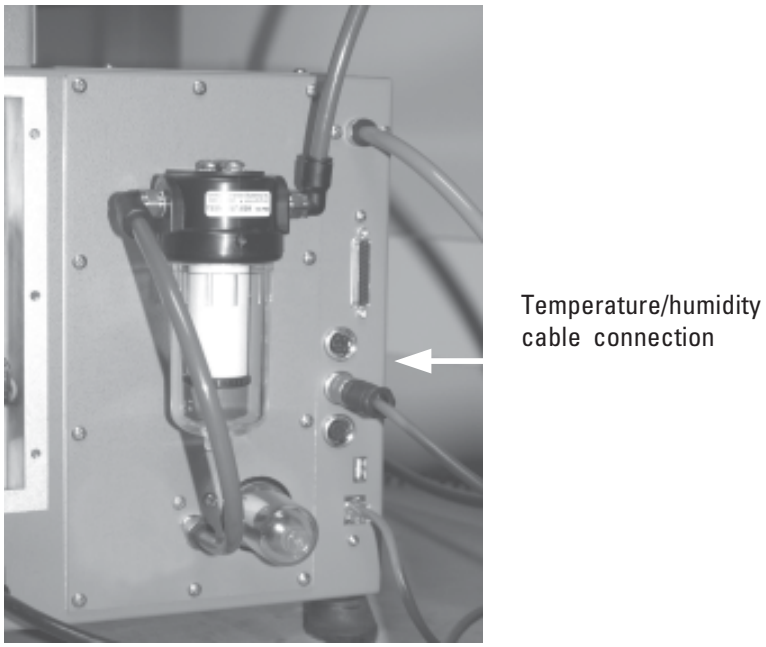


Figure 2-29. Temperature/humidity sensor connection of the back of the TEOM 1405-F unit.



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. ▲

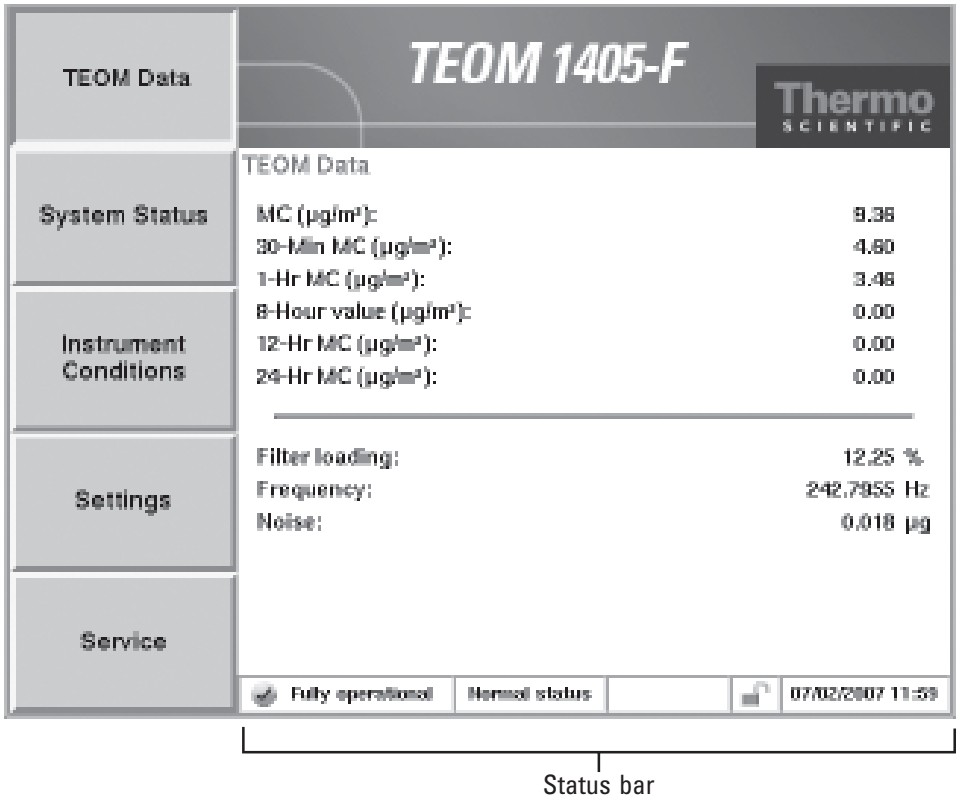
Figure 2-30. Outdoor enclosure with inlet installed.

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.

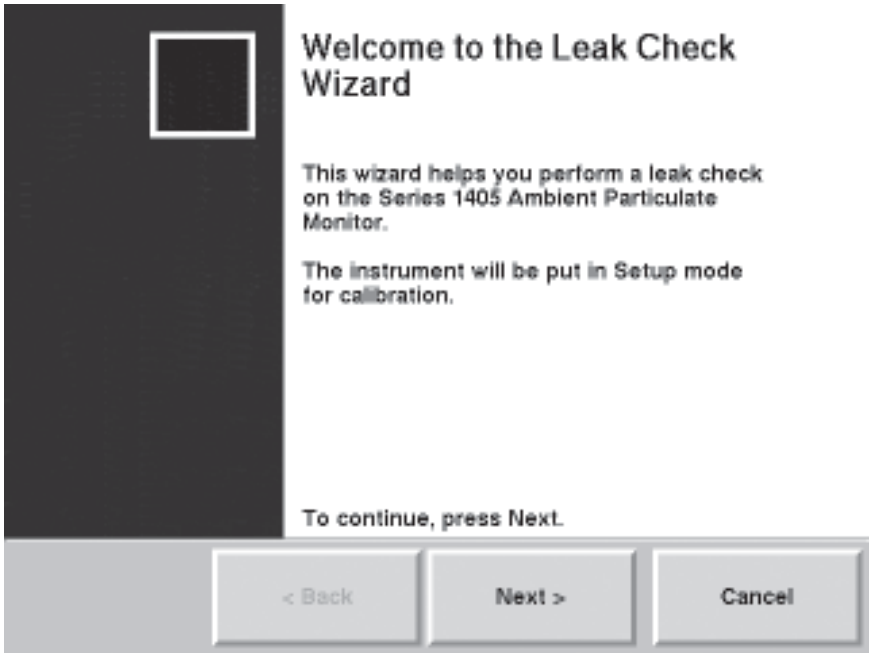
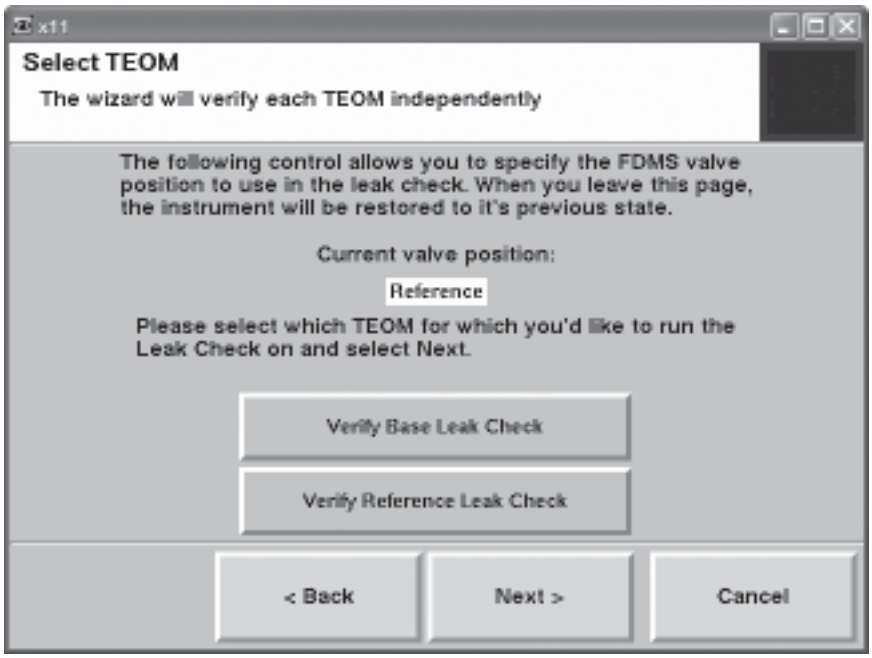


Figure 3-2. Leak Check Wizard start screen.

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. ▲

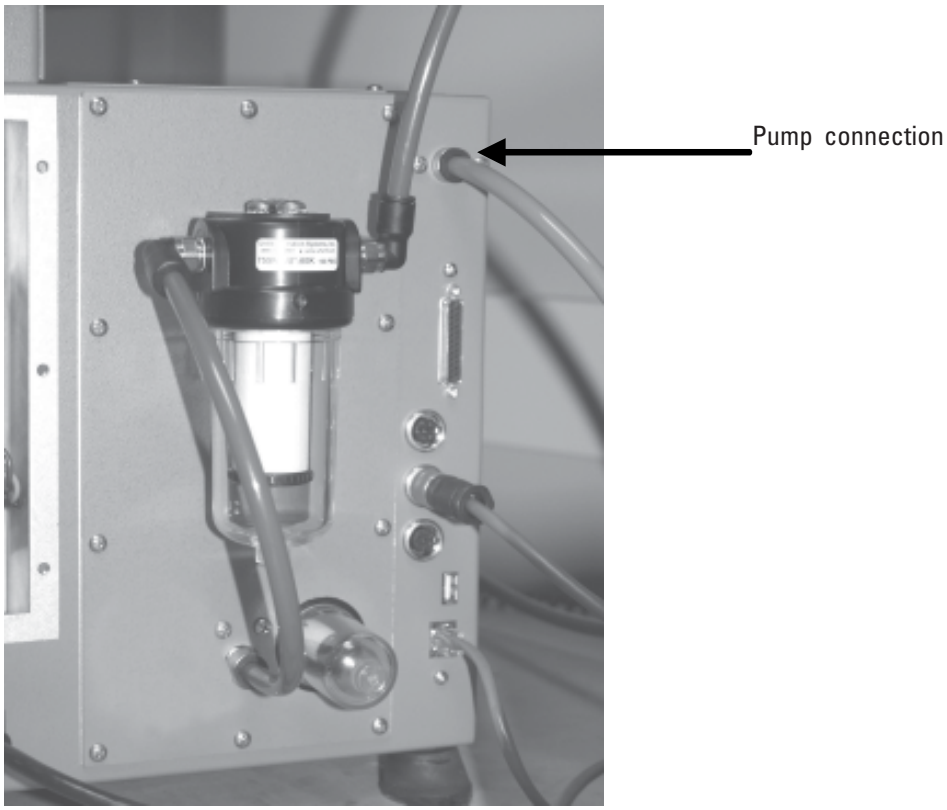
Figure 3-3. Leak Check Wizard screen with current valve position select.



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.

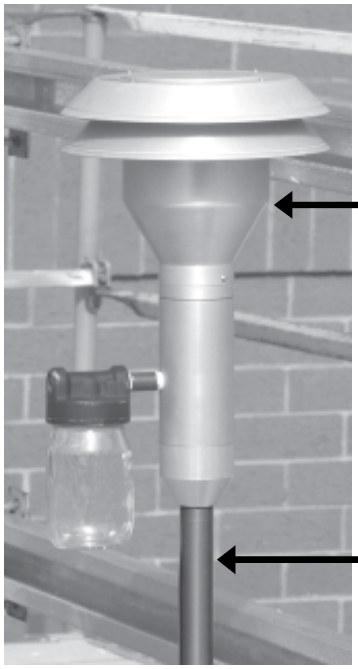
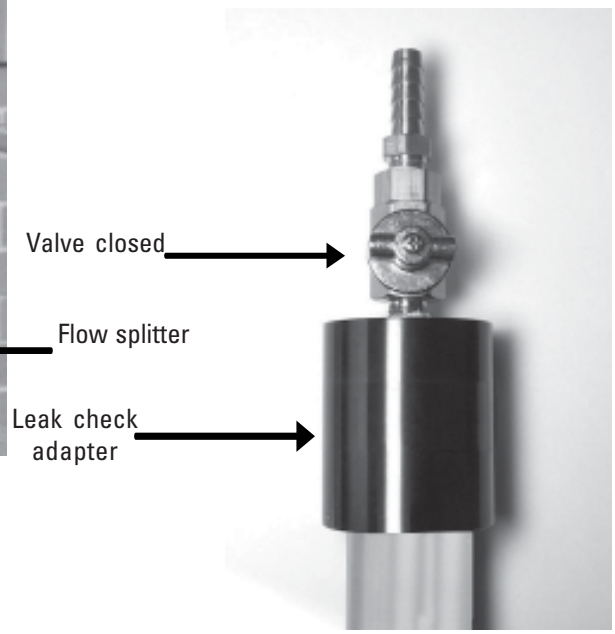


Figure 3-6.
Leak check adapter.



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.

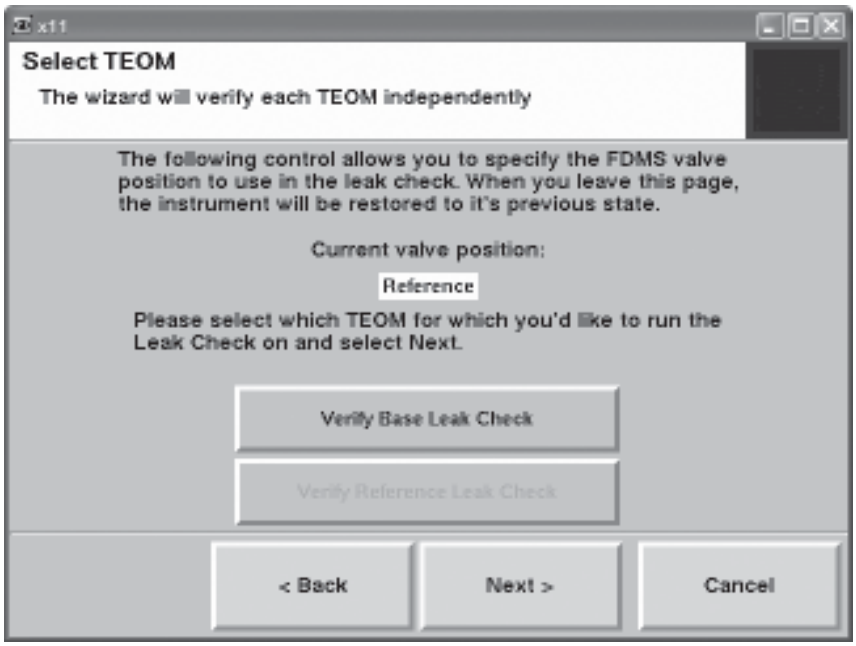
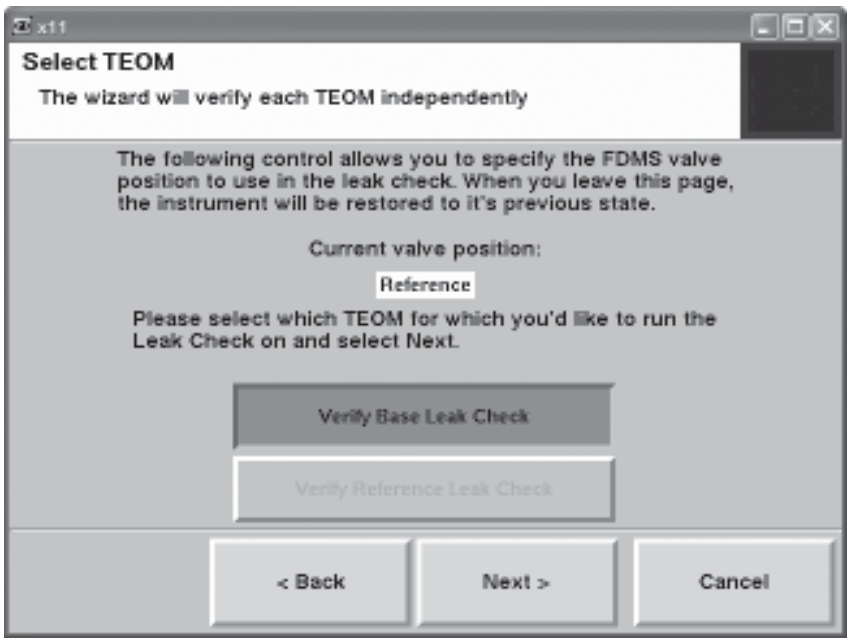


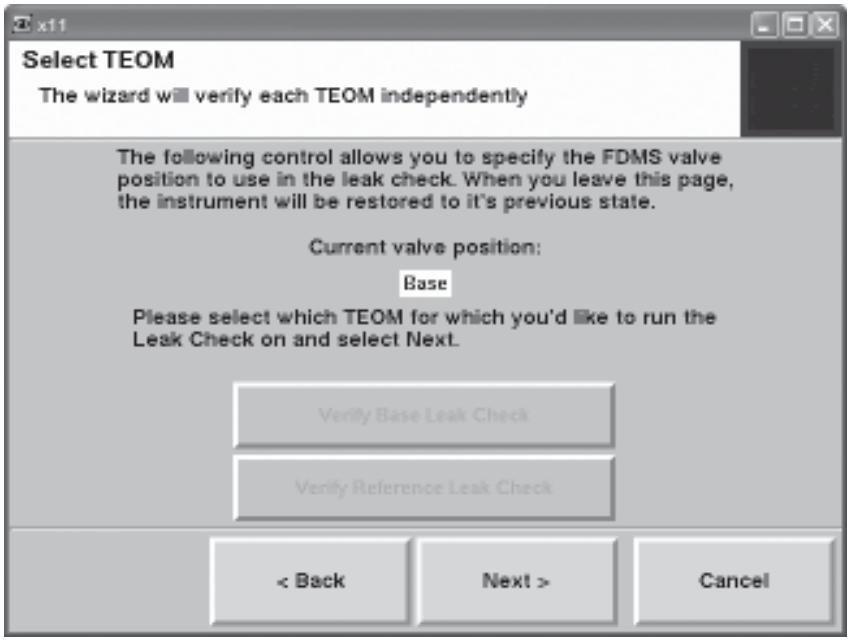
Figure 3-8.
Leak Check Wizard screen with second valve position.



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.

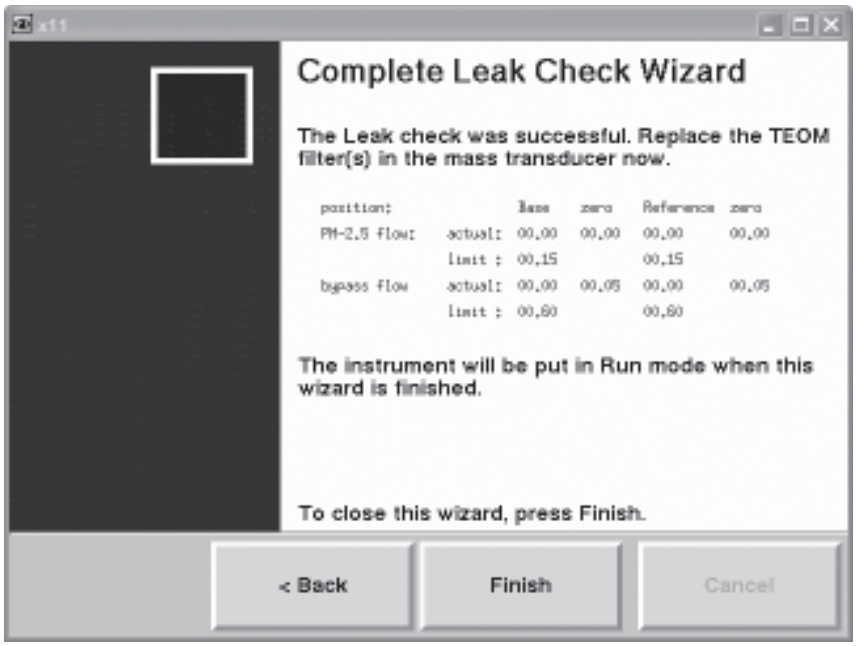
After completing the leak check with the FDMS in both the base and reference positions, the select valve position screen will again appear, but this time with both valve positions desabled. Select the **Next >** button.

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



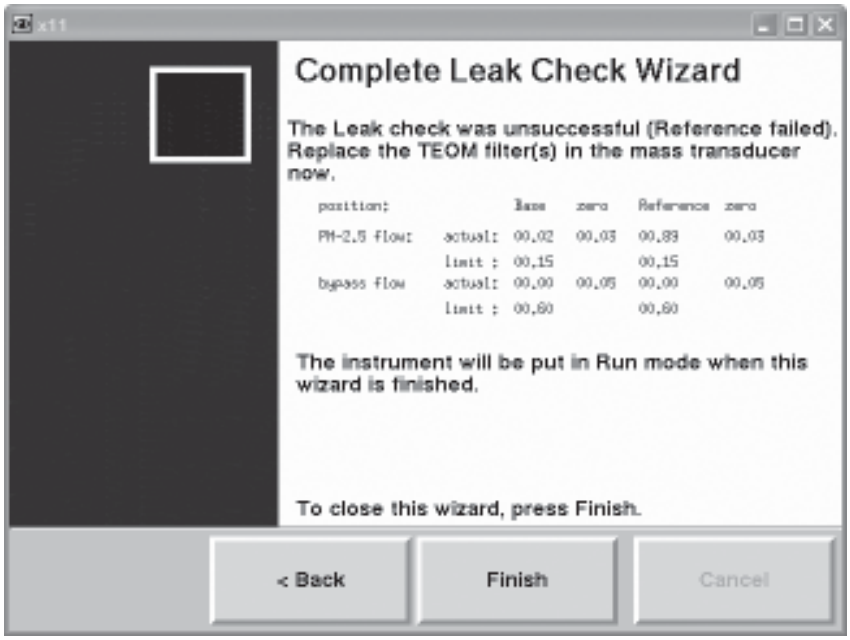
15. The Completing the Leak Check Wizard screen will display. If the leak check passes, a "You have successfully completed the Leak Check" message will display (Figure 3-9).

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).

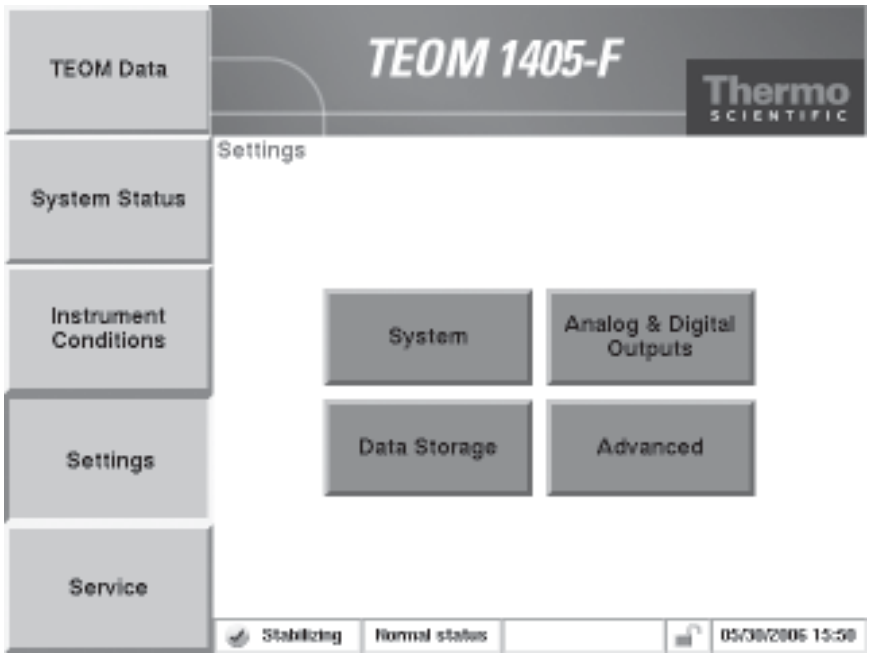
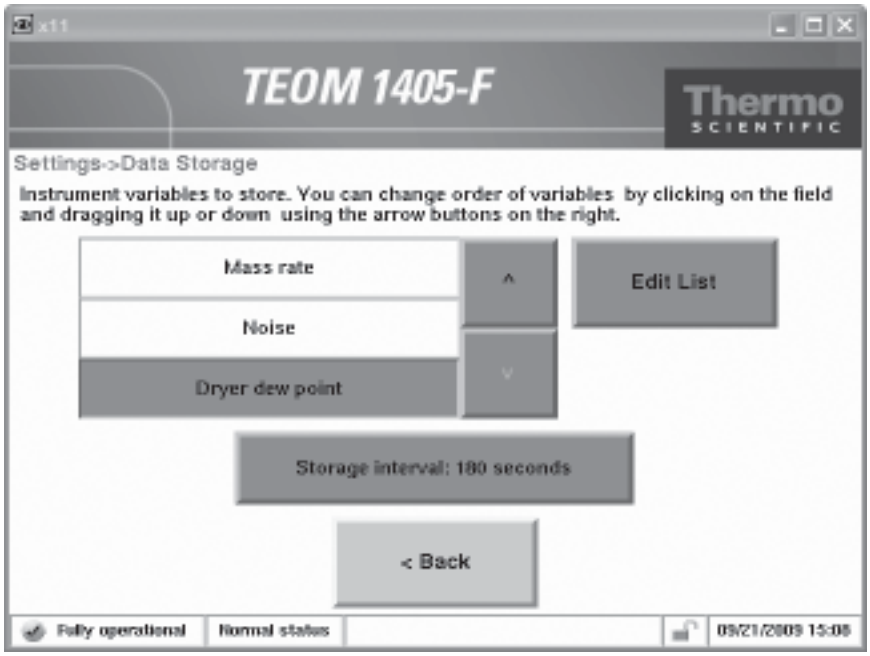


Figure 3-12. Settings screen.

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 **^** 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.

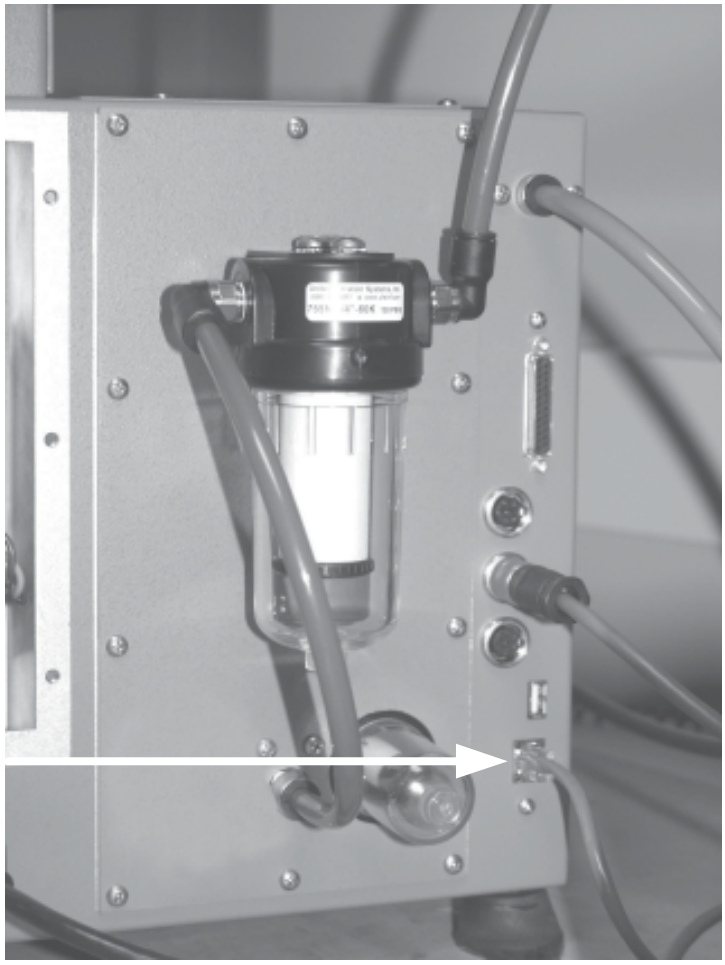
6. The storage order of the variables may be set by moving individual storage registers up or down in the list on the screen. To adjust the order, touch the desired variable and then move the position by pressing the**v** and **^** arrows to the right of the data variable list. For this ordering to work 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.



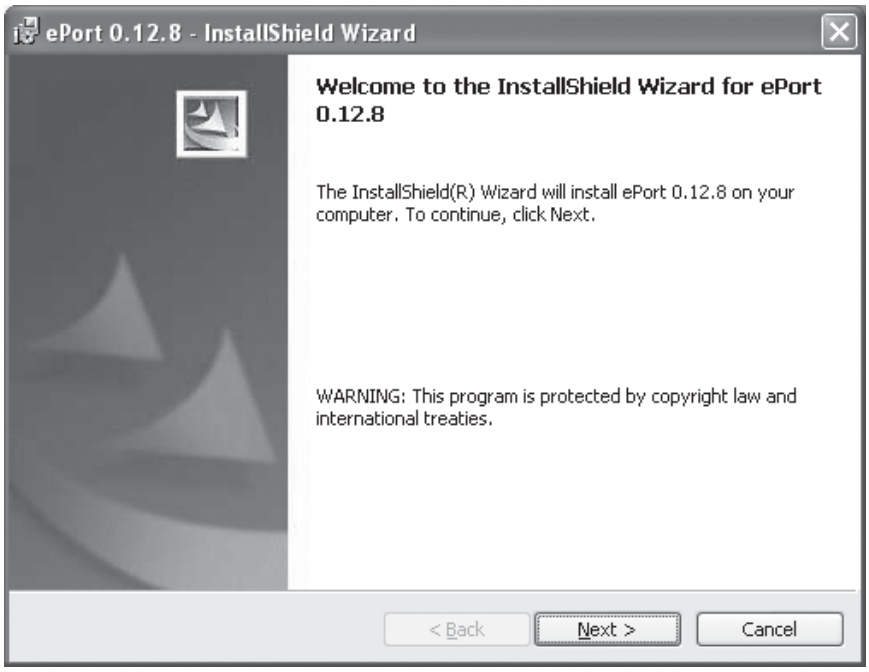
Installing ePort

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.



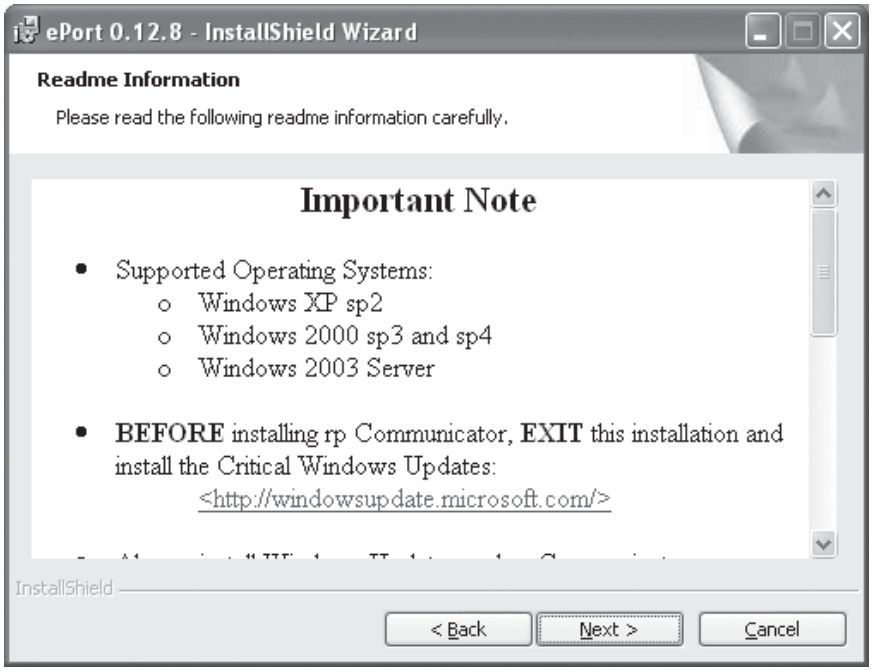
2. Select the "Install" button.

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. ▲

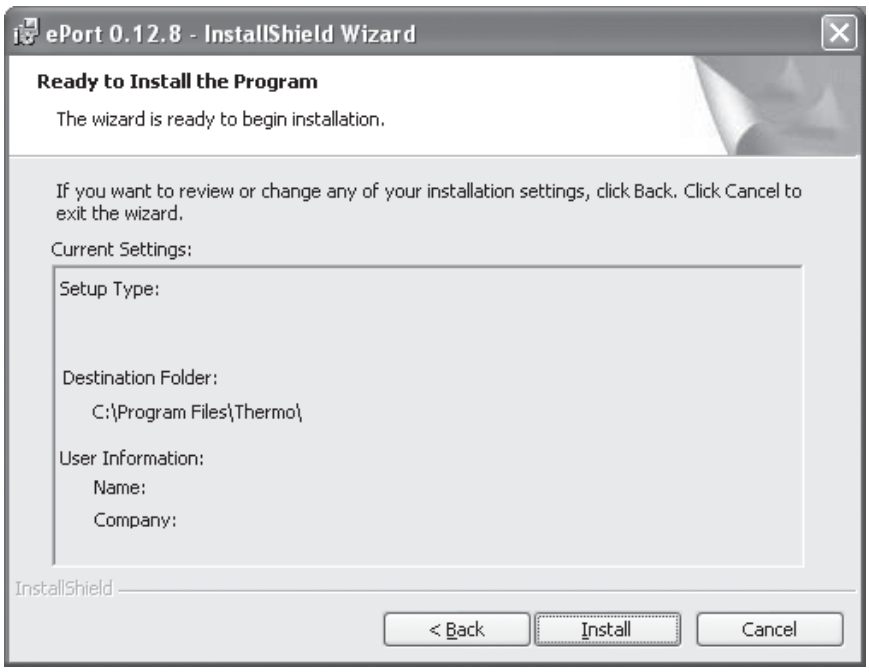
Figure 3-16.
Windows Update notice.



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

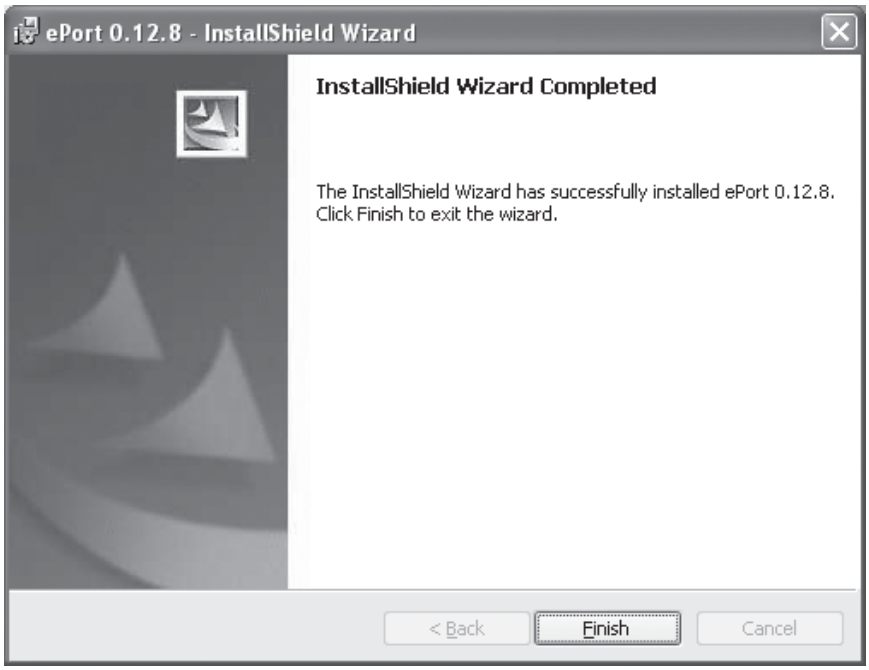
6. The Ready to Install Program screen will display (Figure 3-17). Select the **Install** button.

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



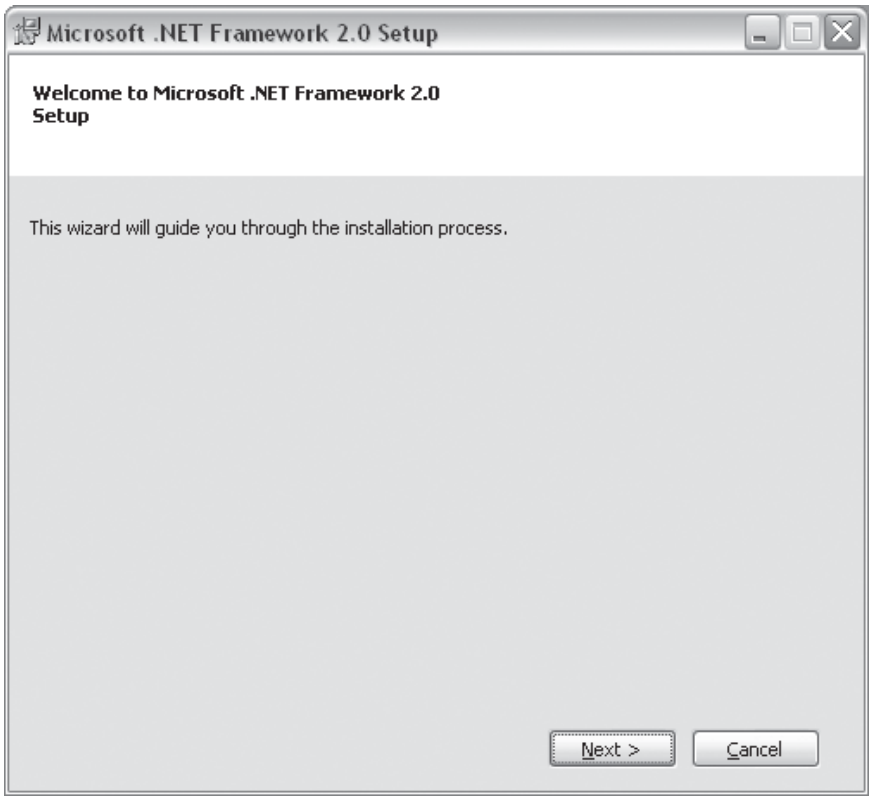
7. The wizard will post messages showing the progress of the installation. When the process is complete, the Finish screen will display (Figure 3-18). Select the **Finish** button.

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.

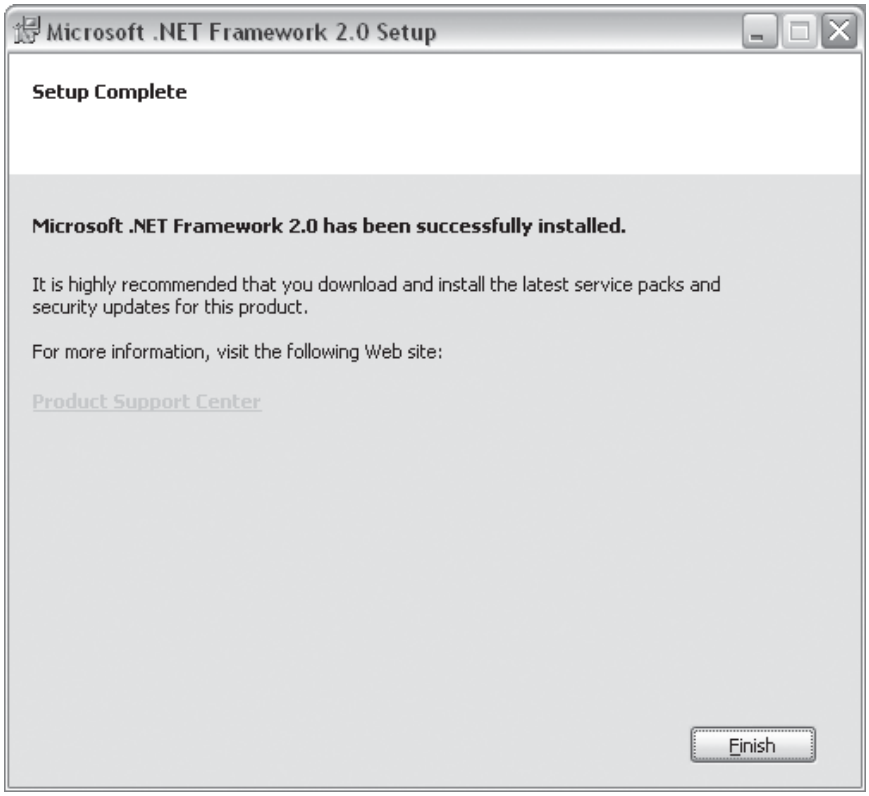


9. Select **Install**. The system will begin installing the Microsoft .NET Framework software. The wizard will post progress messages during the installation.

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.

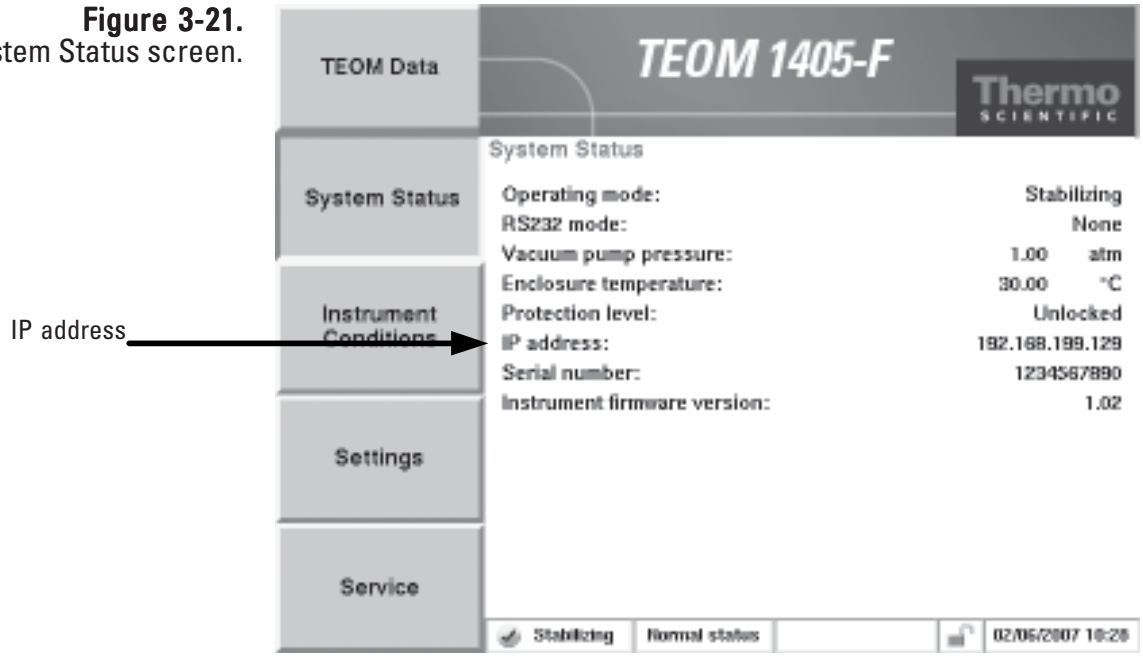
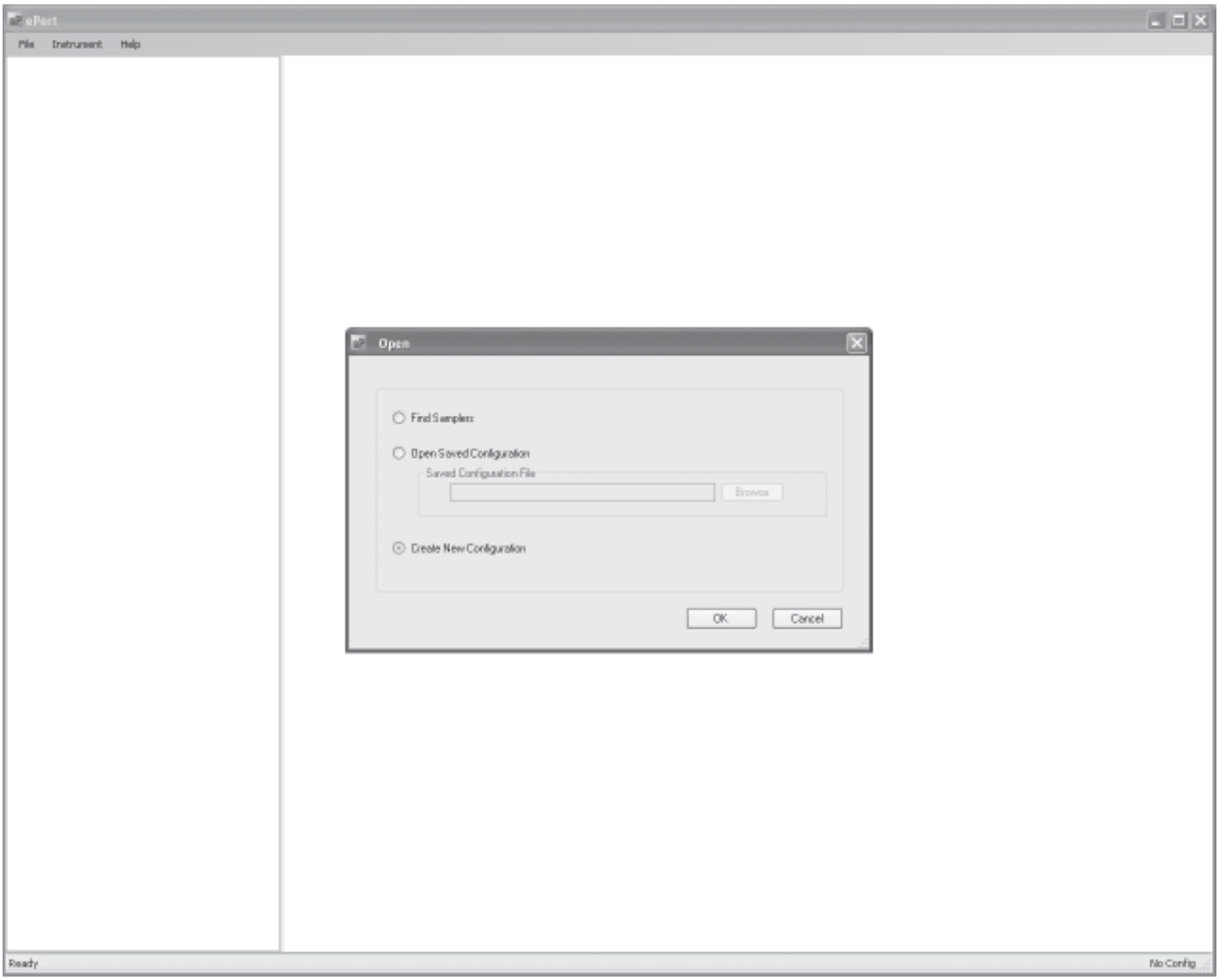


Figure 3-21. System Status screen.

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).

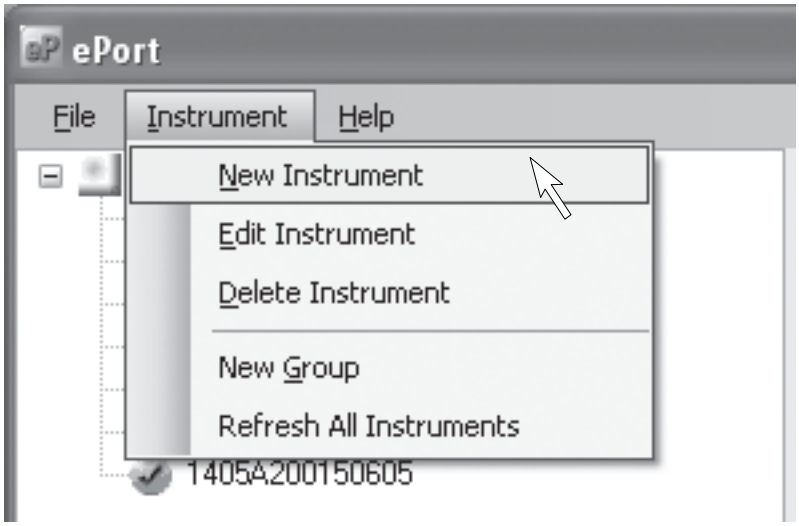
Figure 3-22.
ePort Main screen with Open screen.



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

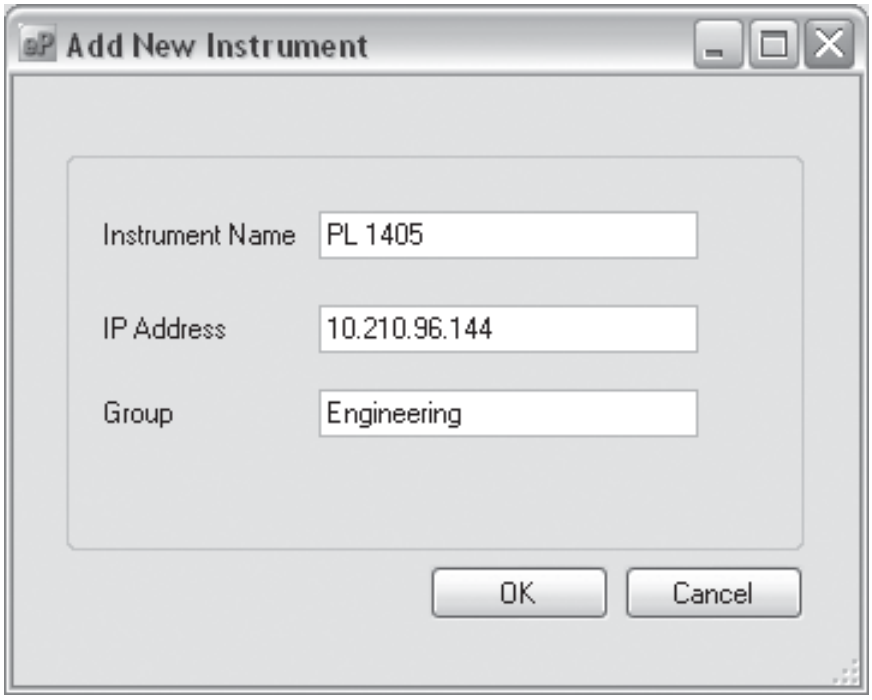
5. Select **Instrument** then **New Instrument** from the menu bar at the top of the ePort Main screen (Figure 3-23).

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.

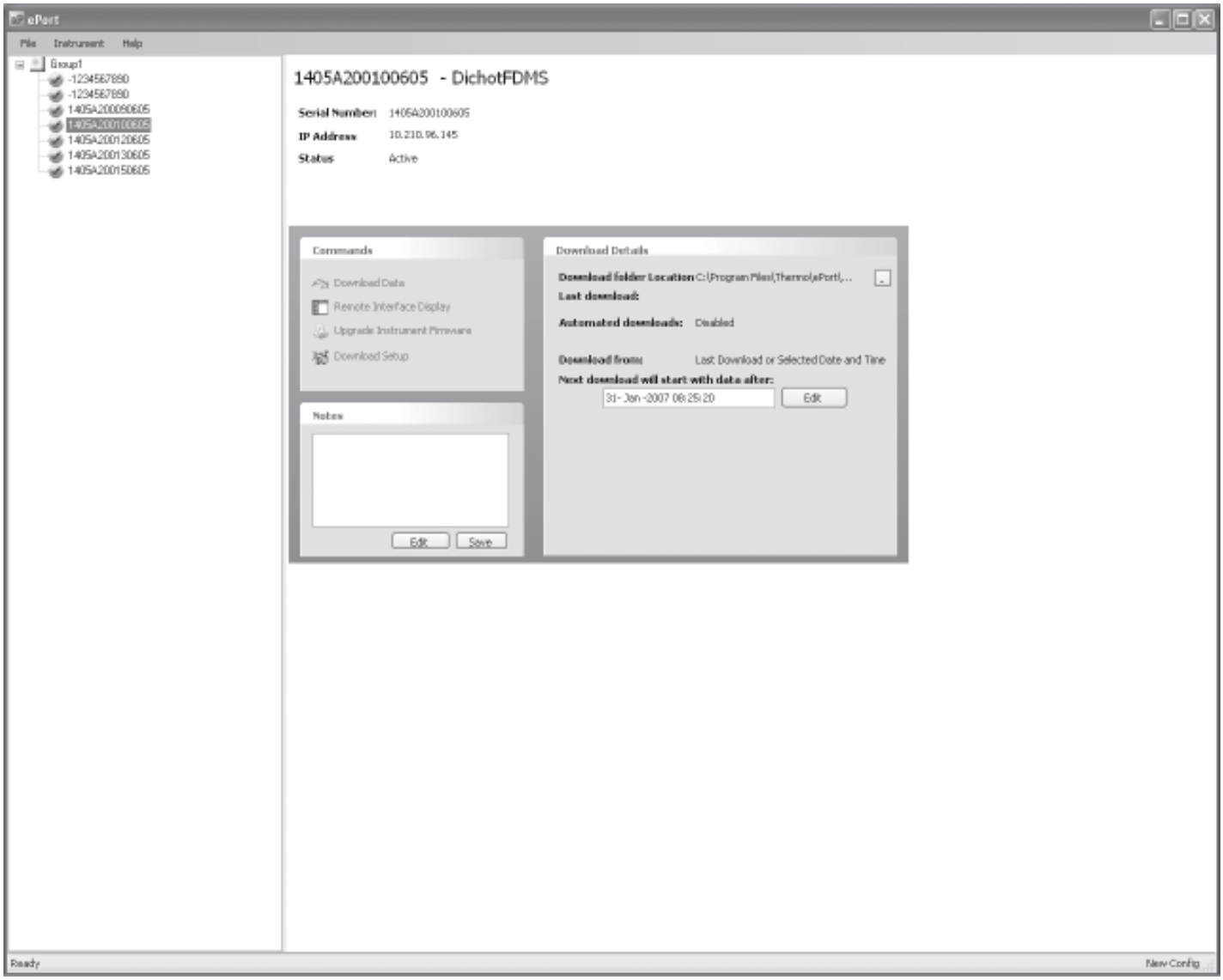


7. The ePort Main screen will display with the selected instrument displayed in the top window (Figure 3-25). Repeat the process to add additional instruments to the list.

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.

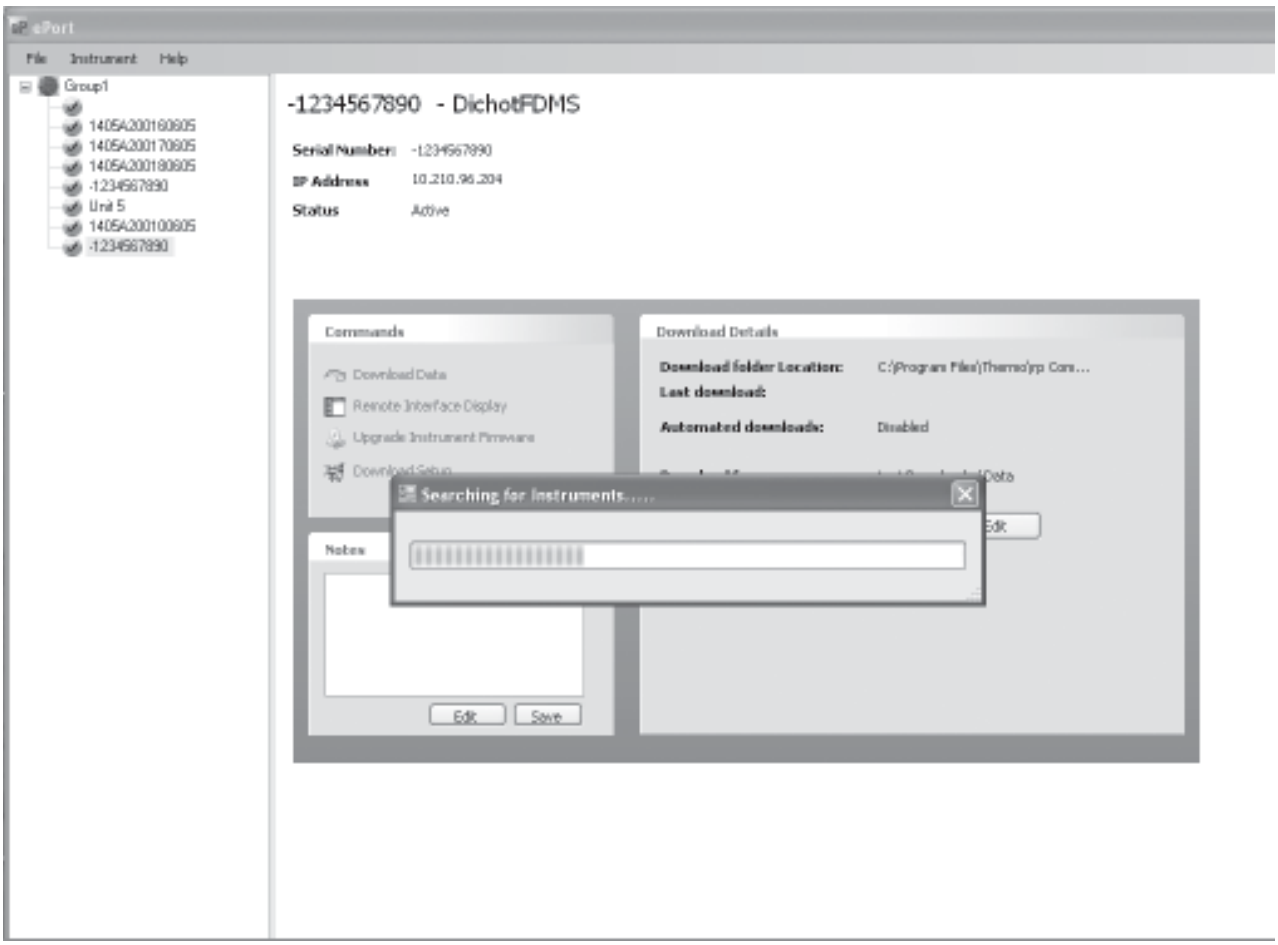
This function will only locate instruments on a local network. To connect to instruments on other connected networks, you must know the IP address of the instruments and connect to the unit manually using the **New Instrument** function of the software (Figure 3-23). Refer to the previous section for 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).

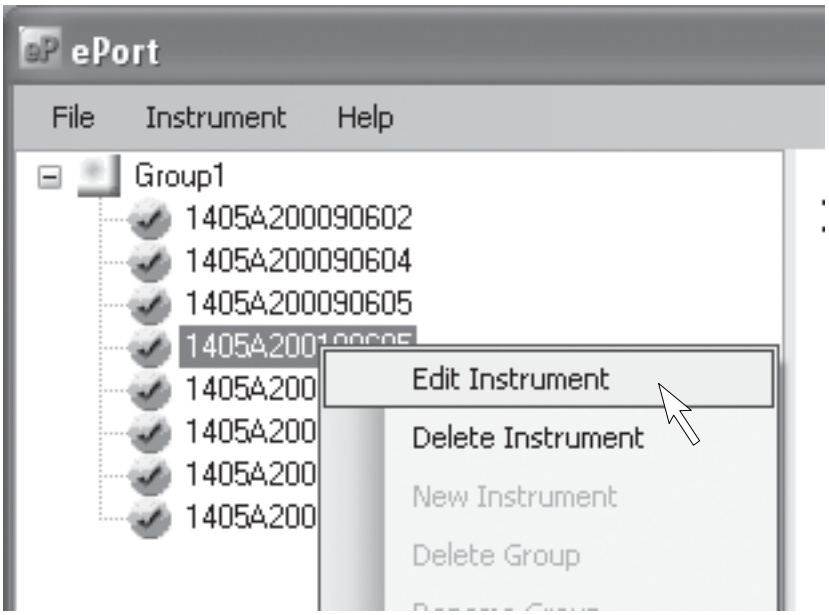
Figure 3-26.
ePort Main screen with "Searching for Instruments..." message.



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

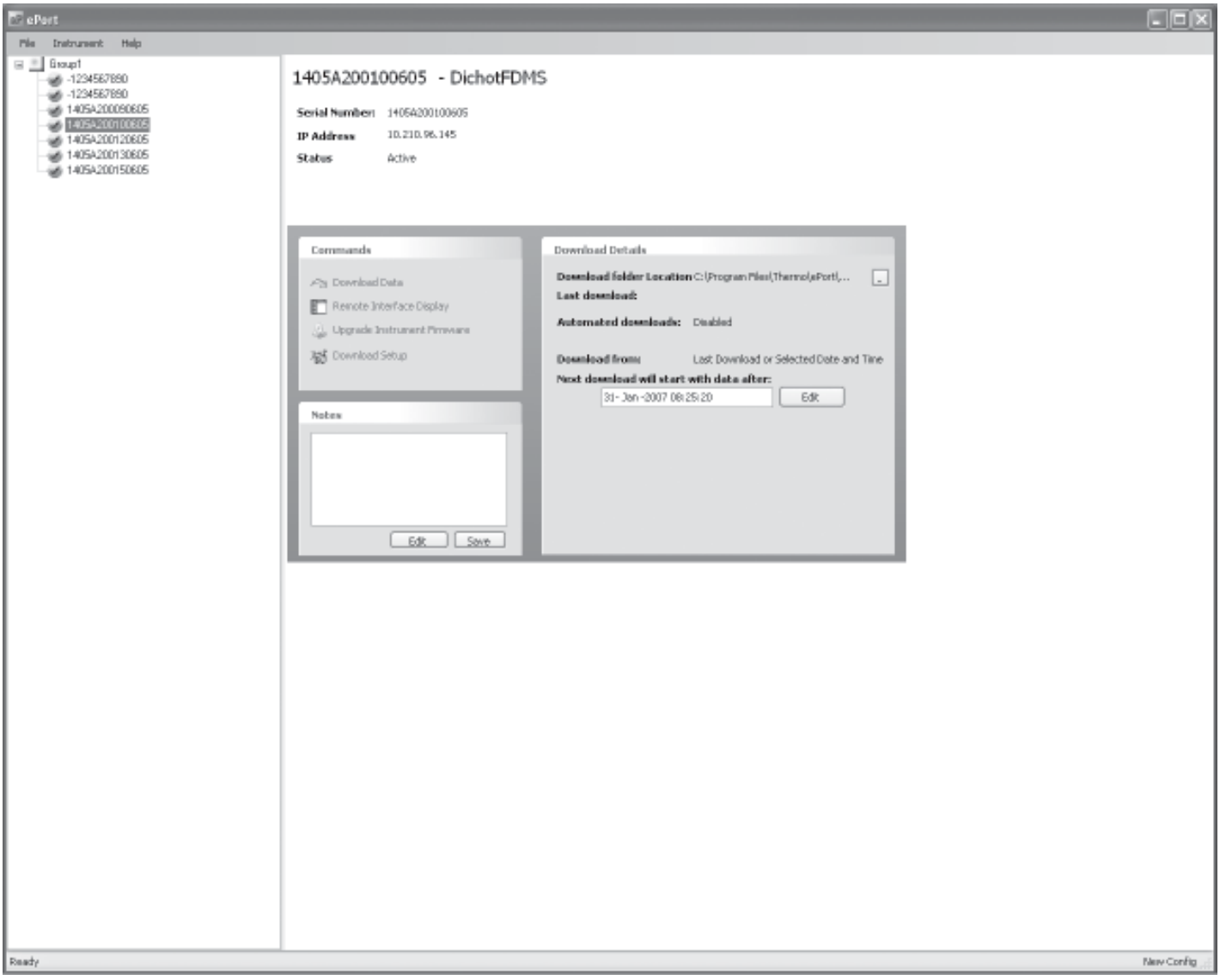
Data can be manually downloaded from the TEOM 1405 monitor through the built-in Ethernet connection using the ePort software.

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.)

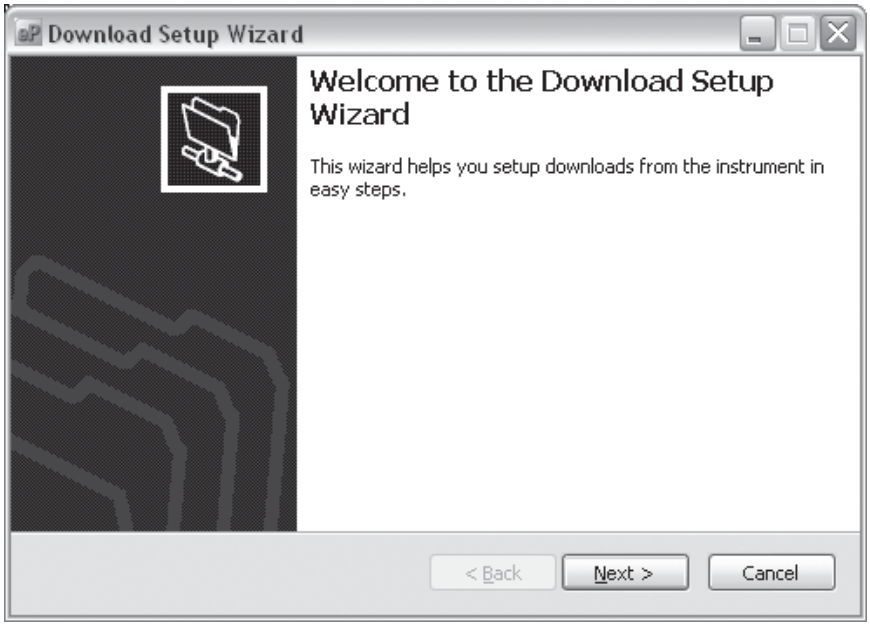
2. Use the ePort PC software to connect to the instrument and display the ePort Main screen (Figure 3-28). (Refer to the previous two sections for information on connecting to the instrument or instruments.)

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.

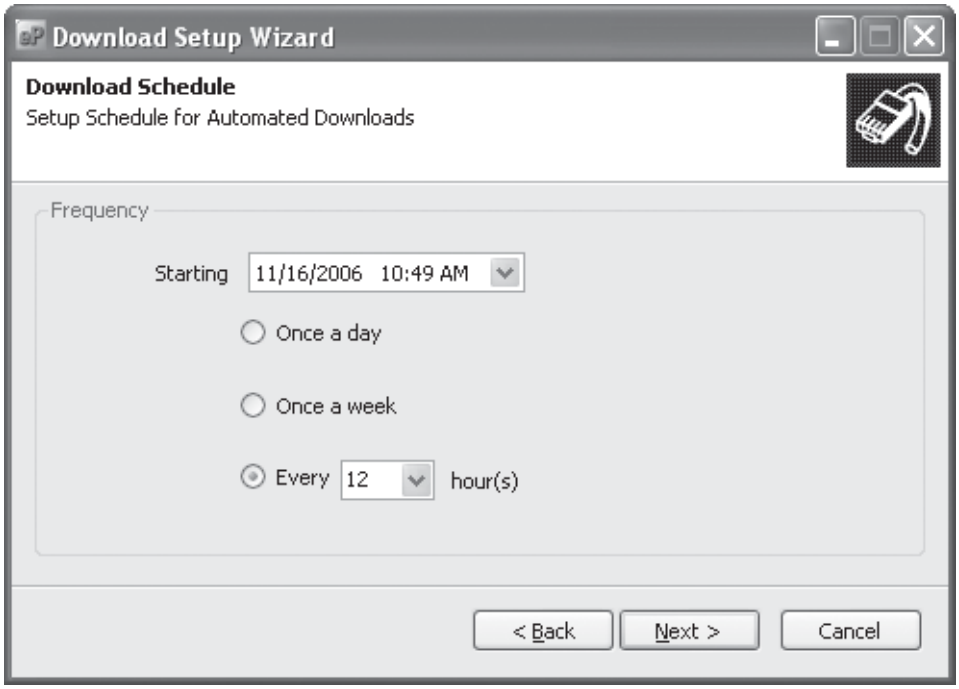
4. The Select Data screen will display. Select the data to download (either all data on the instrument or the data since the last download). Select the **Next >** button.

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

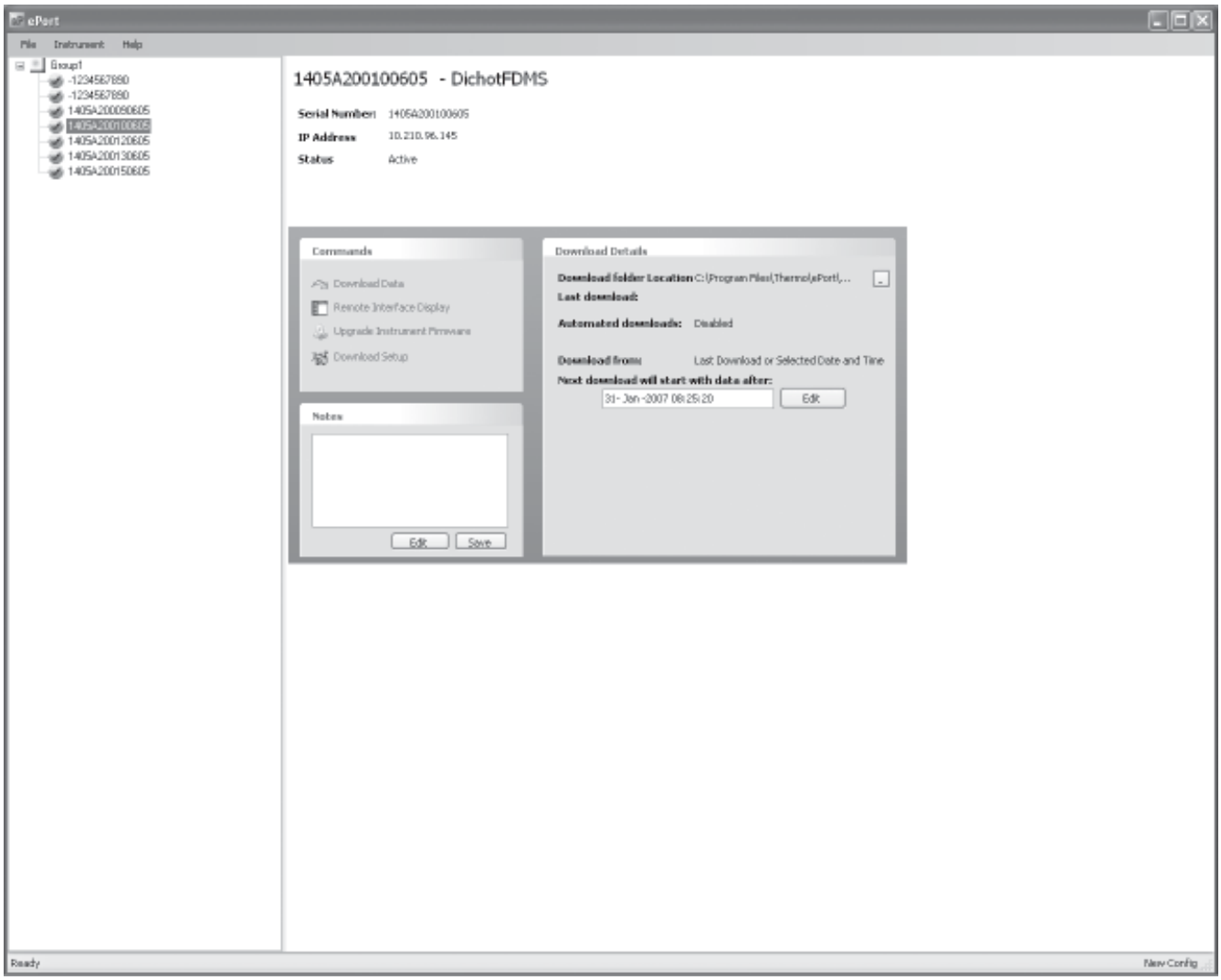
To download data:

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.)

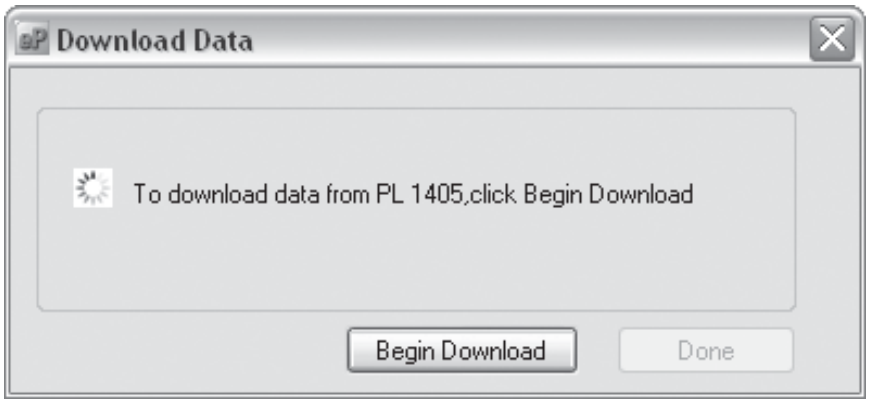
Note. Once you have connected to an instrument (or instruments) and saved a configuration file, select **Open Saved Configuration** in the ePort Open screen to open that configuration and automatically connect to all the instruments that were saved in that configuration. ▲

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

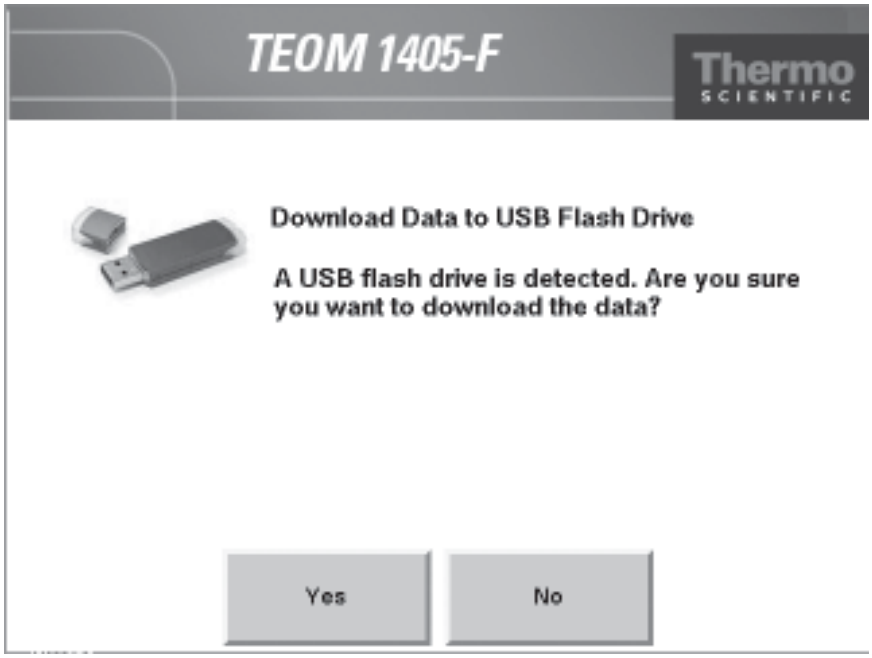
The TEOM 1405 also supports data downloads using the USB connection on the front of the instrument and a USB flash drive.

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).

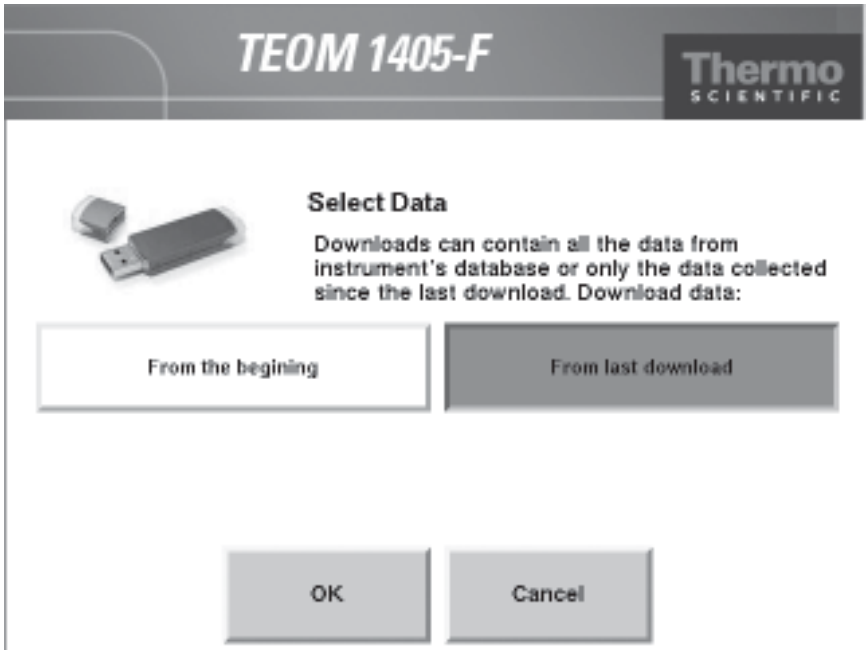
Figure 3-33. Download Data to USB Flash Drive screen.



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.

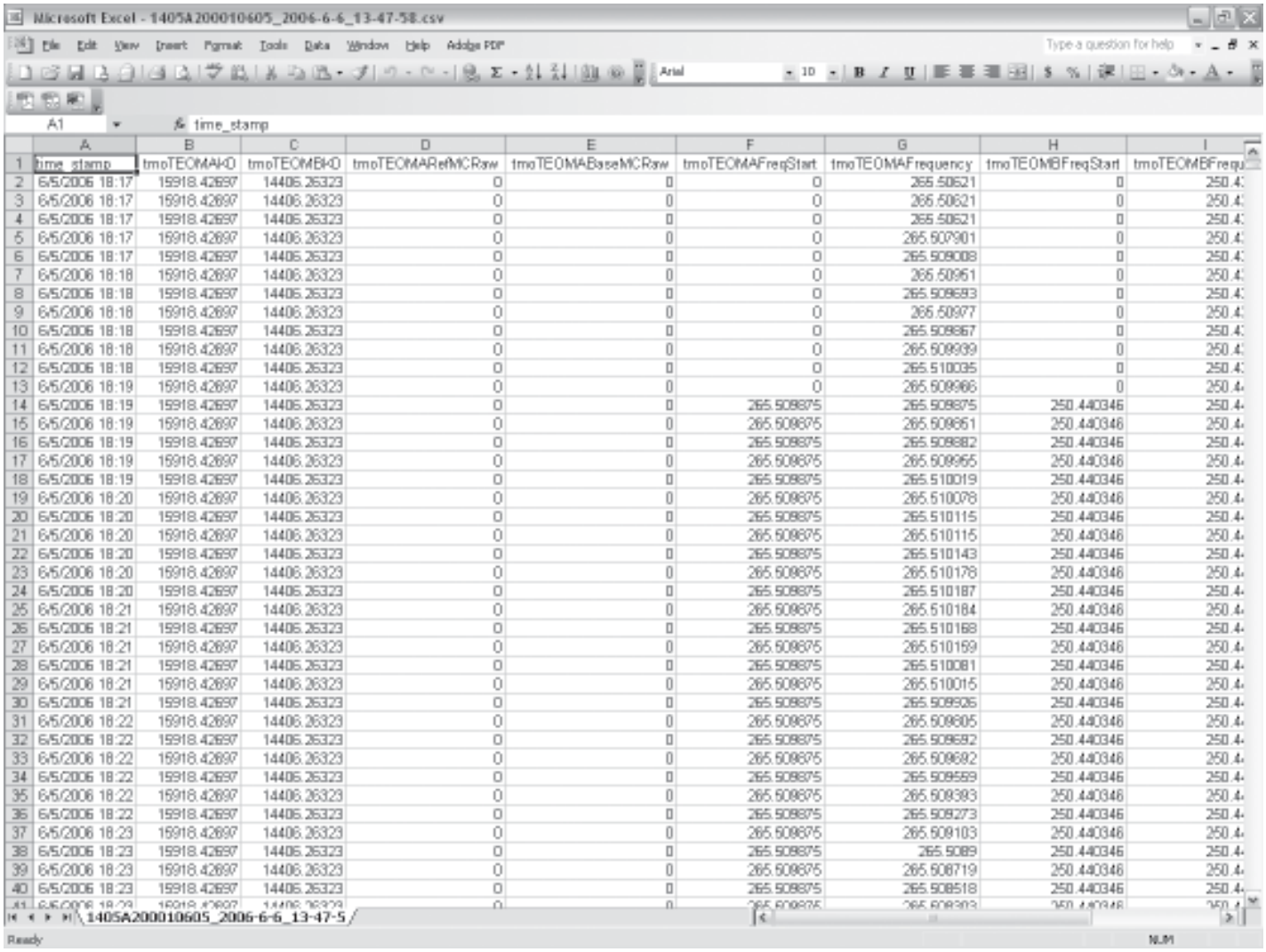
Viewing Downloaded Data

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.



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.

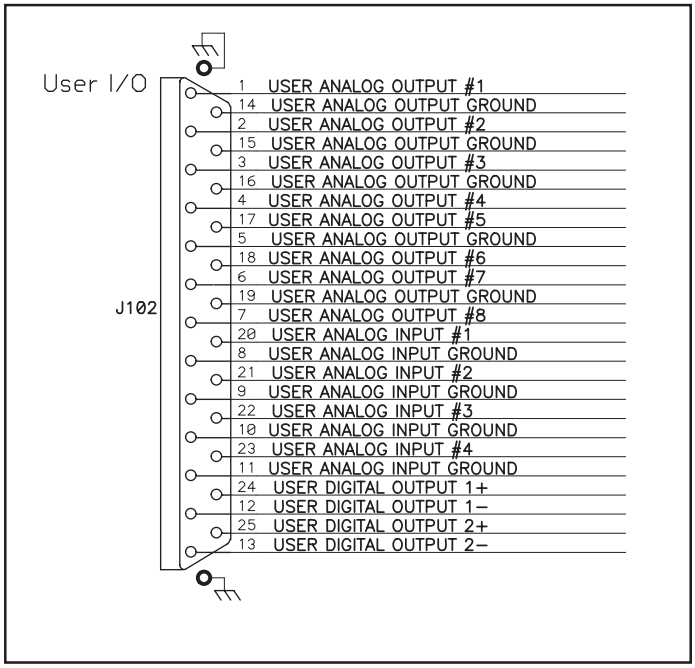


Table 3-1. 1405 USER I/O pin assignments.

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).

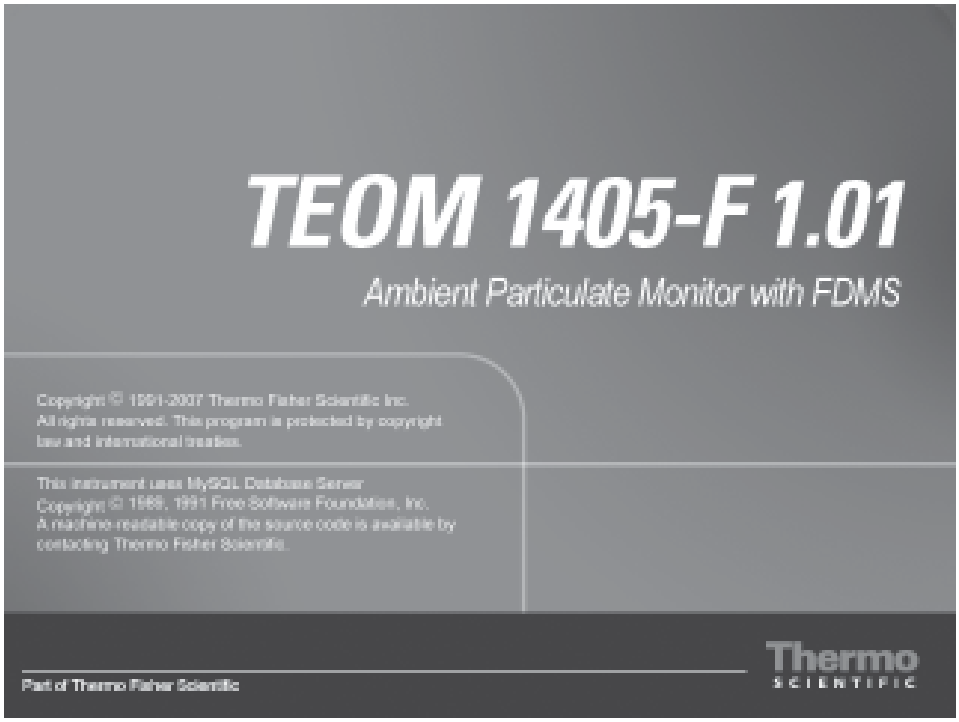
Refer to Section 4 for complete information on setting the inputs/outputs in the Analog Inputs and Analog & Digital Outputs screens.

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.

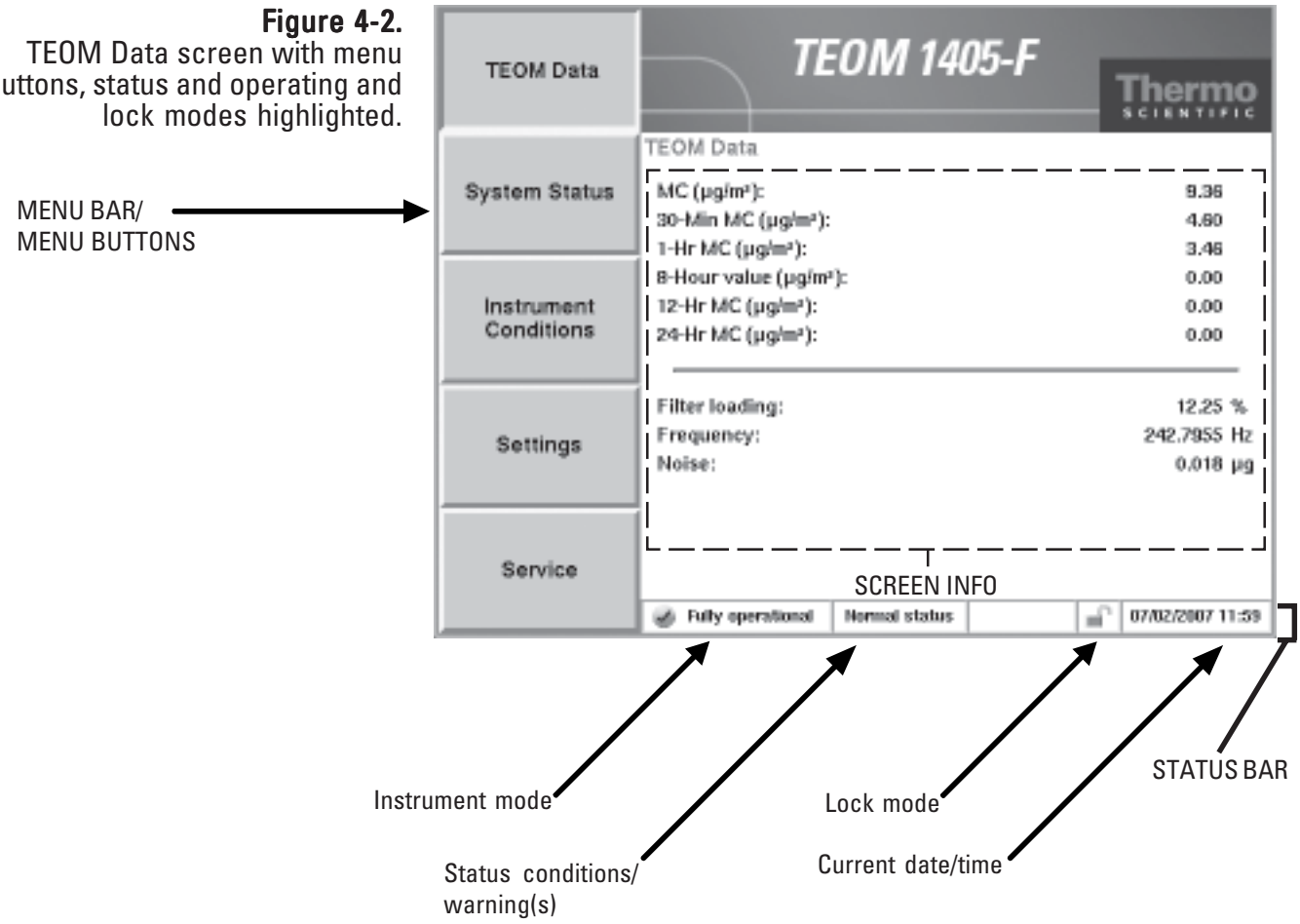


The Title screen includes the instrument model and the firmware version of the instrument.

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.

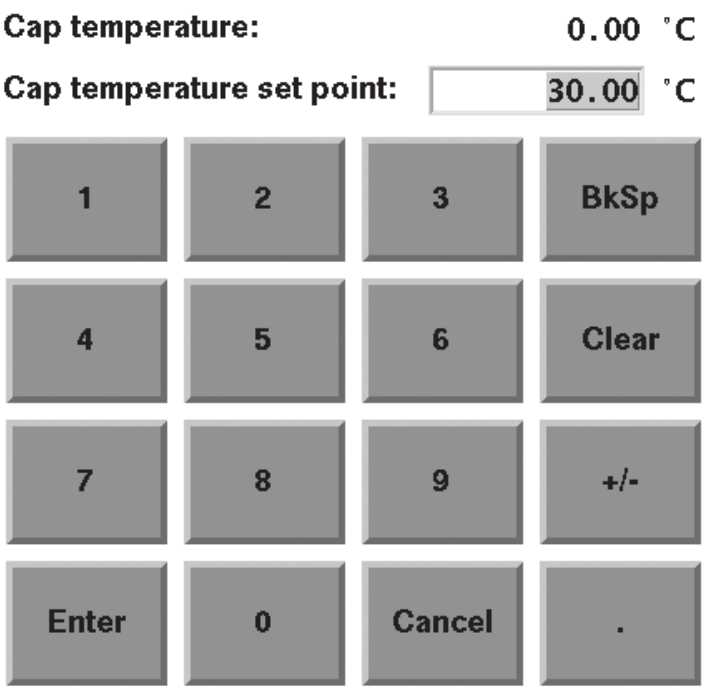
- *Frequency:* This field contains the oscillating frequency of the tapered element (TE) in the mass transducer. This value varies from one TEOM 1405 unit to another, but generally ranges between 150 and 400 Hz. This value cannot be changed by the user.

- *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).

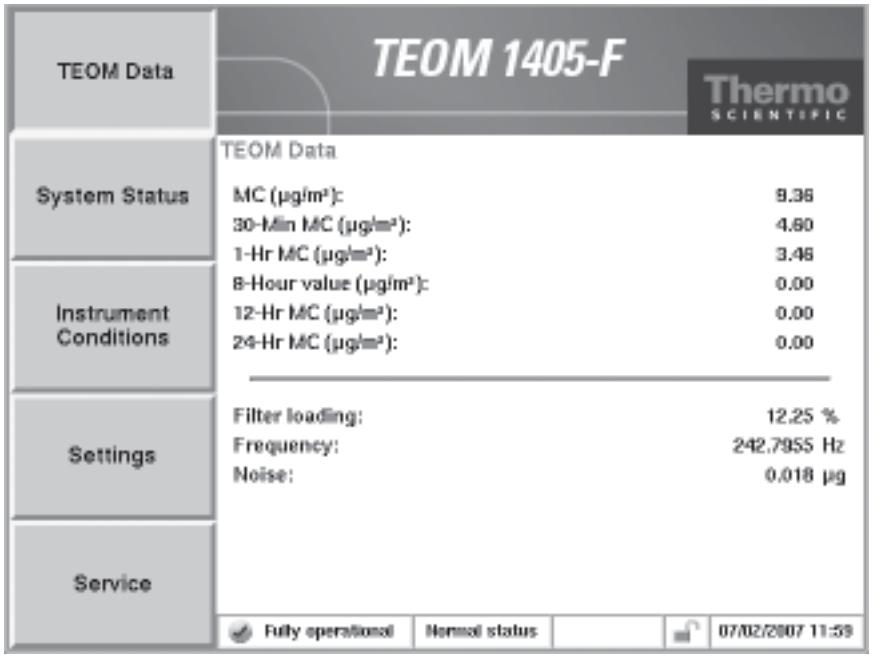


Figure 4-4. TEOM Data screen with "Normal status" message.

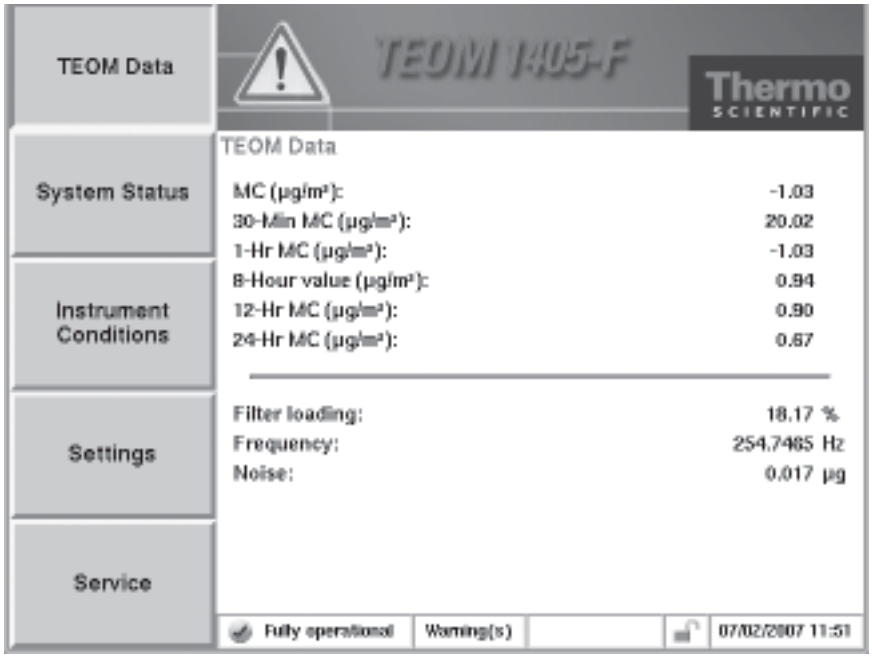
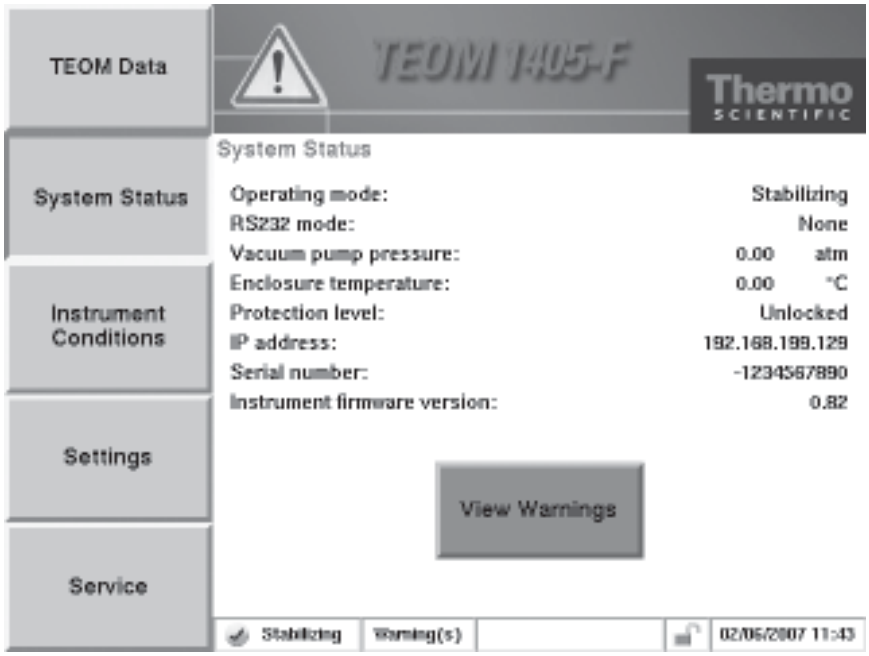


Figure 4-5. TEOM Data screen with "Warning(s)" message and warning triangle.

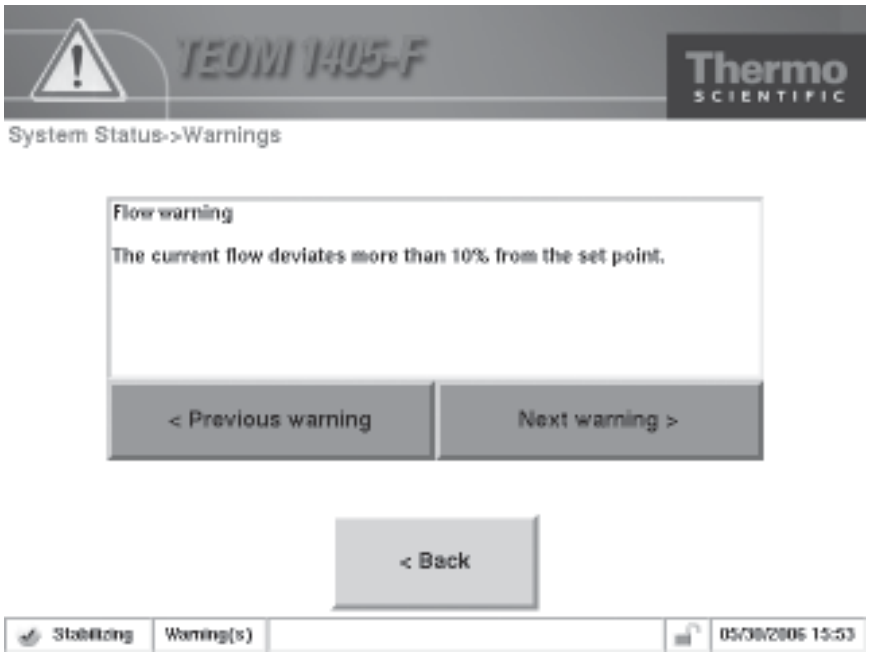
Whenever a status warning is displayed, select the **System Status** button to display the System Status screen (Figure 4-6). The System status screen provides basic operating information and access to the list of the current active status warnings.

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.

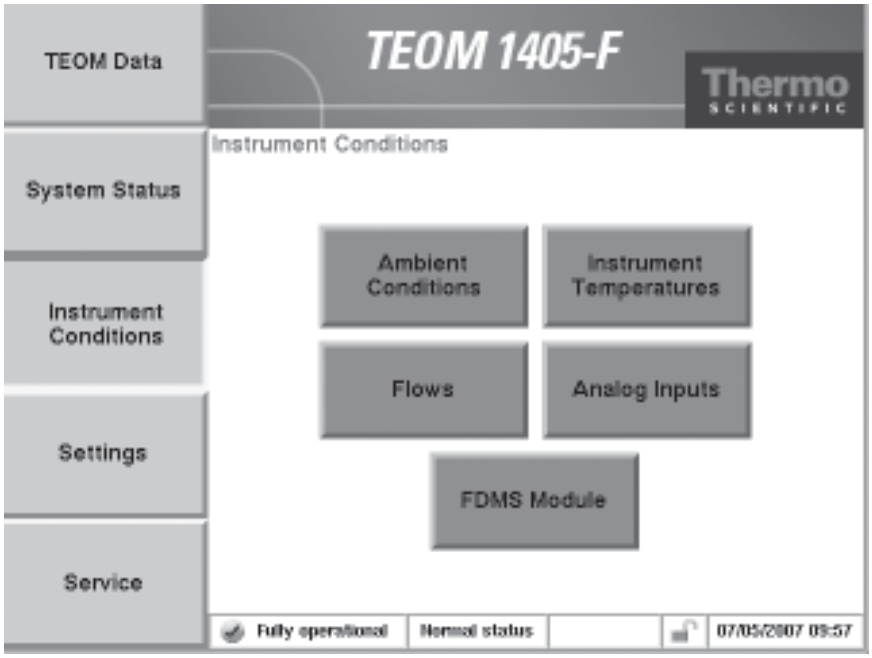
Figure 4-7.
Warnings screen.



Instrument Conditions Screen

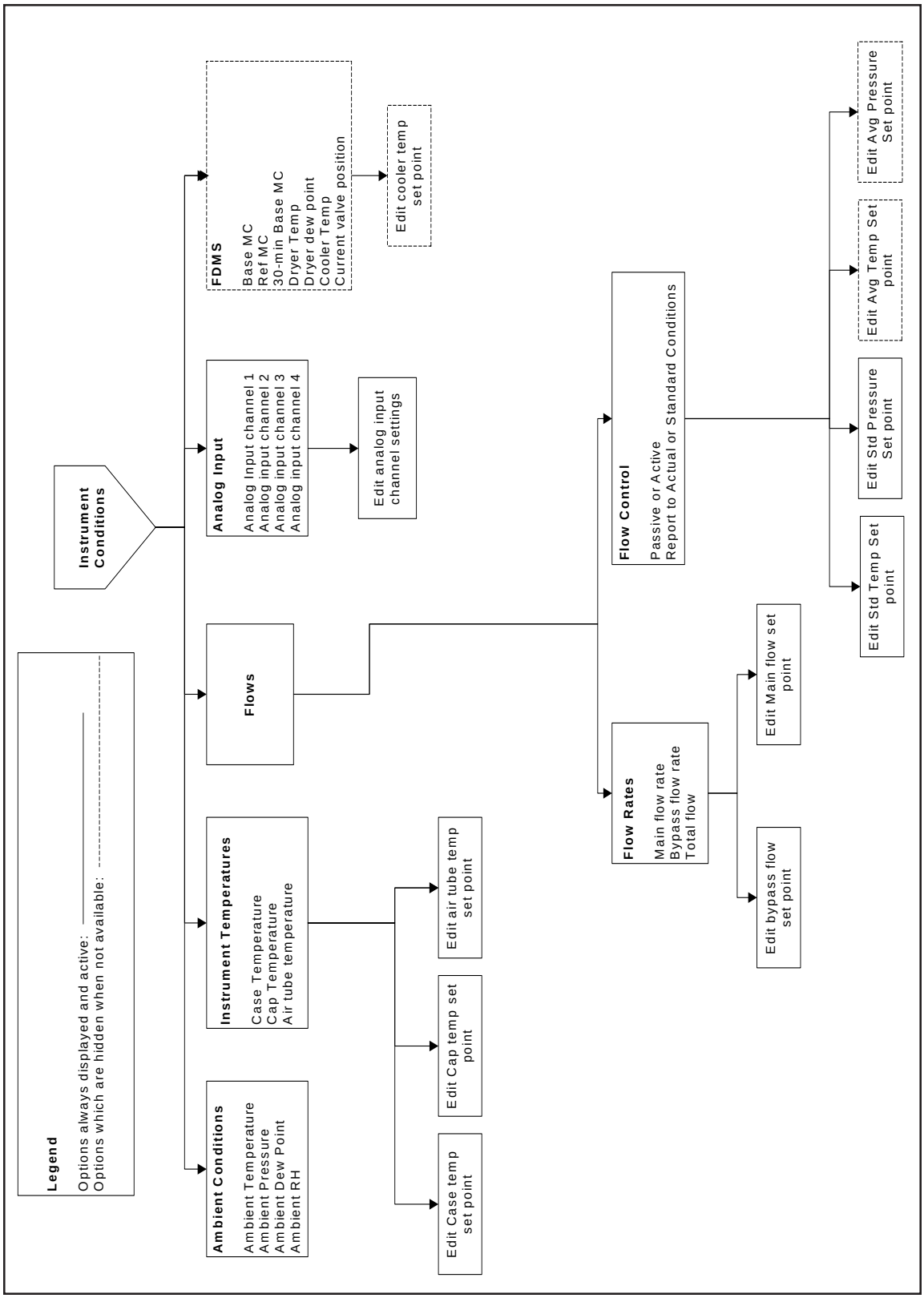
The Instrument Conditions button displays the Instrument Conditions screen (Figure 4-8), and provides access to several temperature and flow settings and the current ambient air conditions for the instrument.

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).

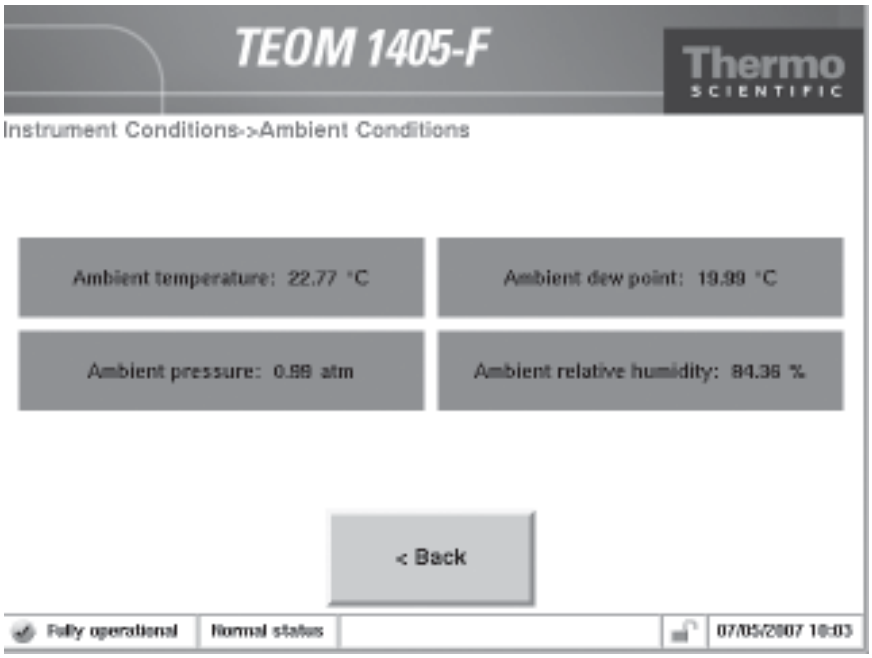
Figure 4-9.
Screens accessible through the Instrument Conditions screen.



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.

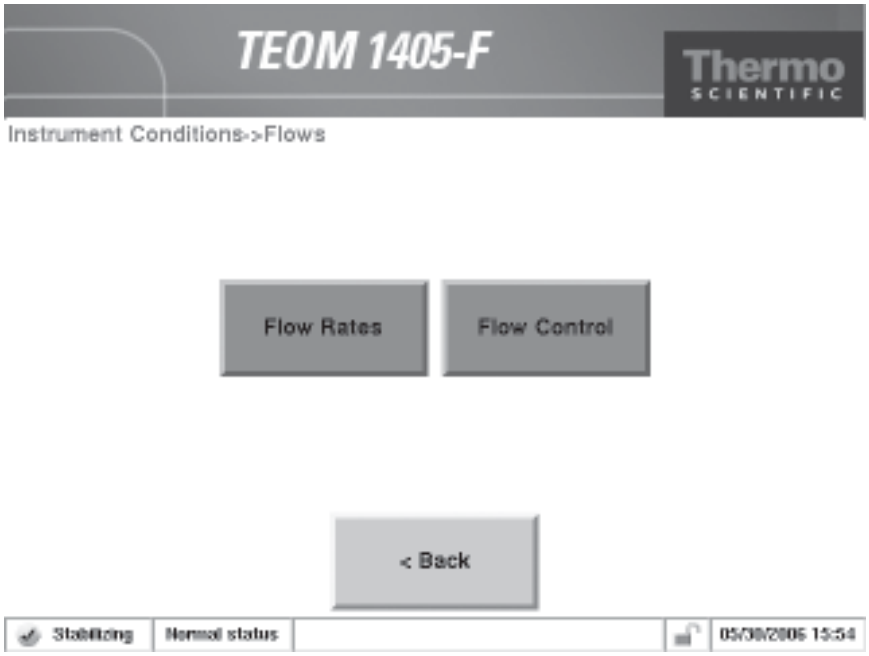
- Ambient Dew Point. This field contains the current ambient dew point (°C) at the site. This value cannot be edited and will be correct only when the ambient temperature/humidity sensor is properly installed.

- 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.



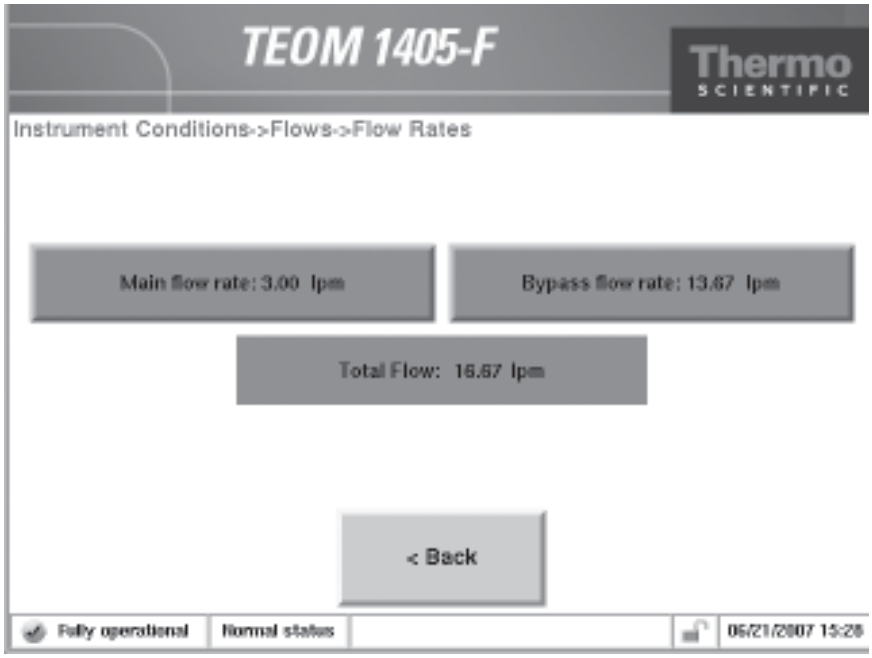
Select the **Flow Rates** button to view or adjust the instrument's flow rates. Select the **Flow Control** button to view or adjust the units standard temperature and pressure settings or select active or passive flow control.

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.

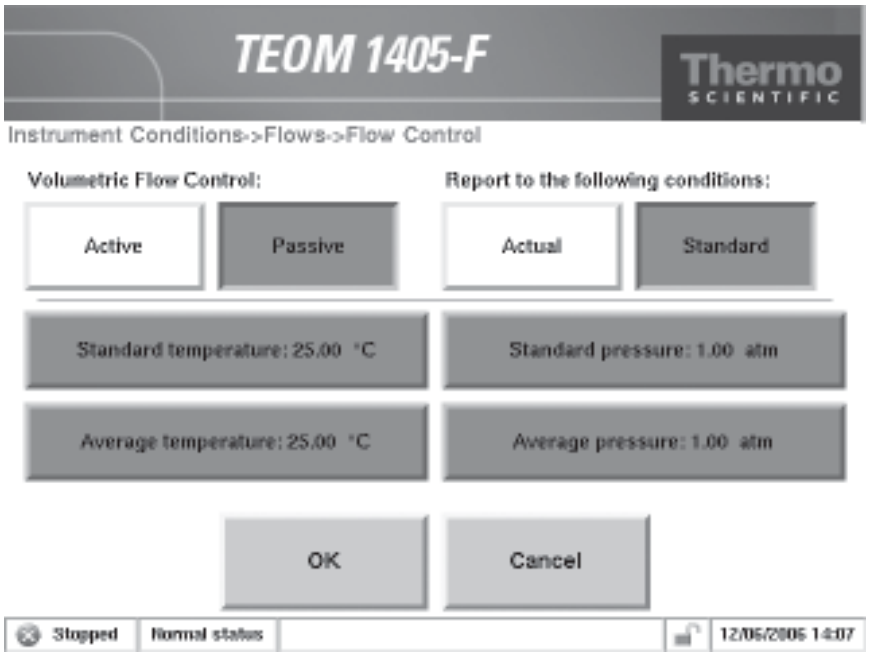
- *Bypass flow rate*. This field contains the current value of the bypass flow rate. The default setting is 13.67 l/min. To view or adjust the setpoint, select the button to display the keypad (Figure 4-3). The current value can not be edited.

- *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.

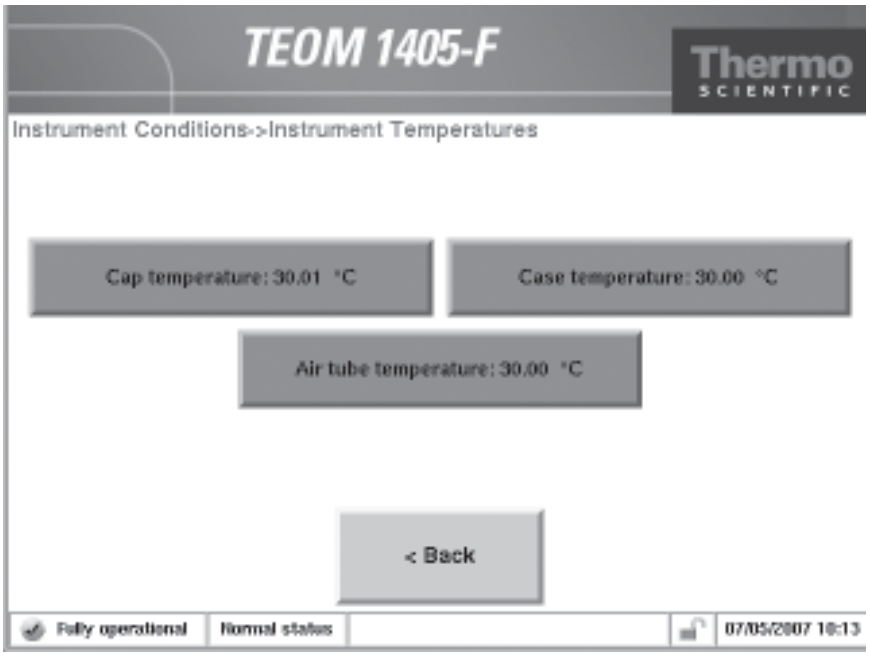
If the user chooses to set the unit to report the mass concentration levels to **Actual** conditions, they must select the **Active** flow control button (Figure 4-13). This will cause the monitor to use the actual ambient temperature and ambient pressure in its flow rate calculations.

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.

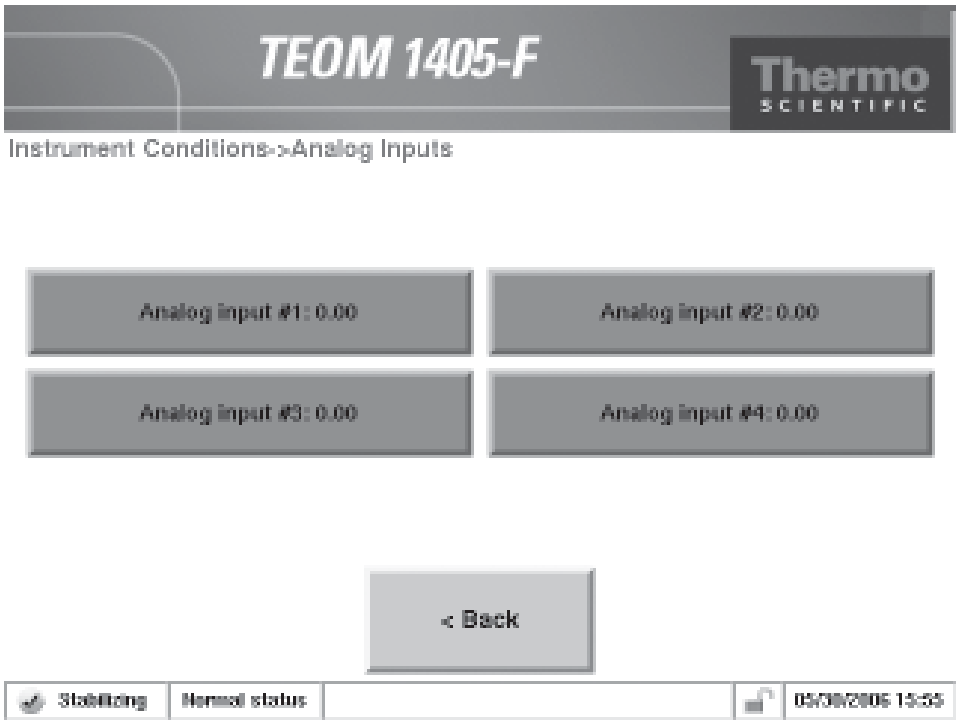
- *Case temperature*. This field contains the current value of the temperature (°C) of the mass transducer case. The default setting is 30° C. To view or adjust the setpoint, select the button to display the keypad (Figure 4-3). DO NOT adjust this value without contacting Thermo Scientific.

- *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.

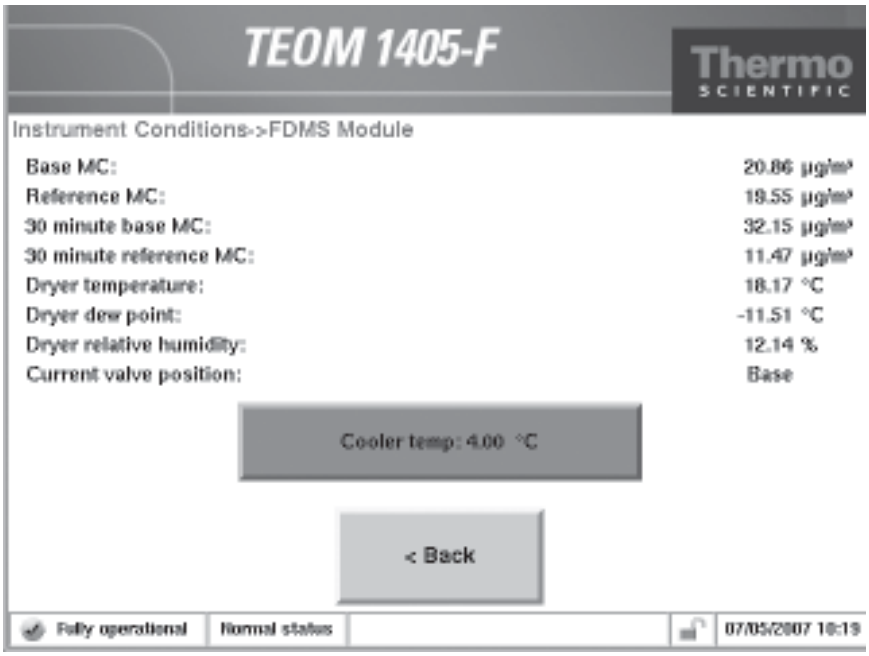
Figure 4-15.
Analog Inputs screen.



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.

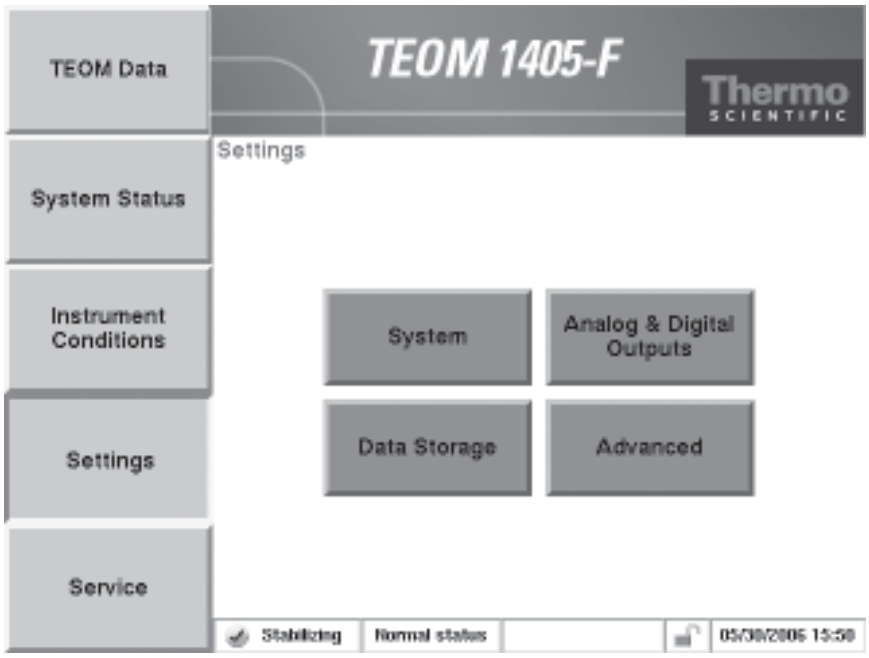
4. Install new TEOM Sample filters.

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.

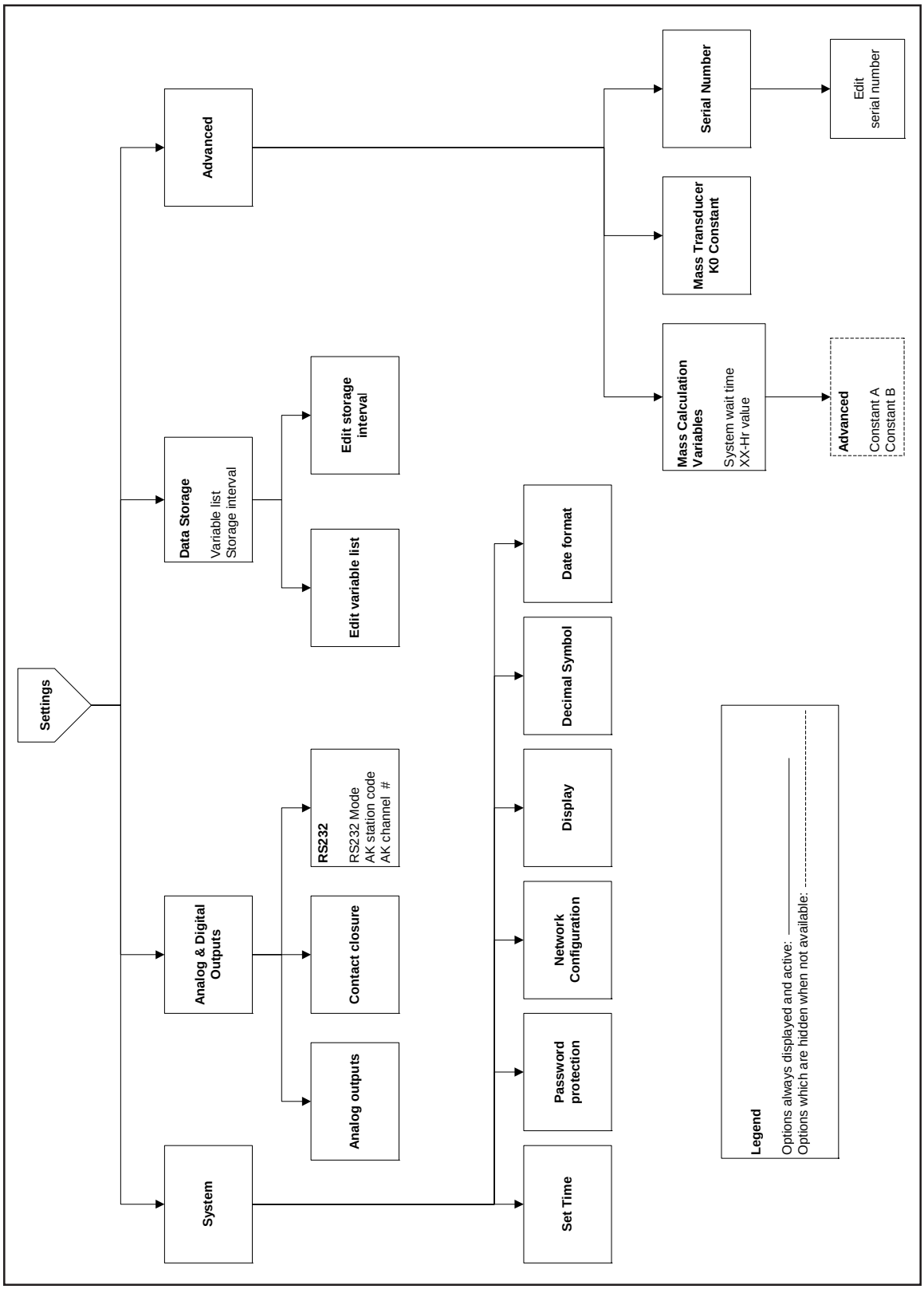
Figure 4-17.
Settings screen.



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. ▲

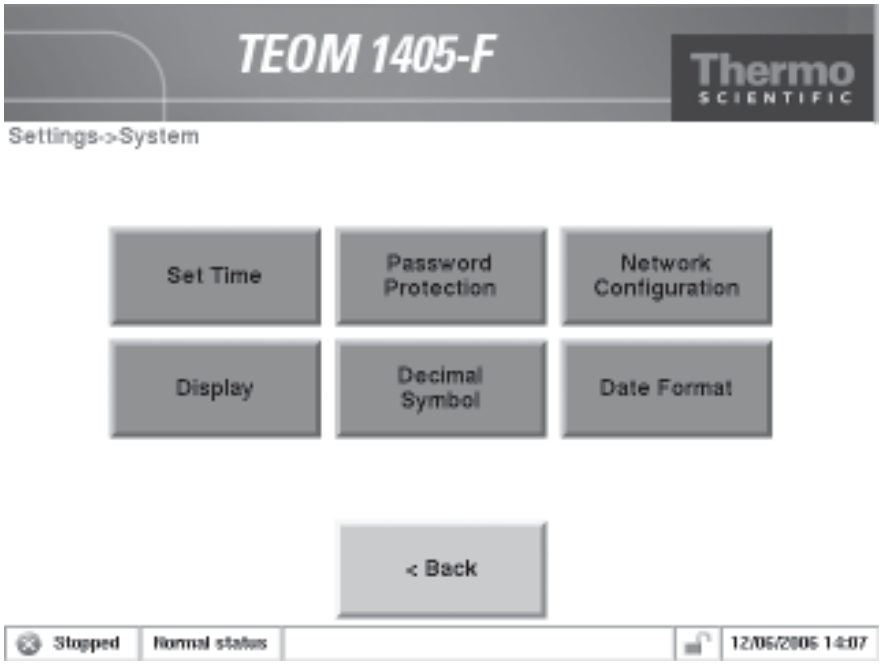
Figure 4-18.
Screens accessible through the Settings button.



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.

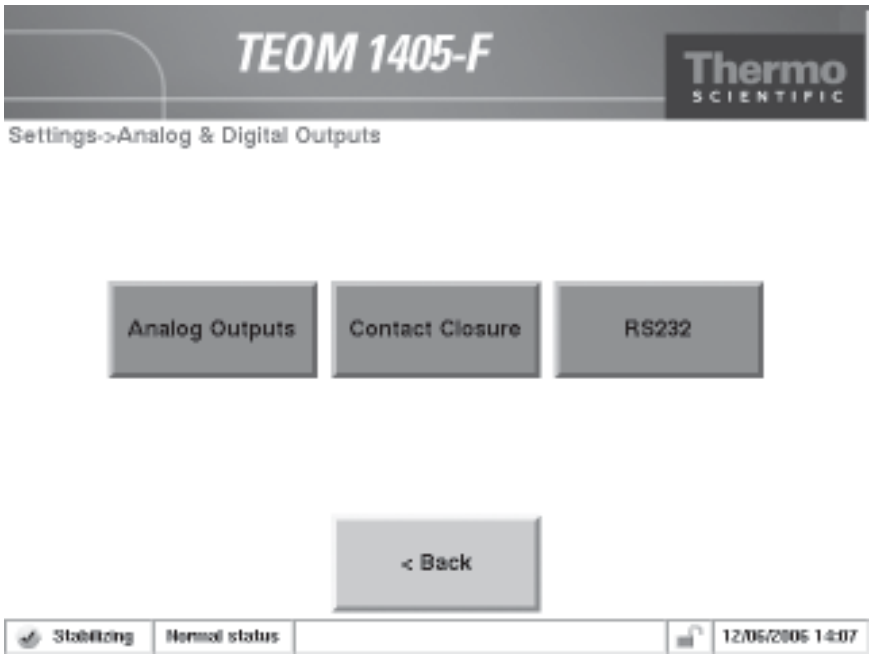
- *Decimal Symbol*. Select the **Decimal Symbol** button to choose whether to separate decimal numbers with a period (".") or a comma (","). The unit must be restarted for this change to take effect.

- *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.

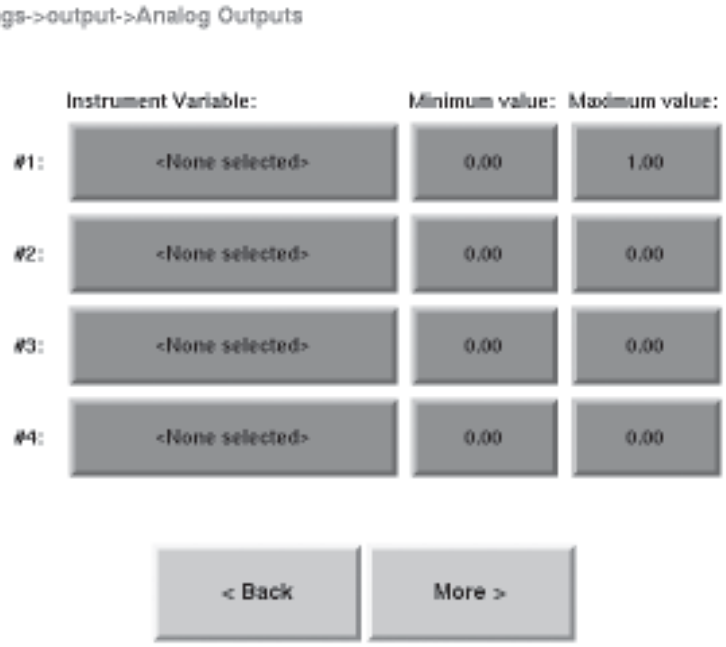


When in the Analog & Digital Outputs screen, select the **Analog Outputs** or **Contact Closure** buttons to set up the analog output and contact closure functions. Select the **RS232** button to set up the unit for serial connections using RPComm or other programs using AK protocol.

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.

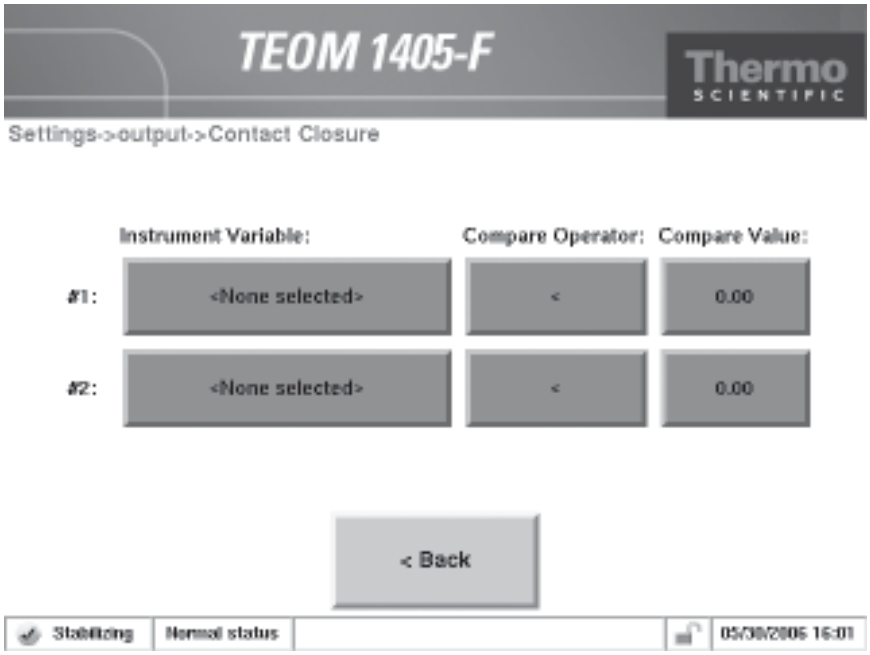
Figure 4-21. Analog Outputs screen.



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).

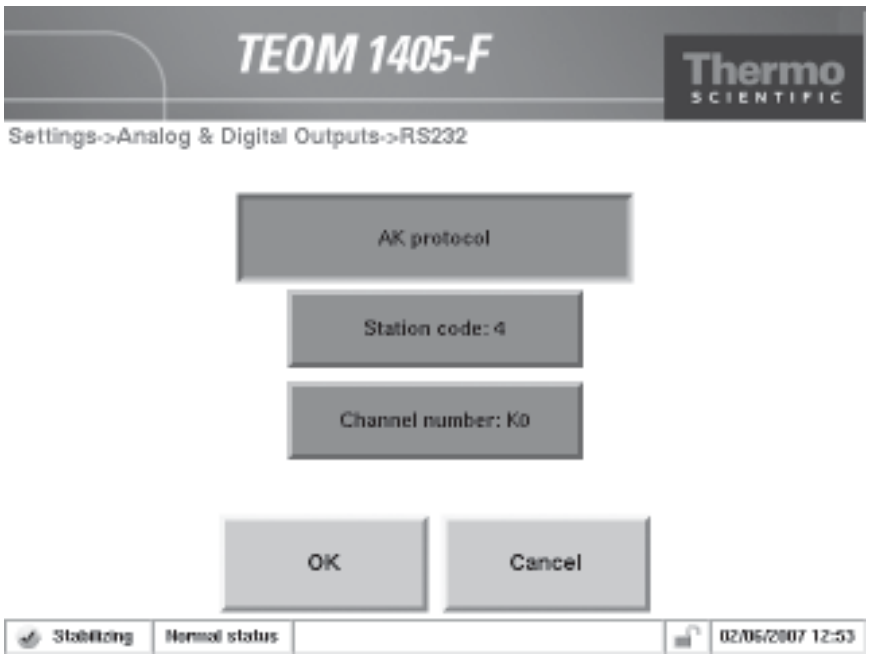
Figure 4-22.
Contact Closure screen.



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.

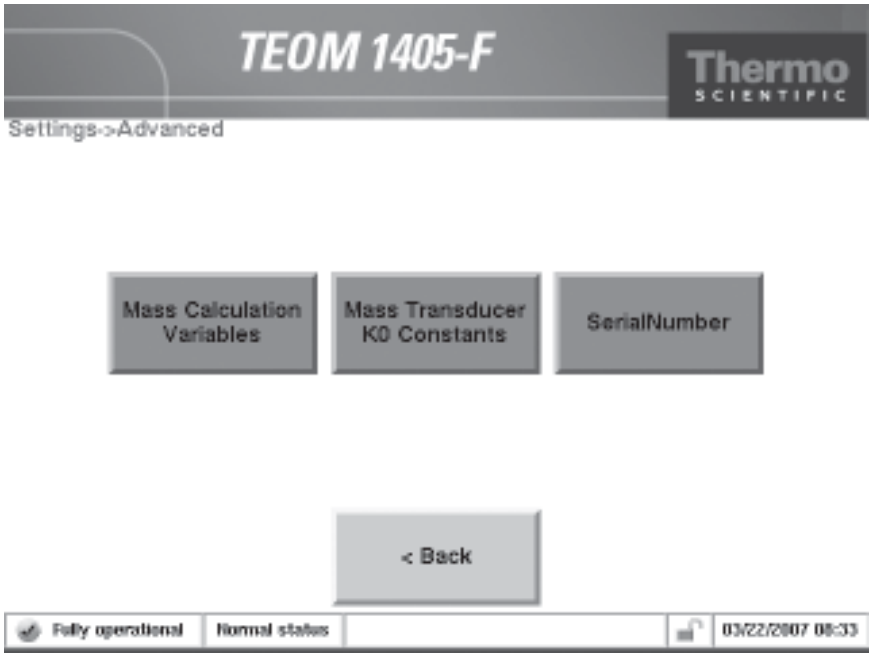
Figure 4-23. RS232 screen.



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:

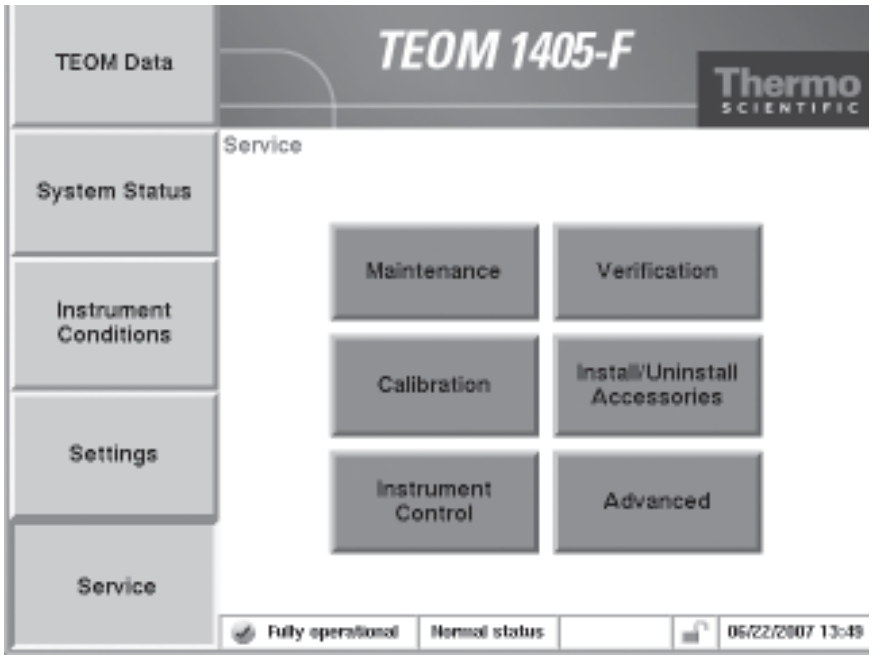
- *TEOM K0*. This field contains the calibration constant, K_0 (K0) (Section 1), for the TEOM.

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.

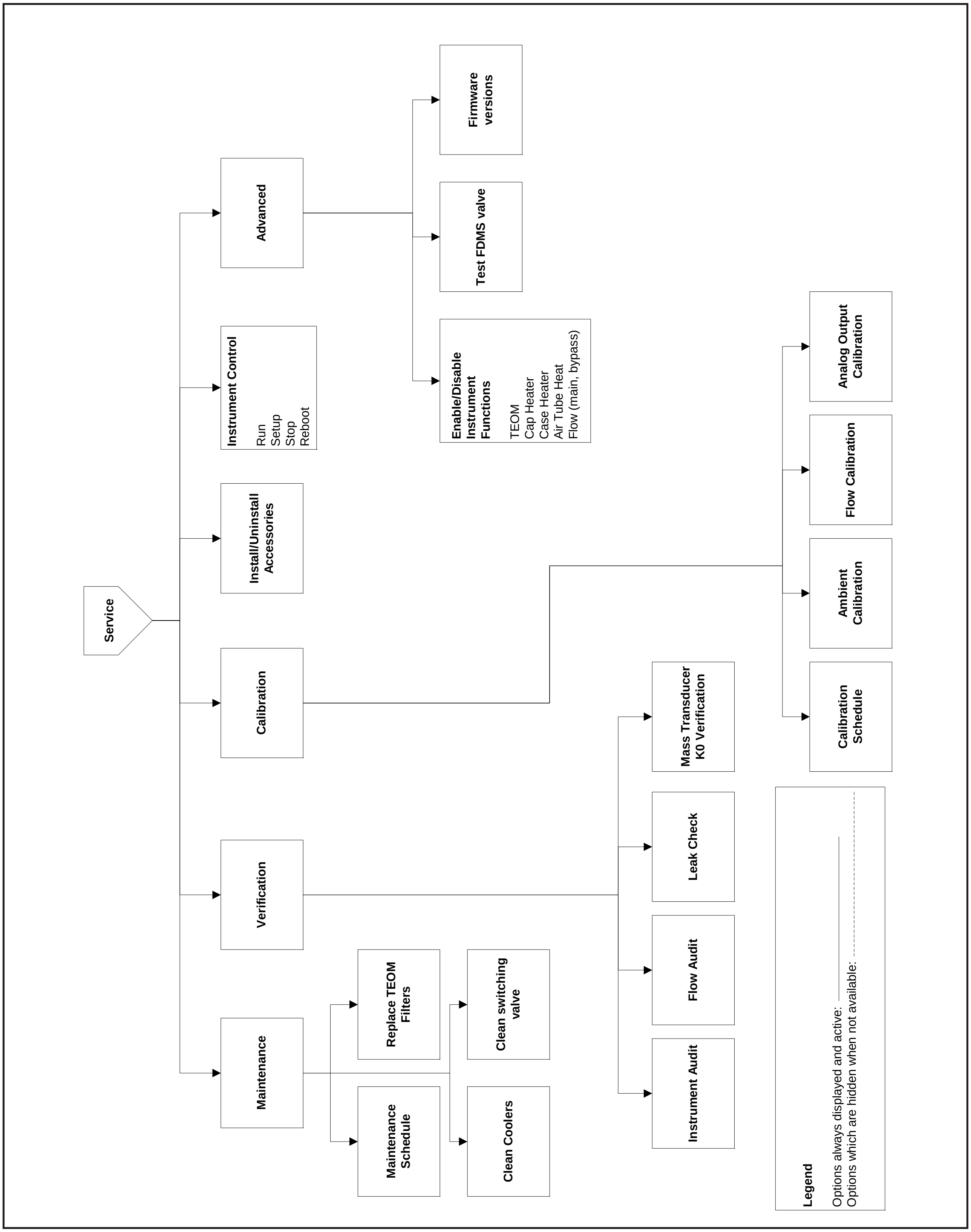
Figure 4-25. Service screen.



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. ▲

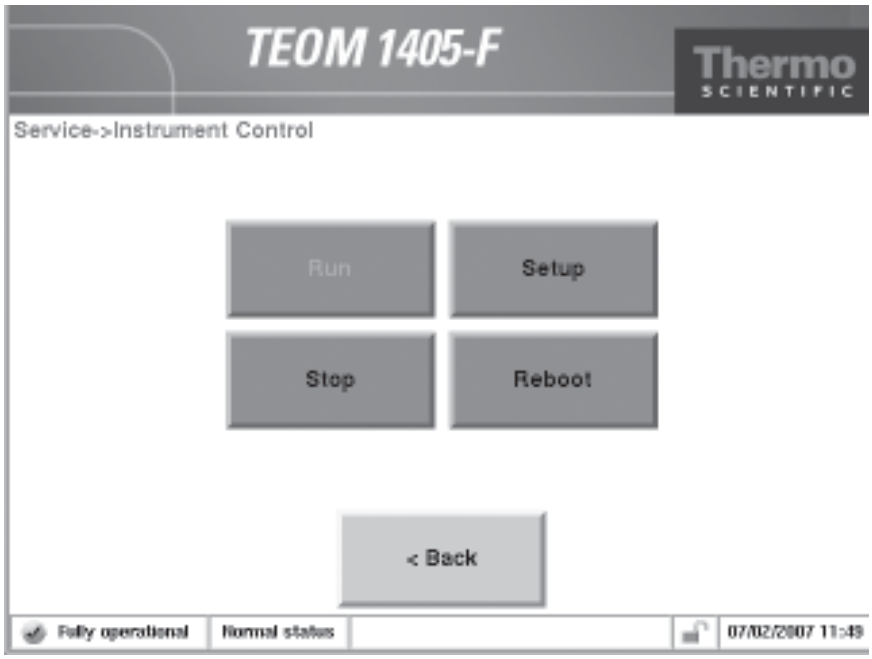
Figure 4-26.
Screens accessible through the Service screen.



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.

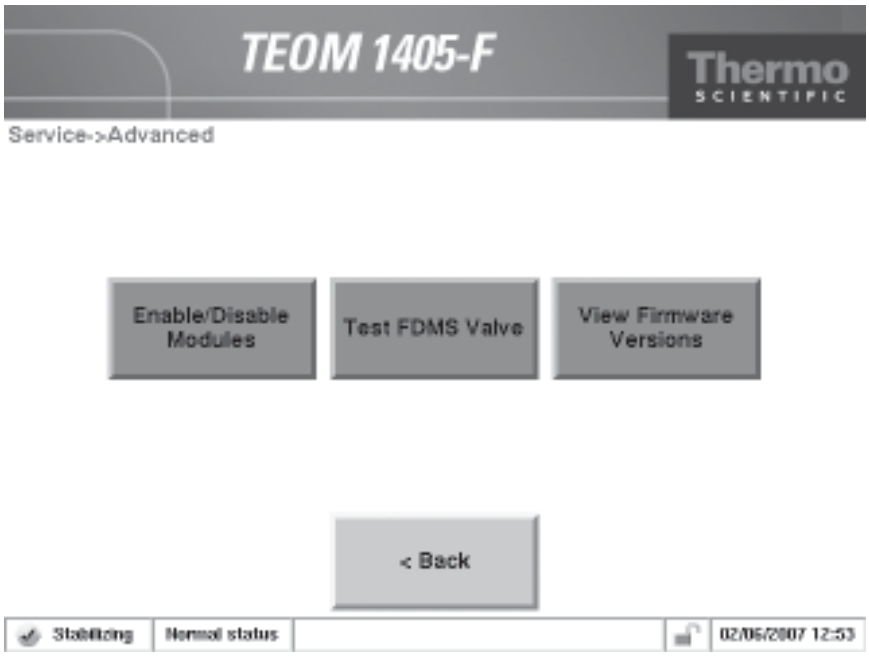
The Instrument Control screen contains the following control buttons:

- *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).

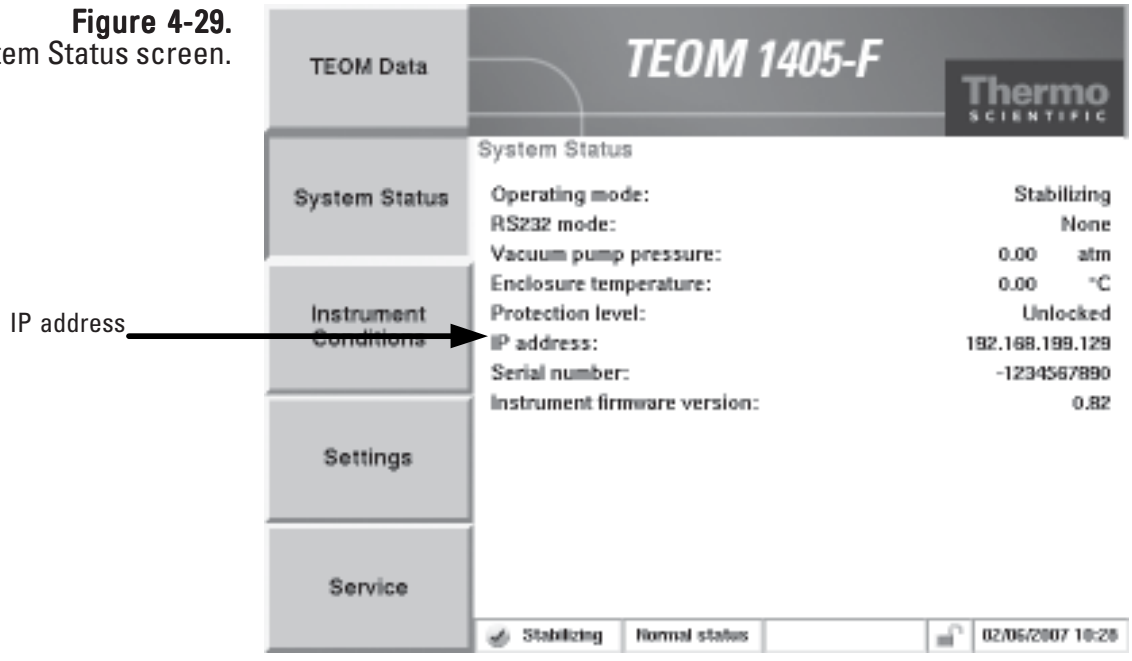
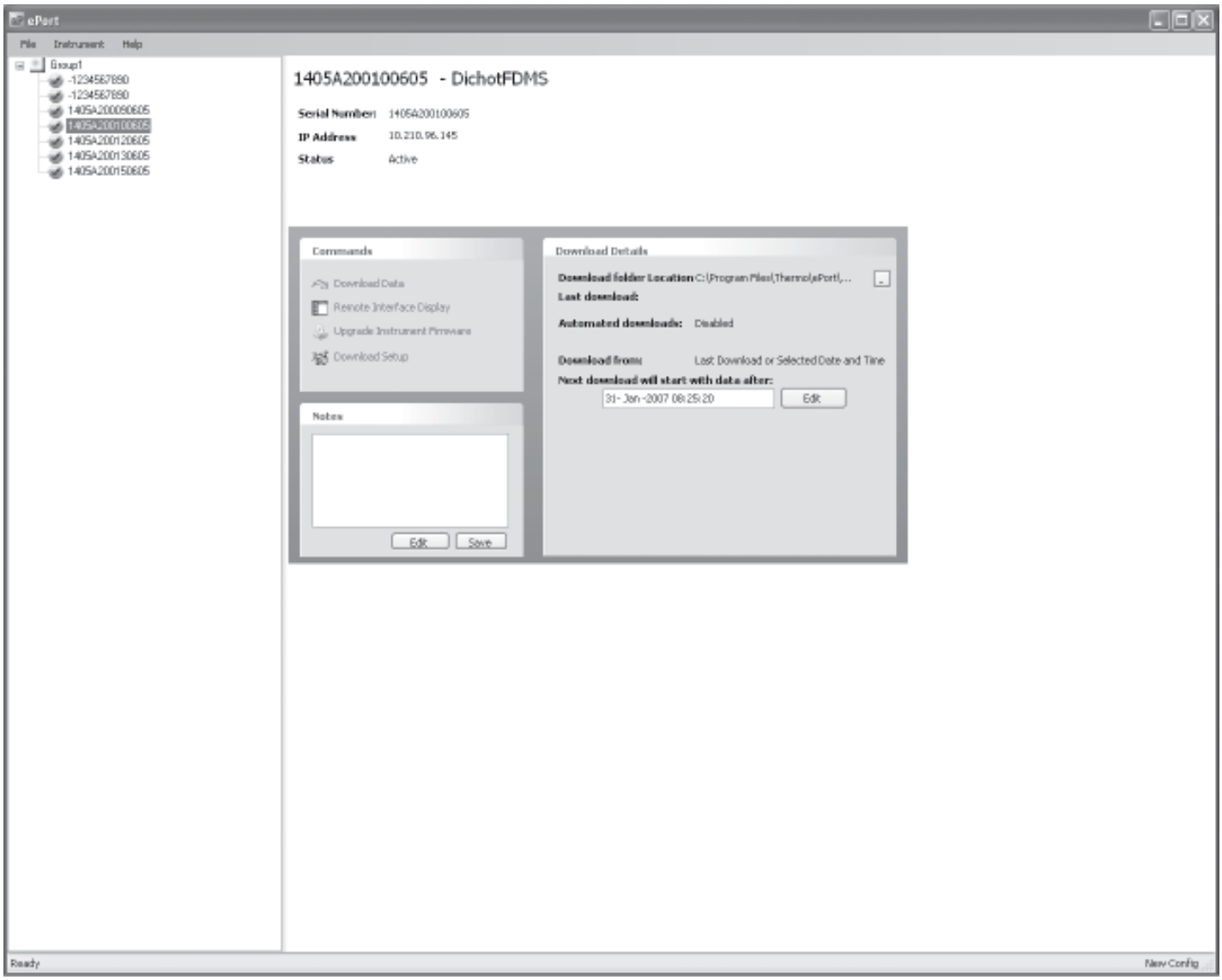


Figure 4-29. System Status screen.

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.

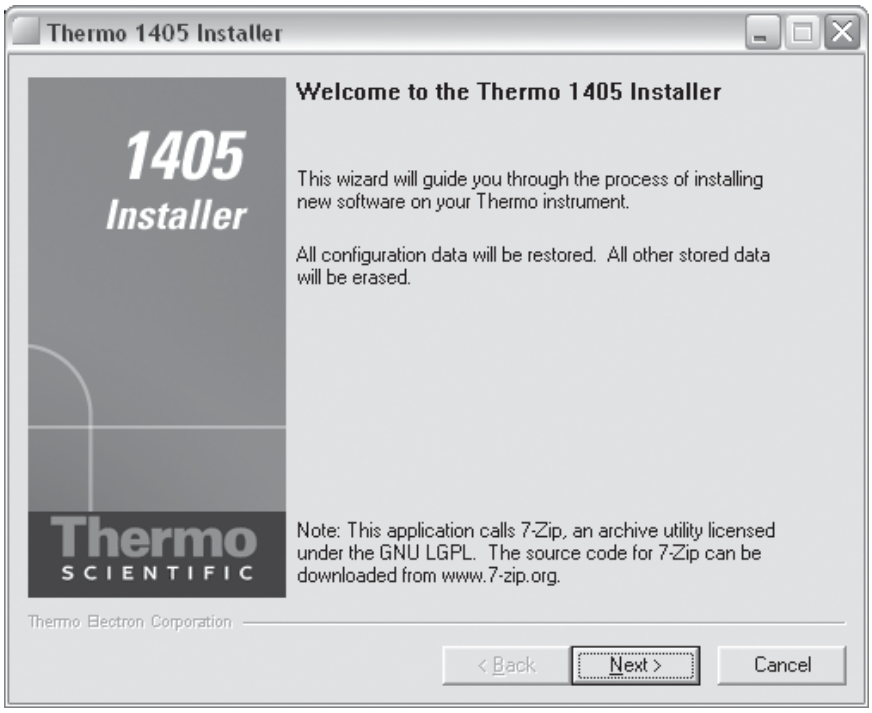
Figure 4-30.
ePort Main screen.



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.

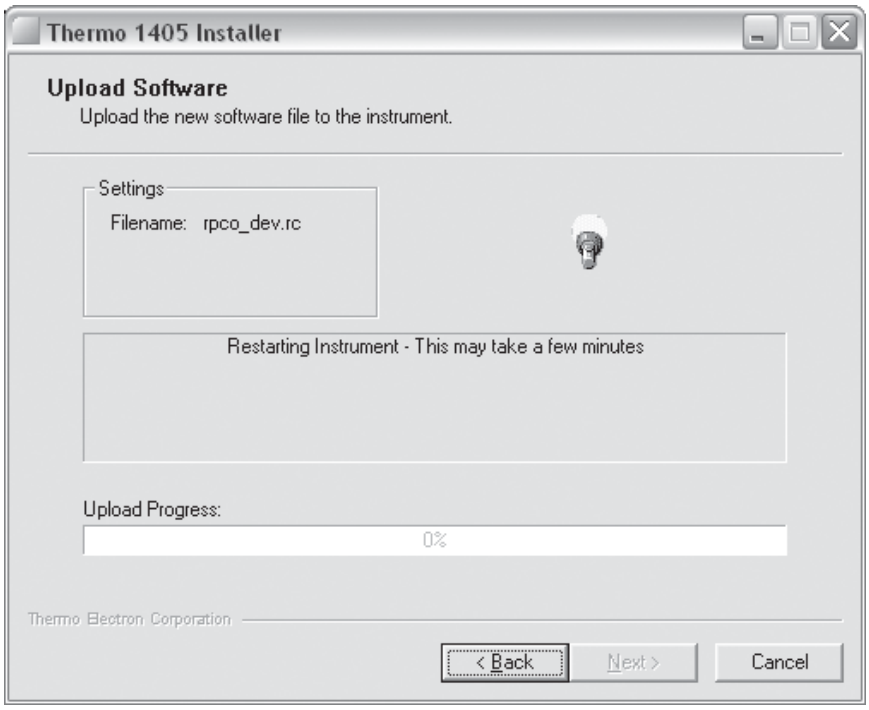
Figure 4-31.
Thermo 1405 Installer screen.



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.

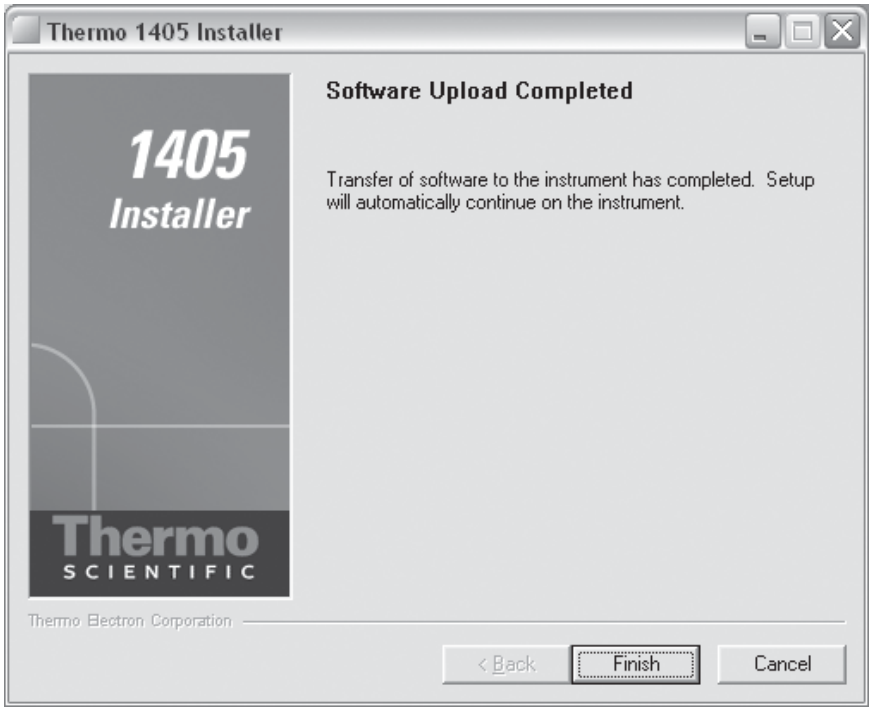
Figure 4-32.
Upload Software screen.



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.

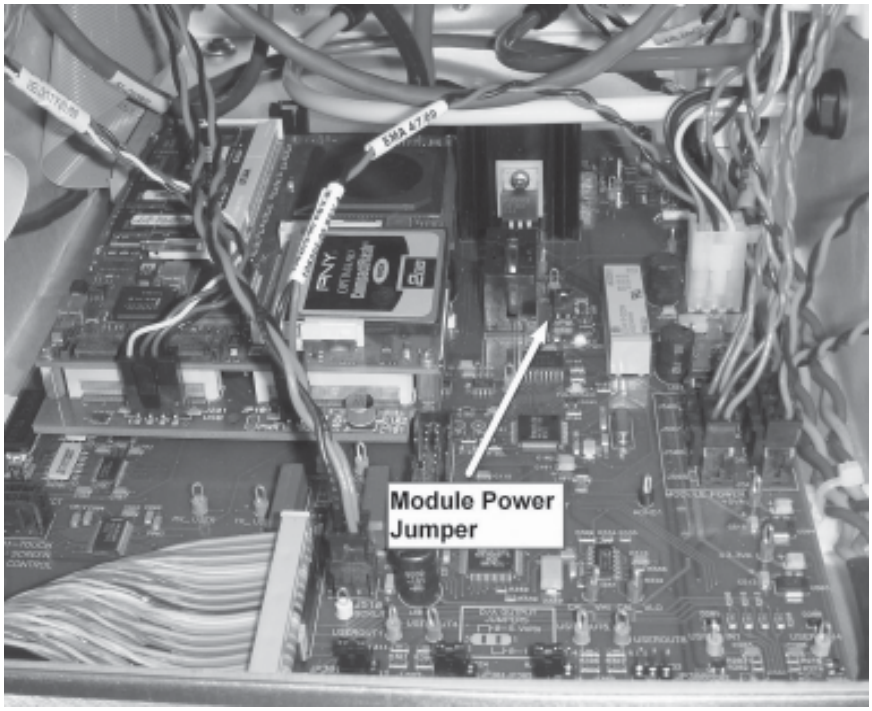
8. At the end of the update process, the instrument will pause for 20 seconds before a blank/white screen appears. Remove the USB Flash Drive. The instrument will reboot automatically to complete the installation of the firmware.

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.

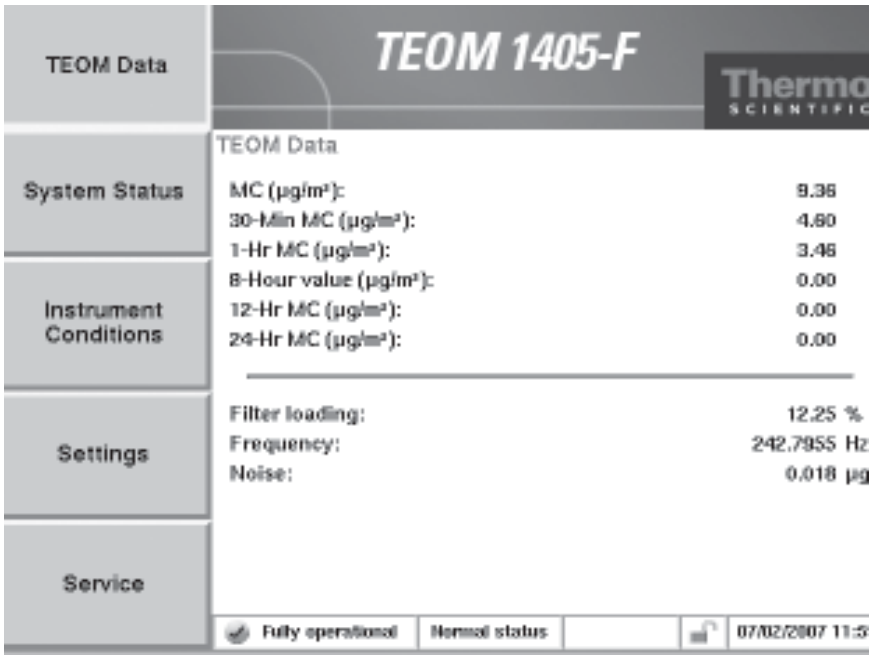


Figure 5-1. TEOM Data screen.

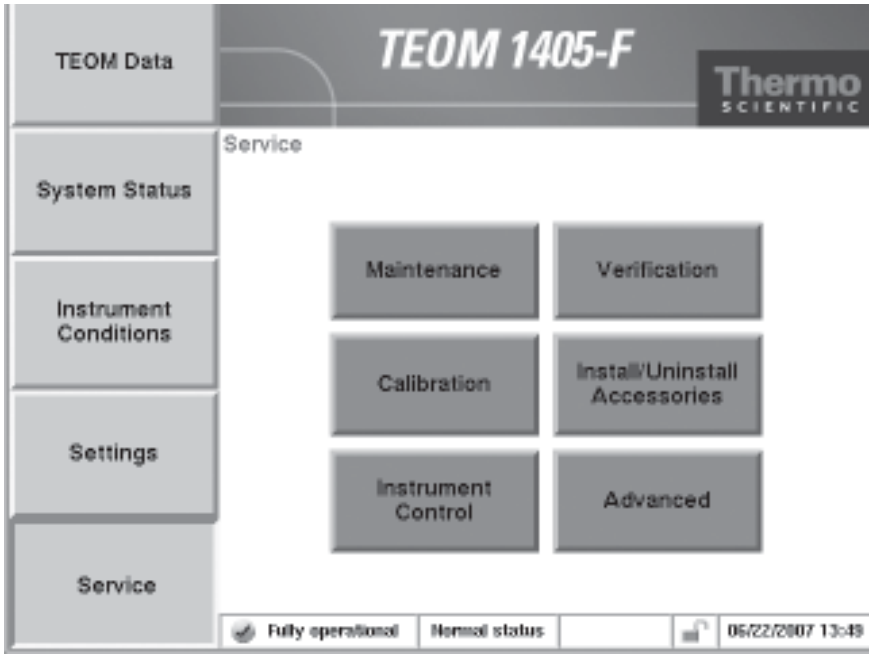
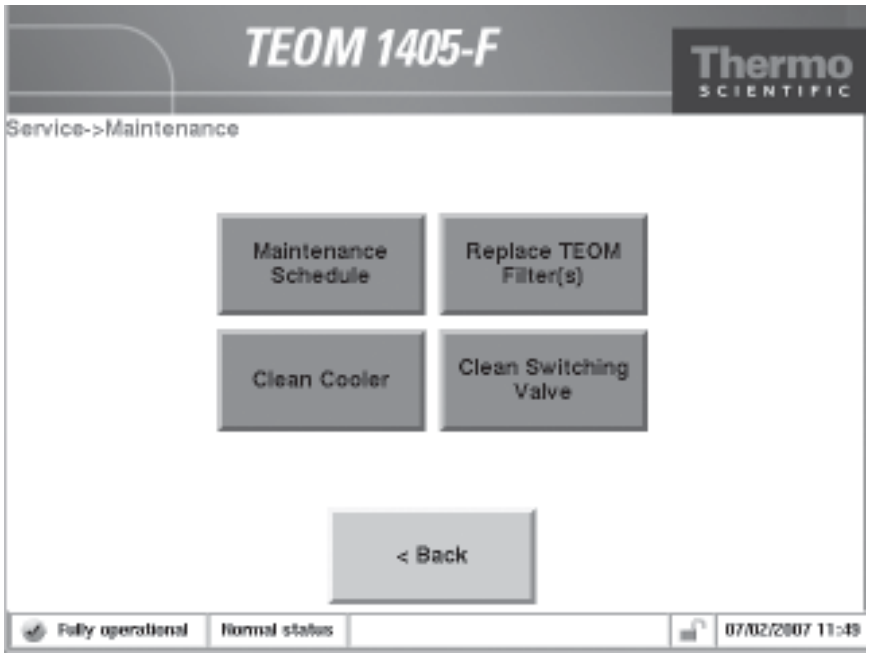


Figure 5-2. 1405 Service screen.

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

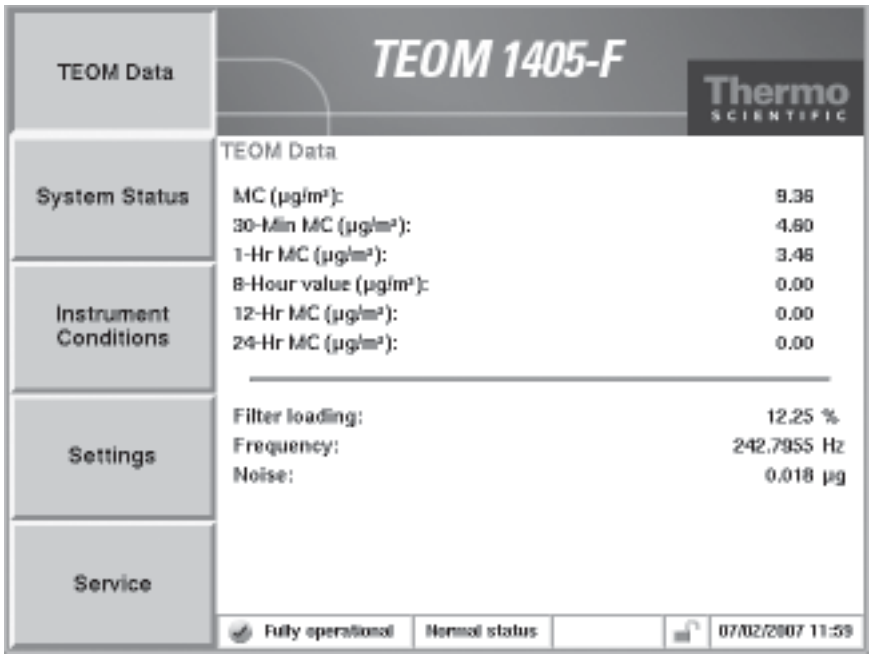
The Series 1405 TEOM filter needs to be changed periodically before filter loading can affect the flow, or at least every 30 days.

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 $\mu g/m^3$. 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. ▲

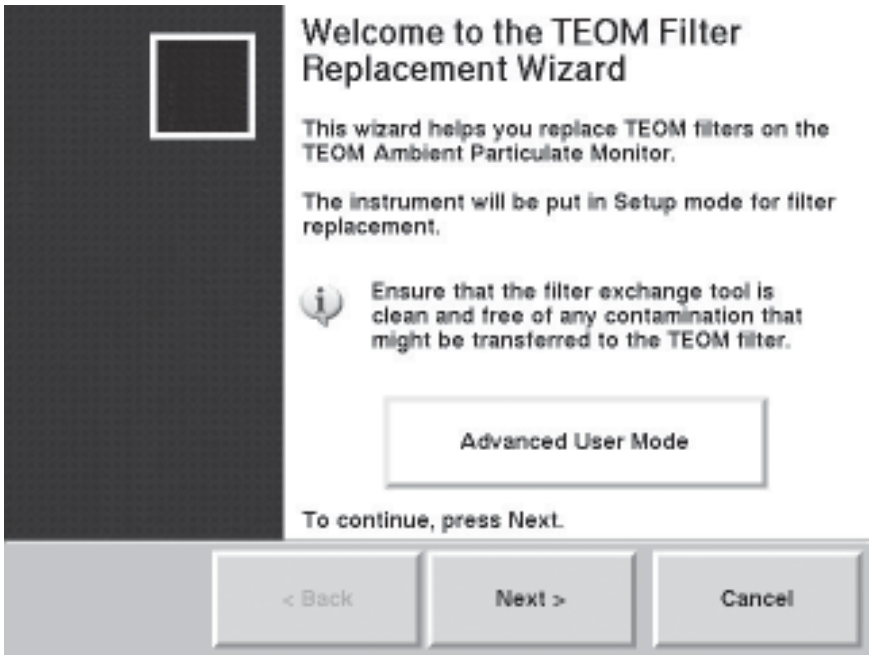


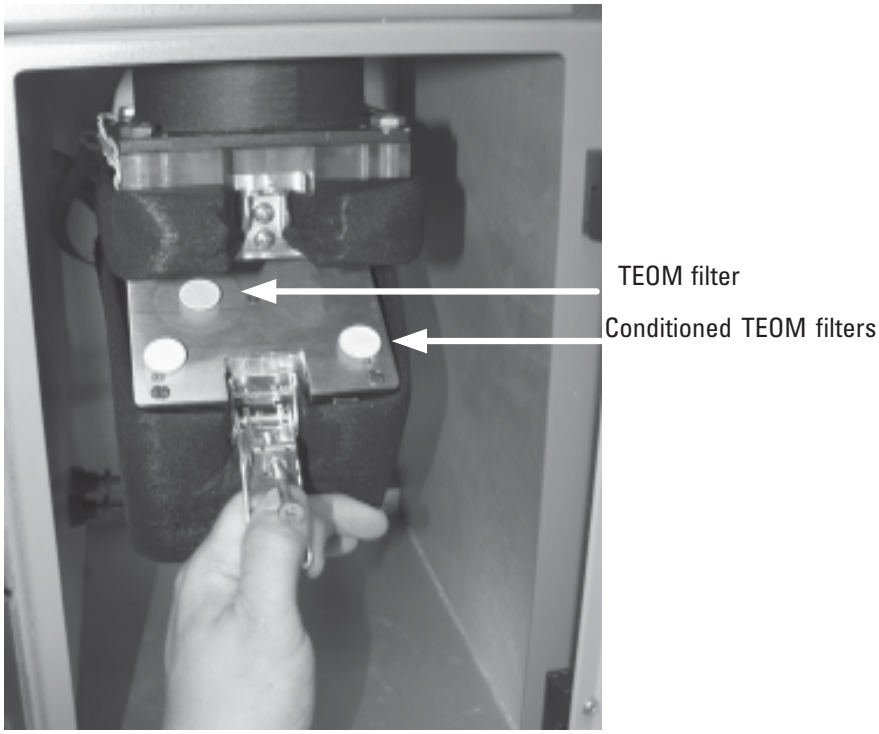
Figure 5-5. TEOM Filter Replacement Wizard starting screen.

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.

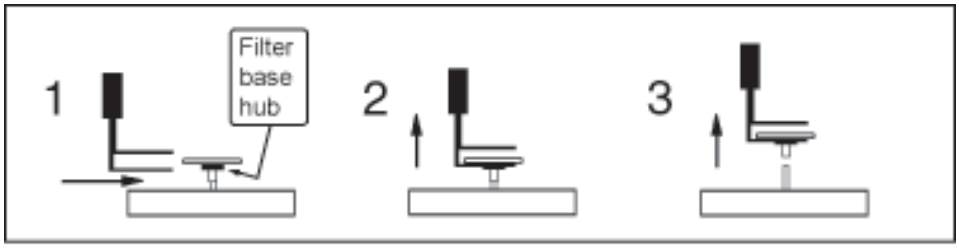
6. With the mass transducer unlatched, swing the bottom of the mass transducer downward, exposing the tapered element (TE) (Figure 5-6). Select the **Next >** button.

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.

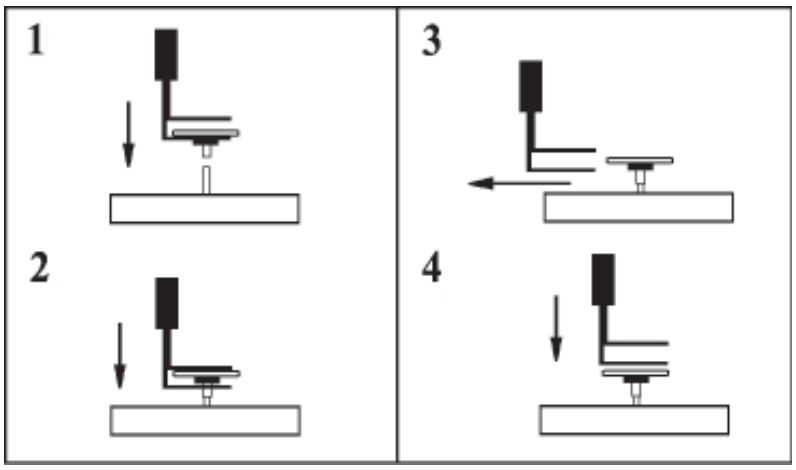
Figure 5-8.
Placing the filter on the tapered element.

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.



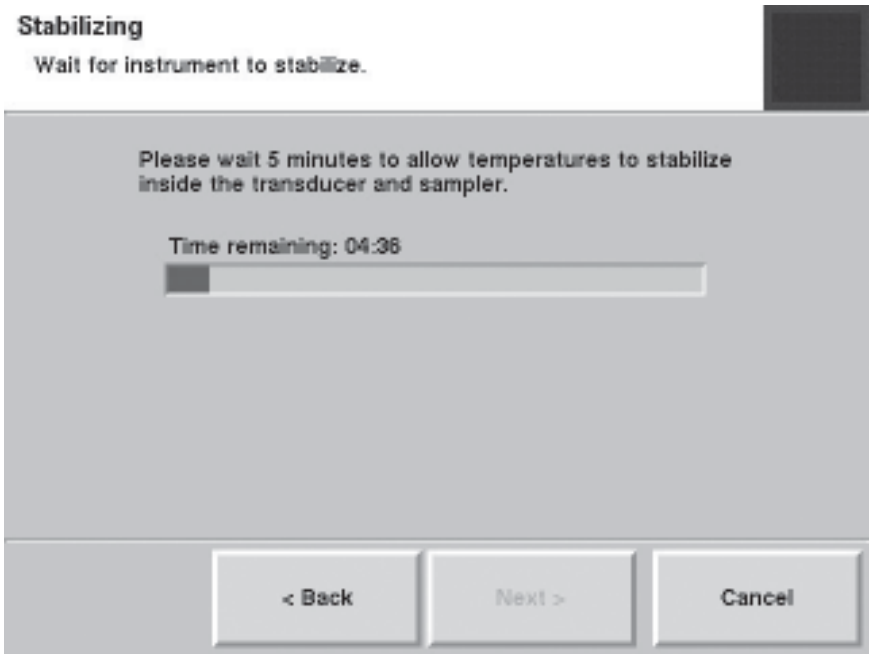
14. The Precondition Filter screen will display. Place a new TEOM filter on the empty conditioning post on the mass transducer. (Refer to the next section for more information on conditioning filters.) Select the **Next >** button.

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.

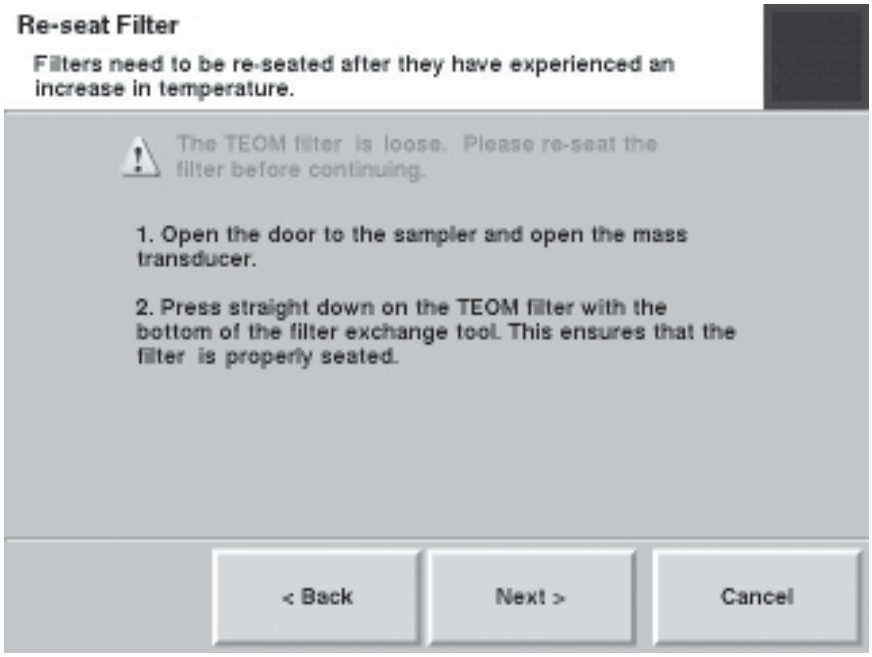
17. The system will automatically test the newly installed TEOM filter to ensure it is firmly seated. The system will display a screen with the wait time (Figure 5-10).

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.

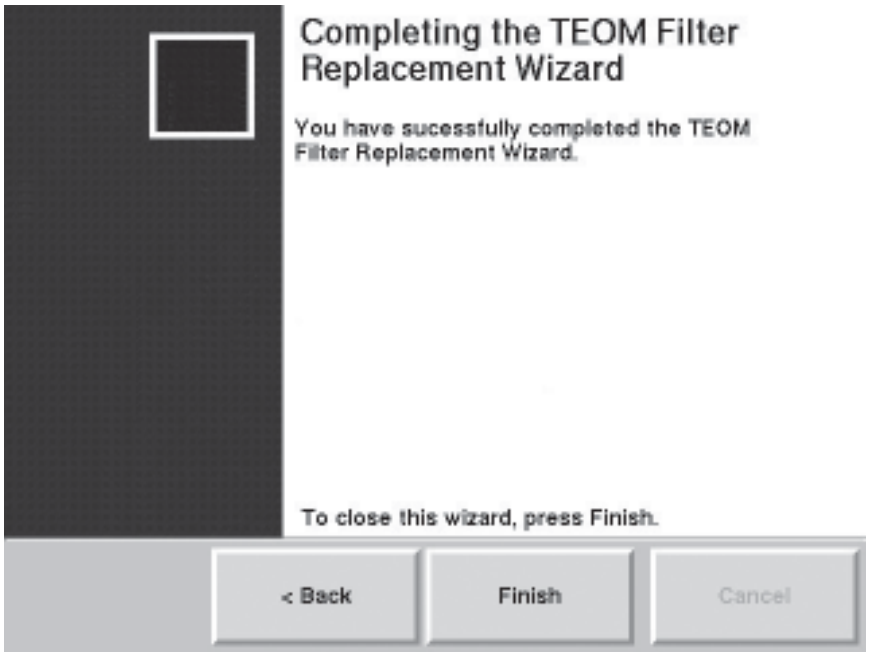


19. If the filter needs to be re-seated, open the door to the sampler and the mass transducer and press straight down on the TEOM filter with the bottom of the filter exchange tool (Figure 5-9). This ensures that the filter is properly seated. Close the mass transducer and sensor unit door. Select the **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.

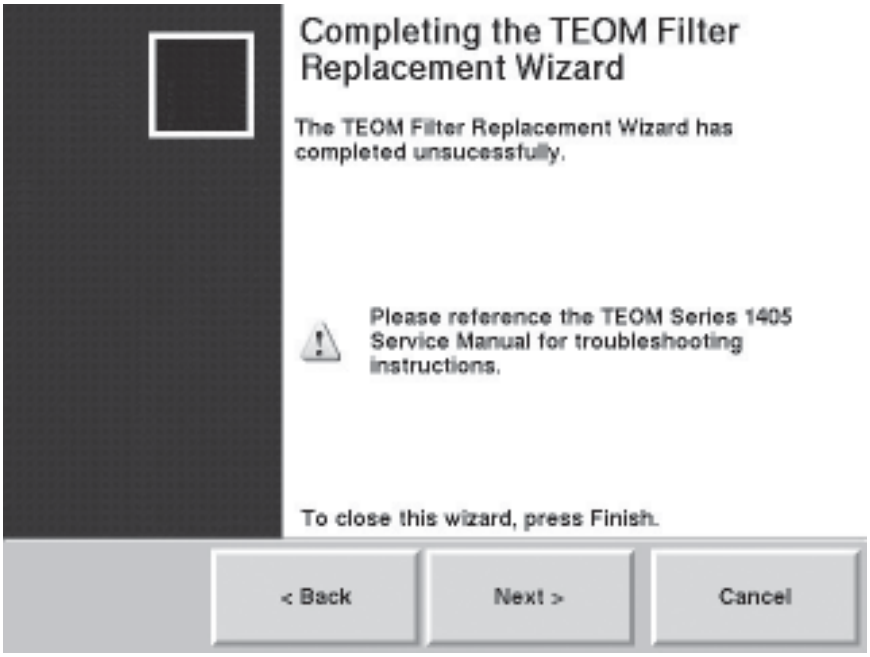
Figure 5-12.
Finish screen with successfully completed message.



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).

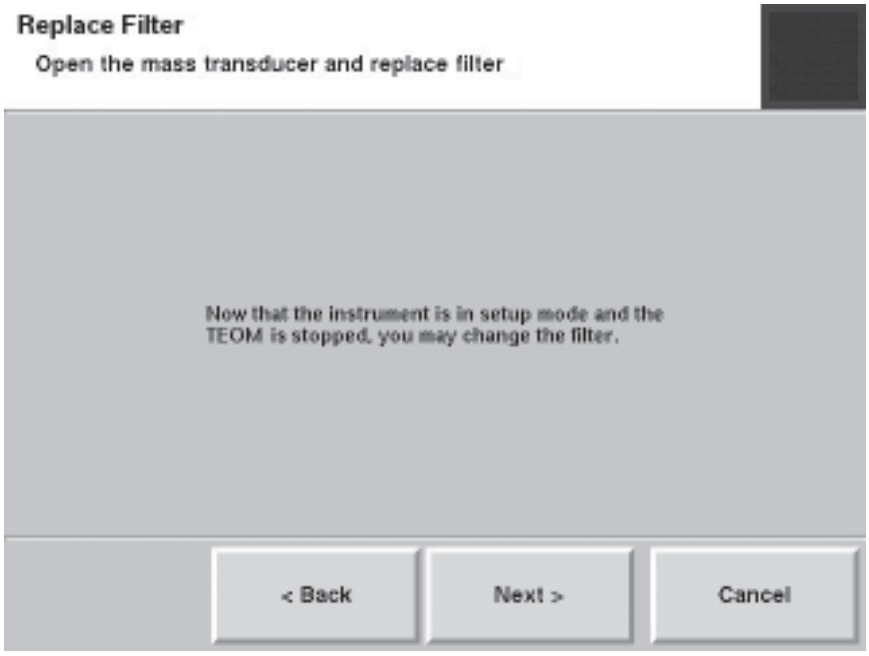


Figure 5-15. Advanced filter change screen.

When the screen displays, change the filters and select the **Next >** button. The finished screen will display (Figure 5-16).

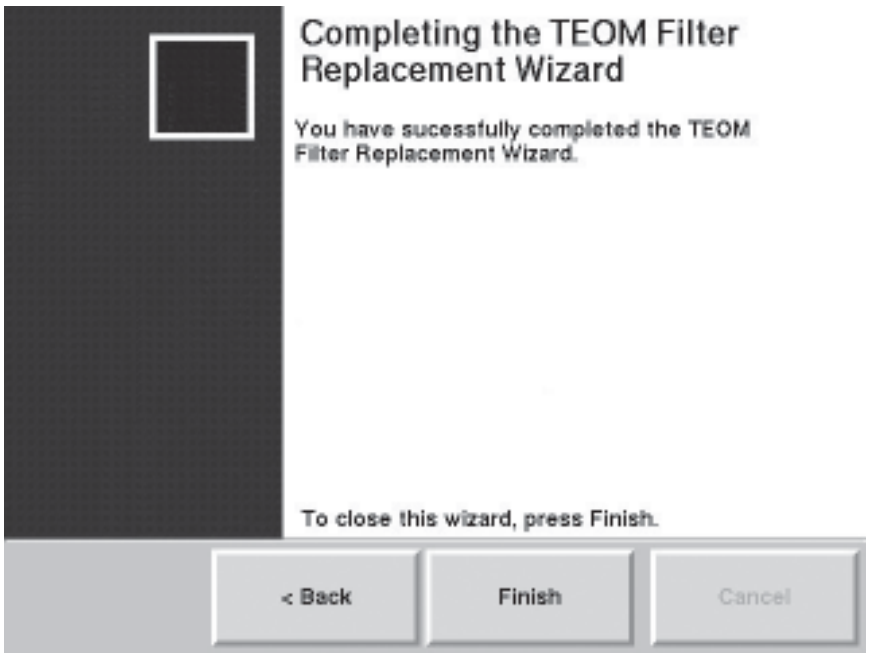
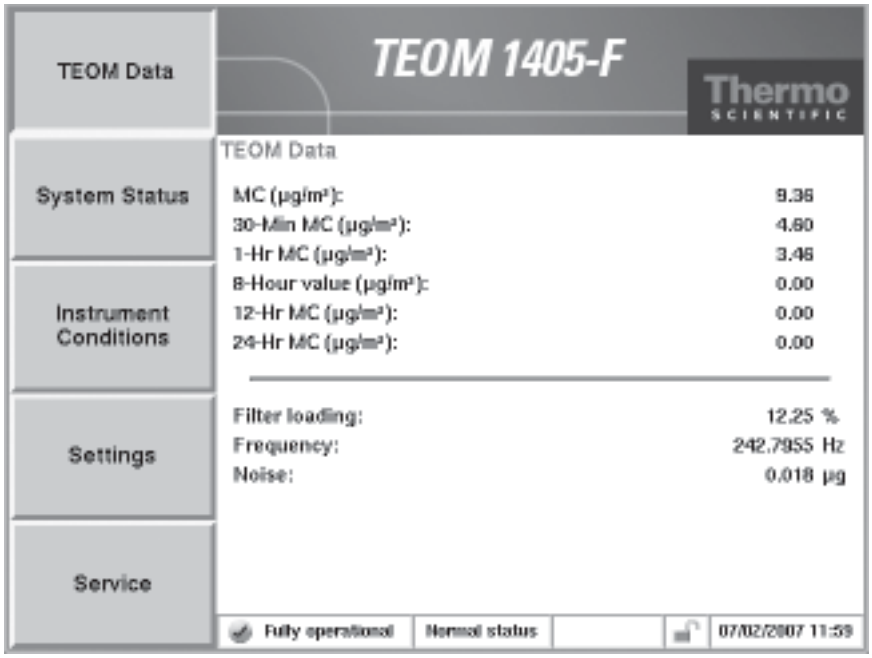


Figure 5-16. Wizard complete message.

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 pre-conditioning filters.

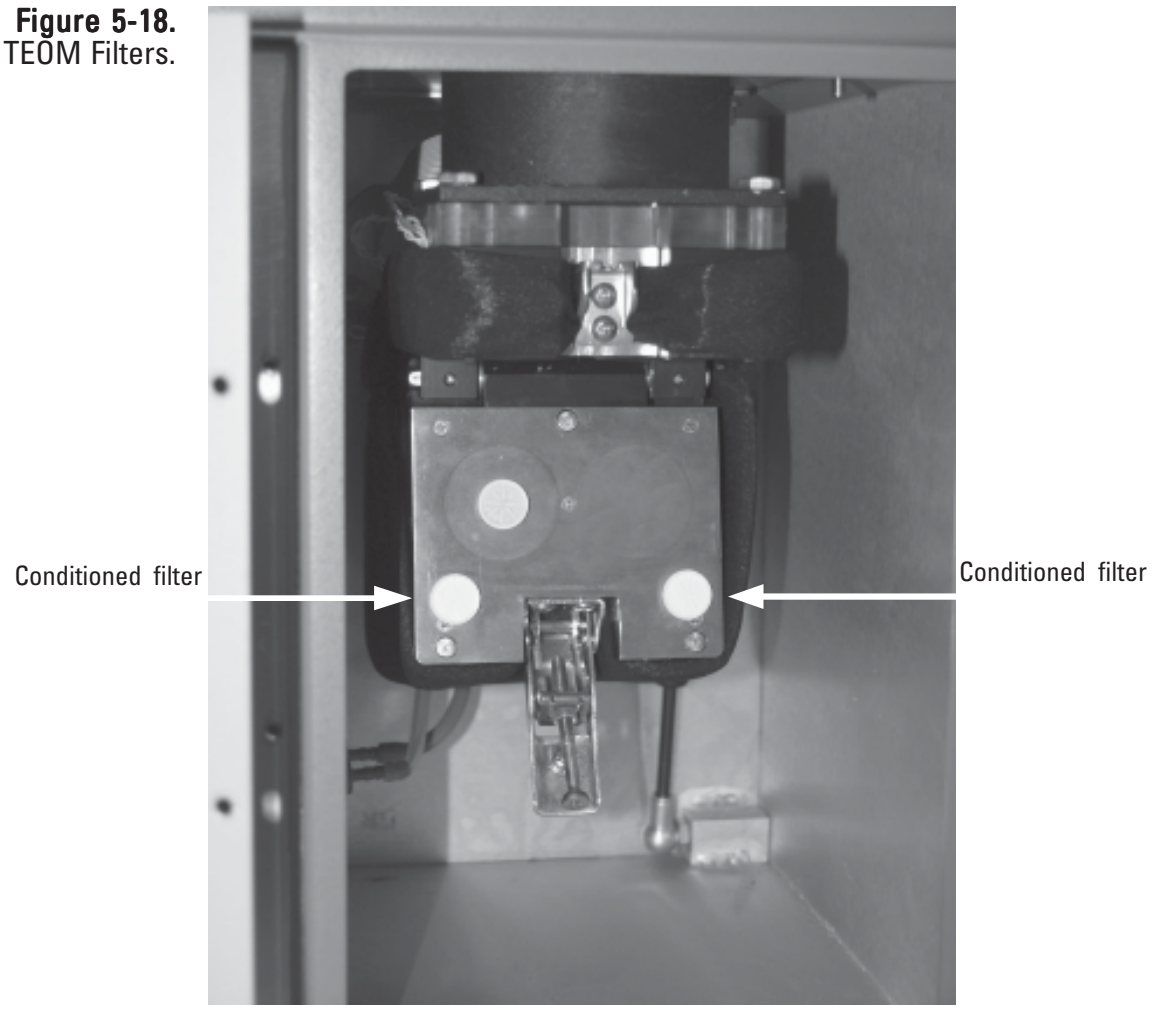
To precondition a TEOM filter:

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. ▲

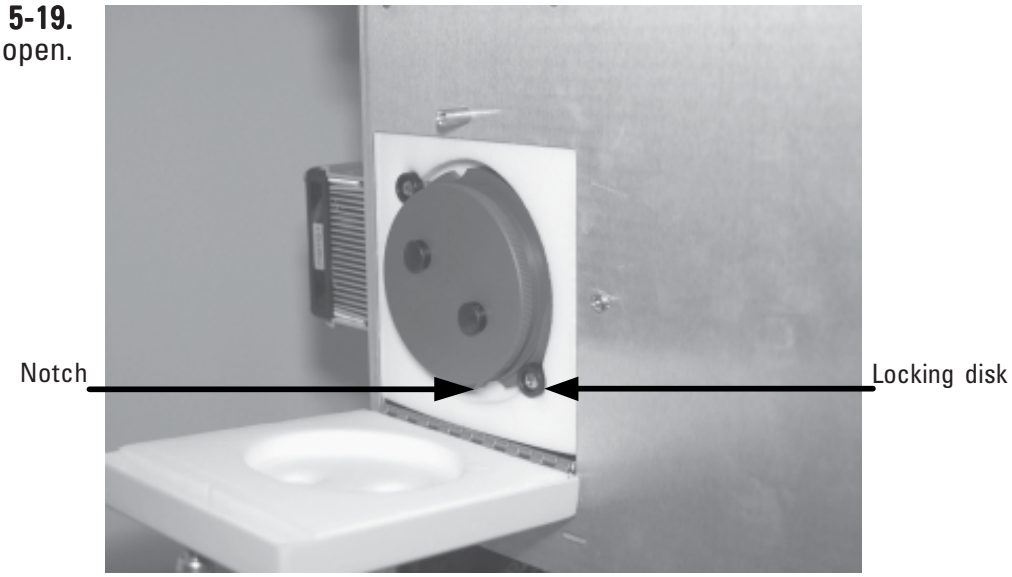
Replacing the 47 mm Filter

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:

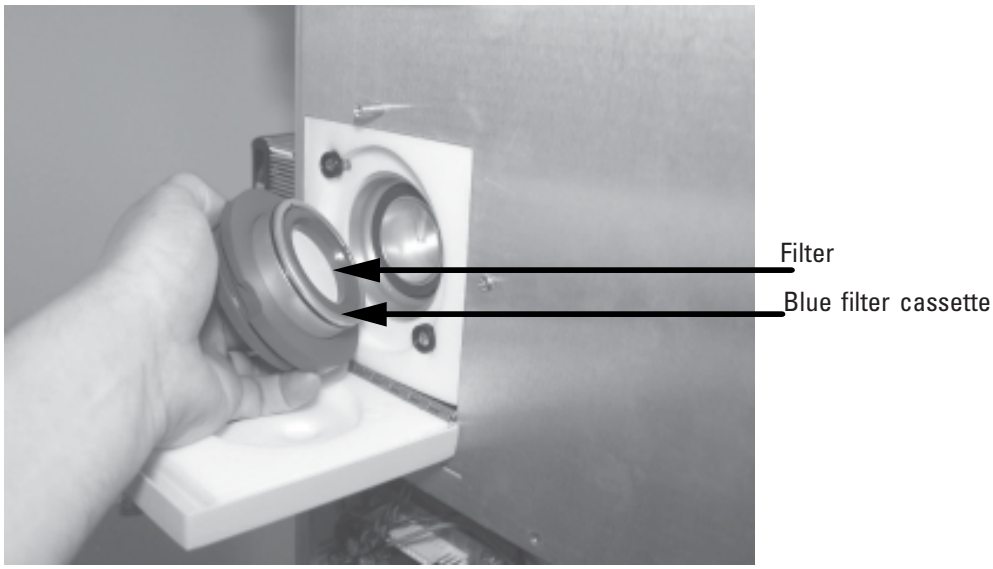
1. Locate the small door on the left side of the TEOM 1405-F unit. Open the small filter door (Figures 5-19).

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.

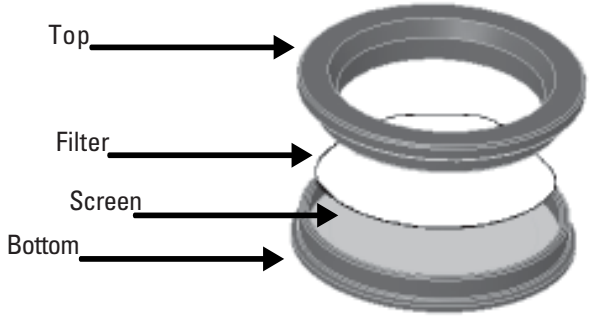
Figure 5-20. Removing the 47 mm filter.



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.

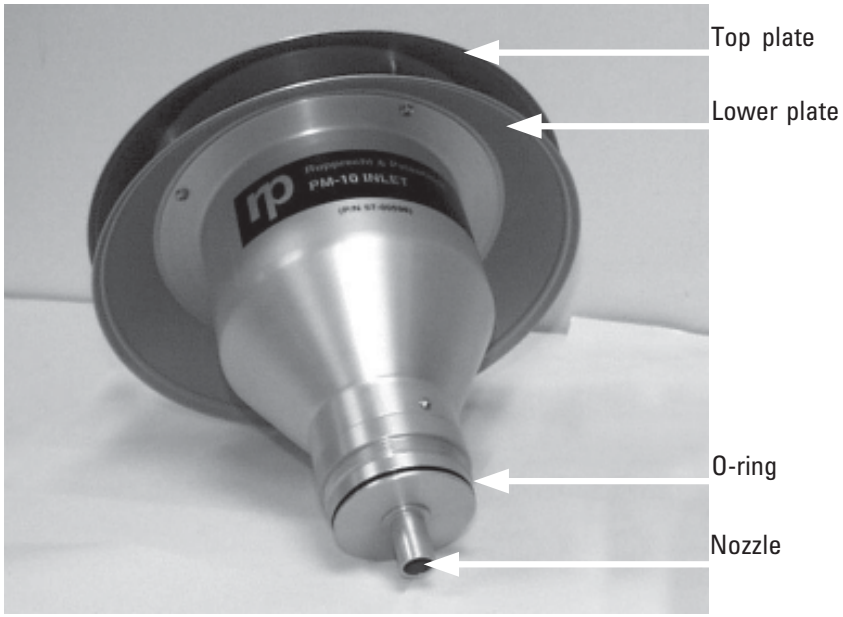
Cleaning the PM-10 Inlet

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.

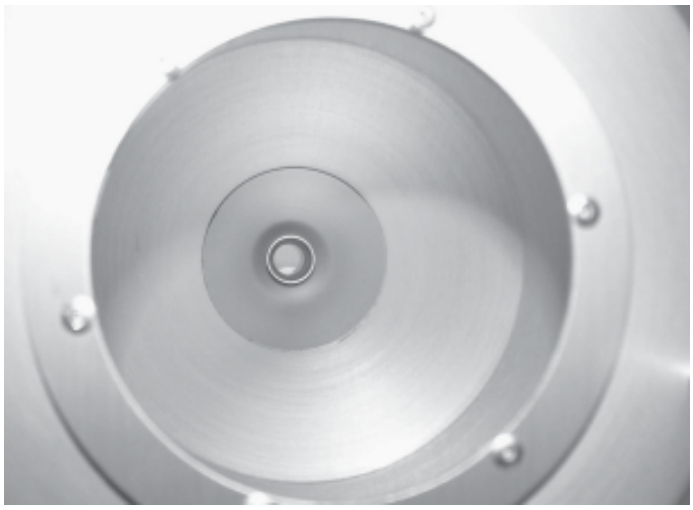
3. Clean the insect screen (with brush or water) then dry.

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.

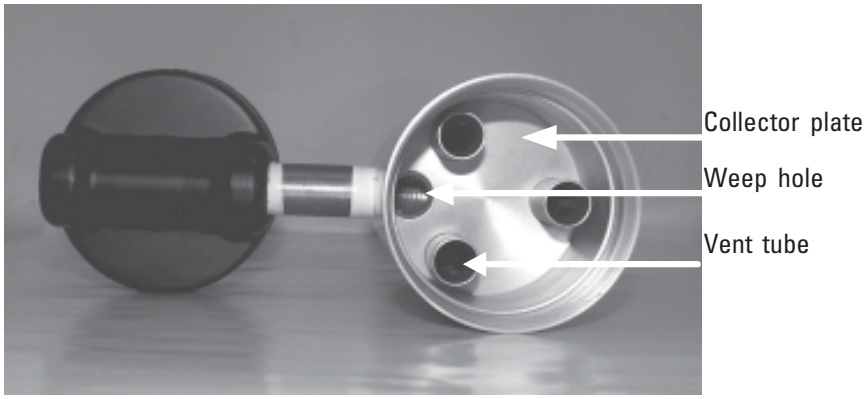


6. Inspect the large diameter, impactor nozzle O-ring for damage or wear (Figure 5-20). Replace it, if necessary. Apply a thin film of silicone grease to the O-ring. Also, apply a light coating of silicone grease to the aluminum threads of the upper acceleration assembly.

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. ▲

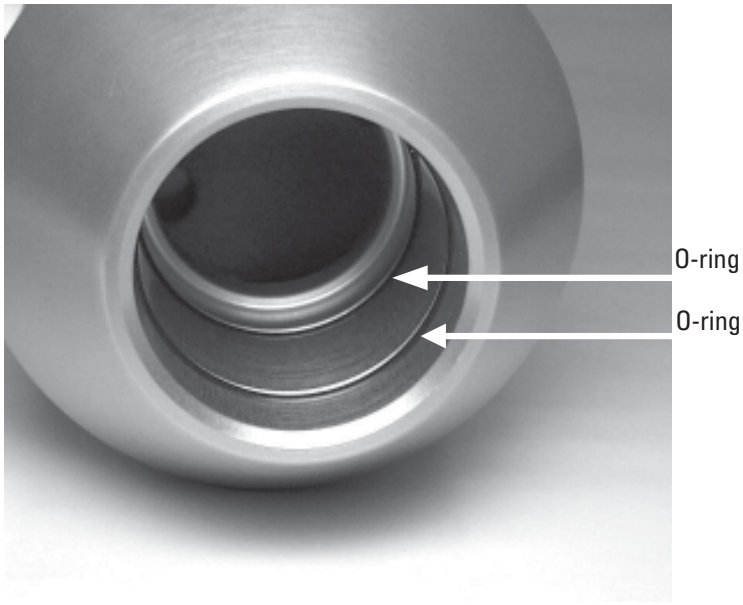
Figure 5-25. Inside of inlet collector assembly.



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.

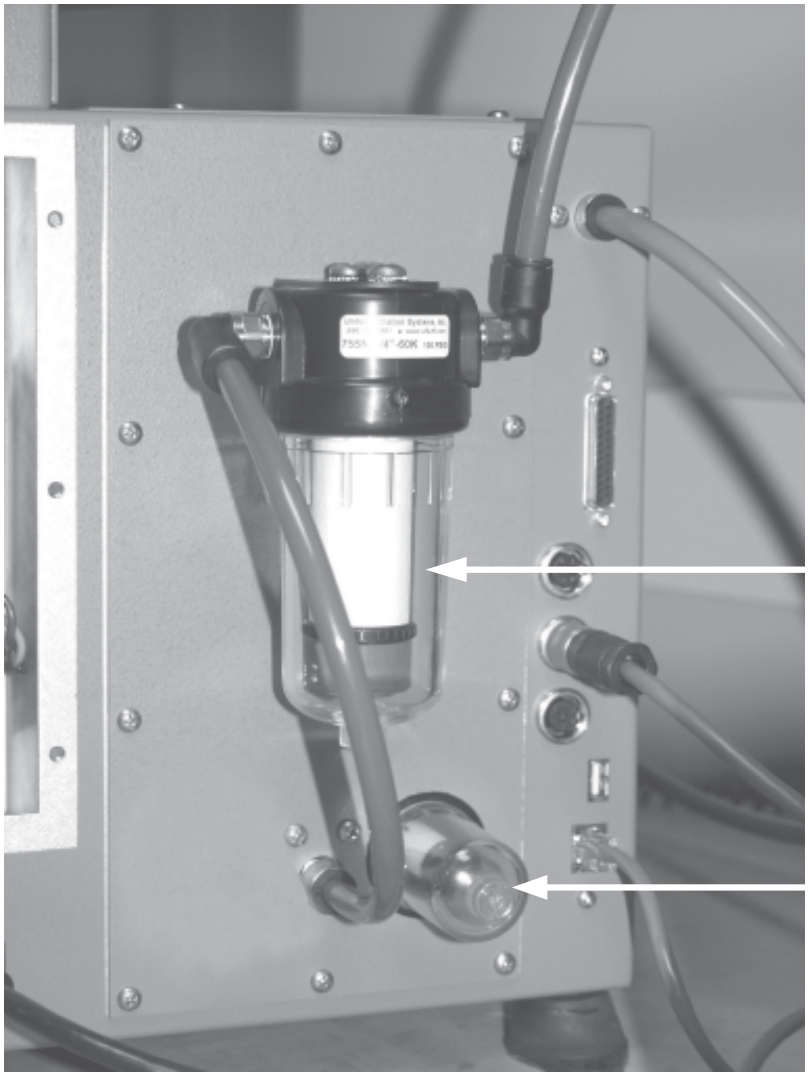
17. Place the inlet on the flow splitter. Take care not to damage the internal O-rings.

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.

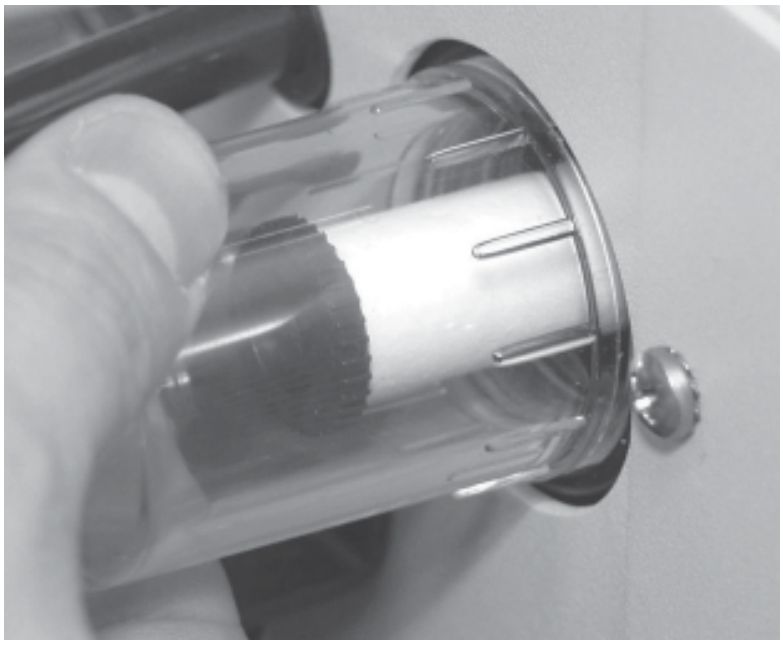


To exchange the in-line filters:

1. Unplug the sample pump.

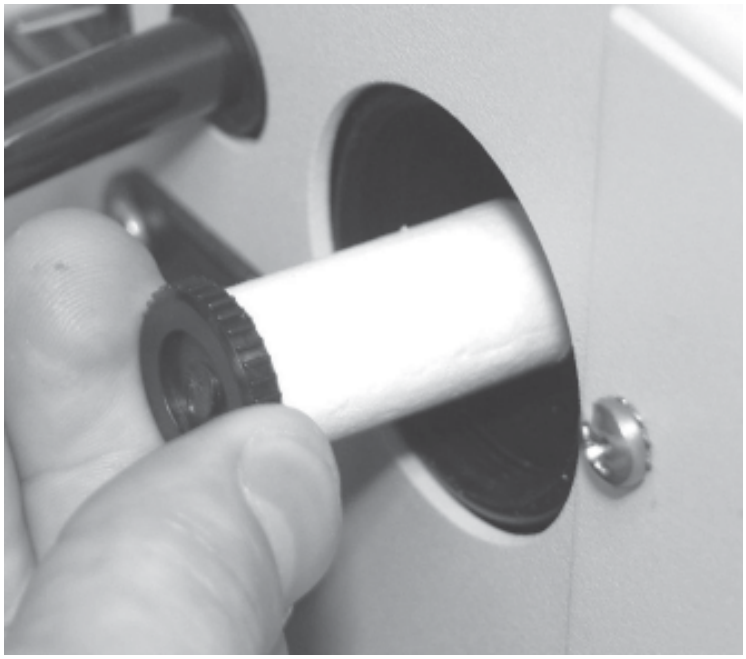
2. Unscrew and remove the small filter cover for the main flow channel on the back of the unit (Figure 5-29).

Figure 5-29.
Removing the filter cover.



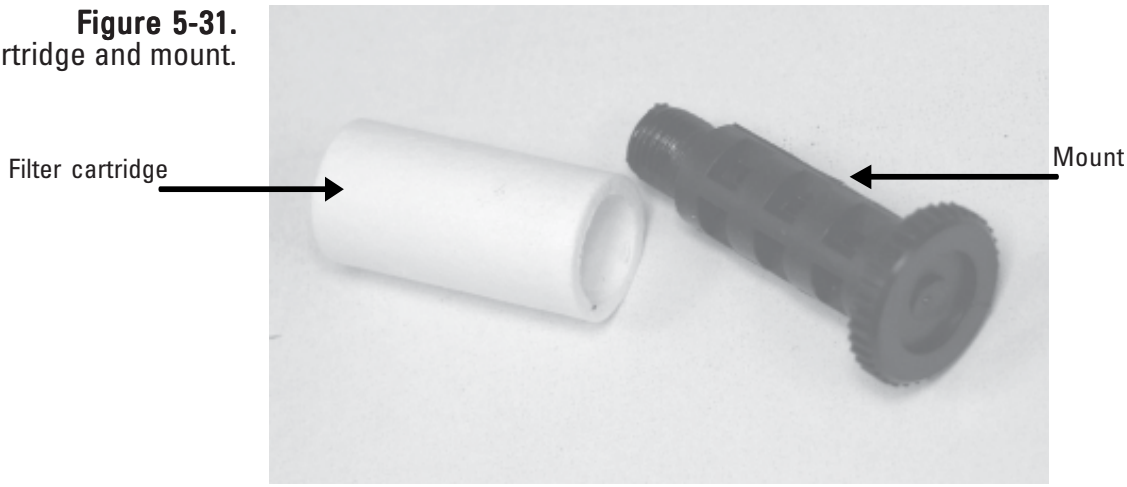
3. Unscrew the filter mount for main flow channel (Figure 5-30).

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).

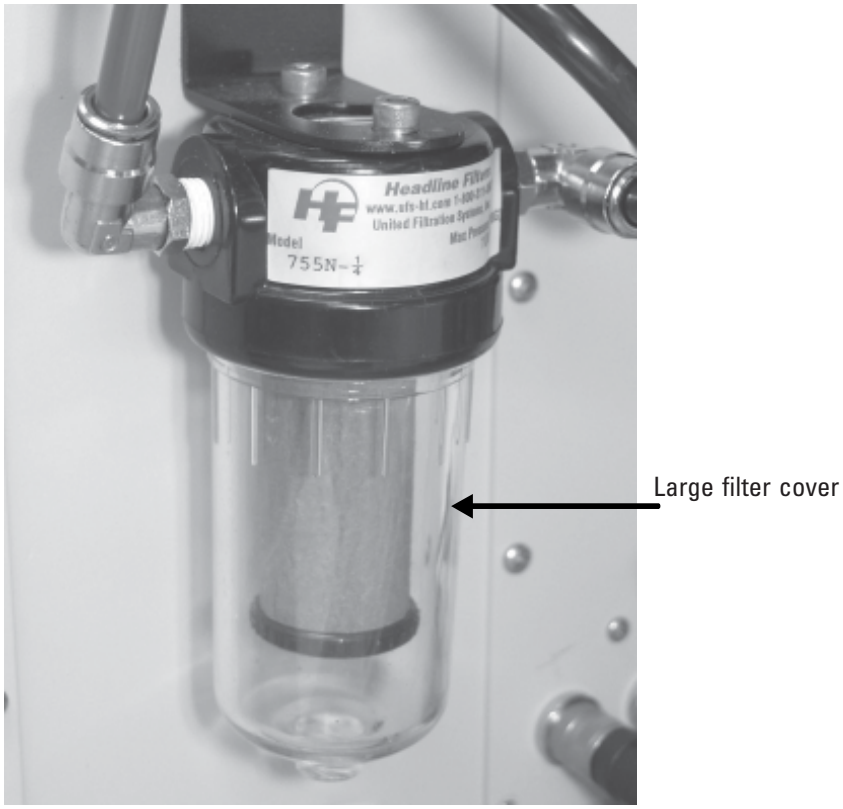
Figure 5-31.
Filter cartridge and mount.



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).

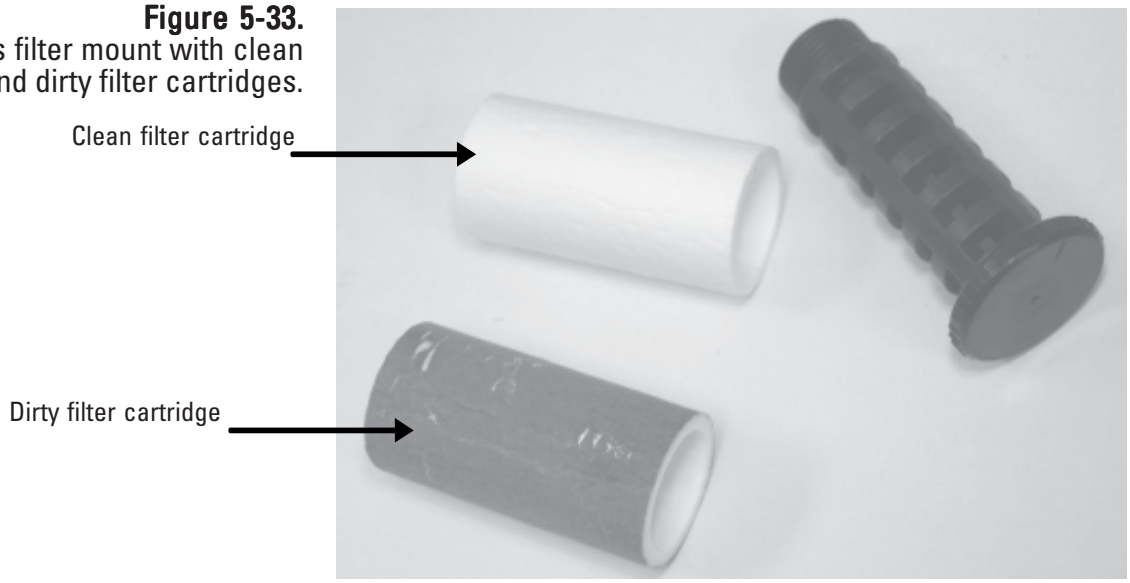
Figure 5-32.
Bypass in-line filter.



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

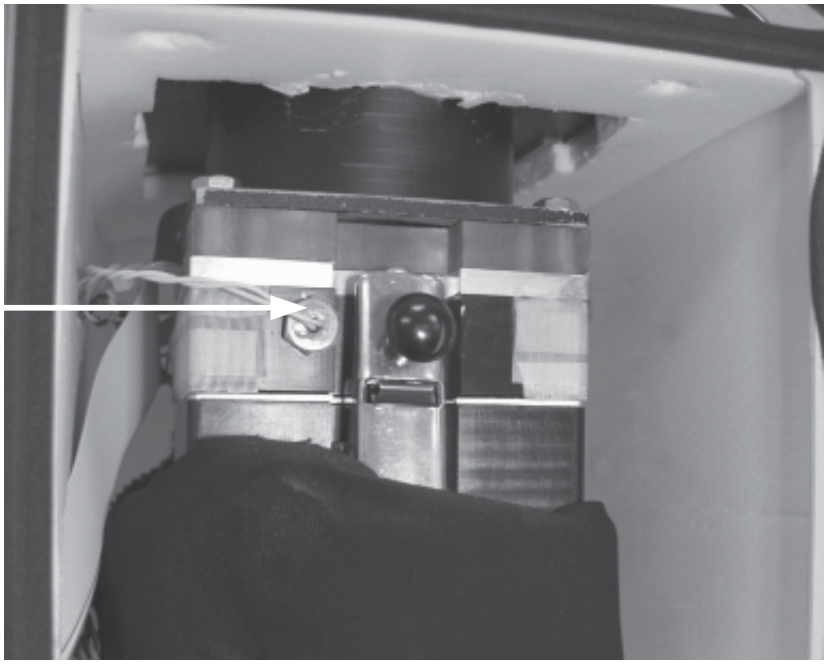
You must clean the heated air inlet in the TEOM 1405 once a year to remove the buildup of particulate matter on its inner walls. You can order a tapered bristle brush that is appropriate for cleaning the air inlet system from Thermo Scientific. You will need a piece of plastic or another protective material; 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.

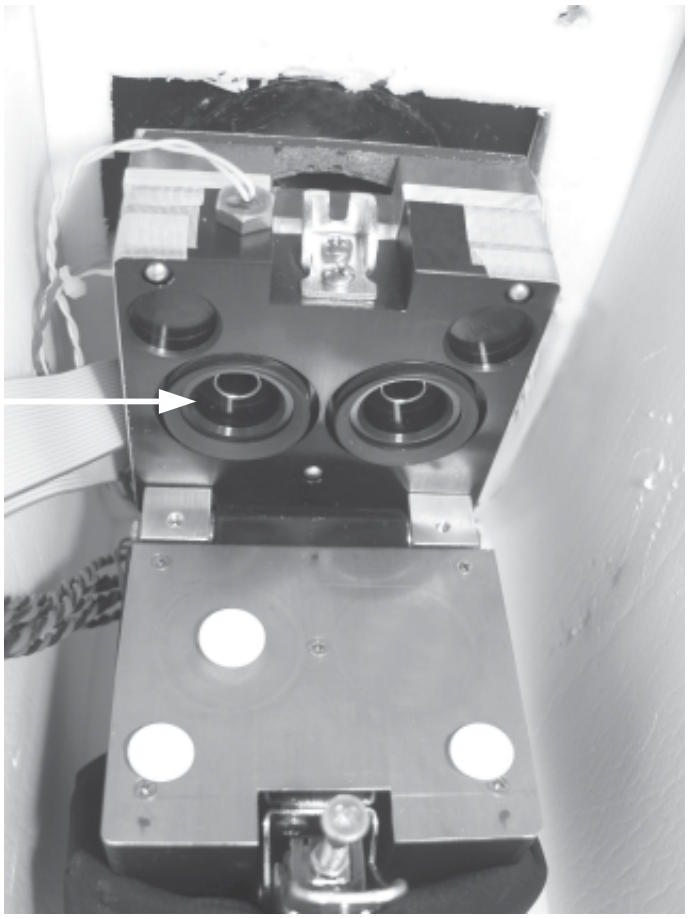
   Note. The thermistor has a short thread depth. Installation/removal should take 1 1/2 to 2 1/2 turns. ▲

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.



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

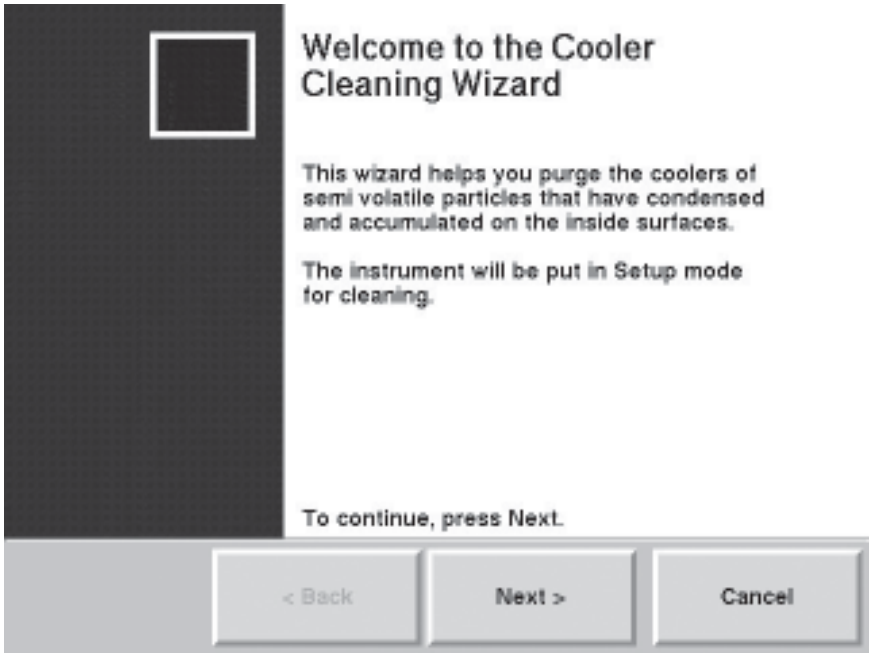
The cooler should be cleaned once per year, or as necessary. The Cooler Cleaning Wizard describes all the steps necessary to clean the cooler. Some additional information is included below.

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.

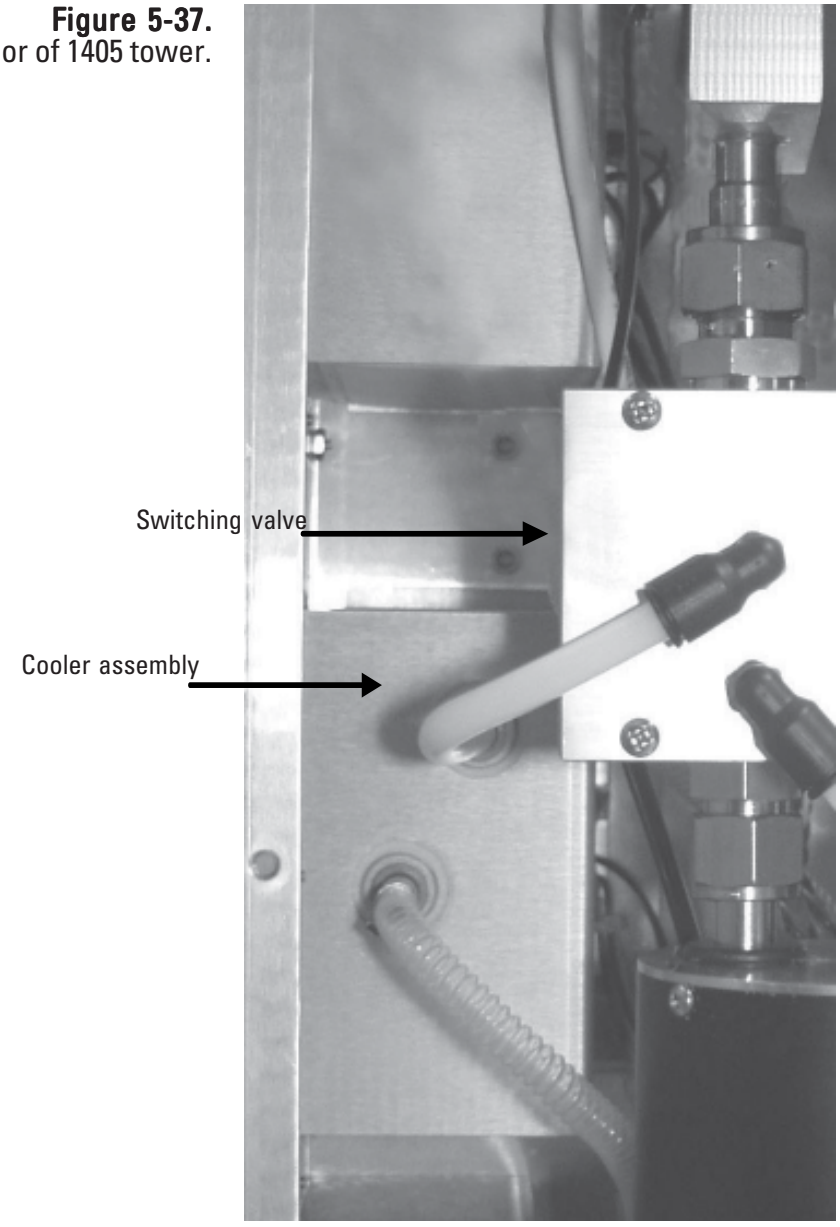
Figure 5-36. Cooler Cleaning Wizard Welcome screen.



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.

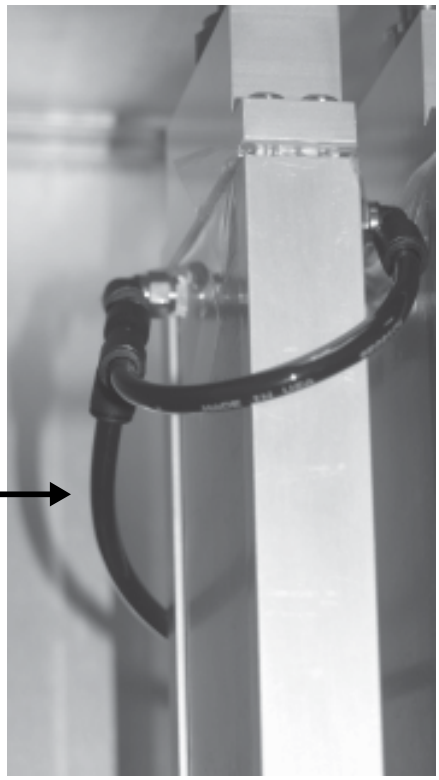
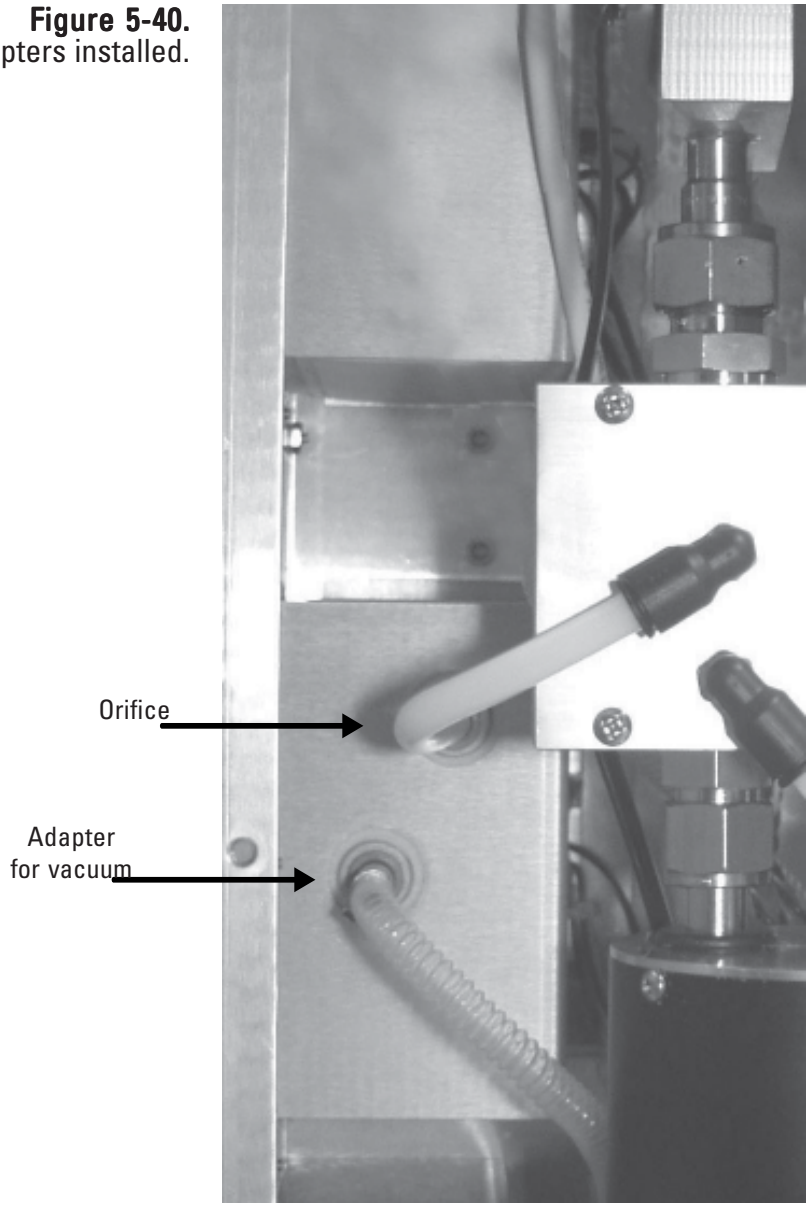


Figure 5-39.
Main dryer vacuum line removed from T-fitting.

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.

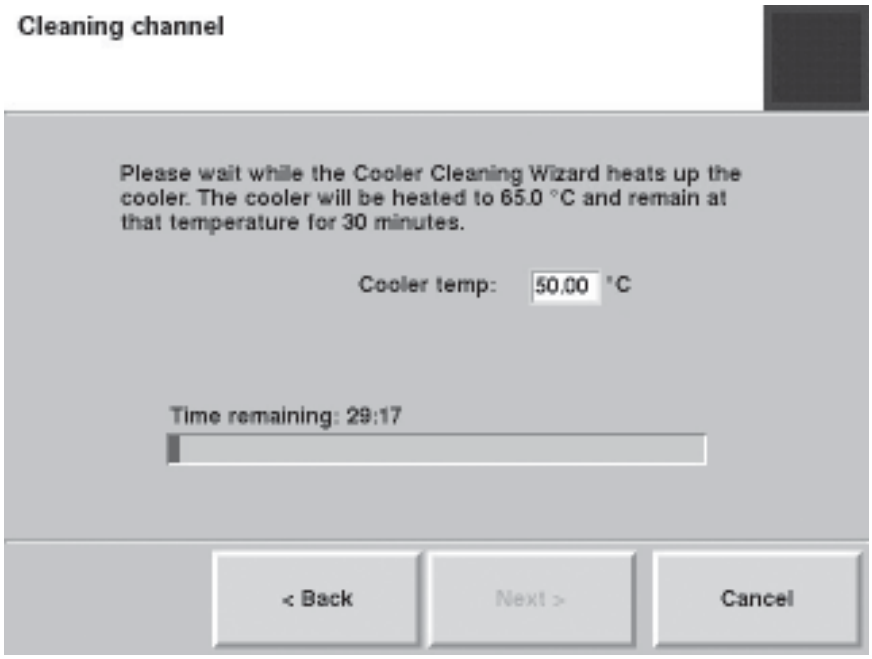


8. Install the main dryer vacuum line removed in step 6 into the bottom of the other adapter (Figure 5-40), and install the piece of tubing into the bottom quick-connect fitting of the cooler assemby. Select the **Next >** button.

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.

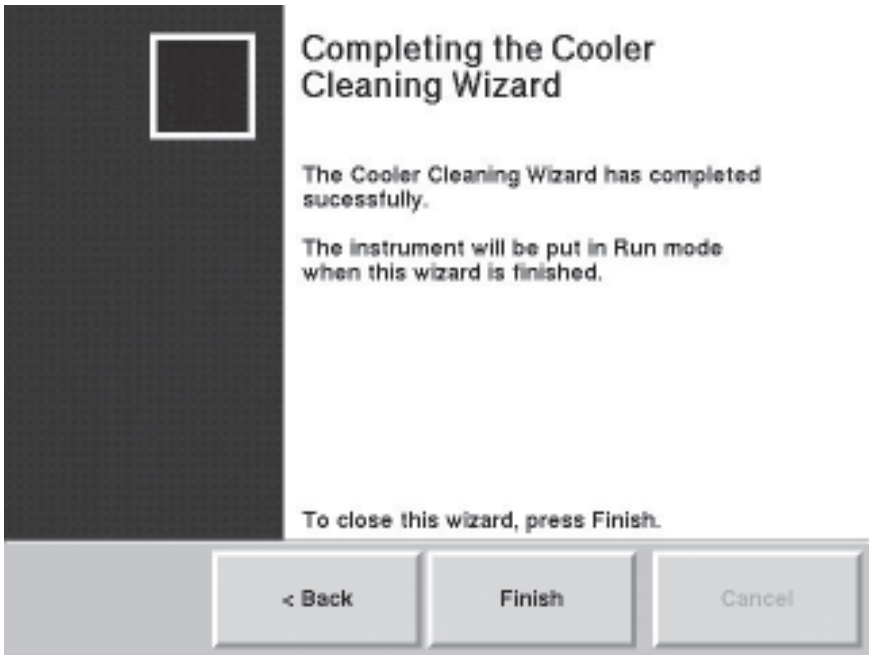
11. The Close Unit screen will display. Disconnect the adapters and reinstall the tubing into the cooler assembly as described by the wizard.

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.

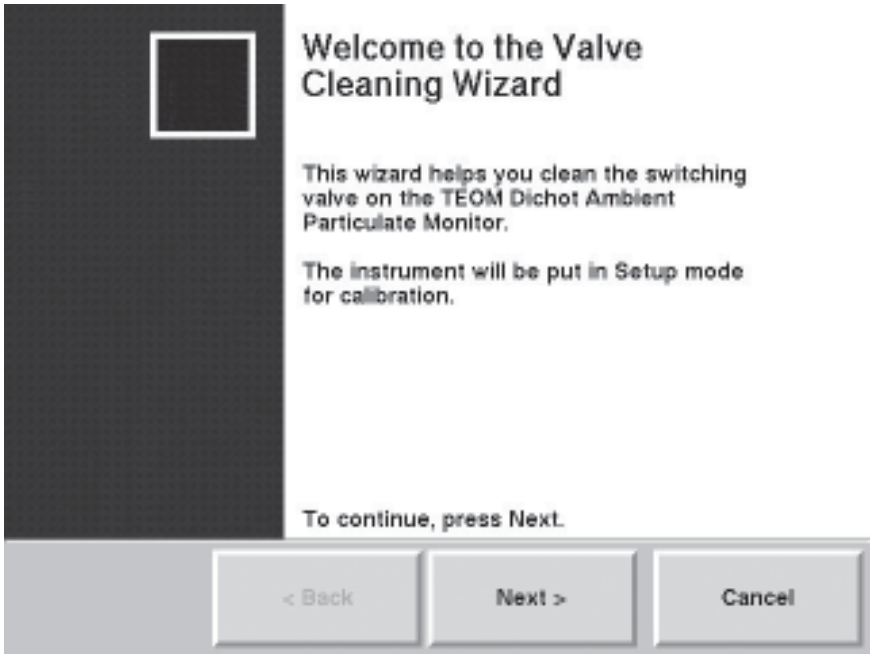
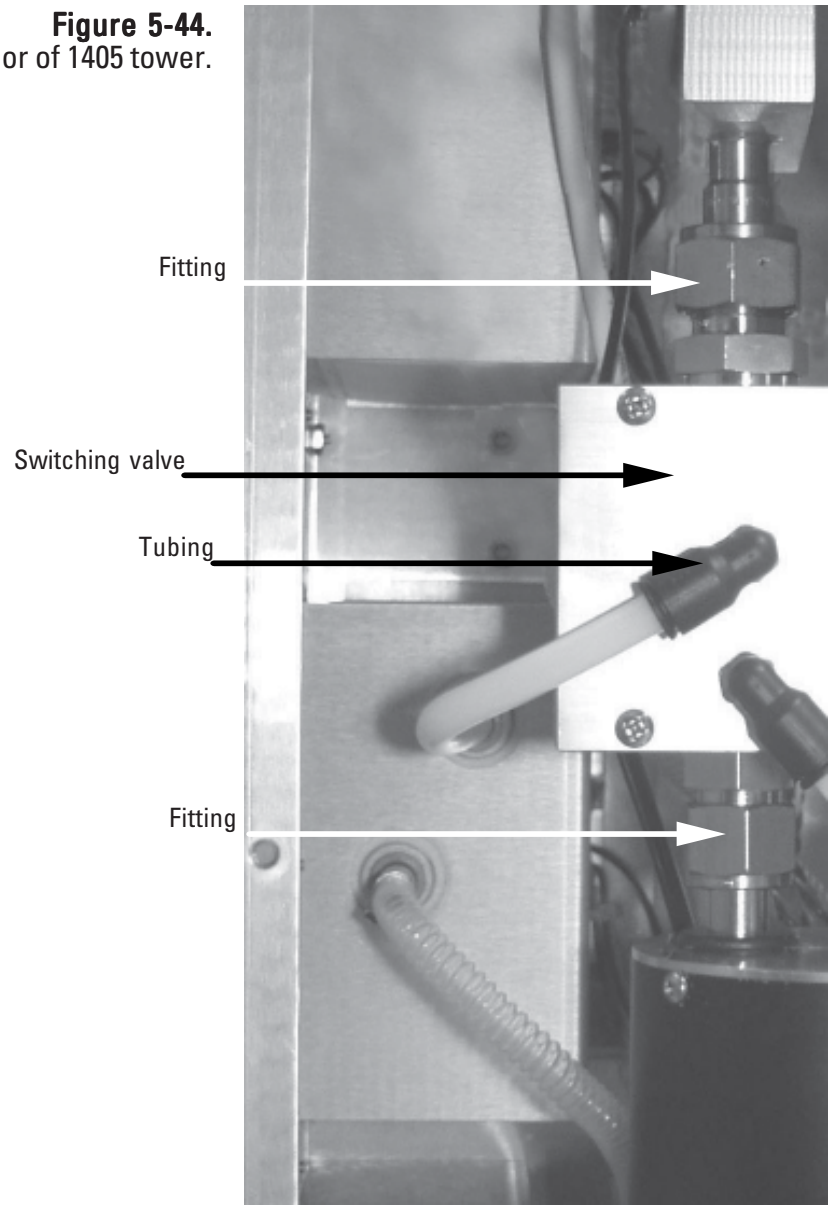


Figure 5-43. Valve Cleaning Wizard Welcome screen.

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.

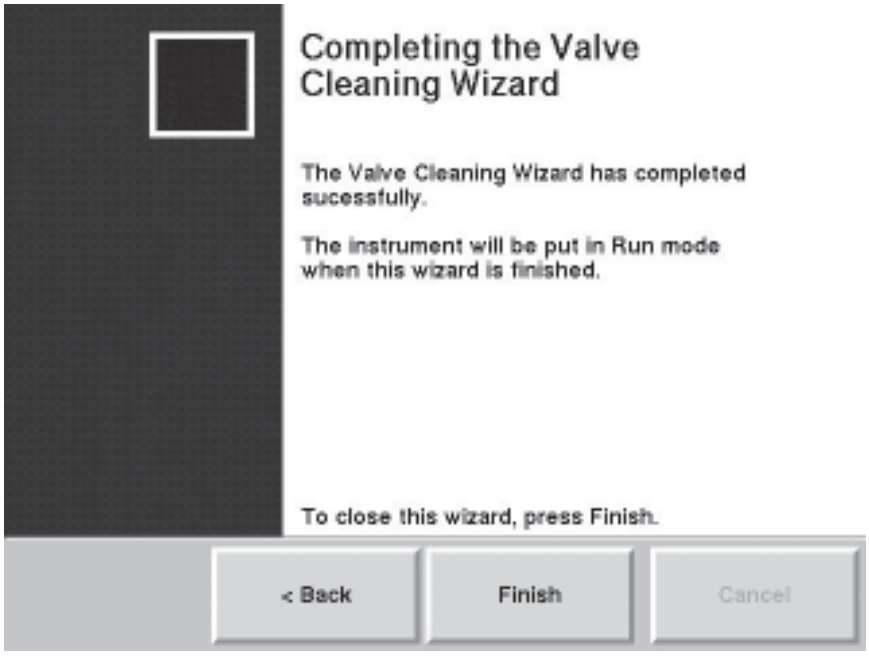


Figure 5-47. Completing the Valve Cleaning Wizard screen.

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.

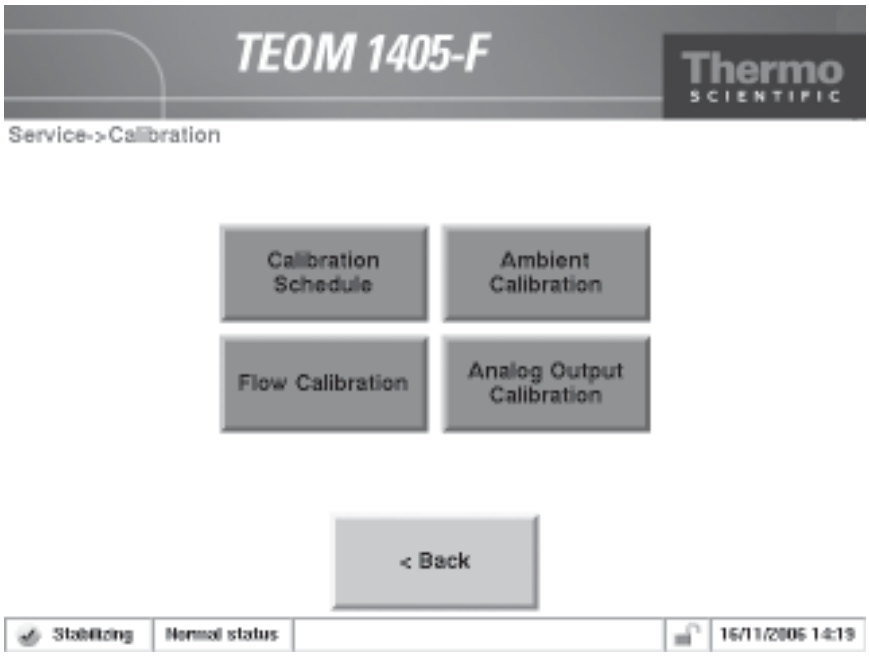
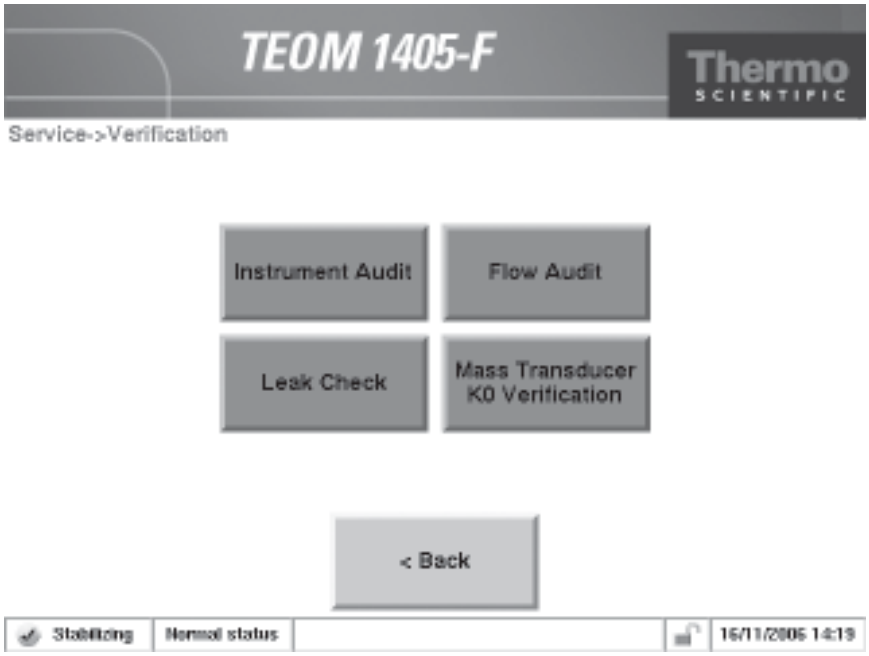


Figure 5-49. Verification screen.



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.

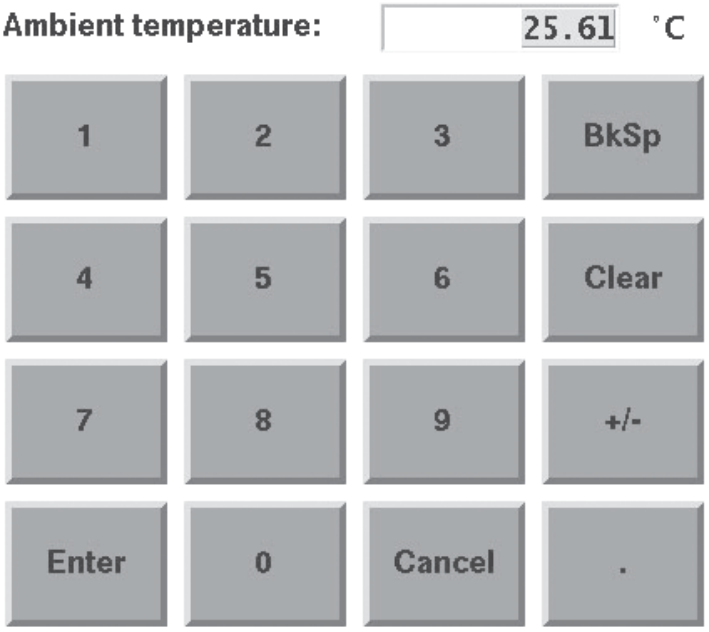


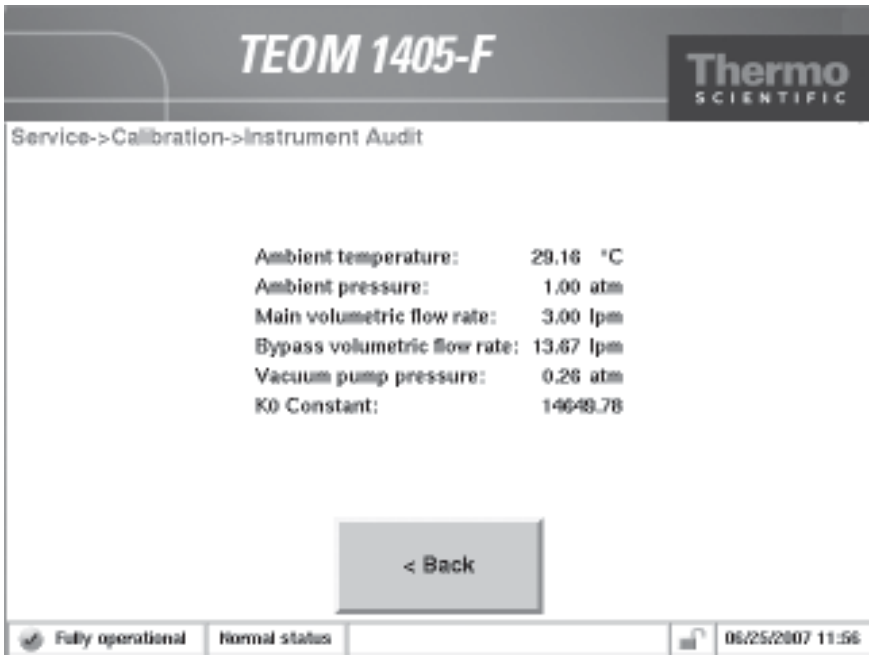
Figure 5-50. Number entry keypad.

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

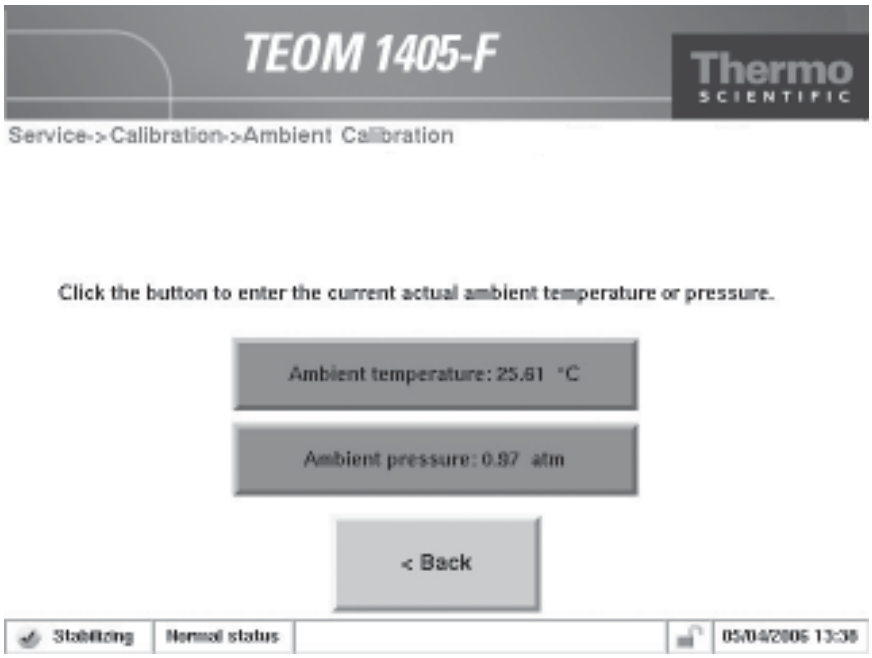
Perform the ambient air temperature calibration, pressure calibration and leak check (Section 3) before executing the flow calibration procedure.

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

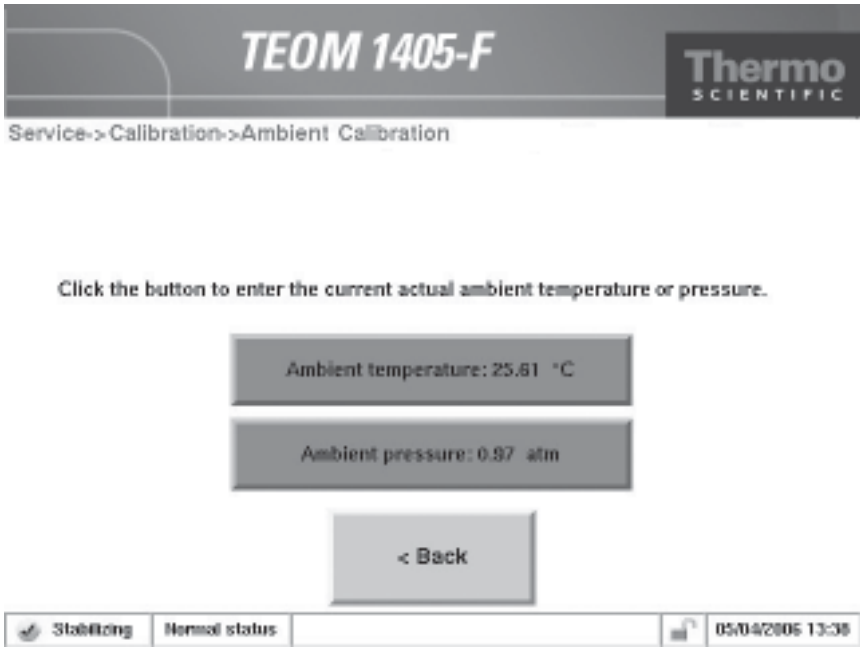
Perform the ambient air temperature calibration, pressure calibration and leak check (Section 3) before executing the flow calibration procedure.

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.

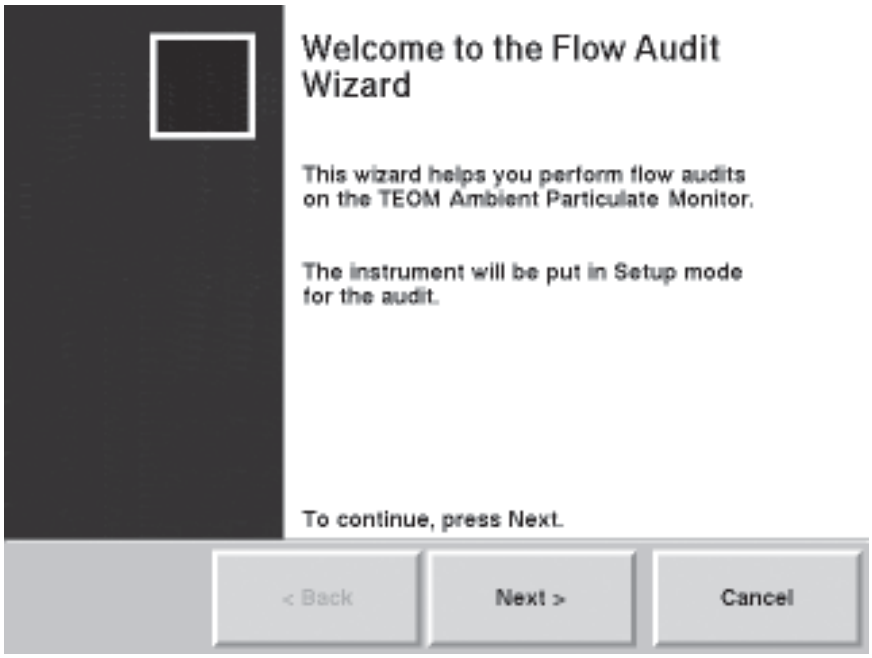
Auditing the Flow Rates

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.

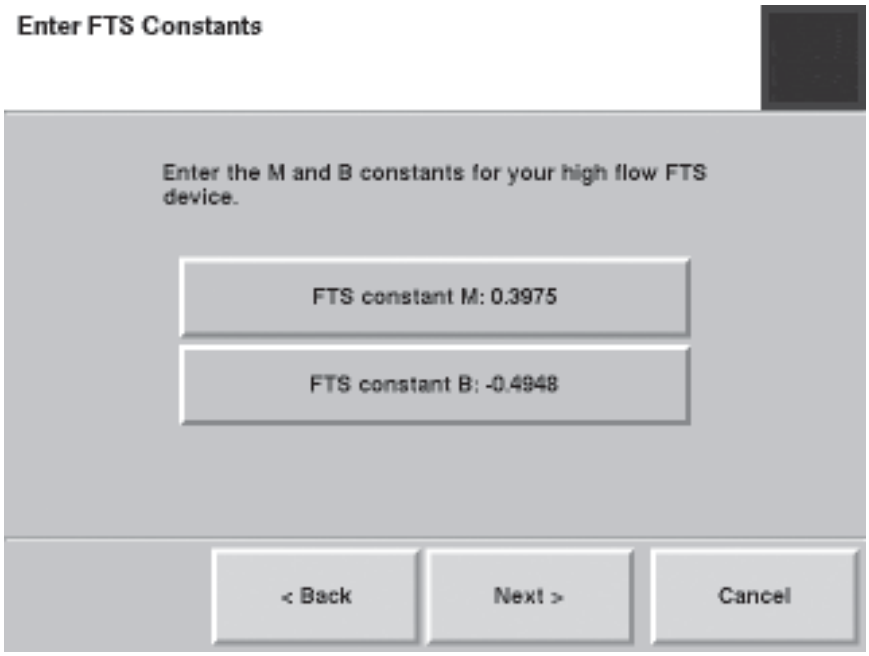


3. The Select a Flow Audit Device screen will display. Select a flow audit device. Select "Direct Flow Device" to audit the flow using a direct flow measuring device (reading "l/min" adjusted for temperature and pressure) such as the Streamline Pro. Select "FTS" to audit the flow using the FTS system. 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.

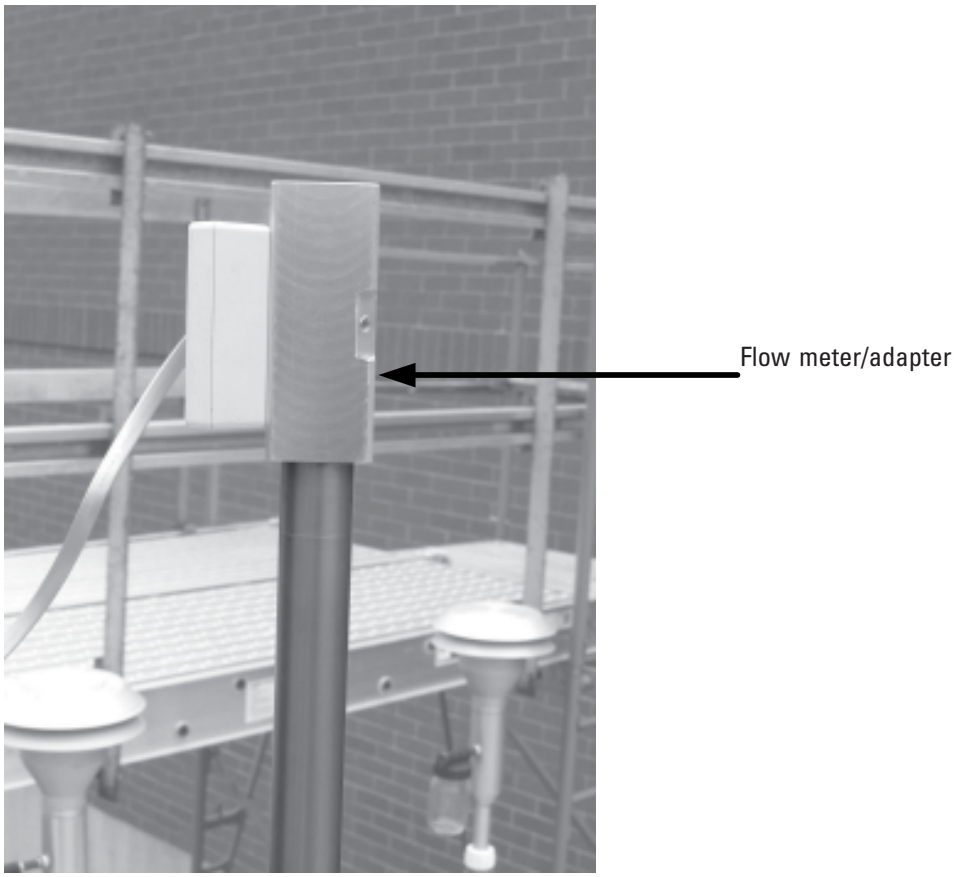
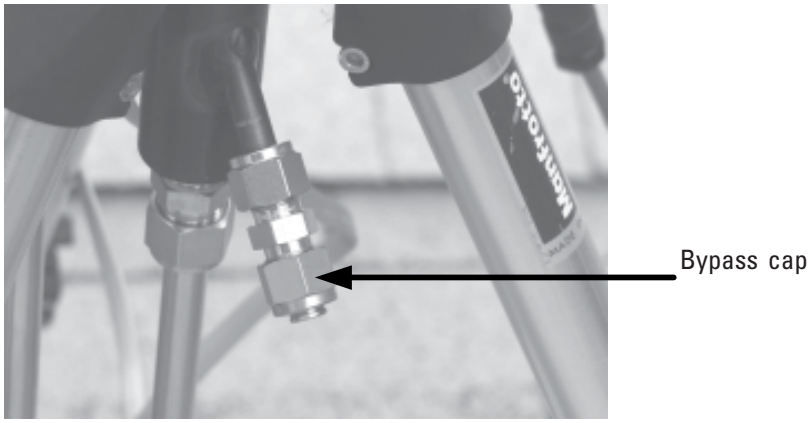


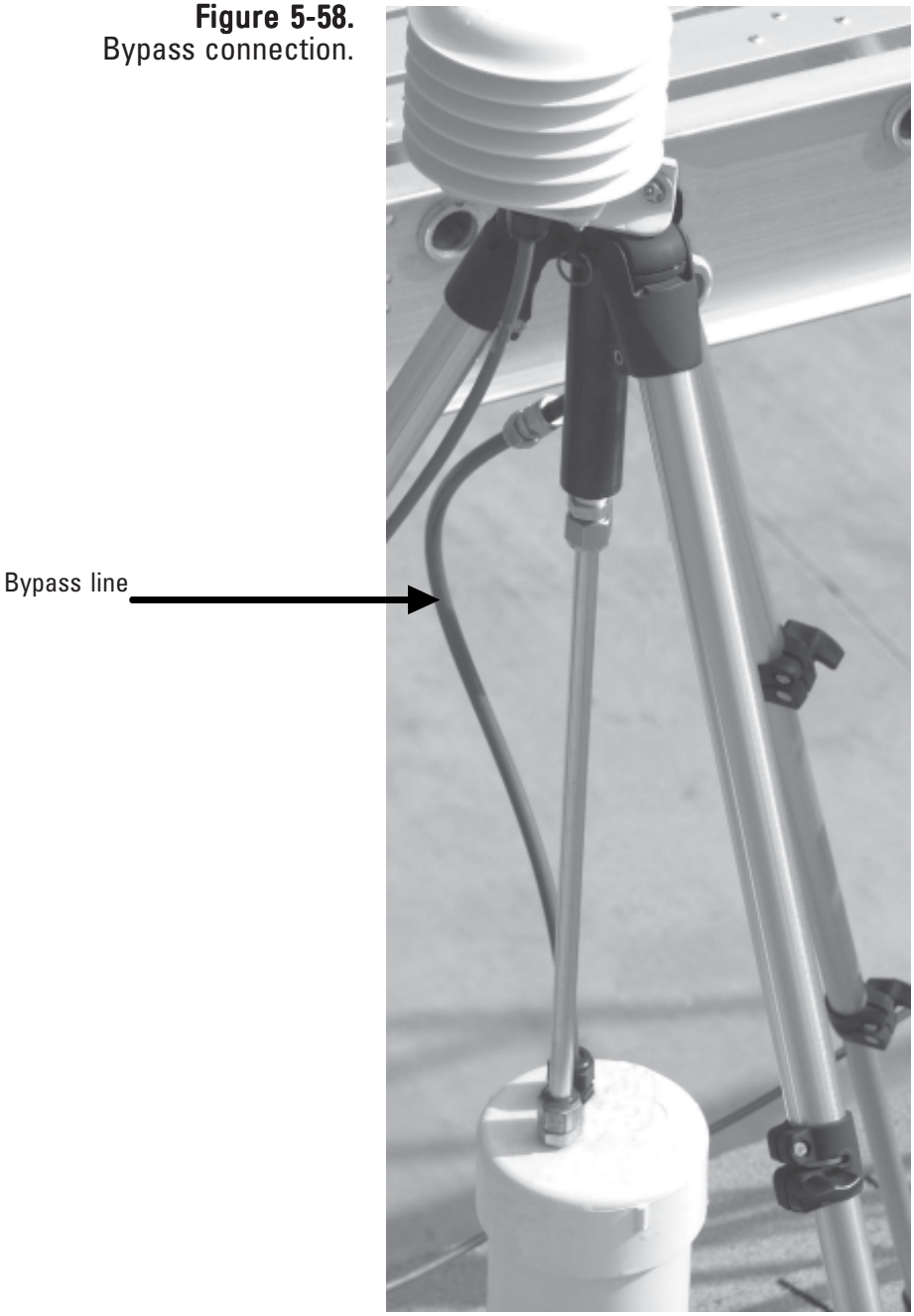
Figure 5-57.
Bypass line capped.



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.

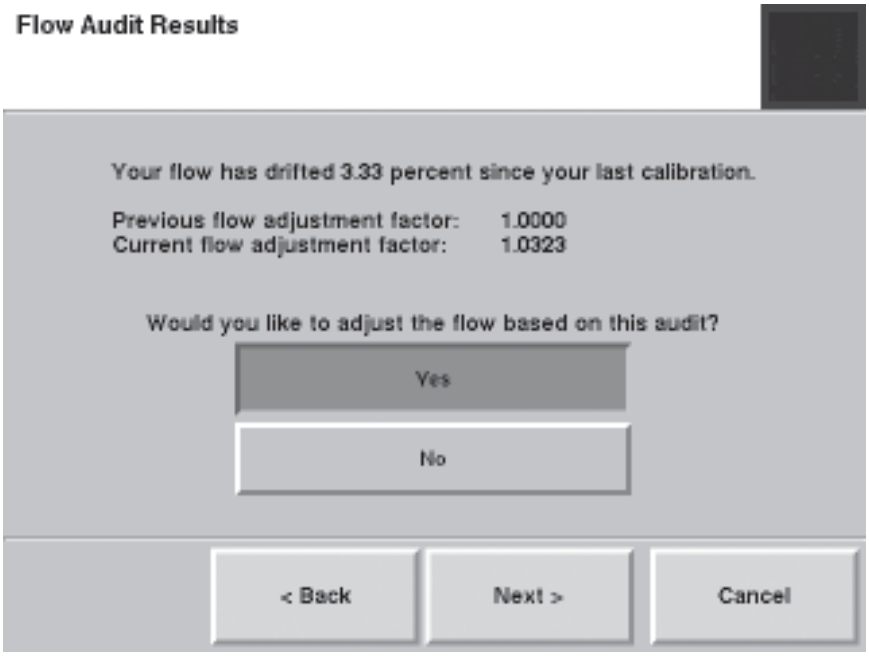
Figure 5-58. Bypass connection.



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.

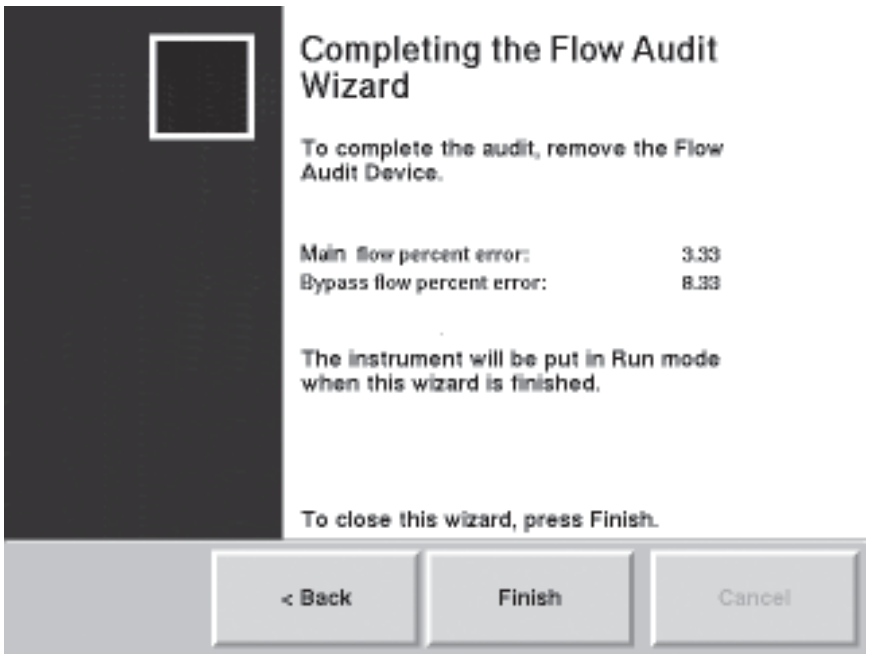
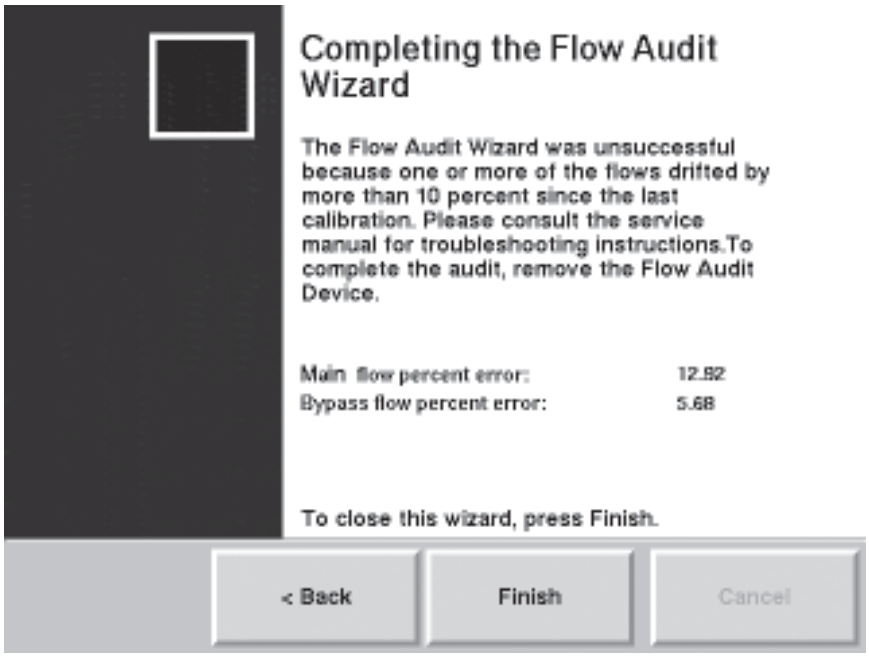


Figure 5-61.
Finish screen with a failed audit.



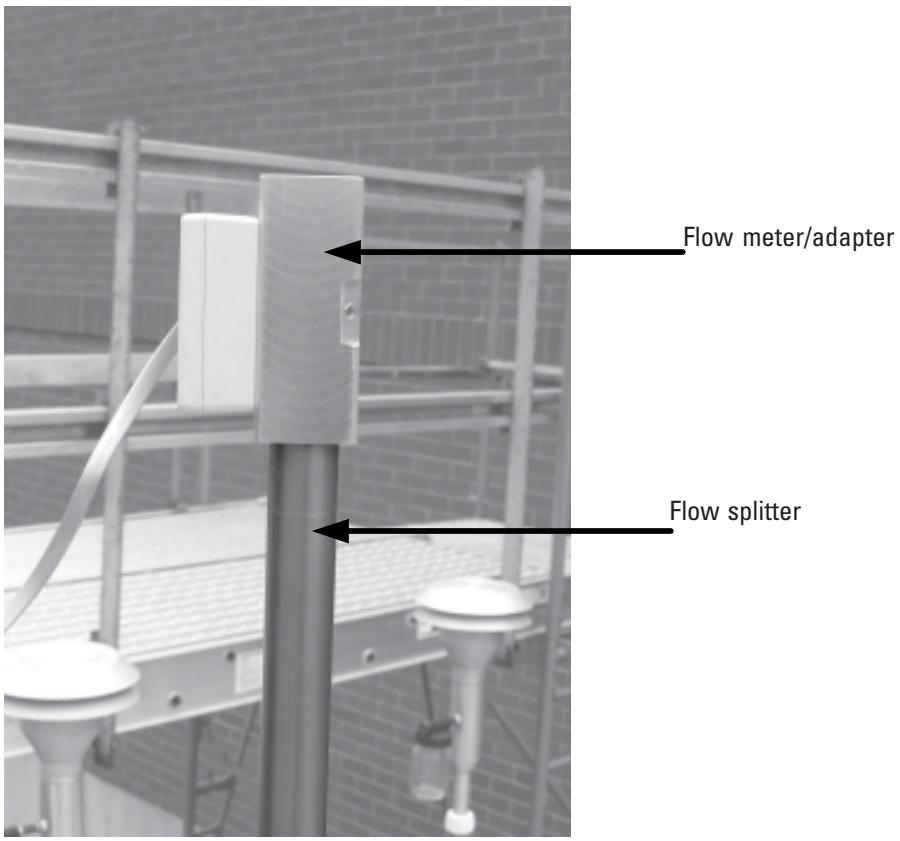
Calibrating the Flow Rates

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.

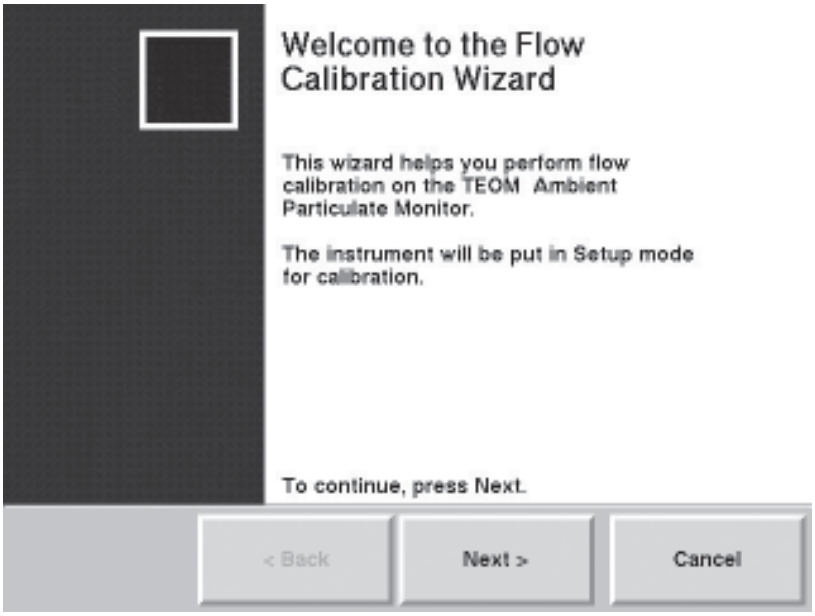


To calibrate the main or bypass flow:

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.

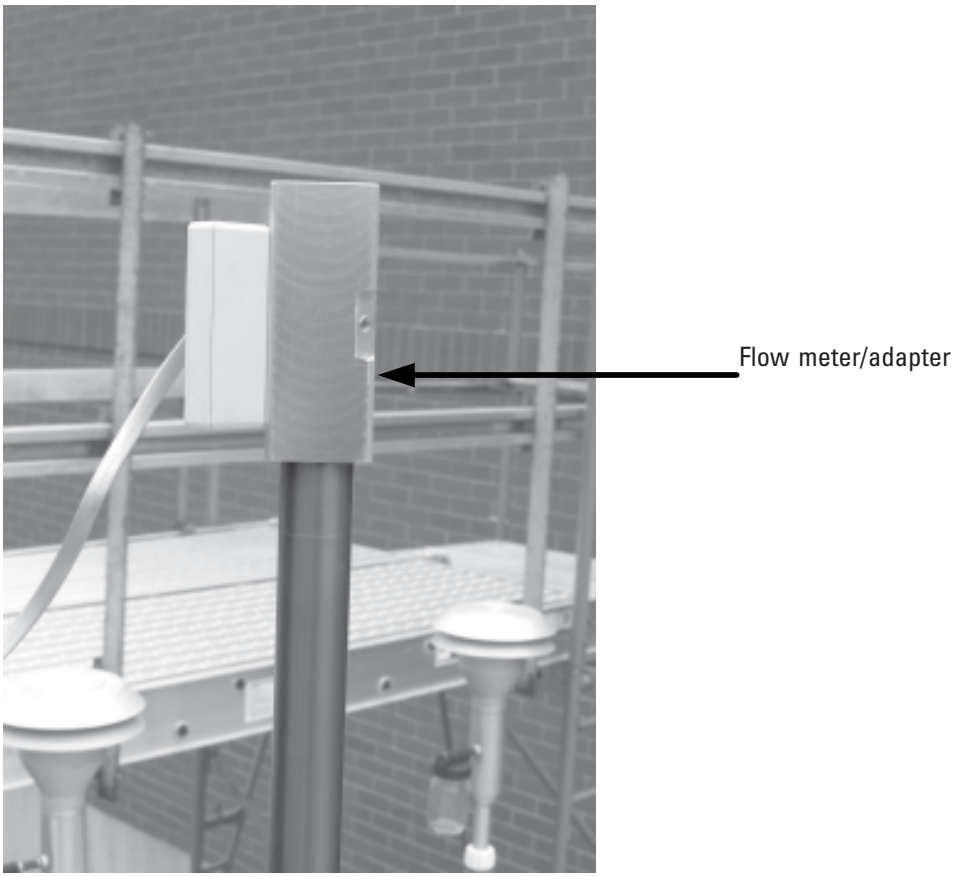
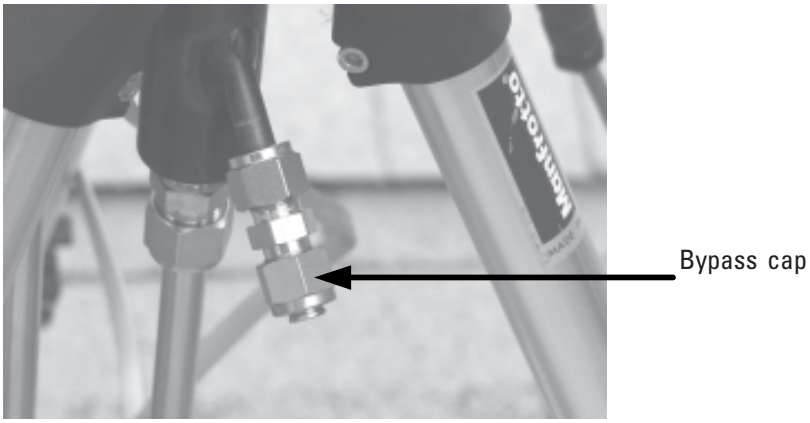


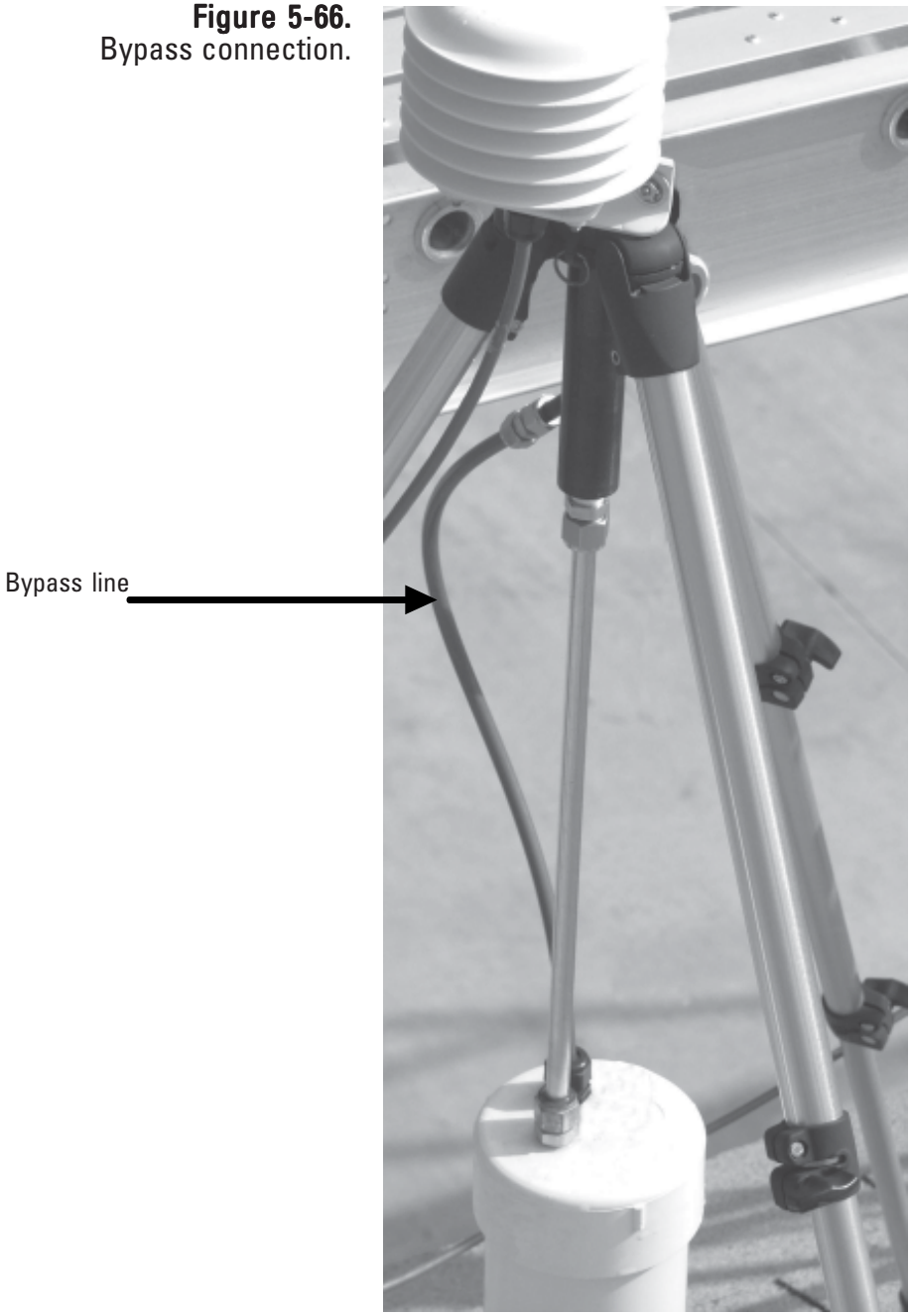
Figure 5-65. Bypass line capped.



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.

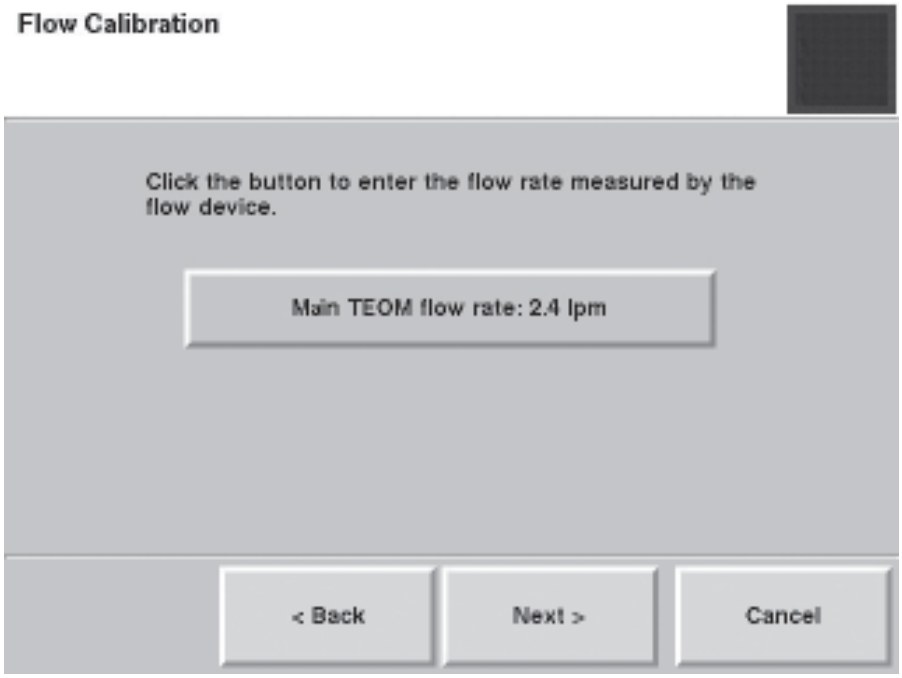
When the flow audit device is attached to the correct channel, select the **Next >** button.

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.

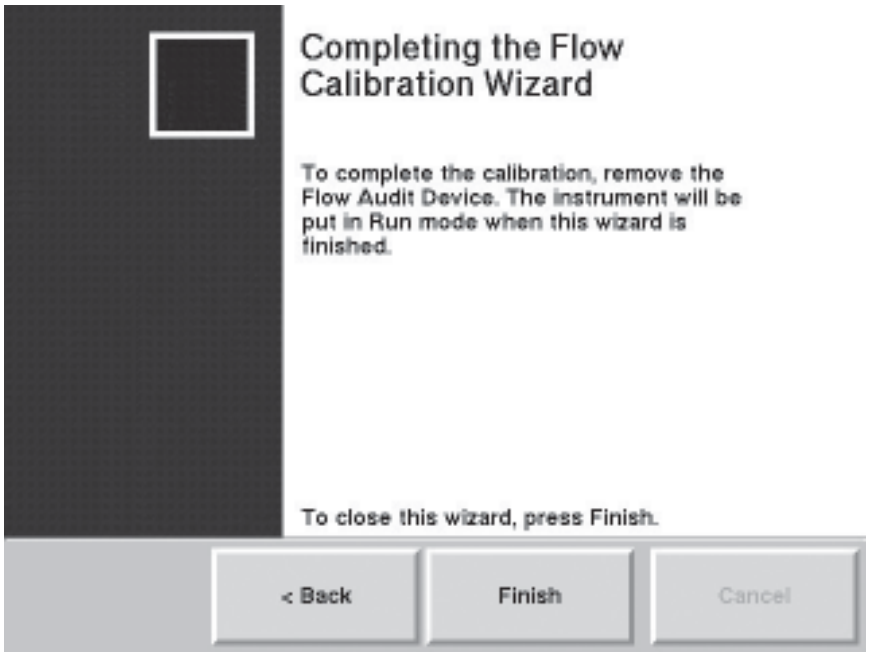
8. The wizard will display a screen that shows the current setpoint flow rate (as measured by the instrument) in the **TEOM flow rate:** button. *Allow the flow to stabilize*. Select the **TEOM flow rate:** button and enter the current flow rate (to two decimal places) as measured by the flow meter into 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. ▲

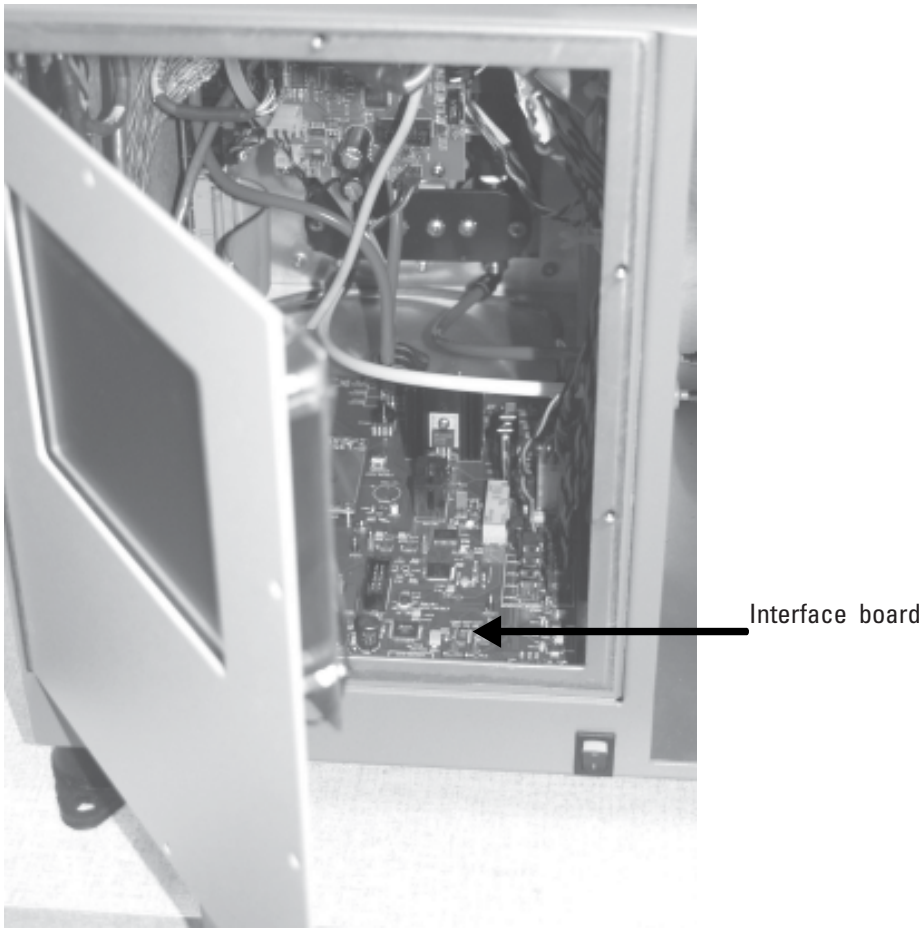
To calibrate the analog outputs:

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.

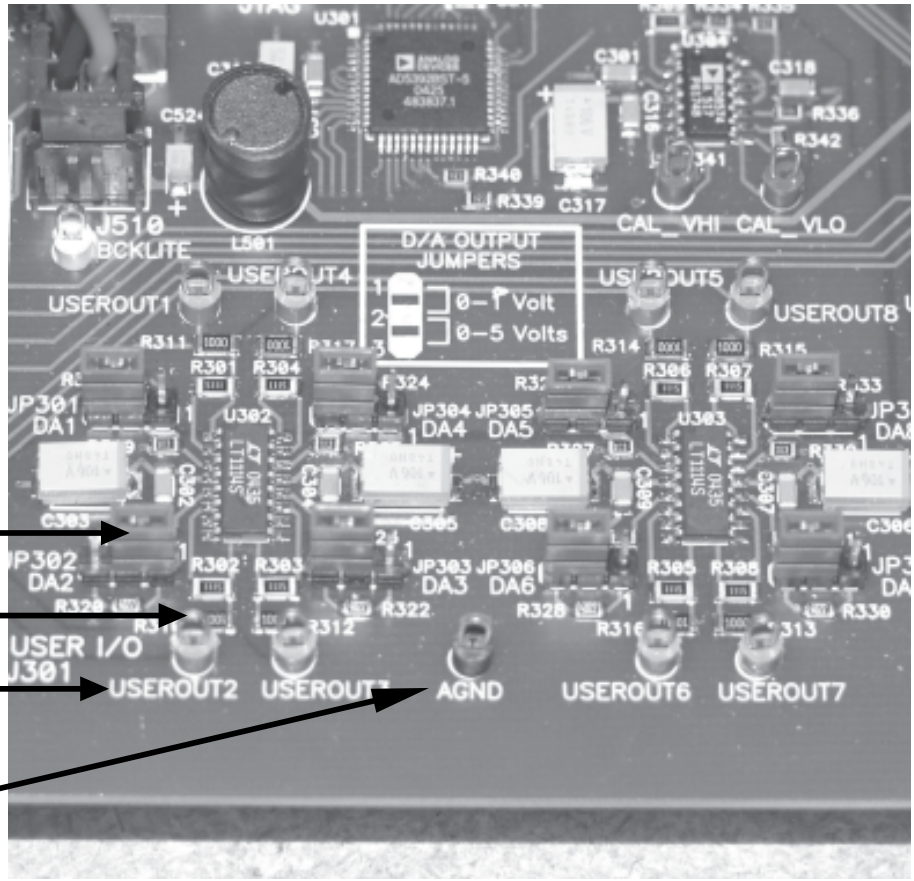
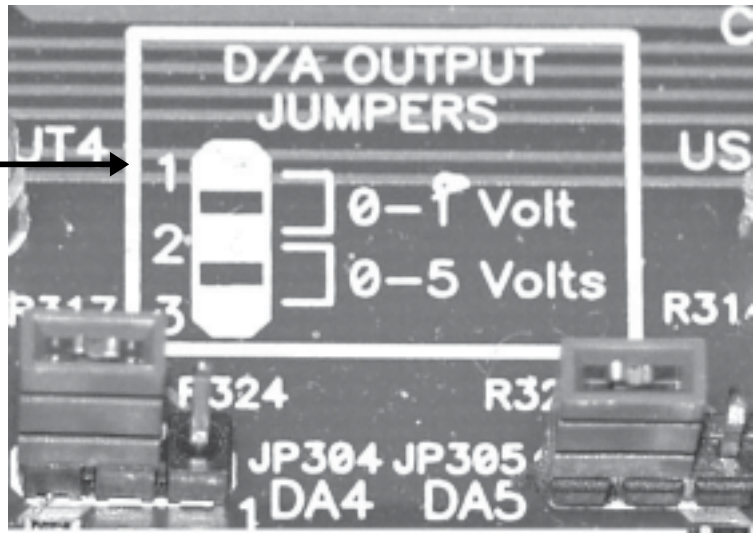


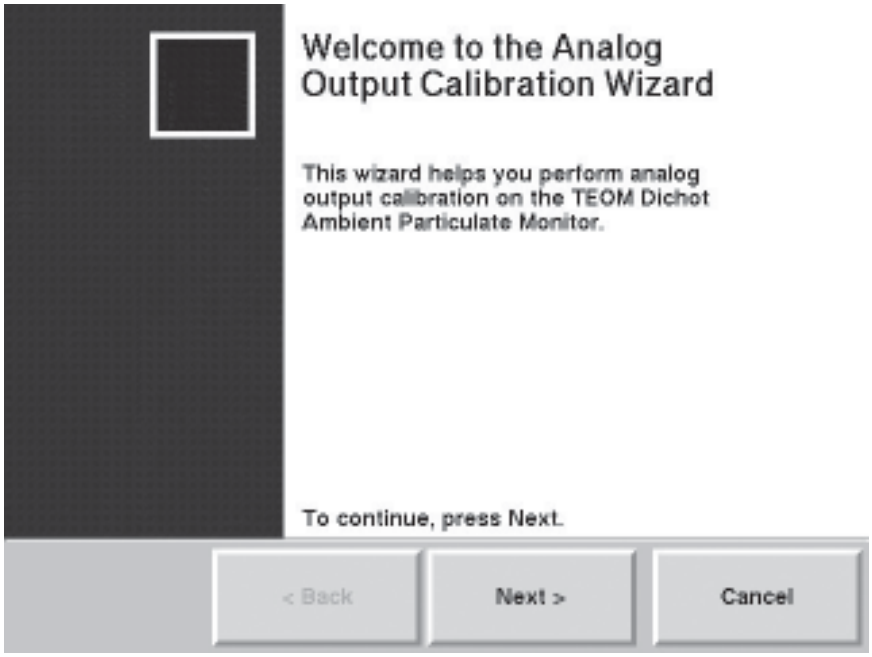
Figure 5-71.
Close-up of setting guide.



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.



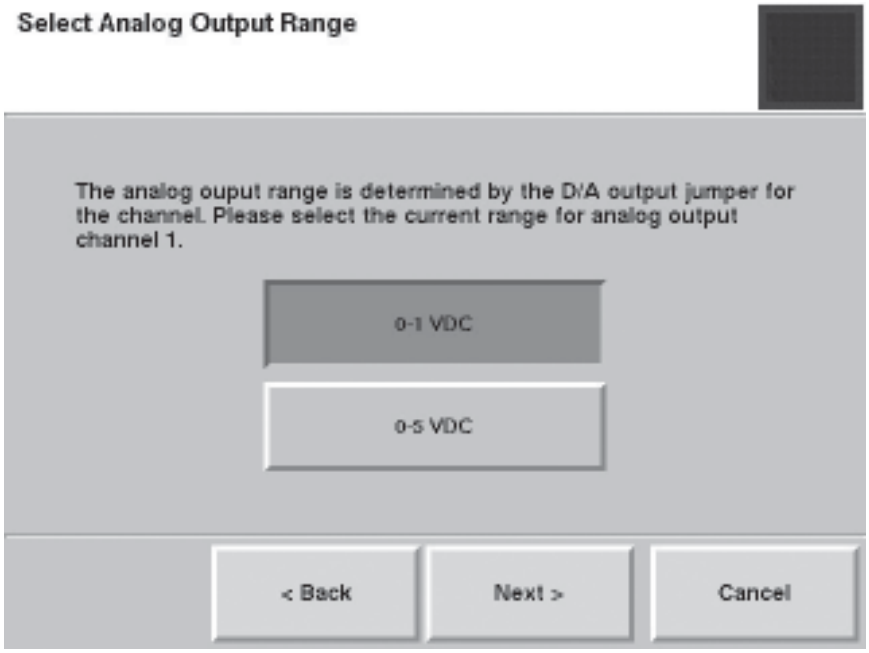
6. The Select Channel to Calibrate screen will display (Figure 5-73). Select which analog output channel you want to calibrate. Select the **Next >** button.

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

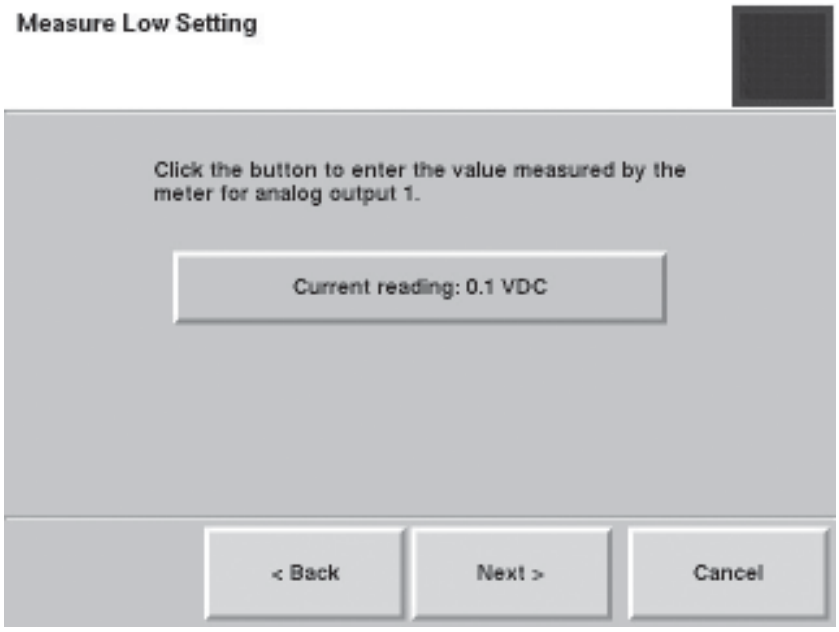


8. The Connect Meter screen will display (Figure 5-75). Locate the test point (Figure 5-70) for the analog output being calibrated and attach a voltmeter set to VDC to the test point and to the ground test point on the board. Select the **Next >** button.

Figure 5-75. Connect Meter screen.

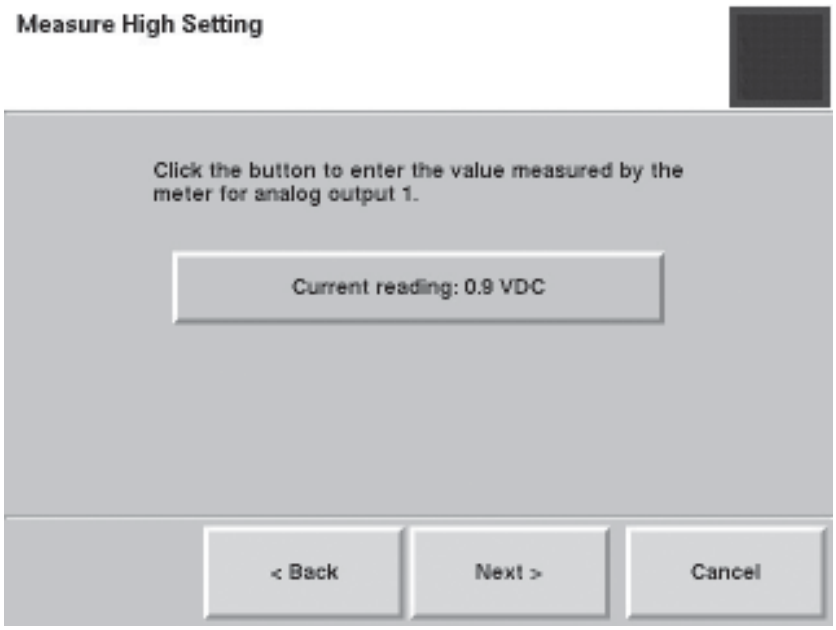
9. The Measure Low Setting screen will display (Figure 5-76). Compare the reading on the volt meter to the reading on the screen. If the readings are different, select the **Current reading:** button to display the number keypad and enter the current reading, and press the **Enter** button. Select the **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.

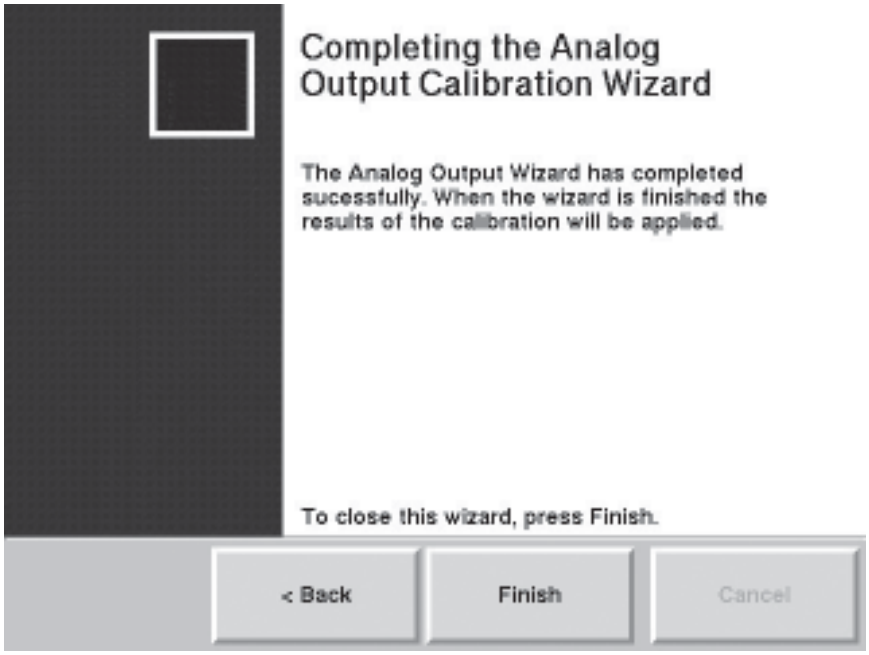
Figure 5-77.
Measure High Setting screen.



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.

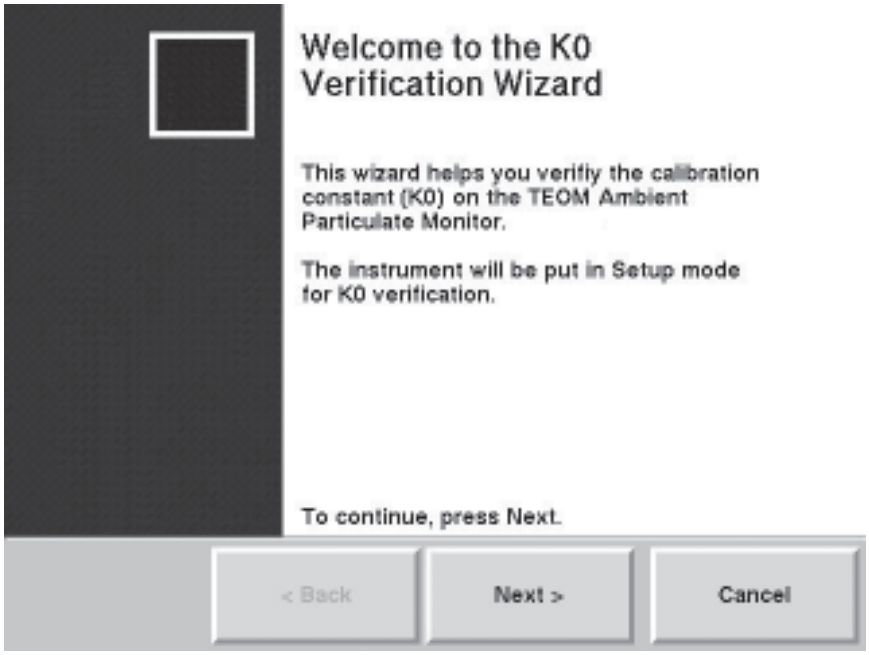


Figure 5-79. Welcome to K0 Verification Wizard screen.

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.

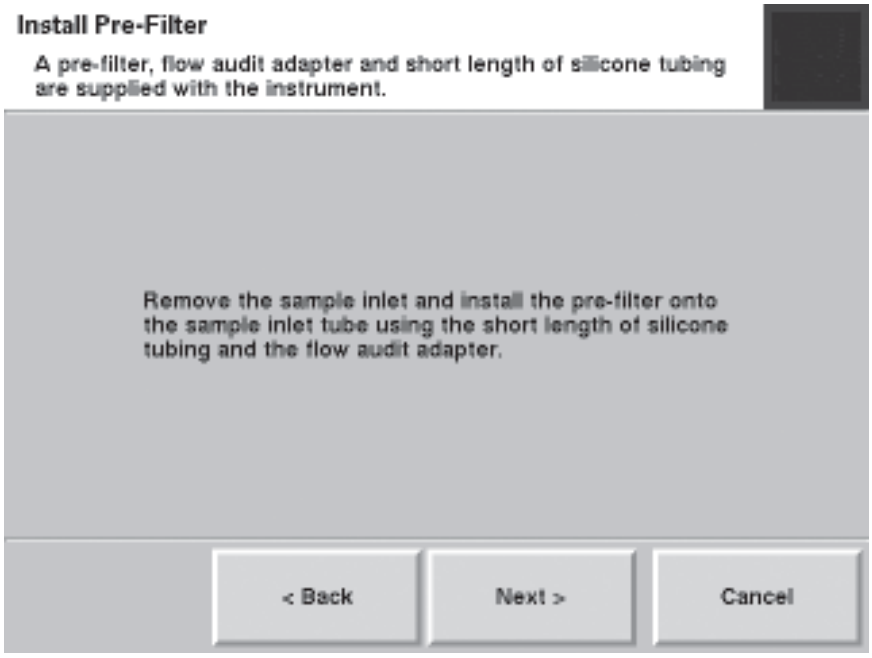
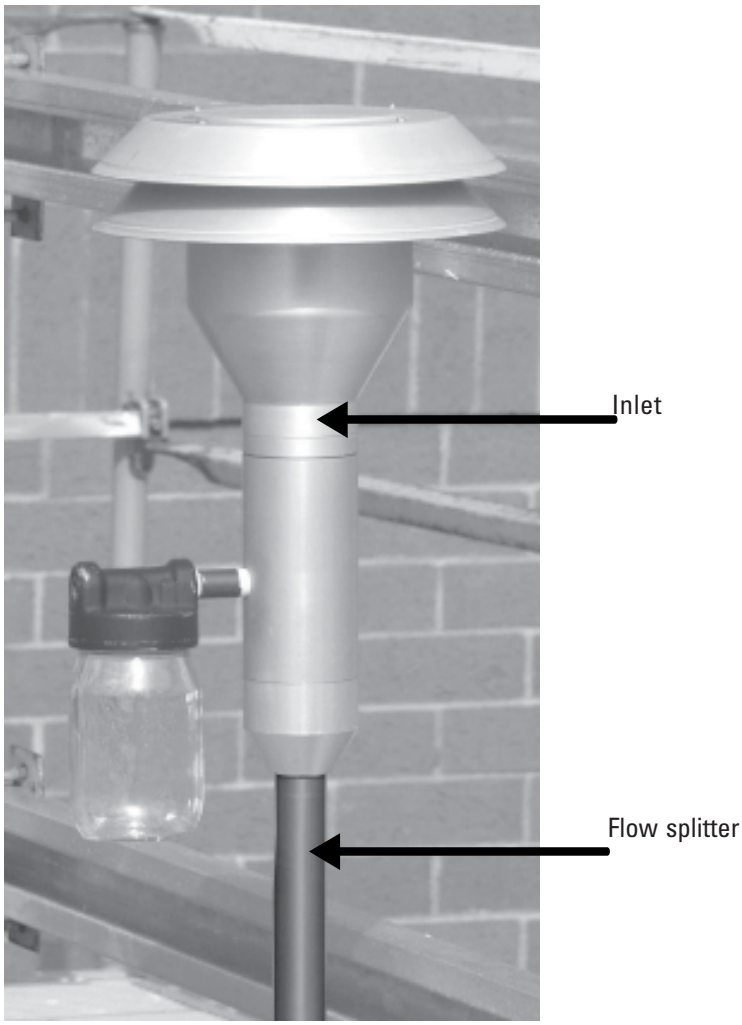


Figure 5-81.
Series 1405 inlet assembly.

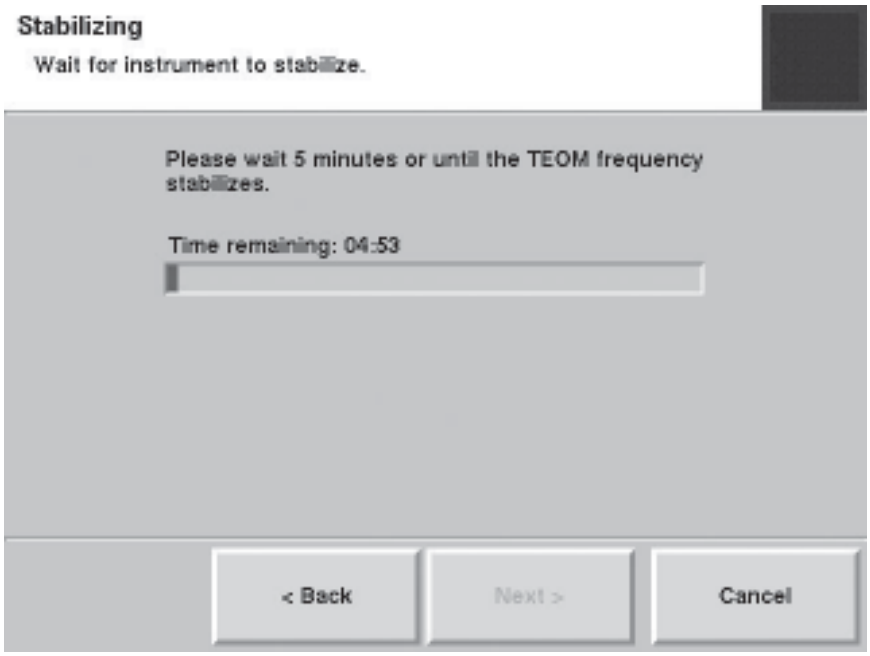


7. The Remove Sample Filter screen will display. Open the mass transducer and remove the standard TEOM filter from the mass transducer. (Refer to the section on installing/removing TEOM filter for assistance on removing the filter.) Close the mass transducer (without installing another filter). Select 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.



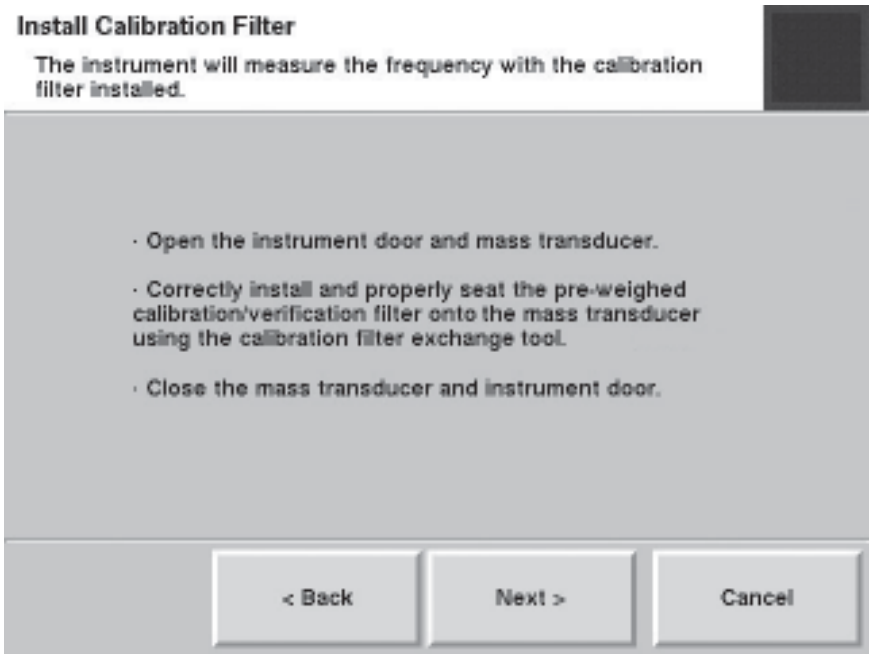
9. The Enter Filter Weight screen will display (Figure 5-83). Select the **Filter Weight:** button. The keypad will display. Enter the weight of the pre-weighed filter into the system and press the **Enter** button to save the value and exit the keypad. Select the **Next >** button.

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.

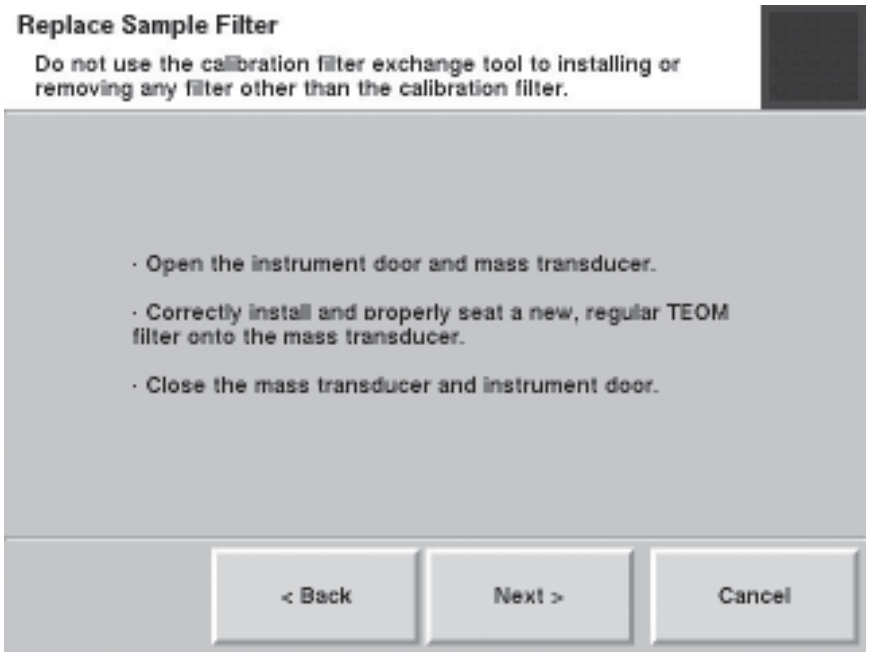
Note. If the frequency doesn't stabilize, the wizard will display a screen with instructions to re-seat the filter. Re-seat the filter and select the **Next >** button. The Stabilizing screen will display. If the unit is unable find a stable frequency the second time, the unit will fail the K0 audit (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. ▲

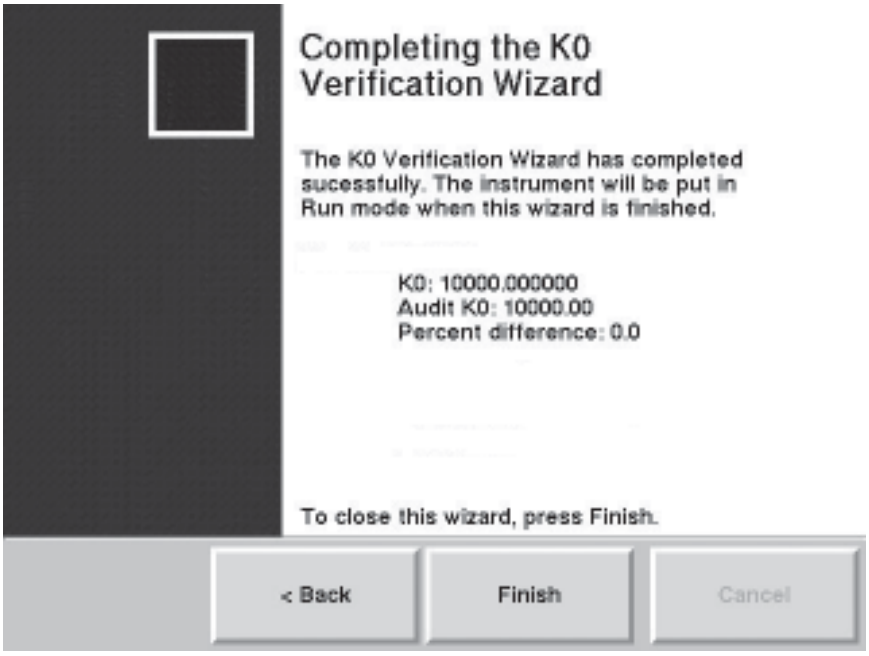


Figure 5-86. Completing to K0 Verification Wizard screen with a pass message.

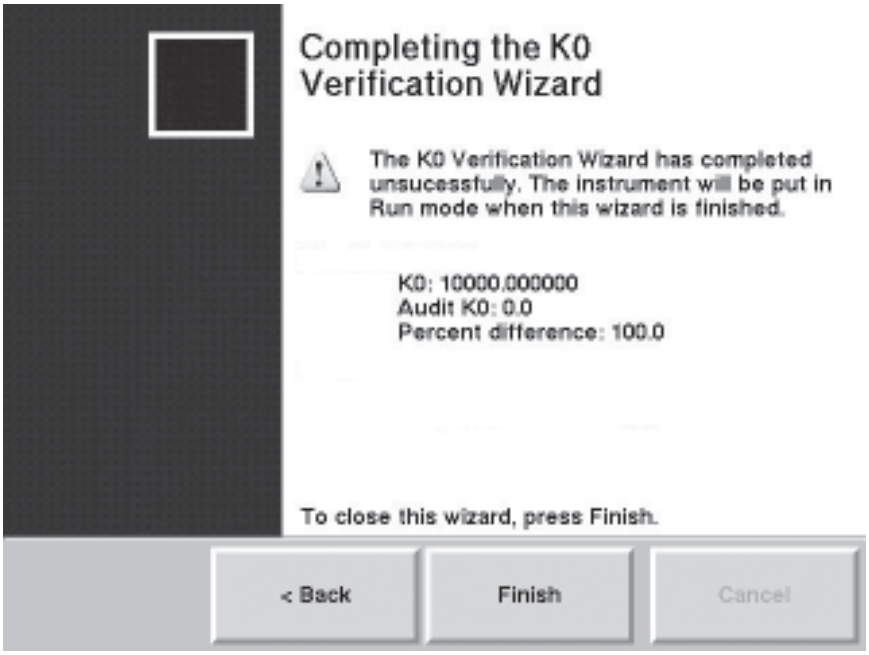


Figure 5-87. Completing the K0 Verification Wizard screen with a fail message.

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

Byte	Example	Description
1	<STX>	ASCII code 002.
2	4	1-digit Station Number, RS-Para 1.
3	E	Enter Register command.
4	R	
5	E	
6	G	
7	<space>	Space.
8	K	2-digit Channel Number, as defined by RS Para 2.
9	0	
10	<space>	Space.
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.
12	3	
13		
14	<space>	Space.
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.
16	3	
17	8	
18	0	
19	<ETX>	ASCII code 003.

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	E	E	4-digit Enter Register command.
4	R	R	
5	E	E	
6	G	G	
7	<space>	<space>	Space.
8	0	0	Number of current status conditions.
9	<space>	<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	3	E	
12		<ETX>	
13	<ETX>	<CR>	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	<LF>		
16			
17			
18			
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	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.		
16			
17			
18			
19			

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

Byte	Example	Description
1	<STX>	ASCII code 002.
2	4	1-digit Station Number, RS-Para 1.
3	A	Ask Storage command.
4	S	
5	T	
6	O	
7	<space>	Space.
8	K	2-digit Channel Number, as defined by RS Para 2.
9	0	
10	<space>	Space.
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.
12	0	
13		
14	<ETX>	ASCII code 003.
15		
16		
17		
18		
19		

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	A	A	4-digit Ask Storage command.
4	S	S	
5	T	T	
6	O	O	
7	<space>	<space>	Space.
8	0	0	Number of current status conditions.
9	<space>	<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	1	E	
12		<ETX>	
13	<ETX>	<CR>	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	<LF>		
16			
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			
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			