Certification Report and Checklist on the Evaluation of the Ambient Air Particulate Matter Test Reports Submitted for Approval and Certification within the MCERTS Scheme for UK Particulate Matter

Evaluation with Respect to:
MCERTS Performance Standards for Ambient Air Quality Monitoring Systems and its Annex:
Requirements of the UK Competent Authority for the Equivalence Testing and Certification of Automated Continuous Methods and Manual Discontinuous Methods that Monitor Particulate Matter in Ambient Air

Instrument Manufacturer:	Thermo Fisher Scientific 27 Forge Parkway, Franklin, Massachusetts, 02038, USA
Type of Instrument Evaluated:	1. TEOM 1405-DF Ambient Particulate Monitor with PM_{10} pre-separator and virtual impactor for the components PM_{10} and $PM_{2.5}$; software version 1.56. 2. TEOM 1405-F Ambient Particulate Monitor with PM_{10} pre-separator for the component PM_{10}; software version 1.56. 3. TEOM 1405-F Ambient Particulate Monitor with $PM_{2.5}$ pre-separator for the component $PM_{2.5}$; software version 1.56.
Report prepared by:	Certification Committee for MCERTS Performance Standard for Automated Continuous Methods and Manual Discontinuous Methods that Monitor Particulate Matter in Ambient Air
Date of Certification Report:	7th June 2013

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Executive Summary

This report provides the MCERTS certification committee's evidence to support the recommendations for certification under the Environment Agency's MCERTS Performance Standards for Continuous Ambient Air Monitoring Systems, and its Annex regarding MCERTS for UK Particulate Matter.

This report considers 3 Candidate Methods:

1. TEOM 1405-DF Ambient Particulate Monitor with PM_{10} pre-separator and virtual impactor for the components PM_{10} and $PM_{2.5;}$
   (Serial Numbers SN 20006 & SN 20107)

2. TEOM 1405-F Ambient Particulate Monitor with PM_{10} pre-separator for the component PM_{10}
   (Serial Numbers SN 20014 & SN 20006)

3. TEOM 1405-F Ambient Particulate Monitor with $PM_{2.5}$ pre-separator for the component $PM_{2.5}$
   (Serial Numbers SN 20012 & SN 20121)

Manufactured by: Thermo Fisher Scientific
27 Forge Parkway
Franklin, Massachusetts, 02038,
USA

Six reports have been considered by the certification committee. There are the three test reports listed below that were prepared by TÜV Rheinland Energie und Umwelt GMBH:

1. Report on the suitability test of the ambient air quality measuring system TEOM 1405-DF Ambient Particulate Monitor with PM_{10} pre-separator and virtual impactor of the company Thermo Fisher Scientific for the components PM_{10} and $PM_{2.5}$
   TÜV-Report: 936/21209885/A, Cologne March 11, 2012.

2. Report on the suitability test of the ambient air quality measuring system TEOM 1405-F Ambient Particulate Monitor with PM_{10} pre-separator of the company Thermo Fisher Scientific for the component PM_{10}
   TÜV-Report: 936/21209885/B, Cologne November 25, 2011.

3. Report on the suitability test of the ambient air quality measuring system TEOM 1405-F Ambient Particulate Monitor with $PM_{2.5}$ pre-separator of the company Thermo Fisher Scientific for the component $PM_{2.5}$
   TÜV-Report: 936/21209885/C, Cologne March 11, 2012.

And three reports prepared by Bureau Veritas, UK:

4. UK Report on the Equivalence of the PM_{10} and $PM_{2.5}$ TEOM 1405-DF.
   Report ref AGGX5508189/BV/DH/2835 dated 5 June 2013

5. UK Report on the Equivalence of the PM_{10} TEOM 1405-F.
   Report ref AGGX5508189/BV/DH/2833 dated 5 June 2013

6. UK Report on the Equivalence of the $PM_{2.5}$ TEOM 1405-F.
   Report ref AGGX5508189/BV/DH/2834 dated 5 June 2013

These six reports are discussed below and referenced below in this Evaluation Report.

The certification committee has concluded that the evidence evaluated in these reports demonstrates that the minimum requirements of the MCERTS Performance Standard for Continuous Ambient Air Monitors Version 8 July 2012 are generally fulfilled, and the requirements of the relevant VDI/DIN Guidelines 2009 & 2010 are also generally fulfilled.

Therefore it is proposed that, as a result, the three types of ambient air particulate monitor listed above and discussed in this Evaluation Report are accepted as conforming to the requirements of the above MCERTS Performance Standard, **and** these three types of ambient PM monitor are also in conformance with the requirements of the Annex to this MCERTS Performance Standard as conforming to the requirements of MCERTS for UK Particulate Matter. The restrictions given in the Summary and Recommendations Section of this Report (Section 5) apply.

1. Introduction to the MCERTS Evaluation Report

1.1 About this Report

This Evaluation Report has been prepared by the MCERTS certification committee that has been appointed to review the equivalence testing and certification of automated continuous methods and manual discontinuous methods that are to be used to monitor particulate matter concentrations in ambient air – generally for UK and EU regulatory compliance purposes.

The evaluation by the above certification committee that is presented in this Report has assessed whether all the testing that was carried out on the candidate particulate measurement methods listed in this Report fulfil comprehensively and rigorously the requirements that are specified in the set of published documents described below. This MCERTS Evaluation Report must be considered together with the published MCERTS certificates for these automated methods for monitoring ambient particulate matter, and together with the associated technical reports listed therein in their certificates.

This Evaluation Report and its associated checklist, have been completed below for the three test reports submitted to SIRA Certification Ltd. (see Section 2.2 of this Report for the complete list of the test reports submitted). There were submitted for consideration as to their suitability in conforming to the requirements of the above documents. A completed checklist is presented as Section 4 of this Evaluation Report.

Additional comments are also included in this Evaluation Report by the MCERTS certification committee in order to address the laboratory test requirements and other test aspects where the TÜV test reports used for the evaluation *differ in some manner* from the specifications of the Environment Agency's MCERTS Performance Standards for Continuous Ambient Air Monitoring Systems, and its Annex, as discussed and referenced below.

A list of specialised terms that are referred to in this Report, together with their definitions, is given in Annex 1. A list of the abbreviations used is given in Annex 2. The references used in this Evaluation Report are listed in Annex 3.

1.2 Background to the Requirements for Equivalence Testing

Initial requirements for the testing of ambient air monitoring methods for their equivalence with the EU specified reference methods were given in the *EU Directive 2008/50/EC* [Ref.1, Annex VI].

Methods for demonstrating this equivalence with the reference methods specified in the above Directive are given in a guidance document prepared for the European Commission entitled *"Guide to the Demonstration of Ambient Air Monitoring Methods", January 2010*

[Ref.2]. It should be noted that this guidance was prepared as a document for the competent authorities and other relevant bodies within the EU Member States - with no mandatory provisions.

Subsequently, this EC guidance on demonstrating the equivalence of any alternative methods to the specified reference methods was incorporated into the Environment Agency's MCERTS Performance Standard entitled:

MCERTS Performance Standards for Ambient Air Quality Monitoring Systems, Environment Agency, June 2012 [Ref.3].

The above document describes the MCERTS Performance Standards that must be achieved for certain categories of ambient air quality monitoring systems (CAMs) to allow these to be granted certification by the MCERTS scheme [Ref.4]. The ambient air pollutants that are covered are nitrogen monoxide (NO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) carbon monoxide (CO), benzene, and benzene-like volatile organic compounds, and particulate matter (PM_{10} and $PM_{2.5}$). These CAMs are generally those that are to be applied to regulatory compliance monitoring applications. The requirements for particulate matter CAMs in this MCERTS performance standards document are given in Sections 6.4 to 6.8 of Ref.3, and are fully consistent with the EC Guidance document [Ref.2].

1.3 Background to MCERTS for UK Particulate Matter.

Following the publication of this MCERTS Performance Standard [Ref.3], the Department of Environment Food and Rural Affairs (Defra), in conjunction with the Environment Agency and its MCERTS scheme, published a further document in order to specify comprehensively and rigorously the requirements for "equivalence testing" (product conformity and certification) in the United Kingdom, of some specific monitoring methods for particulate matter in ambient air, so as to be in alignment with the guidance from the European Commission, in a manner that is fully acceptable to the UK's Competent Authority. This document, which is prepared as a (separate) *Annex* to the above MCERTS Performance standards document, is entitled:

Annex to the MCERTS Performance Standards for Ambient Air Quality Monitoring Systems: Requirements of the UK Competent Authority for the Equivalence Testing and Certification of Automated Continuous and Manual Discontinuous Methods that Monitor Particulate Matter in Ambient Air [Ref.5].

The above Annex document contains the background information and the requirements for equivalence testing that must be carried out in order to achieve certification to the MCERTS Performance Standard for the climate of UK Particulate Matter. This is a new type of certification that has been brought in to provide the formal recognition that Defra and the Devolved Administrations of Scotland, Wales and Northern Ireland, as the Competent Authority for the UK, have provided approval of PM monitoring methods for use in the UK, where they are found to be "equivalent" to the requirements in the relevant CEN Standard,

and also that they meet the requirements of the MCERTS Annex document [Ref.5]. The certification is known as MCERTS for UK Particulate Matter. The procedures are based on those required for MCERTS certification in accordance with the MCERTS Performance Standard for Continuous Ambient Air Quality Monitoring Systems. There are, however, additional requirements that include a specification for full conformance with the Particulate Matter Pollution Climate in the UK.

It should be noted, however, that the Competent Authority for the UK has already approved as “equivalent” a number of measurement methods for monitoring particulate matter, and this new process and requirements does not apply to these already approved methods. In addition, a number of concessions are given by the MCERTS certification committee for methods for which certification is sought, but which were already being tested when the MCERTS for UK Particulate Matter was published. These are detailed in Section 3.3 of the MCERTS for UK Particulate Matter Annex [Ref.5]. The MCERTS for UK Particulate Matter Annex also contains a checklist that has been used in this Evaluation Report for the review of the test reports that were submitted for approval - within the process that is specified in that document [Ref.5].

2. Types of Monitoring Methods and the Test Reports Evaluated

2.1 Types of Ambient Air Particulate Matter (PM) Monitoring Methods

Three types of continuous ambient air PM monitoring methods have been submitted to be approved for certification under the MCERTS scheme:

1. TEOM 1405-DF Ambient Particulate Monitor with PM_{10} pre-separator and virtual impactor for the components PM_{10} and $PM_{2.5;}$
   (Serial Numbers SN 20006 & SN 20107)

2. TEOM 1405-F Ambient Particulate Monitor with PM_{10} pre-separator for the component PM_{10}
   (Serial Numbers SN 20014 & SN 20006)

3. TEOM 1405-F Ambient Particulate Monitor with $PM_{2.5}$ pre-separator for the component $PM_{2.5}$
   (Serial Numbers SN 20012 & SN 20121)

2.2 Test Reports Evaluated by the MCERTS Certification Committee for PM Monitors

Three test reports provided were prepared by TÜV Rheinland Energie und Umwelt GMBH. These were used for the review and evaluation that covered the three PM monitoring Methods listed above, as follows:

1. Report on the suitability test of the ambient air quality measuring system TEOM 1405-DF Ambient Particulate Monitor with PM_{10} pre-separator and virtual impactor of the company Thermo Fisher Scientific for the components PM_{10} and $PM_{2.5}$
   TÜV-Report: 936/21209885/A, Cologne March 11, 2012 [Ref.6];

2. Report on the suitability test of the ambient air quality measuring system TEOM 1405-F Ambient Particulate Monitor with PM_{10} pre-separator of the company Thermo Fisher Scientific for the component PM_{10}
   TÜV-Report: 936/21209885/B, Cologne November 25, 2011 [Ref.7];

3. Report on the suitability test of the ambient air quality measuring system TEOM 1405-F Ambient Particulate Monitor with $PM_{2.5}$ pre-separator of the company Thermo Fisher Scientific for the component $PM_{2.5}$
   TÜV-Report: 936/21209885/C, Cologne March 11, 2012 [Ref.8];

An additional three reports have been made available prepared by Bureau Veritas, in addition to the above. These UK reports re-ordered the TÜV reports into the format

stipulated in the MCERTS Annex document for UK Particulate Matter [Ref.5]. In addition, they include the results of a study of the particulate matter pollution climate of the datasets that was produced, and the implications for the use of the instruments within the UK are discussed. These latter three reports are as follows:

4. UK Report on the Equivalence of the PM_{10} and $PM_{2.5}$ TEOM 1405-DF.
   Report ref AGGX5508189/BV/DH/2835 dated 5 June 2013 [Ref.9];

5. UK Report on the Equivalence of the PM_{10} TEOM 1405-F.
   Report ref AGGX5508189/BV/DH/2833 dated 5 June 2013 [Ref.10]

6. UK Report on the Equivalence of the $PM_{2.5}$ TEOM 1405-F.
   Report ref AGGX5508189/BV/DH/2834 dated 5 June 2013 [Ref.11]

The three TÜV reports listed above have been used as the primary evidence by the UK MCERTS certification committee. Where additional information has been made available in the BV UK reports, then this information is also used and referenced. The results of the evaluation by the MCERTS certification committee are given in the checklist in Section 4 of this Evaluation Report, and also in the comments on the laboratory test programme carried out in Germany that are in Section 3 of this Report.

A summary of this Evaluation Report and the recommendations of this MCERTS certification committee on the equivalence testing of automated continuous and discontinuous methods described here, which are to be used to monitor particulate matter (PM_{10} and $PM_{2.5}$) in ambient air, are given in Section 5 below.

3. Requirements and Options for the Laboratory Test Programme

3.1 Requirements of the MCERTS Annex Document

The Annex to the MCERTS Performance Standards Document [Ref.5 Section 4.2] provides the scope of the laboratory test programme that is specified in the GDE, and also that specified in the MCERTS Performance Standard [Ref.3].

This Section also lists below the additional testing requirements that are specified in current German VDI/DIN Guidelines [Refs. 12 & 13]. These are required to be carried out for suitability testing/type approvals for automated continuous methods to be accepted for use in Germany. There are similar, but not identical to, additional requirements that are in a draft European standard being prepared by CEN, but a precursor of this is *currently published* as a CEN Technical Specification [Ref.14].

The somewhat *different* test requirements of the GDE [Ref 2], the MCERTS Performance Standard [Ref 3], the MCERTS Annex Document [Ref 5], and of these German VDI/DIN Guidelines, are discuss3ed below as applied to the TÜV test reports [Refs. 6, 7, & 8] that have been submitted for MCERTS Certification. The evaluations and the conclusions arising from the MCERTS certification committee's review of these test reports concerned with the laboratory tests are given below in this Section - in each case under the heading "Evaluation and Findings" in *italic text* below.

3.2 The laboratory test programme required by the Guide to Demonstration of Equivalence

3.2.1 Requirements

Section 9.3 of the GDE [Ref. 2], covers only two applications that relate to certain limited modifications of the manual CEN standard method (PM_{10} or $PM_{2.5}$) which the AQD has defined as a reference method. These are:

1a. Application of automated filter changers leading to filter storage conditions deviating from those prescribed in the EN standards;

1b. Use of different weighing conditions, e.g., conditions deviating from the requirements set in the EN standards.

In either of the above circumstances the GDE requires a set of laboratory tests that are given in [Ref. 2] Sections 9.3.2 and 9.3.3 respectively. There are no laboratory tests prescribed in the GDE for different candidate methods.

3.2.2 Evaluation and Findings

The candidate methods discussed in the three TÜV test reports [Refs. 6, 7, & 8] do not relate to limited modifications of the manual CEN standard method as stated in the GDE, and listed in 1a and 1b above. Thus these test reports do not provide any such tests, as they are not required.

3.3 The laboratory test programme required by the MCERTS Performance Standard

3.3.1 Requirements

The MCERTS Performance Standard [Ref. 3] specifies further tests to those of the GDE listed in Section 3.2 above, two of which are related to the stability of the flow through the filter or measurement cell, and the provision of a representative sample. These are:

a. Constancy of the sample volume flow, is tested as specified in the MCERTS Standard [Ref.3 paragraph 6.5.2], using selective filters loaded with particulates to 80%, 50% and 0% of the maximum permissible filter loading specified, and the constancy of the sample volumetric flow is recorded as a 3 minute average every 30 minutes for at least 24 hours – to achieve the performance criteria given in Table 6.2 of the MCERTS Performance Standard [Ref. 3].

b. The leak tightness of the sampling system is carried out using flow and pressure monitoring equipment to determine the leak rate of the entire instrument where feasible, or by evaluating the leaks of different parts separately. The tests can be made by measuring the volume flow at the inlet and outlet of the system, or by determining the pressure drop – to achieve the performance criterion given in Ref. 3 Table 6.2.

c. In addition, the same tests are required in Ref.3 as in the two applications in the GDE [Ref.2] that relate to certain limited modifications of a manual CEN standard method where the AQD [Ref.1] defines it as a reference method. The test procedures in the two documents are identical and are:

   - Application of automated filter changers leading to filter storage conditions deviating from those prescribed in the CEN standards;
   - Use of different weighing conditions, e.g., conditions deviating from the requirements set in the CEN standards.

   In either of the above circumstances the MCERTS Performance Standard [Ref.3] requires a set of laboratory tests that are as given in its Sections 6.6.2 and 6.6.3 respectively.

The laboratory tests that are specified in the MCERTS Performance Standard [Ref. 3] shall be the minimum laboratory tests that are carried out to show conformance with the requirements of this Evaluation Report.

3.3.2 Evaluation and Findings for Paragraph 3.3a above

The laboratory test to be carried out to fulfil Paragraph (a) above from the MCERTS Performance Standard [Ref.3] states:

Constancy of sample volumetric flow: The testing shall be carried out providing loaded filters, volumetric flow measuring device such as, for example, a mass flow meter and a pressure measuring device. Three pre-loaded filters with the particulate load of approximately 0%, 50%, and 80% of the maximum permissible filter loading shall be used. For each filter the constancy of the sample volumetric flow shall be recorded every 30 minutes as a 3 minute average over the time period of at least 24 hours.

The criteria required in Table 6.2 of the MCERTS standard [Ref.3] are:

Table 1: Specific performance criteria for laboratory volume flow and leakage of the PM sampling system given in the MCERTS Performance Standard [Ref.3]

Parameter	Performance requirement
Constancy of sample volumetric flow	Sample volumetric flow averaged over the sampling time to remain constant within ± 3% of the rated value. All instantaneous values to remain within ± 5% of the rated value.
Tightness of the sampling system	Leakage not to exceed 1 % of the sampled volume.

The TÜV testing was carried out using a different procedure, which was implemented during the field tests - using results obtained from all of the test sites for their whole duration. This data was therefore obtained over the different ambient particulate loadings that were encountered during the complete durations of all these three field trials in Germany (see TÜV test reports [Refs. 6, 7, & 8] Section 5.4.7 and the results therein). These utilized the continuously recorded daily averaged PM flows and the CM total flows provided by the CMs' data outputs. These data and the PM loadings of the measured results are presented.

The German performance criteria [Refs. 12 & 13] are the same as given above for the MCERTS Performance Standard [Ref.3]. These were fulfilled within all three TÜV test reports [Refs.6, 7, & 8].
The TÜV results represent a different and possibly more comprehensive evaluation procedure carried out in practice in the field, compared to the requirements of the MCERTS Performance Standard. The criteria for the two types of testing are the same.
The requirements for constancy of the sample volume flow are therefore fulfilled.

3.3.3 Evaluation and Findings for Paragraph 3.3b above

The laboratory test to be carried out fulfil paragraph (b) above of the MCERTS Performance Standard [Ref.3] states:

Tightness of the sampling system: The testing is normally carried out with the help of a pressure measuring device and a volumetric flow measuring system. The leak rate of the entire instrument shall be determined if it is feasible. This includes the inlet as well as the whole sampling system and the measuring system. If because of the instrument design the complete system tightness cannot be measured the leak rate can be determined separately for the sampling part and the measuring part. The leak rate can be measured by the determination of volume flow at the inlet and outlet of the system or by the pressure drop method. In the latter case the system is sealed at the inlet and evacuated by a built in or separate pump and the pressure increase due to leaks is measured over the period of 5 minutes. The leak rate V_L determination shall be repeated three times. It is calculated from the following formula:

$$V = \frac{\Delta P . V_g}{P_0 . \Delta t}$$

Where: ΔP – pressure drop determined over the time interval Δt

P_0- pressure at time t_0
V_g- estimated total volume of the system

The performance criterion to meet the requirements of table 2 of the MCERTS standard [Ref.3] is given in the table above (Leakage not to exceed 1 % of the sampled volume).

The TÜV testing followed a different procedure, specified by the CM manufacturer, with flow rate criteria also specified by the manufacturer. This is given in Section 5.4.8 of each of the TÜV test reports [Refs.6, 7, & 8], with the results obtained also therein. This test procedure states “the tightness check (for leakage) may **only** be carried out using the CMs’ internal tightness check assistant to avoid damage to the instrument”. This manufacturer’s internal tightness check assistant performs the test by comparing the zero flow that is achieved with the vacuum pump turned off, with the flow through the device when the inlet is blocked (ideally zero flows) - recommended to be carried out once per month. This check was performed by TÜV at the beginning of each field trial. The German performance criterion [Ref.13] is the same as that for the MCERTS Performance Standard [Ref.3] - leakage shall not exceed 1 % of the sampled volume.

The TÜV test reports [Refs. 6, 7, & 8] state that the criterion was fulfilled for all three types of CM tested, for all of the field tests, although the TÜV test reports did not carry out the test procedure as specified in the MCERTS Performance Standard [Ref.3] because the manufacturer did not allow this - because of possible damage to their instruments. The TÜV test reports [Refs. 6, 7, & 8] state that the results conformed to these manufacturer’s specifications for these tests. It is understood that the manufacturer’s specifications are not fully consistent with the 1% criterion in the MCERTS standard [Ref.3], and it is not completely clear whether the measurements that are made are accurate and traceable. However, it is recognised that if the manufacturer has a specified internal procedure for

these tests and does not wish for another procedure that may damage the CM, it is a programmatic and acceptable procedure in this event to use the manufacturer's internal test.

The leak test procedure carried out for the 1405-F and the 1405-DF is an internal procedure, implemented in the instruments in order to avoid serious damage to the instrument; the check on leak tightness must be performed using this internal procedure. The implemented test procedure allows certain maximum values for leak rates, which have demonstrated during the field trials of TÜV to be practical and suitable for assessing the instrument flow tightness, although the allowed limits are larger than 1 % of the respective flows. TÜV have described this in detail, and the test reports [Refs. 6, 7, & 8] have been approved by the German certification committee. The requirements for this test are therefore deemed to be fulfilled.

3.3.4 Evaluation and Findings for Paragraph 3.3c above

The laboratory test that should be carried out fulfil paragraph (c) in Section 5.3 of the MCERTS Performance Standard[Ref.3] is not relevant to the three TÜV test reports[Refs. 6, 7,& 8] since these tested CMs do not relate to limited modifications of the manual CEN standard method specified in the GDE [Ref.2]. Thus the test reports do not describe such tests, as they are unnecessary.

3.4 Tests Carried Out as an Option in the UK in Addition to the Requirements of the MCERTS Performance Standard and the MCERTS Annex Document

3.4.1 Requirements

In Germany there are minimum requirements and test procedures for automated continuous methods defined in VDI 4202- Part 1 and VDI 4203-Part 3 (re-published 2010) [Refs. 12 & 13] that are additional to those of the GDE [Ref 2], the MCERTS Performance Standard [Ref 3], and the MCERTS Annex Document [Ref 5], as outlined above. These requirements and procedures would need to be met and followed in addition for automated continuous PM methods that are to be used in Germany for regulatory purposes. These standards include references to EN 12341 (in terms of equivalence testing for PM_{10}) and to the GDE [Ref 2] (in terms of equivalence testing for PM_{10} and $PM_{2.5}$). The additional laboratory tests include:

- Measured value display;
- Easy maintenance;
- Functional test;
- Set-up and warm-up times;
- Instrument design;
- Unintended adjustment;

- Certification and measuring ranges;
- Negative signals;
- Failure in mains voltage;
- Operating states;
- Repeatability STD at zero;
- Dependence of zero and span on surrounding temp (5°C to 40°C);
- Dependence of span on electric voltage;
- Assessment of the measuring range(s);
- Ensuring negative signals are not suppressed;
- Zero level and detection limit;
- Measurement of effects of mains voltage and frequency fluctuations, and of mains voltage failure;

These tests were carried out as described in the three TÜV Test Reports listed [Refs.6, 7, & 8], according to the revised VDI/DIN Guidelines (2010) {Refs. 12 & 13], together with certain clarifications from the Competent Authority in Germany where required (see the TÜV test reports - Refs. 6, 7, & 8). These test procedures employed to produce the test results are listed in the TÜV test reports [Refs.6, 7, & 8] in Sections 4.1, 5.1, 5.2, 5.3, and 5.4 (part – the remainder of Section 5.4 covers the methodology of the equivalence checks), with the actual test results in the corresponding Sections of 6.1 of Refs. 6, 7, & 8.

3.4.2 Evaluation and Findings

The additional laboratory tests referred to directly above, are outside the scope of the requirements of the MCERTS Performance Standard for Continuous Ambient Air Monitoring Systems [Ref.3], and its Annex [Ref.5]. Therefore, as such, the test results do not need to be evaluated within the MCERTS procedures. They have been recognised and accepted by the relevant Competent Authority in Germany. It is proposed that comments concerning the additional tests that are NOT required by the UK Competent Authority are included in the MCERTS Certificates for the three types of monitoring systems discussed in this Report.

4. Checklist for Assessing the Acceptability of an Equivalence-testing Programme

This section provides the Certification Committee's checklist for assessment of conformance with the requirements of MCERTS for the UK Particulate Matter.

Manufacturer of the automated particulate method (including name and address)	Thermo Fisher Scientific 27 Forge Parkway Franklin, Massachusetts, 02038, USA
Is the above manufacturer requiring the equivalence testing or does the manufacturer have an agent? If agent give the name and address.	Manufacturer required equivalence testing: Manufacturer's UK agent: AIR MONITORS Ltd. 2 Bredon Court, Brockeridge Park, Twyning, Tewkesbury, Gloucestershire, GL20 6FF, United Kingdom.
Contact name at manufacturer or manufacturer's agent	Mr. Henk Oele, Thermo Fisher Scientific, Takkesbijsters, 4817 BL Breda, The Netherlands
Telephone number of contact name	+ 31 76 5795643 Email: henk.oele@thermofisher.com
Description of automated PM method (model, serial numbers, software details etc.)	1. TEOM 1405-DF Ambient Particulate Monitor with PM_{10} pre-separator and virtual impactor for the components PM_{10} and $PM_{2.5}$; software version 1.56. 2. TEOM 1405-F Ambient Particulate Monitor with PM_{10} pre-separator for the component PM_{10}; software version 1.56. 3. TEOM 1405-F Ambient Particulate Monitor with $PM_{2.5}$ pre-separator for the component $PM_{2.5}$; software version 1.56.
All the initial stages of the MCERTS Certification process shall have been completed satisfactorily – as summarised in Ref. 5 Section 4.1.	Yes – processed through the MCERTS Certification Body

(i) Details of the Test Laboratories and Additional Laboratories Involved

Name of Company	1. TÜV Rheinland Energie und Umwelt GmbH, Germany 2. National Physical Laboratory, United Kingdom 3. Bureau Veritas UK Ltd. – production of UK summary reports – see Section 2.2 of this MCERTS certification committeee Evaluation Report
Address	1. Am Grauen Stein, 51105 Köln, Germany 2. Hampton Rd. Teddington, Middlesex, TW11 0LW,UK 3. Brandon House, 180 Borough High St,London SE11LB, UK
Contact Name	1. Mr. Karsten Pletscher 2. Mr. David Butterfield 3. Dr. Richard Maggs
Telephone number of Contact	1. +49-221-806-2592 2. +44-208-943-6391
Email address of Contact	1. karsten.pletscher@de.tuv.com 2. David.butterfield@npl.co.uk 3. Richard.maggs@uk.bureauveritas.co.uk
Dates tests were carried out	December 2009 – February 2012
Test Laboratory Report number and date	Report numbers: 936/21209885/A (for 1405 DF); 936/21209885/B (for 1405 F for PM_{10}); 936/21209885/C (for 1405 F for $PM_{2.5}$). For full details see Section 2 of this MCERTS certification committee Evaluation Report, and Refs. 6, 7, & 8.
Laboratory tests shall be carried out - where the tests has been made: ○ According to MCERTS Standard Sections 6.5–6.6 ○ Or to VDI/DIN Germany requirements	Yes MCERTS Performance Standard and VDI/DIN Guidelines – see Sections .3 and 3.4 of this MCERTS certification committee Evaluation Report;

(ii) General Requirements of the Equivalence Testing

Relevant clause of the MCERTS Annex document [Ref.5] (& of GDE Ref.2)	Requirement	Comments: including location of the relevant information in the Equivalence test report, or the FINAL test report, and its acceptability
Ref.5 Section 4.3(i)	All decisions by the Competent Authority with regards to the declaration of equivalence after June 2010 shall meet all the requirements of this document, with concessions at set out in Ref 5.	Not applicable – all the results for the 3 types of CM were obtained prior to publication of the MCERTS Annex requirements document
Ref.5 4.3(ii) (& GDE 9.4.1)	Where the CM is a limited modification of an existing CEN reference method the appropriate sub-set of tests shall be carried out completely and satisfactorily.	Not applicable
Ref.5 4.3(iii)	Where the CM is a modification of an existing equivalent method, the test requirements shall have been specified and agreed with the UK Competent Authority. The tests shall been carried out satisfactorily in conformance with all the specifications, by a laboratory accredited to ISO/IEC EN 17025.	Not applicable
Ref. 5 4.3(iv) (& GDE 9.3)	Two RMs shall be used at all test sites – see 4.2 (iv), 4.2 (v), & 4.3(iii).	Yes – Section 5 of the 3 German test reports submitted [Refs. 6,7 & 8]
Ref. 5 4.3(v)	The RMs shall be of the specified type given in the relevant CEN standard. The gravimetric analyses of the samples in the laboratory shall be applied completely as specified in that standard.	Yes – Section 5 of German test reports submitted [Refs. 6, 7, & 8]
Ref. 5 4.3(vi)	Two complete CMs of the same type shall be used, and they shall be clearly and uniquely identified as such;	Yes – AMSs are identified in Section 4 of the German test reports [Refs. 6, 7, & 8] submitted. However, small modifications were made to some components of the all the AMSs after the first set of field trials carried out at Teddington – see Section 3 table 2 of Refs. 6, 7, & 8. These reports indicate that no changes in performance or an improvement in performance took place.

Ref. 5 4.3(vi) (& GDE 9.2)	The sample head of the CM shall be as specified in the relevant CEN standard. If not the complete Details of the CM sample head shall be documented as specified in Ref. 5 Section 4.2 and GDE [Ref.2] Section 9	Yes – see Section 3 of the German test reports [Refs. 6, 7, & 8].
Ref. 5 4.3(vii)	The two (local) CMs shall be co-located satisfactorily with respect to each other and with respect to the adjacent RMs to sample the ambient air homogeneously	Yes – located in transportable container adjacent to the one of the same type, and the sites were selected to have no significant local emission sources
Ref. 5 4.3(viii) (& GDE 9.1, & 9.4)	Where a "regional" instrument is used with two local CMs in the test programme, their results shall be applied correctly, and their measurement uncertainties calculated correctly.	Not directly applicable to this programme, although reference is made to another Cologne site in the TÜV test reports
Ref. 5 4.3(ix) & 4.6 (GDE 9.4.3)	Acceptable QA/QC checks shall be carried out during the test programme as specified in [Ref 2] GDE Annex D for CMs, and in EN12341 or EN14907 for RMs.	Within the TÜV reports, there is information on the maintenance of the reference methods used during the trials and reference to the use of the appropriate CEN standard but there is no specific description of the QA/QC performed by the test laboratories according to the GDE [Ref 2]. Additional information has also been made available in the UK BV reports [Refs. 9, 10, & 11]. There is sufficient information for us to judge that the quality assurance and quality control carried out is satisfactory and fit for purpose.
Ref. 5 4.3(x) & 5.5.1	All the test results for the 2 RMs and the 2 CMs shall be documented completely - including all results that are rejected as outliers - or otherwise discarded.	Yes - and the outlier rejections of the RM are shown.
Ref.5 4.3(xi) & 5.2	Both CMs shall have a minimum data capture and availability of greater or equal to 90%, as determined in Ref.5 Section 5.2, where tests have begun after Ref 5 entered into force.	The averaged data capture of all the types of CMs in all the test programmes were all >90%. However, this is not an applicable requirement for tests carried out before the MCERTS Annex document [Ref 5] was published

Ref. 5 4.3(xiii), &(xiv)	Where a test laboratory within a European Member State other than the UK produces the test report, at least two sets of valid 40 tests shall be carried out in that Member State at suitable sites. Where only one set of valid (40) equivalence field tests are to be carried out in the UK, there shall be at least three equivalence tests carried out in the other Member State. Where tests are begun before the date of publication of this document there shall be one or more tests carried out in the UK. Where tests are carried out that begin after the date of publication of this document, there shall be at least two tests carried out in the UK. The UK tests shall be carried out at one or more locations in the UK - selected with respect to the UK pollution climate evaluation, and at different seasons - The test laboratories shall be accredited to the ISO/IEC 17025 standard for all the MCERTS tests;	The tests provide 4 test sites each with > 40 valid results, with one test set in the UK for 2 different seasons. The tests were completed before publication. The test laboratories were accredited to EN ISO 17025 for these MCERTS tests.

(iii) Laboratory tests to fulfil the MCERTS Performance Standard and/or the VDI/DIN Requirements

Section 4.2 of Ref.5 & this Evaluation report Section 3	The laboratory test to be carried out to fulfil Paragraph 6.5.2 of the MCERTS Performance Standard [Ref.3] states: Constancy of sample volumetric flow: The testing shall be carried out providing loaded filters, volumetric flow measuring device such as, for example, a mass flow meter and a pressure measuring device. Three pre-loaded filters with the particulate load of approximately 0%, 50%, and 80% of the maximum permissible filter loading shall be used. For each filter the constancy of the sample volumetric flow shall be recorded every 30 minutes as a 3 minute average over the time period of at least 24 hours.	The TÜV testing was carried out using a different procedure, which was implemented during the field tests - using results obtained from all of the test sites for their whole duration. This data was therefore obtained over the different ambient particulate loadings that were encountered during the complete durations of all these three field trials in Germany (see TÜV test reports [Refs. 6, 7, & 8] Section 5.4.7 and results therein). These utilized the continuously recorded daily averaged PM flows and the CM total flows provided by the CMs' data outputs. These data and the PM loadings of the measured results are presented.

		The TÜV results represent a different and probably a more comprehensive evaluation procedure carried out in practice in the field, compared to the requirements of the MCERTS Performance Standard [Ref 5]. The performance criteria are the same as given in the MCERTS standard, and were fulfilled within all three TÜV test reports. The requirements for constancy of the sample volume flow are therefore fulfilled.
Section 4.2 of Ref.5 & this Report Section 3.3	The laboratory test to be carried out to fulfil paragraph 6.5.3 of the MCERTS Performance Standard [Ref.3] states: Tightness of the sampling system: The testing is normally carried out with the help of a pressure measuring device and a volumetric flow measuring system. The leak rate of the entire instrument shall be determined if it is feasible. This includes the inlet as well as the whole sampling system and the measuring system. If because of the instrument design the complete system tightness cannot be measured the leak rate can be determined separately for the sampling part and the measuring part. The leak rate can be measured by the determination of volume flow at the inlet and outlet of the system or by the pressure drop method. In the latter case the system is sealed at the inlet and evacuated by a built in or separate pump and the pressure increase due to leaks is measured over the period of 5 minutes. The leak rate V_L determination shall be repeated three times.	The leak test procedure for the 1405-F and the 1405-DF is an internal procedure, implemented in the instruments in order to avoid serious damaging of the instrument, and the check on leak tightness must be performed using this internal procedure. The implemented test procedure allows certain maximum values for leak rates, which have demonstrated during the field trials of TÜV to be practical and suitable for assessing the instrument flow tightness, although the allowed limits are larger than 1 % of the respective flows. TÜV have described this and the test reports have been approved by the German certification committee. The requirements for this test are therefore deemed to be fulfilled.

Section 4.2 of Ref.5 & this Evaluation Report Sections 3.2.2 & 3.3.4	Laboratory tests are required where relevant, on two applications that relate to certain limited modifications of the manual CEN standard method (PM_{10} or $PM_{2.5}$) specified in the GDE tests, where the AQD defines it as a reference method. These are: • Application of automated filter changers leading to filter storage conditions deviating from those prescribed in the CEN standards; • Use of different weighing conditions, e.g., conditions deviating from the requirements set in the CEN standards. In either of the above circumstances the MCERTS Performance Standard [Ref.3] requires a set of laboratory tests that are as given in its Sections 6.6.2 and 6.6.3 respectively.	The laboratory test that should be carried out fulfil paragraph (c) in Section 5.3 of the MCERTS Performance Standard [Ref.3] and section 4.2 2c of the MCERTS Annex document [Ref.5] is not relevant to the three TÜV test reports since these CMs do not relate to limited modifications of the manual CEN standard method. Thus the test reports do not report any such tests, as they are unnecessary.
Section 4.2 of Ref.5 & this Evaluation Report Section 3.4	There are minimum requirements and test procedures in Germany for automated continuous methods defined in VDI 4202- Part 1 and VDI 4203-Part 3 (re-published 2010) [Refs. 12 & 13] that are additional to those of the GDE [Ref 2], the MCERTS Performance Standard [Ref 3], and the MCERTS Annex Document [Ref 5]. These requirements and procedures would need to be achieved and followed in addition for automated continuous PM methods that are used in Germany for regulatory purposes. These include references to EN 12341 (in terms of equivalence testing for PM_{10}) and to the GDE (in terms of equivalence testing for PM_{10} and $PM_{2.5}$).	The additional tests referred to in Section 3.4 of this Evaluation Report, are outside the scope of the requirements of the MCERTS Performance Standard for Continuous Ambient Air Monitoring Systems [Ref.3], and its Annex [Ref.5], and as such do not need to be evaluated within the MCERTS procedures. They have been recognised and accepted by the relevant Competent Authority in Germany. It is proposed that comments concerning these additional tests are included in the MCERTS Certificates for the three types of monitoring systems discussed in this Report.

(iv) Requirements of the Field Test Conditions

Ref.5 Section 4.4(i)	The equivalence test sites shall be demonstrated to be representative of the UK's PM pollution climate. This shall be done using at least six months, and preferably twelve months of reference method, or equivalent method, PM measurement data. This should ideally be done in a period of time that encompasses the field test period and be co-located with the field test. If either of these is not available, then data from another time period, preferably	The determination of the UK pollution climate has been carried out in the BV UK reports [Refs.10, 11, & 12] and is appropriate One of the sites (Bornheim Germany) did not have > 6 months of calendar daily data

	within the two years previous to the field trial and/or data from an alternative monitoring location, similar in type to the field test site (e.g. urban background, traffic, rural) and in the close proximity to the field test site may be used as the basis for the assessment ([Ref. 5 section 3.2]. The individual atmospheric components that make up the successful demonstration of the pollution climate are *listed below*:	for PM_{10} and $PM_{2.5}$, and also for the Cologne parking lot site for $PM_{2.5}$. An additional site was therefore used to support the PM climate calculation as well.
Ref. 5 Section 4.4(ii)	The geometric mean(s) of the PM data (PM_{10} and/or $PM_{2.5}$) obtained from a minimum of six months of monitoring, shall conform to the requirements of Section 4.4(ii) of Ref.5	Accepted – taking account of the site in Cologne-Chorweiler;
Ref. 5 Section 4.4(iii)	The collocations of the RMs and the CMs shall be acceptable in terms of minimising the spatial inhomogeneity and differences in the PM content of the air sampled by all the methods.	Accepted;
Ref. 5 Section 4.4(iv)	There shall be a minimum of four valid comparisons at a minimum of two sites if all the tests are all carried out in the UK.	Accepted - there are two UK valid test sets for Teddington in summer and winter, and two test sites in Germany. These were all completed before the MCERTS Annex document was published.
Ref. 5 Section 4.4(iv)	There shall be evidence that the sampled PM fractions have both high and low fractions of semi-volatiles during specified periods of the test programme	Accepted – see above and MCERTS Annex document [Ref 5] Table 3
Ref. 5 Section 4.4(iv)	There shall be evidence that the measurements were taken at both high and low ambient atmospheric temperatures and high and low relative humidity during specified times of the complete test programme.	Accepted – see above and MCERTS Annex document [Ref 5] Table 3
Ref. 5 Section 4.4(iv)	There shall be evidence that the measurements were taken at both high and low wind-speed conditions during specified times of the complete test programme.	Accepted – see above and MCERTS Annex document [Ref 5] Table 3
Ref. 5 Section 4.4(iv)	The comparisons should be carried out during different UK climatic conditions;	Accepted – see above and MCERTS Annex document [Ref 5] Table 3
Ref. 5 Section 4.4(iv)	The individual comparative results from both the RMs and CMs shall be taken at regular intervals during all the comparisons;	Accepted;
Ref. 5 Section 4.4(v)	There shall be a comprehensive and valid evaluation of the UK "PM pollution climate" carried out as summarised in Ref. 5 Section 3.2 and given in Ref.5 section 4.4(v), utilising all the variable atmospheric	Accepted – see above and MCERTS Annex document[Ref 5] Table 3

	components given in that Section of Ref.5.	
Ref. 5 Section 4.4(vi)	From the above and other indicators the selected equivalence test sites shall be "representative of the field conditions under which the CMs are likely to operate"	Accepted – see above and MCERTS Annex document [Ref 5] Table 3
Ref. 5 Section 4.4(vii)	The scope of the equivalence claim shall be defined satisfactorily with respect to the evaluation of the PM climate and with respect to the type of the selected test sites (national, regional, station type, etc.)	Accepted – see above and MCERTS Annex document [Ref 5] Section 3.

(v) Requirements of the Candidate Method in the Field Tests

Ref. 5 Section 4.5	The complete type and model number of the CM and type of sampling head, including all its functional parts, its sensors, its software version etc., shall be documented comprehensively so that the two CMs are uniquely identified. The type and all the characteristics of the CM shall be listed on the MCERTS certificate.	Accepted – see TÜV reports [refs.6, 7, & 8] Section 3, which include the modifications made after the UK tests had been completed.
Ref. 5 Section 4.6	There shall be a complete and comprehensive QA/QC programme for the CMs and the RMs throughout the field test programme (see also Checklist (vii)below)	The QA/QC programme is documented generally in different parts of the TÜV reports. Within the BV UK reports [Refs. 9, 10, & 11], the information has been collated in to Section 10
Ref. 5 Section 4.7 & 5.1	All the results of the field test programme shall be documented and reported in units of mass of particulate per unit volume of air sampled at ambient conditions. The results of the CMs shall be averaged correctly over each 24 hour period, to provide at least 40 data set pairs of RM and concurrent CM data for the two RMs and the two CMs, as specified in Ref. 5 Section 4.7. Where the CM results are based on aggregated results of smaller averaging times the percentage of these values available for calculating the 24-hour average shall be at least 75%.	Accepted – all the results are documented on an average daily basis. Within the TÜV reports it is not explicit whether any partial days results have been removed – but there is a statement in each TÜV report that no CM data has been discarded so that this appears to be satisfactory. Further clarifying information is provided in the BV UK reports [Refs. 9, 10, & 11];
Ref. 5 Section 5.1	In the case of filter changes that form part of the operations of a *manual* CM, The times of these changes shall be logged permanently by the CM. The time during which the filter is changed shall be limited to less than 1% of each 24 hour period (This 1% criterion is specified currently in the CEN automatic standard that is now a	Not reported, but this is not required for this test programme;

	draft. If the final published CEN document specifies a different percentage to this then this criterion should be changed.)	
5. Ref. 5 Section 2	The availability (data capture) of the two CMs shall be separately evaluated as given by Ref.5 Section 5.2, equation 2, for all tests that are carried out in or after 2012. This shall be included in the test report and in the MCERTS test certificate, with the acceptance criterion of 90%.	The data capture has been reported – see the three TÜV reports [Refs. 6,7, & 8] but this is not a requirement for this test programme
Ref. 5 Section 5.3	The between-candidate method standard uncertainty defined in Ref 5 Section 5.3 shall be determined (after all the results have been evaluated and any removed or discarded as specified in Ref 5 Section 5.5.1), in order to define the complete set of *valid* results. These shall be ≥ 40 valid results per comparison trial or the data is unsuitable.) - For all the *valid* results of the (minimum) four comparisons in the total dataset together; - Separately for the two datasets obtained by splitting the full dataset according to their concentrations as given in section 5.3.3;	Satisfactory – see TÜV test reports [Refs.6, 7, & 8] Section 5.4.10
Ref. 5 Section 5.3	The between-CM uncertainty of ≤ 2.5 μg m^{-3} shall be satisfied for both instruments and for the two datasets listed above.	Satisfactory – see TÜV test reports [Refs. 6, 7, & 8] section 5.4.9

(vi) Requirements of the Reference Method in the Field Tests

Ref. 5 Section 4.3(iv) & 5.4	The complete type and model number of the RM and the type of sampling head, including all its functional parts, its sensors, its software version etc. (where relevant), shall be documented comprehensively so that the two RMs are uniquely identified. The type of subsequent laboratory analyses of the gravimetric filters shall be documented and shall comply with all the requirements of the relevant CEN standard – to be quoted;	Accepted – TÜV reports Section 5;
Ref. 5 Section 5.4 & 4.3(iv)	Two RMs shall generally be used throughout the complete test programme. If not the reason for this shall be justified comprehensively. Where only one RM is used this shall be accounted for in the evaluation of the uncertainty of the CM – see Ref. 5 Section 5.5.3.1	Accepted – TÜV test reports [refs.6, 7, & 8] Section 5
Ref. 5 Section 5.1	In the case of filter changes that form part of the operations of the RM, the times of these changes shall be logged by the RM.	Not applicable;

Ref. 5 Section 5.4	The between RM standard uncertainty defined in Ref. 5 Section 5.4 equation 3 shall be determined: - After all the results have been evaluated and removed or discarded as specified in Ref. 5 Section 5.5.1 to define the complete set of remaining *valid* results – This shall be ≥ 40 valid results per comparison trial or the data is unsuitable. - For all the *valid* results of the (minimum 4 comparisons) in the total dataset together, then:	Accepted – TÜV test reports [Refs. 6, 7, &8] Section 5.4.9.
Ref. 5 Section 5.4	The between RM uncertainty of ≤ 2.0 $\mu g.m^{-3}$ shall be satisfied for both RMs, across the complete data set [Ref.5].	Accepted – TÜV test reports [Refs.6, 7, &8] Section 6.6

(vii) Requirements of the QA/QC Programme in the Field Tests

Ref. 5 Section 4.6	The requirements of the GDE [Ref 2] Annex D for calibrations and quality control checks shall be met during the complete filed test programme	Requirements met;
Ref. 5 Section 4.6	The requirements for, and the frequency of, QA/QC checks shall in addition be the same as those intended for operational field conditions to the extent that it is demonstrated that no additional significant uncertainty terms would arise during those subsequent field operations. Otherwise an additional uncertainty term shall be added.	Requirements met;
Ref. 5 Section 4.6	All the information listed in Reference 17 Section 4.6 shall be recorded during the entire field test programme and shall be made available for assessment within the MCERTS certification process, in a report in a format given in Reference 17 Section 6.	Accepted; However, the information is distributed in different sections of the TÜV reports. Within the BV UK Reports [Refs. 9, 10, & 11], the information is collated into Appendix E.

(viii) Assessment of the Suitability of the Results Obtained in the Field Tests

Ref. 5 Section 5.5.1	There shall be a minimum of four sets of data from comparisons between the RMs and both the CMs at a minimum of two sites, each containing a minimum of 40 paired results – If not the datasets are unacceptable;	Accepted – there are greater than the minimum required valid results at all sites.
Ref. 5 Section 5.5.1	Paired results may be removed from the complete data set. If so, the removed results shall be tabulated and the removals shall be justified on sound technical grounds.	Accepted –no paired results of the CMs have been removed

Ref. 5 Section 5.5.1	Further results may be removed as statistical outliers. – if so, they shall be removed using only one Grubb's test with an outlier test at the 99% level; This shall not remove more than 2.5% of the data pairs – If more, the results are invalid;	Accepted – Grubbs tests has been applied correctly to the RM results;
Ref. 5 Section 5.5.1	There shall be 40 (valid) measurement paired results *remaining* in each comparison for both CMs – after removal of the paired data by Grubb's tests etc.	Accepted;
Ref. 5 Section 5.5.1	≥20% of the remaining paired results of the full dataset shall have greater than the prescribed PM concentrations as determined by the collocated RM.	Accepted – results tabulated correctly;

(ix) Assessment of the Procedure used to Evaluate the Resultant Final Data Sets of the Field Tests

Ref. 5 Section 5.5.1	The results of all the paired data obtained, after carrying out the procedure in Ref.5 Section 5.5.1, shall be processed assuming a linear relationship between CM and RM of the form given in Ref. 5 equation .4, using a regression technique that leads to a symmetrical treatment of both the variables (e.g. generalised least squares or orthogonal regression), which shall be derived from a recognised and validated source of the regression technique	The TÜV test reports [Refs.6, 7, & 8] state that orthogonal regression was applied, and further clarifying information is given in the BV UK reports [Refs. 9, 10, & 11]. As part of this review, the calculations and the formulae were validated by the MCERTS certification committee, including using the EU accepted and verified RIVM_PM_ spreadsheet_v2.9 (25 October 2011 [Ref. 15].)
Ref. 5 Section 5.5.2	The results above shall be processed using the average results of the two RMs, and regressions shall be established for each of the CMs individually;	Accepted - Correctly processed
Ref. 5 Section 5.5.2	The above results shall be processed: (i) all together and (ii) in datasets with concentrations greater than or equal to 30 µg m^{-3} for PM_{10} or equal to or greater than 18 µg m^{-3} for $PM_{2.5}$, and (iii) datasets at each individual site where testing was performed to produce valid datasets and (iv) separately for each individual site type if applicable.	Accepted - Correctly processed
Ref. 5 Section 5.5.2	For each of the datasets, for each CM, the criteria for the acceptance of the calibration function between the average of the RM results and the CM results shall conform to the requirements of Ref.5 equations 5 and 6. If these criteria are met the calculations in Ref.5 Sections 5.5.3.1 and 5.5.3.5 shall be applied. If these criteria are not met, the CM may be calibrated as in Ref. 5 Section 5.5.3, and as indicated below in this checklist.	Accepted – the criteria for the acceptance of the CMs described in these TÜV Test reports (Refs. 6, 7, & 8] is achieved without the application of calibration functions. However, the intercepts of all four types of CMs show significant non-zero values, and the calibration function has also been applied.

		These calibrated results also meet the acceptance criteria with small differences in the derived slopes and intercepts. Both sets of results should be included on the certificates.

(x) Evaluation of the Method Used to Determine the Uncertainty of the Results of the CM in the field Tests

Ref. 5 Section 5.5.3.1	No correction for the slope or intercept has been applied as specified in Table ix above, and Eq. 8 shall be applied for the evaluation of the uncertainty of the results of both the CMs.	Not applicable;
Ref. 5 Section 5.5.3.2	A valid correction for the intercept has been applied as given in Table ix above, and Ref. 5 Eq.12 shall be applied for the evaluation of the uncertainty of the results of both the CMs.	Accepted – this has been corrected for all 3 TÜV reports. However, it should be noted that in TÜV test report /B [Ref.7] that one of the two CMs tested has a significant intercept and the other does not. This implies a range of CMs that might be expected in practice. This is partially caused by the artefact that the CMs are precise and therefore small uncertainties can be significant. The procedure thus was to average the results from both CMs and to apply corrections to this average as given in GDE [Ref 2] Section 9.7. The other TÜV reports (A & C) [Refs. 6 & 8] had consistent corrections, which were made to both CMs. It should be noted that this range or larger might be expected when these CMs are subsequently deployed for monitoring purposes.
Ref. 5 Section 5.5.3.3	A valid correction for the slope has been applied as given in Table ix above, and Ref. 5 equation .16 shall be applied for the evaluation of the uncertainty of the results of both the CMs.	Not applicable;
Ref. 5 Section.5.3.4	Corrections for both the slope or intercept has been applied as given in Table ix above, and Ref.5 equation 21 shall be applied for the evaluation of the uncertainty of the results of both the CMs.	Not applicable
Ref. 5	In all the above cases the correct values for the uncertainty of the RM,	Within the TÜV test reports, it is not explicitly stated that this has been done but

Section 5.5.3.5	$u(x_i)$ shall be used as specified in Ref. 5 Section 5.5.3.1 as $\mathbf{u_{bs,RM}/\sqrt{2}}$ (Eq.3)	the calculations show that it has been done correctly. Within the BV UK report, the situation is clarified as "In all cases the uncertainty of the reference method was calculated for each individual dataset in accordance with the GDE [Ref 2]. As in all cases there were two reference methods available, it was not necessary to use the recommended default uncertainty of 0.67 for any of the calculations."

(xi) The Overall Relative Measurement Uncertainty Assignment of the CM

Ref. 5 Section 5.5.3.5	The relative standard measurement uncertainty of both the CMs shall be calculated using Ref.5 equation.22	Accepted;
Ref. 5 Section 5.5.3.5	The calculation of Ref. 5 equation.22 shall be carried out using the full dataset.	Accepted;
Ref. 5 Section 5.5.3.5	The $u_{CR}(y_i)$ or $u_{CR}(y_{i,cal})$ values as appropriate used in the equation shall be those at the limit value – where this limit value is 50 µg m^{-3} for PM_{10}, and 30 µg m^{-3} for $PM_{2.5}$ (unless the Competent Authority has specified a different value for $PM_{2.5}$).	Accepted – these "limit" values have been applied correctly
Ref. 5 Section 5.5.3.5	The $u_{CR}(y_i)$ or $u_{CR}(y_{i,cal})$ values as appropriate used in the equation shall be those that are derived using the calculation procedure in *one* of the Ref. 5 Sections 5.5.3.1 –5.5.3.4, where either no corrections, correction to slope or intercept, or corrections to slope and intercept corrections, have been applied to this full dataset	Accepted - there are corrections for intercepts in all three test report results and these should be listed on the MCERTS certificates.
Ref. 5 Section 5.5.3.5	One or more additional terms for measurement uncertainty shall be applied if the QA/QC activities carried out during the equivalence field tests are more stringent than those than will be applied when the method is operated in a network (GDE [Ref 2] Section 9.5.4)	No additional term has been applied and there is evidence that the QA/QC procedures used are satisfactory
Ref. 5 Section 5.5.3.5	All the values obtained for $u_{CR}(y_i)$ or $u_{CR}(y_{i,cal})$ **whichever is applicable,** shall be multiplied by and appropriate coverage factor (k) to provide values for the expanded uncertainty, $\mathbf{W_{CM}}$, of the CM results, expressed at a 95% confidence level;	Accepted;

(xii) The Overall Measurement Uncertainty Calculated for the CM with Respect to the Requirements of the Directive

Ref. 5 Section 5.6	The highest of the expanded uncertainty estimates $\mathbf{W_{CM}}$ arising from both CMs shall be compared with the expanded relative uncertainty stated as the data quality objective, $\mathbf{W_{dqo}}$, in Directive 2008/50/EC [Ref 1];	This comparison has been done correctly both before the intercept correction factors have been carried out and also afterwards.
Ref. 5 Section 5.6	One of two cases shall be determined: (i) $\mathbf{W_{CM} \leq W_{dqo}}$ then the CM is accepted as equivalent to the RM; (ii) $\mathbf{W_{CM} > W_{dqo}}$ then the CM is not accepted as equivalent to the RM;	In both the above cases the measurement uncertainty criterion is achieved, and the CM can be accepted as equivalent, for both the uncorrected data and the corrected data used to determine $W_{cm.}$

5. Summary and Recommendations

The complete set of tests carried out by the National Physical Laboratory (NPL) in the UK, and TÜV Rheinland Energie and Umwelt GMBH in Germany conformed to the scope of the test programme "Combined MCERTS and TÜV PM Equivalence Test Programme". This Test Programme was developed in the context of European harmonisation, and as recommended by the EC Guidance on Equivalence Testing [Ref 2]. It was developed by Bureau Veritas and NPL in the UK, and TÜV Rheinland in Germany.

The three TÜV test reports [Refs. 6, 7, & 8] demonstrate that generally the minimum requirements of the MCERTS Performance Standard for Continuous Ambient Air Monitors Version 8 July 2012 [Ref 5] were fulfilled, and generally the requirements of the relevant VDI/DIN Guidelines [Refs. 12 & 13] were also fulfilled.

It is proposed that as a result of this, the following types of ambient air PM monitor are accepted as meeting the requirements of the above MCERTS Performance Standard [Ref. 3], **and** also is in conformance with the requirements of the Annex to this MCERTS Performance Standard as conforming to the requirements of MCERTS for UK Particulate Matter [Ref. 5].

1. TEOM 1405-DF Ambient Particulate Monitor with PM_{10} pre-separator and virtual impactor for the components PM_{10} and $PM_{2.5;\ software}$ version 1.56.

2. TEOM 1405-F Ambient Particulate Monitor with PM_{10} pre-separator for the component PM_{10}; software version 1.56.

3. TEOM 1405-F Ambient Particulate Monitor with $PM_{2.5}$ pre-separator for the component $PM_{2.5}$; software version 1.56

Manufactured by: Thermo Fisher Scientific
27 Forge Parkway
Franklin, Massachusetts, 02038,
USA

Restrictions:

1. The permitted range of the surrounding temperature in the installation at the field measurement site is $8^{o}C$ to $25^{o}C$.

2. The leak test procedure for the 1405-F and the 1405-DF is an internal manufacturer's procedure, implemented in the instruments in order to avoid serious damage to the instrument. The check on tightness must be performed using this internal procedure. This implemented test procedure allows certain maximum values for leak rates, which have demonstrated during the field trials of TÜV to be practical and suitable to assess the instrument tightness, although the allowed limits are larger than 1 % of the respective

flows. TÜV have described this, and the test reports have been approved by the German certification committee.

Notes:

1. The requirements of the variation coefficient R^2 in the currently published standard EN 12341 were not fully achieved during the field tests at the test sites of Teddington UK (summer), and Bornheim Germany (summer);

2. The requirements of the EC Guidance on "Demonstration of Equivalence of Ambient Air Monitoring Methods" (GDE. [Ref 2]) were also fulfilled for the PM_{10} and $PM_{2.5}$ monitors described in this Report.

3. For the purposes of quality assurance and quality control of these monitors in the field, these should be calibrated on a test site at intervals by use of the gravimetric reference methods EN 12341 or EN 14907 as applicable, and as given in the recommendations of the GDE.

4. The TÜV test reports on the suitability tests are available on the internet at www.qal1.de

Annex 1 Terms and Definitions

For the purposes of this Report, its associated checklist, and for the purposes of the MCERTS Annex document [Ref.5], the following terms and definitions apply. The origins of these terms and definitions are indicated where appropriate by square brackets [Ref.] after the definition, taken from the list of references given in Section (i) P7 of this MCERTS Annex document. These references are also specified below in Annex 3 for convenience.

Ambient air

Outdoor air in the troposphere (excluding workplaces defined by Directive 89/654/EEC, where provisions concerning health and safety at work apply, and to which members of the public do not have regular access) [Ref.1].

Automated (measurement) method

A measurement method or system performing measurements or samplings of a specified pollutant in an automated way, generally directly in the field [Ref.2].

Availability (of the candidate method)

The fraction of the total and consecutive monitoring time during all the field trials involved in the equivalence testing programme for which data of acceptable quality are collected. The times required for scheduled calibrations and maintenance shall not be included. The method for calculating this fractional time is given in reference 5, Section 5.2 Equation 2. Availability defined here is the same as the minimum data capture requirements given in the data quality objectives in Directive 2008/50/EC for the relevant pollutant.

The MCERTS Performance Standard [Ref.3] also has a requirement that both of the candidate methods shall have an availability of greater than or equal to 90% during the entire set of field tests, and this shall be reported on the MCERTS certificate.

Calibration (of a candidate method)

Determination of the function between the concentrations of a specific pollutant in the ambient air as determined with respect to the reference method, and the responses of the candidate method to those same concentrations. This is applicable to the candidate method with time-limited validity [Ref.2].

Candidate method

A measurement method proposed as an alternative to the relevant reference method - for which equivalence is sought to be demonstrated [Ref. 2].

CEN standard

International standard for normalization (norm) developed by the organisation the European Committee for Standardization (CEN) for the objective of removing trade barriers for European industry and consumers [Ref.16].

Combined standard uncertainty

Standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities, equal to the positive square root of a sum of these terms, the terms being the variances or co-variances of these other quantities weighted according to how the measurement result varies with changes in these [Ref.17]. This may be expressed either as a relative (percentage) uncertainty, or as an absolute uncertainty, of the result.

Competent Authority

Organisation within the Member State that is designated by its national government to have overall responsibility for enacting all provisions of a set of European directives and/or other European regulations that are implemented into national regulations [Ref.18].

This is the organisation in the Member State that has national and legal responsibility for the provisions and requirements of Directive 2008/50/EC [Ref.1], and it is generally a national government ministry or an agency of national government, with political and administrative responsibilities for the relevant field of the legislation [Ref.18].

Competent body

Organisation designated by the Competent Authority in the Member State to carry out one or more technical or administrative functions at a national level, that in this document are those required by Directive 2008/50/EC [Ref.1], particularly those functional responsibilities that are specified in Article 3 of that Directive [Ref.18].

This is generally a designated scientific and technical organisation, rather than a government ministry, that enables all the functional responsibilities defined in Article 3 of the Directive 2008/50/EC[Ref.1] to be carried out. These responsibilities are applicable to all of the ambient air pollutants that are regulated across the EU, including those covered by Directive 2004/107/EC. One organisation in a given Member State is not generally capable of carrying out all of these, and there are therefore usually several competent bodies within a Member State [Ref.18].

Coverage factor

Numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty [Ref.17].

Designated body

Particular organisation that is designated for a specific task (type approval tests, equivalence tests, and/or Quality Assurance/Quality Control activities in the field) by the Competent Authority in that Member State.

This is a competent body that has been designated to carry out a particular scope of activities. It is required that a designated body that is appointed at a national level be accredited for the specified task(s) according to the EN ISO/IEC 17025 standard.

Environmental conditions

The specified range of meteorological conditions, the range of PM mass concentrations, and the range of semi-volatile components present in the sampled PM mass, that shall be present during one or more of the comparison tests carried out to demonstrate conformance with the "equivalence" requirements specified in this document.

Equivalent method

A measurement method other than the reference method for the measurement of a specified regulated air pollutant, capable of meeting the Data Quality Objectives given in Ref. 1, for which equivalence has been demonstrated [Ref.1 Annex IV B & Ref.2 Section 4].

Expanded uncertainty

Quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand [Ref.17]. The fraction may be viewed as the coverage probability or level of confidence of the interval. (A specific level of confidence associated with this interval defined by the expanded uncertainty requires assumptions about the probability distribution characterised by the measurement result and its combined standard uncertainty.)

Field (equivalence) test or comparison

Experimental programme carried out by a test laboratory at a selected location in the field to compare the results obtained by the particulate matter reference method with those obtained by a particulate matter candidate method, during the course of establishing whether the candidate method conforms to the requirements for an equivalent method for monitoring particulate matter. This individual experimental field test or comparison forms part of a complete experimental test programme, together with a laboratory test programme where required, for demonstrating whether the candidate method may be deemed to be an equivalent method.

Laboratory (equivalence) test

Experimental programme carried out by a test laboratory in the environment of its laboratory to determine whether a particulate matter candidate method conforms to the requirements for an equivalent method for monitoring particulate matter. This laboratory test programme, where required, forms part of a complete experimental programme, together with the field test programme, for demonstrating whether the candidate method may be deemed to be an equivalent method. There are very limited requirements for laboratory tests in the MCERTS standard (and in the Guide to Demonstration of Equivalence [Ref 2]), but German test laboratories are required to carry out a greater and more comprehensive range of tests, many of which are being incorporated into a new CEN standard. These are discussed in MCERTS Annex document (Reference 5 Section 4.2).

Limit value

A concentration level of a pollutant in the ambient air that is fixed on the basis of scientific knowledge, with the aim of avoiding, preventing or reducing harmful effects on human health and/or the environment as a whole, to be attained within a given period and not to be exceeded once attained [Ref.1].

Manual (measurement) method

A measurement method by which sampling is performed on site, generally for fixed short time intervals, with sample analysis performed subsequently in a laboratory [Ref.2].

Manufacturer (of the equipment)

The manufacturer of the hardware and associated software that makes up part of the *measurement method/candidate method* and is responsible for designing and/or manufacturing a product with a view to placing it on the market under its name. The manufacturer becomes the MCERTS certificate holder and is listed on the certificate, and has responsibility for compliance with the relevant MCERTS performance standards and regulations.

A manufacturer may also be an organisation that assembles, packs, processes, imports or labels ready-made products with a view to them being placed on the market under its name. The manufacturer may also be the manufacturer's agent or the equipment supplier of the automated or manual PM method when it has been MCERTS certified [Ref.4].

The term "manufacturer" is thus used to mean the equipment manufacturer, the manufacturer's commercial agent, or their equipment supplier, whichever is relevant as the customer in the MCERTS certification procedure.

Manufacturer's site audit

Initial and annual visits to the equipment manufacturer's plant by trained technical personnel as agreed by the MCERTS Certification Body to establish that equipment being manufactured is of the same type as that submitted as a candidate method for the equivalence tests [Ref.4].

MCERTS certification

The approval of a candidate particulate matter monitoring method that meets all the MCERTS ***technical requirements*** but it has not necessarily been demonstrated for, or assessed for, use in the UK with its specific pollution climate for ambient PM monitoring [Ref. 5]. This is a decision taken within the MCERTS certification procedure, and does not by itself involve, or denote approval by, the UK Competent Authority. This definition is restricted to the scope of this document, and is not intended to define all systems covered by MCERTS certification.

MCERTS certification for UK Particulate Matter

A candidate particulate matter monitoring method that has achieved all the MCERTS technical requirements, and is also demonstrated as equivalent for use in the UK with its Particulate Matter Pollution Climate for ambient monitoring, by means of additional investigations. This constitutes approval from the UK Competent Authority that the method has been tested satisfactorily for equivalence, and can be used in the UK for undertaking assessment in line with the requirements of Directive 2008/50/EC. Directive 2004/107/EC covers the requirements to monitor certain heavy metals and polycyclic aromatic hydrocarbons using the sample heads that are within the scope of this document, and in certain cases these may be considered as equivalent methods (reference 5 Section 2.6). This MCERTS classification may also be used for other monitoring activities, if required, including those carried out by Local Authorities – where appropriate.

This definition is restricted to and only relevant to the scope of the MCERTS Annex document [Ref.5], and to related reports of the MCERTS certification committee, and the defintion is not intended for other systems covered by MCERTS certification.

MCERTS (Performance) Standard

Standard developed by The Environment Agency of England and Wales to prescribe the performance of monitoring instrumentation, equipment, or personnel, that has to be achieved for MCERTS certification to take place [Ref.3].

Measurement method

A complete description of the total operation of all aspects of the specific equipment, its operating procedures, data collection and storage, and data analysis, initial and on-going

quality control and maintenance, that together make up the method, and that produce specific measurement results of defined quality [Ref.19].

The measurement method comprises: all parts of the hardware (such as the sample head, the analytical equipment, and data processing hardware) and all the software used, all documented procedures for its use, all aspects of the associated control and analysis software, and all other procedures specified for use to enable valid measurement results to be produced.

Particulate Matter Pollution Climate

Characterisation of ambient particulate matter concentrations and certain compositional properties as representative in terms of its concentration range, its geometrical properties, its compositional range at the selected locations, together with selected meteorological conditions (wind speed, atmospheric temperature and ambient humidity) that are also representative.

PM_X

Particulate matter that is suspended in ambient air, and which passes through a size-selective sample inlet with a 50% efficiency cut-off at an aerodynamic diameter of x µm (usually PM_{10} or $PM_{2.5}$).

Pollutant

Any substance present in ambient air and likely to have harmful effects on human health and/or the environment as a whole [Ref.1].

Reference (measurement) method or reference method

European standard method developed by CEN, referred to in Directive 2008/50/EC Annex VI, and/or in Directive 2004/107/EC, and specified in that Directive as the reference method for the measurement of a specific ambient air pollutant. This measurement method produces, by convention, the accepted reference value of the measurand, with only a random uncertainty applicable to that value. (For the case of PM_{10} and $PM_{2.5}$ mass monitoring, these reference methods are specified as manual methods in [Ref.1].)

Regional, national, and local locations (for the equivalence tests)

Types of locations that have a similar PM pollution climate where the Competent Authority may choose to carry out equivalence tests and may install methods that have been deemed equivalent at these locations.

Sampled air

Ambient air that has been sampled through the sampling inlet and sampling system of the measurement method.

Semi-volatile fraction of particulate matter

The fraction of semi-volatile component within a sampled PM_{10} or $PM_{2.5}$ mass measurement result that shall be analysed from a sample obtained by a reference method or a candidate method during the equivalence test programme. (The semi-volatile channel of an automated PM mass analyser will usually indicate this fraction during the tests in the field – requirements for this fraction are given in Reference 5 Section 3.)

Standard uncertainty

Uncertainty of the result of a measurement expressed as a standard deviation [Ref.17].

Test laboratory

Organisation that is capable of carrying out all or part of the laboratory tests and/or the field tests specified in this document; that is contracted by the manufacturer for these; that has the agreement of the MCERTS certification body to perform these; and that is accredited to the EN ISO/IEC 17025 standard (latest published version) for these.

Uncertainty (of measurement)

Parameter, associated with the result of a measurement that characterises the dispersion (variability) of the values that could reasonably be attributed to the measurand [Ref.17].

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Annex 2 Abbreviations used

AQD	Air Quality Directive 2008/50/EC
BV	Bureau Veritas – the organisation that prepared the UK versions of the reports from the TÜV in order that they conform to all the requirements of Ref.5
CAM	Ambient Air Quality Monitoring System (generally means "Continuous" - but this is not restricted to "continuous" in this Document and thus allows certain discontinuous PM samplers to be tested for equivalence)
CEN	European Committee for Standardization [Ref.16]
CM	Candidate method
EC	European Commission
EU	European Union
GDE	EC Guide to the Demonstration of Equivalence of Ambient Air Monitoring Methods, January 2010 [Ref.2]
GM	Geometric mean (of particulate mass concentrations)
MCERTS	The Environment Agency's Monitoring Certification Scheme [Refs.3 & 4]
PM	Particulate matter
RM	Reference method
QA	Quality assurance
QC	Quality control
UKAS	United Kingdom Accreditation Service
VDI/DIN	Verein Deutscher Ingenieure / Deutsches Institut fur Normung e.V [see Refs. 12 & 13]

Annex 3 References

Reference 1: Directive 2008/50/EC of the European Council and Parliament of 21 May 2008 on ambient air quality and cleaner air for Europe, Official Journal of the European Union L152/1, 11.6.2008

Reference 2: Guide to the Demonstration of Equivalence of Ambient Air Monitoring Methods, Report by an EC Working Group on Guidance for the Demonstration of Equivalence, January 2010
http://ec.europa.eu/environment/air/quality/legislation/assessment.htm

Reference 3: MCERTS Performance Standards for Ambient Air Quality Monitoring Systems, Environment Agency, Version 8 June 2012

Reference 4: A Guide to the Certification of Products under the Environment Agency's MCERTS Scheme, Form 1177, July 2006
http://www.siraenvironmental.com/UserDocs/mcerts%20prod%20cert/Form1177.pdf

Reference 5: Annex to the MCERTS Performance Standards for Ambient Air Quality Monitoring Systems: Requirements of the UK Competent Authority for the Equivalence Testing and Certification of Automated Methods and Manual Discontinuous Methods that Monitor Particulate Matter in Ambient Air, Department of the Environment, Food and Rural Affairs, Version 1, July 2012.

Reference 6: Report on the suitability test of the ambient air quality measuring system TEOM 1405-DF Ambient Particulate Monitor with PM_{10} pre-separator and virtual impactor of the company Thermo Fisher Scientific for the components PM_{10} and $PM_{2.5}$
TÜV-Report: 936/21209885/A, Cologne March 11, 2012;

Reference 7: 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;

Reference 8: Report on the suitability test of the ambient air quality measuring system TEOM 1405-F Ambient Particulate Monitor with $PM_{2.5}$ pre-separator of the company Thermo Fisher Scientific for the component $PM_{2.5}$
TÜV-Report: 936/21209885/C, Cologne March 11, 2012;

Reference 9: UK Report on the Equivalence of the PM_{10} and $PM_{2.5}$ TEOM 1405-DF.
Bureau Veritas Report Ref. AGGX5508189/BV/DH/2835 dated 5 June 2013;

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

Bureau Veritas Report ref AGGX5508189/BV/DH/2833 dated 5 June 2013;

Reference 11: UK Report on the Equivalence of the $PM_{2.5}$ TEOM 1405-F.
Bureau Veritas Report ref AGGX5508189/BV/DH/2834 dated 5 June 2013;

Reference 12: Performance criteria for performance tests of automated ambient air measuring systems - Point-related measurement methods for gaseous and particulate air pollutants, Verein Deutscher Ingenieure, VDI RichtLinien VDI 4202-1, September 2010

Reference 13: Testing of automated measuring systems: Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants, Verein Deutscher Ingenieure, VDI RichtLinien VDI 4203 Part 3, 2008

Reference 14: Ambient air quality –Automated continuous measuring systems for the measurement of the concentration of particulate matter (PM_{10}, $PM_{2,5}$), CEN Technical Committee 264 Technical Specification, CEN/TS 16450:2013 .

Reference 15: EC DG Environment website covering "equivalence" – spread-sheet "test the equivalence (xls)"- developed by RIVM the Netherlands;
http://ec.europa.eu/environment/air/quality/legislation/assessment.htm

Reference 16: European Committee for Standardization
http://www.cen.eu/cen/products/en/pages/default.aspx

Reference 17: Guide to the Expression of Uncertainty of Measurement (GUM): International Standardisation Organisation 1993

Reference 18: National Air Quality Reference Laboratories and the European Network – AQUILA: Roles and Requirements for Traceability, Accreditation, Quality Assurance/Quality Control, and Measurement Comparisons, at National and European Levels, December 2009
http://ec.europa.eu/environment/air/quality/legislation/pdf/aquila.pdf

Reference 19: International vocabulary of metrology – basic and general concept and associated terms (international vocabulary of basic and general terms VIM) - Joint Committee for Guides in Metrology, JCGM 200:2008 (E/F)