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BRE Client Report

Testing of a scrubber unit for airborne particle removal in a test room

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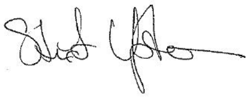
Signature  

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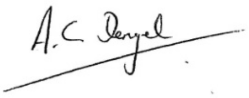
Signature 

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Executive Summary

TCUK Ltd. ("the Client") required BRE to carry out testing of its OptiClean™ 39 10 dual-mode air scrubber (also sold as the CIAT Clean Line™ unit) in recirculation mode, to assess its efficacy in removing airborne particles in the ultrafine range.

The unit is designed for office, hotel, healthcare, education and industry applications, and to operate at an air flow rate of 1000 m^3 hr^{-1}. BRE undertook this testing using a test room facility of volume 190 m^3, with slight positive pressure and the incoming air HEPA-filtered.

Two TSI aerosol generators were used to generate airborne ultra-fine salt (NaCl). These were placed near to where the air was being supplied into the room.

In the first unit test the OptiClean™ (CIAT Clean Line™) unit was located at the centre of the test room. In the second unit test the OptiClean™ (CIAT Clean Line™) unit was located at one of the corners of the test room at the end of the room nearest to the air extraction point (and therefore as far away as possible from the location of the aerosol generators). The second unit test was intended to help demonstrate any potential wider beneficial effect of the unit within a large room.

Two monitoring locations were set up in the test room as follows:

- Location 1: 'upstream' (i.e. between the air supply/particle generators and the central location of the room where the unit was first positioned).
- Location 2: 'downstream' (i.e. between the central location of the room where the unit was positioned for the first test and the air exhaust from the room).

At both monitoring locations the following particle monitoring instruments were set up:

- A TSI P-Trak particle monitor used to measure continuously the level of ultra-fine particles (0.02 - 1.0 µm) as particles per cm^3 of air.
- A TSI DustTrak particle monitor used to measure continuously the level of the PM_1 particle mass-fraction in µg m^{-3}.

The OptiClean™ (CIAT Clean Line™) unit was turned on in recirculation mode and operated throughout all of the tests in order to provide similar amounts of air movement and mixing in the test room.

From the results with the unit operating with its filters in place, the airborne concentrations of particles (both for the ultrafine particles and the PM_1 particle mass-fraction) were generally much lower (by a factor of approximately 3) than in the background test (carried out with the unit's filters removed).

Even with the unit located at the far corner of the room, there was a general, similar reduction in particle concentrations at both measurement locations. With the unit located in the far corner of the test room, slightly lower particle concentrations were measured at sampling Location 1 (compared with those for the unit located at the room centre). These results appear slightly counter-intuitive but could be due to a difference in the airflow patterns (of filtered air) induced in the test room by the unit being placed in a different location relative to the sampling locations.

In the second test, with the unit operating in the corner of the test room, the particle monitoring instruments were left running for a period after the aerosol generators were turned off. As would be expected (with the airflow through the unit's HEPA filters being equivalent to approximately 5 air changes

per hour of the room air), the airborne particle concentrations (both ultrafine and PM_1) decreased very rapidly to very low levels within approximately 30 minutes of the aerosol generators being turned off.

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1 Introduction

TCUK Ltd. ("the Client") required BRE to carry out testing of its OptiCleanTM 39 10 dual-mode air scrubber (also sold as the CIAT Clean Line™ unit) in recirculation mode, to assess its efficacy in removing airborne particles in the ultra-fine range.

The unit is designed for office, hotel, healthcare, education and industry applications, and to operate at an air flow rate of 1000 m^3 hr^{-1}. BRE undertook this testing using a test room facility of volume 190 m^3, with slight positive pressure and the incoming air HEPA-filtered.

2 Description of the project

2.1 Set up of the test room and equipment

The testing was carried out in ‘Room 165’ in BRE’s Building 4.

To meet the requirements of earlier testing projects, the room had been fully lined with vapour-impermeable polythene sheeting, giving the test enclosure internal dimensions of 6.0 x 10.6 x 3.0 metres, and therefore a total volume of approximately 190 m^3. The polythene sheeting was retained in order to render the test room airtight, thus make control of the ventilation rate within the space more practicable.

A mechanical ventilation system was installed temporarily to provide a clean (HEPA filtered) air supply to the room. This was commissioned to provide a controlled air exchange rate (of the order 0.5 air changes per hour (ach)). The room was kept at a slight positive pressure relative to outside in order to minimise any possible adventitious infiltration of air - which is also likely to contain varying and uncontrolled concentrations of ultrafine particles that could otherwise affect the measurements being carried out.

Supply air was taken from the corridor and stairwell outside the test room using an appropriate fan, pre-filtered (HEPA) and ducted through a flange assembly fitted to one of the double doors to the room. The air was distributed as evenly as was practically possible at one end of the room using an ‘airsock’ at floor level. Air was extracted from the other end of the test room in order to provide and maintain a balanced air exchange rate of approximately 0.5 air changes per hour. The extracted air from the test room was discharged to the outside of the building.

Room temperature and humidity level were at ambient levels.

The OptiClean™ (CIAT Clean Line™) unit for testing was provided by the Client and placed on the floor at one of two required locations for the testing, these being the geometric centre of the room, and a corner furthest away from the aerosol production location.

Two TSI aerosol generators were used to generate airborne ultra-fine salt (NaCl). These were placed near to where the air was being supplied into the room.

Two monitoring locations were set up in the test room as follows:

- Location 1: ‘upstream’ (i.e. between the air supply/particle generators and the central location of the room where the unit was first positioned).
- Location 2: ‘downstream’ (i.e. between the central location of the room where the unit was positioned for the first test and the air exhaust from the room).

At both monitoring locations the following particle monitoring instruments were set up:

- A TSI P-Trak particle monitor used to measure continuously the level of ultra-fine particles (0.02 - 1.0 μm) as the number of particles per cm^3 of air.
- A TSI DustTrak particle monitor used to measure continuously the level of the PM_1 particle mass-fraction in $\mu g\ m^{-3}$.

Figures 1 to 3 show the set-up of the test room and equipment.

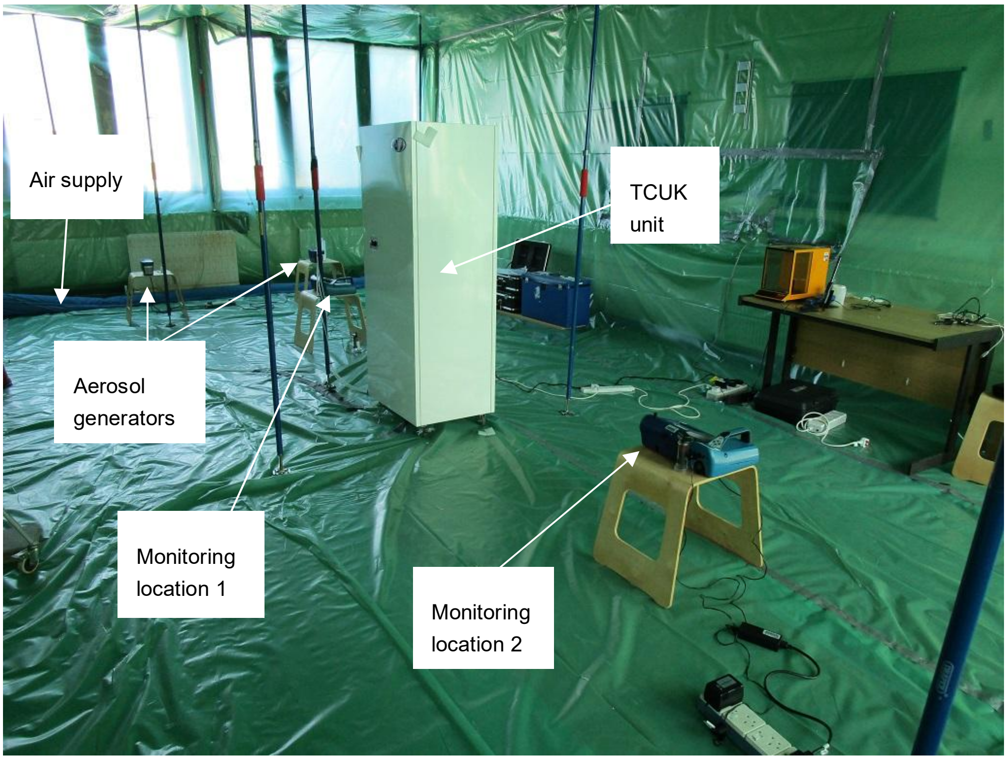

Figure 1: The test room showing the air supply, TCUK unit (central) and instrumentation used.

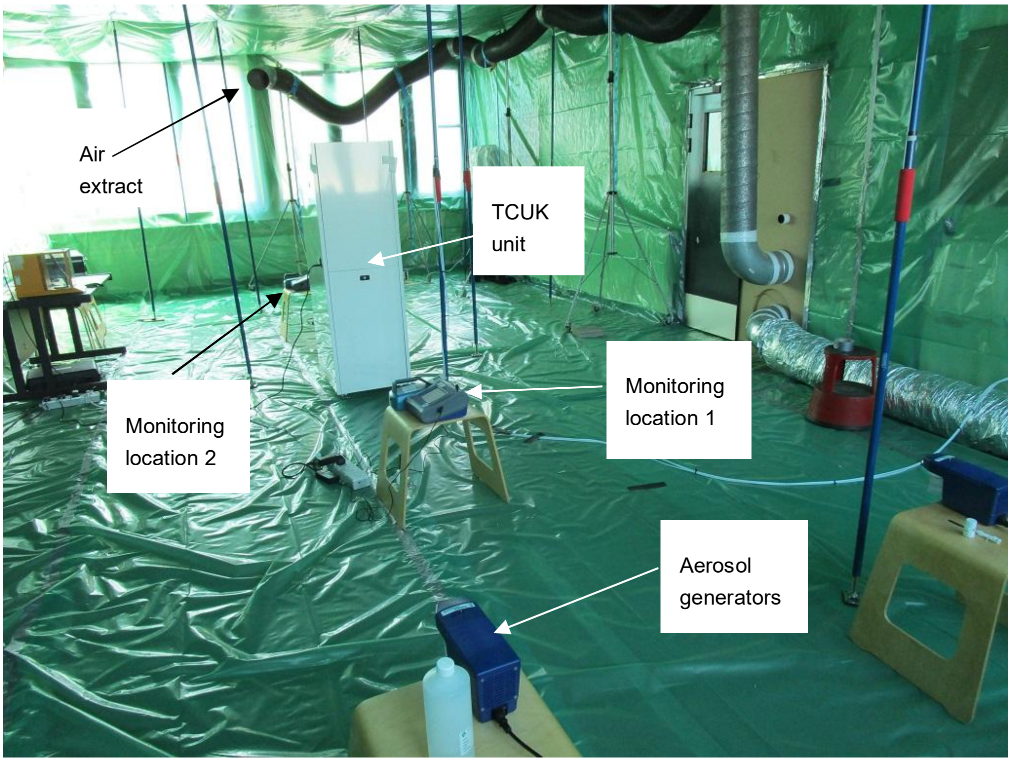

Figure 2: The test room showing the air extract, TCUK unit (central) and instrumentation used.

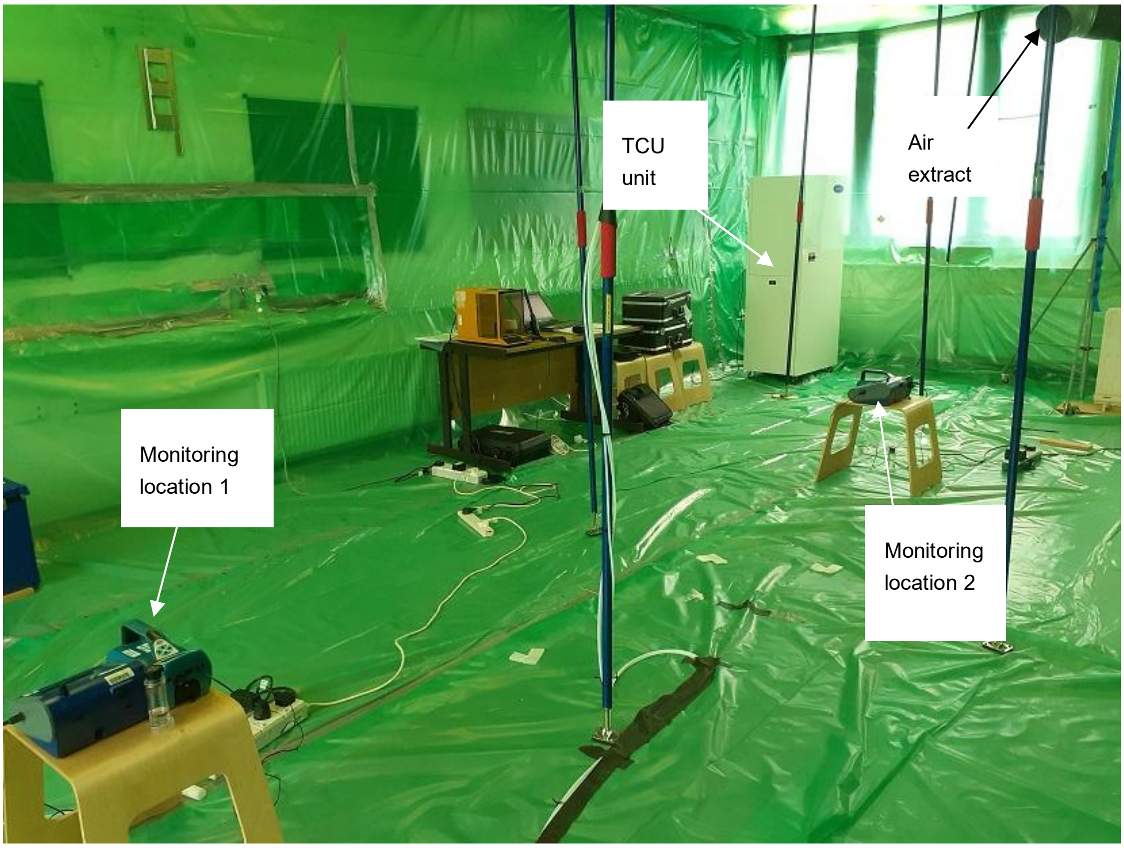

Figure 3: The test room showing the air extract, TCUK unit (corner location) and instrumentation used.

2.2 Air sampling and monitoring methodologies

The following sampling and analytical methodologies were used to monitor the required air parameters/pollutants.

Ultra-fine particles (UFP): UFP concentrations were measured continuously at two locations in the test room using real-time TSI Inc. 'P-Trak' monitors. This instrument type measures the number concentration of particles (in the size range 0.02 to 1µm) in the form of particle number concentration per cubic centimetre of air (# cm^{-3}). One of the P-Trak instruments belongs to BRE and is serviced and calibrated annually by the manufacturer. The second instrument was hired-in specifically for this project.

Particles in the PM_1 particle mass-fraction were also measured continuously at the two monitoring locations. These were measured using TSI Inc. 'DustTrak' monitors and provide data in the form of particle mass concentration as µg m^{-3}. This equipment is serviced and calibrated annually by the manufacturer.

Temperature (T) and Relative Humidity (RH): These parameters were measured continuously near the centre of the test room using a real-time 'Q-Trak' monitor serviced and calibrated annually by the manufacturer.

2.3 Test programme

2.3.1 Background test

The two TSI aerosol generators were deployed in the room and turned on to create airborne ultrafine particles. The OptiClean^{TM} (CIAT Clean Line^{TM}) unit was present in the room and running, but with its filters removed. This was in order to provide, as close as was practically possible, similar air movement/mixing rates in the room as for the subsequent test investigating its effect on airborne particle removal.

2.3.2 Unit tests

The two TSI aerosol generators were deployed in the room near to where air was being supplied and turned on to create an increase in the concentration of airborne ultrafine particles.

The OptiClean^{TM} (CIAT Clean Line^{TM}) unit was turned on in recirculation mode and operated throughout all of the tests in order to provide similar amounts of air movement and mixing in the test room.

In the first unit test the OptiClean^{TM} (CIAT Clean Line^{TM}) unit was located at the centre of the test room (see Figures 1 and 2). In the second unit test the OptiClean^{TM} (CIAT Clean Line^{TM}) unit was located at one of the corners of the test room (see Figure 3) at the end of the room nearest to the air extraction point (and therefore as far away as possible from the location of the aerosol generators). The second unit test was intended to help demonstrate any potential wider beneficial effect of the unit within a large room.

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3 Findings

3.1 Room ventilation rate

The ventilation rate required of approximately 0.5 air changes per hour (ach) was set-up (calculated using the room volume and air volume flow rate of the mechanical ventilation system). This was then measured and confirmed to be 0.5 ach using a tracer-gas decay technique developed by BRE.

3.2 Unit volume flow rate

The volume air flow rate through the OptiClean™ (CIAT Clean Line™) unit was measured using an Airflow Developments balometer of an appropriate volume flow rate operating range. With the flow rate set at the maximum available (as requested by the Client) the measured flow rates were as follows:

- With HEPA filters removed: 1150 $m^3 h^{-1}$.
- With HEPA filters present: 900 $m^3 h^{-1}$.

3.3 Results of particle tests

Graphs of the results of the tests with particles generated in the room are given in Figures 4 and 5 for ultrafine (0.02 to 1 µm) and PM_1 particles respectively. Table 1 contains the approximate equilibrium particle concentrations (for both ultrafine and PM_1 particles) measured during the tests.

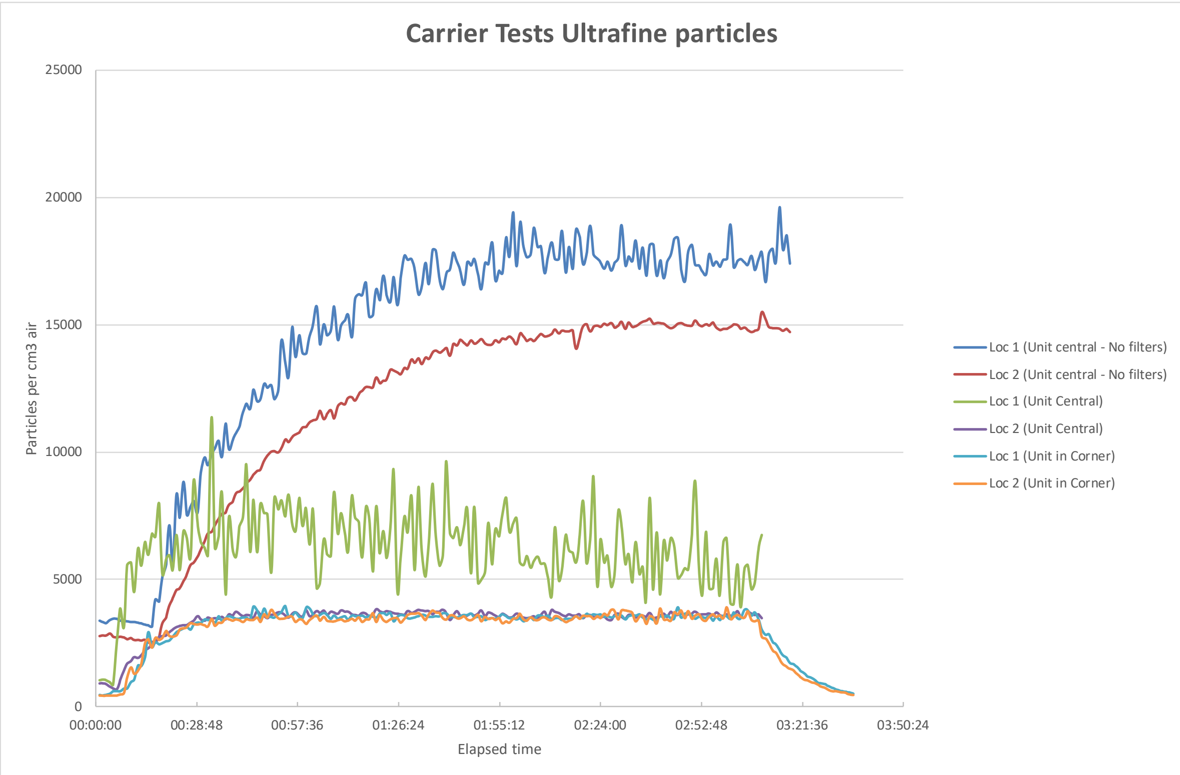

Figure 4: Results: Ultrafine (0.02 to 1 µm) particles.

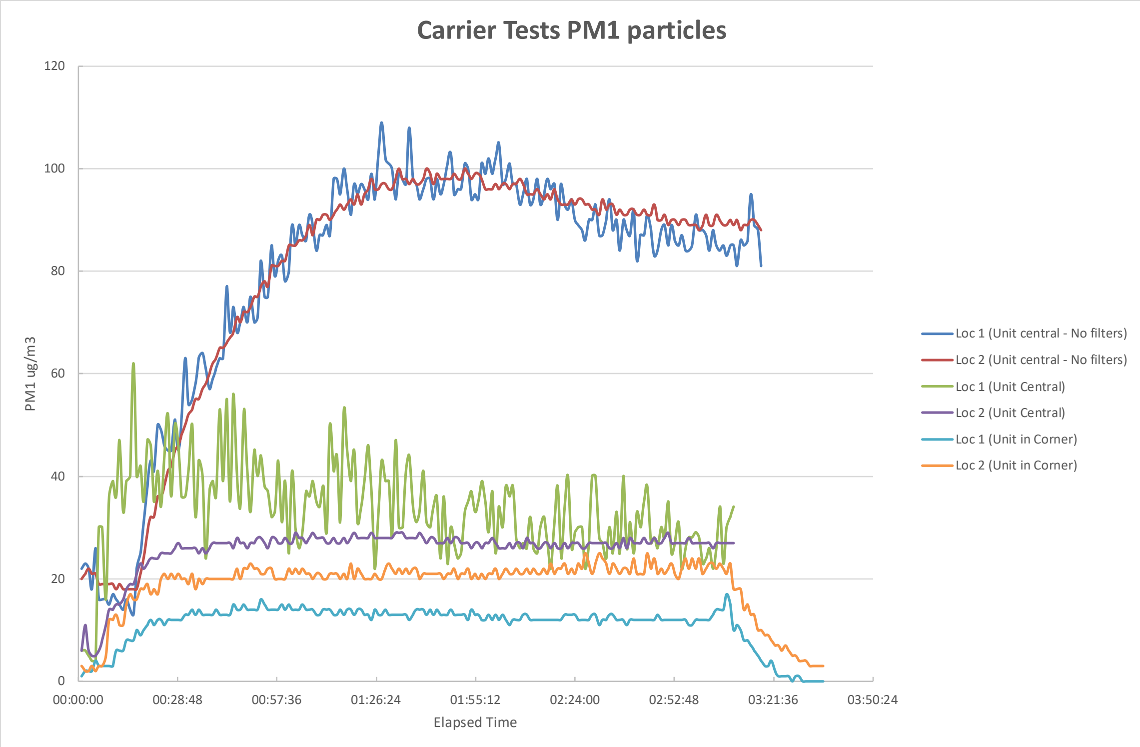

Figure 5: Results: PM_1 particles.

Table 1: Approximate equilibrium particle concentrations during the tests**.**

Test	**Approx. Equilibrium Ultrafine particle conc. (# / cm^3)**		**Approx. Equilibrium PM_1 particle conc. (µg m^{-3})**	
	Location 1 (upstream)	Location 2 (downstream)	Location 1 (upstream)	Location 2 (downstream)
01 (Background)	17,500	15,000	90	90
02 (TCUK unit central)	6,500	3,600	30	25
03 (TCUK unit in corner)	3,600	3,600	15	20

Even with the TCUK unit located at the far corner of the room, there was a general, similar reduction in particle concentrations at both measurement locations. With the unit located in the far corner of the test room, slightly lower particle concentrations were measured at sampling Location 1 (compared with those for the unit located at the rom centre). These appear slightly counter-intuitive but could be due to a difference in the airflow patterns (of filtered air) induced in the test room by the unit being placed in a different location relative to the sampling locations.

In the second test, with the unit operating in the corner of the test room, the particle monitoring instruments were left running for a period after the aerosol generators were turned off. As would be expected (with the airflow through the unit's HEPA filters being equivalent to approximately 5 air changes per hour of the room air), the airborne particle concentrations (both ultrafine and PM_1) decreased very rapidly to very low levels within approximately 30 minutes of the aerosol generators being turned off.

3.4 Temperature and Relative Humidity

For completeness, mean values for the temperature, Relative Humidity (RH) and carbon dioxide (CO_2) concentration are given in Table 2.

Table 2: Mean temperature, Relative Humidity (RH) and CO_2 during the particle tests (190 m^3 room)**.**

Test	Mean temperature (ºC)	Mean Relative Humidity (%)	Mean CO_2 conc. (ppm)
01 (Background)	23.8	54.9	638
02 (TCUK unit central)	24.4	58.0	492
03 (TCUK unit in corner)	26.0	54.8	519

4 References

Department of the Environment, Food and Rural Affairs. The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. Volumes 1 & 2. Defra, July 2007. PB 12654 & PB 12670. Available at: http://archive.defra.gov.uk/environment/quality/air/airquality/strategy/documents/

EN 60335-2-65:2003 'Household and similar electrical appliances - Safety - Part 2-65: Particular requirements for air-cleaning appliances, Section 32 (Radiation, toxicity and similar hazards).

Health and Safety Executive (HSE). EH40/2005. Workplace Exposure Limits (Fourth Edition), 2020. Available at: https://www.hse.gov.uk/pubns/books/eh40.htm

Ministry of Housing, Communities and Local Government (MHCLG). Approved Document F (2010 edition incorporating 2010 and 2013 amendments). Available at: https://www.gov.uk/government/publications/ventilation-approved-document-f

Upton S and Kukadia V. (2011). Ventilation rate measurement: New tracer gases and techniques for healthy indoor environments. BRE Information Paper IP 13/11. BRE, Garston, Watford, Herts, UK, WD25 9XX. October 2011. ISBN 978-1-84806-219-1.

World Health Organization. WHO Air Quality Guidelines for Europe. 2nd Edition, WHO Regional Publications, European Series No. 81, Copenhagen, Denmark, 2000. Available from: http://www.who.int/peh/

World Health Organization. WHO air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulphur dioxide; Global update 2005, Summary of risk assessment, 2010.

Appendix A Air Quality Standards and Guidelines

Guidelines and standards for airborne particles

For the general population, the EU Ambient Air Quality Directive and current UK Air Quality Standard for the PM_{10} particle mass-fraction is 50 µg m^{-3} (24-hour mean concentration).

For $PM_{2.5}$ the Ambient Air Quality Directive has the following target and limit values:

- A Target Value of 25 µg m^{-3} by 2010.
- A Limit Value of 25 µg m^{-3} by 2015 and 20 µg m^{-3} by 2020 (to be reviewed in 2013).

There are currently no health-related air quality standards for the PM_1 mass fraction.

It should be noted that the measurements reported here are 1-minute averages, compared with the 24-hour and 8-hour averages required by the EU Directives and HSE WELs respectively.

(a) General populace and the environment

Reference	Exposure criteria	PM_{10}	$PM_{2.5}$	PM_1
World Health Organization (WHO)	Annual mean	20 µg m^{-3}	10 µg m^{-3}	-
	24-hour mean	50 µg m^{-3}	25 µg m^{-3}	-
EU Ambient Air Quality Directive and current UK Air Quality Standard	24-hour mean	50 µg m^{-3}	-	-

(b) Workplace Exposure limits

Reference	Exposure criteria	Size FractionPM_{10}	Limit concentration (µg m^{-3})
UK Health and Safety Executive (Workplace Exposure Limits)	8-hour mean	Inhalable	10,000
	8-hour mean	Respirable	4,000

Report Ends