Filter leak testing with an LSAPC

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This article is the third of a short series of extracts from Bill Whyte's new book *Cleanroom Testing and Monitoring.* Annex D, Filter leak testing with an LSAPC, is reproduced here with the kind permission of the author, Bill Whyte, the publisher, Euromed Communications, and the owner of the copyright, the Cleanroom Testing and Certification Board – International (CTCB-I)*. The objective in publishing these extracts is to give readers a flavour of the content and depth of the book which is recommended as a comprehensive textbook and an essential reference for cleanroom managers, cleanroom test engineers, cleanroom service engineers, cleanroom designers and specifiers and anybody who is concerned with cleanrooms. High efficiency filters are normally tested by the photometer method given in ISO 14644-3: 2019 and described in Chapter 8 of the book (as reproduced in CACR47). The LSAPC method, also given in ISO 14644-3: 2019 can be difficult to understand. Partly because of this, and partly because of the additional steps that are required, the method is not used, or is used incorrectly. Annex D was written with the object of giving a clearer and shorter explanation, to make the method less difficult to use.

Editor

Annex D: Filter leak testing with an LSAPC

High efficiency filters are tested during manufacturing to ensure that they have the correct overall particle removal efficiency and contain no leaks that are considered excessive for the class of filter being manufactured. This is carried out according to the methods given in ISO 29463 [Ref 1] or EN 1822 [Ref 2] and these methods have been discussed in Chapter 3. After testing, the filters are dispatched to the cleanroom for installation.

To verify that no leaks have occurred during transportation, or installation, the high efficiency filters are tested. This test is carried out by releasing test particles in the air approaching the filter and scanning the cleanroom side of the filter's media, frame, gasket, and housing to locate any leaks that might allow unfiltered air to enter the cleanroom. High efficiency filter installations are also tested in the same way over their lifetime to ensure that no leaks develop.

Leaks in high efficiency air filter installations can be found by a photometer using the method described in Chapter 8. The filter system is challenged with a test aerosol generated from one of the liquids described in Chapter 8. The filters are tested with the ventilation system running and liquid test particles can deposit onto filters and air supply ducts, and 'outgas' into the cleanroom for some time after production starts. This may cause contamination problems in semiconductor and similar types of manufacturing. To avoid this problem, inert particles, such as polystyrene latex spheres (PLSs) are used to challenge the filter, and leaks are found by a light-scattering airborne particle counter (LSAPC), in place of a photometer. However, the LSAPC method can also be used with the same test aerosols as used with the photometer, if contamination is not a problem.

D.1 Overview of the LSAPC method of locating filter system leaks

The LSAPC method for locating leaks in high efficiency filter systems is described in ISO 14644-3: 2019. It was first described by Bruce McDonald [ref 38]. His method was adopted into the IEST Recommended Practice 34 [ref 6] and was progressively modified to be used in ISO 14644-3: 2005 and then in ISO 14644-3: 2019 [ref 9].

The LSAPC method is carried out in two stages. In the first stage, the filter system is scanned with a probe connected to an LSAPC to seek and locate potential leaks. In the second stage, potential leaks are further investigated by holding the probe stationary over the leak; the number of particles coming from the potential leak is counted over a specified time and, if the number is greater than a predetermined number, it is classed as an actual leak.

Stage 1 – Scanning the filter:
To find a potential leak in a filter installation by the LSAPC method, a known concentration of test particles is introduced into the air approaching the filter, and the filter face is scanned by a probe attached to an LSAPC (see **Figure D1**). The scanning method is the same as used in the photometer method explained in Chapter 8 and that chapter should be consulted for information. Potential leaks are detected by LSAPCs if the particle count exceeds a number that is discussed later in this chapter.

Figure D1: A probe scanning over a filter face to locate a leak

Stage 2 – Stationary measurement: The second stage of the test method is used to confirm that a potential leak found by scanning is an actual leak. This requires the probe to be kept stationary over the potential leak for a specified time. If the particle count is greater than a number that is calculated by a method discussed later in this annex, the leak is confirmed as an actual leak.

To find a leak in a filter installation, the following variables must be considered.

a. The air volume sampling rate of the LSAPC,

b. The dimensions of the sampling probe,

c. The scanning velocity of the probe over the filter face,

d. The particle penetration of a filter which, when exceeded, is considered a leak,

e. The type of aerosol test challenge,

f. The number of test particles measured by an LSAPC that indicate a leak.

D.2 Values of variables needed for calculations

Information about the variables listed above, and their values used in calculations, are now discussed.

(a) Air volume sampling rate of the LASPC (*Q_{VS}*)
A typical air volume sampling rate of an LSAPC is 28.3 L/min (0.000472m^3/s), and this is the standard rate suggested by ISO 14644-3: 2019. It is also suggested that the LSAPC should count particles ≥0.3µm.

(b) Probe dimension (*D_P*)
The probe used to scan a filter and to carry out stationary measurements should have the correct dimensions to ensure that the air sample will closely reflect the particle concentration coming from the leak. A good sample is obtained if the air velocity into the probe is the same as the air velocity passing outside the probe i.e. the face velocity of the filter. This type of sampling is known as iso-kinetic sampling and is discussed in more detail in Annex G. In practical situations, it is unlikely that these two velocities will exactly match, and ISO 14644-3: 2019 allows the intake velocity of the probe to be within +/- 20% of the filter face velocity.

ISO 14644-3: 2019 recommends two standard sizes of probe. These are as follows:

Rectangular probe: This probe is often called a ‘fish tail’ probe and is the type shown in **Figure D1**. It has an inlet opening of 8cm x 1cm and its dimension in the direction of scanning *(D_P)* is 1cm. The surface area of the intake is 8cm^2 (0.0008m^2) and the probe’s intake velocity, when used with a LASPC that samples 28.3 L/min (0.000472m^3/s), can be calculated as follows:

$$\text{Intake velocity of probe (m/s)} =$$

$$\frac{\text{sampling rate (m}^3\text{/s)}}{\text{intake area (m}^2\text{)}} =$$

$$\frac{0.000472(\text{m}^3/\text{s})}{0.0008(\text{m}^2)} = 0.59\ \text{m/s}$$

This rectangular type of probe will, therefore, provide the best sampling conditions when the face velocity of the filter is 0.59 m/s. However, a variation in velocity of +/- 20% is acceptable and it can, therefore, be used with a range of velocities of between 0.47m/s and 0.71m/s.

Circular probe: This probe has a diameter of 3.6cm. However, the nominal dimension in the direction of the scan *(D_P)* is not the same as its diameter but, as calculated in ISO 14644-3: 2019, it is 2.54cm. For a sampling rate of 28.3L/min (0.000472m^3/s), the inlet velocity of the probe is 0.46m/s and the range of velocities that it can accommodate is between 0.37m/s and 0.55m/s.

A large proportion of high efficiency filters are manufactured to operate with a face velocity of 0.45m/s and the two standard probes are satisfactory. However, some high efficiency filters are manufactured to operate at higher face velocities and, therefore, to obtain the correct isokinetic conditions for filters with a face velocity greater that 1m/s, a probe with a smaller intake and higher air velocity should be used.

(c) The scanning rate of the probe (*S_R*)
The filter installation should be scanned with a probe held approximately 3cm from the filter face and using overlapping passes. It is necessary to scan over the filter installation at the correct velocity. If it is scanned too fast, a leak may be missed and, therefore, the correct scanning rate should not be exceeded. If the probe moves too slowly over an insignificant leak, additional particles may be sampled and a leak thought to exist. However, in the latter case, the erroneous leak will not be confirmed when stationary measurement is carried out, although this will be an unnecessary waste of time.

ISO 14644-3; 2019 recommends a standard scanning rate (*S_R*) of 5cm/s for the 1cm x 8cm rectangular probe and 12cm/s for the 3.6cm diameter circular probe. However, it is not always possible to achieve the correct concentration of particle challenge that matches these scanning rates, and it may be necessary to adopt a different scanning rate.

(d) What particle penetration of a filter is considered a filter leak (*P_L*)?
The photometer method of testing leaks in filters has been discussed in Chapter 8 of this book, and the chapter reports what ISO 14644-3: 2019 considers a leak. The same information applies to a leak test carried out with an LSAPC.

It is considered in ISO 14644-3: 2019 that a leak exists for most types of filters if there is a location in the filter installation where the penetration *(P_L)* is more than 0.01% of the particle challenge. However, if the overall removal efficiency of the filter is between ≥99.95% and <99.995% (as it is for an EN H13 filter or an ISO 35H filter), there is considered to be a leak when the penetration is greater than 0.1%. When the overall removal efficiency of a filter is less than 99.95%, the penetration that is considered a leak should be agreed between customer and supplier.

(e) What type of aerosol test challenge should be used?
The photometer method of filter leak detection uses a test challenge of aerosols generated from liquids discussed in Chapter 8. However, the particles in the aerosols can deposit on surfaces, and then ‘outgas’ into the supply air during manufacturing, and cause contamination. Aerosols of solid inert particles are used to overcome this problem. In a cleanroom, which is not sensitive to this type of contamination, the same type of aerosol can be used with the LSAPC method as for photometer method.

In some cleanrooms, such as those used in semiconductor manufacturing, solid inert test particles are specified for leak testing and are, typically, Polystyrene Latex Spheres (PLSs). These are shown in **Figure D2** and **Figure D3**. They are available as suspensions of homogeneous spherical particles of various sizes, but 0.3µm particles are used for filter leak testing. The suspensions are diluted in clean water, nebulized by a generator such as a Laskin nozzle, and introduced into the air approaching the filter system.

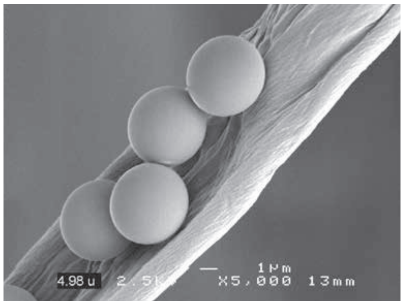

Figure D2: Electron microscope image of PLS test particles deposited on a fibre

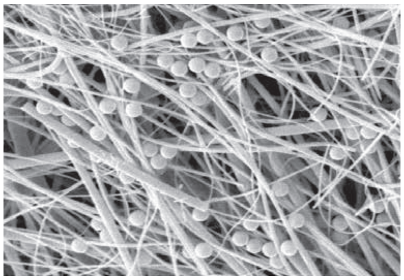

Figure D3: PLS deposited on filter media

(f) How many particles need to be counted by the LSAPC during scanning to indicate a leak?

When scanning a filter, the number of airborne particles that have to be registered by an LSAPC to indicate a potential leak has to be selected. This count is known in ISO 14644-3: 2019 as the 'acceptable' count, and given the symbol N_A. This number should be kept low, or the calculation of the concentration of the challenge aerosol can result in a concentration that is high and difficult to achieve.

In a situation where the undamaged filter is known to remove all the challenge particles and the LSAPC does not record spurious counts in particle-free air, the acceptable count can be taken as zero and any count greater than zero used to indicate a potential leak.

If the LSAPC gives an occasional spurious count from particle-free air, or an occasional particle passes through undamaged filter media, then an acceptable count of 1 may be the best choice to indicate a potential leak. In this situation, any count of 2, or greater, is considered a leak. However, if the background count is higher, a higher count will be required to indicate a potential leak.

When measuring airborne particles coming from a leak, it will be found that the counts have a natural variation around an average value, and this variation conforms reasonably well to the Poisson statistical distribution. When a filter is scanned, an occasional low count may be encountered that is unlikely to be lower than the 95% lower confidence limit (LCL) of the distribution. The 95% LCL count is considered in ISO 14644-3: 2019 to be the 'acceptable count' and given the symbol 'N_A'.

The average count (N_P) of the count distribution is considered in ISO 14644-3: 2019 to characterise the designated leak, and is the value used in the calculation of the required challenge concentration or, if required, the scanning rate. In a Poisson statistical distribution, the average count of the distribution (N_P) can be calculated from knowledge of the acceptable count (95% LCL) and use of *Equation D1*.

Equation D1

$$N_P = (N_A + 2) + 2\sqrt{1 + N_A}$$

Average values of the count distribution (N_P) that correspond to N_A are given in **Table D1**. It should be noted that the values N_A of 0 and 1, which are the preferred values, have corresponding values of N_P of 4 and 5.8, respectively, and these are the values that are used in the calculations. However, if higher values of N_A are encountered because of high background counts, the corresponding values of N_P that can be used in the calculations can be obtained from **Table D1**.

D.3 Summary of standard values

Information in the previous section gives the standard values of the variables that ISO 14644-3: 2019 suggests for use with the LSAPC method of leak testing. These are summarised as follows:

a. Q_{VS} is the sampling rate of an LSAPC of 28.3L/min (0.000472m^3/s).

b. D_P is the dimension of the probe's intake in the direction of the scan. A standard rectangular probe has a rectangular inlet of 1cm x 8cm, and the dimension in the direction of the scan (D_P) is 1cm. A standard circular probe has a diameter of 3.6cm, and the dimension in the direction of scan (D_P) is 2.54cm.

c. S_R is the scanning velocity of 5cm/s that is used for a 8cm x 1cm rectangular probe, and 12cm/s is required for a 3.6cm circular probe.

d. P_L is the proportion of particles that passes through the filter and, when exceeded, is considered a leak. A proportion of 0.0001 (0.01%) is used as the standard value but exceptions are applied to low efficiency filters.

e. N_A is the acceptable number of particles that is considered to show a potential leak when a filter installation is scanned, and the preferred values are 0 or 1. The corresponding average values of N_P that are used to calculate

Table D1. Average values (N_P) of the Poisson distribution

Acceptable particle count from a leak (N_A) – 95% LCL	Average count of distribution (N_P)
0	4.0
1	5.8
2	7.5
3	9.0
4	10.5
5	11.9
6	13.3
7	14.7
8	16.0
9	17.3
10	18.6

the particle challenge, or scanning rate, are 4 and 5.8, respectively.

Although it is best to use the standard values in the list, non-standard values may be required when locating leaks. The calculations carried out with standard and non-standard values in the two stages of the LSAPC test method are now discussed.

D.4 Stage 1: Calculation of particle challenge concentration or scanning velocity

A common approach to locating leaks in filter installations by means of an LSAPC is to start by calculating the concentration of test particles needed to challenge the filter installation. This should, preferably, be carried out using the standard values given in the previous section but it may be necessary to modify one, or more, of the standard values.

When setting up the required particle concentration it may not be possible to achieve the correct airborne particle concentration. In this situation, the standard scanning velocity of 5cm/s may have to be modified to correspond with the concentration that can be achieved. How the particle challenge concentration and scanning velocity are calculated is now described.

Calculation of test challenge concentration:

The variables needed to calculate the test challenge concentration have been previously discussed and shown in Figure D4.

The concentration of airborne particles used to challenge a filter is calculated as follows:

Equation D2

$$C_C = \frac{N_P \times S_R}{Q_{VS} \times D_P \times P_L}$$

Where,

C_C = concentration of airborne particles ≥0.3µm used to challenge the filter (number/m^3);

N_P = average count of particles that characterise a leak.

S_R = scanning rate of the probe over the filter surface (cm/s);

Q_{VS} = air sampling rate of the LSAPC (m^3/s);

D_P = probe dimension in direction of scanning (cm);

P_L = penetration of the challenge particles ≥0.3µm through the filter that is considered a leak. This is given as a proportion e.g. 0.0001, and not a percentage (0.01%).

It should be noted that centimetres are used in both the numerator and denominator of the equation for dimensions associated with the probe.

If the standard values listed in the previous section are used, including a P_L value of 0.0001 and a D_P value of 1cm, the following result is obtained.

$$C_C = \frac{N_P \times S_R}{Q_{VS} \times D_P \times P_L} = \frac{N_P \times 5}{0.000472 \times 1 \times 0.0001} = N_P \times 105{,}932{,}203/m^3$$

If this result is rounded up, the following equation may be useful during testing,

$$C_C = N_P \times 106{,}000{,}000/m^3$$

The above calculation uses recommended standard values, but should any variation from the standard values be required, *Equation D2* can be used to calculate the corrected concentration. In these non-standard situations, a spreadsheet is useful, or an LSAPC with suitable computational abilities.

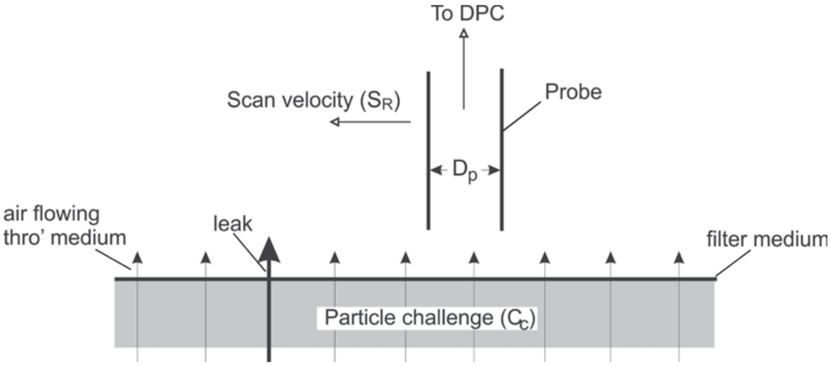

Figure D4: Diagram of probe scanning over a filter surface

If the recommended standard values of N_P are entered into the *Equation D2*, the rounded values of the challenge concentrations are shown in **Table D2**.

It can be seen from the results in **Table D2** that the required particle challenge concentrations are high, and it may be necessary to use a diluter to avoid coincidence losses in the LSAPC. Coincidence losses and diluters are discussed in Chapter 10.

Table D2. Particle challenge concentration required for standard values of N_P

N_A	N_P	Challenge test concentration/m^3
0	4	424,000,000
1	5.8	614,000,000

Calculation of scanning velocity

The method described in the previous section is used to set the particle challenge concentration for the standard values suggested by ISO 14644-3: 2019. However, it may be found that it is difficult, if not impossible, to establish the required particle concentration. It may, therefore, be necessary to employ a different challenge concentration and modify the scanning velocity. The modified scanning velocity can be calculated by use of *Equation D3*.

Equation D3

$$S_C(\text{cm/s}) = \frac{C_C \times P_L \times Q_{VS} \times D_P}{N_P}$$

Where, D_P is 1cm for the fish tail probe, and 2.54cm for the circular probe.

Again, a spreadsheet, or an LSAPC with suitable computational abilities, is useful to carry out the calculation.

D.5 Stage 2: Confirmation of a leak by stationary measurement

It has been previously explained that the method of determining leaks is divided into two stages, namely:

Stage 1: The filter system is scanned to locate potential leaks, and,

Stage 2: The potential leaks are confirmed as actual leaks by stationary measurement.

The presence of an actual leak is confirmed by holding the probe over the potential leak (**Figure D5**) and obtaining, in a specified time, a particle count that is greater than the count calculated for the circumstances of the testing. It is suggested in ISO 14644-3:2019 that the

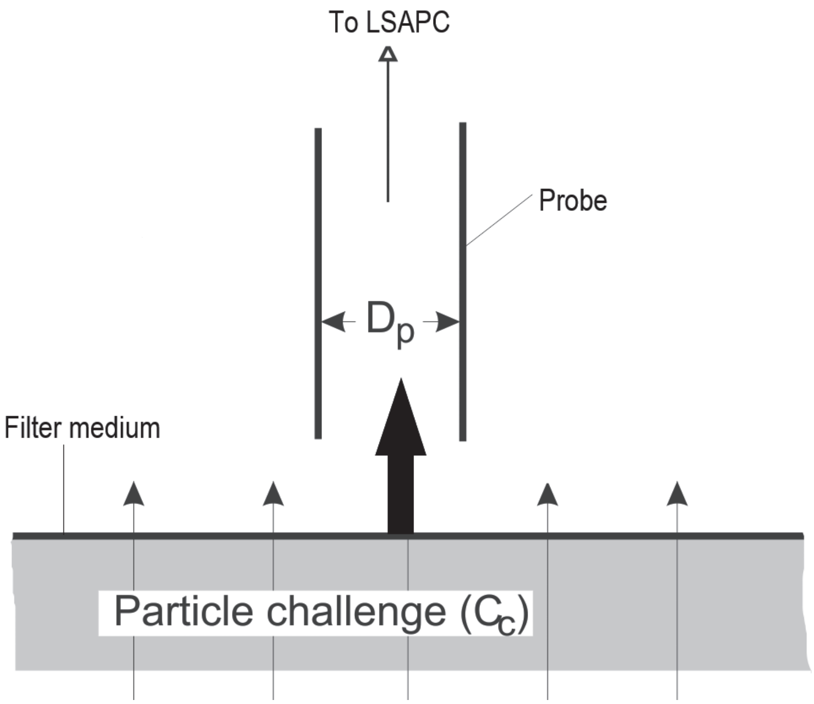

Figure D5: Diagram showing a probe stationary over a filter surface

standard time the probe is held over the leak (T_R) should be 10 seconds.

The number of particles needed to confirm that a potential leak (found by scanning) is an actual leak is calculated in two steps. Firstly, the average number of particles that will characterise the leak (N_{PR}) is calculated by *Equation D4.*

Equation D4

$$N_{PR} = C_C \times P_L \times Q_{VS} \times T_R$$

Where,

C_C = concentration of airborne particles ≥0.3µm used to challenge the filter (number/m^3);

P_L = penetration of the challenge particles through the filter that is considered a leak. This is given as a proportion e.g. 0.0001, and not a percentage (0.01%).

Q_{VS} = air volume sampling rate of the LSAPC (m^3/s);

T_R = residence time the probe should be held over a potential leak (10s).

The counts obtained from a leak will vary over time, and it can be assumed that they are distributed in a way that can be predicted by the Poisson statistical distribution. The value of N_{PR} is considered to be the average value of the count from the leak, and the minimum count that might be encountered during the stationary measurement is known as the 'acceptable count' (N_{AR}). N_{AR} is the minimum count that confirms a leak and is given by the 95% lower confidence limit (LCL). Assuming a Poisson distribution, it can be calculated as follows.

Equation D5

$$N_{AR} = N_{PR} - 2\sqrt{N_{PR}}$$

If, for example, N_{PR} had been calculated by *Equation D4* to be 100, the 95% lower confidence limit, which is the acceptable count (N_{AR}), is calculated by *Equation D5* and is found to be 80. If the count measured during a residence time of 10s is greater than 80, the presence of an actual leak is confirmed.

D.6 Practical example of how to find a leak in a filter installation

An example is considered of a high efficiency filter that has to be leak tested by the LSAPC method and is an EN 1822 Type H14 (ISO 45H), with an overall removal efficiency of ≥99.995%. To locate leaks, the following steps should be carried out.

Step 1: Before starting the test, it is necessary to establish the following requirements:

a. The filter to be tested is supplied with the correct air supply volume and, therefore, has the correct filter face velocity.

b. The choice of test aerosol. If it is the same as used in the photometer method, then Chapter 8 should be consulted for relevant information. If inert solid particles are required, Section D2 of this annex should be consulted.

c. The following standard values are chosen for the LSAPC and its probe:

  - The sampling rate (Q_{VS}) of the LSAPC is 28.3 l/min i.e. 0.000472m^3/s.
  - A 'fish tail' probe is selected with an intake of 8cm × 1cm, and the dimension in the direction of scanning (D_P) is 1cm.
  - The scanning rate of the probe (S_R) is 5cm/s.

Step 2: The 'acceptable' number of particles (N_A) that indicates a potential leak when scanning has to be decided. To ensure the required aerosol challenge concentration is not excessive, the acceptable count would preferably be either 0 or 1. It is known from a preliminary scan of the filter that an occasional particle is counted. Therefore, the acceptable count that is chosen is 1. A potential leak will therefore be indicated by a count of 2, or greater.

Step 3: Knowing the acceptable count (N_A) is 1, the N_P value is obtained, which is the value used in the calculations. This is obtained from **Table D1** and is 5.8.

Step 4: The penetration of a filter by the challenge particles (P_L) that is considered to be a leak is required. For the type of filter being tested, the leak should be greater than a proportion of 0.0001 (0.01%).

Step 5: The particle challenge concentration required for the scanning test can now be calculated by use of *Equation D2.*

$$C_C = \frac{N_P \times S_R}{Q_{VS} \times D_P \times P_L} = \frac{5.8 \times 5}{.0.000472 \times 1 \times 0.001} =$$

$$6.1 \times 10^8/m^3$$

It should be noted that this is the same value as given in **Table D2**.

Inspection of the literature of the manufacturer of the LSAPC shows that this particle concentration is greater than the particle counter's coincidence level of 1 x 10^7/m^3. Therefore, a diluter should be used to obtain an accurate measure of the challenge concentration. Diluters are discussed in Chapter 10.

Step 6: The test aerosol is introduced before the filter to obtain a constant concentration that is very close to 6.1 x $10^8/m^3$. The location where it is introduced should be chosen to assist in the mixing of the aerosol, and to obtain an even concentration across the back of the filter. The evenness of the challenge concentration should be confirmed, as should the consistency of concentration over the time of testing.

Step 7: The filter gasket, frame, and filter media should be scanned at a rate of 5cm/s. The method of scanning has been discussed in Chapter 8, and this method should be applied.

Step 8: The value of the acceptable leak that has been chosen is 1 and, therefore, the number of particles that must be registered by the LSAPC to show a potential leak is 2, or greater. If this occurs, then the exact location of the leak should be determined. This can be found by turning the fish tail probe though 90 degrees and scanning back and forwards over the location to exactly locate the leak. A small piece of masking tape can then be used to mark where the leak is located.

Step 9: To confirm that a potential leak found by scanning is an actual leak, a stationary test must be carried out. This is carried out by holding the same probe over the potential leak for a standard time of 10 seconds. The average number of particles that characterise a leak (N_{PR}) and must be exceeded in 10s is calculated by *Equation D4*, and is as follows:

$$N_{PR} = C_C \times P_L \times Q_{VS} \times T_R = 6.1 \times 10^8 * 0.0001 * 0.00047 * 10 = 287$$

$$N_{PR} = C_C \times P_L \times Q_{VS} \times T_R = 6.1 \times 10^8 * 0.001 * 10 = 287$$

However, the counts of airborne particles coming through the leak will vary and, to take this variation into account, *Equation D5* is used to calculate the lowest acceptable count (N_{AR}) that confirms a leak.

$$N_{AR} = N_{PR} - 2\sqrt{N_{PR}} = 287 - 2\sqrt{287} = 287 - 34 = 253$$

The actual result obtained during the test by counting the particles for 10s was 285. This count was higher that the lowest acceptable count of 253 and the leak confirmed as an actual leak. It should be noted that it may be unnecessary to sample for the full 10s, but only as long as it is necessary to show that the lowest acceptable count (N_{AR}) has been exceeded.

References (numbered as at the end of the book)

1. ISO 29463-1: 2017. High efficiency filters and filter media for removing particles from air. Classification, performance, testing and marking. International Organization for Standardization, Geneva. Switzerland.

2. EN 1822-1: 2019. High efficiency air filters (EPA, HEPA and ULPA). Classification, performance testing, marking. CEN European Committee for Standards, Brussel, Belgium.

38. McDonald B (1993). Scanning high-efficiency air filters for leaks using particle counting methods. *Journal of the Institute Environmental Sciences*, **36(5)**, 28-37.

6. IEST RP-CC 0034 HEPA and ULPA filter leak tests. Institute of Environmental Science and Technology, Schaumburg, USA.

9. ISO 14644-3: 2019 – Part 3: Test methods. International Organization for Standardization, Geneva, Switzerland.

Acknowledgement

The images in **Figures D2** and **D3** were obtained from Duke Scientific, a division of Thermo Fisher Scientific.

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He was founder and former chair of both the Scottish Society of Contamination Control and the Cleanroom Testing and Certification Board – International. He is a member of BSI and ISO working groups that are writing, or have written, cleanroom standards. He has extensive experience as an industrial consultant and presenter of educational courses about cleanrooms.

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