PERFORMANCE TESTING OF HEPA FILTERS: PROGRESS TOWARDS A EUROPEAN STANDARD PROCEDURE

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SUMMARY

Proposals for a future European testing procedure for "High Efficiency Particulate Air Filters (HEPA and ULPA)" are being developed by CEN (Comité Européen de Normalisation). The new standard will be given the status of national standard in participating countries, conflicting national standards being withdrawn.

The standard will comprise 5 parts covering the grouping and classification of HEPA and ULPA filters according to their efficiency, fundamental principles of testing, marking etc (in part 1). Part 2 will cover aerosol production, measurement principles, counting equipment and statistics. Parts 3-5 will cover testing flat sheet media, leak testing of filter elements and the efficiency testing of filter elements respectively.

The efficiency test methods allow the use of either homogeneous monodisperse or polydisperse aerosols for the determination of particulate filtration efficiencies as a function of particle size. The particle size at which maximum penetration occurs is first determined in flat sheet media tests; tests on filter elements (constructed using the same filter medium) may be carried out using either a homogeneous monodisperse aerosol of the size at which maximum penetration occurs (MPPS) or a polydisperse aerosol whose median size is close to the MPPS. Tests with monodisperse aerosols may be conducted using condensation nucleus counting equipment; tests using polydisperse test aerosols require the use of optical sizing particle counters.

When determining the efficiency of filter elements the downstream aerosol concentrations may be determined from air samples obtained using either an overall method (single point sampling after mixing) or a scan method. The scan method also allows "local" efficiency values to be determined.

INTRODUCTION

The standardization body involved is the Comité Européen de Normalisation, (CEN) which has its headquarters in Brussels.

Technical committees of CEN comprise delegations from European national standardization bodies(Figure 1) including British Standards Institute (BSI) for the UK, AFNOR (France) and DIN (Germany). Technical committees usually appoint working groups from individual experts nominated by the national bodies. The drafting process consists of a number of stages after production of the initial draft. Separate opportunities are given for changes to be proposed by individual experts, by national standardization bodies and by the general public in all participating countries before the final voting process.

REQUIREMENT FOR NEW STANDARD

Requirements for a future European test standard were initially compared with/against the characteristics of existing standard methods, both the national standards eg BS 3928, AFNOR X44011, DIN 24184 etc, as well as relevant trade association standards such as Eurovent 4/5.

Filtration performance testing requirements continue to advance as the technology of micro miniature electronic devices advances; by and large the nuclear industry filtration efficiency requirements are not subject to the same upward pressure; the availability of the improved performance potential of ULPA filters could in some circumstances be beneficial.

It was concluded that the existing standard methods did not provide an adequate technical basis to meet these requirements. Deficiencies in existing procedures were in the following areas:-

(a) the need to adopt a generally acceptable continuous classification system for HEPA and ULPA filters.

(b) the need for a test method capable of covering the whole range of efficiency from 85% to 99.999999%, a range of DF over 10E07.

(c) the requirement to test at the MPPS (particle size for maximum penetration).

(d) the need to express test results in terms of particle numbers rather than particulate mass.

(e) the need to include leakage measurements in the testing arrangements and to relate them to the overall efficiency and classification of the filters.

(f) the need to include particle size efficiency measurements within the overall procedure.

(g) the need to establish correlation between results from test-rigs operated by different organizations.

TECHNICAL BASIS FOR THE NEW TEST PROCEDURES

The technical basis for the new procedures are rooted firmly in existing advanced particle generation and measurement technology. It allows the use of laser optical particle counters (OPC), continuous condensation nuclei counters (CNC), differential mobility particle analysers (DMA) and computer controlled scanning and data processing.

Descriptions of the new procedures have evolved gradually over the last 3 years and have appeared as 5 separate parts; these reflect the fact that the complete standard comprises a number of procedures with options depending the classification of the unit and the purpose for which the test procedure is being carried out.

The requirements to be met and the procedures to be employed are prescriptive but the equipment to be used is not, provided it has the appropriate measurement capabilities, accuracy and consistency.

One main aim of the procedure is to be able to provide sufficient filtration efficiency data on a HEPA or ULPA filter to enable its suitability and adequacy for a particular purpose or purposes to be ascertained. Thus the procedures include a "single-point" efficiency test which may be used as a production control test for filters to be used in gas cleanup applications. Where filters for use in ultracleanrooms are to be tested the procedures include scanning at specified traverse rate, and particle size sensitivity. For all cases the procedures include a specified method for determining the MPPS (Maximum Penetrating Particle Size) for the filter medium being used at the face velocity used in the filter.

CONTENTS OF THE DOCUMENTATION (denoted prEN 1822)

The documentation has been developed in 5 parts:-

<u>Part 1: Requirements, Testing and Marking</u>.
This includes extensive definitions, establishes groups and classes of HEPA and ULPA filters according to their performance as measured by the procedures in this standard. It sets out testing options available and the steps to be followed according to the filter class and the purpose for which the testing is to be conducted. It also specifies the data to be recorded in test certificates and the information to be marked on the filter itself. It specifies that the test aerosol will be a liquid with a vapour pressure $<20\ \mu\text{Pa}$ at 20°C with an index of refraction between 1.45 and 1.60 at 630 nm.

Part 2: Aerosol Production, Measuring Equipment and Statistics.
The aerosol material is not specified but physical data of DEHS (diethylhexylsebacate), DOP (dioctylphthalate) and paraffin oil (low viscosity) are tabulated. Principles of the methods for producing monodisperse aerosols (Sinclair LaMer and Rapaport & Weinstock) by heterogeneous condensation are outlined. The principle of homogeneous condensation is also described together with the use of a differential mobility analyser as a classifier with the capability of extracting a monodisperse component from a polydisperse aerosol. The use of nebulisers for polydisperse aerosol production is described. The requirements for electrical neutralisation of aerosols is covered. Other necessary parameters for aerosol generators are defined.

Essential performance parameters for measuring instrumentation such as optical particle sizers and counters (OPC), condensation nucleus counters (CNC), differential mobility analysers (DMA), dilution systems and other measuring equipment are defined, explained and quantified.

Part 3: Testing Sheet Filter Media. The main purpose of the procedures in this part of the standards to measure the efficiency of the filter medium as a function of particle size. This enables the MPPS to be determined, and also provides initial guidance on the eventual classification of the filter.

The recommended procedure employs a monodisperse challenge aerosol generated by separation of a monodisperse "cut" from a polydisperse aerosol source using an electrical mobility analyser; CNCs may be used to count the particle streams both upstream and downstream. Alternatively a polydisperse challenge aerosol may be used directly, with OPC(s) to assess the particle content in each size channel, both upstream and downstream.

The procedure requires a minimum of six determinations of efficiency at particle sizes spaced uniformly either side of the MPPS; at least 5 samples of filter medium of diameter not less than 200 mm must be tested.

Part 4: Scan Method for Leak Testing and Efficiency Testing of Filter Elements.
This procedure may be carried out using either monodisperse or polydisperse aerosols; the particle size used must be close to the MPPS as determined by the procedures of part 3. When a monodisperse or quasi-monodisperse aerosol is used a condensation nucleus detector may used (as an alternative to OPC) for assessing particle concentration.

The standard defines a monodisperse aerosol as having $\sigma_g < 1.15$, a quasi-monodisperse aerosol having $1.15 < \sigma_g < 1.5$, and a polydisperse aerosol as having $\sigma_g > 1.5$. The median size of a monodisperse aerosol should not deviate from the MPPS by more than 10% and that of a polydisperse aerosol by not more than 50%.

The aerosol sampling probe geometry, velocity of traverse and flowrates for the scanning process are defined; calculation procedures to be followed to determine the presence or otherwise of significant leakage are also defined; these are based on the statistical premise of 95% confidence. Examples of calculated parameters are given for filter classes H13 to U17.

An annex gives a short description of the "oil thread" test which may be used to confirm the absence of leakage in filters of class H12 - H14.

Part 5: Testing the Efficiency of Filter Elements. This part gives requirements for rig testing of HEPA and ULPA filters when scanning is not a requisite, ie it gives and average or overall "single-point" efficiency. As in the case of the scanning test either a monodisperse or polydisperse challenge aerosol may be used in conjunction with CNC(s) or OPC(s) as appropriate. Detailed test-rig requirements are given together with statistical procedures for calculation of results. Examples of calculated parameter values are given for the range of filter classes from H10 - U17.

Cross-checking of Techniques.
Results of "round-robin" tests between European test laboratories using the techniques outlined above have been published by Wepfer[1]. Although at the time of the test programme the test equipment assemblies were by no means standardised the comparative performance values obtained had at least as good a degree of correspondence and consistency as has been encountered in the past with other exercises of a similar nature.

Progress Towards Implementation of the New Standard.
CEN Technical committee 195 (TC/195) in 1990 instructed its working group 2 to develop a European standard test procedure for HEPA and ULPA filters. Preliminary work began immediately but was limited to the assessment of existing standards and underwriting the decision to develop a new standard rather than adapt an existing one. An early draft of Part 1 was available in 1993 and parts 2 & 3 appeared shortly afterwards. Parts 1,2 & 3 have now passed through several editing stages and are ready for a formal voting procedure. Parts 4 & 5 are somewhat less advanced. The target date for voting on the complete document is June 1997. Implementation in accordance with the results of the voting process will take place after that time.

REFERENCES

(1) Filtration and Separation 1995

FILTER GROUP	FILTER CLASS	MAX. OVERALL PENETRATION(%)	MAX. "LOCAL" PENETRATION(%)
H	10	15	--
H	11	5	--
H	13	0.5	2.5
H	13	0.05	0.25
H	14	0.005	0.025
U	15	0.0005	0.0025
U	16	0.00005	0.00025
U	17	0.000005	0.0001

TABLE 1: CLASSIFICATION OF HEPA AND ULPA FILTERS ACCORDING TO FILTRATION PERFORMANCE: (Penetration values refer to performance against MPPS aerosol)

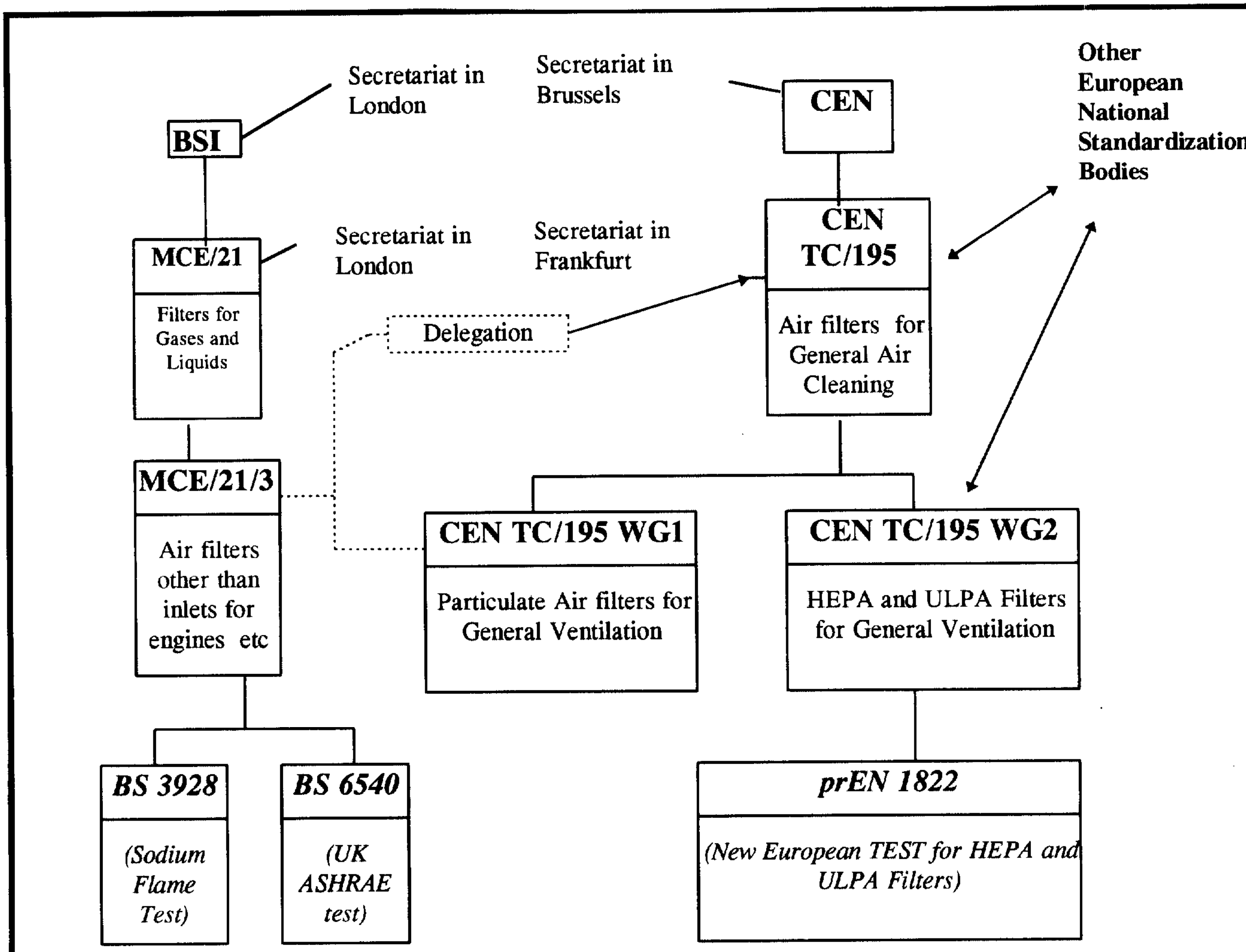

FIGURE 1: COMMITTEE STRUCTURE FOR PRODUCING CEN STANDARDS

DISCUSSION

BERGMAN: I have a question about very high efficiency filter testing. There comes a point where you no longer have a non-destructive test, where, when you try to measure the initial efficiency, you need a sufficient number of particles upstream to get enough particles downstream. About six years ago, in the Proceedings, there was a description of very high efficiency steel filters that had a minimum efficiency of eight or nine times. It took us about half-a-year to verify that the number was correct because the filter would plug up while we were trying to get enough downstream counts. I do not know what others' experience is on these more efficient filters, but you have to be very cautious in terms of filter clogging in order to get the filter efficiency. Just one recommendation, or caution: back-to-back efficiency tests can tell you quickly whether or not you are clogging. People have used pressure drop as a reference to indicate clogging, but we have observed practically zero change in the pressure drop over several orders of magnitude change in the efficiency. That is one caution for measuring very high efficiency filters. Another thing is selection of aerosols, whether you pick a solid or a liquid test aerosol makes a big difference. For example, when you test the same filter with liquid particles you lose at least three orders of magnitude of efficiency relative to filter efficiencies with solid particles. In this area of very high efficiency filters, using particle counting and statistical analysis, plus all of the other factors, it is very difficult.

DYMENT: Efficiency testing procedures, particularly for the highest efficiency filters, include the use of liquid aerosols in preference to solid particles. I think there is an awareness of the problems you mentioned, particularly for the highest efficiency filters.

SCRIPSICK: I was glad to hear what John Dyment presented today, it parallels a number of the activities that are going on in this country. It is good to see that people are coming independently to some of the same general conclusions about assuring performance of filters. I was confused by the distinction between leak testing and efficiency testing. My understanding is that leak testing is done to look at systems where you have particle size independent leaks, that is, 0.1μm particles might penetrate as easily as 1.0μm particles. If leak testing is referring to that, I think it is a step backward. Or does it just refer to scan testing? One of the later slides linked leak testing to scan testing and it is a qualitative rather than a quantitative test.

DYMENT: The aim is to integrate a scan testing result with an overall efficiency result. One has to take into account the fact that all the very high efficiency filters have a scan test. It is the test we carried out for the U16 and U17 filters and the procedure does specify that the scan test shall be carried out. The aim is to use the results of the scans to produce an overall efficiency result.

SCRIPSICK: So your test is associated with scan testing. In-place testing is sometimes referred to as leak testing, where you test a whole bank.

DYMENT: Yes, I think we have a slight difficulty in terminology here. This work I am discussing does not relate to in-place testing, a separate area.

SCRIPSICK: It is component testing, that is what it is.

DYMENT: We are talking about qualification of filters and filter elements, not installations.

FRANKLIN: Is the CEN vote of approval of a standard by consensus?

DYMENT: I wish it was possible to give a yes or no answer on that. There is more than one international standardization body. ISO is worldwide, it has the disadvantage of being a voluntary system. If people do not want to adopt it, they do not, whereas when a CEN standard is voted in by a majority vote, everyone is obligated to implement it within a certain period of time, that is, everyone within the umbrella of CEN is obligated to do so.

FRANKLIN: It sounds like it needs to be approved only by a majority, not by everybody.

DYMENT: Approved by a majority, yes. The voting system is not just a straight yes or no, there are many shades of reservation, approval subject to technical change, subject to editorial change, and so on. And not all nations have the same status of voting. The answer is yes, but maybe.

PORCO: How long does the cycle take from inception of a working group to issuance of a standard? Approximately how many years are there in your cycle?

DYMENT: So far, it is about seven years. The first couple of years were taken up determining which way to go. Once having got moving, the process was on the order of five years. I think the official timetable allocation is a shorter period than that. If one was starting on a new standard today, one would not be allocated five years, it would be less.

WILHELM: The test that has been performed until now is the mass test, on the basis that a certain amount of mass on the downstream side compared to the upstream side gives you the decontamination factor. The decontamination factor is very important for health physics calculations. If you now count particles, then we have to know how many electrical charges are on one particle. Therefore, I do not see how this test could work in a way that fits the needs of the nuclear industry. It will fit the needs of the electronic industry because they always ask for particle counts. Clean room technology is related to particle numbers, but the decontamination factor is not.

DYMENT: I agree with you. The main driving force for this particular standard has been the microelectronic industry, they are particularly interested in particle numbers. But as the test is focused on a particular size of particle, the most penetrating particle, it is possible to calculate effective mass penetration. In fact, if one could obtain a strictly monodisperse aerosol, the answer would be the same whether you are interested in particle number, particle surface area, particle mass, it would give the same answer.

HAYES: You indicate that the European countries have been progressing toward a common standard. What do you believe is the feasibility of CEN and the United States reaching a common standard for HEPA filters?

DYMENT: I know that some members of the technical committee belong to international filter corporations which do have affiliations in the United States. I think there is a fair amount of interchange of views and knowledge of what is going on. As I said earlier, I do not know whether standardization is going to be driven entirely by manufacturers. It is also driven by regulation as far as the nuclear industry is concerned. For the microelectronic industry regulation is not a concern, the standard will have the requirements of the customers. I think the two areas are somewhat different, but, in the end, I think if there is a commercial incentive for an internationally-accepted standard, I am certain it will come.

HAYES: You indicated that you have a copy of that standard with you. Is it a possibility that we could get a copy of that standard and maybe include it in the Proceedings?

DYMENT: I think we would not wish to include it in the Proceedings. As I said, it is a discussion document. I have discussed a summary of each of the five sections in my presentation, but for permission to print the full document I would have to consult with the chairman of the technical committee.

HAYES: If you do not want to include it in Proceedings, perhaps you could exchange it with the ASME Code Section FC committee. We are willing to provide you with a draft of our standards for a draft of yours, maybe we can cooperate a little bit. I have two more questions. I noticed your paper includes all filters. Are you currently using ULPA filters in nuclear facilities?

DYMENT: Not that I am aware of.

HAYES: Your testing requirements use laser particle counters. Are you planning on requiring all production filters to be tested using a laser particle counter? How much time is required for a statistically valid test?

DYMENT: For a very high grade filter such as an ULPA, U16 or U17, you need quite an appreciable length of time. For the H14, normally used in nuclear applications, the time would be much less.

HAYES: Do you know what that time is?

DYMENT: I am afraid I do not.