



BS 6540 : Part 1 : 1985

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British Standard

Air filters used in air conditioning and general ventilation

**Part 1. Methods of test for atmospheric dust spot
efficiency and synthetic dust weight arrestance**

Filtres à air utilisés en conditionnement d'air et en ventilation générale
Partie 1. Méthodes d'essai de rendement sur poussière atmosphérique et sur poussière synthétique

Luftfilter zum Einsatz in Raumklimageräten und für die allgemeine Raumlufttechnik
Teil 1. Prüfverfahren zur Bestimmung des Wirkungsgrades bei Staub aus der Luft und
des Massewirkungsgrades bei synthetischem Staub

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Foreword

This Part of BS 6540 has been prepared under the direction of the Mechanical Engineering Standards Committee and supersedes BS 2831 which is withdrawn. The standard is being published in two Parts. Part 1 gives an atmospheric dust spot efficiency test and a synthetic dust weight arrestance test. Part 2, which is in preparation, will give a more rapid alternative method of test.

The test procedures given in this Part are based on EUROVENT 4/5 'Method of testing air filters used in general ventilation' prepared by the European Committee of the Constructors of Air Handling Equipment. EUROVENT 4/5 is in turn based on ASHRAE Standard 52-76 'Method of Testing Air Cleaning Devices used in General Ventilation for removing Particulate Matter' which was established by the American Society of Heating, Refrigerating and Air Conditioning Engineers in 1968.

Part 1 of BS 6540 describes methods of test for air filters which are practised internationally. There is an overwhelming commercial attraction in the ability to obtain reports of test conducted in any of the EEC countries and the USA each having identical test procedures.

Part 1 of BS 6540 includes a staining efficiency test and a gravimetric test and in both cases an attempt has been made to simulate atmospheric dust conditions inside the test duct. In the case of staining efficiency this standard uses atmospheric air whilst the gravimetric efficiency (or arrestance) is obtained by the injection into the test duct of a dust comprising a mixture of dusts chosen from the examination of many filters which have been in service. The dust mixture is obtained from a common source in a controlled ratio of ingredients (i.e. carbon, sand, lint).

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

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Section one. General

1 Scope

This Part of BS 6540 describes a standard method for comparative testing to evaluate the performance of air filters used in general ventilation having an air flow rate greater than $0.236 \text{ m}^3/\text{s}$ ($850 \text{ m}^3/\text{h}$) with an average atmospheric dust spot efficiency of up to 98 %.

The test procedures given in this standard permit the evaluation of the performance of air filters under particular test conditions in the following two forms:

- (a) an atmospheric dust spot efficiency test giving an efficiency value produced using an atmospheric staining technique;
- (b) a synthetic dust weight arrestance test giving a value produced when the filter is tested by being fed with a synthetic dust.*

These two forms are used to provide a test programme for the determination of dust holding capacity, average efficiency, average arrestance and pressure loss.

A method for reporting the test results is also described.

NOTE. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this Part of BS 6540 the following definitions apply.

- 2.1 device.** Air cleaning equipment used in general ventilation for removing particulate matter.
- 2.2 test air.** Air of the composition, temperature, pressure and atmospheric dust concentration prevailing at the time of the test in a plenum chamber.
- 2.3 rated air flow rate.** The quantity of air the device is designed to handle as specified by the manufacturer, expressed in cubic metres per second.
- 2.4 face area.** The area of the inside section of the test duct immediately upstream of the device (without transition pieces, nominal value $0.61 \text{ m} \times 0.61 \text{ m} = 0.37 \text{ m}^2$, with transition pieces (see figure 2), nominal value $W_1 \times W_2 \text{ m}^2$).
- 2.5 face velocity.** The air flow rate divided by the face area, expressed in metres per second.
- 2.6 net effective filtering area.** The total filtering surface of the device in contact with the test air, expressed in metres squared.
- 2.7 media velocity.** The air flow rate divided by the net effective filtering area, expressed in metres per second.
- 2.8 initial pressure loss.** The pressure loss of the clean device operating at its rated air flow, expressed in pascals.
- 2.9 rated final pressure loss.** The maximum operating pressure loss of the device as recommended by the manufacturer at rated air flow rate, expressed in pascals.

2.10 atmospheric dust spot efficiency. A measure of the ability of the device to remove atmospheric dust from the test air, measured on a light transmission basis, expressed as a percentage.

2.11 initial atmospheric dust spot efficiency. The first determined dust spot efficiency value before any synthetic dust is fed to the filter, expressed as a percentage.

2.12 average atmospheric dust spot efficiency. The calculated average of the dust spot efficiency values, expressed as a percentage.

2.13 light transmission. The proportion of incident light passed by a translucent material as compared with the incident flux, expressed as a percentage.

2.14 relative light transmission. The light transmission of a sampling target relative to the light transmission of a translucent standard, expressed as a percentage.

2.15 dust spot opacity. The decrease in relative light transmission of a dust spot sampling target resulting from the build-up of atmospheric dust on the target, expressed as a percentage.

2.16 synthetic dust weight arrestance. A measure of the ability of the test device to remove injected synthetic dust from the test air, calculated on a weight basis, expressed as a percentage.

2.17 initial synthetic dust weight arrestance. The first dust weight arrestance obtained from a dust fed increment of 30 g, expressed as a percentage.

2.18 average synthetic dust weight arrestance. The average of the values of synthetic dust weight arrestance, expressed as a percentage.

2.19 final air filter. The air filter used to collect the synthetic dust passing the device.

2.20 dust holding capacity. The amount of synthetic dust fed to a disposable or non-self-renewable device multiplied by its average arrestance until one of the limiting conditions occurs, expressed in grams.

3 Test rig

The test rig (see figure 1) shall comprise six duct parts. The nominal internal dimensions of duct parts 1, 3, 4, 5 and 6 shall be $610 \text{ mm} \times 610 \text{ mm}$. Duct part 2 where the device shall be installed shall have a nominal internal dimension of $622 \text{ mm} \times 622 \text{ mm}$. The length shall be 1 m or 1.1 times the length of the device whichever is the greater. If the filter to be tested is of a size different from the cross section of the test duct, transition pieces with dimensions as shown in figure 2 shall be used.

Duct part 1, which shall be situated upstream of the device under test, shall consist of a mixing orifice on the air intake side, upstream of which shall be positioned the dust feeder and downstream of which shall be a perforated plate to act

*In British Standards it is practice to use the term 'mass' instead of 'weight'. However in this standard, weight has been used throughout for consistency with 'dust weight arrestance' which is used in the industry.

as a dust distributor. In the last third part of this duct shall be situated the upstream sampling head (see figure 1), and the upstream pressure tapings.

Downstream of the device is duct part 3 which shall contain the downstream pressure tapings for measuring the pressure loss across the device and shall be connected to duct part 4 or 5 dependent upon the part of the test being undertaken. For the arrestance test, duct part 4 which contains the final filter shall be used. For the efficiency test, duct part 5 which contains the downstream sampling head shall be used.

Duct part 4 and duct part 5 shall have the same dimensions.

NOTE. If duct part 5 is not available, duct part 4 may be used both for dust spot efficiency and arrestance determination.

When measuring with the final filter in position, either the downstream sampler shall be blanked-off or the complete

downstream sampling assembly shall be removed from the duct and the opening shall be blanked-off with a flat plate in such a manner as to avoid leakage.

Duct part 6 shall be a permanent part of the rig fitted with a flow measuring device such as given in BS 1042 : Part 1.

If the air flow is measured after passage through the fan the measuring instrument in duct part 6 of the test rig may be omitted, but the total length of duct part 6 shall be maintained.

The dimensions of the test rig and the positions of the pressure taps shall be as shown in figure 3.

The test ducts shall be isolated from vibration caused by the main fan or any other equipment producing vibration in the area where the test rig is installed. The test rig shall be exhausted as far as possible from the air intake.

Section two. Atmospheric dust spot efficiency test

4 Principle

Samples of test air are drawn at equal mass flow rates from the upstream and downstream sides of the devices tested. Equal flow rates through the samples are established by means of flow nozzles. The downstream test air is sampled continuously and the upstream test air is sampled intermittently as controlled by a percentage timer.

An elapsed time meter is provided to record the total 'on' time. This value together with the flow rate (1 L/s) established by the flow nozzle allows verification of the gas meter readings.

Dust from the sampled air, up and downstream of the device, is captured on equal area targets of filter paper. The percentage of 'on' time for the upstream sample is adjusted by previous experiments so that the upstream and downstream targets are of approximately equal opacity at the end of the test.

5 Apparatus for the measurement of atmospheric dust spot efficiency

5.1 Sampling head and target holder and the nozzle shall be assembled as shown in figure 4. Through the inlet branch, a partial flow shall be drawn in by the vacuum pump through a target. The rate of the partial volume flow shall be determined by the nozzle downstream of the target. The target placed in the target holder shall be correctly positioned by the locating pins. It shall be loaded with particles from the atmospheric air flow, and shall be removed at intervals given by the test programme, to be placed, always in the same position, in the photometer for measuring the opacity increase. During the test run, the target holder shall be fitted into the sampling head without any leakage.

5.2 Flow control. The sampling flow rate for each sampler shall be fixed by identical nozzles calibrated to provide a flow of $1 \text{ L/s} \pm 1\%$ (see figure 5). This flow rate shall be checked periodically. The pressure difference across the nozzle shall be at least 20 kPa. Gas meters will show higher values due to system vacuum.

5.3 Target shall consist of a circular paper disc with a diameter of 36.5 mm. This disc shall be provided with two holes positioned on a circumference of 30.2 mm, the holes having respective diameters of 4 mm and 2.4 mm and forming an angle of 135° between them with respect to the centre of the target. Locating pins in the target holder shall ensure that the two targets cannot be inserted back to front (see figure 4). Thus no error shall be possible due to difference in the nature of the surface and hence in opacity.

The target shall be made of white filter paper of glass fibres, having a penetration of not greater than 0.01 % at a velocity of 25 mm/s when tested in accordance with BS 3928.

For uniform cutting of the target, a target punch shall be used.

As the strength of the target paper is too low to guarantee that it will not stretch excessively or burst in the course of a test, a polyamide marquisette or lightweight non-woven material shall be inserted to support the target paper. This target support shall be punched to the same dimensions as the target paper by using the target punch.

When a target support is used, the assembly comprising the target holder, target, and target support, shall be used both for the sampling in the test duct and for the light transmission measurements by means of the opacity meter.

5.4 Piping arrangements and wiring diagram for programme control of sampling. A timer with a fixed 5 min interval and a timer with an adjustable interval of between 0 min and 5 min shall be used for programme control. Needle and solenoid valves, with appropriate piping arrangements and wiring, shall regulate the depression in the system to a constant value of 20 kPa at the outlet of the gas meters during the different operations obtained by the selector switch S and even during a programme for intermittent sampling (see figures 6 and 7, and table 1).

5.5 Opacity meter shall comprise a photometer, a null indicator and a light transmission standard (see figures 8 and 9).

The opacity meter shall have features meeting the following specifications.

- Tungsten illumination of 2500 K to 3000 K.
- Photocells of photovoltaic or photoelectric type and sensitive to wavelengths of between $0.5 \mu\text{m}$ and $0.6 \mu\text{m}$.
- Light beam striking the target, essentially parallel, with a diameter of $12.7 \pm 1.3 \text{ mm}$.
- Photometer read-out with a minimum reading approximating to $1/900$ of the transmission standard and a full scale range of 1000 intervals.
- Opacity meter of null type. If an analogue measuring instrument is used, the minimum intervals from the zero marking shall be 2 mm.
- Overall instrument drift per hour from balance, with the standard in place, which does not exceed 10 times the least value detectable.
- Potentiometer of 10 turn type with a resistance of 25Ω and a linearity of 0.1 %. The null indicator shall be electronic with a logarithmic scale having a precision of $10^{-3} \mu\text{A/mm}$ at the zero point.

Table 1. Valve positions with programme control

No.	Position of selector switch	Valve positions			
		Valve A controlling upstream sampling head	Valve B controlling downstream sampling head	Valve F controlling upstream solenoid valve	Valve C controlling downstream solenoid valve
1	Off	Shut	Shut	Shut	Shut
2	Warm-up	Shut	Shut	Open	Shut
3	Normal sampling	Open	Open	Shut	Shut
4	Measuring position				
	Valve A open Valve A shut	Open Shut	Open Open	Shut Shut	Shut Open
5	Adjusting the sampling cycle	Shut	Open	Shut	Open

6 Preparation of atmospheric dust spot equipment

6.1 Sampling head location

Locate the sampling heads (5.1) centrally, with the inlet tip facing the inlet of the rig, parallel to the air flow, upstream and downstream of the device under test (see figure 1).

6.2 Preparation of opacity meter

For an exact measurement ensure that the optical system of the opacity meter (5.5) is clean and free from dust.

Apply the voltage to the opacity meter (5.5) and adjust the potentiometer reading to 1000 intervals when using a light transmission standard composed of three discs; allow a warm up period.

For calibration, introduce the light transmission standard in the holder of the opacity meter (5.5), and adjust the reading of the null indicator to '0' by means of the light damper. Make this calibration before any determination of target light transmission.

6.3 Target preparation

Punch the two targets (5.3) required for one test from a single sheet of filter paper, making sure the stock sheet is not inverted during the punching. In addition, punch two support screens using the same punch.

Install one support screen on each downstream target holder (5.1), fitting the holes punched in the screens over the locating pins. Then place the target paper disc in the same manner, and cover it on its rim by the upstream target holder (5.1).

6.4 Determination of relative light transmission of targets

Successively place each target holder (5.1) with its target (5.3) into the opacity meter (5.5) with the downstream side of the target holder (5.1) towards the light source. Adjust the read-out of the potentiometer until a null reading is reached. The potentiometer read-out indicates the relative light transmission of the unused target, ensure that this is between 800 and 1000 intervals for the light transmission standard. Record the relative light transmission of each target and identify. Replace the light transmission standard, adjusting potentiometer to give a null reading. If the potentiometer does not read 1000 intervals, reset the reference photocell and repeat the readings. Ensure that the difference in initial relative light transmission of the two unused targets (5.3) for a single test is not greater than 2 % of the larger value.

6.5 Selection of the sampler inlet tip

Carry out sampling isokinetically. In order to achieve this, select the proper inlet tip by first determining the duct velocity at the sampler location. If the velocity is between 0.6 m/s and 1.6 m/s, use the 30.8 mm diameter inlet tip. For velocities between 1.6 m/s and 3.8 m/s, use the 21.8 mm inlet tip.

6.6 Schedule of sampling

Operate the downstream sampler continuously for the test period, but vary the upstream sampling time in accordance with expected efficiency.

Ensure that the opacity of the target stains at the conclusion of a test is no less than 10 % and no more than 40 %.

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Section two

Furthermore, ensure that the opacity of the stains differs by no more than 20 % of the higher value. If a test fails to meet these criteria, re-estimate the time required to obtain the specified opacities.

Divide this estimated time in minutes by five to obtain the number of 5 min intervals in the test.

Estimate the percentage efficiency of the device, divide by 100, subtract from 1 and multiply the difference by 300 (5 min) to obtain the number of seconds for which the upstream sampler is to operate during each 5 min increment. Set the timer to open the upstream solenoid for the period calculated.

7 Preparation of the device

Prepare the device in accordance with the manufacturer's recommendations and weigh it to the same accuracy as the master filter.

Seal the device including its normal mounting frame into duct part 2 in a manner that prevents leakage between duct parts 1 and 2.

After the installation of the device in the test duct, position the moveable downstream sections, duct parts 3 and 5, so as to obtain accurate measurement.

8 Test air

Obtain outdoor air from a location as representative as possible of the general outdoor conditions. Avoid local effects on the representative nature of the test air (e.g. by prevailing wind, industrial effluents, local traffic conditions) by ducting the outdoor air, if need be, from a different elevation or side of the laboratory building.

NOTE 1. When determining the synthetic dust weight arrestance, room air may also be used as test air.

NOTE 2. Ducting or vents may be provided with screens or louvres.

Take precautions so that fog, rain or snow are not drawn into the test duct. To this end, ensure that the test duct receives the test air from a plenum chamber, having minimum dimensions 2 m x 2 m x 2 m and a volume not exceeding 10 m³. If percentage saturation of the outside air exceeds 75 %, provide heating so that the percentage saturation at the entry of the duct does not exceed 75 %. Ensure that the heating devices employed are designed in a way which excludes any formation of significant deposits of airborne dust.

9 Test procedure

9.1 Start the fan and adjust for rated air flow of the device.

9.2 After installation of the sampling system, allow the vacuum pump to warm-up for a period as indicated by the manufacturer. For that purpose, turn the selector switch S (figure 6) to position 2 (warm up).

9.3 Adjust the pressure differential to 20 kPa across the nozzle by means of the valve G (figure 6).

9.4 Turn the selector switch S to position 3 (normal sampling), and then adjust the vacuum again to 20 kPa by means of the valve E (figure 6).

9.5 Afterwards, turn the selector switch S to position 5 (downstream sampling) the vacuum being also adjusted to 20 kPa by means of the valve D (figure 6).

9.6 At the end of these preparations, turn back the selector switch S to position 2 (warm up).

9.7 Make these adjustments rapidly so as not to load the targets more than necessary with dust.

9.8 Record gas meter readings and reset elapsed time meters.

9.9 Start the sampling cycle by turning the selector switch S to position 4 (measuring position).

9.10 At the conclusion of the sampling schedule turn selector switch S to position 2 (warm up). Record gas meter and elapsed time meter readings and stop the fan.

9.11 Remove the targets assemblies from the samplers.

9.12 Recalibrate the opacity meter. Then read relative light transmission of dirty targets, using same procedure as for clean targets. Record the readings.

9.13 Calculate the percentage decrease in relative light transmission for both targets.

9.14 Make sure that the conditions of the schedule of sampling (6.6) have been met.

9.15 Calculate efficiency E using the equation given in clause 10.

9.16 Repeat steps 9.1 to 9.15. If these two values for E are within the allowable variation range as established by appendix A, average these results and record the average. If this agreement is not achieved, make three additional determinations and record the average of all five values.

9.17 Do not use the actual value of the atmospheric dust spot efficiency if the initial or the average value exceeds 98 %, but indicate 'over 98 %'. Indicate the initial atmospheric dust spot efficiency as 'less than 20 %', if the result is less than 20 %. Do not report the average efficiency. Do not make any further efficiency tests.

10 Calculations

Calculate the atmospheric dust spot efficiency E (in %) given by:

$$E = 100 \left(1 - \frac{Q_1 O_2}{Q_2 O_1} \right)$$

where

Q_1 is the total volume of air drawn through upstream target;

Q_2 is the total volume of air drawn through downstream target;

O_1 is the opacity of dust spot upstream target given by:

$$O_1 = \frac{T_{u1} - T_{u2}}{T_{u1}}$$

where

T_{u1} is the initial upstream light transmission (in %);

T_{u2} is the final upstream light transmission (in %);

O_2 is the opacity of dust spot downstream target given by:

$$O_2 = \frac{T_{d1} - T_{d2}}{T_{d1}}$$

where

T_{d1} is the initial downstream light transmission (in %);

T_{d2} is the final downstream light transmission (in %).

Section three. Synthetic dust weight arrestance test

11 Principle

The final filter and the device are weighed and then fitted to the test rig. A predetermined weight of synthetic dust is fed into the test rig, and the dust passing the device is collected on the final filter. The final filter is then removed and reweighed and the increase in weight is used to calculate the synthetic dust weight arrestance. At least four arrestance measurements shall be made.

12 Apparatus for measurement of dust weight arrestance

12.1 Dust feeder* (see figures 10 and 11) shall supply the synthetic dust to the test air in fully dispersed form at a constant rate over the test period. The quantity of dust required for the test period planned shall be loaded into the mobile dust feed tray.

Because of the constant movement of the tray the dust paddle wheel takes up the dust continuously and carries it to the slot of the dust pick-up tube of the venturi-ejector. The ejector shall disperse the dust with compressed air and shall direct it into the test rig through the dust feeder tube. The compressed air shall be clean, dry and free from oil.

12.2 Synthetic test dust shall be composed of 72 % by weight Standardized Air Cleaner Test Dust, Fine; 23 % by weight Molocco black; 5 % by weight No. 7 cotton linters. It shall be procured in this composition, already mixed, from the manufacturer†.

12.3 Final filter shall be either self supporting, integral cartridge or replaceable media design, and shall be of the dry type, having no dust adhesive coating and shall contain the collected dust in a manner which minimizes loss during handling.

The final filter shall not gain or lose more than 1 g as a result of humidity variations met during one test cycle.

At the test conditions this filter shall have a minimum average dust spot efficiency of 95 % and a minimum arrestance of 98 %.

If a bag filter is used, any special supports shall form an integral part of the filter. Any external supports of the wire cage type which remain in the test rig during weighing operations shall not be admissible.

12.4 Balances for weighing the final filter shall have an accuracy of 0.5 g. The balance for weighing the dust increments shall have an accuracy of 0.1 g.

12.5 Compressed air wand for redispersing dust settling on the floor of the test duct shall be provided. It shall be so designed that a direct jet of compressed air cannot impinge upon the filter face. A recommended design is shown in figure 12.

13 Test procedure

13.1 Determination of initial pressure loss of the device

13.1.1 Measure the air flow. Maintain the dimensions of the test rig as shown in figure 3.

13.1.2 Measure and record pressure loss of the device at a minimum of four air flow rates of 50 %, 75 %, 100 % and 125 % of rated air flow to establish a curve of pressure loss as a function of air flow rate. Measure the pressure loss between static pressure taps located as shown in figure 3. Provide pressure taps at four points, distributed over the periphery of the duct and connected together by a ring line.

13.2 Determination of synthetic dust weight arrestance

13.2.1 Weigh the final filter (12.3) and then install it in the test duct. Clamp the section comprising the filter in the test rig in such a way as to avoid leakage.

13.2.2 Remove the complete upstream sampling assembly and blank-off the duct opening with a flat plate.

13.2.3 Position the dust feeder tube so that the feeder nozzle is centrally located in the inlet mixing orifice with the nozzle tip in the same vertical plane as the orifice.

13.2.4 After thoroughly mixing weigh the quantity of synthetic dust accurately to 0.1 g for one increment of loading. Feed dust increments for arrestance measurements into the test rig at a rate of $70 \text{ mg/m}^3 \pm 10 \%$. Ensure that the first increment is of 30 g.

NOTE. Subsequent increments may be increased or decreased in weight.

Make a minimum of a further four equal dust increments until reaching the final pressure loss.

13.2.5 Distribute the synthetic dust uniformly in the feeding tray.

13.2.6 Start the test rig fan and adjust the air flow to rated air flow.

13.2.7 Start the dust feeder (12.1) and adjust the pressure regulator in dust feeder line to four bar $\pm 10 \%$.

*Obtainable from Air Filter Testing Laboratories Inc., 4632 Old La Grange Road, Crestwood, KY 40014, USA as ASHRAE 52/76 dust feeder.

†Obtainable from Air Filter Testing Laboratories Inc., 4632 Old La Grange Road, Crestwood, KY 40014, USA as ASHRAE 52/76 dust test dust.