MDHS 81

Methods for the Determination of Hazardous Substances
Health and Safety Laboratory

HSE
Health & Safety Executive

Dustiness of powders and materials

September 1996

INTRODUCTION

1 The control of dust emission during the production, handling and transportation of powders and materials is an important consideration in the design and operation of industrial processes.

2 Excessive airborne dust levels in workplaces are undesirable for a number of reasons: a) they can cause adverse health effects; b) their control can involve the use of costly ventilation and filtration systems; c) they can be costly in terms of lost product; d) they can contaminate machinery and products. Factors (a) and (b) mean that knowledge of the propensity of a material to release dust may be required by those responsible under the Control of Substances Hazardous to Health Regulations (COSHH) for assessing the likely health risk from materials or for controlling dust emissions. Although factors (c) and (d) may have no direct bearing on health, their economic impact could be significant.

3 Dusts emitted during the handling of powders and materials contain particles of a wide range of sizes. The likely health risk from inhalation of a specific particle is dependent upon the nature and size of the particle. The International Standards Organisation (ISO) and the Comité Européen de Normalisation (CEN) have published conventions for health-related sampling.[1,2] The three main size fractions are inhalable, thoracic and respirable. This publication describes a method for determining the dustiness of materials, based on these three internationally recognised health-related fractions. Other methods based on different principles are also available and have a range of applications.[3]

DEFINITIONS

4 The dustiness of a material is defined as the propensity of that material to produce airborne dust when handled.[3]

5 The inhalable fraction E_I is the mass fraction of total airborne particles which is inhaled through the nose and mouth. The ISO and CEN standards specify that samplers for this fraction should have a collection efficiency:

$$E_I = 50(1 + \exp[-0.06D])$$

where D is the particle aerodynamic diameter, and E_I is expressed as a percentage.

6 The thoracic fraction E_T is the mass fraction of inhaled particles penetrating beyond the larynx. The CEN and ISO convention for this fraction declines from 100% at 0 µm with the shape of a cumulative log-normal curve with a median diameter of 11.64 µm and a geometric standard deviation of 1.5.

7 The respirable fraction E_R is the mass fraction of inhaled particles which penetrates to the unciliated airways. The CEN and ISO convention for this fraction declines from 100% at 0 µm with the shape of a cumulative log-normal curve with a median diameter of 4.25 µm and a geometric standard deviation of 1.5.

SCOPE OF THE METHOD

8 The method described is suitable for the determination of the health-related dustiness of powders and materials in use in industrial processes, including powders, pelletised material and loosely-packed fibrous material.

9 The lower limit of detection for the dustiness value for each health-related fraction is governed by the accuracy of the weighing procedures. If emitted dust levels are too low to allow reliable measurements of the three fractions separately, the particle size-selective stages can be removed and results for one combined fraction - an approximation to the inhalable fraction - can be obtained.

PRINCIPLE

10 A measured mass of material is tumbled in a rotating drum, through which air is passed at a known flowrate for a fixed time. The resulting dust cloud is passed through a three-stage dust sampling system, comprising two size-selective foams and a filter. The masses of dust collected are determined by weighing the foams and filters before and after the measurement run. The total amount of dust collected gives a measure of the dustiness in terms of the inhalable fraction. Values for the dustiness of the material in terms of the thoracic and respirable fractions are also calculated from the amounts passing through the size-selective foams.[4]

APPARATUS

Dustiness test apparatus

11 The apparatus required to determine the dustiness of materials is shown in Figure 1. Sets of engineering drawings are available from the Health and Safety Laboratory, for a small charge, to enable the apparatus to be constructed. Alternatively the complete test apparatus is available from JS Holdings, Stevenage (see Appendix 2 for addresses).

The apparatus comprises a 300 mm diameter drum rotating at 30 rpm, equipped with longitudinal vanes to lift and let fall 200 g of the material under test, and a three-stage dust sampling system (the outlet stage) through which the emitted dust cloud is drawn by a vacuum pump at a flowrate of 38 l min^{-1} for 1 minute.

The sampling system comprises two particle size-selective foams in series followed by a back-up filter. Dust entering the conical passage and into the sampling system gives an estimate of the inhalable fraction. The size selectors, in the form of cylindrical plugs of 30 pores per inch (ppi) and 90 ppi porous polyester foam, are chosen to select the thoracic and the respirable fractions, respectively. The foams and the back-up filter are weighed before and after the test to provide the dustiness estimates of the three size fractions.

An identical set of foams and filter is positioned at the inlet to the drum (inlet stage), and serve as controls by taking account of weight changes due to the passage of air through the foams and filter. Extra filters are positioned either side of the inlet stage to prevent dust contamination.

The flowrate through the device is monitored using an in-line rotameter and the volume of air sampled is measured with a calibrated gasmeter. The operation of the apparatus is automatically controlled by a timing control circuit.

Size-selective foams

12 Porous polyester foam size selectors with a reticulated open-cell structure are used to select the thoracic and respirable dust fractions. These are manufactured by Recticel PRB in Belgium, and are available in the UK from Foam Engineers Ltd, High Wycombe (see Appendix 2 for addresses). Both size selectors are 150 mm diameter, 25 mm thick foam plugs, and they are housed in carrier frames to facilitate both handling and weighing.

Filters

13 150 mm diameter reinforced glass fibre filters (for example, GF/A filters made by Whatman) are used to collect the fine respirable particles that penetrate the foams.

Ancillary equipment

14 The balance room or chamber where weighing is carried out should have temperature and humidity maintained at a stable level. A balance capable of weighing 250 g with a reproducibility of ± 0.1 g should be available for weighing the samples of test material.

A balance capable of weighing 150 g with a reproducibility of ± 0.1 mg should be used for accurate determination of the foams and filters. The weighing chamber of the balance should be large enough to hold a 150 mm foam carrier without it touching the walls. A weighing frame to position the foams and filters on the balance pan may be used.

PROCEDURE

15 Detailed instructions are given in Appendix 1. The following is a summary of key stages.

Preparation of test sample

16 A test sample should be prepared from the bulk material using a method which would result in representative sampling. Methods given in BS3406[5] should be used. Sealable sample bottles should be used to minimise spread of contamination. Each test sample should weigh 200 g ± 0.1g.

Preparation of apparatus

17 Prior to the tests being carried out, the rotating drum is cleaned thoroughly using a suitable vacuum cleaner and wiped with a damp cloth. For material that sticks to the internal surfaces it may be necessary to wash the surfaces with a solution of a detergent in water followed by thorough washing with water, or to clean with a suitable solvent (for example, propan-2-ol), and allow the apparatus to dry. Assemble the inlet and outlet stages to appropriate ends of the drum. Switch on the pump and set the flowrate to 38 l min^{-1}.

Running the test

18 Remove the inlet and outlet stages at both ends of the drum. Replace the inlet stage with a fresh set of foams and filter. Spread the sample evenly along the bottom of the drum. Assemble the outlet stage to the drum.

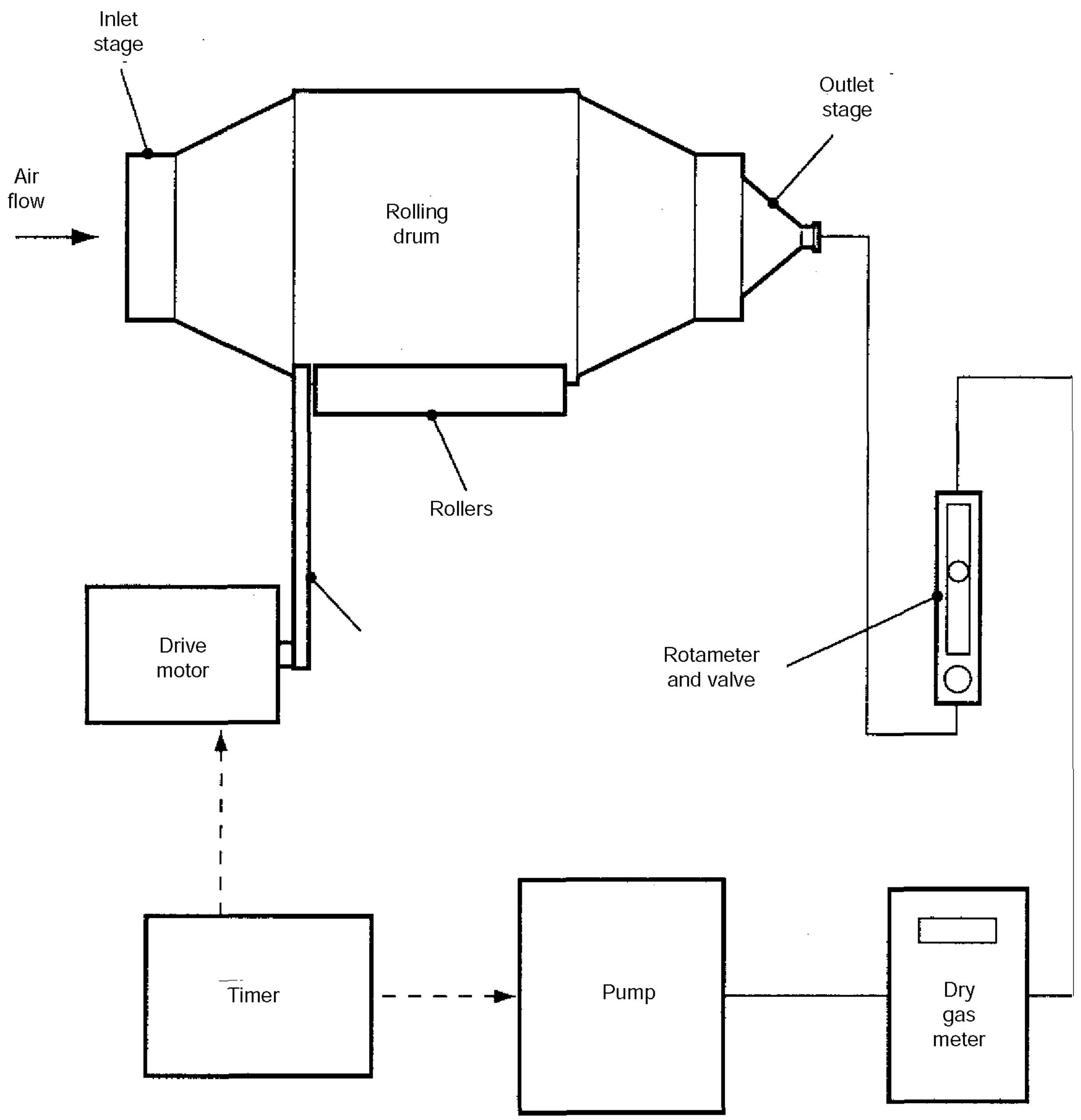

Figure 1 Schematic diagram showing the main features of the test apparatus

19 The timing circuit is then switched on and the test programme allowed to proceed. At the end of the test, carefully remove the foams and the filters from either end of the drum and place them in the balance room, taking care not to disturb the collected dust.

Weighing the foams and filters

20 The weight of dust collected is determined by weighing the foams and filters before and after the test. They should be weighed in their carriers following a defined sequence. After the test, the foams and filters are reweighed in the same sequence. As the foams are sensitive to moisture and electrostatic conditions in the atmosphere, it is essential that a protocol be followed as to when the weight indicated by the balance should be recorded. It is recommended that the weight be taken 30 seconds after the specimen is placed on the balance pan and the balance door closed.

21 In order to minimise the risk of contamination it is recommended that handling of the foam carriers should be kept to a minimum. Gloves should be worn or tweezers used to lift or carry the foams and only tweezers used when handling the filters. If the weight of either of the control (30 and 90 ppi) foams changes by more than ± 20 mg it would indicate contamination or loss of foam material. The measurement should be repeated with a fresh sample.

22 The weights of dust captured in the size-selecting stages are calculated in the following equation:

$$D_n = (T_{Fn} - T_{In}) - (C_{Fn} - C_{In})$$

where

D_n = Weight of dust captured on the *n* th stage
T_{Fn} = Final weight of the *n* th test stage
T_{In} = Initial weight of the *n* th test stage
C_{Fn} = Final weight of the *n* th control stage
C_{In} = Initial weight of the *n* th control stage

The *n* th stage corresponds to the 30 ppi foam, the 90 ppi foam or the backing filter in the foam/filter assembly. This process allows for any weight changes in the foams and filters during the test to be corrected.

DETERMINATION OF THE DUSTINESS VALUES

23 The dustiness values for each fraction are calculated using the equations shown in Figure 2.[6] At least three replicate tests should be carried out for each material and the mean values are then calculated for each fraction, together with the standard deviation.

REPORTING OF RESULTS

24 The dustiness of the test material is reported in terms of (D_I, D_T, D_R). For example, a dustiness value of (4, 20, 5) means that 4% of the dust tested became airborne and was collected as inhalable dust; that 20% of the inhalable fraction was able to penetrate past the larynx (thoracic); and that 5% of the inhalable fraction was able to penetrate past the unciliated airways (respirable).

25 If the masses of dust collected on the foams are too low for meaningful results to be obtained, tests may be carried out in which both foams are omitted and all the dust collected on the filter to give an indication of the inhalable fraction dustiness value only, ie (D_I, -, -).

HEALTH AND SAFETY

26 This work may be subject to the Control of Substances Hazardous to Health (COSHH) Regulations 1994 (or to the Control of Lead at Work Regulations 1980 or the Control of Asbestos at Work Regulations 1987, if the materials contain lead or asbestos). HSE guidance on the appropriate regulations should be consulted.[7,8,9] In general, it will be necessary to assess the risk to health from exposure to the substances used, to assess the measures necessary to comply with the regulations, and to prevent or adequately control exposure, taking into account applicable occupational exposure limits.[10] The assessment should take account not only of the materials tested, but of others used, such as cleaning solvents; and not only of exposure by inhalation, but of other routes such as skin absorption.

Figure 2

$$D_I = \frac{\text{weight gain on the two test foams + weight gain on the backing filter}}{\text{weight of test sample}} \times 100\%$$

$$D_T = \frac{\text{weight gain on the 90 ppi test foam and backing filter}}{\text{weight gain on the two test foams + weight gain on the backing filter}} \times 100\%$$

$$D_R = \frac{\text{weight gain on the backing filter}}{\text{weight gain on the two test foams + weight gain on the backing filter}} \times 100\%$$

where D_I = the dustiness value of the inhalable dust fraction;
D_T = the dustiness value of the thoracic fraction; and
D_R = the dustiness value of the respirable fraction.

27 Other physical hazards should also be considered. Explosion risks may result from the material becoming airborne; in particular organic dusts can form explosive mixtures with air at concentrations above the lower explosive limit.[11,12] Precautions such as earthing the tester to minimise the build-up of static electricity, removal of hot surfaces and flame from the vicinity of the test should be introduced.

ADVICE

28 Advice on this method and the equipment used may be obtained from the Aerosols Section, Health and Safety Laboratory, Health and Safety Executive, Broad Lane, Sheffield S3 7HQ (telephone 0114 289 2000, fax 0114 289 2500 or e-mail aerosols@dust.demon.co.uk). The Health and Safety Executive wishes, wherever possible, to improve the methods described in this series. Any comments that might lead to improvements would, therefore, be welcome and should be sent to the above address.

ACKNOWLEDGEMENT

29 Preparation of this document was overseen by Working Group Two of the Committee on Analytical Requirements. At the time of writing, CAR/WG2 consisted of Dr K Chung, Mr A Griffin, Dr H Jackson, Dr T Ogden and Dr N West (all of HSE), together with Mr C Hammonds (Michelin Tyre plc), Mr D Mark (University of Birmingham) and Dr B Wells (formerly Unilever Research Laboratories).

REFERENCES

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APPENDIX 1 Operating procedure for the HSE Rotating Drum Dustiness Tester model EDT38L

1 Context and scope

1.1 This Appendix describes how to operate the HSE Rotating Drum Dustiness Tester model EDT38L. The tester is suitable for any dry material.

1.2 The work may be subject to the Control of Substances Hazardous to Health (COSHH) Regulations 1994 (or to the Control of Lead at Work Regulations 1980 or the Control of Asbestos at Work Regulations 1987 if the material contains lead or asbestos). HSE guidance on the appropriate regulations should be consulted.

1.3 Other physical hazards, such as explosivity, should be considered and appropriate measures taken.

2 Description of equipment

2.1 The EDT38L Dustiness Tester consists of a steel drum which rotates on a pair of rollers. Material inside the drum is lifted up by a system of blades and let drop, thus producing a dust cloud. Dust-laden air is drawn through an assembly of size-selecting foams and filter. The propensity of dust release and size distribution of the airborne component of the material are determined by weighing the foams and filters.

2.2 The tester is housed inside a toughened plastic enclosure. A microswitch is incorporated which will turn off power to the equipment when the lid is not properly down.

3 Equipment required

3.1 The EDT38L assembly, foams carriers, filter cassettes, foams, filters and a suitable balance.

3.2 For materials that are considered hazardous to health it may be necessary to use the equipment inside a fume extraction hood. Suitable personal protection equipment, such as gloves, may also be required.

3.3 Vacuum cleaner fitted with HEPA filter and a hose extension.

4 Main operational procedures

4.1 Preparation.

4.1.1 Check the drum is clean and ready for use.

4.1.2 Insert two 30 ppi foams into their carriers and weigh to 0.1 mg.

4.1.3 Insert two 90 ppi foams into their carriers and weigh to 0.1 mg.

4.1.4 Weigh two 150 mm reinforced ream GF/A glass fibre filters to 0.1 mg.

4.2 Assembly of the inlet stage (see Figure A.1).

4.2.1 Insert a filter in the inlet outer case as the outer guard filter.

4.2.2 Insert a filter support grid.

4.2.3 Insert one of the preweighed filters as the control filter with its filter support grid.

4.2.4 Clip one of the 30 ppi foam carriers and one of the 90 ppi foam carriers together to form the control foam set and insert into the inlet outer case.

4.2.5 Insert the inner guard filter and a filter support grid.

4.2.6 Attach the inlet stage to the drum and secure with the latches.

4.3 Assembly of the outlet stage (see Figure A.2).

4.3.1 Insert a filter support grid and the other preweighed filters into the outlet outer case.

4.3.2 Clip the other 30 ppi foam and 90 ppi foam carriers together to form the sampling foam set and insert into the outer case.

4.3.3 Attach the outer case to the exit end of the drum and secure with the latches.

4.3.4 Connect the outlet of the outlet stage to the rotating coupling with the clasp and secure the wing nut.

4.4 Disassembly of the outlet stage.

4.4.1 Undo the wing nut to release the rotating coupling to the outlet stage.

4.4.2 Gently turn the drum on the rollers so that the latches are accessible.

4.4.3 Hold the outlet stage in place with one hand while removing the latches.

4.4.4 Gently slide the stage out and down from the drum and carefully place it on the bench.

4.4.5 Lift the foam carriers out of the outer case and turn the top one gently clockwise to undo the bayonet fitting to release the two foam carriers.

4.4.6 Place both foam carriers on a tray.

4.4.7 Release the bayonet fitting on the assembly case and slide the top piece down.

4.4.8 With two pairs of tweezers carefully lift the filter off its support grid.

4.4.9 Place the filter with the foams for re-weighing.

4.5 Disassembly of the inlet stage.

4.5.1 Rotate the drum so that the latches are accessible.

4.5.2 Hold the inlet stage with one hand and undo the latches.

4.5.3 Gently slide the stage out and down from the drum and carefully place it on the bench.

4.5.4 Lift the foam carriers out of the outer case and turn the top one gently clockwise to release the bayonet fitting to release the two foam carriers.

4.5.5 Place both foam carriers on a tray.

4.5.6 Carefully push the outer guard filter up the case until the control filter support grid and the filter can be lifted off, remove the control filter and place it with the control foams for re-weighing.

4.6 Flowrate check.

4.6.1 Flowrate check should only be necessary once a week for continuous use, or at the beginning of a test if the equipment has not been used for a long period of time.

4.6.2 Assemble the drum as 4.1 - 4.3.

4.6.3 Press the green switch to turn on the pump.

4.6.4 Adjust the rotameter to 38 l/min. After the first cycle take the reading at the gasmeter.

4.6.5 Press the green button again and read the gasmeter when the pump stops.

4.6.6 Compute the difference between the first gasmeter reading and the second, and if the difference is not within 38 ± 1 l/min adjust the valve at the pump.

4.6.7 Repeat 4.6.3 to 4.6.6 until 38 ± 1 l/min is achieved.

4.7 Testing a sample.

4.7.1 Prepare the drum, foams and filters as described in 4.1, and enter the values in proforma A1.

4.7.2 Assemble the inlet stage of the tester as described in 4.2.

4.7.3 Weigh out about 200 g of sample to 0.1 g.

4.7.4 Spread the sample evenly along the bottom of the drum.

4.7.5 Assemble the outlet stage of the tester as in 4.3.

4.7.6 Record the gasmeter reading, the temperature and relative humidity in the laboratory in proforma A1.

4.7.7 Close the lid and press the green button to start the rotation and pump.

4.7.8 Take the gasmeter reading when the drum stops rotating and the pump stops.

4.7.9 Disassemble the drum (4.4 and 4.5).
4.7.10 Weigh the foams and filters, and enter the values in proforma A1.

4.7.11 Clean the drum either with a vacuum cleaner and a damp cloth or by washing it out with water. If organic solvent is used, care must be taken not to create a flammable or harmful vapour hazard.

5 Calculation of results

5.1 The dustiness values should be calculated as described in paragraph 23.

APPENDIX 2 Suppliers of equipment

Equipment	Supplier
Rotating Drum Dustiness Tester EDT38L	JS Holdings Unit 5 Willows Lane Stevenage Herts SG2 8AB Tel: 01438 316994
Size-selective foams	Foam Engineers Ltd Dashwood Avenue High Wycombe Bucks HP12 3EA Tel: 01494 459537
Reinforced glass fibre filters	Whatman International Ltd St Leonard's Road 20/20 Maidstone Kent ME16 0LS Tel: 01662 674821

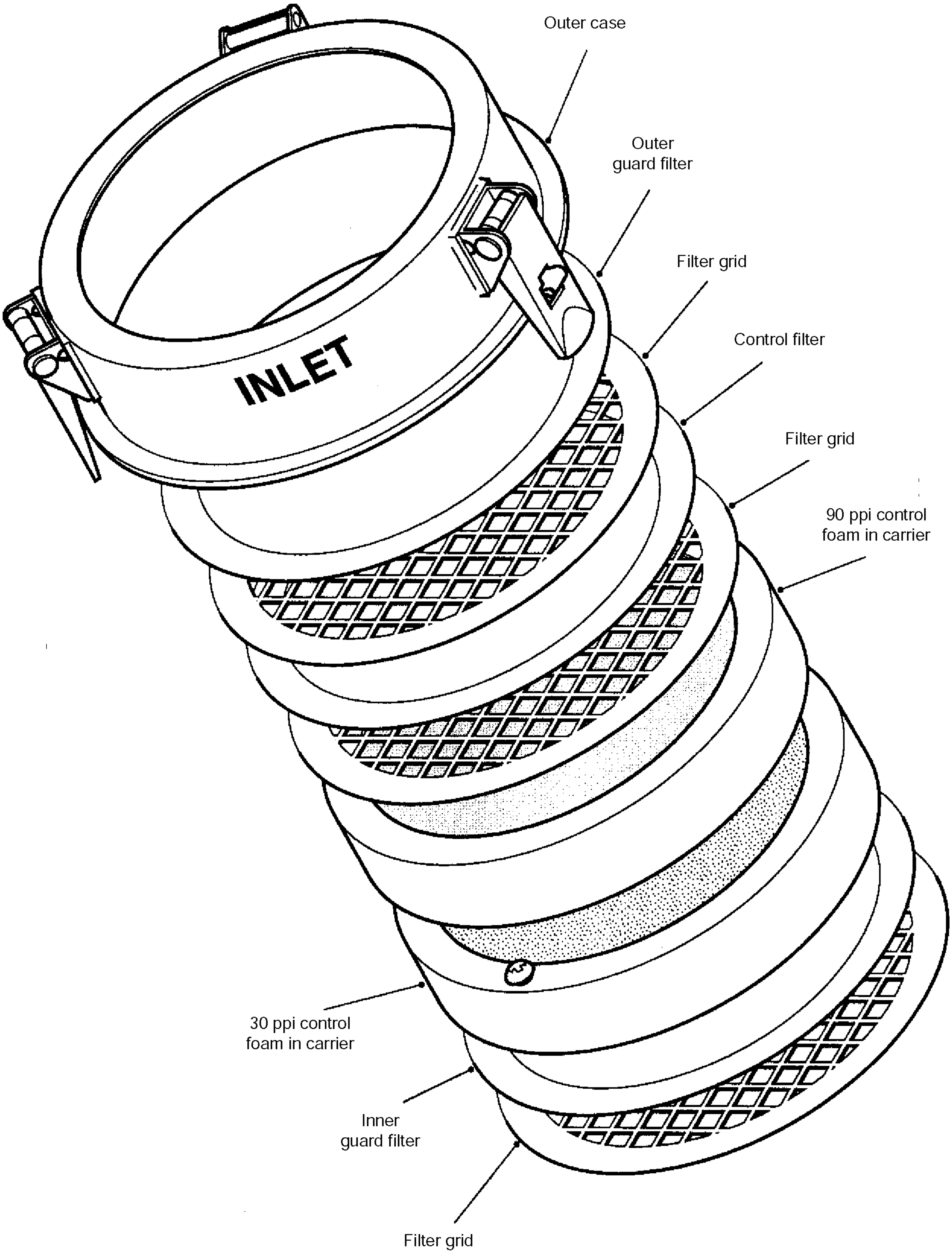

Figure A.1 The inlet stage of the HSE Rotating Drum Dustiness Tester model EDT38L

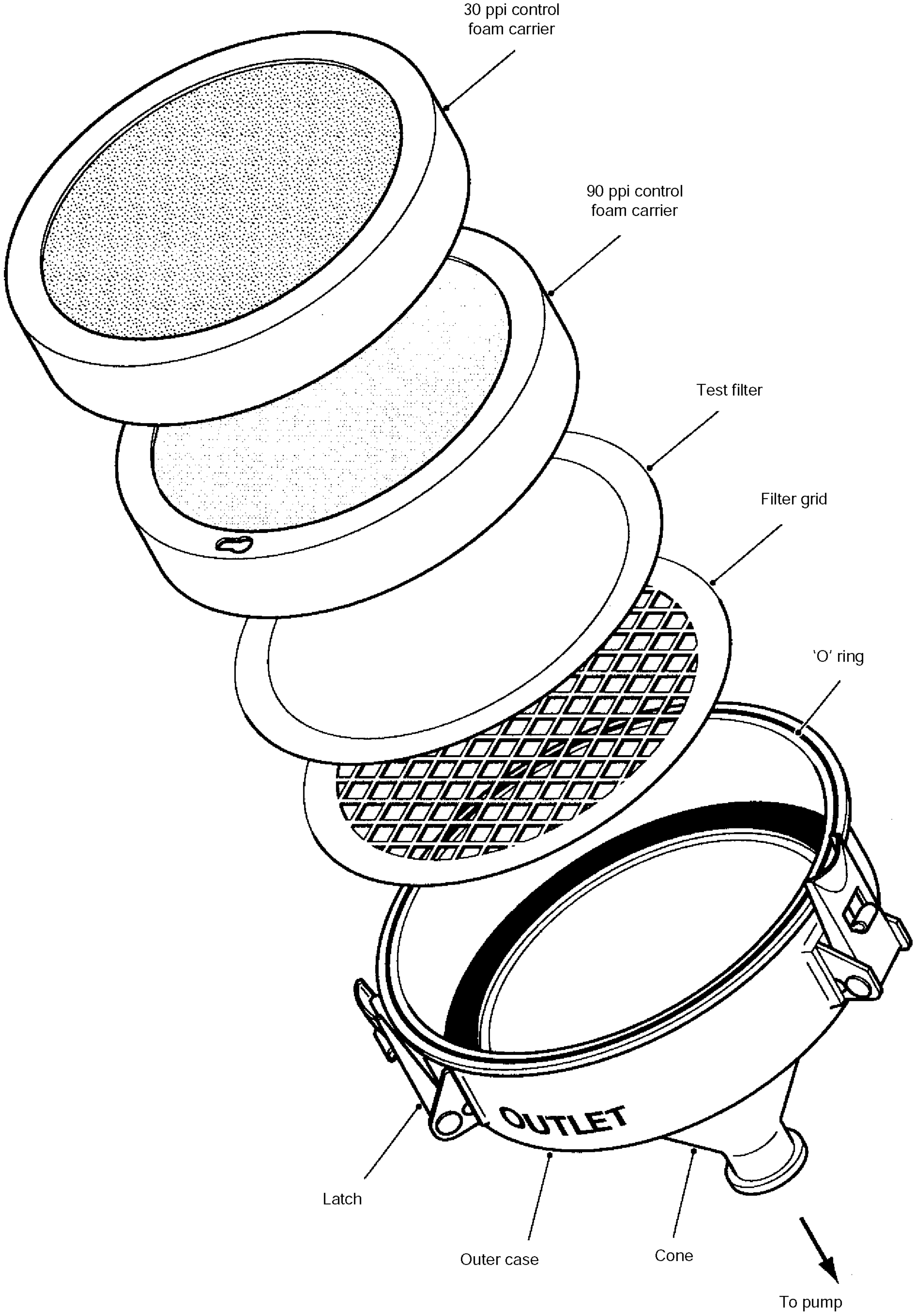

Figure A.2 The outlet stage of the HSE Rotating Drum Dustiness Tester model EDT38L

Proforma A1 - Report

Test material/sample number							Date
Test conditions			Test components		Control weights (mg)	Test weights (mg)	Dust collected (mg)
Gas meter readings (l/m)	Reading before		30 ppi foam	Weight before			M_{T30} - M_{C30}
	Reading after			Weight after			
	Difference			Difference	M_{C30} =	M_{T30} =	
Temperature (°C)			90 ppi foam	Weight before			M_{T90} - M_{C90}
RH(%)				Weight after			
Sample mass (g)				Difference	M_{C90} =	M_{T90} =	
Mass of sample + bottle			Filter	Weight before			M_{TF} - M_{CF}
Mass of bottle				Weight after			
Mass of sample				Difference	M_{CF} =	M_{TF} =	

Comments: ....

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9 Tetra alkyl lead *personal monitoring*
10/2 Cadmium *AA*
11 Cadmium *XRF*
12/2 Chromium *AA*
13 Chromium *XRF*
14 Total inhalable and respirable dust *gravimetric*
15 Carbon disulphide *charcoal tube/GC*
16 Mercury *adsorbent tube (Hydrar) AA*
17 Benzene *charcoal tube/GC*
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20 Styrene *pumped charcoal tube/GC*
21 Glycol ethers *charcoal tube/GC*
22 Benzene *thermal desorption/GC*
23 Glycol ethers *thermal desorption/GC*
24 Vinyl chloride *charcoal tube/GC*
25/2 Organic isocyanates *reagent bubbler/HPLC*
26 Ethylene oxide *charcoal tube/GC*
27 Diffusive sampler evaluation protocol
28 Chlorinated hydrocarbons *charcoal tube/GC*
29/2 Beryllium *AA*
30/2 Cobalt *AA*
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47 Rubber fume in air measured as total particulates and cyclohexane soluble material
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49 Aromatic isocyanates *acid hydrolysis/ diazotisation*
50 Benzene *diffusive/thermal desorption/GC*
51/2 Quartz in respirable dusts *X-ray diffraction (direct method)*
52/2 Hexavalent chromium in chromium plating mists *colorimetric (1,5-diphenylcarbazide)*
53 1,3 Butadiene *thermal desorption/GC*
54 Protocol for assessing the performance of a pumped sampler for gases and vapours
55 Acrylonitrile *diffusive/thermal desorption/GC*
56/2 Hydrogen cyanide *ion-selective electrode*
57 Acrylamide *liquid chromatography*
58 Mercury vapour
59 Manmade mineral fibres
60 Mixed hydrocarbons
61 Total hexavalent chromium compounds in air *colorimetric*
62 Aromatic carboxylic acid anhydrides
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