

Method for

Sodium chloride particulate test for respirator filters

UDC 621.65.01

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	Textile Council
	Trades Union Congress
	United Kingdom Atomic Energy Authority*

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Leathercloth and Coated Fabrics Manufacturers' Association	Steel Castings Research and Trade Association
Ministry of Agriculture, Fisheries and Food	Individual users of respiratory protective equipment
Ministry of Defence, Air Force Department	

This British Standard, having been approved by the Personal Safety Equipment Standards Committee, was published under the authority of the Executive Board on 10 June 1969

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The following BSI references relate to the work on this standard:
Committee reference PSM/14/1
Draft for comment 67/25731

ISBN 580 00442 2

Amendments issued since publication

Amd. No.	Date of issue	Comments
918	March 1972	Indicated by a sideline in the margin

Contents

	Page
Co-operating organizations	Inside front cover
Foreword	ii
1 Scope	1
2 Description of apparatus	1
3 Description of the method for respirator canister tests	1
4 Assembly and adjustment	2
5 The electronic apparatus	4
6 Calibration	4
7 Testing of air filters	6
8 Notes on operation	6
Appendix A Ancillary apparatus	8
Figure 1 — Flow diagram	9
Figure 2 — Stem	10
Figure 3 — Flange	11
Figure 4 — Nozzle	11
Figure 5 — Atomizer bottle	12
Figure 6 — Screwed ring	12
Figure 7 — Atomizer body assembly	13
Figure 7a — Atomizer head assembly	14
Figure 7b — Atomizer assembly	15
Figure 7c — Evaporation tube	16
Figure 8 — Control cock	17
Figure 9 — Photo-multiplier, test tube and flame tube assembly	20
Figure 10 — Sodium chloride test apparatus, general arrangement	23
Figure 11 — Burner	30
Figure 12 — Flow restrictor	31
Figure 13 — Circuit diagram for E.H.T. unit	32
Figure 14 — Photo-electric sodium chloride apparatus circuit diagram	33
Figure 15 — Housing wiring details	35
Figure 16 — Dilution circuit for calibration	36
Figure 17 — Concentration v. deflection graph	37

Foreword

This standard makes reference to the following British Standards:

BS 249, *Leaded brass (58 % copper, 3 % lead) rods and sections (other than forging stock).*

BS 970, *Wrought steels in the form of bars, billets, and forgings, up to 6 in ruling section, for automobile and general engineering purposes. En Series.*

BS 1400, *Schedule of copper alloy ingots and copper and copper alloy castings.*

BS 2091, *Respirators for protection against harmful dusts and gases.*

BS 2577, *Methylene blue particulate test for respirator canisters.*

BS 2874, *Schedule of copper and copper alloys. Rods and sections (other than forging stock).*

BS 3012, *Low density polythene sheet.*

This method of test was developed by the Chemical Defence Experimental Establishment of the Ministry of Defence and acknowledgement is made to the Director, Biological and Chemical Defence for permission to use Provisional Porton Specification No. 1760 and relevant drawings. Acknowledgement is also made to the United Kingdom Atomic Energy Authority (A.E.R.E.) for permission to reproduce Figure 2, Figure 3, Figure 5, Figure 6 and Figure 7.

By this method, an aerosol of sodium chloride particles is employed as a test cloud and the canister is tested by estimating the percentage penetration of the test cloud by means of flame photometry. It has advantages over the methylene blue test in that it gives indication on a galvanometer of the penetration of the canister under test, it is rapid in its response, and accurate determinations are possible in the range 0.001 % to 100 % penetration. Other designs of sodium flame equipments are available to cover all or part of the range of penetrations (0.001 % to 100 %) measurable by the apparatus described in this standard¹⁾.

This test method is also used with modifications for testing face seal leakage of respirators as required by BS 2091, "*Respirators for protection against harmful dusts and gases,*" in which standard the modifications are described.

NOTE Except for the description of the test apparatus, this standard is written in terms of metric (SI) units except for the use of the bar and its submultiples for the expression of pressures (1 bar = 10^5 N/m²), and gives metric (technical) and also inch equivalents which for the purpose of this standard are equally valid. The test apparatus was designed, and is therefore described in inch units.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 37 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

¹⁾ If other designs are employed they must be known to give the same size distribution of the sodium chloride aerosol and substantially the same concentration and penetration in the range of flow rates 15–85 litres/minute. In the event of disagreement between the standard and other designs the results obtained by the standard equipment will be accepted for the purposes of assessing compliance. Details of suitable alternative sodium chloride equipment are available from:

(1) Evans Electroselenium Ltd., Halstead, Essex (The "Respirator Tester"); (2) A.E.R.E. Harwell.

1 Scope

This British Standard gives a method of test for the assessment of the penetration of respirator canisters and cartridges fitted with particulate filters. With modifications it is also for the assessment of face-seal leakage of respirators.

2 Description of apparatus

The apparatus comprises the following main sections:

- 1) *Test cloud generator.* The components employed to produce the test cloud are the atomizer A, (Figure 1), needle valve T_1 , compressed air flowmeter B, pressure gauge C, evaporation tube D, low pressure air flowmeter E and valve T_2 .
- 2) *Control cock.*
- 3) *Test circuit.* The test circuit comprises the bleed valve F, the canister holder G, (which will normally be designed for the particular type of canister to be tested) and the flowmeter H, which measures the flow through the canister.
- 4) *Detector.* The detector is in the form of a flame photometer with its associated apparatus. The flow of air from the canister passes through the test tube J, to which is attached the vertical flame tube K, the horizontal tube L, the light filter box M, and the photo-multiplier and housing N. The photo-multiplier is operated by a power unit P and deflections are observed on a galvanometer $Q^{2)}$.
- 5) *Air supply.* A source of compressed air, a blower and an air dryer are also required.

3 Description of the method for respirator canister tests

3.1 General description. A test cloud of sodium chloride particles is formed by atomizing an aqueous solution of salt and then evaporating the water. A fixed proportion of the cloud which penetrates the container under test is vaporized in a hydrogen flame. The intensity of the yellow colour thus produced is a measure of the amount of salt penetrating the container. Light falling on the cathode of the photo-multiplier is limited to a narrow band of wavelengths in the region of the sodium yellow radiation by a suitable light filter and the resulting photo-current is measured by means of a sensitive galvanometer. The greater the penetration through the container, the greater is the intensity of the yellow coloration and the larger the deflection of the galvanometer.

3.2 Function of the apparatus. The apparatus is shown diagrammatically in Figure 1. A continuous flow of mist from a 1 % solution of sodium chloride in water is produced by atomizer A, (Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, Figure 7, Figure 7a and Figure 7b). The atomizer is operated by a constant flow of compressed air of between 12.5 l and 13.0 l (0.44 and 0.46 ft³) of free air per minute, indicated on flowmeter B, and pressure, regulated by the valve T_1 , maintained at 3.45 bar³⁾ (3.5 kgf/cm² (50 lbf/in²) indicated on the gauge C. The mist passes into the evaporation tube D (Figure 7c), where it mixes with a stream of dry air, from a blower W, which is regulated to a flow of 72.5 l (2.56 ft³) per minute by valve T_2 , the flow being registered by the flowmeter E. During their passage through the tube the droplets evaporate, leaving dry cubes of salt which form the test cloud. The sizes of the particles after evaporation range from 2 microns downwards. To prevent damage to the blower W, a filter S is placed between it and the drying tower to trap particles of the drying material. A similar filter S_2 is placed immediately behind the blower to catch small oil particles.

After leaving the evaporation tube the cloud passes through the two way cock (Figure 8). When the cock is in the OFF position the cloud escapes into the atmosphere and when the cock is turned to the TEST position the cloud is passed to the canister under test and then through the test tube J of the flame photometer.

²⁾ Detailed working drawings of the photo-multiplier, test tube and flame tube assembly may be obtained through the British Standards Institution.

³⁾ 1 bar = 10⁵ N/m².

The hydrogen burner is situated in the vertical flame tube K (Figure 9) which opens at the lower end into the test tube J. Some of the test cloud which has penetrated the filter passes up the flame tube by convection, the convective effect being almost independent of the rate of flow through J.

The hydrogen burner, which gives a flame symmetrical about the vertical axis, is surrounded by a glass tube through which the light passes to the photo-multiplier. The tube, which is made of heat-proof glass, must be free from striations. Hydrogen flow to the burner is regulated by means of the fine control needle valve T_3 to a flow of 30 l/h (1 ft³/h). After adjustment of the flow restrictor the differential pressure should be 10 mbar⁴⁾ (100 mm H₂O; 4 in H₂O).

A small quantity of clean air is blown continuously into the test tube J from the nozzle X. The air is filtered at S_3 and the flow is regulated by the small valve T_4 . The function of this supply is to prevent room air, which might contain considerable amounts of sodium salts, from reaching the test burner when the control cock is in the OFF position.

As the photo-multiplier tube is sensitive over a wide band of wavelengths an interference filter is used to isolate, as far as possible, the yellow sodium lines. At the same time neutral density filters are employed to keep the illumination of the photo-multiplier cathode at a sufficiently low level. The higher the penetration through the container, the higher the value of the neutral density filter required.

The instrument is calibrated by successively bleeding off and diluting to different degrees the cloud of salt particles. The meter deflection is linearly proportional to the mass of salt passing through the flame, up to a salt concentration of about 8 % of the unfiltered test cloud, after which deflection increases more slowly than concentration.

4 Assembly and adjustment

4.1 Panel

4.1.1 The layout on the panel is shown in Figure 10. This design is adequate and may be stood upon a table. There is, however, no objection to enclosing the back of the apparatus in a dust-proof box or to providing legs so that the apparatus is self supporting. The atomizer is to be placed behind the panel in such a manner that the outlet pipe is co-axial and in contact with the mist inlet pipe of the evaporation tube.

4.1.2 The following connections are to be made with $\frac{3}{16}$ inch bore $\frac{1}{12}$ inch wall, rubber tubing:

- 1) Outlet of fine control needle valve for hydrogen to one arm of a $\frac{1}{4}$ inch "T" junction.
- 2) Side arm of "T" junction to manometer connection tube.
- 3) Third arm of "T" junction to inlet of flowmeter.
- 4) Outlet of flowmeter to test burner inlet pipe.
- 5) Valve T_4 to air inlet pipe.
- 6) Filter S to valve T_4 .

4.1.3 The following connections are to be made with $\frac{1}{4}$ inch bore, single braid compressed air hose:

- 1) Compressed air needle valve outlet to lower end of compressed air flowmeter.
- 2) Flowmeter to "T" junction.
- 3) Side arm of "T" junction to pressure gauge.
- 4) "T" junction to atomizer.
- 5) Hydrogen supply line.
- 6) Compressed air supply line.

4.1.4 The following connections are to be made with $\frac{1}{2}$ inch bore $\frac{1}{10}$ inch wall rubber tubing:

- 1) Air inlet "T" junction to filter S_3 .
- 2) Air inlet "T" junction to air flowmeter valve T_2 .
- 3) Air flowmeter outlet to side inlet of evaporation tube.
- 4) Atomizer outlet to mist inlet pipe of evaporation tube.

4.1.5 The following connections are to be made with $\frac{3}{4}$ inch bore $\frac{1}{8}$ inch wall rubber tubing:

- 1) Evaporation tube outlet to inlet of control cock.
- 2) Control cock to bleed valve.
- 3) Bleed valve to canister holder.
- 4) Canister holder to flowmeter.
- 5) Flowmeter to flame photometer test tube.
- 6) Drying tower to filter S_1 .
- 7) Filter S_1 to blower.
- 8) Blower to filter S_2 .
- 9) Filter S_2 to air inlet "T" junction.

4.1.6 Connections are to be of minimum length consistent with the condition that at no point will the connecting tube be bent sharply so as to cause a constriction of the bore. The connections to the container holder shall not be more than 6 feet long.

4.1.7 All tubing shall be washed free from french chalk and dried free from dust before installation.

⁴⁾ 1 mbar = 10^2 N/m².

4.1.8 All connections are to be made gas-tight, those under high pressure being secured with Jubilee type screw clips.

4.2 General layout

4.2.1 The assembled panel with photo-multiplier bracket and control cock is to be mounted rigidly on a bench or table. The electronic unit is also to be sited close to the container holder, but on a separate base as rapid changing of containers will cause a certain amount of vibration which will be transmitted to the electronic part of the apparatus if the same base is used.

4.2.2 The air compressor, air blower and hydrogen cylinder may be placed in any convenient position near the main apparatus.

4.2.3 The apparatus is to be situated in a position free from strong draughts and screened from direct sunlight.

4.3 The burner. The burner of copper (Figure 11), slips over the brass flow restrictor (Figure 12). To secure the correct flame size the hydrogen supply to the burner shall be regulated to 30 l/h and indicated by a flowmeter. A manometer may be employed as an additional check by adjusting the hydrogen pressure to 10 mbar⁵⁾ (100 mmH₂O; 4 in H₂O) at the flow of 30 l/h (1 ft³/h) by counterdrilling the small orifice in the flow restrictor (Figure 12). Drill number 78 (0.016 in dia) should first be used and the hole counterdrilled number 73 (0.024 in dia) in small stages to achieve the required differential pressure.

The height of the burner should be adjusted so that the top is approximately 2 mm ($\frac{3}{32}$ in) below the edge of the opening through which the photo-multiplier views the flame. This is the optimum signal/background position and should be maintained by a suitable spacing collar (Figure 9, item 19).

4.4 Hydrogen supply and flame

4.4.1 The pressure reducing valve on the hydrogen cylinder is to be set to deliver the gas at 138 mbar⁵⁾ (0.14 kgf/cm²) (2 lbf/in²). The pressure at the burner is then adjusted to 10 mbar⁵⁾ (100 mm H₂O; 4 in H₂O) by means of a fine control needle valve on the panel.

4.4.2 To light the hydrogen adjust the pressure as above to about 10 mbar⁵⁾ (100 mm H₂O; 4 in H₂O) and after about a minute apply a match to the top of the chimney; a slight pop indicates that the flame has been lit. The manometer must be watched carefully before the gas is alight as the pressure may change rapidly. The flame is to be lit before the main air flow is turned on, but shall not be allowed to burn for more than a few seconds without this main flow.

4.4.3 The hydrogen flame should burn steadily both when the control cock is turned off and when it is turned so that the air stream passes through the test tube. A small transient flicker will usually occur as the cock is changed from OFF to TEST. Any unsteadiness of the flame when there is no air flow through the apparatus will probably be due to draughts and must be corrected. An imperfect balance of air pressure within the horizontal test tube will cause the flame to flare when the control cock is turned to the TEST position. In the test tube the fall in pressure at the conical expanding inlet is balanced against the resistance of the remainder of the path of the air stream, so that the pressure at the base of the flame tube is equal to that of the atmosphere and there is no forced draught to the burner. Any obstruction near the outlet of the test tube will disturb this balance which is effected by means of a second air stream from a nozzle within the test tube. A second function of this additional air stream is to prevent unfiltered atmospheric air from entering the test tube when the control cock is in the OFF position.

4.5 Adjustment of flow from clean air nozzle.

The adjustment of the air stream from the nozzle is facilitated by allowing the atomizer to produce a cloud of sodium chloride particles in the air surrounding the apparatus. The functioning of the air pipe is to be tested with the control cock in the OFF position, both when the container holder is open and empty, as when containers are being changed, and when the holder is closed with a container in position. An excessive flow from the air pipe may cause flaring of the test flame when the cock is in the TEST position and the main air flow is passing through the tube; this is to be checked. The background light reading when the cock is in the OFF position may be a little different from the reading on TEST but this is of no great consequence.

⁵⁾ 1 mbar = 10² N/m².

5 The electronic apparatus

5.1 Power supply. The stabilized E.H.T. unit for the photo-multiplier is shown in Figure 13. It consists of a half-wave rectifier with resistor-capacitor smoothing followed by a corona discharge stabilizer. The unit provides an output of 1 000 V negative for the photo-multiplier and the total current loading consists of 80 μ A through the dynode chain and less than 2 μ A through the photo-multiplier anode circuit under normal operating conditions. The current from the photo-multiplier is passed through a galvanometer and, in order to reduce the effects of occasional flicks when dust or fibre are drawn through the flame, a 25 k Ω resistor and 250 μ F low working voltage electrolytic capacitor are connected across its terminals (Figure 14). Photo-multiplier wiring details are shown in Figure 15.

5.2 Detector. The deflection of the galvanometer when the photo-multiplier views the clean flame depends on the attenuation by the interference filter and any neutral density filter in the filter box, on the sensitivity of the photo-multiplier and on the E.H.T. voltage. In order to simplify the power unit the voltage is fixed and the galvanometer deflection is therefore controlled by the interference filter and the photo-multiplier characteristics which vary from article to article. The voltage recommended for operation is therefore one which is high enough to give a good clean flame deflection with a high attenuation interference filter and a neutral density filter permanently installed in the light filter box when using a high sensitivity photo-multiplier. To test particulate filters of penetration 0.001 % it is recommended that a clean flame background of about 50 mm (2 in) should be used when the galvanometer is switched to range 1. The galvanometer should always be read on range 1 and deflections reduced to scale by insertion of neutral density light filters in order to preserve the calibration which depends on the resistance of the galvanometer.

6 Calibration

6.1 Clean flame background. The variations in sensitivities of photo-multipliers, transmissions of interference filters, and so on, make it essential that each instrument be calibrated separately. Before assembly all parts shall be washed and dried and be free from dust. The apparatus is then assembled as shown in Figure 1, in the form it will take when filters are being tested. An efficient filter is placed in circuit so that air passing through it, and thence to the burner, is clean.

The following procedure shall then be followed:

- 1) Check that the photo-multiplier is masked.
- 2) Place the sodium line interference filter and a neutral density filter of value at least 3.0 in the light filter box.
- 3) Switch on the galvanometer and zero on range 1.
- 4) Switch on the E.H.T. unit, allow a minute or so for the apparatus to warm up and check the photo-multiplier dark current. This should not be more than 2 mm.
- 5) Light the hydrogen burner and turn on the main air flow adjusting it to 72.5 l/min (2.56 ft³/min). Turn the control cock to TEST.
- 6) Adjust hydrogen pressure to 10 mbar⁶⁾ (100 mm H₂O; 4 in H₂O).
- 7) Turn the galvanometer sensitivity switch to the least sensitive range and unmask the photo-multiplier.
- 8) Return the galvanometer switch to more sensitive ranges noting the galvanometer deflection at each step.
- 9) Add or remove neutral density filters so that on range 1 the deflection from the clean flame is about 50 mm.
- 10) The apparatus should now be left for half an hour and the stability of this background deflection checked every minute or so.

(It is necessary to follow these instructions carefully to check on the clean flame background. It is this background which is used in penetration measurements and as a check on instrumental stability. If the burner is dirty or salt contaminated air reaches the flame, the background will be too large but contaminant on the burner will usually clear itself in a few minutes and this will show as a gradual reduction in deflection. The normal flame should be barely visible and slightly blue.)

When it is obvious that the background is steady the deflection and the value of the neutral density filter in the light filter box are to be noted. In future work this clean flame deflection should be maintained by slight adjustment of the hydrogen pressure when necessary. The pressure should not need to be changed by more than ± 10 % of the standard value.

⁶⁾ 1 bar = 10⁵ N/m².

6.2 Penetration of particles

6.2.1 General details. The apparatus is calibrated in terms of the percentage of the mass of salt in the test cloud which penetrates the particulate filter. It has been shown that the response of the instrument is linearly proportional to the mass of salt penetrating over the range up to about 8 % penetration and over the whole range it is independent of the particle size of the salt. Calibration is, therefore, readily effected by successively bleeding off and diluting the test cloud to a known extent. The test cloud, generated from a 1 % solution of common salt sprayed at 3.45 bar⁷⁾ (3.5 kgf/cm²) (50 lbf/in²) pressure has a size distribution similar to that of the methylene blue cloud (BS 2577:1955⁸⁾) 1 % solution sprayed at 2.07 bar⁷⁾ (2.1 kgf/cm²) (30 lbf/in²). Penetrations measured by the sodium chloride and methylene blue tests agree well for filters having penetrations greater than 0.1 %. For filters of higher efficiency the methylene blue test is less accurate.

6.3 Main calibration. The apparatus needed for bleeding off and diluting the cloud is comprised of the following:

- 1) Two small air blowers, each capable of delivering a flow of 100 l/min (3.53 ft³/min) against a small resistance or one large blower capable of delivering 200 l/min (7.06 ft³/min).
- 2) Two mixing jars of approximately 5–10 litres (0.18–0.35 ft³) capacity to each of which can be connected three rubber hoses of 1 inch internal diameter.
- 3) Three flowmeters, 10–100 l/min (0.35–3.53 ft³).
- 4) Two flowmeters, 1–10 l/min (0.035–0.35 ft³).
- 5) Four high efficiency air filters (it is desirable that each has a charcoal element) to filter air at flow rates of up to 100 l/min (3.53 l/min) with resistance of, preferably, not more than 5 mbar⁹⁾ (50 mm H₂O; 2 in H₂O).
- 6) Bunsen screw clips and rubber hosing of 1 inch internal diameter.

This apparatus shall all be washed and dried free from dust and then assembled as shown in Figure 16.

6.3.2 Procedure for calibration

- 1) With the atomizer off turn on the main and diluting air flows and adjust them so that about 0.1 % of the flow through the test tube is from the main air flow.
- 2) Switch on the electronic apparatus and check dark current.

3) Light the hydrogen and check the clean flame background as previously described. The reading should be within ± 10 % of that decided upon in 5.1 and any discrepancy should be corrected by slight adjustment of the hydrogen pressure.

4) Add a neutral density filter of value at least 3.0 to the filter already in the box, turn on the salt spray and check that the flow and pressure are correct.

5) Read all flowmeters.

6) Reduce the value of neutral density until a steady deflection of at least 30 mm above background is obtained on galvanometer range 1.

7) Allow the salt cloud to flow through the mixing jars for a minute or so, read flowmeters and deflection again and note the value of the neutral density filter.

8) Turn off the salt and note the clean flame background.

9) Alter flow in the diluting circuit by means of the screw clips and repeat 4) to 8).

10) Obtain at least twelve deflections corresponding to concentrations of between 0.01 % and 1 % of the test cloud and at least ten deflections between 1 % and 100 % of the test cloud.

11) Reduce all deflections to those which would have been observed on a galvanometer of infinite scale with only the standard interference and neutral density filter in position (for method see 6.3.4).

12) Construct a graph on logarithmic scales of corrected deflections against concentration. The best line drawn through the plotted points represents the calibration curve and is used in subsequent tests to measure penetration through air filters (Figure 17). It may be more convenient, especially for staff unfamiliar with logarithms, to re-draw deflection/penetration curves (on linear graph paper) over short ranges of penetration.

6.3.3 The following points should be noted.

1) The clean flame background should be checked regularly and any necessary adjustment made to the hydrogen pressure.

2) The flowmeter may not be perfectly steady because of small pressure fluctuations; in consequence there may be a spread of points about the best straight line. The error should, however, be less than 5 %.

⁷⁾ 1 bar = 10⁵ N/m².

⁸⁾ BS 2577:1955, "Methylene blue particulate test for respirator canisters".

⁹⁾ 1 mbar = 10² N/m².

- 3) Care must be taken not to overtighten screw clips or to use flowmeters with small orifices or needle valves otherwise impaction of particles will take place and readings will not be reliable.
- 4) The mixing must be carried out effectively and small baffles may be necessary in the mixing jars.
- 5) Should it be necessary to change the power unit voltage, photo-multiplier or interference filter, the apparatus must be recalibrated as these factors alter the overall sensitivity. It is advisable to carry out spot checks on calibration from time to time. A daily spot check shall be made by measuring the deflection produced when the unfiltered test cloud is passed through the test tube.

6.3.4 Example calibration. Suppose a clean flame background deflection of 53 mm is obtained with the interference filter and a neutral density filter of 0.3 in position. Suppose too, that with a concentration of 0.04 % of the test cloud flowing into the test tube and an additional neutral density filter of 0.9, the galvanometer deflection is 87 mm. It is necessary to correct the reading to that which would have been found (on a galvanometer of longer scale) with a neutral density of 0.3 only.

The transmission of neutral density filters is expressed on a logarithmic scale to base 10, so to the logarithm of 87 (that is 1.9395) add 0.9. The antilog of the sum (2.8395) is the required deflection in millimetres and is found to be 691. From this the clean flame background of 53 mm must be subtracted leaving a deflection, caused by salt, of 638 mm.

If such a point had been found on the best line, which is straight in this region of the calibration, (see 6.2) it would have followed that the deflection for a penetration of 0.001 % was 638/40 (that is 16 mm) on the instrument described for a standard background of 53 mm.

6.4 Accuracy. When the apparatus is properly maintained and used the error should be within ± 5 % at high penetrations (e.g. 70 ± 5 %) and within ± 10 % at the 0.001 % level (e.g. 0.001 ± 0.0001 %). Increased humidity due to the spray depresses the clean flame background by about 3 % (2 mm) and must be taken into account when estimating penetrations of less than 0.001 %. Oil smoke also depresses the clean flame background and care must be taken to eliminate oil droplets.

7 Testing of air filters

7.1 Scope of apparatus. The instrument as described may be used to measure the penetration of filter canisters at flow rates up to 85 l/min (3 ft³/min). The unwanted portion of the test cloud should be allowed to flow to room air through the bleed valve, the remainder being passed through the filter under test, then through a flowmeter to enable the correct flow to be set by the bleed valve and thence to the test tube of the flame photometer. The standard calibration curve may be used for all flows below 85 l/min (3 ft³/min) as the concentration of the cloud passing to the filter is constant and the coloration of the flame only depends on the penetration. However, it is not desirable that flows of less than 15 l/min (0.53 ft³/min) be used as the flame may flicker and a small proportion of the air from the clean air nozzle may dilute the salt cloud entering the test tube. For testing at flows above 85 l/min (3 ft³/min) clean air shall be fed to the apparatus and mixed with the test cloud. In this case the concentration of the cloud will be reduced and the necessary corrections shall be made to the calibration curve.

The control cock shall be turned to the OFF position before the filter under test is removed from the canister holder otherwise time will be wasted while the galvanometer deflection stabilizes after passing the test cloud of full concentration.

It is essential that the test cloud be composed of dry salt particles or the penetration measurements will be incorrect; when the particles are wet the sizes are larger than when dry and the measured penetration is too low.

8 Notes on operation

8.1 Cleaning the burner. The burner is of high conductivity material which ensures that, except for a small area at the tip, the temperature is maintained below that at which salt is vaporized. The effects of contamination are thereby very much reduced. It may be advantageous to rub the tip of the burner with a cloth when, for any reason, the photometer is dismantled.

8.2 Atomizer

8.2.1 The salt solution in the atomizer is consumed at a rate of approximately 15 ml/h. This loss is due in part to the atomization of the solution and in part to evaporation of water from the main bulk of the liquid. The concentration of the solution in the reservoir increases during the operation of the apparatus. The volume of the reservoir is chosen so that the change in concentration and loss in volume of the solution during a period of 8 hours will not cause an appreciable change in concentration of the test cloud.

At the end of 8 hours' use, the reservoir should be emptied and refilled with fresh salt solution. The level of liquid in the bottle must never be above the orifices of the atomizer.

8.2.2 A 1 % solution of common salt is prepared by dissolving 10 g of the salt in 1 litre of distilled water. When the salt has dissolved the liquid is filtered through chemical filter paper to remove dirt etc. which would otherwise clog the jets.

8.2.3 It has been found that the composition of the test cloud remains constant within acceptable limits so long as the flow of air in the atomizer is 12.5–13.0 l/min (0.44 and 0.46 ft³/min) with working pressures of 3.31–3.59 bar¹⁰⁾ (3.37–3.66 kgf/cm²) (48–52 lbf/in²). Care must be taken not to enlarge the small air holes in the atomizer when they are cleared after blockages or the flow of air will become too great.

8.2.4 Blockages of the air holes in the atomizer may be caused by small particles from the rubber pressure hose or the fibre washer. In such cases they may be cleared by removing the nozzle, turning it upside down, and tapping vigorously on a clean surface. Small blockages may sometimes be cleared by rapidly turning the pressure to the atomizer on and off several times. When such treatment fails it will be necessary to prick the holes with a steel wire of 0.013 in diameter. This should be done with the pressure on the nozzle so that cleaning can be stopped as soon as the flowmeter records the correct flow and unnecessary wear is thereby avoided. A particulate filter in the compressed air line will help to prevent blockage of the jets by small particles.

8.3 Neutral density filters. The filters should be inspected regularly and kept clean by polishing with a soft cloth. If of the gelatine-glass type they may be damaged by heat, or by damp which may be deposited soon after lighting the flame, and it is recommended that the edges be sealed to prevent ingress of moisture. These filters slowly change characteristic with use and a better type of neutral density filter is composed solely of glass. To obtain accurate results the density values should be found for sodium light by a substitution method, calculating the appropriate density value from the attenuation of a signal produced by a diluted test cloud.

8.4 Clogging of filters. High quality filters, especially of paper, often clog rapidly and tests should be made in the minimum of time. The instrument can be used to measure clogging rates.

8.5 Limits of test. The test described is suitable for determination of filter penetrations between less than 0.001 % and 100 %; this is due, in part, to the combination of photo-multiplier and power unit, the current delivered by the latter being self-limiting. With different photo-multipliers or power supplies this range of measurement may not be possible and, if the power supply is capable of delivering high currents, damage may be caused to part of the apparatus.

8.6 Cleanliness of the photometer. The interference filter should be cleaned in the same way as the neutral density filters and should be placed in the light filter box close against the opening to the photo-multiplier so that dust is excluded from the multiplier housing.

The condition of the matt black surface inside the flame tube should be checked at regular intervals and the surface paint retouched if necessary.

8.7 Glass chimney. The plain glass chimney in the flame tube should be washed and polished periodically to remove deposits of salt.

¹⁰⁾ 1 bar = 10⁵ N/m².

Appendix A Ancillary apparatus

A.1 Relative humidity control

Accurate results will be obtained only if the particulate matter of the test cloud consists of dry salt particles and for this condition to hold, the relative humidity of the air issuing from the evaporation tube must be below 60 %. Any apparatus for controlling the relative humidity below this limit, which applies when the atomizer is in operation, shall be connected to the inlet side of the blower. The relative humidity of the air can be reduced by passing it first through a drying tower containing 4.5 Kg (10 lb) of activated alumina followed by about 200 g ($\frac{1}{2}$ lb) of calcium chloride. The towers shall be re-charged at regular intervals or when the calcium chloride shows signs of moisture on its surface.

A.2 Air blower

An air blower¹¹⁾ to deliver 100 l/min ($3\frac{1}{2}$ ft³/min) of air at a pressure of 70 mbar¹²⁾ (0.07 kgf/cm²) (1 lbf/in²) is to be provided. The air is to be delivered clean and free from oil and water.

A.3 Compressor

A source of compressed air¹³⁾ capable of delivering 20 litres (0.7 ft³) of dust free air per minute at a pressure of 3.45 bar¹²⁾ (3.5 kgf/cm²) (50 lbf/in²) is required. The air is to be delivered clean and free from water and oil; the pressure of the supply is to remain constant to within 70 mbar¹²⁾ (0.07 kgf/cm²) (1 lbf/in²).

A.4 Photo-multiplier

The photo-multiplier shall be of high sensitivity (approximately 200 A per lumen at 1 000 V) and have a dark current of less than 0.003 μ A¹⁴⁾. Special attention shall be paid to the photo-multiplier housing in order to prevent the ingress of stray light.

A.5 Power supply

The E.H.T. circuit for the photo-multiplier is shown in Figure 13 and Figure 14. It consists of a half-wave rectifier with resistance capacity smoothing. The output is controlled by a corona-discharge stabilizer¹⁵⁾.

A.6 Galvanometer

The signal shall be measured on a suitable galvanometer¹⁶⁾ which will always be read in the sensitive range.

A.7 Neutral density filters

The neutral density filters¹⁷⁾ should reduce by the same amount the intensity of light in the visible spectrum irrespective of its wavelength. The reduction factor is found by taking the anti-logarithm of the neutral density value; thus, neutral density filters of values 0.3 and 2.0 will reduce the intensity of light passed to one half and one hundredth respectively. Suitable values of the neutral density filter may be 0.3, 0.7, 1.0, 2.0 and 3.0. In addition, a further filter will be required to fix the clean flame background at a suitable value; this will probably be in the range 0.2–0.9. For accurate results filters should be calibrated as described in 7.3.

A.8 Interference filters

The sodium light interference filter¹⁸⁾ is employed to reduce the amount of unwanted radiation falling on to the photo-multiplier cathode and hence to increase the signal/background ratio.

¹¹⁾ An air compressor type 1A by Keith and Blackman, 27 Farringdon Avenue, London, E.C.4 is suitable.

¹²⁾ 1 bar = 10^5 N/m²; 1 mbar = 10^2 N/m².

¹³⁾ A Type AC2 air compressor with type S.J. air transformer by Aerograph Co. Ltd., Lower Sydenham, London, S.E.26 is suitable.

¹⁴⁾ A suitable "end window" photo-multiplier is manufactured by E.M.I. Ltd. Type 9542A should be ordered, quoting above date.

¹⁵⁾ A suitable stabilizer is manufactured by the General Electric Co. Ltd., Reference No. SC1/1000.

¹⁶⁾ A suitable instrument, having a 2 second time constant, may be obtained from Pye & Co. Ltd., and is known as the Scalamp Galvanometer Type 7904/S.

¹⁷⁾ Suitable 2 inch square gelatine glass filters of "Grade A" quality may be obtained from Ilford Ltd. Chance Brothers Ltd. produce filters made solely of glass.

¹⁸⁾ A suitable sodium interference filter of 2 inches diameter and having a band width of 90Å is manufactured by Barr and Stroud Ltd., Anniesland, Glasgow, W.3.

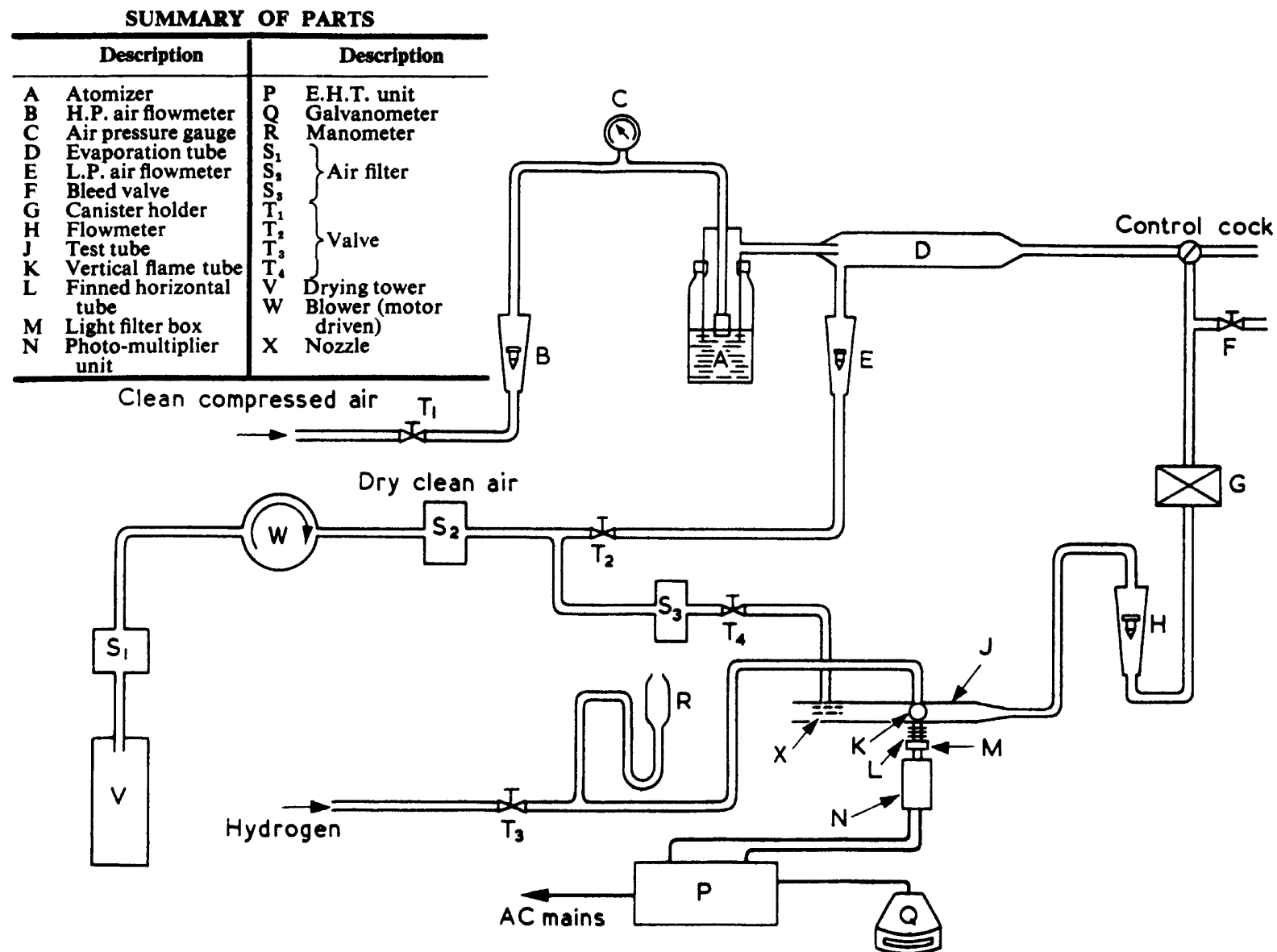


Figure 1 — Flow diagram