

Dec. 27, 1960

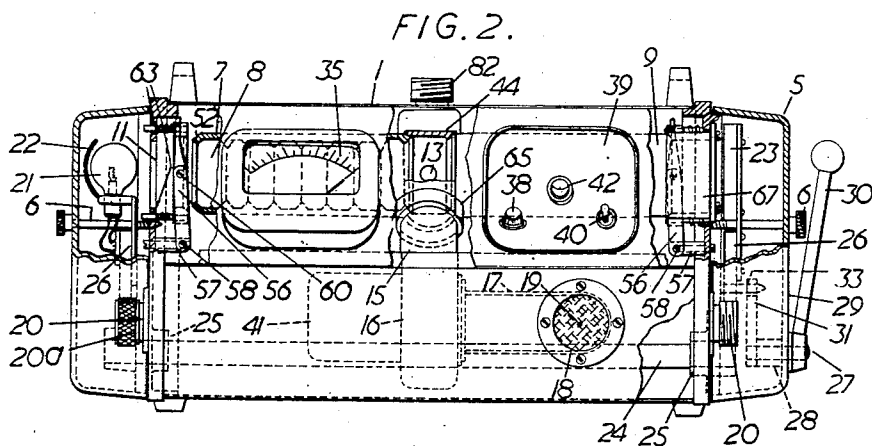
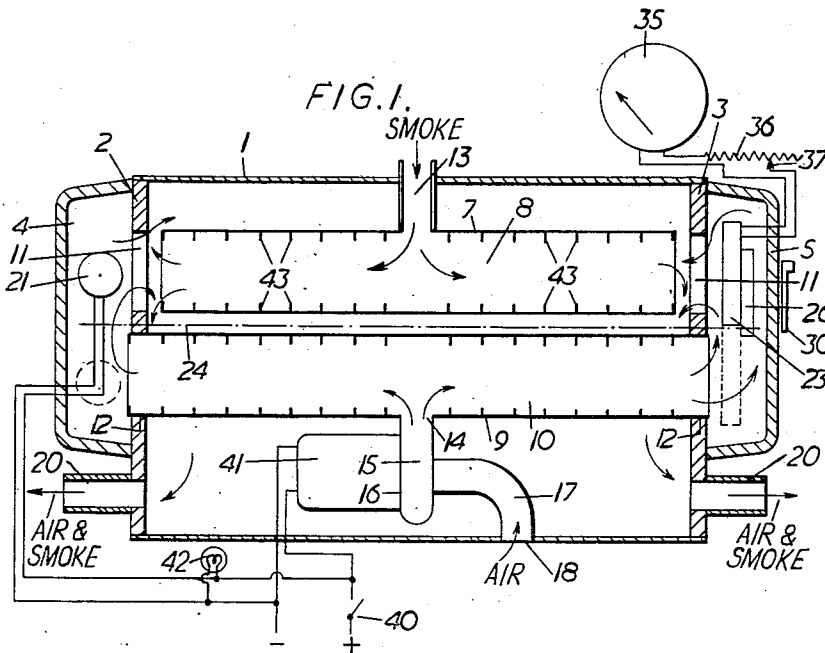
L. HARTRIDGE

2,966,092

SMOKEMETERS

Filed April 28, 1959

3 Sheets-Sheet 1



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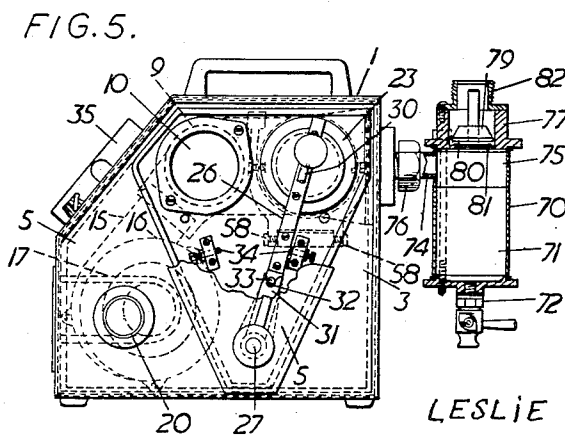
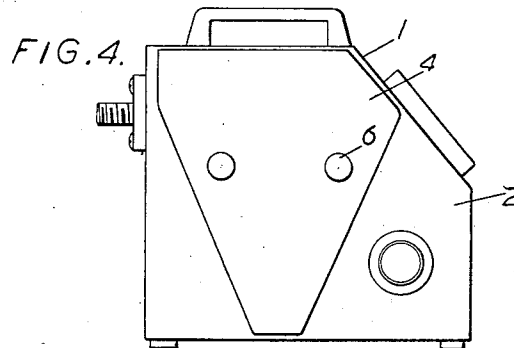
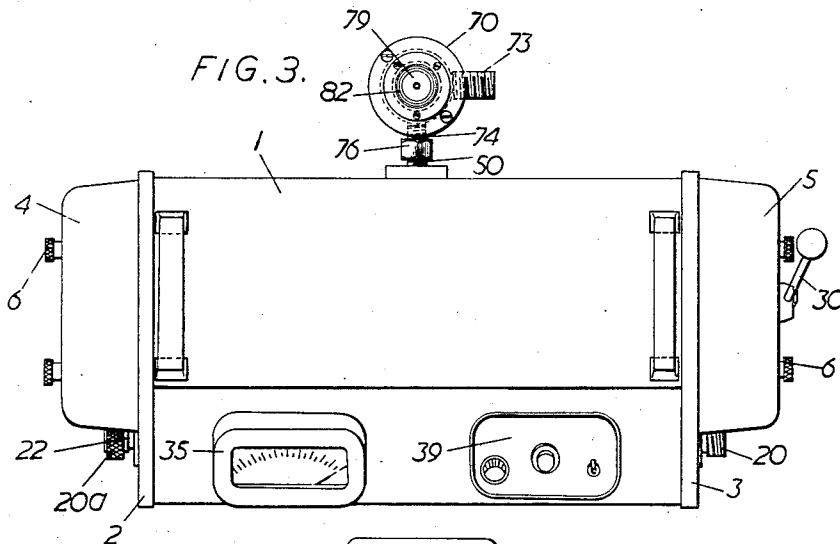
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SMOKEMETERS

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3 Sheets-Sheet 2



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FIG. 6.

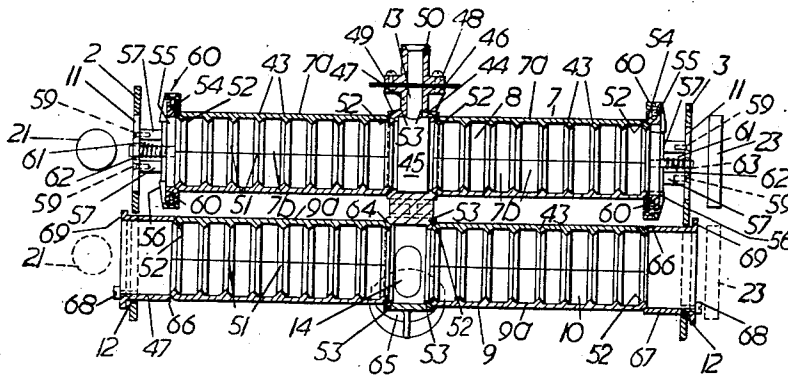


FIG. 7.

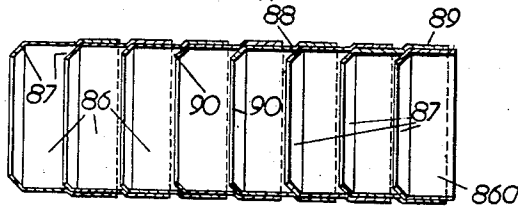


FIG. 8.

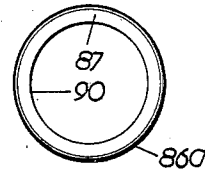
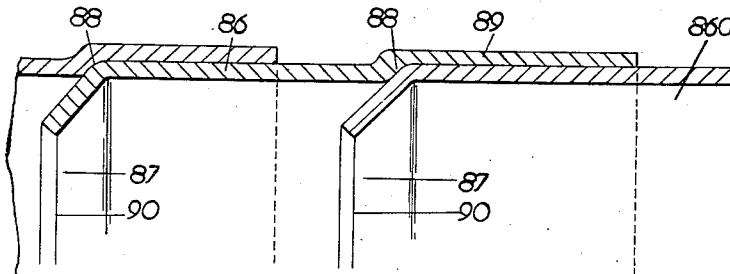


FIG. 9.



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2,966,092

SMOKEMETERS

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7 Claims. (Cl. 88—14)

This invention has reference to improvements in and relating to devices, so-called smokemeters, for use in ascertaining the densities of smoke samples or for comparing the samples with a standard gas, such as air.

Smokemeters to which the invention relates comprise a chamber adapted to have smoke introduced into it, the smoke preferably flowing continuously into and out of the chamber, a source of illumination, a photoelectric cell adapted to receive light from the said source after it has passed through the smoke in the chamber and a micro-ammeter associated with the photoelectric cell to give a reading commensurate with the intensity with which the cell is illuminated by the light source; and said smokemeters preferably comprise a clean air reference chamber to the interior of which the light-source and the photo-cell can be exposed alternatively to being exposed to the interior of the chamber into which smoke is introduced. Thus, when the smokemeter includes a clean air reference chamber the light-source and photo-cell are alternately exposed to the interior thereof and to the smoke chamber so that the micro-ammeter reading resulting from the passage of light through the smoke chamber can be compared with the reading obtained when the light passes to the photo-cell through the reference chamber.

After smokemeters at present in use have been operating for a short time an inaccuracy is introduced into the smoke density reading owing (a) to moisture in the smoke condensing on the inner surface of the chamber and, by reflection, increasing the amount of light which strikes the cell by an amount in excess of that which would reach the cell were the said surface dry and (b) to the deposition of soot particles on the surface of the chamber which reduces the amount of light reaching the cell; and these factors when present together cannot be relied upon to balance each other out because each is a variable. Lagging the material defining the chamber and feeding the smoke at elevated temperature to the chamber partially overcomes the objection arising out of moisture-condensation on the surface of the chamber but the objection arising out of soot-deposition can only be satisfactorily overcome by frequent cleaning of the surface of the chamber.

The principal object of the present invention is the provision of a smokemeter wherein the effect of factors a and b above referred to is for all practical purposes nullified by substantially confining the light from the light source which strikes the photo-cell to light passing directly from the light source to the photo-cell. As a result varia-

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tions of light intensity arising out of increased or lessened reflectivity of the chamber walls affect the photo-cell output only after a prolonged period of use.

In accordance with the invention the internal surface of the chamber into which smoke is introduced is provided at intervals along its length with light barriers adapted to intercept light reflected by the said surface or by soot deposits on the said surface and so prevent the reflected light from reaching the photo-cell. Said light barriers form, in conjunction with the surface of the chamber, pockets in which soot can collect before any light reflected by the soot can affect the reading of the milli-ammeter. Eventually of course the soot builds up to an extent such that the light barriers are unable to intercept the reflected light: at this stage cleaning or replacement of the chamber is necessary.

In order that the said barriers shall not themselves present surfaces parallel with the axis of the tube from which reflection to the photo-cell could take place, the inner peripheries of the barriers have sharp edges the extremities of which, therefore, have no appreciable area.

The smoke chamber may be defined by a number of aligned elemental tubes each having an annular flange directed towards the axis of the tube and terminating in a sharp edge. The material of which the said elemental tubes is made may be of any suitable kind, e.g., plastic or anodised aluminium. Anodised aluminium is at present used because this material has been found to be reasonably resistant to corrosive acids contained in smoke.

Alternatively, the smoke chamber may be defined by a tube or tubes of heat and acid resistant moisture-absorbent material provided with internal ribs forming the light barriers. Suitable material is unglazed ceramic ware or biscuit ware. The or each tube may comprise two semi-cylindrical troughs arranged edge to edge.

When a smokemeter according to the invention comprises the clean air reference chamber, the reference chamber is preferably rendered optically similar to the chamber into which smoke is introduced by providing the reference chamber with barriers as previously set forth; such reference chamber may be provided by aligned elemental tubes previously described or by the tube or tubes of heat and acid resistant, moisture-absorbent material with internal ribs as previously described.

The invention will now be described with reference to the accompanying drawings wherein:

Fig. 1 is a diagrammatic plan view of a smokemeter having a smoke chamber and a reference chamber both provided by tubes and both provided with internal baffles in accordance with the invention;

Fig. 2 is a front elevation of a constructional example of a smokemeter in accordance with the invention, parts of the device being shown in section;

Fig. 3 is a plan view thereof;

Figs. 4 and 5 are views from the left-hand end and righthand end respectively of the said smokemeter;

Fig. 6 is a sectional plan view showing, more particularly, the tubes providing the respective chambers and one way in which the tubes may be mounted;

Fig. 7 is a sectional elevation of a tubular unit built up from a number of nested elemental tubes, four such units providing an alternative to the tubes shown in Fig. 6;

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Fig. 8 is an end view of the unit shown in Fig. 7;
Fig. 9 is a detail relating to the elemental tubes of Figs. 7 and 8;

Figs. 7 and 8 are to a larger scale than Figs. 2 to 6 and Fig. 9 is to a considerably larger scale than Figs. 7 and 8.

The smokemeter shown in Figs. 1 to 5, which is intended more particularly for use in ascertaining the density of the exhaust gases of an internal combustion engine, comprises a main case 1 to the outer faces of the end plates 2 and 3 of which end cover plates 4 and 5 of 10
dished form are secured by fixing screws 6 (best shown in Fig. 2).

A tube 7 adapted to receive a continuous flow of smoke defines the smoke chamber, indicated by 8; a tube 9 adapted to receive a continuous flow of clean air defines the clean air reference chamber, indicated by 10. The ends of the tube 7 terminate short of the end plates 2 and 3 opposite to holes 11 in the said plates; the ends of the tube 9 extend into holes 12 in the end plates 2 and 3 and terminate at about the outer faces of the plates. Smoke is introduced into the chamber 8 through a duct 13 at about the centre of the chamber, said duct entering the interior of the case 1 through the back wall thereof. Clean air is introduced into the chamber 10 at about the centre thereof through a duct 14 communicating with the discharge passage 15 of a blower 16; the intake passage 17 of the blower receives clean air through an opening 18 in the front of the case 1, which openings is covered by a gauze 19. The case 1 has outlet ducts 20 in the end plates 2 and 3.

An electric lamp 21 in the cover 4 provides the light source for the smokemeter at one end of the tubes 7 and 9 whilst the photo-electric cell, indicated by 23, is located at the other end of the tubes in the cover 5. A shaft 24 which is supported in bearing bushes 25 on the end plates 2 and 3 with its axis equidistant from and below the axes of the said tubes has upwardly extending arms 26 rigid with it on which the light source and the cell are mounted at such points that the axes of the source and cell, which are coincident, can be brought into coincidence with the axis of either tube by swinging the arms on the axis of the shaft. For this purpose a stub shaft 27 turnably supported in a boss 28 on the end wall 29 of the cover 5 has a lever 30 secured to it at the end which projects outwardly from the said wall and has at its other end, i.e., the end within the cover, an upwardly extending fork 31 in the slot 32 of which is a pin 33 projecting laterally from the arm 26. Thus forward and rearward movements of the lever 29 swing the arms correspondingly so that the light source and the cell can be aligned with either tube. Exact alignment is ensured by adjustable stops 34 mounted on the end plate 3. The pin and slot connection 33—32 between the lever 30 and the shaft 24 is to provide a readily disconnectible and re-connectible coupling between these elements when the cover 5 is removed, to give access to the cell and, if required, to the tubes, and is replaced.

A micro-ammeter 35 connected to the photo-cell through a circuit comprising a resistance 36 is mounted on the case 1 at the front of the machine, said resistance having a contact 37 movable by means of a knob 38 mounted in a panel 39 at the front of the said case. A convenient range for the micro-ammeter is 0 to 100 microamps. The panel also carries a switch 40 for the light source and for an electric motor 41 driving the blower 16 and carries a pilot lamp 42 in parallel with the lamp 21.

When a test is to be made the switch 40 is closed to energise the light source and the motor 41, the said source and the photo-electric cell are swung into alignment with the tube 9 and the resistance 36 is adjusted to bring the micro-ammeter reading on the scale to a pre-selected value. Smoke is then introduced into the smoke chamber 8 through the duct 13, by conducting the smoke to the duct through a pipe open to a smoke stream, so that the smoke passes continuously through the chamber

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from the middle to the ends thereof, and the light source and cell are swung into alignment with the chamber 8 and the resulting micro-ammeter reading is taken. The smoke passes from the chamber 8 to the interior of the case 1 and escapes therefrom through the ducts 20—which ducts may have hose connected to them for conducting the smoke to a convenient discharge point. Air passing through the chamber 10 enters the interior of the case 1 by way of the hollows of the end covers 4 and 5 and the opening 11 in the end plates 2 and 3 and escapes through the outlet ducts 20. The clean air flow is maintained throughout a test so that the air provides barriers between the smoke issuing from the chamber 8 and the light source and photo-cell. Also the air assists the passage of the smoke towards the outlet ducts 20.

Soot or moisture deposition on the internal surface of the tube would seriously affect the accuracy of the reading obtained in the test above described were provision not made to nullify the effect of such deposition.

In accordance with the principal feature of the present invention such provision resides in furnishing the interior surface of the tube 7 defining the chamber 8 with a plurality of light barriers 43 which intercept all light reflected or likely to be reflected by the interior surface of the tube so that whether the amount of reflected light be large or small only light passing directly from the light source (i.e. without reflection) strikes the photo-cell. The light barriers 43 are also deep enough to define pockets in which soot collects; hence the useful life of the tube before cleaning is necessary is prolonged.

The said barriers may take any suitable form provided they act as efficient interceptors of light which would otherwise be reflected or of reflected light and do not themselves present surfaces parallel with the axis of the tube from which reflection to the photo-cell could take place. This latter condition is satisfied according to the invention by providing the inner peripheries of the barriers with sharp edges the extremities of which, therefore, have no appreciable area.

Two examples of construction of suitable tubes are shown in the accompanying drawings. One of the examples, shown in Figs. 2, 3, 5 and 6, comprises two similar aligned tubular units 7a, 7a each provided by two similar semi-cylindrical troughs 7b arranged edge to edge and a hollow cylindrical muff 44 between them, the hollow 45 of the cylinder being in alignment with the said units. The muff has a flange 46 on a neck portion 47 which flange enables the muff to be mounted in the case 1 by means of screws 48 passing through a flange 49 on a connector 50 outside the case and through holes in the wall of the case and thence to the flange 46. The connector and the flanged neck of the muff define the duct 13. The troughs may be of any suitable material, preferably heat and acid resistant, moisture-absorbent material such as ceramic ware or biscuit ware so that moisture contained in the smoke will be at least partly absorbed by the tube, and each has a plurality of equally spaced knife-edged ribs along its internal surface so positioned as to coincide with the ribs on the other trough and thereby form the barriers 43. The sharp edges of the barriers representing no appreciable area from which light can be reflected are indicated by 51, Fig. 6.

The following test results illustrate the effectiveness of the said light barriers. In the tests smoke of uniform density was passed through a tube not provided with light barriers (Test 1) and through a tube provided with light barriers according to the invention (Test 2). The micro-ammeter scale used in the tests was calibrated to show zero at full photo-cell emission i.e., when the photo-cell was illuminated through clean air and to show greater numerical readings as the cell emission decreased, said readings representing smoke density in arbitrary units compared with clean air. At zero cell emission the micro-ammeter read "100." Prior to each test the micro-

ammeter reading was set to zero on the scale by means of the resistance.

TEST 1

Tube without light barriers

Actual micro-ammeter reading taken while smoke is introduced at intervals for periods of 1 minute	Actual micro-ammeter reading taken during the said intervals after tube had been cleared of smoke, showing effect on reading of light-absorption by sooted surface of tube
First Minute=24.....	2
+1 Minute=23.....	4
+1 Minute=33.....	9
+1 Minute=35.....	12
+1 Minute=38.....	14
+1 Minute=40.....	17
+1 Minute=42.....	19
+1 Minute=42.....	20
+1 Minute=44.....	22
+1 Minute=49.....	27
+1 Minute=51.....	30
+1 Minute=55.....	34

TEST 2

Tube with light barriers

Actual micro-ammeter reading taken while smoke is introduced at intervals for periods of 1 minute	Actual micro-ammeter reading taken during the said interval after tube had been cleared of smoke, showing that soot deposited as during Test 1 does not affect micro-ammeter reading
First Minute=24.....	0
+1 Minute=24.....	0
+1 Minute=24.....	0
+1 Minute=24.....	0
+1 Minute=24.....	0
+1 Minute=24.....	0
+1 Minute=24.....	0
+1 Minute=24.....	0
+1 Minute=24.....	0
+1 Minute=24.....	0
+1 Minute=24.....	0
+1 Minute=24.....	0
+1 Minute=24.....	0

The units 7a, 7a above referred to are mounted within the case 1 in easily removable and replaceable manner. For this purpose, the ends of the units are chamfered at 52 and the ends of the muff have seats 53 complementary to the chamfers on the adjacent ends of the units, and the chamfers at the ends of the units nearest to the end plates 2 and 3 are received in the complementary seats 54 in rings 55 which are spring-urged towards the muff. The mounting for each ring comprises a fork 56 pivotally secured at its lower end to two blocks 57 by screws 58, said blocks being fixed to the end plates 2 and 3 by screws 59. The lower part of each ring lies between the limbs of the fork and the ring is pivotally attached to the limbs by screws 60 diametrically opposite to each other. Hence the pivoted forks and the screws 60 provide mountings for the rings enabling the seats 54 to lie flush on the chamfers 52 with the rings in alignment with the units. The rings are urged into contact with the said chamfers by springs 61 between the respective end plates and the tops and bottoms of the rings, said springs being borne by pegs 62 projecting from the rings and entering holes 63 in the end plates. Removal of the units thus requires the simple operations of removing a detachable part of the casing and forcing the rings away from the units so that the latter can be lifted. Replacement is equally simple and the manner in which it is effected is obvious.

In order that the reference chamber 10 shall be optically similar to the chamber 8 it is formed of aligned units 9a similar in all respects to the units 7a and of a muff 64 which is located between the aligned units 9a and is substantially similar to the muff 44. Muff 64 is integral with muff 44 so it is held in position in the base by the screws 49 and like muff 44 has seats

53 complementary to the chamfers 52 on the adjacent ends of the units 9a. Duct 14 is formed in a hollow boss 65 with which the blower outlet 15 is connected. The chamfers 52 at the other ends of the units 9a bear against seats 66 at the ends of sleeves 67 which pass through the holes 12 in the end plates and are secured to the end plates by screws 68 passing through flanges 69 on the sleeves, said sleeves providing end extensions to the tubes which place the chamber 10 in communication with the interior of the end covers 4 and 5.

The inner surface of the units 7a, 9a are preferably finished matt black in order to assist suppression of reflected light.

The outlet ducts 20 for smoke and air in the constructional example shown are screw-threaded to facilitate the connection thereto of hose and to take a cap nut 20a in the event of one outlet only being utilised for exhausting the smoke and air from the case 1.

Smoke to be introduced into the chamber 8 is preferably first passed through a liquid trap 70 in order to reduce to some extent the moisture entering the chamber. The trap comprises a container 71 having a drain cock 72 at its bottom and having a smoke inlet 73 and a smoke outlet 74 near its top, a baffle 75 being located in the container between the inlet and the outlet. The outlet 74 is attached to the connector 50 by the nut 76, Fig. 5.

It is desirable that the pressure of the smoke sensible at the ends of the tube 9 shall not be in excess of the pressure of the clean air. Otherwise the effectiveness of the air barrier between the ends of the tube 7 and the light source and photo-cell would be impaired. Accordingly the smoke-meter is provided with a smoke-pressure relief valve. Conveniently and as shown the relief valve is located at the top of the water trap. It comprises a hollow cylindrical extension 77 to the top plate 78 of the liquid trap, in which extension is a weight 79 normally resting on a seat 80 at the bottom of the hollow. The seat surrounds a passage 81 between the interior of the trap and the hollow of the extension. The said extension 77 has an outlet connector 82 for hose (not shown). Smoke pressure above a predetermined maximum lifts the weight and smoke escapes through the connector 82. The valve may be of spring-loaded type instead of or as well as of weight-loaded type.

The second example of construction of tubes according to the invention is built up from units of which one is shown in Figs. 7 and 8. The said unit comprises a plurality of elemental tubes 86 and a tube 86a shorter than the tubes 86. One end of each tube bends inwards to provide a flange 87 making an angle of about 45° with the tube axis whilst the other end of each tube 86 is sharply enlarged to provide a shoulder 88 near this end and a socket 89 at this end. The diameter of the socket is such that it can receive the flanged end of a like tube or the flanged end of tube 86a, the extent of inward movement of the said end into the socket being limited by the shoulder 88. Hence a number of tubes nested in alignment as shown provide one unit containing a number of internal light barriers; and four such units can replace the units 7a and 9a, Figs. 2 to 6. The internal periphery of each flange 87 lies in a cone coaxial with the axis of the unit so that sharp edges 90 of no appreciable thickness corresponding to the sharp edges 51 of the units 7a and 9a are presented to the interior of the unit. The material of which the elemental tubes are made may be plastic, anodised aluminium or the like.

I claim:

1. A smoke-meter comprising means defining a chamber, said chamber having open ends, means for introducing smoke into said chamber, a source of illumination located at one end of said chamber, a photoelectric cell, said photoelectric cell being located at that end of said

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chamber opposite to the end at which the source of illumination is located, a microammeter and an electrical connection between said photoelectric cell and said ammeter, and light barriers in said chamber, said light barriers being located along said chamber on the inner surface thereof to intercept all light from said source other than light passing directly from said light source to said photoelectric cell, said light barriers being directed towards that axis of said chamber extending from end to end thereof and having sharp edges opposite to said axis.

2. A smokemeter as claimed in claim 1, wherein said chamber is defined by a plurality of elemental tubes, said tubes being in alignment with each other and each having a flange directed towards its axis, the inner periphery of said flange having a sharp edge.

3. A smokemeter as claimed in claim 1 comprising a hollow cylindrical muff, the axis of said muff being coincident with said axis extending from end to end of chamber, said muff having a part defining a smoke-entry duct, tubular elements abutting the muff at the ends thereof in alignment with the axis of said muff, said muff and said tubular elements defining said chamber, said tubular elements carrying said light barriers, and spring-loaded rings abutting the ends of the tubular elements furthest from the muff, said rings being movable away from the tubular elements to permit of easy removal of said elements from the smokemeter and of easy replacement thereof.

4. A smokemeter comprising means defining a first chamber, said first chamber being open at its ends, means defining a second chamber, said second chamber being open at its ends, said second chamber being located alongside said first chamber substantially parallel to said first chamber, a source of illumination at one end of said chambers, a photoelectric cell at the other end of said chambers, means movably supporting said light source and means movably supporting said photoelectric cell permitting said source and said cell to be brought selectively into alignment with said first chamber or with said second chamber at the open ends of said chambers, a microammeter and an electrical connection between said photoelectric cell and said microammeter, means for introducing smoke into said first chamber and means for introducing clean air into said second chamber, and means for rendering the interiors of said chambers optically similar, said last named means comprising light barriers in said chambers to intercept all light passing through said chambers by way of the open ends thereof other than light passing through said chambers directly from said source to said photoelectric cell, said second chamber and said microammeter permitting a comparison

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to be made between the intensity of direct light reaching said photoelectric cell from said lamp when said direct light passes through clean air in said second chamber and the intensity of direct light reaching said photoelectric cell from said lamp when said direct light passes through said first chamber.

5. A smokemeter as claimed in claim 4 wherein said light barriers are located along the respective chambers on the inner surfaces thereof and are directed towards the longitudinal axes of the respective chambers, said axes being the axes which pass through the open ends of the chambers, said light barriers having sharp edges opposite to said axes.

6. A smokemeter as claimed in claim 4 comprising a first hollow cylindrical muff and a second hollow cylindrical muff, the axis of said first muff being coincident with that axis extending from end to end of said first chamber and the axis of said second muff being coincident with that axis extending from end to end of said second chamber, said first muff having a part defining a smoke-entry duct, said second muff having a part defining a clean air entry duct, tubular elements abutting the respective muffs at the ends of said muffs, said tubular elements being in alignment with the respective muffs, said first muff and said tubular elements abutting said first muff defining said first chamber and said second muff and said tubular elements abutting said second muff defining said second chamber, said light barriers being mounted on said tubular elements, and spring-loaded rings abutting the ends of the tubular elements furthest from the respective muffs, said rings being movable away from the respective tubular elements which they abut to permit of easy removal of said tubular elements from said smokemeter and of easy replacement thereof.

7. A smokemeter as claimed in claim 4, said means for introducing smoke into said first chamber and said means for introducing clean air into the second chamber being located intermediately of the ends of the respective chambers, means at the ends of said second chamber for directing clean air passing through said ends from said clean air introducing means across the ends of said first chamber, and means for limiting the pressure of smoke passing from the ends of said first chamber from said smoke introducing means to a figure not exceeding the pressure of said clean air directed across the ends of said second chamber.

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