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(21) International Application Number: PCT/US83/00593 (22) International Filing Date: 22 April 1983 (22.04.83) (31) Priority Application Numbers: 371,628 371,629 371,630 (32) Priority Dates: 26 April 1982 (26.04.82) 26 April 1982 (26.04.82) 26 April 1982 (26.04.82) (33) Priority Country: US (71) Applicant: WESTERN ELECTRIC COMPANY, INC. [US/US]; 222 Broadway, New York, NY 10038 (US). (72) Inventors: ANDREJCO, Matthew, Julius ; R.D. #2, 203 Hanover Drive, Wrightstown, NJ 08562 (US). POT- KAY, Eugene ; 1015 Hughes Drive, Apt. 17, Hamil- ton Square, NJ 08690 (US).		(74) Agents: HIRSCH, A., E., Jr. et al.; Post Office Box 901, Princeton, NJ 08540 (US). (81) Designated States: BE (European patent), CH (Euro- pean patent), DE (European patent), FR (European patent), JP, NL (European patent), SE (European pa- tent). Published <i>With international search report.</i> <i>With amended claims.</i>
(54) Title: VAPOR-PHASE AXIAL DEPOSITION SYSTEM (57) Abstract <p>A vapor-phase axial deposi- tion system for fabricating, by means of a torch generated soot stream, a glass preform (62) for use in optical fiber production. A nov- el torch (114) is provided having a position adjustable inner tubing (116) allowing simple adjustments of the torch during the fabrication process. Also, the configuration of the deposition chamber (10) and the exhaust system are arranged so as to minimize turbulent flow of the various gases within the chamber to minimize flicker of the torch flame. This results in a more reproducible deposition process.</p> <div data-bbox="813 1366 1340 1859" data-label="Diagram"> </div>		

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VAPOR-PHASE AXIAL DEPOSITION SYSTEM

Technical Field

This invention relates to the fabrication of a
5 lightguide preform using vapor-phase axial deposition techniques.

Background of the Invention

Lightguide fiber is drawn from a solid glass cylinder or preform. One particular technique for
10 fabricating such a preform is described in U.S. Patent 4,062,665 to Izawa et al., which issued December 13, 1977, and is commonly referred to as the vapor-phase axial deposition (VAD) method.

The VAD technique uses a refractory starting
15 member projecting axially into the central portion of an elongated cylindrical chamber. The member rotates along its axis of rotation, which is coincident with the chamber axis, as it is withdrawn therefrom. A glass raw material is introduced into a high temperature portion of a flame
20 near the tip of a stationary torch producing a glassy particulate or soot which is directed onto the end of the rotating refractory starting member. A substantially cylindrical boule of porous soot is formed on the starting member as it is continuously withdrawn from the chamber at
25 a rate equal to the growth rate of the soot upon the boule. The withdrawn soot boule is then subjected to an elevated temperature to consolidate the porous material into a solid, clear cylindrical lightguide preform. Such a technique has been found capable of fabricating lightguide
30 preforms from which low loss lightguide fiber has been drawn. However, several problems are present with presently known systems to perform this process.

It has been observed, for example, that the torch flame in the prior known systems tends to wander and
35 flicker. This results in an inefficient and nonuniform deposition of the soot, loss of reactant materials, and a



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lack of repeatability between runs.

Also, for various processing reasons, it is often desirable to change the physical characteristics of the torch used in the process. In the past, this has been a relatively time consuming and expensive process.

Summary of the Invention

We have discovered that flickering of the torch flame can be reduced by each of several techniques; namely, the use of a deposition chamber so shaped to avoid the presence of dead spaces which give rise to non-constant gas movement within the chamber, thereby causing flame flicker, and the use of a more efficient exhaust system which prevents: a) the presence of clouds of excess soot which move about the chamber in uncontrolled fashion, and b) variations in the chamber gas pressure (which cause flame flicker) caused by fluctuations in the exhaust system. Further, a novel torch is provided allowing rapid and simple changes in the torch configuration and characteristics.

Brief Description of the Drawing

FIG. 1 is an isometric view of the inventive VAD chamber;

FIG. 2 is an isometric view of a soot torch used in the VAD chamber;

FIGS. 3, 4 and 5 are isometric views of the innermost, intermediate and outer tubes of the torch;

FIG. 6 is a cross-sectional view of the soot torch;

FIGS. 7, 8 and 9 are exemplary end configurations of the soot torch;

FIG. 10 is a schematic view of the VAD system;

FIG. 11 is a side view of an exhaust tube; and

FIG. 12 is a cross-sectional view of a soot collection chamber used in the exhaust system.

Detailed Description

FIG. 1 is an isometric view of the instant VAD system, generally referred to by the numeral 5, comprised



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of a housing 10, a torch 12, an input section 14 and an exhaust system 16 (also see FIG. 10).

The housing 10 has a short cylindrical body 18 with front and rear flanges 22 and 24, respectively. The diameter of the cylindrical body 18 is greater than the length thereof. A substantially planar, circular, coverplate 26 is removably fastened to the rear flange 24 by bolts 28-28. A similar coverplate (not shown) is also fastened to the front flange 24 during operation. An arcuate shaped baffle 32 having an opening 34 therein is mounted within the housing 10. The body 18 has an elongated slot 36 and first and second ports 38 and 39, respectively, therethrough. An arcuate plate 40 is slidably positioned between opposed guide members 41-41 and the cylindrical body 18.

The input section 14 is comprised of a hollow, cylindrical member 46, a tapered section 52 and a hollow, small diameter section 56 which passes through the port 39, and terminates at the opening 34 in the baffle 32. A starting member 58 which may be a hollow glass tube having a rounded end portion 62 (e.g., a test tube) is removably connected to a rotatable rod 64 which can move towards or away from the center of the housing 10.

The torch 12 is comprised of a nozzle 112 and a base 114. The nozzle 12 is comprised (FIG. 2) of an inner glass tube 116, a plurality of intermediate glass tubes 118, 120 and 124 and an outer glass tube 126 all of which are concentrically mounted one inside the other. Additionally, a large diameter cylinder or shroud 127 (FIG. 1) is slidably mounted on the outer glass tube 126 and extends beyond the end of the nozzle 112. The axial position of the shroud 127 is adjustable to alter the focusing of the flame emanating from the nozzle 112 during the soot deposition process.

The inner tube 116, as can be seen in FIG. 3, is comprised of a first elongated, small diameter, section 128 having a bore 129 and a large diameter section 130. A



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plurality of splines 132-132 are fixedly mounted and equally spaced about the periphery of the section 128. The splines can comprise glass rods bonded to the tubing section 128.

5 Each of the intermediate tubes 118, 120 and 124 is substantially the same, but of different diameters. Accordingly, only the tube 118 (see FIG. 4) is described in detail. The tube 118 has a substantially uniform diameter bore 134, a plurality of fixedly mounted, equally spaced
10 splines 132-132 on the periphery thereof and a radially extending flange 136 on one end thereof.

 The outer tube 126 (see FIG. 5) is similar to the intermediate tubes 118, 120 and 124, having a large diameter bore 138, but not having any splines on the outer
15 surface thereof. A flange 136 radially extends from one end thereof.

 The concentrically mounted tubes 116, 118, 120, 124 and 126 extend into, and are held in place by, the base 114 as can be seen in the cross-sectional view of FIG. 6.
20 The base 114 is comprised of a plurality of annular support members 140-140 and an annular top member 142. The support members 140-140 and the top member 142, which may be a Teflon polymer material or the like, are held between a top plate 144 and a bottom plate 146 by a plurality of threaded
25 rods 148-148 which pass therethrough and are screwed into the bottom plate 146. Each of the members 140-140 has an opening 152 into the wall thereof to threadably receive a gas line connector 153. Each of the openings 152-152 communicates with a respective one of a plurality of inner
30 annular chambers 154-154 via a respective one of a plurality of channels 156-156. A plurality of washer shaped spacers 158-158 are located between respective flanges 136-136 of the intermediate tubes 118, 120 and 124 and the outer tube 126. A ferrule 162 having an axial
35 passageway 164 therethrough is threadably inserted into the lowermost support member 140 while a locking nut 166 having an opening 168 therein is threadably positioned thereon.



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As shown, the intermediate tubes 118, 120 and 124 are inside, and concentric with, the outer tube 126. The splines 132-132 have an accurately machined thickness which maintains a predetermined, spaced relation between said tubes. The flanges 136-136 are positioned between the ring support members 140-140. Additionally, the annular shaped spacers 158-158 are located between each flange 136. Advantageously, the number of spacers 158-158 between each flange 136 may be readily changed in order to alter the height of one or more of the tubes relative to the other tubes. Thus, the end configuration of the nozzle 112 may be readily rearranged resulting in various configurations, three of which are shown in FIGS. 7, 8 and 9.

In addition to the ability to alter the configuration of the exhaust end of the nozzle 112, the positioning of the inner tube 116 can be adjusted by moving it forwardly or back through the ferrule 162 and then locking it in place by means of the lock nut 166.

The exhaust system 16 is shown in FIG. 10 and is comprised of the serial combination of an exhaust tube 226, an outlet pipe 227, a first injection venturi 228, a soot collection chamber 232 and a discharge line 234 with a second injection venturi 236 therein. A third injection venturi 238 is connected to an air intake line 241 which joins the discharge line 234 for connection to an exhaust hood (not shown).

The exhaust tube 226 (see FIG. 11) has a substantially hollow cylindrical output end 242 and a flared intake 244 having a gradually turned back lip 245. The tube 226 has a constricted throat section 246 intermediate the output end 242 and the intake 244.

The output end 242 of the exhaust tube 226 is fixedly positioned in a mounting plate 247 (FIG. 10). The mounting plate 247 is sealably fastened to a flange 248 on a first end 249 of the outlet pipe 227.

The soot collection chamber 32, shown in cross section in FIG. 12, is comprised of a cylindrical housing



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250 having top and bottom plates 252 and 254, respectively. The top plate 252 has an opening 256 through which a connecting pipe 229 from the venturi 28 passes and projects into the central portion of the chamber 32. The housing
5 250 also has an opening 262 therein to receive a first end 264 of the discharge line 234. First and second concentric cylinders 266 and 268 are mounted within the housing 250. The first cylinder 266 is fixedly attached to, and depends from, the top plate 252 and has an unattached end 269 in
10 spaced relation with the bottom plate 254. The second cylinder 268 is fixedly mounted on the bottom plate 254, within the first cylinder 266, and projects upward, towards and in spaced relation to, the top plate 252.

The injection venturries 228, 236 and 238 are of
15 the known in-line, injection type manufactured, for example, by the Nortel Machine Company, Buffalo, New York, USA (model AM-1500, glass filled Teflon polymer). Filtered compressed air is supplied to each injection venturi 228, 236 and 238 by controlled flow air pumps 272, 274 and 276,
20 respectively. As generally known, such injection venturries operate to control the rate of gas flow therethrough in response to the supplied rate of compressed air, and are useful to control the pressure profile along gas flow lines.

25 In the present arrangement, the operation of the injection venturi 236 influences the pressure measured at P_1 , in the housing 10, while the injection venturi 228 influences the differential pressure between the housing at P_1 and the outlet pipe 227 at P_2 . Based upon the
30 measurement of the differential pressure, the air pump 274 is adjusted until the desired pressure (e.g., standard atmosphere 760 mm Hg) in the housing 10 is achieved. A pressure measuring apparatus 277 references ambient room pressure P_A which is monitored by a barometer 278. The
35 differential pressure ($P_1 - P_2$), monitored by a pressure gauge 279 is nominally selected to a predetermined pressure by adjusting the air pump 272 which controls the flow of



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gas through the injection venturi 228. The injection venturi 238 is also useful to control the overall pressures in the exhaust line 234.

The meters 277 and 279 and the barometer 278 can be of known type and can provide outputs connected to a computer control (not shown) which provides a feedback signal to the air pumps 272, 274 and 276 to control the flow of air to the venturies 228, 236 and 238 to continuously control the pressure within the system 16 and the housing 10.

In operation (see FIGS. 1 and 10), the arcuate plate 40 is moved within the guide members 41-41 to position the axis of the nozzle 112 of the torch 12 at a predetermined angle (e.g., 35°) to the axis of the starting member 58 with the nozzle directed at the end portion 62 thereof.

Gaseous reactants such as SiCl_4 ; GeCl_4 ; POCl_3 or the like, in an argon carrier gas, flow from a source, not shown, into a flexible tube 176 and through the inner tube 116 as shown in FIG. 6. Other gases are caused to flow through the channels 156-156 into their respective chambers 154-154 and out the discharge end of the nozzle 112. Gases such as SiCl_4 flow between the tubes 116 and 118, hydrogen flows between the tubes 118 and 120, argon flows between tubes 120 and 124 while oxygen flows between tubes 124 and 126.

The selection of the various gases, the flow rates thereof, and the like, to produce the soot boule 62 is in accordance with prior known technology.

The nozzle produces a soot which is deposited to form a rotating boule 302 as shown in FIG. 10. The soot boule 302 is simultaneously rotated and withdrawn from the VAD system 5 through the input section 14. Inert gas is directed into the chamber 5 between the surfaces of the growing porous boule 302 and the inner surface of the small diameter section 56 of the input section 14 as indicated by the arrows. The intake 244 of the exhaust tube 226 is



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located proximate the rotating soot boule 302. The undeposited soot and gases are drawn into and through the exhaust tube 226.

It has been found that the flared intake 244 with the gradually turned back lip 245 is effective in removing undeposited soot from behind the flared intake as indicated by the arrows. Additionally, the gradually turned back lip 245 substantially eliminates turbulence of gases at the intake 245 which further enhances soot deposition on the boule 302.

The constricted section 246 of the exhaust tube 226 accelerates the flow of the combustion by-products and undeposited soot extracted from the deposition chamber 5 and as a consequence, produces a forward pressure drop, e.g., 1.2 mm Hg, between the chamber and the outlet pipe 227.

The exhausted gases and undeposited soot pass from the exhaust tube 226, through the outlet pipe 227 and the injection venturi 228 into the soot collection chamber 232. The chamber 232 performs the dual function of extracting soot from the exhaust stream while providing some degree of isolation between the housing 10 and downstream pressure fluctuations. The soot collection chamber 232 (see FIG. 12) provides a serpentine path for the soot and exhaust gases directed therein. The exhaust gases and soot are directed axially into the chamber 232 through the pipe 229. The exhaust gases exiting the inlet pipe 229 expand radially outward and move upward, toward the top plate 252 where the gas again expands. This process is repeated until the gases are finally exhausted through the opening 262 and pass into the discharge line 234. The heavier soot particles deposit on the bottom plate 254 while lighter particulate deposit on the surfaces of the cylinders 266 and 268 as well as the inside wall of the housing 250.

The gases, with any soot residue therein are moved through the discharge line 234 (see FIG. 10), under



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the control of the injection venturies 236 and 238, and exit into an exhaust hood (not shown).

It has been found that the configuration of the housing 10 substantially eliminates large secondary gas circulation cells (i.e., chamber spaces providing unequal heating and cooling of the various gases thereby giving rise to non-uniform or non-constant gas flow patterns). Such elimination of secondary gas circulation cells appears to be due to the confinement imposed by the limited depth of the housing 10. The ratio of the diameter of the housing 10 to the housing depth should be greater than 1.5:1 while the ratio of the housing depth to the diameter of the soot boule 302 is less than 3:1. In one embodiment, the diameter of the housing 10 is 25 cm, the depth is 12 cm, and the boule diameter is 5 cm.

Additionally, as shown in FIG. 1, the elongated axes of the nozzle 112, the boule 62, and the exhaust tube 226 are disposed in a common plane. This further reduces secondary gas circulation.

The foregoing deposition chamber arrangement and exhaust system, it is found, results in a gas flow pattern that substantially eliminates flame flicker and wander resulting in a soot deposition process in which the deposition rate, the density of the soot boule, the boule growth rate and the shape of the deposition surface are reproducible to a degree not heretofore attainable.

The housing 10, the baffle 32, the end plates 26-26, the input section 14 and the exhaust tube 226 are fabricated from Pyrex glass. However, various other glasses or metallic materials may be used.



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CLAIMS

1. A system for exhausting soot from a vapor-phase axial deposition chamber (10) including an exhaust line (27) having first and second ends;

5 CHARACTERIZED BY

a hollow, substantially cylindrical, exhaust tube (26) having a flared intake (44) with a gradually turned back lip (46) projecting into the chamber, an output end (42) connected to the first end of the exhaust line, and a
10 constricted portion (48) intermediate said intake and said output end; and

a collection chamber (51) connected to the second end of the exhaust line to collect soot passing from the deposition chamber via the exhaust tube and exhaust line.

15 2. The exhaust system as set forth in claim 1, wherein the soot collection chamber is comprised of a plurality of tubular members (57, 68, 66) mounted concentrically to provide a circuitous path for the exhausting soot to extract particles therefrom while
20 isolating the deposition chamber from downstream pressure fluctuations.

3. The exhaust system as set forth in claim 1 or 2, comprising at least one in-line injection venturi (28) in the exhaust line to cause gas flow through the system
25 for controlling pressures therein.

4. A vapor-phase axial deposition system including a deposition chamber 10 for fabricating a lightguide soot boule (62) in which a boule starting means (58) is rotated about and along an axis thereof within said
30 chamber and including means (112) for projecting a stream of soot towards the starting means to form the soot boule, thereon,

CHARACTERIZED IN THAT

the axes of the starting means and the soot stream
35 are in a first plane; and
said deposition chamber includes first and second



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walls (24 and 26) disposed generally parallel to and on opposite sides of the first plane, the distance between said walls and said first plane being sufficiently close so as to substantially eliminate flame flicker and wander
5 during the formation of the soot boule.

5. The vapor-phase axial deposition system as set forth in claim 4, including an exhaust system having an exhaust tube with a longitudinal axis in said first plane.

6. The system as set forth in claim 4 or 5,
10 wherein the distance between said walls is less than three times the diameter of the soot boule to be fabricated.

7. A torch for use in an axial-phase deposition system comprising plurality of coaxially aligned tubes

CHARACTERIZED BY

15 an inner tube (116) that is adjustable in an axial direction relative to an outer tube (118).

8. The torch as set forth in claim 7, wherein each of the inner tubes (116, 118, 120) has a plurality of accurately machined splines (132) on the outer surface
20 thereof to maintain a predetermined distance between said tubes.

9. The torch as set forth in claim 7, wherein each of the tubes other than the innermost (116) thereof has a radially disposed flange (136) on a first end
25 thereof.

10. The torch as set forth in claim 9, wherein the radially disposed flanges are separated and held between a plurality of annular spacer members (140).



AMENDED CLAIMS

(received by the International Bureau on 22 September 1983 (22.09.83))

1. A system for exhausting soot from a vapor-phase axial deposition chamber (10) including an exhaust line (27) having first and second ends;

5

CHARACTERIZED BY

a hollow, substantially cylindrical, exhaust tube (26) having a flared intake (44) with a gradually turned back lip (46) projecting into the chamber, an output end (42) connected to the first end of the exhaust line, and a
10 constricted portion (48) intermediate said intake and said output end; and

a collection chamber (51) connected to the second end of the exhaust line to collect soot passing from the deposition chamber via the exhaust tube and exhaust line.

15

2. The exhaust system as set forth in claim 1, wherein the soot collection chamber is comprised of a plurality of tubular members (57, 68, 66) mounted concentrically to provide a circuitous path for the exhausting soot to extract particles therefrom while
20 isolating the deposition chamber from downstream pressure fluctuations.

25

3. The exhaust system as set forth in claim 1 or 2, comprising at least one in-line injection venturi (28) in the exhaust line to cause gas flow through the system for controlling pressures therein.

30

4. A vapor-phase axial deposition system including a deposition chamber 10 for fabricating a lightguide soot boule (62) in which a boule starting means (58) is rotated about and along an axis thereof within said
30 chamber and including means (112) for projecting a stream of soot towards the starting means to form the soot boule, thereon,

CHARACTERIZED IN THAT

35

the axes of the starting means and the soot stream are in a first plane; and
said deposition chamber includes first and second



walls (24 and 26) disposed generally parallel to and on opposite sides of the first plane, the distance between said walls and said first plane being sufficiently close so as to substantially eliminate flame flicker and wander
5 during the formation of the soot boule.

5. The vapor-phase axial deposition system as set forth in claim 4, including an exhaust system having an exhaust tube with a longitudinal axis in said first plane.

6. The system as set forth in claim 4 or 5,
10 wherein the distance between said walls is less than three times the diameter of the soot boule to be fabricated.

7. (Cancelled)

8. (Cancelled)

9. (Cancelled)

15 10. (Cancelled)

11. (New) A torch for fabricating lightguide preforms by the vapor-phase axial deposition process, comprising a plurality of coaxially aligned elongated tubes, characterized by a coaxially aligned inner tube (116) that
20 is movable in an axial direction relative to the other tubes (118, 120);

each of the inner and intermediate tubes having a plurality of accurately machined splines (132) on the outer surface thereof to maintain a predetermined distance
25 between said tubes; and

each of the plurality of outer tubes having a radially extending flange (136) on a first end thereof held between a plurality of annular spacer members (140) to control the axial positioning of the tubes.

30



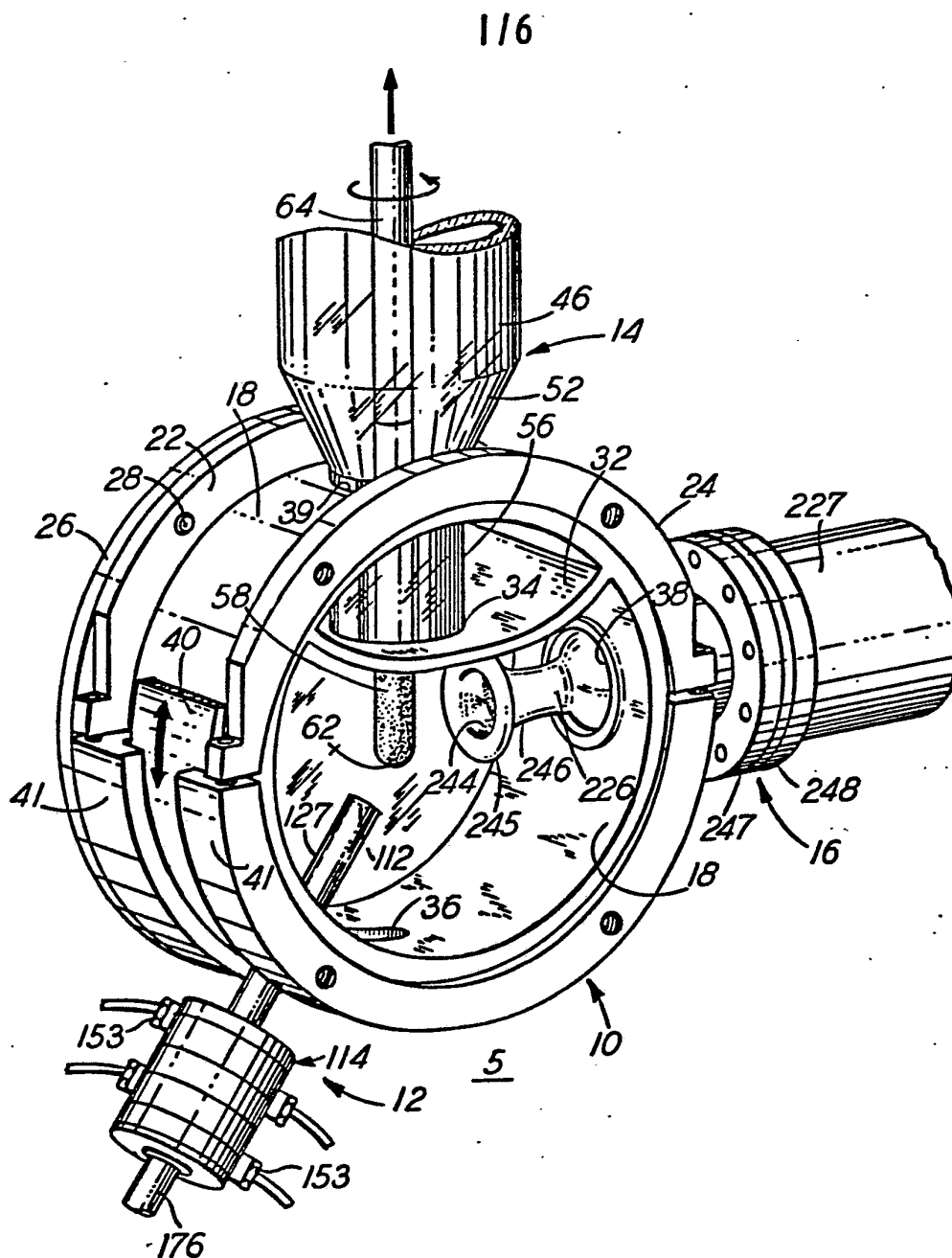
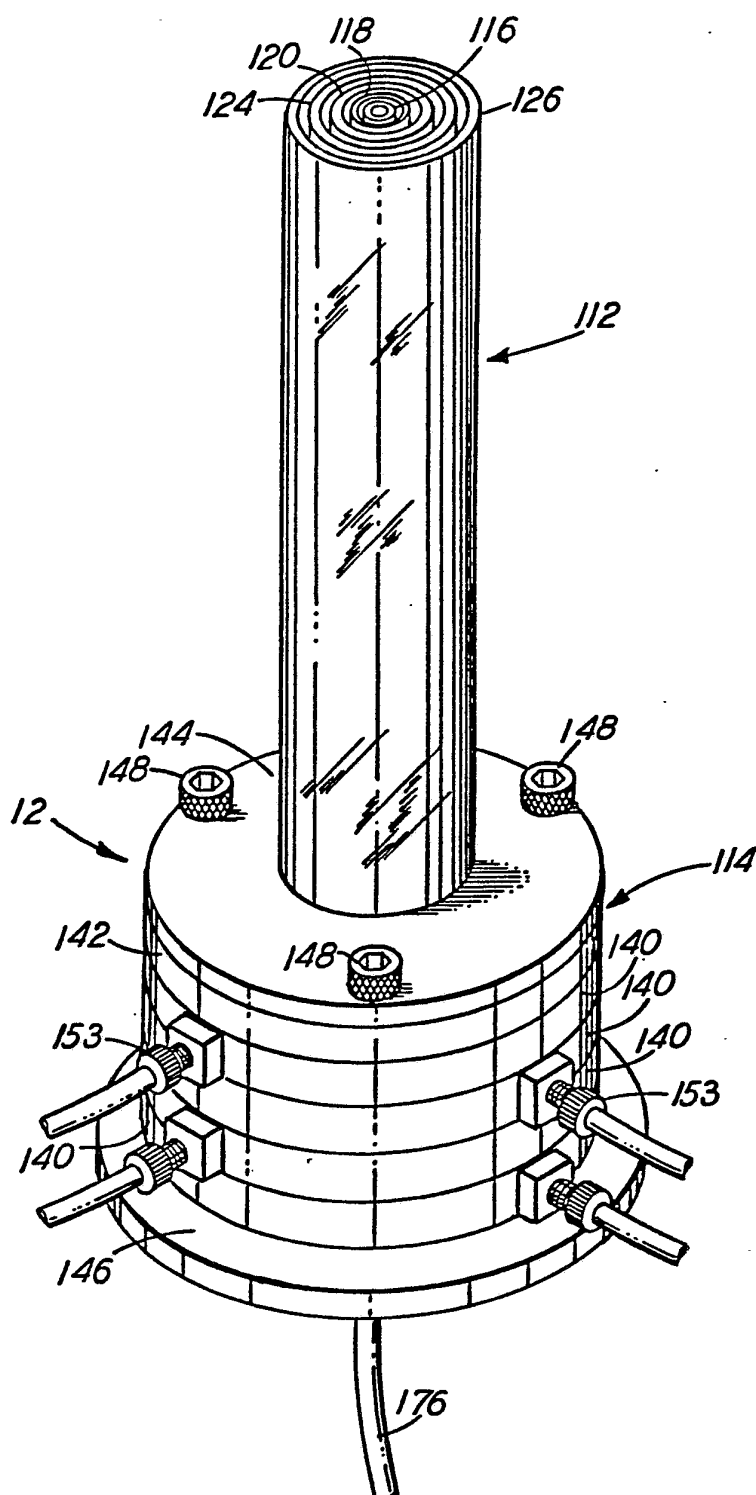


FIG. 1

FIG-2

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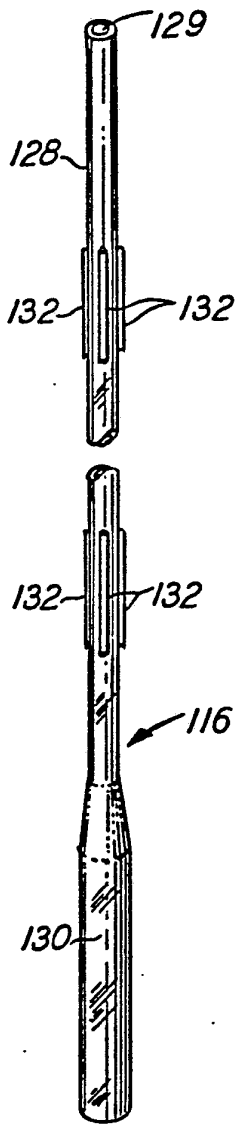


FIG-3

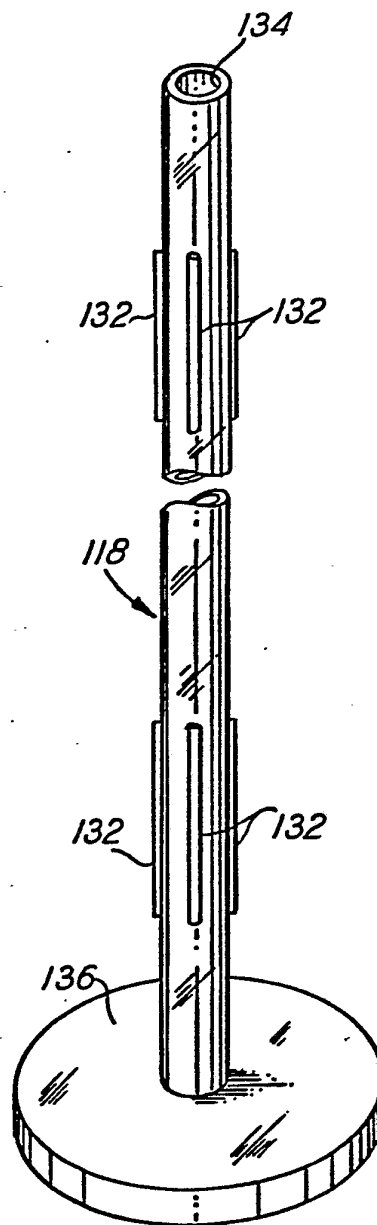


FIG-4

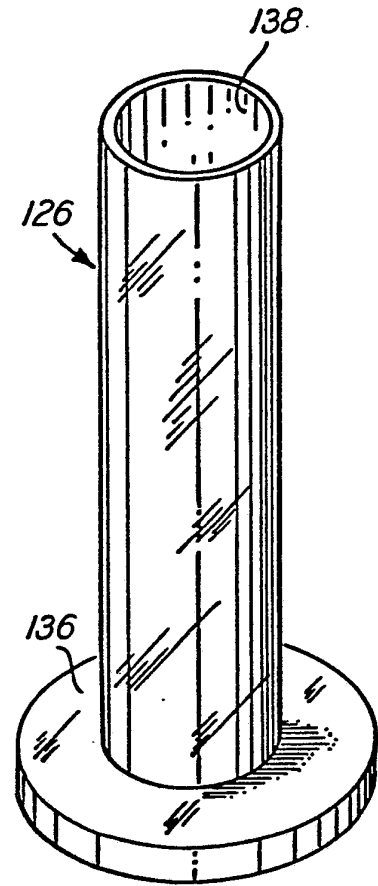


FIG-5

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FIG-6

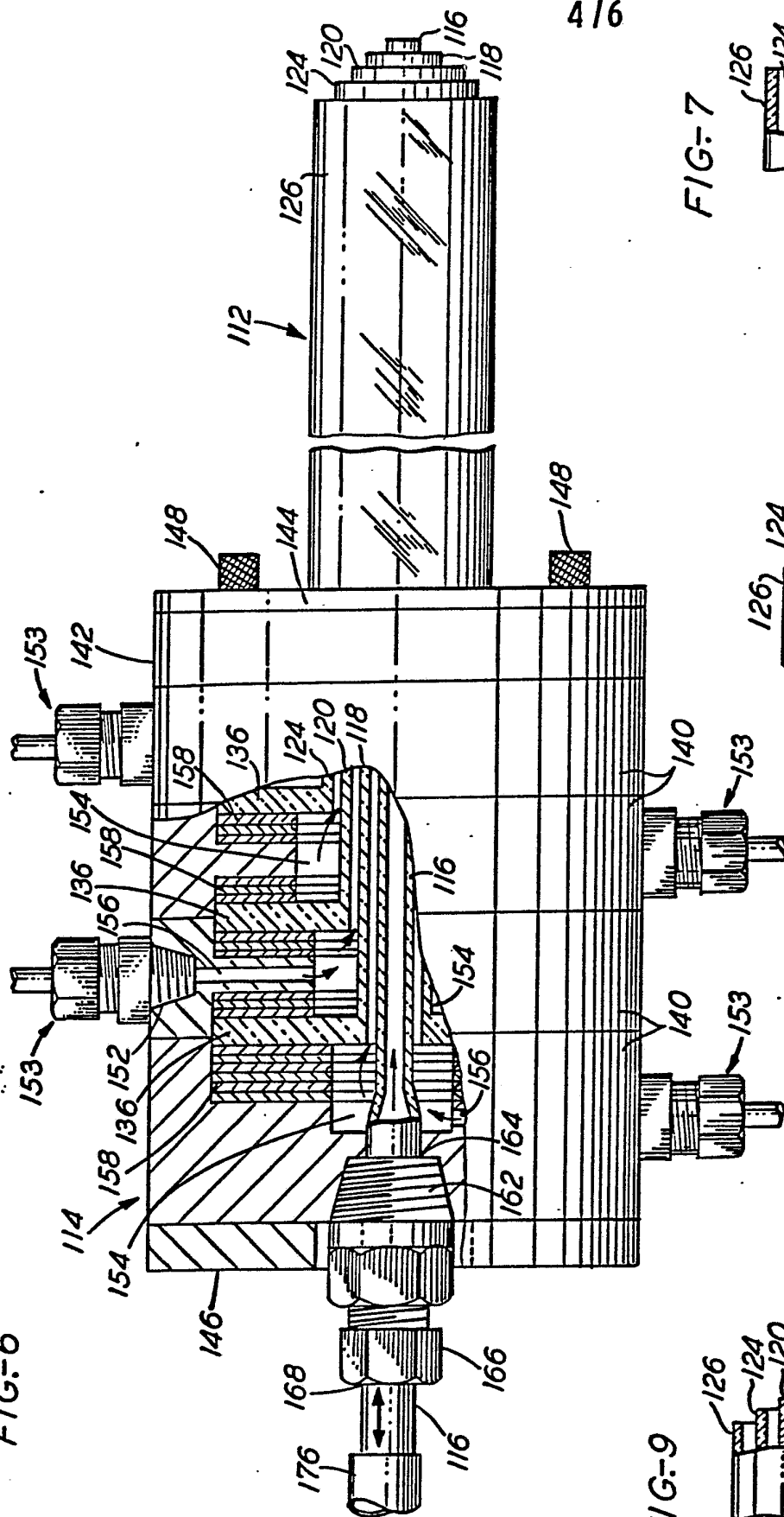


FIG-7

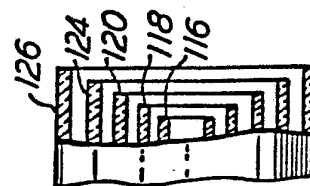
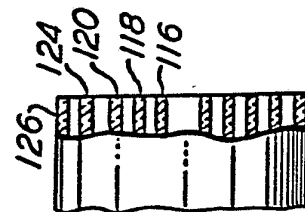
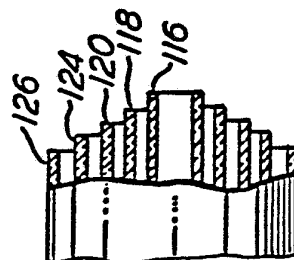


FIG-8

FIG-9



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FIG-10

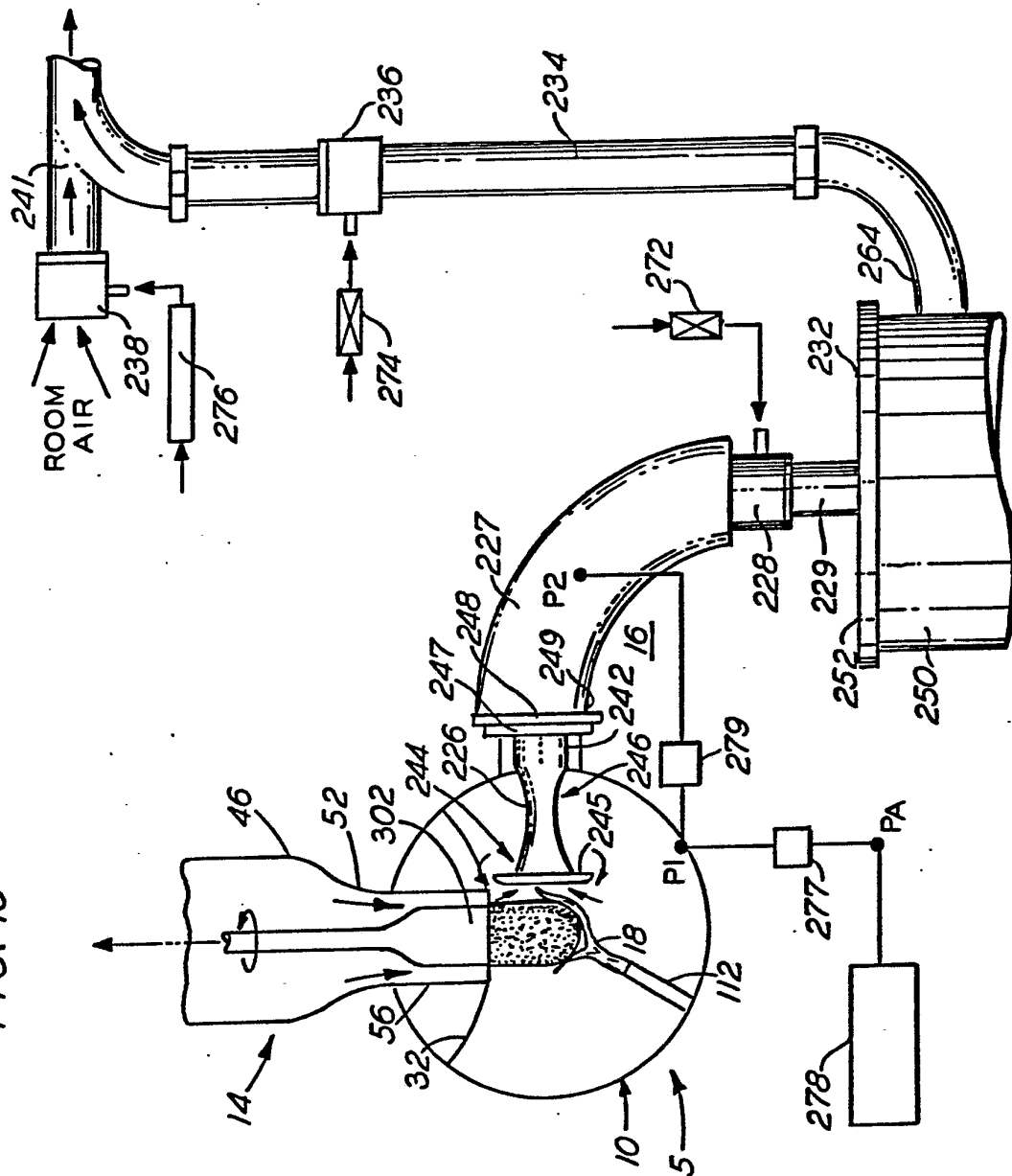


FIG-11

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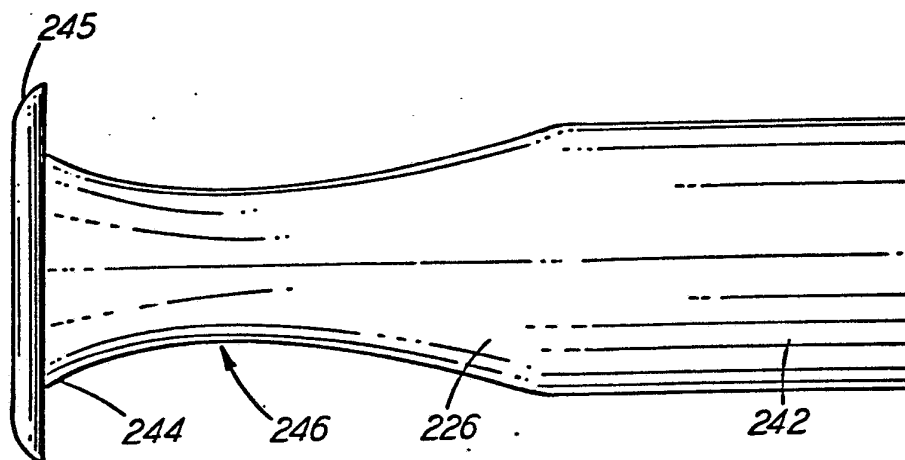
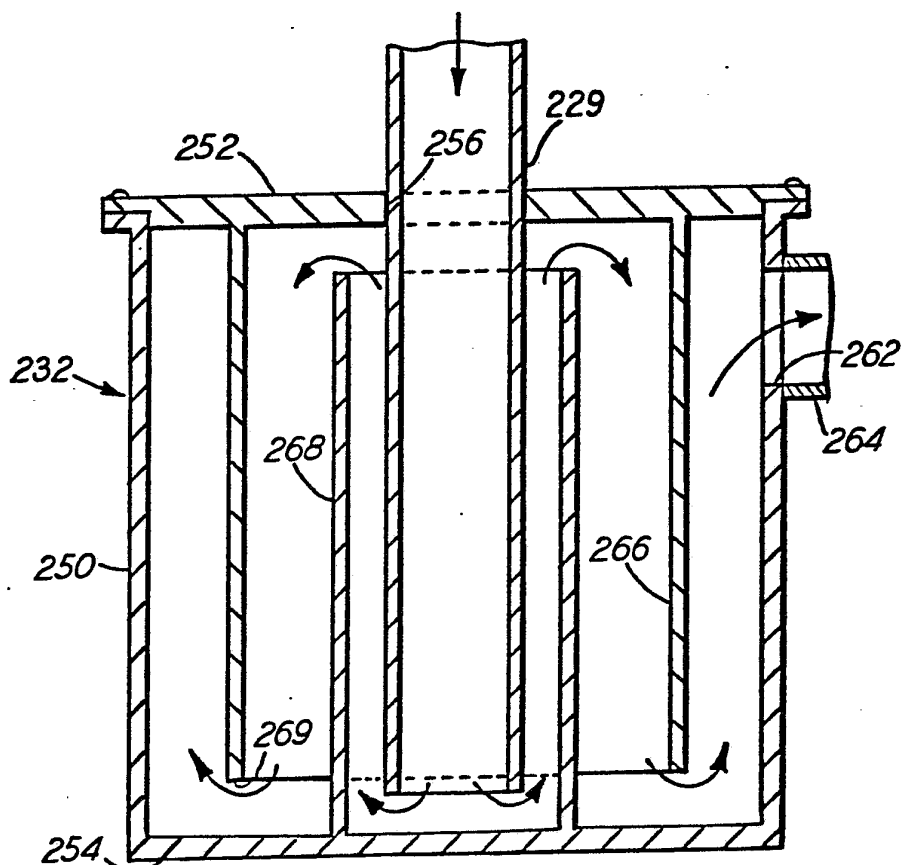


FIG-12



INTERNATIONAL SEARCH REPORT

International Application No PCT/US83/00593

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ³ According to International Patent Classification (IPC) or to both National Classification and IPC INT. CL ³ B01D 53/00, C03B 19/00, F23D 11/12.																																						
II. FIELDS SEARCHED <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black; margin: 5px 0;">Minimum Documentation Searched ⁴</div> <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 25%; border-bottom: 1px solid black;">Classification System</th> <th style="border-bottom: 1px solid black;">Classification Symbols</th> </tr> <tr> <td style="text-align: center; vertical-align: middle; padding: 5px;">U.S.</td> <td style="padding: 5px;">55/1,418,441,468; 65/3.12,11.1,18.2,27,144,335;73/716,736; 118/724,730;138/44;239/416,417,420,422,424;417/155,165,166; 427/163.</td> </tr> </table> <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black; margin: 5px 0;">Documentation Searched other than Minimum Documentation to the extent that such Documents are Included in the Fields Searched ⁵</div>			Classification System	Classification Symbols	U.S.	55/1,418,441,468; 65/3.12,11.1,18.2,27,144,335;73/716,736; 118/724,730;138/44;239/416,417,420,422,424;417/155,165,166; 427/163.																																
Classification System	Classification Symbols																																					
U.S.	55/1,418,441,468; 65/3.12,11.1,18.2,27,144,335;73/716,736; 118/724,730;138/44;239/416,417,420,422,424;417/155,165,166; 427/163.																																					
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴ <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 10%; border-bottom: 1px solid black;">Category ⁶</th> <th style="border-bottom: 1px solid black;">Citation of Document, ¹⁵ with indication, where appropriate, of the relevant passages ¹⁷</th> <th style="width: 10%; border-bottom: 1px solid black;">Relevant to Claim No. ¹⁸</th> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US,A; 932,739, PUBLISHED 31 AUGUST 1909 (WISS), SEE LUGS <u>5</u>.</td> <td style="text-align: center; vertical-align: top; padding: 5px;">8</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US,A; 1,313,605, PUBLISHED 19 AUGUST 1919 (REYNOLDS).</td> <td style="text-align: center; vertical-align: top; padding: 5px;">7-10</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US, A; 1,385,884, PUBLISHED 26 JULY 1921 (MOSS).</td> <td style="text-align: center; vertical-align: top; padding: 5px;">3</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US, A; 1,820,530, PUBLISHED 25 AUGUST 1931 (DAVIES).</td> <td style="text-align: center; vertical-align: top; padding: 5px;">2 and 3</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US, A; 2,104,958, PUBLISHED 11 JANUARY 1938 (THOMPSON), SEE TUBE <u>3</u>.</td> <td style="text-align: center; vertical-align: top; padding: 5px;">1-3</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US,A; 2,944,386, PUBLISHED 12 JULY 1960 (BERTIN ET AL), SEE TUBE <u>5</u>.</td> <td style="text-align: center; vertical-align: top; padding: 5px;">1-3</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US,A; 3,073,534, PUBLISHED 15 JANUARY 1963 (HAMPSHIRE) SEE <u>2,8,13</u>.</td> <td style="text-align: center; vertical-align: top; padding: 5px;">9 and 10</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US,A; 3,642,521, PUBLISHED 15 FEBRUARY 1972 (MOLTZAN ET AL).</td> <td style="text-align: center; vertical-align: top; padding: 5px;">7</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US,A; 3,644,607, PUBLISHED 22 FEBRUARY 1972 (ROGUES ET AL).</td> <td style="text-align: center; vertical-align: top; padding: 5px;">7</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US,A; 3,668,835, PUBLISHED 13 JUNE 1972 (VICARD), SEE INLET <u>3</u>.</td> <td style="text-align: center; vertical-align: top; padding: 5px;">1-3</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US,A; 3,698,936, PUBLISHED 17 OCTOBER 1972 (MOLTZAN).</td> <td style="text-align: center; vertical-align: top; padding: 5px;">7</td> </tr> </table>			Category ⁶	Citation of Document, ¹⁵ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸	A	US,A; 932,739, PUBLISHED 31 AUGUST 1909 (WISS), SEE LUGS <u>5</u> .	8	A	US,A; 1,313,605, PUBLISHED 19 AUGUST 1919 (REYNOLDS).	7-10	A	US, A; 1,385,884, PUBLISHED 26 JULY 1921 (MOSS).	3	A	US, A; 1,820,530, PUBLISHED 25 AUGUST 1931 (DAVIES).	2 and 3	A	US, A; 2,104,958, PUBLISHED 11 JANUARY 1938 (THOMPSON), SEE TUBE <u>3</u> .	1-3	A	US,A; 2,944,386, PUBLISHED 12 JULY 1960 (BERTIN ET AL), SEE TUBE <u>5</u> .	1-3	A	US,A; 3,073,534, PUBLISHED 15 JANUARY 1963 (HAMPSHIRE) SEE <u>2,8,13</u> .	9 and 10	A	US,A; 3,642,521, PUBLISHED 15 FEBRUARY 1972 (MOLTZAN ET AL).	7	A	US,A; 3,644,607, PUBLISHED 22 FEBRUARY 1972 (ROGUES ET AL).	7	A	US,A; 3,668,835, PUBLISHED 13 JUNE 1972 (VICARD), SEE INLET <u>3</u> .	1-3	A	US,A; 3,698,936, PUBLISHED 17 OCTOBER 1972 (MOLTZAN).	7
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<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>¹⁶ * Special categories of cited documents: ¹⁵</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 50%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"A" document member of the same patent family</p> </div> </div>																																						
IV. CERTIFICATION <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; border-bottom: 1px solid black; padding: 5px;"> Date of the Actual Completion of the International Search ¹ 03 AUGUST 1983 </td> <td style="width: 50%; border-bottom: 1px solid black; padding: 5px;"> Date of Mailing of this International Search Report ² <div style="text-align: center; font-size: 1.2em; font-weight: bold;">12 AUG 1983</div> </td> </tr> <tr> <td style="border-bottom: 1px solid black; padding: 5px;"> International Searching Authority ¹ ISA/US </td> <td style="border-bottom: 1px solid black; padding: 5px;"> Signature of Authorized Officer ²⁰ <div style="text-align: center;"> RICHARD V. FISHER </div> </td> </tr> </table>			Date of the Actual Completion of the International Search ¹ 03 AUGUST 1983	Date of Mailing of this International Search Report ² <div style="text-align: center; font-size: 1.2em; font-weight: bold;">12 AUG 1983</div>	International Searching Authority ¹ ISA/US	Signature of Authorized Officer ²⁰ <div style="text-align: center;"> RICHARD V. FISHER </div>																																
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FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	US,A; 3,966,446, PUBLISHED 29 JUNE 1976 (MILLER).	4-6
A	US,A; 4,062,665, PUBLISHED 13 DECEMBER 1977 (IZAWA ET AL).	1-6
A	US,A; 4,135,901, PUBLISHED 23 JANUARY 1979 (FUJIWARA ET AL).	4-6
A	US,A; 4,162,908, PUBLISHED 31 JULY 1979 (RAU ET AL).	1-10
X	US,A; 4,224,046, PUBLISHED 23 SEPTEMBER 1980 (IZAWA ET AL) SEE TUBE <u>11</u> .	7-10
A	US,A; 4,242,118, PUBLISHED 30 DECEMBER 1980 (IRVEN).	4-6

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE ¹⁰

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers _____, because they relate to subject matter ¹² not required to be searched by this Authority, namely:

2. ☐ Claim numbers _____, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out ¹², specifically:

VI. ☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING ¹¹

This International Searching Authority found multiple inventions in this international application as follows:

Invention I: Claims 1-6 drawn to a vapor-phase axial
deposition system; and

Invention II: Claims 7-10 drawn to a torch.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☒ No protest accompanied the payment of additional search fees.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No ¹⁸
A	US,A; 4,261,720, PUBLISHED 14 APRIL 1981 (HELBING).	1-3
P	US,A; 4,345,928, PUBLISHED 24 AUGUST 1982 (KAWACHI ET AL), SEE FIGURE 2A.	4-6
P	US,A; 4,367,085, PUBLISHED 04 JANUARY 1983 (SMTO ET AL), SEE FIGURE 6.	1-6
A	GB, A; 163,782, PUBLISHED 23 MAY 1921 (CATERALL).	7-10