

[54] **BURNER CONSTRUCTION FOR FLAME SPECTROPHOTOMETER AND SYSTEM THEREFOR**

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[22] Filed: **Oct. 30, 1970**

[21] Appl. No.: **85,347**

[52] U.S. Cl. ....**431/90, 356/87, 431/126**

[51] Int. Cl. ....**F23n 3/00**

[58] Field of Search .....**431/4, 126, 90; 356/87, 187;**  
**234/338, 403, 486, 405, 418**

[56] **References Cited**

**UNITED STATES PATENTS**

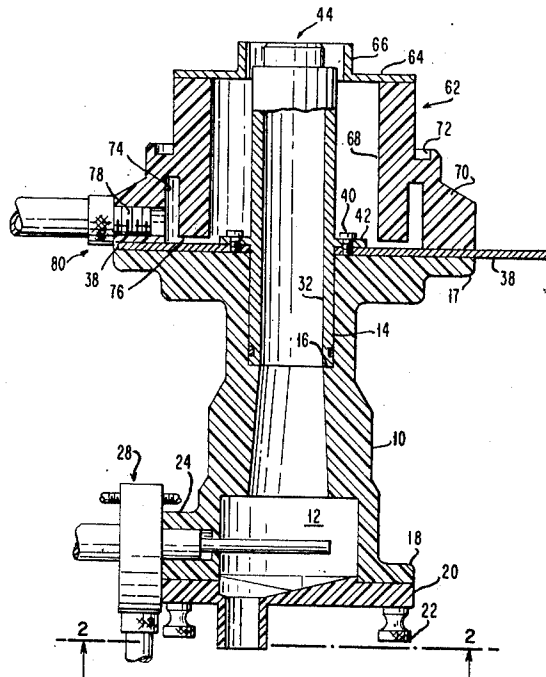
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*Primary Examiner*—Edward G. Favors  
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[57] **ABSTRACT**

There is provided a spectral flame burner of the preatomizer type having a sample tube the outlet of which is disposed within a carrier gas conduit terminating in a nozzle. The spacing between the outlet of the sample tube and the outlet of the nozzle is adjustable during the normal operation of the analyzer system, including the burner. Improved means is provided to withdraw the outlet of the sample tube to a position in which sufficient gas pressure is developed in the sample tube to blow out any obstruction in the latter, including a lead screw mechanism operatively associated with the sample tube. The burner has an improved cap construction and a control system is provided for the burner to safely shut down the burner when a defect is detected in the burner system.

**22 Claims, 9 Drawing Figures**



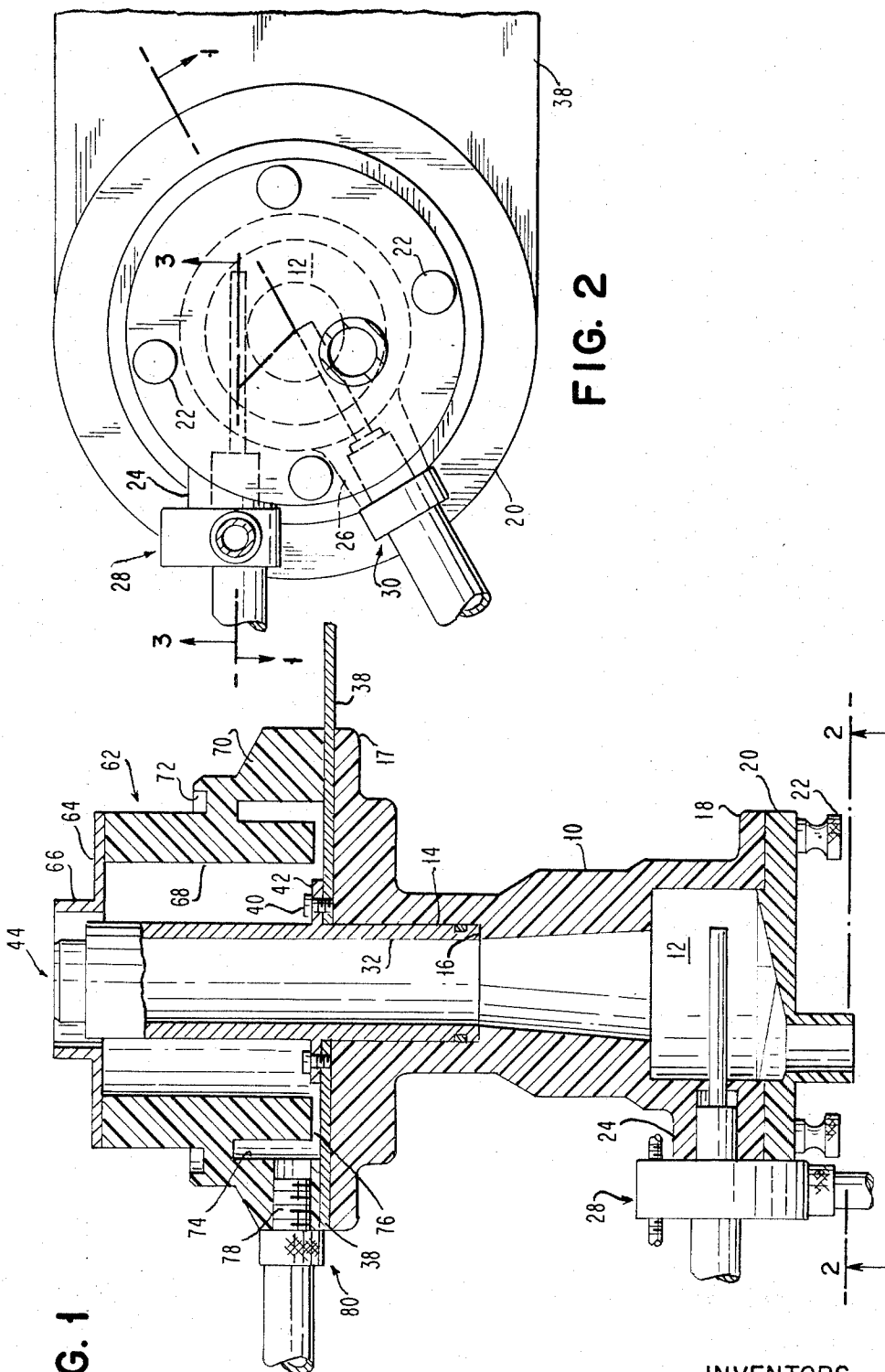


FIG. 1

FIG. 2

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FIG. 3

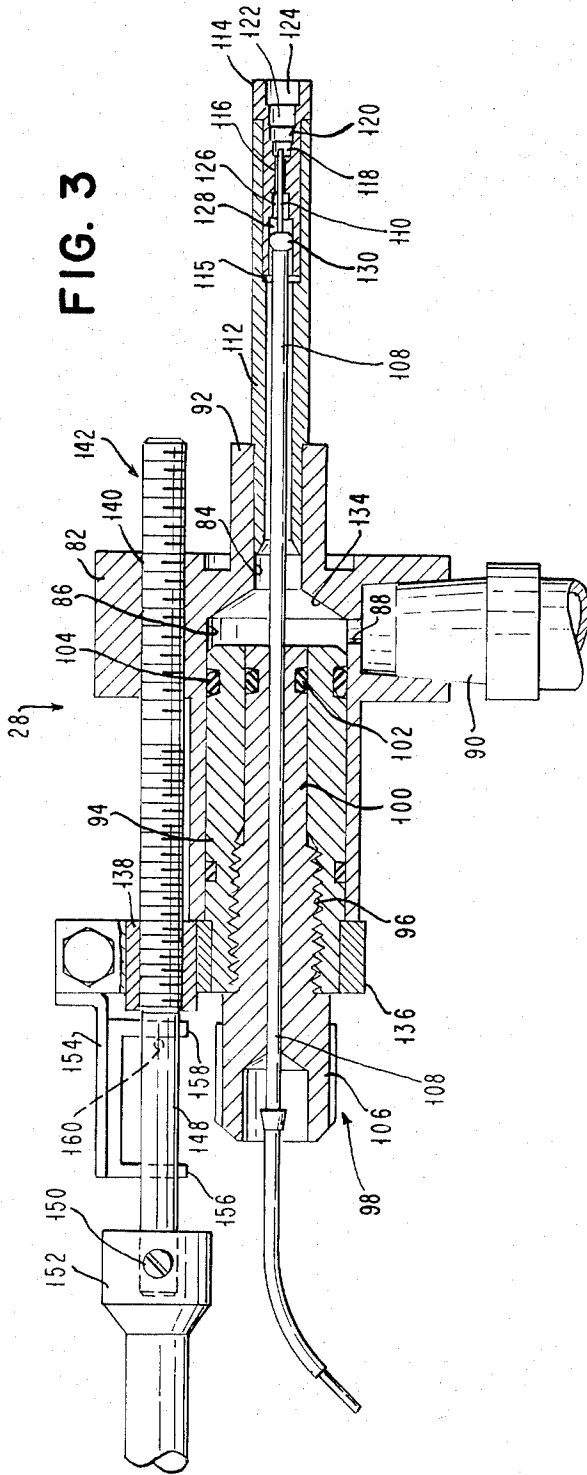


FIG. 3A

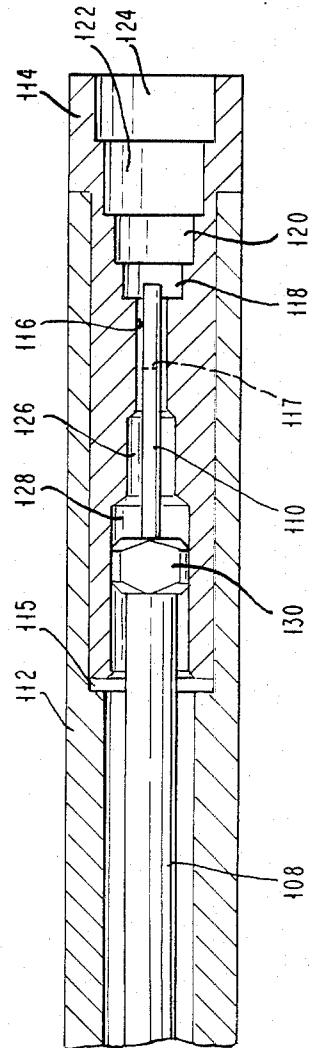


FIG. 4

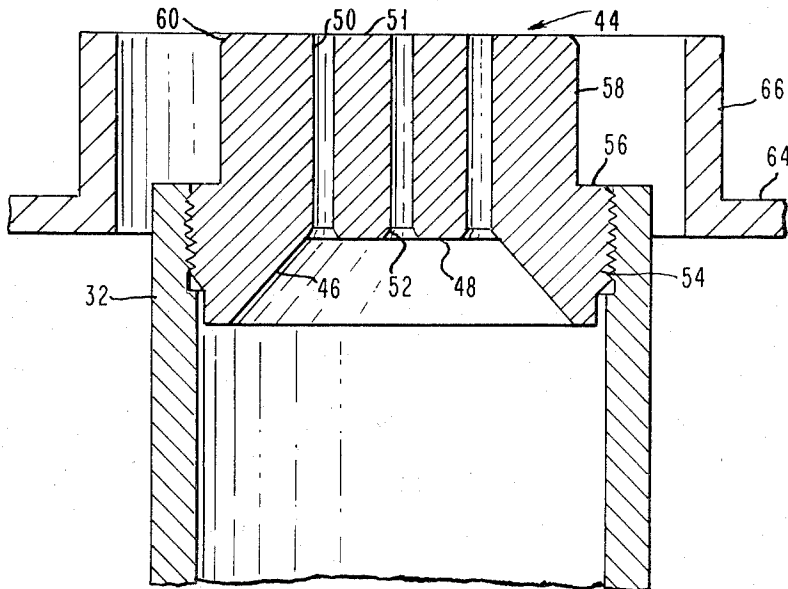
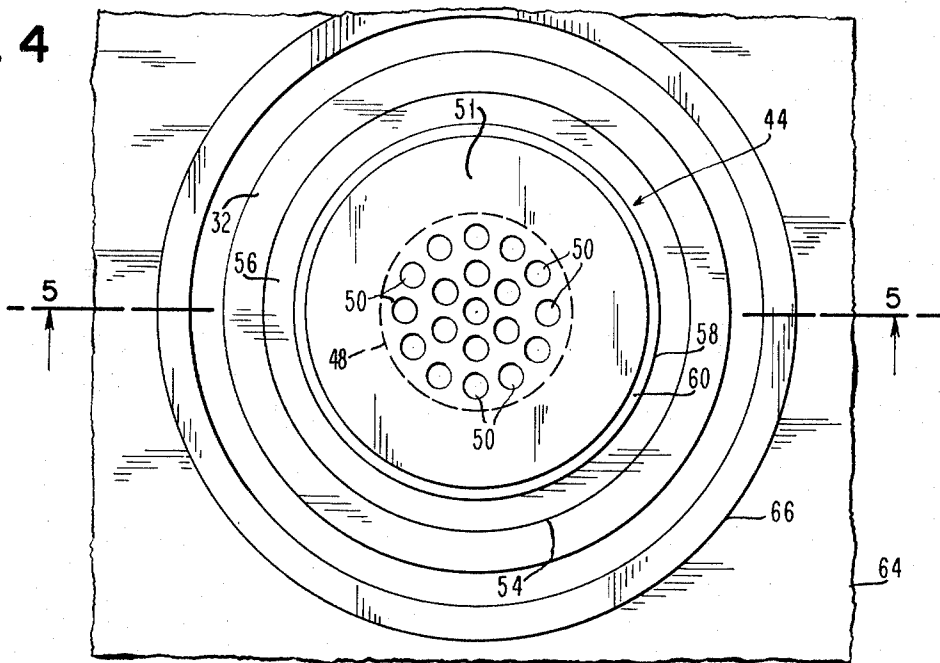


FIG. 5

FIG. 6

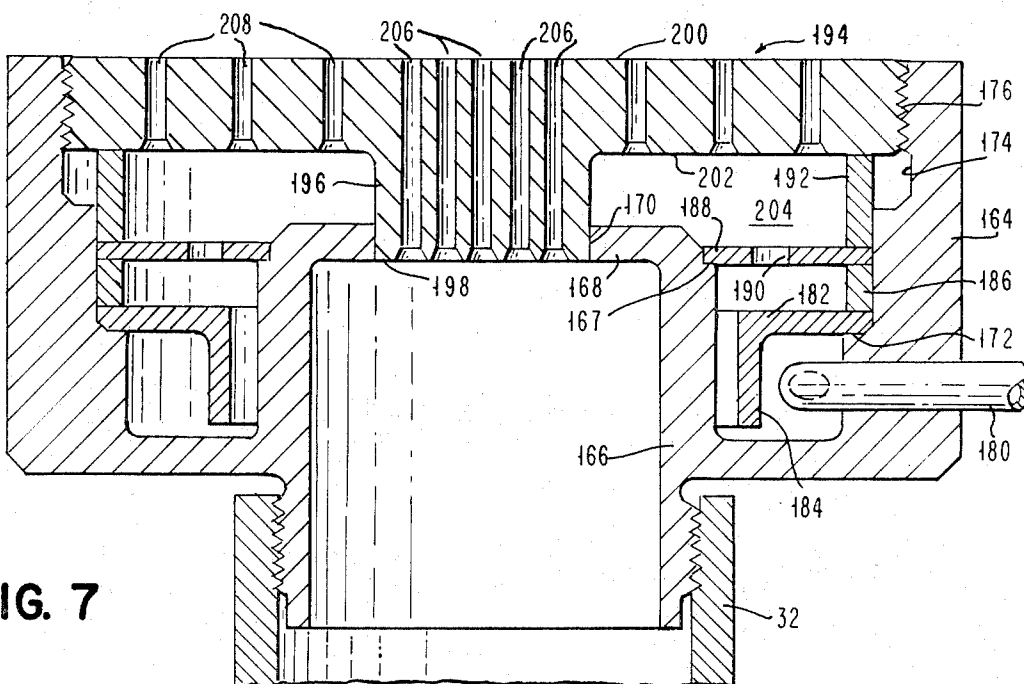
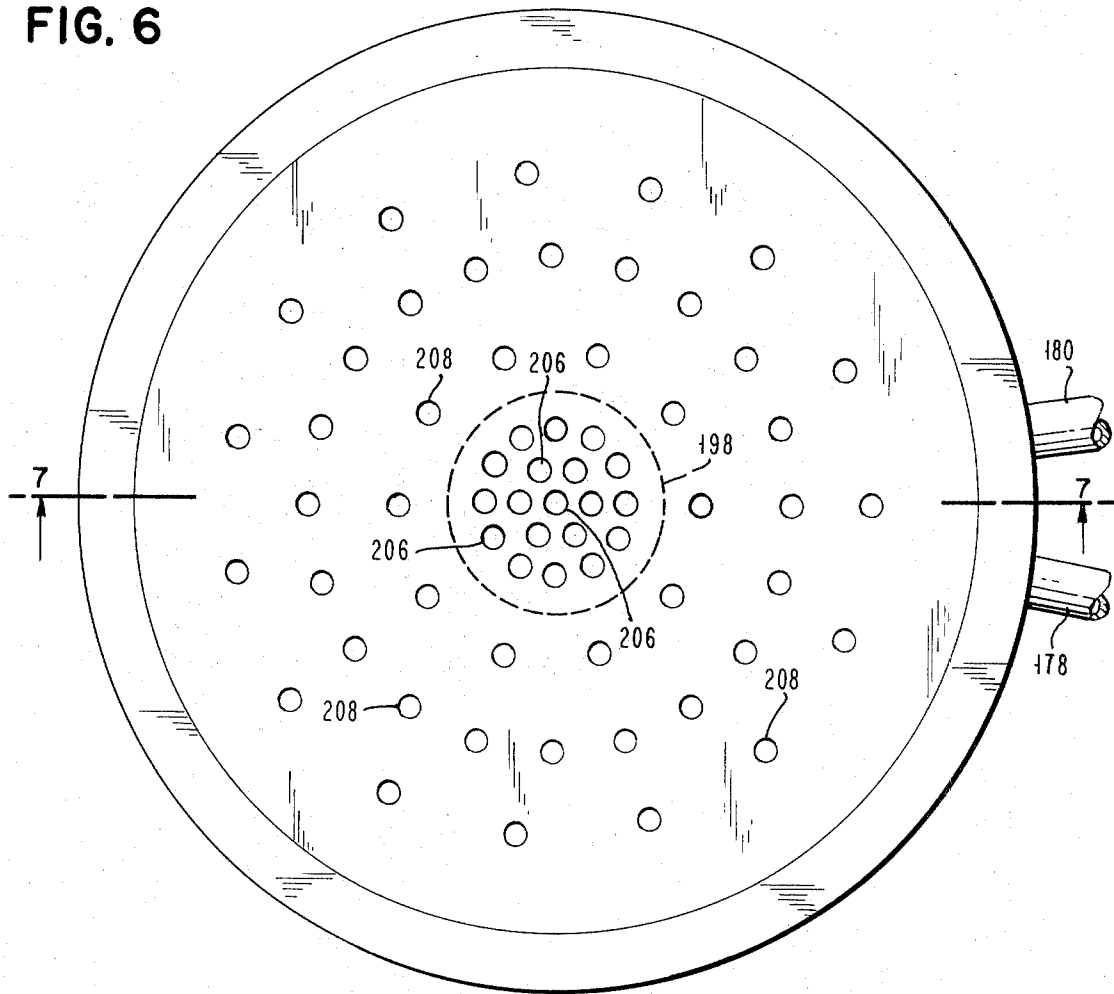
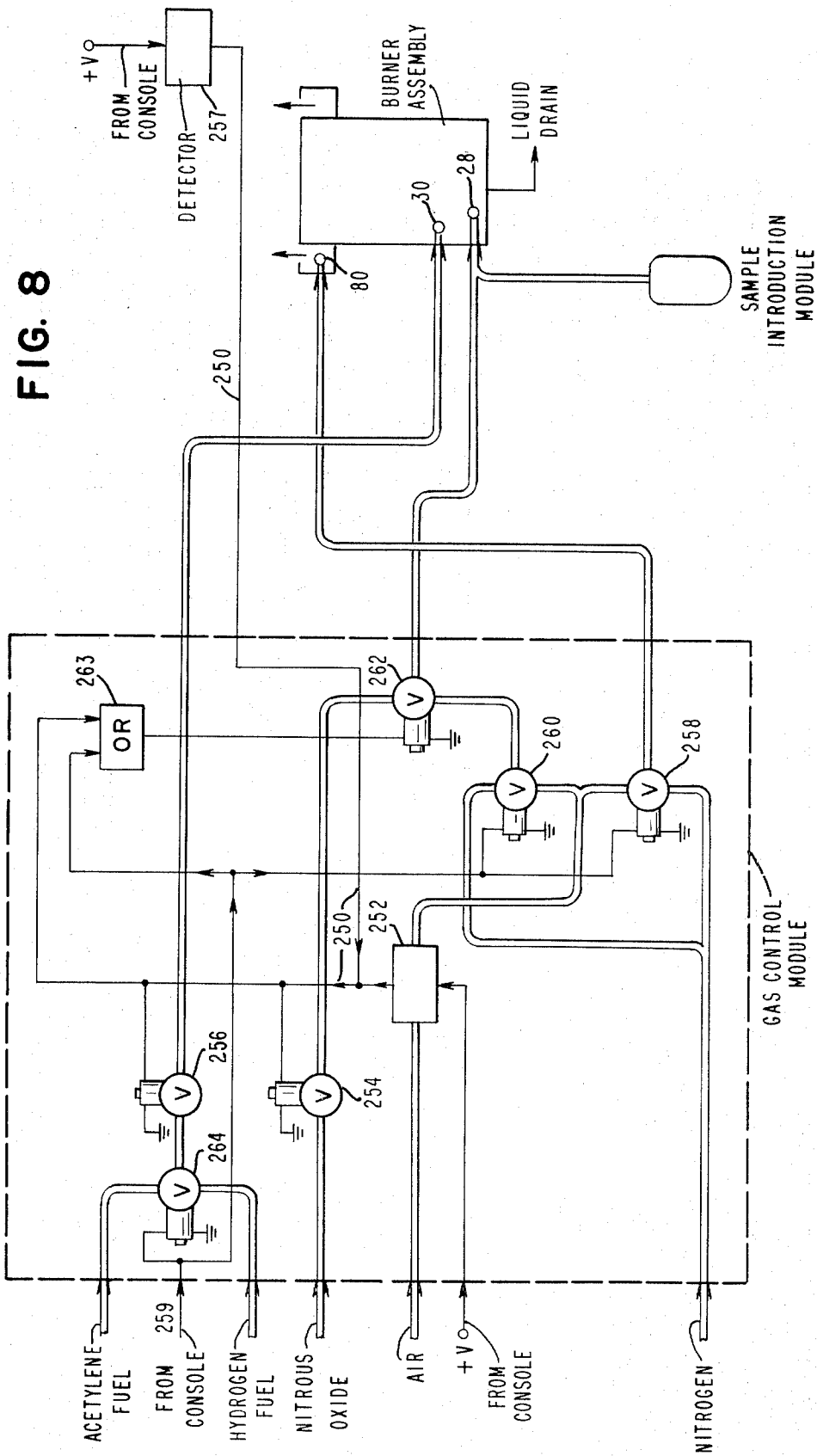


FIG. 7

FIG. 8



# BURNER CONSTRUCTION FOR FLAME SPECTROPHOTOMETER AND SYSTEM THEREFOR

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

This invention relates to spectral flame burners for providing a spectral flame for the quantitative analysis of various liquids with respect to one or more substances therein. The analytical technique involved may utilize either emission or absorption (including fluorescence) of light of a significant wavelength.

### 2. Prior Art

A spectral flame photometer burner is disclosed in Isreeli et al. U.S. Pat. No. 3,531,203 issued Sept. 29, 1970, having a substantially circular mixing chamber with means to introduce a flow of combustion-supporting gas and an atomized liquid sample into the chamber in such a manner as to produce a swirling motion therein and means to introduce fuel gas into a relatively low pressure region created in the flow path of the combustion-supporting gas and the atomized sample.

U.S. Pat. application, Ser. No. 742,260 filed July 3, 1968, and now U.S. Pat. No. 3,550,858, discloses an improvement of the burner of U.S. Pat. No. 3,531,203, supra, wherein the spectral flame burner, also of the preatomizer type, has a sample tube the inlet of which is disposed within a carrier gas conduit terminating in a nozzle. The spacing between the outlet of the sample tube and the outlet of the nozzle is adjustable during the normal operation of the system, including the burner. There is provided means to withdraw the outlet of the sample tube to a position whereby positive gas pressure is developed in the sample tube to blow out any obstruction in the latter and which means includes a driven shaft driving a gear train operatively connected to the sample tube to effect axial movement of the latter with reference to the nozzle.

A burner constructed in accordance with that U.S. patent application was found lacking in certain aspects with reference to the atomization of the sample wherein it is desirable to achieve such a fine division of particles in the carrier gas that they constitute what may be referred to as a fog. Moreover, it was found that the adjustability of the sample tube outlet with reference to the nozzle was not as fine as needed to produce the best flame in certain applications. It was also found that the gear mechanism to adjust the sample tube outlet with reference to the nozzle lacked the fineness of adjustment of the tube desirable in an atomizer of this type in at least certain applications.

Also, known prior art burners have lacked the ability to provide a suitable flame, for purposes such as described above, with various combustible gas mixtures such as a mixture of acetylene and air, a mixture of acetylene and nitrous oxide or a mixture of hydrogen and air. Furthermore, known prior art burners of this type utilizing a fuel mixture of acetylene and nitrous oxide have built up carbon deposits on the burner cap with such rapidity in operation that they have required after only a very short period of operation a cleaning of the holes in the burner cap in order to avoid such plugging of these holes as would result in an explosion of the burner. Still further, known prior art burners of the aforementioned type have not provided the stability of flame necessary for optimum photometric results of

analyses. Still another drawback to known prior art burners of this type is that they lack automated means to shut down the operation of a burner when a defect occurs in the system in which the burner is utilized.

## SUMMARY OF THE INVENTION

One object of the invention is to provide a burner construction for a flame spectrophotometer, of the type characterized above, which includes an improved atomizer for the sample liquid under analysis and which is so constructed as to provide an improved mixture of the sample with a combustion-supporting gas and mixture of these with a fuel gas, including an improved flow path of the resulting mixture toward the point in its travel at which it burns in a flame. There is also provided an improved atomizer construction and one in which there is improved adjustability of the sample tube outlet with reference to the nozzle as characterized above. Another object is to provide an improved mechanism by which the sample tube is moved with respect to the nozzle and including a differential lead screw operatively associated with the sample tube.

Furthermore, there is provided a burner susceptible of burning various combustible gas mixtures such as a mixture of acetylene and air, a mixture of acetylene and nitrous oxide or a mixture of hydrogen and air. Still another object is to provide a burner such as characterized above which is particularly well suited for burning a mixture of acetylene and nitrous oxide, which effectively tends to inhibit a buildup of carbon deposits on the burner cap. Another object is to provide an improved burner cap construction. A further object is to provide a burner cap providing a very stable flame. Also, there is provided a burner cap construction of a dual type having a central flame portion and an outer circumferential flame portion for certain applications, and in which in other applications only sample mixed with combustion-supporting gas (no fuel being added to the mixture) is fed to and through the central portion of the cap to be ignited and thereby form a cool flame by the aforementioned outer flame portion of the dual flame cap. The cap construction provides a flame which is particularly susceptible to good photometric analysis of samples.

Still further, there is provided a burner construction in which the combustion-supporting gas and the fuel may be switched rapidly in sequence to permit a plurality of types of flame analysis of a single sample. There is also provided according to the invention a system for the burner including automated means to shut down the operation of the burner when a defect occurs in the system in which the burner is utilized.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a sectional view taken on line 1-1 of FIG. 2 of a burner assembly embodying the invention;

FIG. 2 is a sectional view taken on line 2-2 of FIG. 1;

FIG. 3 is a sectional view on an enlarged scale taken on line 3-3 of FIG. 2;

FIG. 3A is a fragmentary sectional view similar to FIG. 3 illustrating on a larger scale certain details of the discharge portion of the atomizer;

FIG. 4 is a fragmentary top plan view of the burner assembly;

FIG. 5 is a sectional view taken on line 5—5 of FIG. 4;

FIG. 6 is a top plan view of burner cap of modified form with additional fuel and combustion-supporting gas conduits connected thereto;

FIG. 7 is a sectional view taken on line 7—7 of FIG. 6; and

FIG. 8 is a diagrammatic view illustrating a system in which the burner assembly may be utilized.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

A flame photometer main assembly includes a burner assembly shown in FIG. 1. It customarily also comprises a sample emitted light detector assembly, an infra-red flame detector assembly and a flame igniter assembly, all not shown but disclosed in U.S. Pat. No. 3,531,203, supra. It also includes a chimney, not shown.

The burner assembly as shown in FIG. 1 includes an upright tubular main body 10 which may be formed of a fluoroplastic material having in axial alignment a lower mixing chamber 12, an upper burner-tube-receiving bore 14 therein having formed at its lower extremity a lower radially inwardly extending shoulder 16 of annular form, an upper annular flange 17 and a lower annular flange 18. A base plate 20 is releasably sealed to the lower flange 18 by a plurality of thumb screws 22. The main body 10 also has a boss 24 with an axial bore therethrough to receive a fitting for the supply of sample liquid and a supply of combustion-supporting gas, and a boss 26 (FIG. 2) having an axial bore therethrough for a fitting to supply fuel gas. The first-mentioned fitting, indicated generally at 28, is mounted in the main body 10 on a transverse axis in cord-like relation to the chamber 12 and terminating at its outer end in proximity to the circular chamber wall as shown in FIG. 2. The fitting in the boss 26 shown in FIG. 2, indicated generally at 30, for the supply of fuel, may be similar to that shown in application, Ser. No. 742,260, supra, and is mounted in the main body on a transverse axis which is displaced slightly from a radius of the main body as shown in the last-mentioned view. The fittings 28 and 30 are located in the same horizontal plane.

A burner tube 32, seated on the annular shoulder 16, is sealed within the upper bore 14 of the main body and extends upwardly, through and beyond a central bore in a support plate 38 which may be formed of metal and serve the function of a heat sink, with the main portion of the plate 38 resting on the upper surface of the flange 17. The plate 38, through which the tube 32 extends has in the region spaced around the tube 32 a series of tapped holes to receive bolts 40, respectively, which extend through respective holes in an annular outwardly extending flange 42 of the tube 32 in the manner shown in FIG. 1 to secure the burner tube 32 to the plate 38.

The upper end of the burner tube 32 is internally threaded as shown in FIG. 5 to threadedly receive a burner cap indicated generally at 44. The cap 44 may be formed of stainless steel metal for example or of carbon material and have substantial mass as indicated in FIGS. 4 and 5. The cap 44 has an upwardly extending recess 46 therein which may be advantageously is parabolic form but in the illustrated embodiment is

formed as a truncated cone having through the flat upper surface 48 thereof a series of vertically disposed bores 50 extending through the upper flat surface 51 of the cap as shown in FIG. 5. As shown in the last-mentioned views, the series of bores 50 may include an outer ring-like set, and inner ring-like set and a center bore, the bores of each set being closely spaced with reference to one another and to the next set, the center bore 50 being closely spaced in the center of the inner set. The number of bores 50 may approximate 20, 19 being shown. The main diameter of the bores 50, which is shown to be uniform from bore to bore, may be approximately 0.031 to 0.036 inch. As shown in FIG. 5 the lower ends of the bores 50 are flared as at 52.

The bores 50 may be grouped in a circular area concentric with the upper surface 51 of the cap which circular area may be approximately 0.31 inch while the diameter of the surface 51 may be approximately 0.56 inch. The aforementioned recess 46 in the lower face of the cap is of substantially greater diameter at its mouth than the aforementioned circular area containing the bores 50. The last-mentioned mouth may have a diameter of approximately 0.61 inch. The aforementioned threads on the cap are formed on a radially enlarged portion 54 thereof of the upper surface of which portion 54, when the cap is assembled with the burner tube 32, is flush, as at 56, with the upper extremity of the burner tube 32. Above the enlargement 54, the cap has a cylindrical outer surface 58 as shown in FIGS. 4 and 5. If desired this portion may be provided with suitable flats for engagement by a wrench for threading the cap 44 into or out of the burner tube 32. The upper edge of the cap may be chamfered, as to 60, only to the degree shown.

An auxiliary air manifold block 62 of annular form is disposed on the support plate 38 and has the upper end thereof partially closed by an annular plate 64 secured thereto as by machine screws not shown. The plate 64 has an upwardly directed sleeve-like flange 66 thereon (FIGS. 1 and 4) which is paced from the burner tube 32, in the manner shown, to form a relatively narrow gap therearound to provide for the escape of air from the manifold. In practice thus far it has proven advantageous to terminate the sleeve 66 at substantially the height of the burner cap 44 as shown.

The block 62 includes central bore 68, an outer flange 70 which rests on the support plate 38 and is sealed and secured thereto by suitable means, not shown, and an intermediate annular recess 72 to support the chimney not shown. The block also includes a lower annular cavity 74. The cavity 74 communicates with the bore 68 of the block through a gap 76 between the block and the support plate 38. The block 62 also has radial bore 78 extending through the flange 70 in communication with the annular cavity 74, the bore 78 being provided to receive an air fitting 80 for the introduction of air under pressure.

As shown in FIG. 3, the fitting 28 for the supply of sample liquid and the combustion-supporting gas includes an atomizer body 82 having a longitudinal bore 84 extending into an enlarged bore portion 86, and a radial bore 88 in communication with the bore portion 86 and enlarged to receive coupling nipple 90 or for a conduit to supply combustion-supporting gas. The bore 84 extends through a boss 92 of the fitting which is

received for support in the boss 24 of the main body 10. Any suitable means, not shown, may be provided to give additional support to the fitting 28 through the body 82 thereof.

An intermediate body 94 of generally hollow cylindrical form is engaged in part within the bore portion 86 and may be longitudinally advanced or retracted therein. As shown in FIG. 3, the body 94 is internally threaded at its left-hand end, as at 96, to receive an atomizer capillary assembly indicated generally at 98. The assembly 98 includes a tubular member 100 received in the hollow intermediate body 94 and carrying O-ring 102 providing a seal between the tubular member 100 and the intermediate body 94. The intermediate body carries an O-ring 104 for sealing engagement with the atomizer body 82. The tubular member 100 intermediate the ends thereof has a threaded part engaging the thread 96 of the intermediate body 94, and the tubular member 100 is also provided with an enlarged, ribbed head 106 extending without the body 94 which may be grasped manually for threading movement to assemble or disassemble bodily the member 100 with the tubes 108 and 110.

The capillary assembly 98 also includes an outer tube 108 sealed in the tubular member 100 and extending therethrough in both directions, and into which an inner tube 110, extending therethrough in both directions, is sealed and supported.

The right-hand end of bore 84 receives, as shown in FIG. 3, the reduced left end portion of the atomizer tube 112 which tube has a shoulder which abuts the boss 92. The tube 112 may have a press fit in the bore 84. The right-hand end of the tube 112 receives a tube 114 providing an atomizer tip or nozzle, which tube 114 may have a pressed fit in an enlarged portion 115 of the bore of the tube 112. The tube 114 providing the tip has an enlarged head abutting the right end of the tube 112. As shown, the left end of the tube 114 is spaced somewhat from the bottom of the bore enlargement 115.

As best shown in FIG. 3A the tubular nozzle tip 114 has an axial bore 116 therethrough, the right-hand portion of which is enlarged step-wise toward the discharge end of the nozzle, four steps being shown and indicated at 118, 120, 122 and 124, respectively. Beyond the intermediate portion of the bore 116, to the left, the last-mentioned bore is enlarged at 126, and, to the left, is further enlarged at 128.

The outer tube 108 of the capillary tube assembly extends with clearance into the left end of the tubular nozzle tip 114. The inner tube 110 extends through a supporting spider 130 in the enlargement 128 of the bore 116, and in the extreme advanced position of the tube 110, carried by the tube 108, extends with clearance into the enlargement 118 of the last-mentioned bore. The inner tube 108 has approximately 0.004 inch clearance with the portion of the bore 116 of smallest diameter. From the foregoing it will be appreciated that the tube 110 has clearance in varying degrees with the bore 116 throughout the extent of its extension into the tubular nozzle tip 114, which clearance provides for the flow of combustion-supporting gas around the discharge or right end of the inner tube 110 from the bore portion 86 supplied by the inlet 88. The bore portion 86 is tapered as at 134 to merge

with the right-hand end of the bore 84 as shown in FIG. 3. Also, as shown in the last-mentioned view, the right-hand end of the intermediate body 94 is chamfered to facilitate its introduction into the bore portion 86 from its left end.

A yoke 136 is clamped on the intermediate body 94 at the left end thereof as viewed in FIG. 3 and supports in stationary relation thereto a bushing 138 above the intermediate body 94 and to the left of the atomizer body 82. The bushing 138 is internally threaded and axially aligned with a threaded bore 140 in the atomizer body 82.

A lead screw, indicated generally at 142 coacts with the threaded bore 140 and the threads of the bushing 138, and is so structured as to have a differential action with reference to the atomizer body 82 and the yoke 136 connected to the capillary assembly 98. As viewed in FIG. 3, the threads on the left-hand portion 144 of the lead screw number approximately 48 turns to the inch, while the threads on the right-hand portion 146 thereof number approximately 40 to the inch. In other words, portion 144 has 20 percent more threads to the inch than portion 146. Hence, when the lead screw 142 is rotated in a direction to retract it with reference to the atomizer body 82, that is, to the left as viewed in FIG. 3, the bushing 138 and the screw 142 have relative axial movement therebetween.

The bushing 138 is, in effect, a nut held against rotation by the clamp 136 which is in fixed relation to the capillary assembly 98 which includes the discharge end of the capillary tube 110. Because of the thread differential between the portions 144 and 146 of the lead screw 142, on retraction of the screw as aforesaid, the degree of retractive movement of the threaded bushing 138 and, therefore, the capillary tube assembly is very much smaller than the degree of retractive movement of the screw 142.

This permits extremely fine adjustments of the capillary tube 110 within a travel of approximately one-tenth inch from its extreme advanced position to its extreme retracted position shown by broken line 117. Moreover, when adjusted to the desired position the threaded engagement between the bushing 138 and the threaded portion 144 of the screw provides a positive holding force to maintain the capillary assembly in the adjusted position thereof.

Furthermore this construction is advantageous in that it is less expensive in that it does not require a screw having, say, 100 threads per inch or a bearing between the clamp 136 and the screw shaft. Such a bearing might also have the disadvantage of permitting some axial play between the shaft and the bearing. With the illustrated construction, the degree of axial movement of the capillary tube 110 can be exactly calculated per revolution of the screw 142 for control of the adjustment of the atomizer.

Sample liquid may be aspirated from the discharge end of capillary tube 110 by the flow of gas around such discharge end. If desirable the sample liquid may be pumped through the capillary tube 110 as by a peristaltic pump. When the capillary tube 110 is disconnected from the source of sample supply and the tube 110 is retracted in the aforementioned manner in the bore 116 to or near the extreme retracted position 117 shown in FIG. 3A, gas pressure in the bore 116 is

sufficient, following a path of least resistance, to blow out any obstruction in the tube 110.

As shown in FIG. 3, the screw 142 has a shaft portion 148 extending to the left of the threaded portion 144, which shaft portion is unthreaded and is suitably connected, as by a fastener 150, at its left end to coupling 152 of a shaft, not shown, which may be of the flexible type and have suitable drive means. To limit extension and retraction of the screw 142, a stop means is provided between the clamp 136 and the shaft portion 148.

In the illustrated form the last-mentioned stop means comprises a bracket 154 suitably fixed on the clamp 136 in a manner not shown and comprising arms 156 and 158 spaced from one another axially of the shaft portion 148. A pin 160 projects through the shaft portion 148 transversely thereof to be engaged by the arm 158 of the stop to limit the advance of the screw 142, and to be engaged by the arm 156 of the stop to limit retraction of the screw 142.

The aforementioned stepped construction of the nozzle tip 114 provides a series of baffles for the atomized sample liquid so that the atomized portion of the sample which issues from the tip tends to be in the form of a fog. The mixture has a swirling motion imparted to it by the chamber 12 before it passes upwardly in the burner tube 32. Any larger droplets of the sample liquid tend to hit one of the steps 118-124 and thereafter fall by gravity from the nozzle tip into the bottom of the chamber 12 of the burner from which any liquid may drain in the manner shown and described in aforementioned application, Ser. No. 742,260.

There is shown in FIGS. 6 and 7 a modified form of burner cap which may be substituted for the burner cap 44 previously described and which has most of the functions of the cap 44 and others in addition. The modified form of the cap may be assembled to the burner after the plate 64 has been removed from the air manifold block 62 and after the cap 44 has been unthreaded and separated from the burner tube 32.

The cap construction shown in FIGS. 6 and 7 includes a cup-shaped member 164 having an integral tubular part 166 extending through the bottom thereof which tubular part has an external shoulder at 167. The last-mentioned part 166 has at the upper end thereof a radially inwardly extending flange 168 defining a central opening 170. The lower end of tubular part 166 is externally threaded to thread into the upper end of burner tube 32 for assembly with the burner assembly as shown in FIG. 7. Within the cup-shaped member in the lower portion thereof there is provided an annular internal shoulder 172. The upper portion of the cup-shaped member has its wall thickness reduced as at 174. Threads 176 are provided internally in the mouth portion of the cup-shaped member. Extending into the lower portion of the cup-shaped member there is provided a fuel inlet 178 and a combustion-supporting gas inlet 180, these inlets being arranged in the same horizontal plane.

Above the last-mentioned inlets, there is provided in the cup-shaped member an annular plate 182 supported on the shoulder 172 of the last-mentioned member and having a depending skirt 184 spaced from the tubular part 166 and also spaced upwardly

somewhat from the bottom of the cup-shaped member as shown in FIG. 7. This construction and arrangement permits fuel and combustion-supporting gas from the aforementioned inlets to mix and pass upwardly under the skirt 184 and through the space between the skirt and the tubular part 166.

A ring 186 is seated, as shown in the last-mentioned view, on the plate 182 and supports on its upper surface an annular plate 188 also supported from the shoulder 167 of the tubular part 166. The plate 188 has a series of holes 190 arranged circumferentially thereabout and through which the fuel mixture may pass upwardly. A ring 192 is supported on the outer margin of the annular plate 188.

A cap member, indicated generally at 194, comprises a thickened depending central portion 196 of cylindrical form extending into and filling the opening 170 of tubular part 166 in the manner shown in FIG. 7. The bottom surface of the portion 196 is flat, as indicated at 198, and flush with the undersurface of the flange 168. The cap member 194 has a flat upper surface 200, and the radial extension of the cap member beyond the central portion 196 has a flat undersurface as indicated at 202. The circumferential portion of the last-mentioned radial extension is threaded to cooperate with the threads 176 of the cup-shaped member, and the cap member 194 is threaded thereinto so as to be flush with the mouth of the cup-shaped member as shown in FIG. 7.

When so assembled, it will be noted that the cap member 194 supportingly engages the ring 192 to provide support in turn for the plate 188, the ring 186 and the plate 182. The cap member 194, together with the upper portion of the tubular part 166, the plate 188 and the ring 192, defines a chamber 204 of annular form into which the fuel mixture flows through the aforementioned openings 190 in the plate 188.

In the thickened, central portion 196 of the cap member 194, bores 206 extend upwardly through the member 194 similar to the bores 50 of the previously described burner cap 44 and similarly arranged with reference to one another, which bores 206 communicate with the burner chamber 12 in a similar manner. The bores 206, like the previously mentioned bores 50, provide upward laminar flow of the fuel gas mixed with combustion-supporting gas to the top of the burner assembly. This laminar flow achieved by both cap constructions facilitates a steadier flame above the respective caps. As shown in FIGS. 6 and 7, the cap member 194 is provided in the radially outward extension thereof from the central portion 198 with a series of bores 208 similar to the aforementioned bores 206 but communicating with the aforementioned cavity 204 in the cup-shaped member 164. The bores 208, extending through the upper surface 200 of the cap member are arranged circumferentially around the central portion 196 of the cap member, as shown in FIG. 6, and may include inner and outer and intermediate sets of the bores 208 as shown. For the sake of convenience fewer bores 208 are shown in the cap member 194 than are preferably provided in the last-mentioned member.

The burner cap is of the dual type, having an inner burner section provided by the bores 206 and an outer or second burner portion provided with the bores 208. The number of bores 208 provided in the outer burner

section of the cap is best determined by the degree of flame on the outer section, when the central section is burning, necessary to exclude ambient air from the center section of the burner cap. The mixture of fuel gas and combustion-supporting gas flowing upwardly through the bores 208 of the outer burner section of the cap and supplied by the inlets 178 and 190 previously described may be the same, for example as the fuel and combustion-supporting gas supplied to the chamber 12 as previously described and burned above the center section of the cap member 194 as previously indicated. The flame on the outer burner section of the burner cap has a steadying effect on the flame of the inner burner section of the cap.

It is to be noted that in the operation of the burner cap 44 shown in FIGS. 4 and 5 with the encircling sleeve 66 that carbon deposits on the upper surface 51 of the cap tend to be retarded very effectively for a considerable period of time when nitrous oxide is used as a combustion-supporting gas. As previously indicated such a buildup could result in an explosion of the burner assembly. It is believed that such carbon deposits do not tend to form on the upper surface 51 of the cap 44 to clog the holes 50, due at least in part to a provision of the vertical wall surface 58 of the cap 44 as opposed to the conical or tapered outer surface of such caps used heretofore. The sleeve 66 which embraces the cap also makes for a steadier flame. It will be understood from the foregoing that in both cap constructions, the fuel and combustion-supporting gas mixture from the chamber 12 passes upwardly in the burner tube 32 for egress from the burner cap located at the upper extremity of the burner tube 32.

It will be apparent from the foregoing description that in the operation of the burner assembly, when the capillary tube 110 of the capillary assembly 98 is in the advanced position thereof previously described, less sample liquid will be entrained in the gas flowing around the discharge end of the tube 110 than when the capillary tube is retracted toward the broken line position 117 of FIG. 3A in which the discharge end of the tube 110 is fully retracted. Atomization of the sample liquid is controlled in this manner.

It is believed that many different types of fuel may be burned by the burner assembly utilizing the burner cap of FIGS. 6 and 7 including acetylene, hydrogen, propane, butane or methane gas. With the dual burner cap of the last-mentioned views, a fuel mixture of air-acetylene may be supplied for burning both from the chamber 12 and the chamber 204, for flame on both the inner and outer sections of the dual cap. Also with a cap of the last-mentioned construction, a diffusion-like flame, well known in the art, may be obtained by supplying acetylene gas to the fuel inlet 178 and air to the combustion-supporting gas inlet 180 while shutting off the fuel supplied to the chamber 12 by the fitting 30 and providing air or nitrogen gas under pressure through the inlet 88 of the atomizer assembly shown in FIG. 3. If a hotter flame is desired than can be obtained from the first-mentioned air-acetylene mixture used with the dual burner cap, air may be supplied to the chamber 12 through the bore 88 of the atomizer while acetylene is supplied to the chamber 12 by the fitting 30, at the same time that acetylene is supplied to fuel inlet 178 and nitrous oxide is supplied to combustion-supporting gas inlet 180.

With the use of the burner cap 44 shown in FIGS. 4 and 5 air may be supplied to the atomizer fitting 28 as aforesaid while acetylene gas is supplied to the fuel fitting 30 and air is supplied to the air manifold 62 through the fitting 80. A "separated" flame may be obtained with this burner cap construction by supplying air to the atomizer as aforesaid, acetylene to the fuel fitting 30 and nitrogen gas to the fitting 80. A hotter flame than that first mentioned with reference to the use of the burner cap 44 may be obtained by supplying nitrous oxide to the atomizer fitting 28, acetylene to the fuel fitting 30 and air to the fitting 80.

Another form of "separated" flame may be obtained with the use of the burner cap 44 by supplying nitrous oxide to the atomizer fitting 28, acetylene to the fitting 30 and nitrogen to the fitting 80. Another possible combination is to provide air to the atomizer fitting 28, hydrogen to the fuel fitting 30 and air to the fitting 80. Still another combination is possible by supplying air to the atomizer fitting 28, propane to the fitting 30 and air to the fitting 80. Another type of diffusion flame may be obtained by supplying nitrogen to the atomizer fitting 28, hydrogen to the fuel fitting 30 and air to the fitting 80. It is to be understood, of course, that in all of the combinations, including those discussed with reference to the dual burner of FIGS. 6 and 7, the atomized sample liquid is supplied to the chamber 12 along with the particular gas supplied to the atomizer fitting 28 and it will be noted that in at least one of the combinations discussed with reference to the dual burner cap operation that a so-called cool flame may be obtained by shutting off the fuel supply to the chamber 12.

It will be noted from the foregoing that with the various fuels and gas combinations many different types of flame may be obtained with the use of the burner assembly. It may be used for atomic fluorescence for providing a pool of atoms of a constituent of interest in a sample which atoms fluoresce when excited by a suitable light beam from a source, not shown, and which fluorescence is detected photometrically. The burner assembly may also be used for well known emission detection techniques. It is also well known that some substances can be at least better detected in some flames than others.

In FIG. 8 there is shown diagrammatically and by way of example only a system in which the burner assembly of FIGS. 1-5 may be utilized. In this diagram, fuel lines are shown for the flow under pressure of fuels designated "ACETYLENE" and "HYDROGEN," respectively. These fuel lines are connected as indicated to the gas-supply fitting 30. A conduit is also shown for the supply of combustion-supporting gas and designated "NITROUS OXIDE." Another such conduit is designated "AIR." The last two mentioned conduits are connected as shown to the atomizer fitting 28. It will be understood that nitrous oxide and air are provided under pressure. Still another conduit for gas under pressure is designated "NITROGEN" and the last-mentioned conduit is connected to the gas inlet fitting 80 and fitting 28. These fluid lines and their connections to be described hereinafter are largely contained in a module designated "GAS CONTROL MODULE."

Also shown in the last-mentioned diagram, the flow of air is through a pressure-responsive switch 252. The

flow of nitrous oxide is through a solenoid-operated valve 254 and the flow of either acetylene fuel or hydrogen fuel, as selected by solenoid-operated three-way valve 264, is controlled through solenoid-operated valve 256. The flow of nitrous oxide is controlled through solenoid-operated three-way valve 262. A cable 250 from the console, not shown, interconnects switch 252, valve 254, valve 256, and, through OR 263, valve 262. Thus, when the flow of air falls below a predetermined value the pressure responsive switch 252 closes to energize the circuit through the cable 250 to shut off the valve 254 and valve 256 and place valve 262 in a mode to shut off the flow of nitrous oxide.

There is also shown connected to the cable 250 a flame-out detector 257 which in the event that the flame of the burner is extinguished before the burner is shut down by the operator, serves to close the valves 254, 256 as aforesaid and place the solenoid-operated three-way valve 262, through OR 263, in the last-mentioned condition. In either event any further flow of fuel or nitrous oxide to the burner assembly is precluded by this operation. The flame-out detector 257 comprises a photosensitive device which responds to the flame but not to ambient light. Since air is essential to the burner's safe operation either in its supply to the burner or in sequencing the supply of nitrous oxide which will appear hereinafter, this shut-down feature protects the equipment and the operator.

Either air or nitrogen can be selected for use as a sheath gas supplied to fitting 80 through solenoid-operated three-way valve 258. Air as a sheath gas provides added stability to the flame and helps prevent carbon deposits from forming on the burner cap when nitrous oxide-supported flame is used. Nitrogen as a sheath gas is used when a "separated" flame is desired. It is also possible to rapidly sequence alternately beneath air or nitrogen so that the advantages of both can be utilized on the same sample as will be apparent from the diagram of FIG. 8 and the description to follow.

Either air or nitrogen can be provided to the atomizer fitting 28 through solenoid-operated three-way valve 260. Air would normally be used here with acetylene or hydrogen for most fluorescence or emission determinations. Nitrogen would be used when sulphur, phosphorus or the halogens were being determined utilizing a hydrogen diffusion flame (cool flame). It is also possible to sequence rapidly alternately between air or nitrogen so that the advantages of both can be utilized on the same sample as indicated in the diagram of FIG. 8 and the description to follow.

Either air or nitrous oxide can be provided to the atomizer 28 through solenoid-operated three-way valve 262. Sequencing between air and nitrous oxide through valve 262 is extremely important so that any possibility of a flashback may be eliminated.

The sequencing valve 262 will not open to allow nitrous oxide to flow to the flame chamber 12 unless an air-supported flame is burning at the time and nitrous oxide is being supplied at a minimum pressure above that at which a flashback could occur. When switching the flame off, fuel is not shut off until air only is flowing to the atomizer by the closing of sequencing valve 262 before the closing of valve 256. It is also possible through valve 262 to sequence rapidly alternately

between an air and a nitrous oxide-supported flame so that the advantages for both can be used with the same sample.

Either of two fuels may be introduced to the flame through solenoid-operated three-way valve 264. As indicated, normally acetylene or hydrogen would be used as a fuel selected alternatively by the valve 264. It is also possible to sequence rapidly alternately between these fuels by the operation of valve 264 so that the advantages of both fuels can be utilized on the same sample.

Cable 259 from the console operates the aforementioned valves 258, 260 and 264 and, through the OR 263, the sequencing valve 262.

It is believed that many advantages of this invention will be apparent to those skilled in the art. The foregoing description is illustrative, rather than limiting, as a number of various and modifications may be made without departing from the spirit and scope of the invention. The invention is limited only by the scope of the following claims.

What is claimed is:

1. A spectral flame photometer burner, comprising: an upstanding burner conduit having an upper outlet and a lower inlet; means defining a mixing chamber coupled to said burner conduit inlet; a conduit member terminating in a nozzle within said chamber, having an intermediate inlet for a gas supplied under pressure, to flow out through said nozzle into said chamber and up said burner conduit; a sample tube member having an inlet external to said conduit member, and a portion supported in said conduit member, on the side of the gas inlet remote from said nozzle, in sealed relation thereto, for axial adjustment therein, said sample tube member having an outlet disposed within said conduit member and around which said gas flows to said nozzle so that a sample liquid, when transmitted through said tube member, will be carried along by said gas and atomized at said nozzle, the amount of sample liquid being carried by said gas being dependent, within limits, on the axially adjusted position of said discharge end of the sample tube member; and means for providing relative movement between said conduit member and said sample tube member, for said adjustment of the latter comprising a nut element externally located with reference to said conduit member, and a screw element cooperating with the nut element, one of said elements being a driving element and the other of said elements being driven by said one of the elements, said other element being axially fixed to one of said members to move it.

2. A spectral flame photometer burner as defined in claim 1, wherein: said movable one of said members is said sample tube member.

3. A spectral flame photometer burner as defined in claim 1 wherein said driven one of said elements is said nut element.

4. A spectral flame photometer burner as defined in claim 1, wherein said movable one of said members is said sample tube member, and said driven one of said elements is said nut element.

5. A spectral flame photometer burner as defined in claim 1, wherein: said conduit member is formed at least in part by an atomizer body providing an enlargement of the conduit member passageway which

receives said portion of the sample tube member in sealed relation to said conduit member, said sample tube member being slidable in said enlargement and comprising an intermediate body extending into said enlargement, said intermediate body being of tubular form, having an internally threaded portion receiving a tubular member extending thereinto having threads coacting with said threaded portion, the last-mentioned member embracing said sample tube member, in sealed, fixed relation and being provided for disassembly bodily with said sample tube member.

6. A spectral flame photometer burner as defined in claim 1, wherein: said screw element has two threaded portions thereof axially arranged with reference to one another, one of said screw element portions having more threads thereon per unit length than the other of said portions per the same unit length, one of said threaded portions coacting with said nut element and the other of said threaded portions coacting with means defining a threaded bore and in fixed relation to said conduit member, whereby said driven element imparts a differential movement to said movable member.

7. A spectral flame photometer burner as defined in claim 4, wherein: said screw element has two threaded portions thereof axially arranged with reference to one another, one of said screw element portions having more threads thereon per unit length than the other of said portions per the same unit length, the threaded portion having more threads per unit length coacting with said nut element and the other threaded portion coacting with means defining a threaded bore and in fixed relation to said conduit member, whereby said nut element imparts a differential movement to said sample tube member.

8. A spectral flame photometer burner as defined in claim 4, wherein: said nut element has in fixed relation thereto a stop member coacting with a stop member carried by said screw element to limit axial movement of the screw element in both directions.

9. A spectral flame photometer burner, comprising an upstanding burner conduit having a support, an upper outlet and a lower inlet; means defining a mixing chamber coupled to said burner conduit inlet; means for introducing an atomized liquid sample to said chamber; means for introducing a fuel gas to said chamber; a gas manifold in embracing relation to the burner conduit having a lower inlet for gas under pressure and having an upper gas outlet encircling said burner conduit outlet end in proximity thereto, said manifold having an upwardly directed sleeve providing a circumferential outer boundary of the last-mentioned outlet; and a burner cap coupled to said burner conduit at the outlet thereof, and of substantial mass and vertical dimension, said cap having a peripheral surface in shear relation to a substantially flat upper surface of the cap which is substantially flush with the upper extremity of said sleeve, said cap having a concentric upwardly tapered recess in the bottom thereof, and said cap having a multiplicity of vertical bores in the central region thereof in spaced apart relation both circumferentially and in depth from the cap center, which bores extend through said upper surface of the cap into said cap recess with flared lower extremities, and said bores providing for the laminar flow of the gas mixture from said chamber to the upper surface of the cap for a flame thereabove.

10. A spectral flame photometer burner as defined in claim 9: further comprising means for introducing to said chamber an additional gas either of a non-combustion-supporting character or of a combustion-supporting character.

11. A spectral flame photometer burner as defined in claim 9: wherein said burner cap is removably mounted on said burner conduit.

12. A spectral flame photometer burner, comprising: an upstanding burner conduit having a support, an upper outlet and a lower inlet; means defining a mixing chamber coupled to said burner conduit inlet; means for introducing an atomized liquid sample to said chamber; means for introducing a fuel gas to said chamber; a burner cap having a top extending over said burner conduit outlet and having in the central region thereof a multiplicity of elongated vertical bores therethrough in communication with said burner conduit, said bores being in spaced apart relation both circumferentially and in depth from the cap center, said cap top having a radial extension from said central region thereof, extending beyond the passageway formed by said burner conduit, having means defining at least in part an annular chamber; and means for introducing a fuel gas into said annular chamber, said cap top having in aid radial extension thereof means defining a multiplicity of openings extending therethrough in communication with said annular chamber and spaced apart both circumferentially and in depth from said central region of the cap.

13. A spectral flame photometer as defined in claim 12; further comprising an additional gas inlet into said annular chamber.

14. A spectral flame photometer as defined in claim 12, wherein: said burner cap has a baffle structure therein intermediate said means for introducing fuel gas into said annular chamber and said openings in said radial extension of the cap top.

15. In a system for utilizing a spectral flame photometer burner having a sample inlet, an inlet for fuel gas and an inlet for combustion-supporting gas, the combination of: a first conduit for fuel gas under pressure connected to said fuel gas inlet, normally open valve means in said first conduit to shut off the flow of fuel therein, means to supply a liquid sample to said sample inlet, a second conduit for combustion-supporting gas under pressure connected to said inlet for combustion-supporting gas, and pressure-responsive means in said second conduit coupled to said valve means and operative, on a lessening of flow in said second conduit below a predetermined limit, to close said valve means to shut off the flow of fuel to said fuel inlet of the burner.

16. A burner system as defined in claim 15, further comprising: a third conduit for a different combustion-supporting gas under pressure and having an inlet and an outlet, valve means connecting said outlet of said third conduit to said second conduit and operable to select one of said combustion-supporting gases for flow through said second conduit to said combustion-supporting gas inlet, and normally open valve means in said third conduit to shut off the flow of gas therein, said pressure-responsive means being coupled to the last-mentioned valve means and operable to shut off the flow of gas in said third conduit on closing of said valve means in said first conduit.

17. A burner system as defined in claim 16, further comprising: means controlling said valve means connecting said second and third conduits and operative to sequence the flow of combustion-supporting gases through said second conduit to said combustion-supporting gas inlet of the burner.

18. A burner system as defined in claim 17, wherein: said means controlling said valve means connecting said second and third conduits for sequencing said combustion-supporting gases is operative to permit flow of one combustion-supporting gas through said second conduit to said combustion-supporting gas inlet, only if the flow of the other combustion-supporting gas to the last-mentioned inlet has immediately preceded the flow of said one of the combustion-supporting gases.

19. In a system for utilizing a spectral flame photometer burner having a sample inlet, an inlet for fuel gas and an inlet for combustion-supporting gas, the combination of: means to supply a liquid sample to said sample inlet, means to supply a fuel gas under pressure to said fuel gas inlet, a first gas conduit having an inlet and having an outlet connected to said combustion-supporting gas inlet, a second gas conduit for conveying a first combustion-supporting gas under pressure, a third gas conduit for conveying a different combustion-supporting gas under pressure, and valve means interconnecting said inlet of said first gas conduit to outlets of said second and third gas conduits and operable to sequence the flow of said combustion-supporting gases to said first conduit, during the supply to the burner of a single liquid sample.

20. A burner system as defined in claim 19, wherein: said means to supply a fuel gas under pressure comprises; a fourth conduit having an inlet and having an outlet connected to said fuel gas inlet, a fifth conduit for conveying a first fuel gas under pressure, a sixth conduit for conveying a different fuel gas under pressure, and valve means interconnecting said inlet of said fourth conduit and outlets of said fifth and sixth conduits and operable to sequence the flow of said fuel gases to said fourth conduit, during the supply to the

burner of a single liquid sample.

21. In a system for utilizing a spectral flame photometer burner having a sample inlet, inlet means for a fuel gas and an additional gas for admixture with a sample, and an inlet for a sheath gas, the combination of: means to supply a liquid sample to said sample inlet, means to supply a fuel gas and an additional gas under pressure to said inlet means for admixture with the sample, a first gas conduit having an inlet and having an outlet connected to said sheath gas inlet, a second gas conduit for conveying a first sheath gas under pressure, a third gas conduit for conveying a different sheath gas under pressure, and valve means interconnecting said inlet of said first gas conduit to outlets of said second and third gas conduits and operable to sequence the flow of said sheath gases to said first conduit, during the supply to the burner of a single liquid sample.

22. A spectral flame photometer burner, comprising: an upwardly elongated burner conduit having a support, an upper outlet and a lower inlet; means defining a mixing chamber coupled to said burner conduit inlet; means for introducing an atomized liquid sample to said chamber; means for introducing a fuel gas to said chamber; a gas manifold in embracing relation to the burner conduit having a lower inlet portion for a gas under pressure and having an upper gas outlet portion; and a burner cap coupled to said burner conduit at the outlet thereof, and of substantial mass and vertical dimensions, said cap having a substantially flat upper surface which is substantially flush with the upper gas outlet portion of said manifold, which outlet portion of the gas manifold extends around said cap, said cap having a concentric upwardly tapered recess in the bottom thereof, and said cap having means defining a multiplicity of vertical bores in spaced apart relation both circumferentially and in depth from the cap center, which bores extend through said upper surface of the cap into said cap recess with flared lower extremities, said bores providing for the laminar flow of the gas mixture from said chamber to the upper surface of the cap for a flame thereabove.

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