

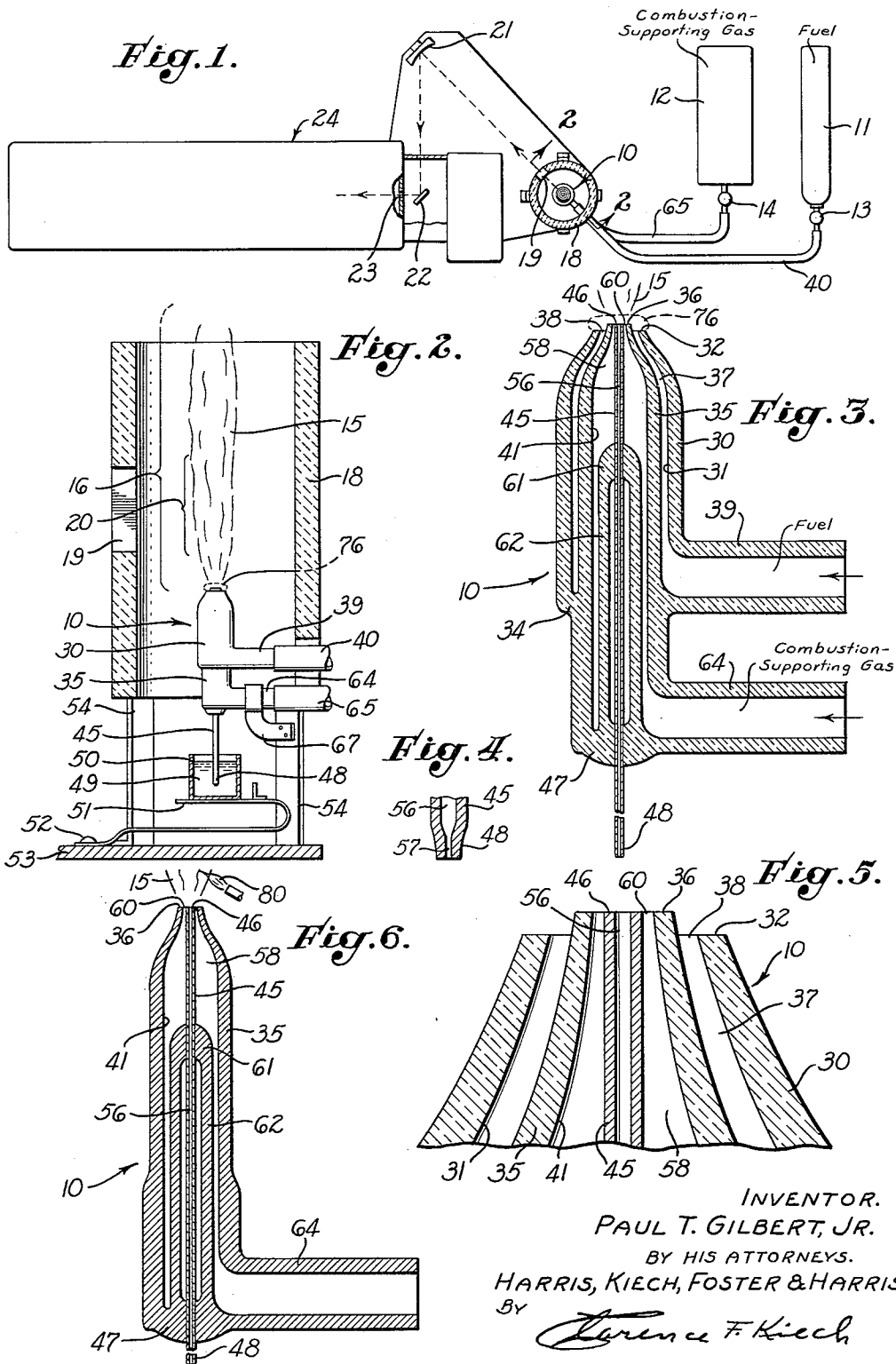
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BURNER STRUCTURE FOR PRODUCING SPECTRAL FLAMES

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My invention relates to the production of spectral flames useful in flame photometry and in other arts. More particularly it relates to a simplified burner structure for producing a source of light in the form of a flame whose spectrum is characteristic of the material to be analyzed. The invention will be exemplified as applied to the art of spectrophotometry and in association with a monochromator for obtaining a spectrum which can be studied in its different zones or wave lengths to determine quantitatively and qualitatively the elements or components of a liquid sample to be analyzed. It is to be understood, however, that the invention is equally applicable to other photometry systems as well as to interferometry, refractometry, polarimetry and other systems wherein the burner can be used as a light source which may be substantially monochromatic as determined by the material, e. g., sodium, delivered to the flame.

In the past, all practical flame photometers having any claim to precision, for example, better than 10%, have atomized the liquid sample into a chamber remote from the burner. A jet of compressed air or other gas was discharged into the chamber to atomize the liquid. The larger of the atomized droplets, impinging on the walls of the chamber, were caught and drained from the chamber in some prior art devices. Additionally, it has been proposed to evaporate the atomized liquid in the chamber as by heating the chamber or adding to the liquid sample an alcohol or the like to reduce the surface tension and decrease the droplet size. From the spray chamber, the mist was conducted to a suitable burner to discharge into the flame zone and impart to the flame a spectrum characteristic of the liquid sample.

In such prior designs it was necessary to await equilibrium conditions before readings were taken. This introduced a time element determined by the time required for equilibrium in the spray chamber. In addition, it was usually necessary to clean carefully the atomizer and often the spray chamber and the burner between tests. Condensates and incrustations often formed in the spray chamber and in and on the burner, considerable inconvenience and delay being occasioned by the careful removing thereof. In addition, it was often necessary to shield the burner from drafts and to water-cool it.

It is an object of the present invention to provide a simplified burner structure in which these difficulties are eliminated, yet which provides a high degree of stability in light intensity level of the flame and which produces a flame free from any flicker due to drafts encountered during operation.

For quantitative or qualitative analyses by spectrophotometric means, the temperature of the flame should be adjustable yet extremely steady at any setting. The flame is preferably a blue flame with a relatively low background light. Its temperature should remain at a constant level. It is an object of the invention to pro-

vide a novel photometric burner having such characteristics.

In such a method of quantitative or qualitative analysis, it is an important object of the present invention to atomize the sample to be analyzed directly into the flame zone and to eliminate the use of the aforesaid spray chamber. In this connection, it is an object of the invention to incorporate an atomizer in the burner and at a position to discharge an atomized liquid sample directly into the flame zone.

Direct atomization of the sample into the flame zone permits achievement of high spectral intensity with consequent high sensitivity. In prior burners, the transfer of the sample into the flame was inefficient due to the expansion occurring in the spray chamber and partial precipitation of vapor droplets on the walls thereof and in the connecting tubes. It is an object of the invention to overcome such difficulties and to achieve high spectral intensity by atomizing the sample directly into the flame zone.

For high photometric accuracy, e. g., in quantitative determinations, the sample should be admixed with the flame at a constant rate. It is an object of the present invention to admix with the flame or its combustible materials the sample to be analyzed, this admixing being at a constant rate.

Another object of the invention is to eliminate the necessity of water-cooling the burner and to reduce the area of the burner grill.

A further object of the invention is to provide a substantially tubular burner structure producing a high velocity flame not unduly influenced by drafts and which may even ride in the air above the burner to prevent coloration of the flame by dirt or other contaminations on the burner. Another object is to provide a burner structure suitable for use with gas combinations of widely different flame-propagation velocities without the necessity of employing pilot flames.

A further object is to provide a burner structure which can be made very small and which conserves the fuel and combustion-supporting gases delivered thereto.

In prior practice, the streams of fuel and combustion-supporting gases have often been obtained from pressured vessels equipped with the usual commercial pressure regulators. However, it has previously been the practice to employ auxiliary pressure regulators of a more sensitive type to regulate the pressure of the gases applied to the atomizer and burner. It is an object of the present invention to simplify the pressure control of the gases and to provide a burner structure in which the commercial pressure regulators give entirely satisfactory results, thus eliminating the need of additional pressure-regulating equipment.

Another object is to provide a burner structure which produces a full-intensity flame almost instantly after applying the sample, thus permitting rapid measurements with no waiting period for equilibrium.

In prior practice, there was a tendency toward drifts in flame intensity as a result of temperature drifts or other changing conditions in the spray chamber and burner. Additionally, the walls of the spray chamber tended to produce turbulent currents around the atomizer. It is an object of the present invention to eliminate such difficulties by spraying the liquid sample directly into the flame zone.

Additionally, in prior designs the clogging of the small inlet tube of the atomizer, supplying the sample liquid thereto, has been a source of trouble. It is an object of the present invention to minimize this difficulty by employing a straight and unconstricted sample tube of larger bore than is feasible with atomizers which operate in

conjunction with spray chambers and which are intended for highest precision.

A further object is to provide a burner structure which can be economically manufactured and which may, if desired, be formed substantially entirely of glass.

Another object is to provide a burner structure of novel design for an instrument for rapidly measuring small concentrations of chemical substances in a liquid sample, in many cases to a precision well below 1% and which may reach 0.1%.

Further objects and advantages of the invention will be evident to those skilled in the art from the following description of an exemplary embodiment.

Referring to the drawing:

Fig. 1 is a top view, partially in section, of a flame spectrophotometer employing the burner structure of the invention;

Fig. 2 is a vertical sectional view taken along the line 2—2 of Fig. 1;

Fig. 3 is an enlarged vertical sectional view of the burner structure of the invention;

Fig. 4 is a greatly enlarged view of the lower end of one type of sample-conducting tube of the invention;

Fig. 5 is a greatly enlarged sectional view of the upper end of the burner structure of Fig. 3; and

Fig. 6 is a vertical sectional view of a modified embodiment of the invention.

Referring particularly to Figs. 1 and 2, the invention includes a burner structure 10 illustrated as supplied with a fuel gas and a combustion-supporting gas from pressured containers 11 and 12, respectively equipped with commercial-type pressure regulators 13 and 14 having the usual valves and gages, not specifically shown. The burner structure 10 produces a flame 15 in a flame zone 16 extending upwardly from the burner structure. The flame 15 may extend downwardly substantially to the top of the burner structure 10 but may be adjusted to ride in the flame zone a slight distance above the uppermost portion of the burner structure.

The burner structure 10 is shown as positioned in a muffie or light shield 18 having a port 19 through which light from a color zone 20 of the flame may reach a concave mirror 21 for reflection to a slit mirror 22 and thence through a slit 23 of a spectrophotometer 24. This spectrophotometer may be of the quartz type and will desirably provide a monochromator by which the light from the flame 15 is analyzed into its spectrum, the spectrophotometer providing suitable means for measuring the intensity of any chosen wave length or range of wave lengths to determine quantitatively or qualitatively the existence of certain chemical substances in a liquid sample atomized into the flame zone 16. The function of the shield 18 is primarily to absorb sound. It is not essential from the standpoint of shielding the flame 15 from the usual drafts that might be encountered in a room in which the equipment is being used.

Referring particularly to Figs. 3-5, the burner structure 10 includes an outer burner element, shown as a thin-walled outer gas tube 30 having a centrally disposed passage bounded by a wall 31. The outer gas tube 30 is constricted at its upper end, the walls of this tube converging upwardly somewhat sinuously to a tip having an upper end or face 32.

Centrally within and secured to an end portion 34 of the outer gas tube 30 is an inner burner element shown as comprising an inner gas tube 35. The upper end of the inner gas tube converges upwardly in a somewhat sinuous form to a tip having an upper end or face 36, preferably a small fraction of an inch above the face 32. Alternatively, the face 36 may be flush with the face 32 but should not be positioned therebeneath to lie within the passage bounded by the wall 31.

The outer and inner gas tubes 30 and 35 form an outer burner structure with an upwardly directed orifice means, these gas tubes being preferably concentric and spaced

slightly from each other to define an outer annular gas passage 37 terminating in an outer annular orifice 38 between the tips of the tubes 30 and 35 which may be of a cross-sectional area of several sq. mm. and which jets fuel gas into the flame zone. Fuel gas, e. g., acetylene, is supplied to the outer annular gas passage 37 through an inlet tube 39 connected by a rubber tubing 40 (Fig. 1) to the pressure regulator 13.

The inner gas tube 35 provides a central passage 41 bounded by a wall 41. A sample-conducting tube 45 extends within this passage and provides a tip which extends centrally in the tip of the inner gas tube 35, having an upper end or face 46 which preferably terminates substantially flush with the upper end 36 but which may extend a few thousandths of an inch thereabove. The sample-conducting tube 45 extends through an end portion 47 of the thickened lower end of the inner gas tube 35 to provide a lower end 48 adapted to be submerged in a body of the liquid sample 49 (Fig. 2) which can conveniently be retained in a small cup or vessel 50 resting on the free end of a bent leaf spring 51. The fixed end of this spring may be secured by a screw 52 to a base 53 carrying posts 54 supporting the muffie or shield 18. By depressing the free end of the spring 51, the vessel 50 can be moved into and from its position shown in Fig. 2, the spring raising this vessel, when released, to submerge the lower end 48 of the sample-conducting tube 45.

The sample conducting tube 45 provides a minute passage 56 which may be of a diameter of 0.3-0.5 mm. or somewhat more, being thus of larger diameter than atomizer tubes used in earlier burner structures. The extreme lower end of this passage 56 may be constricted, as suggested in Fig. 4, to form a restricted orifice 57 of a diameter in the neighborhood of 0.1 mm., if greater economy of sample consumption is desired. In other instances, the passage 56 may be made straight without such constriction.

The sample conducting tube 45 cooperates with the wall 41 of the inner gas tube 35 in providing an inner gas passage 58 terminating in an inner annular orifice 60 directed into the flame zone, this annular orifice having a cross-sectional area which is only a fraction of a sq. mm. It is desirable that the sample-conducting tube 45 be concentric with the outer and inner gas tubes 30 and 35. To provide adequate rigidity of the sample-conducting tube 45 it is desirable to provide a support 61 therefor a short distance below the end 46. The support 61 is preferably formed as a part of a thimble 62 extending upwardly inside the inner gas tube 35 from its end portion 47. A stream of combustion-supporting gas, e. g., oxygen, is delivered to the annular space between the thimble and the inner gas tube 35 to flow along the inner annular gas passage 58 and jet from the inner annular orifice 60, this gas being supplied to an inlet 64 connected by a rubber tubing 65 to the pressure regulator 14 of the pressured vessel 12. The entire burner structure 10 may be suitably mounted in an upright position, as by employing a mounting means 67 (Fig. 2) encircling the inlet 64 and connected to one of the posts 54.

In practice, the entire burner structure thus far described can be made of heat-resisting glass, with the exception of the sample-conducting tube 45 which is preferably made of metal, typically a platinum iridium alloy. However, if desired, the entire burner structure can be made of assembled metal elements, with the inner gas tube 35 sealed relative to and extended downward externally from the lower end of the outer gas tube 30 and with the sample-conducting tube 45 sealed relative to and extended externally from the lower end of the inner gas tube 35.

The inner gas tube 35 and the sample-conducting tube 45 form a part of an atomizer serving the dual purpose of aspirating a minute stream of the sample

liquid from the body 49 and subdividing or atomizing this sample liquid as it issues from the minute passage 56 of the sample conducting tube 45. Thus, in a typical operation, a pressured combustion-supporting gas such as oxygen is delivered through the inlet 64 to jet at extremely high velocity past the tip of the sample-conducting tube and into the flame zone 16. This aspirates and atomizes the sample liquid. The reduction in pressure at the end 46 due to the high velocity stream of gas is sufficient to elevate the sample liquid from the vessel 50. The sample liquid is then broken up into minute mist-like particles at the end 46 by the high velocity stream of gas. It is important to note that this atomization is directly into the base of the flame zone 16. The pressured gaseous fuel such as acetylene is simultaneously supplied from the container 11 through the inlet 39 to discharge through the outer annular orifice 38 into the flame zone in surrounding relationship with the combustion-supporting gas issuing from the inner annular orifice 60 containing the atomized sample liquid. The two streams intermix almost instantaneously in the open atmosphere at the bottom of the flame zone to form a combustible mixture which can be ignited to produce the flame 15. The relative positions of the faces or ends 32, 36 and 46 are such that a steady blue flame is produced which will not build up a cylinder of carbon when a carbon-containing gas such as acetylene is used.

Distinctly better results have been obtained with the face 32 of the outer gas tube disposed a small distance below the face 36 of the inner gas tube, particularly when employing gas combinations of widely different flame-propagation velocities. For example, with acetylene and oxygen, the downward flame propagation velocity may be less than the high upward velocity of the gas mixture necessary for atomization in which event the flame may be unable to maintain itself in the absence of an auxiliary pilot flame. This is particularly true if the faces 32 and 36 are made flush. However, when the face 32 is slightly lower than the face 36, as suggested in Figs. 3 and 5, it has been found that a quiet disk-shaped mantle of flame, due to acetylene burning in air, is continuously present at the base of the flame zone. This mantle is suggested by dotted lines 76 of Figs. 2 and 3 and serves as a pilot light, thereby maintaining the flame without the necessity of any supplementary pilot flame.

It is an important feature of the invention that the usual commercial pressure regulators 13 and 14 can be employed. In a typical operation, acetylene may be reduced in pressure by the regulator 13 to a value typically less than 1 p. s. i. Oxygen in the pressure vessel 12 may be reduced in pressure by the regulator 14 to about 10-25 p. s. i. At the low flow rates involved, relatively small pressured vessels 11 and 12 will provide for many hours of operation.

While various gas combinations can be employed, oxygen-acetylene or oxygen-hydrogen combinations have been found to be the most successful, such combinations being much better than an oxygen-natural gas combination.

In the preferred practice, the combustion-supporting gas is the inner stream, effecting the atomization, and the fuel gas is the outer stream. However, in an alternative mode of use, the gaseous fuel can be jetted from the inner annular orifice 60 at high velocity, the combustion-supporting gas being discharged through the outer annular orifice 38 at lower pressure.

For certain purposes, the invention can be modified by eliminating the outer gas tube 30, as suggested by the showing of Fig. 6. Here the inner gas tube 35 and its inlet 64 receives a gaseous fuel, e. g., acetylene, at a pressure up to about 15 p. s. i., the fuel serving to aspirate and atomize the liquid sample as previously described. Air, serving as the combustion-supporting gas, is entrained from the atmosphere and mixed with the

fuel containing the atomized sample liquid. In this embodiment, it is usually necessary to maintain the flame 15 by means of one or more small pilot flames 80 placed a few millimeters beyond the end of the burner structure and directed into the flame zone, leaving a space between the pilot flames and the burner structure for admixture of air.

Various changes and modifications may be made without departing from the spirit of the invention, the embodiments herein described being suggestive of other variations which will be apparent to those skilled in the art.

I claim as my invention:

1. In a spectrophotometric burner structure for creating a flame having a spectrum that is characteristic of the chemical composition of a liquid sample to be analyzed, said liquid sample being contained in a small cup, said burner structure including: upright walls defining inner and outer gas passages terminating in concentric inner and outer orifices facing upwardly and discharging side by side into a flame zone, said inner orifice being a restricted orifice bounded at its uppermost portion by a circular edge lying in a horizontal plane; means for respectively closing the lower ends of said inner and outer gas passages; an inlet tube communicating with said inner gas passage above its closure for delivering to said inner gas passage a stream of oxygen under pressure; an inlet tube communicating with said outer gas passage above its closure for delivering to said outer gas passage a fuel gas; and a sample-conducting tube extending centrally along said inner gas passage and providing a lower portion extending through, sealed to and mounted by said closure for said inner gas passage, said lower portion providing a lowermost terminal end in said small cup to be submerged in said liquid sample, said sample-conducting tube providing an upper portion terminating in an atomizing tip disposed centrally within said inner restricted orifice, said tip providing an upper end face exposed to and facing said flame zone and lying substantially in said horizontal plane whereby said stream of oxygen sweeps past said end face at high velocity and lowered pressure to aspirate a stream of said sample liquid from said cup through said sample-conducting tube and atomize such aspirated stream into said flame zone as it issues from said tip, said sample-conducting tube providing a substantially capillary-size open-ended passage extending therethrough from said lowermost terminal end to said end face of said tip and through which said stream of sample liquid flows because of the high velocity stream of oxygen sweeping past said end face of said tip.
2. In the art of spectrophotometrically determining the chemical composition of a sample liquid to be analyzed, a spectrophotometric flame-producing burner structure for atomizing the sample directly into the base of a flame zone to impart to the flame a spectrum characteristic of the chemical components of the sample liquid, said burner structure including in combination: a small cup adapted to contain a body of said sample liquid; a burner; and means for mounting said burner at a position above said sample cup, said burner including an upright gas tube providing a longitudinally extending gas passage having a central axis, a closure for closing the lower end of said gas tube, said closure having an opening co-axial with said central axis, said gas tube being restricted at its upper end to provide a circular restricted aperture co-axial with said central axis, said upright gas tube providing an upper end face on which said circular restricted aperture opens, said end face being open to and bounding the bottom of said flame zone, a sample-conducting tube sealed in said opening of said closure and providing a lower portion below said closure having a lower open end positioned in said small cup to be submerged in said body of said sample liquid therein, said sample-conducting tube providing an upper portion extending along said gas passage with an uppermost atomizing tip portion dis-

posed in said circular restricted aperture, said tip portion providing an end face open to and bounding the bottom of said flame zone, said uppermost tip portion being spaced laterally from the walls of said circular restricted aperture to define therebetween an annular orifice of substantially smaller cross-sectional area than said gas passage, said sample-conducting tube providing a longitudinal passage from end to end therethrough of substantially capillary dimension terminating at said end face of said tip portion of said sample-conducting tube in an orifice of substantially capillary size, an inlet tube for introducing a gas into said gas passage under pressure, said inlet tube communicating with said gas passage at a position between said closure and said annular orifice, said gas flowing at sufficient velocity through said annular orifice and past said end face of said sample-conducting tube to reduce the pressure at such end face of said sample-conducting tube and effect aspiration of said minute stream of sample liquid and atomization of same directly into the base of said flame zone immediately upon issuance of the aspirated sample liquid from said orifice.

3. A burner structure as defined in claim 2 including an outer tube around said upper end of said gas tube spaced therefrom to define an outer annular space providing orifice means discharging into said flame zone at a position outwardly beyond said circular restricted aperture, and an inlet tube connected to said outer annular space for supplying thereto another gas, such other gas issuing from said orifice means around the aspirating gas and its entrained sample liquid and mixing therewith in said flame zone, one of said gases comprising a fuel gas and the other of said gases comprising a combustion-supporting gas.

4. In a flame photometry burner structure for creating a flame having a spectrum that is characteristic of the chemical composition of a liquid sample to be analyzed, the combination of: a small cup adapted to contain a body of said liquid sample; a burner; and means for mounting said burner at a position above said sample cup, said burner including a sample-conducting tube providing an orificed tip at its upper end terminating in an end face exposed to and facing the zone of said flame and providing a lower end extending into said small cup to be submerged in said body of said liquid sample when placed therein, said sample-conducting tube providing a passage extending from end to end thereof and terminating in an orifice of substantially capillary size in said tip, an inner gas tube surrounding a portion of said sample-conducting tube to define an inner annular gas passage therebetween terminating in an inner annular orifice around said tip and discharging into said flame zone, a centering support within said inner gas tube for said sample-conducting tube, a connection opening on said inner annular gas passage for supplying thereto a stream of a first gas to sweep through said annular orifice and past said tip to aspirate a stream of said liquid sample and atomize same into said flame zone, an outer gas tube surrounding said inner gas tube to define an outer annular gas passage therebetween terminating in an outer annular orifice concentric with said inner annular orifice and discharging into said flame zone, and a connection opening on said outer annular gas passage for supplying thereto a stream of a second gas, said second gas discharging as an annular stream through said outer annular orifice into said flame zone around said first gas and mixing therewith exclusively in said flame zone, said second gas being a fuel gas and said first gas being a combustion-supporting gas, the mixture thereof forming a combustible mixture creating said flame, said inner gas tube providing a tip terminating in an end face, said outer gas tube providing a tip terminating in an end face, the end face of said inner gas tube extending a small fraction of an inch beyond said end face of said outer gas tube, said burner structure producing a mantle of flame at the base of said flame zone.

5. In a flame photometry burner structure for creating a flame having a spectrum that is characteristic of the chemical composition of a liquid sample to be analyzed, the combination of: a small cup adapted to contain a body of said liquid sample; a burner; and means for mounting said burner at a position above said sample cup, said burner including a sample-conducting tube providing an orificed tip at its upper end terminating in an end face exposed to and facing the zone of said flame and providing a lower end extending into said small cup to be submerged in said body of said liquid sample when placed therein, said sample-conducting tube providing a passage extending from end to end thereof and terminating in an orifice of substantially capillary size in said tip, an inner gas tube surrounding a portion of said sample-conducting tube to define an inner annular gas passage therebetween terminating in an inner annular orifice around said tip and discharging into said flame zone, a centering support within said inner gas tube for said sample-conducting tube, a connection opening on said inner annular gas passage for supplying thereto a stream of a first gas to sweep through said annular orifice and past said tip to aspirate a stream of said liquid sample and atomize same into said flame zone, an outer gas tube surrounding said inner gas tube to define an outer annular gas passage therebetween terminating in an outer annular orifice concentric with said inner annular orifice and discharging into said flame zone, and a connection opening on said outer annular gas passage for supplying thereto a stream of a second gas, said second gas discharging as an annular stream through said outer annular orifice into said flame zone around said first gas and mixing therewith exclusively in said flame zone, one of said gases being a fuel gas and the other of said gases being a combustion-supporting gas, the mixture thereof forming a combustible mixture creating said flame, said inner gas tube providing a lower end portion through which said sample-conducting tube extends, said centering support extending upward from said lower end portion within said inner gas tube and around said sample-conducting tube to support the latter and maintain its tip centered in said inner gas tube.

6. In a flame photometry burner structure for creating a flame having a spectrum that is characteristic of the chemical composition of a liquid sample to be analyzed, the combination of: a small cup adapted to contain a body of said liquid sample; a burner; and means for mounting said burner at a position above said sample cup, said burner including a sample-conducting tube providing an orificed tip at its upper end terminating in an end face exposed to and facing the zone of said flame and providing a lower end extending into said small cup to be submerged in said body of said liquid sample when placed therein, said sample-conducting tube providing a passage extending from end to end thereof and terminating in an orifice of substantially capillary size in said tip, an inner gas tube surrounding a portion of said sample-conducting tube to define an inner annular gas passage therebetween terminating in an inner annular orifice around said tip and discharging into said flame zone, a centering support within said inner gas tube for said sample-conducting tube, a connection opening on said inner annular gas passage for supplying thereto a stream of a first gas to sweep through said annular orifice and past said tip to aspirate a stream of said liquid sample and atomize same into said flame zone, an outer gas tube surrounding said inner gas tube to define an outer annular gas passage therebetween terminating in an outer annular orifice concentric with said inner annular orifice and discharging into said flame zone, and a connection opening on said outer annular gas passage for supplying thereto a stream of a second gas, said second gas discharging as an annular stream through said outer annular orifice into said flame zone around said first gas and mixing therewith exclusively in said flame zone, one of said gases being a fuel gas and the other of

said gases being a combustion-supporting gas, the mixture thereof forming a combustible mixture creating said flame, said inner gas tube providing a lower end portion through which said sample-conducting tube extends, said outer gas tube providing an end portion sealed with reference to said inner gas tube.

7. In apparatus for use in spectrophotometric analysis, a burner assembly comprising; means defining a generally annular first orifice on one side of said assembly; means for conducting a fuel gas under pressure to said orifice; means defining a second orifice substantially centrally concentric to said first orifice and on the same side of said assembly; means for conducting a combustion-supporting gas under pressure to said second orifice; and an aspirator tube having a capillary passageway there-through, said tube extending through said burner assembly with an open end of said passageway positioned substantially centrally of said second orifice and so arranged that the venturi effect of gas issuing from said second orifice and past the open end of said tube aspirates and entrains fluid from said tube, the other end of said tube being open and projecting a substantial distance from the other side of said assembly whereby the said other end of said tube may be selectively positioned in a liquid sample to be aspirated therethrough for analysis.

8. In the art of producing a spectrophotometric flame whose spectrum is characteristic of a liquid sample to be analyzed, a burner structure for producing such a flame when connected to pressure sources of fuel and combustion-supporting gas, said burner structure comprising in combination: upright walls defining an outer annular gas passage concentric with an inner gas passage, said passages respectively discharging into a flame zone at the upper end of the burner structure through an outer annular orifice and an inner circular orifice immediately within the outer annular orifice; a closure for respectively closing the lower end of each of said gas passages; a sample-conducting tube sealed in said closure for said inner gas passage, said sample-conducting tube having a lower portion depending below said closure for said inner gas passage and adapted for insertion into a body of said liquid sample, said sample-conducting tube having an upper portion extending axially along said inner gas passage with its upper end positioned centrally and co-axially in said inner circular orifice to form an inner annular orifice immediately within said outer annular orifice, both annular orifices discharging directly into said flame zone; a first connection openly communicating with said outer annular gas passage above its closure and adapted for connection to said pressure source of fuel to supply fuel from said pressure source thereof to said outer annular gas passage to issue from said outer annular orifice as an annular gaseous stream of fuel; and a second connection openly communicating with said inner gas passage above its closure but below the closure of said outer annular gas passage, said second connection being adapted for connection to said pressure source of combustion-supporting gas to supply said combustion-supporting gas from said pressure source thereof to said inner gas passage to issue from said inner annular orifice as an annular stream of combustion-supporting gas mixing with said annular stream of fuel in said flame zone to create a combustible mixture exclusively in said flame zone and which burns as a flame therein, said annular stream of combustion-supporting gas being projected by said pressure source thereof at high velocity past the upper end of said sample-conducting tube to aspirate a minute stream of the liquid sample from said body thereof and to subdivide same directly into the flame zone to impart its spectral characteristic to said flame.

9. In the art of producing a spectrophotometric flame whose spectrum is characteristic of a liquid sample, a burner structure for producing a flame when connected to pressure sources of fuel and combustion-supporting

gas, said burner structure including in combination: an upright inner gas tube providing an inner gas passage and terminating in an upper tip having an inner orifice; an upright outer gas tube fixed concentrically with said inner gas tube and providing an upper tip surrounding the tip of said inner gas tube, said inner and outer gas tubes being spaced from each other to define an outer annular gas passage therebetween terminating in an outer annular orifice between the tips of said inner and outer gas tubes; a closure for the lower ends of each of said gas passages; a sample-conducting tube extending through said closure for said inner gas passage, said sample-conducting tube providing an upper portion extending axially along said inner gas tube and terminating in a tip within said inner orifice to form a narrow inner annular orifice between the tips of said inner gas tube and said sample-conducting tube, said narrow inner annular orifice being immediately within said outer annular orifice, said inner and outer annular orifices being directed upwardly into a flame zone of the atmosphere, there being an inner annular gas passage within said inner gas tube around said upper portion of said sample-conducting tube below said narrow inner annular orifice, said sample-conducting tube providing a lower portion projecting downwardly below said closure for said inner gas passage and providing an open lower end adapted for insertion into a body of said liquid sample; a centering support in said inner gas tube and engaging the periphery of said sample-conducting tube at a position below said narrow inner annular orifice and above said closure for said inner gas passage for centering said sample-conducting tube in said inner orifice; a fuel connection opening on said outer annular gas passage at a position above its closure, said fuel connection extending from said outer gas tube and being adapted for connection to said pressure source of fuel for supplying such fuel to said outer annular gas passage to issue from said outer annular orifice as an annular gaseous stream of fuel containing substantially no combustion-supporting gas; and another connection opening on said inner annular gas passage above its closure and extending from said inner gas tube, said other connection being adapted for connection with said pressure source of combustion-supporting gas for supplying a stream of the combustion-supporting gas to said inner annular gas passage to issue from said inner annular orifice at high velocity around and past said tip of said sample-conducting tube as an annular gaseous stream of combustion-supporting gas, this annular stream of combustion-supporting gas mixing with the annular stream of fuel in said flame zone and aspirating a minute stream of the liquid sample from said body thereof and sub-dividing same directly into the flame zone to impart its spectral characteristic to said flame.

10. In a spectro-photometric analytical apparatus, a flame generating burner comprising an elongated cylindrical shell chamber having an inlet tube adjacent one end for introducing a combustible gas into the chamber, said cylindrical shell chamber being provided at its other end with a diametrically reduced substantially circular aperture, a nozzle-tube of substantially smaller diameter extending through said cylindrical shell chamber and having at one end a discharge nozzle adjacent to and substantially concentrically within and spaced from the substantially circular aperture producing an annular flame port therewith and being provided with a portion having a constricted passage opening adapted to create therewith a Venturi effect, said nozzle-tube being provided adjacent its other end with an inlet tube for receiving a high-pressure combustion-supporting gas, and a liquid-sample intake tube of smaller diameter disposed within and extending coaxially through the nozzle-tube, said liquid-sample intake tube terminating at one end substantially concentrically within the constricted passage opening and at its other end projecting outwardly from the burner for insertion into a body of liquid to be analyzed.

11. In a spectro-photometric analytical apparatus, a flame generating burner comprising an elongated cylindrical shell chamber having an inlet tube adjacent one end for introducing a combustible gas into the chamber, said cylindrical shell chamber being provided at its other end with a diametrically reduced substantially circular aperture, a nozzle-tube of substantially smaller diameter extending through said cylindrical shell chamber and having at one end a discharge nozzle adjacent to and substantially concentrically within and spaced from the substantially circular aperture providing an annular flame port therewith and being provided with a portion having a constricted passage opening adapted to create therewith a Venturi effect, said nozzle-tube being provided adjacent its other end with an inlet tube for receiving a high-pressure combustion-supporting gas, and a substantially straight liquid-sample intake tube of smaller diameter disposed within and extending coaxially through the nozzle-tube, said liquid-sample intake tube terminating at one end substantially concentrically within the constricted passage opening and at its other end projecting outwardly from the burner for insertion into a body of liquid to be analyzed.

12. In a spectro-photometric analytical apparatus, a flame generating burner comprising a first tubular member being closed at one end and being constricted at its other end to provide a substantially circular aperture, a gas inlet means opening into the interior of the first tubular member adjacent the closed end thereof for introducing a combustible gas therein, a second tubular member disposed within, and being of substantially smaller diametral size than the first tubular member and being closed at one end adjacent to the closed end of the first tubular member and terminating at its other end in concentric relation to the aperture for providing in cooperation therewith an annular flame orifice, an inlet tube opening into the second tube adjacent the closed end thereof for introducing therein a flame supporting gas, and a substantially straight liquid-sample intake tube extending coaxially through the second tubular member, said liquid-sample intake tube being of substantially capillary dimensions and terminating at one end adjacent to the annular flame orifice providing a discharge opening, said liquid-sample intake tube projecting outwardly from the closed end of the second tubular member for insertion into a body of liquid to be analyzed, said second tubular member further being provided at its other end with means having a constricted passage opening around the upper end of the liquid-sample intake tube providing a Venturi constriction for producing suction around the upper end of the liquid-sample intake tube whereby to cause the liquid sample to flow upwardly through the liquid-sample intake tube and through the discharge opening thereof.

13. In a spectro-photometric analytical apparatus, a flame generating burner comprising a first tubular member being closed at one end and being constricted at its other end to provide a substantially circular aperture, a gas inlet means opening into the interior of the first tubular member adjacent the closed end thereof for introducing a combustible gas therein, a second tubular member disposed within, and being of substantially smaller diametral size than the first tubular member and being closed at one end adjacent to the closed end of the first tubular member and terminating at its other end in concentric relation to the aperture for providing in cooperation therewith an annular flame orifice, an inlet tube opening into the second tube adjacent the closed end thereof for introducing therein a flame supporting gas, and a substantially straight liquid-sample intake tube extending coaxially through the second tubular member, said liquid-sample intake tube being of substantially capillary dimensions and terminating at one end adjacent to the annular flame orifice providing a discharge opening, said liquid-sample intake tube projecting outwardly from the

closed end of the second tubular member for insertion into a body of liquid to be analyzed, said second tubular member further being provided at its other end with means having a constricted passage opening around the upper end of the liquid-sample intake tube providing a constriction for producing suction around the upper end of the liquid-sample intake tube whereby to cause the liquid sample to flow upwardly through the liquid-sample intake tube and through the discharge opening thereof.

14. In the art of spectrophotometrically determining qualitatively and quantitatively the chemical composition of a sample liquid to be analyzed, a spectro-photometric flame-producing burner for atomizing the sample liquid directly into the base of a flame zone to impart to the flame a spectrum characteristic of the chemical components of the sample liquid, said burner including in combination: upright walls defining concentric inner and outer gas passages terminating at their upper ends in concentric inner and outer orifices of smaller cross-sectional area than their respective gas passages, each of said orifices facing, discharging directly into and bounding the base of said flame zone; closures for respectively closing the lower ends of said gas passages; a first inlet tube communicating with said inner gas passage above its closure for delivering to said inner gas passage a stream of oxygen under pressure; a second inlet tube communicating with said outer gas passage above its closure for delivering to said outer gas passage a fuel gas under pressure to issue from said outer orifice as an annular fuel gas stream; a sample-conducting tube extending through said closure for said inner gas passage, said sample-conducting tube providing a lower portion below said closure for said inner gas passage and having a lower open end adapted for submergence in a body of said sample liquid, said sample-conducting tube providing an upper portion within and extending axially along said inner gas passage, said upper portion providing an upper end extending coaxially within said inner orifice and terminating adjacent the upper end of said inner orifice to form with the walls of the latter an annular restricted orifice having a cross-sectional area which is only a fraction of a sq. mm. and through which said oxygen moves past the upper terminus of said sample-conducting tube with sufficient velocity to aspirate sample liquid from said body thereof and atomize the aspirated sample liquid issuing from said upper terminus of said sample-conducting tube to produce a stream of oxygen containing atomized particles of sample liquid, said last-named stream discharging into said flame zone, said annular fuel gas stream mixing with said stream of oxygen containing such atomized particles exclusively in said flame zone; and a centering support for said upper portion of said sample-conducting tube, said centering support being disposed in said inner gas passage and engaging the periphery of said sample-conducting tube at a position between said first inlet tube and said annular restricted orifice, said sample-conducting tube providing a longitudinal central passage extending from end to end thereof and terminating at said upper terminus as a minute capillary-sized orifice facing said flame zone.

15. In the art of spectrophotometrically determining qualitatively and quantitatively the chemical composition of a sample liquid to be analyzed, a spectrophotometric flame-producing burner for atomizing the sample liquid directly into the base of a flame zone to impart to the flame a spectrum characteristic of the chemical components of the sample liquid, said burner including in combination: an upright gas tube providing a longitudinally extending gas passage having a central axis; a closure for closing the lower end of said gas tube, said closure having an opening co-axial with said central axis, said gas tube being restricted at its upper end to provide a circular restricted aperture co-axial with said central axis, said upright gas tube providing an upper end face on which said circular restricted aperture opens, said end face being open to and bounding the bottom of said flame zone; a

sample-conducting tube sealed in said opening of said closure and providing a lower portion below said closure having a lower open end adapted for insertion into a body of the sample liquid to be analyzed, said sample-conducting tube providing an upper portion extending along said gas passage with an uppermost atomizing tip portion disposed in said circular restricted aperture, said tip portion providing an end face open to and bounding the bottom of said flame zone, said uppermost tip portion being spaced laterally from the walls of said circular restricted aperture to define therebetween an annular orifice of substantially smaller cross-sectional area than said gas passage, said sample-conducting tube providing a longitudinal passage from end to end therethrough of substantially capillary dimension terminating at said end face of said tip portion of said sample-conducting tube in an orifice of substantially capillary size; a support within said gas passage of said gas tube between said closure and said upper end face of said gas tube, said support engaging the periphery of said sample-conducting tube for maintaining its uppermost atomizing tip portion centered in said circular restricted aperture so that said annular orifice is of equal width at all of its circumferential positions; and means for aspirating a minute stream of the sample liquid from said body thereof to issue from said orifice and for atomizing the issuing sample liquid directly into said flame zone, said last-named means including an inlet tube for introducing a gas into said gas passage under pressure, said inlet tube communicating with said gas passage at a position between said closure and said annular orifice, said gas flowing at sufficient velocity through said annular orifice and past said end face of said sample-conducting tube to reduce the pressure at such end face of said sample-conducting tube and effect such aspiration of said minute stream of sample liquid and such atomization of same directly into the base of said flame zone immediately upon issuance of the aspirated sample liquid from said orifice.

16. A spectrophotometric burner as defined in claim 15 in which said circular restricted aperture intersects said upper end face of said gas tube in a circular edge, and in which said end face of said sample-conducting tube is in substantially the plane of said circular edge.

17. In the art of spectrophotometrically determining qualitatively and quantitatively the chemical composition of a sample liquid to be analyzed, a spectrophotometric flame-producing burner for atomizing the sample liquid directly into the base of a flame zone to impart to the flame a spectrum characteristic of the chemical components of the sample liquid, said burner including in combination: an upright inner gas tube providing a longitudinally extending inner gas passage having a central axis; a closure for closing the lower end of said inner gas tube, said closure having an opening co-axial with said central axis; walls at the upper end of said inner gas tube providing a circular restricted aperture of substantially smaller diameter than said inner gas passage therebelow and communicating therewith, said circular restricted aperture being co-axial with said central axis, said walls providing an end face open to and bounding the bottom of said flame zone, said circular restricted aperture opening on said upper end face; a sample-conducting tube sealed in said opening of said closure and providing a lower portion below said closure having a lower open end adapted for insertion into a body of the sample liquid to be analyzed, said sample-conducting tube providing an upper portion extending along said inner gas passage and having an uppermost atomizing tip portion disposed in

said circular restricted aperture, said tip portion providing an end face open to and bounding the bottom of said flame zone, said uppermost atomizing tip portion being spaced laterally from the walls of said circular restricted aperture to define therebetween an inner annular orifice of substantially smaller cross-sectional area than said inner gas passage, said sample-conducting tube providing a longitudinal passage from end to end therethrough terminating at said end face of said tip portion of said sample-conducting tube in an orifice of substantially capillary size; a centering support within said inner gas passage between its closure and said upper end face of said inner gas tube, said support engaging the periphery of said sample-conducting tube for maintaining said uppermost atomizing tip portion thereof centered in said circular restricted aperture so that said inner annular orifice is of substantially equal width at all circumferential positions; means for aspirating a minute stream of the sample liquid from said body thereof to issue from said orifice and for atomizing the issuing sample directly into said flame zone, said last-named means including an inlet tube adapted for connection to a pressure source of gas for introducing such gas into said inner gas passage, said inlet tube communicating with said inner gas passage at a position between said closure and said inner annular orifice, said gas flowing at sufficient velocity through said inner annular orifice and past said end face of said sample-conducting tube to reduce the pressure at such end face of said sample-conducting tube and effect such aspiration of said minute stream of sample liquid and such atomization of same directly into the base of said flame zone immediately upon issuance of the aspirated sample liquid from said orifice; an outer gas tube surrounding and spaced from said inner gas tube to define therebetween an outer annular gas passage; a closure for the lower end of said outer annular gas passage; walls defining an outer orifice means directed upwardly into said flame zone at a radial position beyond said inner annular orifice and communicating with said outer annular gas passage; and another inlet tube adapted for connection to another pressure source of gas for delivering same to said outer annular gas passage, said other inlet tube opening on said outer annular gas passage at a position between its closure and said outer orifice means to expel its gas upwardly through said outer orifice means to mix in the lower portion of said flame zone with the atomizing gas issuing from said inner annular orifice, said gases being of different composition but comprising fuel gas and a combustion-supporting gas mixing in the lower portion of said flame zone to form a combustible mixture creating said flame.

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