March 25, 1969 E. A. BOLING 3,434,668

GAS BURNER FOR ATOMIC ABSORPTION SPECTROSCOPY

Filed May 31, 1966

Sheet 1 of 2

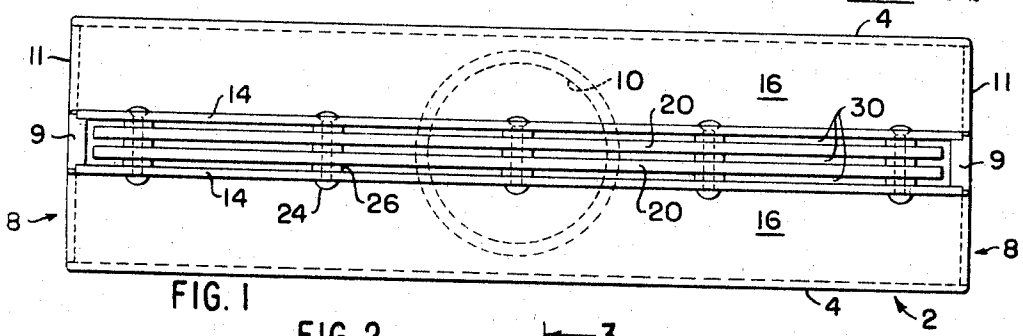
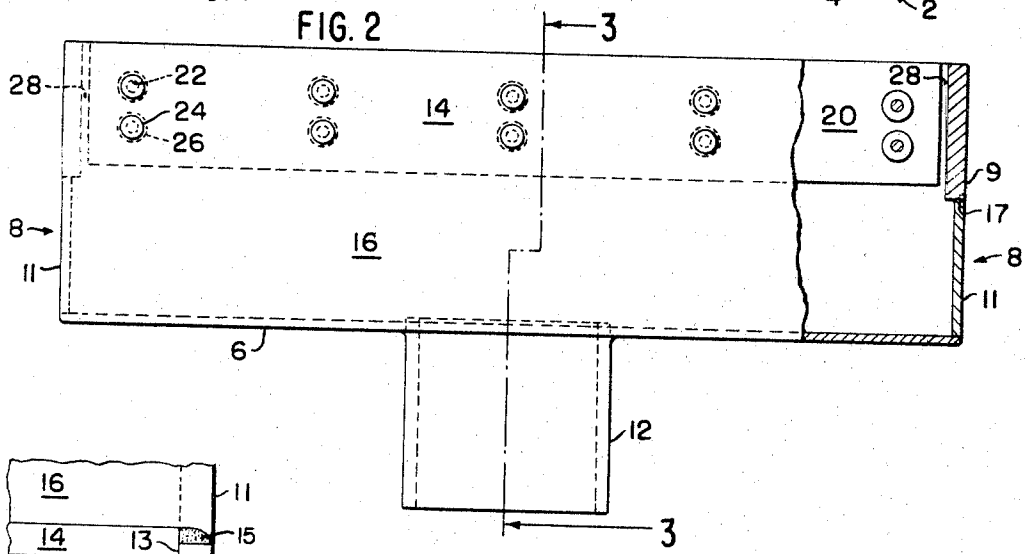


FIG. 1



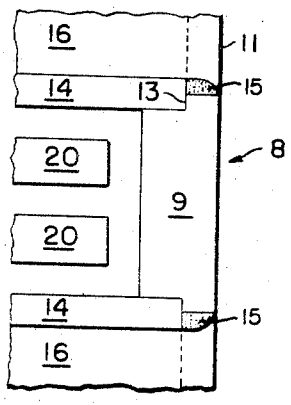


FIG. 4

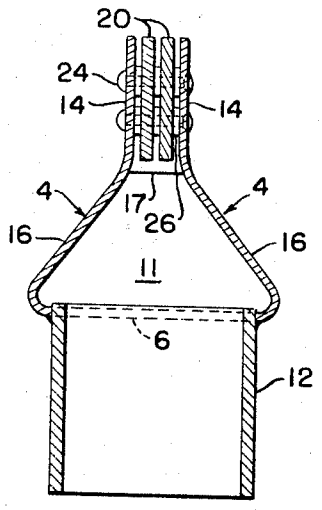


FIG. 3

INVENTOR.
ELDON A. BOLING

BY
Kenway, Jenney & Hildreth

ATTORNEYS

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GAS BURNER FOR ATOMIC ABSORPTION SPECTROSCOPY

Filed May 31, 1966 Sheet 2 of 2

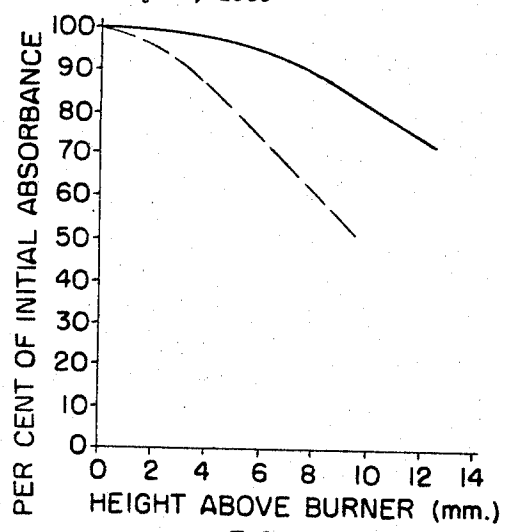

FIG. 5

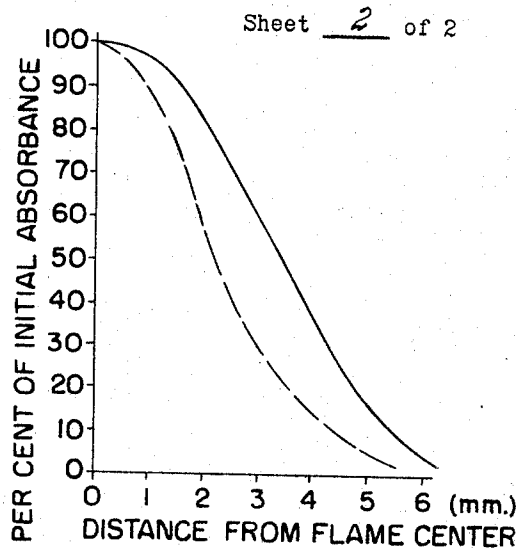

FIG. 6

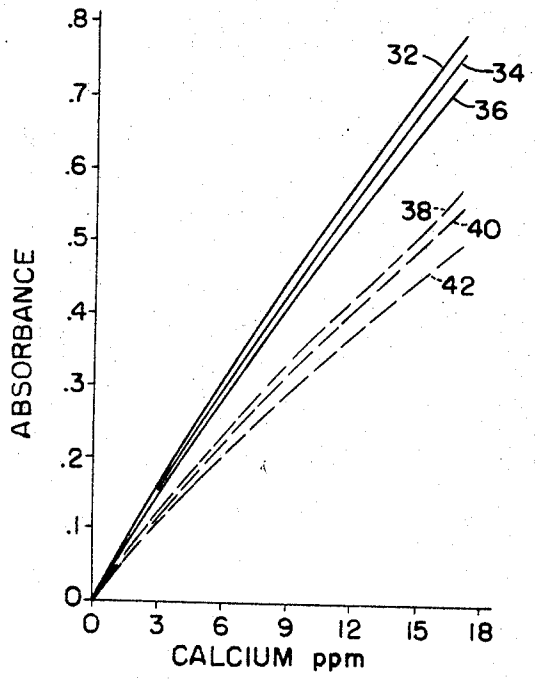

FIG. 7

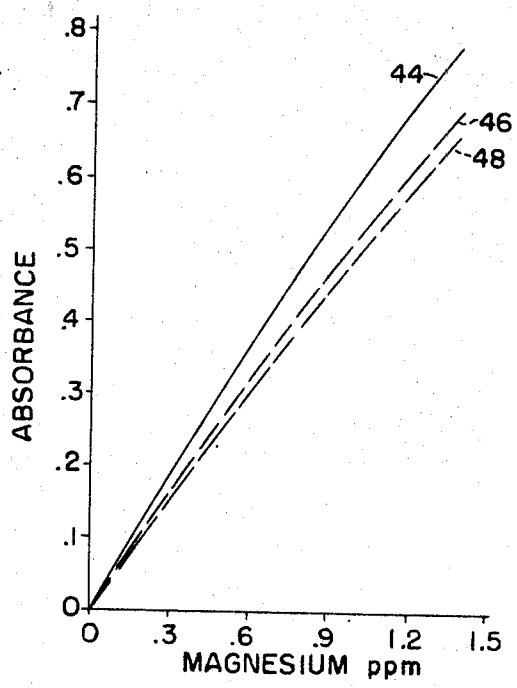

FIG. 8

INVENTOR.
ELDON A. BOLING

BY
Kenway, Jenney & Hildreth

ATTORNEYS

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3,434,668

GAS BURNER FOR ATOMIC ABSORPTION SPECTROSCOPY

Eldon A. Boling, 222 Warren St., Brookline, Mass. 02146

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Int. Cl. B05b 1/14
U.S. Cl. 239—552
4 Claims

ABSTRACT OF THE DISCLOSURE

This invention is a burner for atomic absorption spectroscopy having a plural number of slots for the passageway of combustion gasses, the slots being elongated and of a critical width for the gasses used in order to prevent blowback of the burner, the burner providing an extremely stable and optically homogeneous (and therefore transparent) flame for absorption studies.

This invention relates to gas burners, and in particular to a burner primarily designed for atomic absorption spectroscopy.

In connection with atomic absorption spectroscopy, where the mixture of combustible fuel and atomized solution containing the material to be studied are fed into the burner and then emerge into the flame together, it has been the practice to use burners having a single slit or slot, the burner being of elongated length, and the absorption of the substance being analyzed being measured from one end of the flame to the other. However, the presently known burners have some problems in connection with their use, and it is the general purpose of this invention to provide a burner which overcomes these problems.

In the single slit burner, as an example, the absorption is somewhat dependent upon the height of the burner flame and the flame alignment. The flame may be also somewhat unstable; and because of its small cross-sectional size, there is a limitation placed on the amount of the monochromator optical beam that is usable. This same limitation causes sensitivity as to alignment with respect to the optical beam. The single slit burner is also sensitive, for some of the substances being studied, to the slit width of the monochromator. In addition, some single slit burners are prone to burner flashback, particularly when acetylene gas is being used.

There is always some flame "noise" present in these burners which it is desirable to minimize. Also, if the cross-sectional area of the flame is smaller than that of the light beam being used, the relationship of absorbance against concentration of the element being studied must be a curve rather than a straight line. The ideal would be no flame "noise" and curves as straight as possible.

In a single slot burner, because of the fact that flames are infiltrated by the surrounding air, there will exist a zone near the periphery of a fuel-rich flame which is better oxygenated than the center, and in such a burner, this peripheral zone makes up a significant fraction of the total flame volume. Therefore, for studies in which a reducing flame seems best (for example, chromium, molybdenum, and calcium) an even smaller area of the single slot flame is available for use in measurement of the spectrum. Because of this reduction in cross-sectional area of the usable portion of the flame for such studies, less of the optical beam is utilized, the relationship of absorbance on concentration of the substance being studied becomes more of a curve.

It is therefore the general purpose of this invention to provide a multiple slot burner for atomic absorption studies which incorporates features minimizing and in some cases eliminating completely the above problems.

Among the several objects and advantages of the invention, therefore, may be noted the following:

One object of the invention is to provide a burner of the general class set out above, which has a greater sensitivity for absorption studies than a single-slot burner.

Another object of the invention is to provide a burner of the indicated classes which is less dependent on flame height, flame alignment and monochromator slit width.

Another object is to provide a burner of the above classes which has a larger cross-sectional area of reducing flame which can be used for spectrum measurements.

A further object of the invention is to provide a burner of the above classes in which flame "noise" (i.e., the instrumental variation which is the direct consequence of the characteristic of the flame) will be at a minimum.

A still further object of the invention is to provide a burner of the classes set forth above, in which for some substances the absorption sensitivity curves are straighter than those experienced in the use of prior art burners.

Yet another object of the invention is to provide a burner of the classes set forth above in which flashback of the flame is greatly minimized, and clogging of the burner is also minimized.

Still another object of the invention is to provide a burner for atomic absorption spectroscopic studies in which the flame is more stable than those found in the prior art.

Other objects and advantages of the invention will be in part obvious and in part pointed out hereinafter.

The invention accordingly comprises the elements and combinations of elements, features of construction, and arrangements of parts which will be exemplified in the structure hereinafter described, and the scope of the application of which will be indicated in the appended claims.

In the accompanying drawings in which one embodiment of the invention is illustrated:

FIG. 1 is a plan view of the invention;

FIG. 2 is a side elevation, partly in section, of the FIG. 1 embodiment;

FIG. 3 is a sectional end view, taken in the direction of sight lines 3—3 on FIG. 2;

FIG. 4 is an enlarged plan view of an end portion of the embodiment, given to show in greater detail certain features of construction.

FIG. 5 is a graph showing a comparison of the effect of light beam height on calcium absorbance for the burner of this invention and a single-slot burner;

FIG. 6 is a chart showing a comparison of the effect of light beam movement perpendicular to the plane of the flame, on calcium absorbance, using this invention and a single-slot burner;

FIG. 7 shows the effect of variation in monochromator slit width on calcium absorbance using the burner of this invention as compared to the prior art single-slot burner; and

FIG. 8 shows the effect of monochromator slit widths on magnesium absorbance using the burner of this invention and that of the prior art burners.

In the drawings, similar reference characters indicate corresponding parts throughout the several views, and dimensions of certain of the parts shown in the drawings may have been modified and/or exaggerated for the purposes of clarity of illustration.

Referring to FIGS. 1–4, the burner of this invention is a plural slot burner (the word "slot" being synonymous with the word "slit" but used herein by preference in order to distinguish the slots of the burner from the customarily-used word "slit" as applied to the monochromator slit), and comprises an elongated chamber indicated generally by numeral 2 having the side walls 4,

bottom 6 and the end walls 8. The burner is preferably made of stainless steel, and preferably is made by forming the bottom and side walls from a sheet of stainless steel into the configuration shown, (see FIG. 3) and then the end walls 8 (also preferably of stainless steel) are placed in position and welded to the ends of the side walls and bottom.

Referring to FIG. 4, a preferred construction of the joint between side wall ends and the end walls is shown in greater detail. The end walls 8 are each preferably of two-piece construction and comprise the top portions 9 and bottom portions 11. Portion 9 is thicker than portion 11, the latter being the thickness of the bottom and side walls. Portions 9 are rabbeted along their vertical edges to provide the shoulders 13, into which are received the ends of the upper portions 14 of the side walls. The lateral width of the portions 9 is less than the combined thicknesses of the side walls and the portions 9 in order to leave an external rabbet into which the welding bead 15 is placed. The portions 11 are welded along their top edges 17 to the bottom edges of portions 9, and along their other edges to the ends of the bottom and lower portions 16 of the side walls.

In construction, the portions 9 are first placed between the ends of portions 14, and this assembly is then tightly clamped together. Then welding is done, as shown. Thereafter the portions 11 are put in place and welded. The purpose of this construction is to ensure sharp inside corners where the inner surfaces of portions 9 abut the inner surfaces of the side wall upper portions. It will be found that this construction is simple and relatively inexpensive to make and assemble.

An opening 10 is provided in the bottom, preferably at the center thereof, into which is suitably fastened, as by welding or silver soldering, a tubular neck 12 which functions as a mounting means for the turner and means for the introduction of atomized solution of the element being studied and combustible fuel such as a mixture of acetylene and air, acetylene and nitrous oxide, or propane and air.

It will be noted that the side walls 4 have upper portions indicated by numeral 14 and lower portions 16. The lower portions 16 converge inwardly toward each other and then are bent upwardly perpendicularly to the bottom 6 to form the opposed elongated upper side portions 14 which lie in planes which are spaced from each other and which are parallel for the length of the burner.

Mounted between parallel side walls 14 are dividers 20, these dividers being flat elongated plates whose vertical width, (as viewed) is approximately equal to the vertical width of the side wall portions 14, and whose thickness is less than their vertical width. (By vertical width or depth is meant herein the dimension of the plates 20 from the upper or top edges of the plates-as-viewed to their bottom edges, and from the upper edge of portions 14 to where these portions join portions 16.) Dividers 20 are mounted in spaced parallel relationship to the upper portions 14 of the side walls, and while other means may be used for mounting than those shown, it wil be found that the indicated method is convenient and is as follows: each of the side wall portions 14 and the plates 20 is provided with axially aligned holes 22 through which are passed the rivets 24, the latter then being headed over. The plates 20 are held in laterally spaced relationship by means of the spacing washers 26 interposed as shown.

It will be also noted that the dividers 20 end just short of the inner surfaces of end walls 8, thus leaving a slot 28 at each end of the dividers, this slot connecting the plurality of longitudinal slots 30.

Longitudinal slots 30 have a transverse width lying in the range of 0.018 inch to 0.032 inch. It will be found that for the use of an acetylene-air combustible gas mixture, or propane and air, a lateral or transverse width of the slots of approximately 0.025 inch will work very satisfactorily. For a mixture of acetylene-nitrous oxide combustible gas, it will be found advantageous to decrease the lateral width or thickness of the longitudinal slots to approximately 0.018 inch, and conventional means of cooling the slot assembly in the latter case (not shown) may be used if desired. (In view of this teaching, it is within the skill of the art to construct a burner having longitudinal slots of a lateral width which is best suited for the particular gas being used. For example, a burner of this invention with slot widths of 0.018 inch when used with acetylene and air has not been made to flash back by applicant. However, a burner of 0.025 inch slot width which can be made to flash back under certain circumstances, is preferable for use with acetylene and air. In view of the fact that there are numerous mixtures of these gases, it is impossible to list all of the optimum widths, one for each of the numerous gases that may be used.) The transverse width of the end slots 28 should be the same as that of longitudinal slots 30.

As an example of a burner constructed in accordance with this description, the following approximate dimensions were used. The wall thickness of the sides 4, bottom 6, and portions 11 was 0.053 inch. The washers 26 were 0.025 inch thick, thus giving slots 30 the same lateral width. Slots 28 were 0.025 inch in lateral width. The dividers 20 were 4.36 inches long by 0.062 inch thick by 0.622 inch in vertical width (as viewed). The end wall portions 9 were 0.127 inch thick. The inside diameter of the neck 12 was 0.865 inch. The outside dimensions of the total burner were as follows: across the bottom, the burner was 1.26 inches wide; in length, it was 4.51 inches; and in height it was 1.4 inches.

The burner assembly is very rigid as thus constructed, and no distortion of the slot configuration has been observed during the use of the burner even under conditions in which accidental overheating was experienced. When the burner is properly operated at normal fuel and air flow, it can actually be touched while in prolonged operation. In addition, burner flashback (under proper operating conditions) has not been experienced, presumably due in part to the cooling effects of the relatively long vertical width of the dividers and the upper side wall portions 14.

In operation, when the flame is viewed end-on, the flame provided by the three slots shown has a peripheral zone which is an intense bright blue. The central flame area is transparent, and distant objects can be viewed through the flame with little or no distortion. As to that portion of flame noise which is due to dust in the atmosphere and its relationship to single-slot and multiple-slot burners, light flashes from sodium-containing dust can be seen to exist only in the peripheral bright blue zone. The central flame area is quite clean. The outer (bright blue) portion of the flame thus becomes, in this invention, a "flame curtain" which tends to prevent atmospheric contaminants from reaching that portion of the flame which is traversed by the monochromator light beam.

Atmospheric dust and smoke can cause very serious absolute analytical errors. For example, the potassium contained in tobacco smoke can give rise to spurious "concentrations" twenty times that of potassium in blood serum. This use of the peripheral flame as a gas curtain to shield the portion of the flame used for a light path has distinct benefits for some analyses, and also prevents memory effects when operating the flame in an atmosphere contaminated by previous samples. The exterior shape of the burner of this invention will also easily permit the incorporation of a peripheral air curtain, which would tend to eliminate atmospheric contaminants from even the peripheral zone of the flame. The flame noise level of burners can be assessed by measuring the standard deviation for repetitive data collection in ten second periods using an integrating analogue computer readout. The standard deviatino for a single-slot flame is about $\pm 0.3\%$ absorption. In marked contrast, the standard de-

viation for the burner of this invention is the same with the flame lit as it is with the flame out, or about ±0.3% absorption. That is, the effect of the flame upon the reproducibility of the $I/I_0=1.0$ setting is not perceptible.

Ideally, the central area of clean flame should be sufficiently large to completely contain the light beam at its largest section. This ideal is closely approached with the use of the present invention.

It is known that burners with narrow slots are notorious from the viewpoint of clogging. Tests have shown that burner performance as to clogging can be improved by widening the slots. Burners with slot widths of 0.018 inch, 0.022 inch, and 0.025 inch (all approximate) were compared. As slot width increased, there was a slight but definite increase in absorption, and a striking decrease in the tendency of the burner to be clogged by solutions of high solid content. In fact, undiluted blood serum can be atomized for periods sufficiently long to permit accurate analytical measurements with burners of the present invention using a 0.025-inch slot width. However, the wider the slot is, the more will be the tendency for the flame to strike back when the flame is extinguished. As to acetylene mixtures, this can be prevented if the acetylene flow is turned up considerably (when it is desired to extinguish the flame) and then is suddenly stopped using a quick release valve.

Referring now to FIGS. 5–8, there is shown a series of graphs in which the performance of a burner of this invention is compared to that of a conventional single-slot burner. In all graphs, the broken lines are the plots of the results using the single-slot burner, and the full lines are plots using a burner of this invention.

Table 1 shows the calcium and magnesium concentrations which were used in making the tests shown in FIGS. 5–8. Ten solutions were used, each containing either calcium or magnesium. Only solution 5 was used for FIGS. 5 and 6. All solutions were used for FIGS. 7 and 8.

TABLE 1

Solution	Concentration, p.p.m.	
	Magnesium	Calcium
1	0.276	3.4
2	0.553	6.8
3	0.830	10.2
4	1.106	13.6
5	1.383	17.0

Referring first to FIG. 5, there is plotted the percent of initial absorbance against the height (in millimeters) of the light beam above the burner. In making these tests, the acetylene-air fuel mixture was adjusted so that the flame height was about 11 centimeters, and the air content was reduced very nearly to the point where luminescence appeared in the flame. A fuel flow of about 3.3 liters per minute was used.

As shown in FIG. 5, for both burners, maximum calcium absorbance occurred when the burner was elevated so that the burner top just began to infringe on the sample beam. The fall in absorbance with increasing height of the light beam in the flame is much more marked for the single-slot burner than for the burner of this invention.

FIG. 6 shows the effect of light beam movement in a direction perpendicular to the flame plane in tests for calcium absorbance. It is seen that this adjustment is far less critical for a burner of this invention than for the prior art single-slot burner.

FIG. 7 shows the effect of variation in monochromator slit width on calcium absorbance for the two burners. Curves **32** and **38** are for monochromator slit widths of 0.03 millimeter; curves **34** and **40** are for slit widths of 0.3 millimeter; and curves **36** and **42** are for slit widths of 3.0 millimeters. Curves **32**, **34** and **36** are for the burner of this invention; and curves **38**, **40** and **42** are those for the single-slot burner. It is seen that there is much less dependence upon monochromator slit width for the burner of this invention than for the single-slot burner. It is also seen that the sensitivity is appreciably higher for the former than for the latter.

FIG. 8 shows the effect of variation of monochromator slit width on magnesium absorbance for the two burners. Curve **44** represents data at all monochromator slit widths (0.03, 0.3 and 3.0 millimeters being the widths tested) for the burner of this invention. Curve **46** represents the average of the values found for monochromator slit widths of 0.03 and 0.3 millimeter, and curve **48** represents the values found for monochromator slit widths of 3.0 millimeters, curves **48** and **46** being for the prior art single-slot burner. For the burner of this invention, no effect of monchromator slit width on magnesium absorbance could be discerned. The effect of monochromator slit width on magnesium absorbance for the single-slot burner is readily seen, although it is less marked than that found for calcium. It is also seen that the sensitivity is higher for the burner of this invention than for the single-slot burner.

Test results also show that in the measurement of chromium, molybdenum, and tin, the sensitivity of measurement is approximately doubled by the burner of this invention over that obtained with a single-slot burner.

In the drawings, a particular configuration of the burner itself is shown, but it is not necessary to follow the triangular shape (cross-section) provided the parallel longitudinally extending slots of the indicated lateral thickness or width are provided. So also, while a riveted construction is shown, other forms of fastening the several parts together may be used.

In view of the above it will be seen that the several objects of the invention are achieved and other advantageous results attained.

It is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also, it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

As many changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense.

Having described the invention, what is claimed is:

1. A burner for atomic absorption spectroscopy comprising an elongated open-topped chamber having a bottom, side and end walls, and dividing means partially closing the top opening of the chamber; spacing means located between each of said dividing means and between the latter and said side walls; the dividing means forming a plurality of spaced parallel elongated slots whose vertical depths are greater than their transverse widths; the slots extending the length of the chamber and communicating with the interior thereof, all of the slots being of the same transverse widths throughout their lengths and depths and lying within the range of 0.018 inch to 0.032 inch in said width; whereby said slots form uniform parallel restricted flow passages to shape combustion supporting gas flowing therethrough into substantially parallel and flat sheaths, and whereby the depthwise extending opposed parallel walls of the dividers and side walls enhance laminar flow of said gas through the slots; and an opening in one of the walls of said chamber for the introduction of combustible gas thereinto.

2. A burner for atomic absorption spectroscopy and adapted for burning a mixture of acetylene and air, comprising:

an elongated open-topped chamber having a bottom and side and end walls, the side walls having at least upper portions extending the length of the burner and in spaced parallel relationship;

a plurality of dividers mounted between said upper por-

tions and dividing the top opening of the chamber into a plurality of spaced parallel elongated longitudinal slots communicating with the chamber, whose vertical depths are at least ten times greater than their transverse width and whose transverse width is 0.024 to 0.026 inch, the dividers comprising flat elongated plates vertically mounted in spaced parallel relationship to each other and to said upper portions with spacers therebetween and with their lengths extending along the length of the chamber, the dividers ending short of the end walls to provide end slots between the ends of the dividers and the end walls which connect the ends of said elongated slots, the transverse widths of the end slots being approximately the same as the longitudinal slots; and

an opening into the chamber for the introduction thereinto of combustible gas; whereby said longitudinal slots form uniform parallel restricted flow passages to shape said gas into a laminar flow and into substantially parallel and flat sheets, and whereby the depthwise extending opposed parallel walls of the dividers and side walls enhance laminer flow of the gas through the slots.

3. The burner of claim 2 in which said dividers are two in number, and said elongated slots are three in number.

4. A burner for atomic absorption spectroscopy comprising an elongated open-topped chamber having a bottom, side and end walls, dividing means partially closing the top opening of the chamber, and an opening in said bottom for the introduction of combustible gas into the chamber; the bottom and side walls comprising an unitary structure formed from a sheet of metal, a central portion thereof constituting the bottom and the edge portions thereof being bent upwardly at an angle to the central portion to form the side walls, the latter first converging toward each other and then bending upwardly and substantially perpendicularly to the bottom to form

a pair of flat elongated spaced side wall upper portions in parallel relationship throughout their lengths; the end walls comprising flat closure plates of metal having the shape of the transverse cross-section of said unitary structure, the said plates being attached along their edges to the ends of the bottom and side walls; and the dividing means constituting a pair of flat elongated metal divider plates mounted between said upper portions and spaced in parallel relation thereto by means of washers and a plurality of rows of fasteners passing through the washers and said upper portions, thereby to provide, in conjunction with said upper portions, longitudinal slots extending outwardly from the interior of the chamber to the exterior thereof, all slots having the same transverse widths throughout their lengths and depths and the slots lying in the range of 0.018 inch to 0.032 inch in width, the divider plates being in vertical width approximately the same as the vertical depth of said upper portions of the side walls, the length of the divider plates being less than the distance between the inner surface of the end closure plates, whereby end slots of approximately the same transverse widths as said elongated slots are provided between the ends of the divider plates and said inner surfaces, the end slots connecting the ends of the longitudinal slots.

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M. HENSON WOOD, JR., *Primary Examiner.*

HOWARD NATTER, *Assistant Examiner.*

U.S. Cl. X.R.

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