United States Patent

[11] 3,574,508

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[21] Appl. No. 721,461
[22] Filed Apr. 15, 1968
[45] Patented Apr. 13, 1971
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[54] **INTERNALLY FIRED INDUSTRIAL GAS BURNER**
19 Claims, 13 Drawing Figs.

[52] **U.S. Cl.** **431/351**
[51] **Int. Cl.** **F23d 15/00**
[50] **Field of Search** .... 431/158, 173, 185, 348, 351, 352, 8—10; 263/19 (A); 60/39.65, 39.72

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ABSTRACT: A burner assembly includes a mixing and ignition chamber of a conical contour with the gaseous fuel being introduced through a series of nozzle discharge ports at the small end of the cone and directed generally parallel to the diverging cone surface. The combustion air is introduced into the cone through a plurality of cone apertures arranged in a series of axially spaced stages. Preferably, the cone apertures are canted to develop a swirling of the air about the cone center axis thereby enhancing fuel-air intermixture, ignition control and flame retention. A series of inwardly projecting circumferential bosses are preferably formed on the interior cone surface between respective aperture stages to divide the burner into a series of firing zones and also further enhance the aforesaid characteristics. Other features are disclosed.

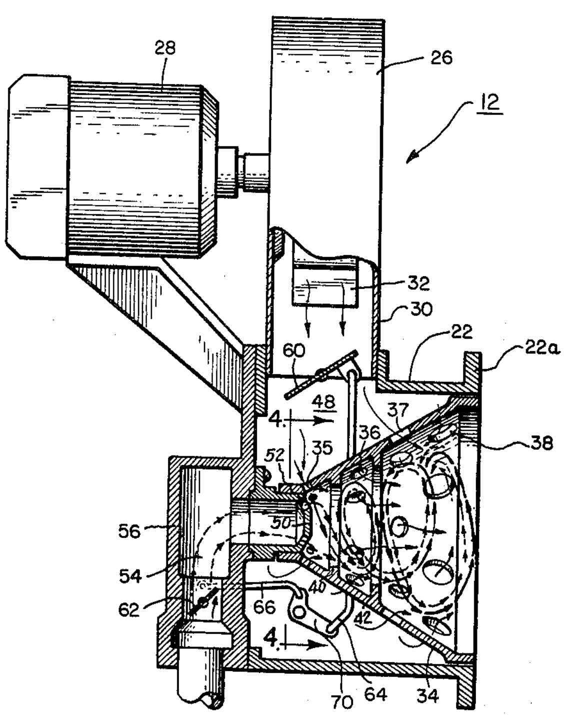

FIG. 1

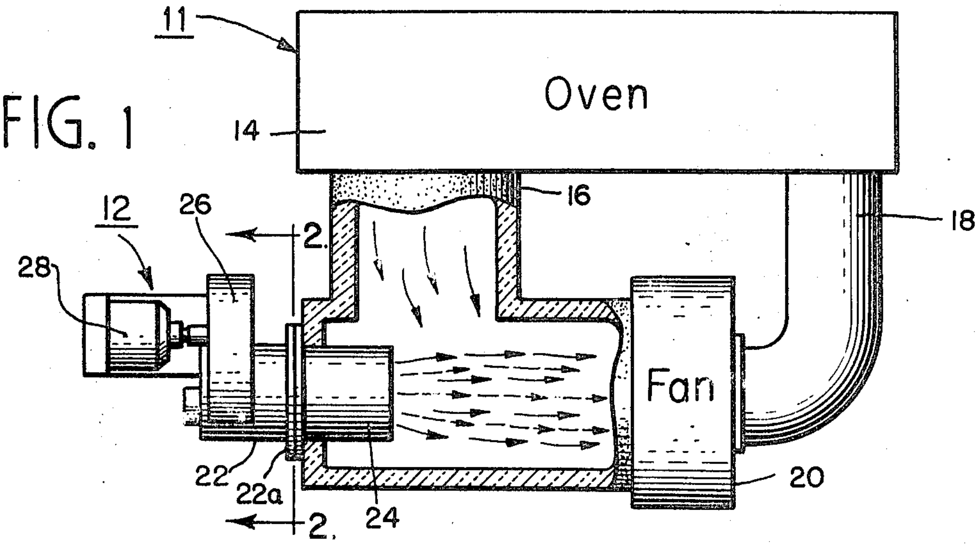

FIG. 7

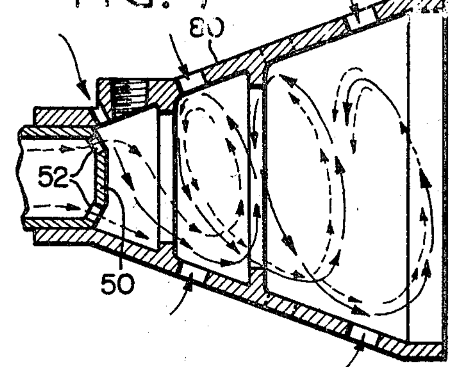

FIG. 8

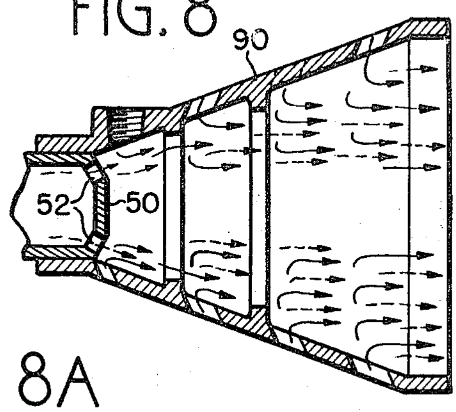

FIG. 7A

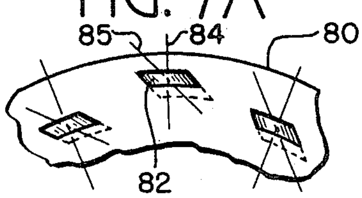

FIG. 8A

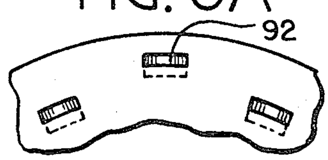

FIG. 10A

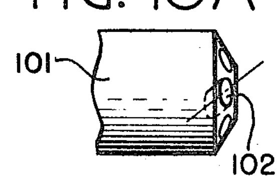

FIG. 9

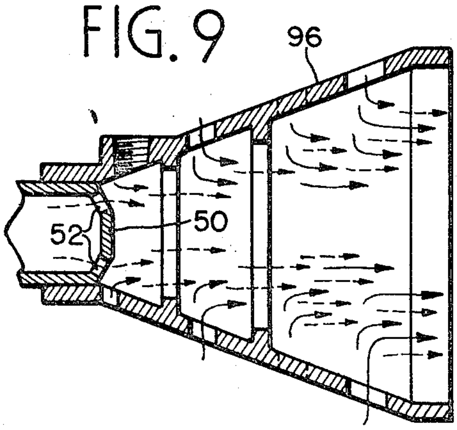

FIG. 10

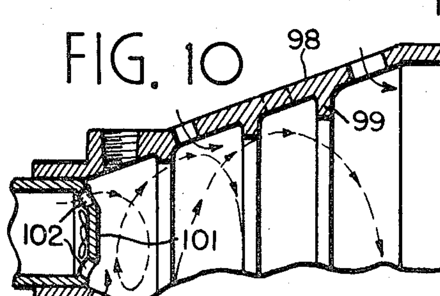

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FIG. 2

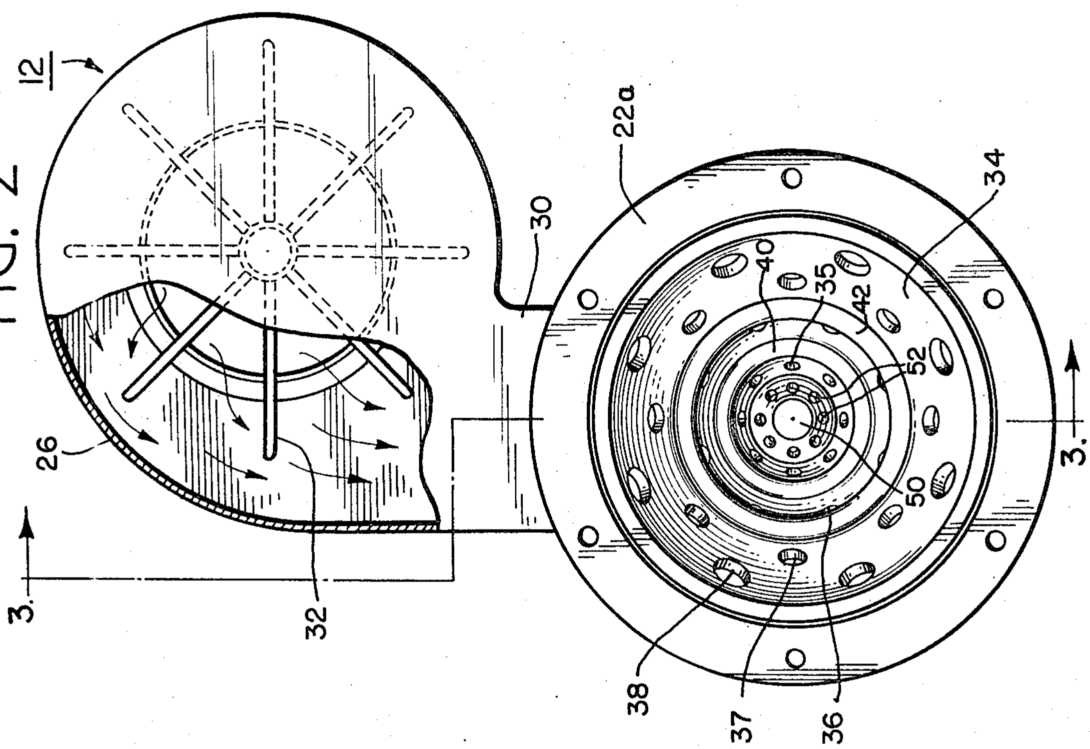
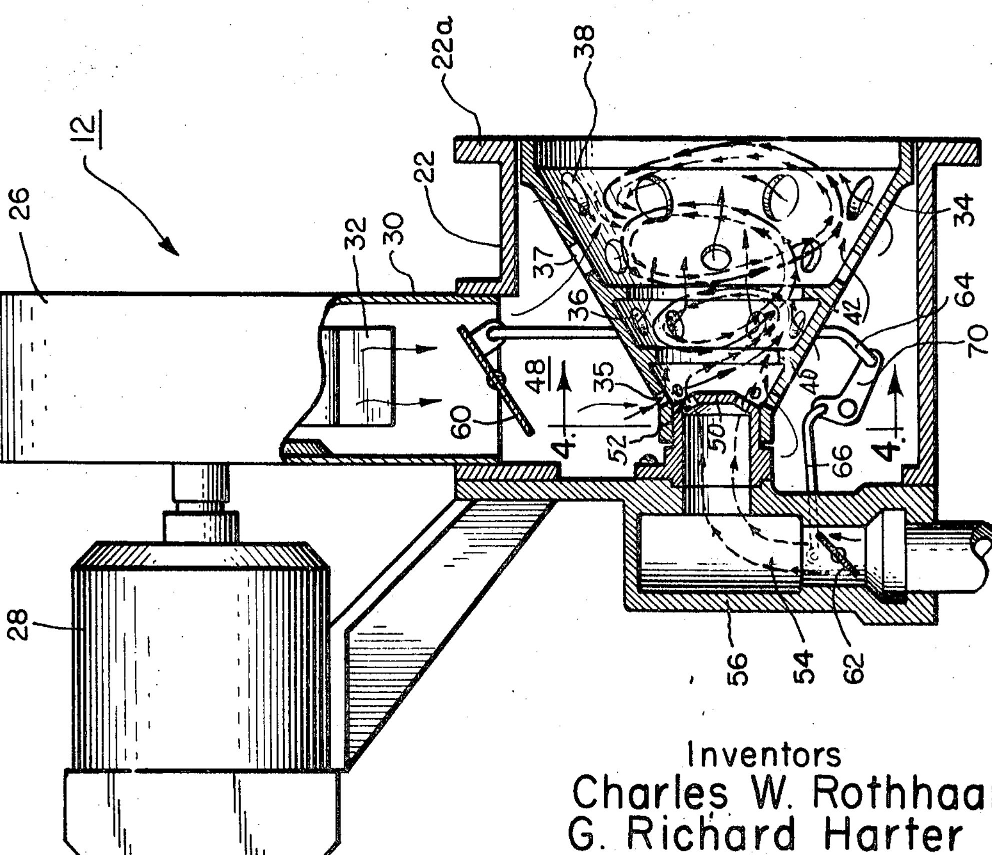


FIG. 3



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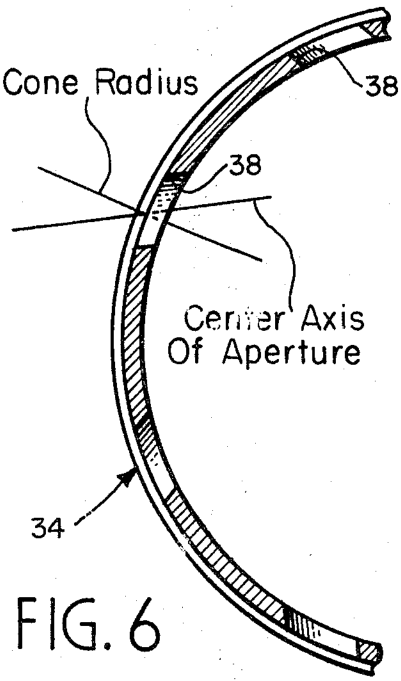
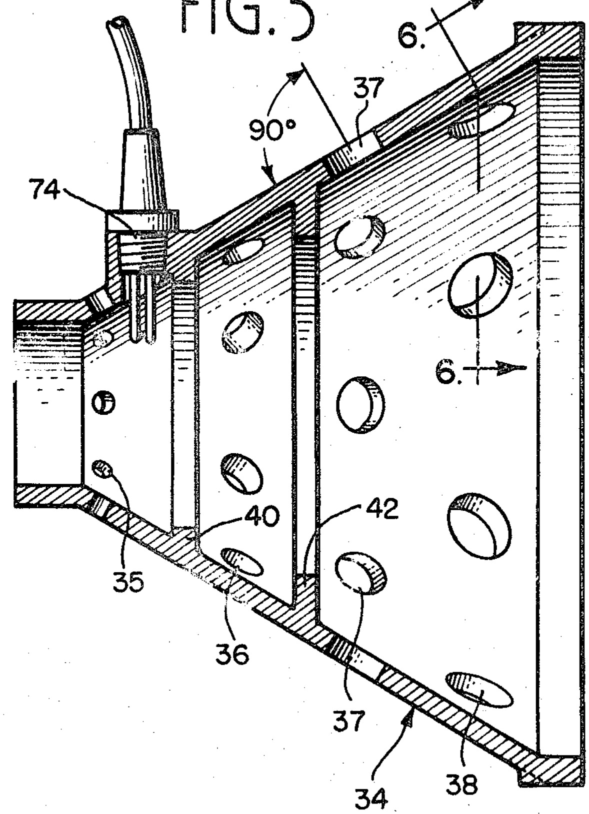


FIG. 6

FIG. 5



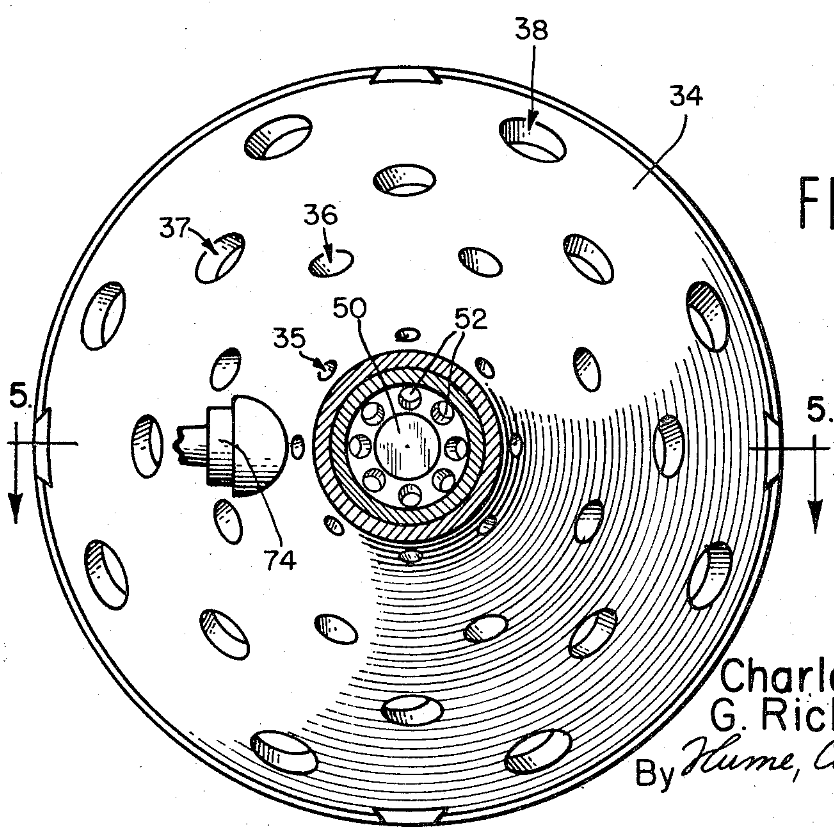


FIG. 4

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INTERNALLY FIRED INDUSTRIAL GAS BURNER

The present invention relates generally to gas burners. More particularly, the invention is directed to a burner of the packaged or self-contained type and to a new and improved gas-air mixing and ignition chamber. Although the burner assembly of the invention is of general utility for air heating and furnace applications, it is particularly suited for use in industrial heating processes and, accordingly, the invention will be described in this latter context.

SUMMARY OF THE INVENTION

The burner assembly includes a combustion air supply source that, in its preferred application, is wholly external to the environment being heated. Thus, the burner is particularly useful in those system environments where the air to be heated varies widely in percentage of oxygen, humidity and inert gas content. Interconnected valves in the air and gas inlet passages afford precise control over the relative quantities of combustion air and gas introduced into the burning chamber thereby assuring proper air-gas proportioning over the full firing range of the burner from a single thermostatic control. The air and gas are not united until they enter the burning chamber and, therefore, the problem of preignition is effectively obviated. The lateral or right-angle mounting of the combustion air fan relative to the burning chamber provides a package of short overall length and low weight that is suited for easy mounting on either the pressure or suction side of the circulating fan of the processing system.

The combustion chamber of the assembly is constructed and arranged to promote a thorough intermixture of the gaseous fuel and combustion air in proper proportions for complete stoichiometric combustion over the entire firing range of the burner. Specifically, the mixing and ignition chamber is of a conical contour with the gaseous fuel being introduced at the small end of the cone and directed along the interior cone surface, while the combustion air is introduced with a swirling or rotational motion component through appropriately canted apertures in the cone surface. The resultant swirling of the air and gas provides greater time for intermixing and aids in providing excellent ignition control and flame retention qualities for the burner. In this latter regard, a series of circumferential bosses on the interior cone surface divide the cone into a plurality of firing zones to further assist in flame retention and ignition control at each firing level. The aforesaid cone design also provides a high turn down ratio, i.e., a high ratio of maximum to minimum firing rates and the burner is also capable of being throttled over its entire range of operation with a smooth and continuous variation in heat output.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features of the present invention are set forth with particularity in the appended claims. The invention together with further objects and advantages thereof may best be understood, however, by reference to the following description taken in conjunction with the accompanying drawings in the several FIGS. of which like reference numerals identify like elements and in which:

FIG. 1 is a diagrammatic view of an industrial process heating system including a gas burner embodying the features of the present invention;

FIG. 2 is a sectional view of the burner assembly taken along the lines 2–2 of FIG. 1;

FIG. 3 is a sectional view of the burner taken along lines 3–3 of FIG. 2;

FIG. 4 is a sectional view of the burner assembly taken along lines 4–4 of FIG. 3;

FIG. 5 is a sectional view of the mixing and ignition cone taken along lines 5–5 of FIG. 4;

FIG. 6 is a fragmentary sectional view of the cone taken along lines 6–6 of FIG. 5;

FIG. 7 is a sectional view of another embodiment of the gas burner of the present invention wherein the cone apertures comprise rectangular slots angularly disposed in the cone surface as shown in the enlarged detail view of FIG. 7*a;*

FIG. 8 is a sectional view of a further embodiment of the gas burner of the present invention wherein the cone apertures comprise rectangular slots canted rearwardly toward the cone inlet as shown in the enlarged detail view of FIG. 8*a;*

FIG. 9 is a sectional view of yet another embodiment of the gas burner of the present invention;

FIG. 10 is a fragmentary sectional view of still another embodiment of the gas burner of the present invention; and

FIG. 10*a* is a detail view of the discharge nozzle of FIG. 10.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is illustrated a conventional industrial process heating system 11 which includes an externally mounted burner assembly 12 embodying the features of the present invention. The heating system 11 includes an oven or baking chamber 14 having exit and entry air circulation ducts 16 and 18, respectively, communicating with the oven enclosure at its opposite ends. A high volume recirculating fan 20 is connected in series between the system ducts 16 and 18 to provide a continued recirculation of the air as well as a mixing of the high temperature burner gases therewith, as schematically indicated in the drawing by the solid and dashed line arrows. The burner 12, as will presently be explained, utilizes a combustion air supply source entirely external to the processing system 11 and, therefore, the recirculating air may vary widely in percentage of oxygen, humidity or inert gas content, etc. without in any way adversely influencing the operation of the burner 12.

The burner 12 is mounted to the return air duct 16 although it is understood that the burner may also be mounted to the entry duct 18. At any rate, the burner assembly is adapted for convenient installation and removal by provision of an outer support casting 22 having an annular end mounting flange 22*a*. In the present system, the flange 22*a* is bolted to a mating flange of a discharge sleeve 24, the discharge sleeve 24 being in turn securely fastened to the wall of the duct 16 and having an elongated tubular portion extending a substantial distance there within.

Alternatively, the burner assembly 12 may be mounted by bolting the flange 22*a* directly to the wall of duct 16. It is preferred, however, that the discharge sleeve 24 be used since it provides a convenient conduit for entry of the hot gases into the air recirculating through the oven and also serves as a shield to protect the burner combustion chamber from hostile environmental conditions, such as moisture-laden air, inert gases, etc., which might tend to adversely influence the burning process.

As further shown in FIG. 1, the burner assembly 12 includes an impeller housing 26 supported at right angles to or laterally of the casting 22 and a drive motor 28 mounted in line with a center drive shaft of the impeller housing 26.

Referring now to FIGS. 2 and 3, the impeller housing 26 is of a cylindrical configuration and there is centrally mounted therewithin a multielement impeller blade 32 adapted to be rotationally driven by the motor 28 to forcefully direct combustion air into an exit duct 30 as schematically depicted by the arrows in the drawing. The impeller unit provides all of the combustion air utilized by the burner 12 and procures this air from the room environment.

The burner assembly 12 also includes a gas-air mixing and ignition chamber, herein a cone 34 having an inlet end of a narrow diameter diverging outwardly toward an enlarged exit end. The exit end of the cone 34 terminates flush with the face of the flange 22*a* of the casting 22. The enlarged end of the cone and the concentric cylindrical casting 22 are spaced apart, although alternatively these surfaces may be in contact with one another.

In order to provide the air for the combustion process, the cone **34** includes a plurality of circumferentially spaced apertures in each of a series of axially spaced stages. In the present embodiment, there are four such stages although there may be more or less depending upon the burner size, etc., the apertures of each stage being generally designated by the respective reference numerals **35—38**. The apertures of the several stages are progressively graduated in size from the first stage **35**, positioned closely adjacent the input end of the cone, to the fourth or last stage of apertures **38** located near the exit end of the cone to thereby provide the proportionately greater volume of combustion air required at successively higher firing levels of the burner. Also, as will be explained in greater detail, the apertures are preferably formed in the cone surface so as to impart a rotational motion component to the air passing therethrough.

The quantity, size and angular disposition of the apertures in each stage is dependent upon the physical size, heating capacity, and desired combustion characteristics, etc. of the burner, these various parameters being selected so that a uniform and complete stoichiometric combustion is maintained at all points between a minimum firing level and a maximum firing level.

In order to enhance the flame retention and ignition control properties of the burner, the cone **34** further includes a plurality of circumferential bosses **40** and **42** extending inwardly from the interior cone surface and axially disposed intermediate aperture stages **35—36** and **36—37**, respectively. The boss **42** projects inwardly to a somewhat greater extent than does the boss **40**, as is needed to provide equivalent operational characteristics for the larger cross-sectional area encompassed by the boss **42**. As will be explained later herein, the bosses **40** and **42** segregate the cone into a progression of firing zones that enhance fuel-air intermixture, flame retention and combustion efficiency at each of a corresponding progression of firing levels. Similar annular bosses or flanges (not shown) may be disposed between the aperture stages **37—38** and at the exit end of the cone for like purposes although such flanges are generally unnecessary since the burner is inherently more stable at the higher firing levels of these burner zones.

The bosses and the swirling combustion air cooperatively tend to preclude premature outward movement of the ignition point as, for example, may be caused by the negative 3-inch water column (w.c.) or greater suction of the recirculation fan **20** (FIG. **1**). The bosses **40** and **42** are not so large, however, as to result in abrupt steps in heat output between the successive firing zones and as the flame moves outwardly it promptly reattaches to the cone wall beyond each flange. The illustrated burner assembly develops at all firing levels a comparatively short, intense blue flame with uniform burning occurring across the entire cone cross section.

The outer support casting **22** is formed to define an air inlet means for the exit duct **30** of the impeller housing **26**. The annular casting **22** in combination with the exterior surface of the cone **34** defines an annular plenum chamber denoted generally by the reference numeral **48** in the drawing. Preferably, the plenum **48** is of comparatively small volume to maintain the overall burner assembly as light in weight and as compact as possible. The plenum **48** entirely surrounds the cone **34** and the volume of air delivered to the plenum by the impeller is such that a substantially constant positive pressure is maintained therewithin at any given firing rate. Therefore, the combustion air is directed at a uniform pressure through all of the cone apertures into the region enclosed by the cone. Preferably, the air pressure within plenum **48** is such that there is produced between the plenum **48** and the chamber defined by the cone **34** a range of pressure differentials of about 0 to 5 inches w.c. for normal operation.

A gas discharge nozzle **50** is disposed at the input end of the cone **34**; more specifically, the nozzle is snugly seated within a surrounding inlet neck of the cone **34**. The nozzle **50** includes a plurality of circumferentially spaced gas discharge ports **52**, there being eight such ports in the illustrated embodiment. As seen in FIG. **3**, the center axes of the ports **52** are disposed substantially parallel to the interior surface of the cone for directing a gaseous fuel along a like path. A gas inlet passage **54** from a source (not shown) to the nozzle **50** is formed by an appropriately hollow cast rear portion **56** of the casting **22**.

Interconnected flow control valve means, herein butterfly valves **60** and **62** located respectively in the air duct **30** and the gas inlet passage **54**, are provided for maintaining a predetermined interrelation of the quantity of gaseous fuel and combustion air introduced into the enclosed region of the cone throughout the full firing range of the burner. The valves **60** and **62** are interconnected by linkage arms **64** and **66** respectively, that engage opposite ends of a pivotally mounted lever control arm **70**. Pivotal movement of the arm **70** and thus valves **60** and **62** is accomplished by rotational adjustment of a temperature control or thermostat dial (not shown) to thereby effect a proportioned increase or decrease in the amount of gas and combustion air communicated to the enclosed region of the cone **34**.

Referring now to FIGS. **4** and **5**, the structural features of the mixing and ignition cone **34** may be considered in greater detail. The cone **34** is cast from a high silica ductile iron (4.5–5 percent silica) and has an included angle depending upon the minimum heat output, maximum heat output, and the like desired for a particular burner assembly. In proposed preferred commercial forms, the included angle of the cone **34** of the burner assembly is within the range from about 40° to about 66°. However, acceptable burner performances may be achieved by using a cone having an included angle of less than 40° or greater than 66°.

The respective aperture stages of the cone **34** are axially spaced in predetermined intervals from the cone input to the exit end thereof and the apertures of each stage graduated in size, as earlier stated. More specifically, the apertures **35** of the first stage are positioned adjacent the input end or neck of the cone **34** to provide prompt intermixing of the air and gas entering the cone. A conventional spark ignitor **74** extends through the cone **34** with its parallel ignitor elements positioned immediately beyond the apertures **35** to ignite the air-gas mixture.

The total area of the first stages apertures **35** is such as to provide adequate combustion air at the minimum burner firing level whereat the ignition point of the gas-air mixture is rearward of the first annular boss **40**. In the present embodiment, the first aperture stage includes eight individual circular openings **35** disposed in equally spaced intervals about the circumference of the cone **34**. The exact number of apertures in each of the several stages and the exact number of stages are not critical although they should be sufficient in number to provide a reasonably uniform distribution of air about the circumference of the cone so that thorough air-gas intermixing is occasioned promptly after entry of the air into the cone and prior to combustion. On the order of 6 to 12 apertures is usually suitable, a greater number of apertures per stage only increasing the manufacturing cost of the cone and perhaps reducing in its structural integrity without significantly, if at all, enhancing the operating efficiency of the burner.

The second through fourth aperture stages **36—38** of the present embodiment likewise include eight apertures equally spaced about the cone circumference, the individual apertures of each stage also being equal in size. However, to provide adequate combustion air as the flame ignition point moves toward the exit end of the cone with increased burner firing levels, the total aperture area of each succeeding stage is progressively increased relative to that of a preceding stage. In proposed preferred commercial forms, the average ratios of the total aperture area for the stages **36**, **37** and **38** is about 3.5, 6 and 9.5 times greater than the area of the initial aperture stage. However, acceptable burner performance may be achieved by using cone apertures leaving ratios greater or less than 3.5, 6 and 9.5 to 1.

As an alternative to the foregoing, the individual aperture size for each stage may be maintained more nearly uniform or constant and the circumferential spacing between each aperture reduced by progressively increasing the number of apertures in each of the successive stages. This latter arrangement is not generally preferred, however, because the increased number of apertures adds significantly to manufacturing cost while the inherently greater turbulence, etc. at relatively high firing levels assures satisfactory air-gas intermixture without this modification. Also, the larger apertures represent a lower impedance to the inrushing combustion air.

On the other hand, it has been found that the intermixing of the gas and combustion air is enhanced by angularly offsetting the apertures of each stage relative to those of the adjacent stages. Thus, each of the eight apertures **35** of the first stage are spaced one from the other by 45° while the similarly spaced apertures **36** are angularly offset relative to the apertures **35** so as to lie approximately midway therebetween. The apertures of the stage **37** are in line with those of the stage **35** while the apertures of stages **36** and **38** are in line.

It has been found that the angular disposition of the apertures in the cone surface has a very marked effect on the combustion properties or characteristics of the cone. As typified by a cone aperture **37** of FIG. **5**, the central axis of this and the remaining cone apertures is perpendicular to the cone surface, as viewed in a longitudinal cone section taken through the aperture. The apertures of each of the stages **35**—**38** are also formed in the cone surface so as to create a swirling or a rotational movement of the combustion air about the cone center-axis. The angular disposition of the apertures necessary to create this effect is illustrated by the representative aperture **38** of FIG. **6**. A cone radius is shown as drawn through the center of the representative aperture **38**. In the proposed preferred commercial forms, the center axis of apertures **38** in the cone of the burner assembly **12** defines an angle within the range of 25° to 45° with the cone radius. However, acceptable burner performance may be achieved by orienting the center axis of the apertures **38** in the cone of the assembly **12** so that it defines an angle with the cone radius of less than 25° or more than 45°. Thus, the entering combustion air is provided a tangential vector of movement and such is reinforced by the similar angular orientation of the remaining apertures of that stage as well as the other stages.

In the present embodiment, the apertures of each stage are all of a like angular orientation (30°) relative to respective radial lines drawn through their geometric centers. The rotational movement of the combustion air results in substantial agitation of the gas and air streams to promote a thorough intermixture and also tends to retard forward movement of the combined gas-air mass to provide excellent flame stability and flame retention characteristics.

The greater the rotational or tangential component of the combustion air, the greater is the retarding effect on the forward movement, i.e., movement toward the cone exit end, of the gas-air intermixture. The angular disposition of the apertures in the preferred embodiment of FIGS. **1**—**6** is such that the ignition point progresses toward the cone exit with increased firing level at a rate to assure continued flame retention and flame stability but not so slowly that overheating of the cone occurs.

Although in the illustrated embodiment the angular orientation of all of the cone apertures is identical, it may be desirable in certain applications that the apertures of each stage be of different angular orientations or in fact that one stage be counterphased relative to an adjacent aperture stage thereby to develop counterrotating air masses. For example, counterphasing of the apertures in successive stages continues to afford thorough gas-air intermixture while permitting a relatively long flame at each firing level, as may be desired in certain burner applications.

In summary, the operation of the preferred embodiment of the burner assembly and the mixing cone of the invention may best be understood by referring again to FIG. **3**. The multielement impeller blade **32** is driven by motor **28** to deliver an ample external air supply to the plenum **48** through the impeller exit duct **30** and the inlet aperture of the casting **22**. Similarly, a suitable gaseous fuel such as propane or natural gas is communicated to the cone **34** through the inlet passage **54** and the nozzle **50** from a pressurized source (not shown). Typically, the gas pressure in the inlet passage **54** is such that there is produced between the passage **54** and the chamber defined by the cone **34** a range of pressure differentials of about 0 to 4 inches w.c. and typically the air pressure in the plenum **48** is such that there is produced between the plenum **48** and the chamber defined by the cone **34** a range of pressure differentials of about 0 to 5 inches w.c. for normal operation. Proper air-gas proportions are maintained over the full firing range of the burner and the firing level selected by adjustment of a single thermostatic dial (not shown) to thereby appropriately throttle the interconnected butterfly valves **60** and **62**.

The circumferentially spaced apertures **52** in the nozzle **50** are oriented to direct eight tubular streams of gas along respective paths approximately parallel to the interior cone surface. The combustion air introduced through the eight first stage apertures **35** is directed at approximately right angles to corresponding ones of the tubular gas jets resulting in substantial interaction of the air-gas streams. Additionally, the air jets include a rotational component, as schematically illustrated by the arrows in the drawing, to provide a greater time period for intermixing as well as to retard the forward movement of the gas.

At the settings of the flow control valves **60** and **62** in the drawing, the ignition point of the mixture is approximately in the plane of the first annular boss **40**. The boss **40** aids in preventing the ignition point from being drawn excessively forward at low firing levels such as may tend to occur due to the suction of the recirculation fan **20** (FIG. **1**) or the inherent forward inertia of the air-gas mixture. The combustion flame is spread across the entire cross section of the cone and a short, intense blue flame is produced.

As the interconnected valves **60** and **62** are further opened, the flame progresses forward of the annular boss **40** and promptly reattaches to the interior cone surface beyond this point. The intermixture of combustion air and gases in this second firing stage occurs in like fashion to that of the first stage. The annular boss **42** extends somewhat further into the cone region than the boss **40** in order to provide an equivalent shielding for this larger cross-sectional area.

Similar operation takes place as the burner is brought to its maximum or full firing level. The illustrated construction of the mixing and ignition cone provides a high turn down ratio for the burner, i.e., a high ratio between its maximum and minimum firing rates. In the present embodiment, the turn down ratio exceeds 40:1.

An alternate embodiment of the mixing cone is illustrated in FIGS. **7** and **7*a***. The cone **80** is substantially identical in construction to that of the cone **34** excepting that the apertures in the surface of the cone **80** are of a circumferentially elongated rectangular contour. A representative one of these apertures **82** is depicted in the enlarged view of FIG. **7*a***. The apertures **82** like the circular apertures of the cone **34** is formed to provide a rotational air flow as indicated by the angle between the segment **84** of a cone radial line and the center axis **85** of the aperture **82**. The total aperture area of each of the aperture stages in cone **80** as the number of apertures per stage is identical to that of the cone **34**. Accordingly, a similar swirling or rotational movement of the gas-air intermixture is provided as schematically represented in FIG. **7** by the solid and dashed arrows. Of course, the quantity and size of the apertures of cone **80** may vary in the same manner as earlier described herein with regard to cone **34**. The number of annular bosses, the cone angle of rotation, etc. may also vary in like fashion.

In the alternate embodiment of FIGS. **8** and **8***a*, a mixing and ignition cone **90** includes four aperture stages except that the apertures of each stage, unlike those of cone **34**, are formed to direct the combustion air rearwardly toward the nozzle **50** to further retard outward movement of the gas and air intermixture. As shown in FIG. **8***a*, the representative aperture **92** is again of a circumferentially elongated rectangular outline but, unlike the apertures **82** of FIG. **7**, the aperture **92** is formed to project the combustion air toward the center axis of the cone **90** and rearwardly toward the nozzle **50**. Again except for the configuration and angular orientation of the apertures in the cone **90**, this embodiment is structurally identical to the cone **34**. In operation, the gaseous fuel and combustion air intermix in the manner schematically illustrated in FIG. **8** by the dashed and solid arrows, respectively. This embodiment is not preferred since a less satisfactory intermixture of the air and gas occurs than in the cone **34**. However, the canting of the apertures rearwardly toward the input end of the cone **90** does aid in flame retention.

Another embodiment of the invention is represented by the cone **96** of FIG. **9**. This construction is likewise identical to that of cone **34** excepting that all of the apertures in the cone **96** are formed such that their respective center axes are linear with respective radial lines drawn from the center axis of the cone **96**. Thus, the air and gas intermix in the fashion schematically represented by the solid and dashed arrows, respectively, in the drawings. This embodiment is again not preferred since the absence of a rotational movement for the combustion air affords a less satisfactory gas-air intermixture and flame stability and flame retention are also somewhat impaired.

In the embodiment of FIG. **10**, the mixing and ignition cone **98** is identical to the cone **34** excepting that all of the apertures are formed to direct the combustion air radially inward rather than providing a tangential or swirling motion component thereto. Furthermore, a third annular boss **99** is positioned intermediate the third and fourth aperture stages of the cone **98**. A fourth annular boss (not shown) may be provided between the fourth stage of apertures and the exit end of the cone if so desired. Such additional annular bosses are generally required only where the processing system to which the burner is coupled creates a substantial low pressure condition at the exit of the burner tending to draw the flame outwardly of the cone to an undesired extent. The added flanges also protect or shield the flame from hostile environments of the processing oven and may be needed in certain instances to prevent deleterious effects of these environments on the burner flame, especially in those instances where the discharge sleeve **24** (FIG. **1**) is omitted. In the embodiment of FIG. **10**, a tangential vector of movement is given to the gas-air intermixture by the provision of an appropriately designed nozzle **101**. As shown in FIGS. **10** and **10***a*, the nozzle **101** includes a series of circumferentially spaced apertures adapted to direct the gas outwardly in tubular jets oriented approximately parallel to the diverging interior surface of the cone **98**. The apertures **102** are, however, formed to provide a rotational movement of each of the gas jets, as schematically indicated in FIG. **10** by the dashed arrows. A swirling of the gas generally does not significantly aid the intermixing process at any but the lowest firing level. This is because the mass of the air utilized in the combustion process far exceeds that of the gas and, accordingly, the rotational movement of the gas is substantially cancelled by the axial movement of the combustion air even before burning occurs at the second aperture stage. Of course, it will be understood by those skilled in the art that various features of the above-described embodiments may selectively be combined to provide a mixing-ignition cone and burner assembly of optimum construction for a wide range of design conditions.

While particular embodiments of the present invention have been shown and described, it is apparent that various changes and modifications may be made, and it is therefore intended in the following claims to cover all such modifications and changes as may fall within the true spirit and scope of this invention.

We claim:

1. A burner assembly comprising:

mixing and ignition cone means including an outwardly diverging substantially conical wall means defining a circumferentially enclosed air-gas mixing space, said wall means having a plurality of circumferentially spaced apertures in each of a series of axially spaced stages for admitting combustion air into said mixing space and said apertures being formed in said wall means for developing a rotational motion component of said combustion air relative to the central axis of said wall means to provide a layer of rotating combustion air about the interior surface of said conical wall means;

air inlet means defining, in combination with the exterior surface of said wall means, a plenum chamber for accommodating combustion air that passes through said cone aperture into said mixing space;

a gas discharge nozzle disposed at the smaller end of said wall means and including a plurality of gas discharge ports, the central axis of each of said ports being substantially parallel to the interior surface of said wall means for directing a gaseous fuel generally parallel to said interior surface of said wall means into interaction with said rotating combustion air to provide a predetermined gas-air intermixture and combustion characteristic within said mixing space at each of a progression of burner firing levels; and

a plurality of circumferential bosses extending inwardly from the interior surface of said wall means and axially disposed intermediate respective stages of said cone apertures for defining a progression of firing zones within said mixing space to promote flame retention, fuel-air intermixture and combustion efficiency at each of a corresponding progression of firing levels of said burner.

2. The burner of claim **1** in which each of said cone aperture stages from the narrowed inlet to the discharge end of said wall means is of a progressively greater total aperture area than a preceeding aperture stage.

3. The burner of claim **2** and further including impeller means coupled to said air inlet means for providing the total combustion air inlet to said mixing space.

4. The burner of claim **3** and further including gas inlet means coupled to said gas discharge nozzle and additionally comprising interconnected flow control valve means in respectively said gas inlet and said air inlet means for maintaining a predetermined interrelation of the quantity of said gas and said combustion air introduced into the enclosed region of said cone throughout the full firing range of said burner.

5. The burner of claim **4** in which the central axis of each of said cone apertures forms a predetermined acute angle with a radial of said cone means drawn through the center of said respective apertures.

6. The burner of claim **5** in which the angle between said center axis of said cone means and the interior surface thereof is within a predetermined range for providing a preselected combustion characteristic between the minimum and maximum burner firing levels.

7. The burner of claim **6** in which said cone means includes a series of four axially spaced aperture stages and in which the total cross-sectional area of the first through fourth stages progressively increases in a proportion to provide sufficient combustion air volume for complete stoichiometric combustion at each burner firing level.

8. The burner of claim **7** in which said burner assembly is adapted for operation with an air inlet pressure differential between said plenum chamber and said mixing space in the range of 0 to 5 inches water column and a gas inlet pressure differential between said gas inlet and said mixing space within the range of 0 to 4 inches water column.

9. The burner of claim 8 in which each of said aperture stages includes within the range of 6 to 12 apertures disposed in approximately equally spaced intervals about the circumference of said wall means and further in which the apertures of each stage are angularly offset relative to the apertures of an adjacent stage.

10. The burner of claim 9 in which the central axes said apertures are perpendicular to the surface of said wall means as viewed in respective longitudinal sections of said cone means taken through each of said apertures.

11. In a burner, the combination comprising:

ignition and combustion cone means having an inlet end diverging outwardly toward a discharge end and defining an enclosed air-gas mixing space, said cone means having a plurality of circumferentially spaced apertures in each of a series of axially spaced stages for admitting combustion air into said mixing space and having a plurality of circumferential bosses extending inwardly from the interior surface of said cone for defining, in conjunction with said axially spaced aperture stages, a progression of burner firing levels;

gas air inlet means for introducing combustion air through said apertures into said mixing space;

gas inlet means including a discharge nozzle having an exterior dimension approximately equal to the interior of said cone inlet and positioned within said inlet of said cone means for introducing a gaseous fuel into said mixing space to effect a predetermined interaction with said combustion air; and

flow control means coupled to both said air and said gas inlet means for proportionately regulating the quantities of air and gas introduced into said air-gas mixing space over the full firing range of said burner.

12. The burner according to claim 11 in which the central axes of said cone apertures are angulated toward the narrowed inlet of said cone means.

13. The burner according to claim 11 in which the central axes of said cone apertures are perpendicular to the central axis of said cone means.

14. The burner of claim 11 in which said cone apertures are in the form of circumferentially elongated rectangular slots.

15. The combination of claim 11 in which said gas discharge nozzle comprises a series of circumferentially spaced gas inlet ports, said ports being formed to develop a rotational motion component of said gas about the central axis of said cone means.

16. The combination of claim 11 in which said cone apertures are formed so as to develop a rotational motion component of said combustion air about the central axis of said cone means.

17. The combination of claim 15 in which said cone aperture stages are of progressively greater total aperture area in the order of their sequence from said inlet to said discharge end.

18. The combination of claim 17 in which said plurality of annular bosses extend progressively further inwardly toward said center axis of said cone means in the order of their sequence from said inlet to said discharge end of said cone means.

19. The combination of claim 18 in which said gas discharge nozzle includes a plurality of circumferentially spaced gas discharge ports having respective central axes defining respective angles with the central axis of said cone means which respective angles are at least as great as the angle formed between said central axis and the interior surface of said cone means.