United States Patent [19]

Briggs

[11] **3,720,496**

[45] **March 13, 1973**

[54] **FUEL BURNER**

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[73] Assignee: **Koehring Company,** Milwaukee, Wis.

[22] Filed: **March 29, 1971**

[21] Appl. No.: **128,734**

[52] **U.S. Cl.** **431/353,** 431/183, 239/405

[51] **Int. Cl.** **F23d 15/02**

[58] **Field of Search**......431/183, 264, 265, 351–354; 239/405, 406

[56] **References Cited**

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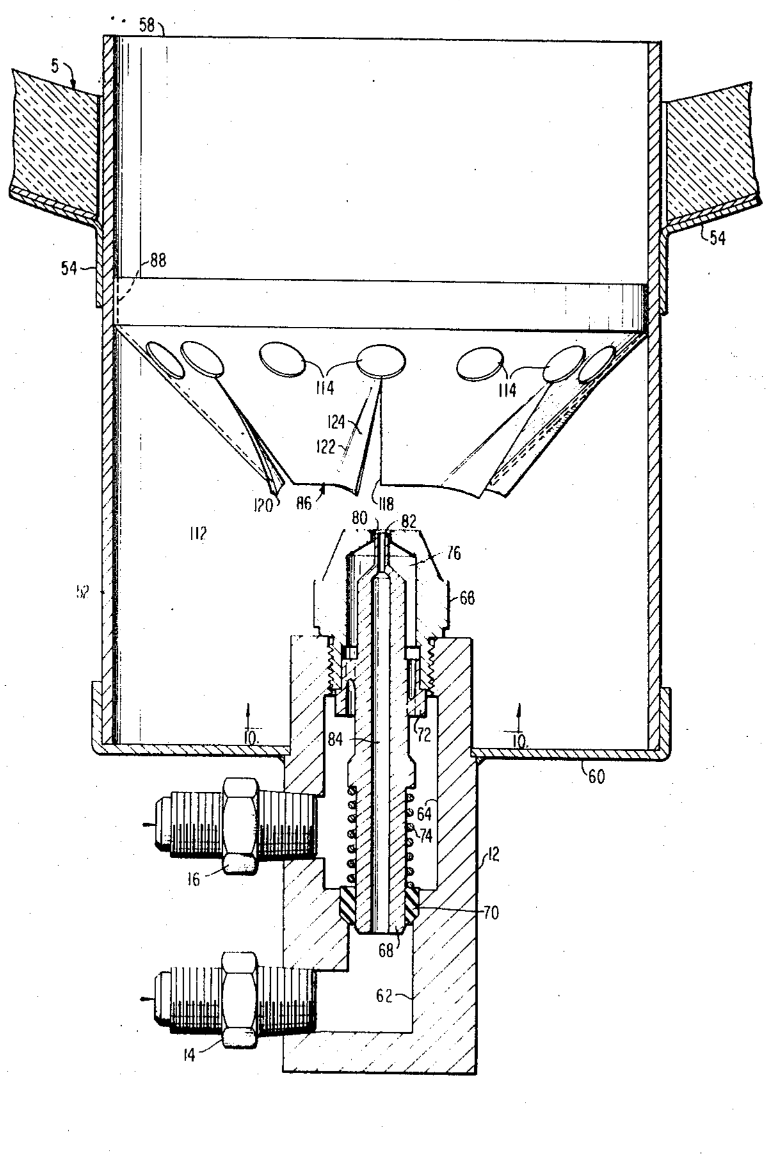
Primary Examiner—Carroll B. Dority, Jr.
Attorney—Andrew J. Beck and Charles W. Walton

[57] **ABSTRACT**

A burner nozzle projects a mixture of fuel oil and air into a burner tube fitted with an open ended flame retention head having the general configuration of a frustum of a cone the small end of which faces the nozzle and the large end of which abuts the interior wall of the burner tube. The zone on the nozzle side and around the circumference of the conical flame retention head is supplied with air under pressure. Slots each having an outwardly inclined vane adjacent one of its margins extend longitudinally of the head and open at both the periphery and the small end of the head to direct air from the pressure zone into an axially swirling pattern of motion within the head. Additional openings of circular configuration are disposed in a ring about the conical head in the vicinity of but spaced from its large end, and the slots terminate at individual ones of these circular openings. The openings provide additional passages for directing air from the pressurized zone toward the axis of the head.

7 Claims, 12 Drawing Figures



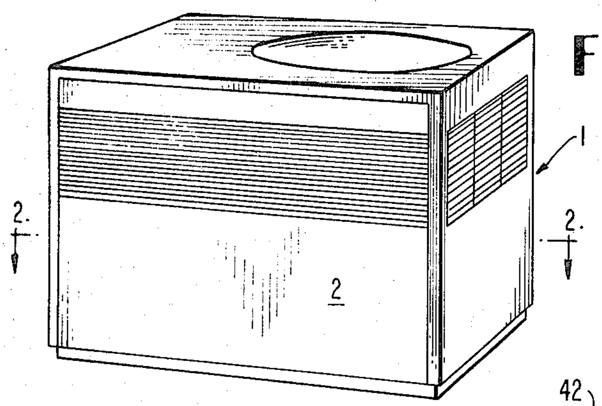


FIG. 1

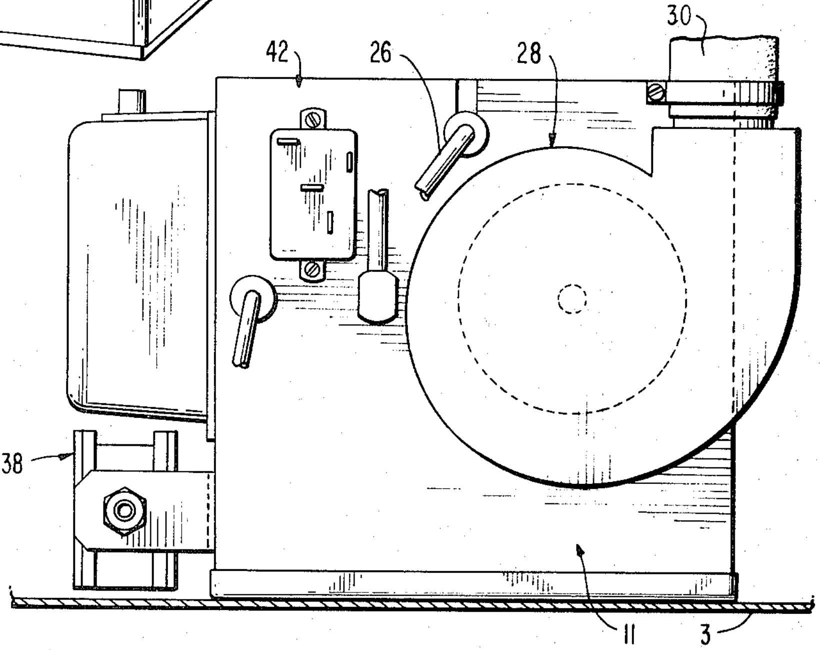


FIG. 4

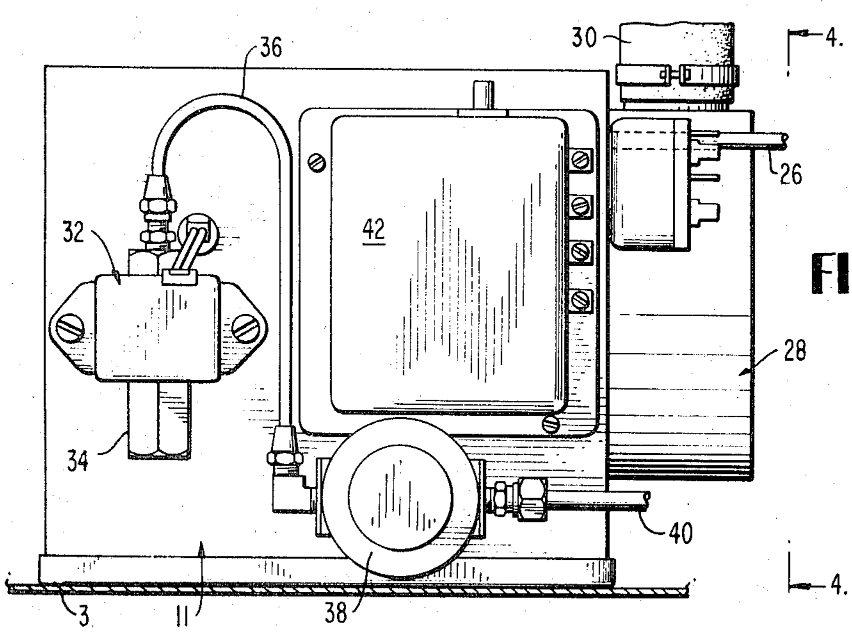


FIG. 3

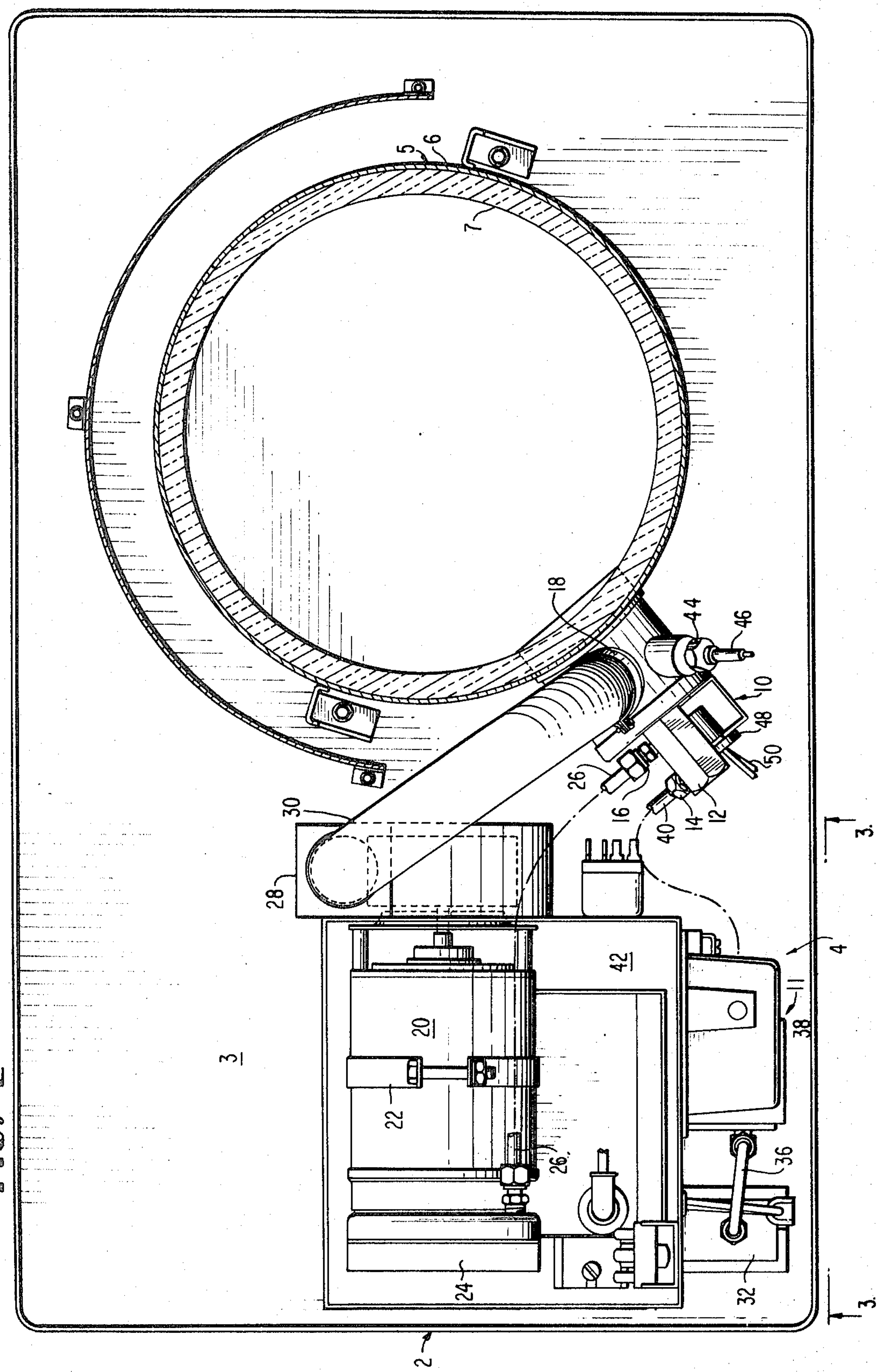


FIG. 2

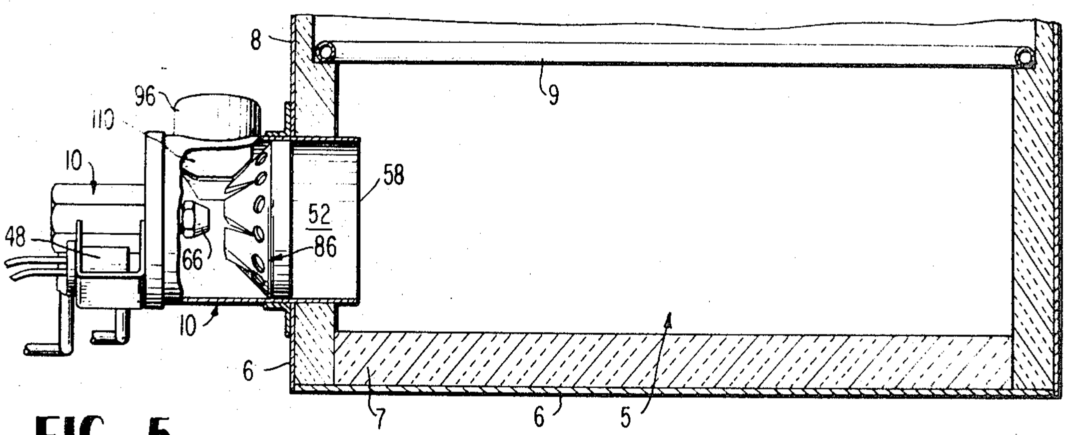


FIG. 5

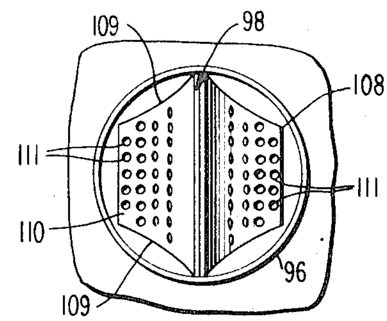


FIG. 12

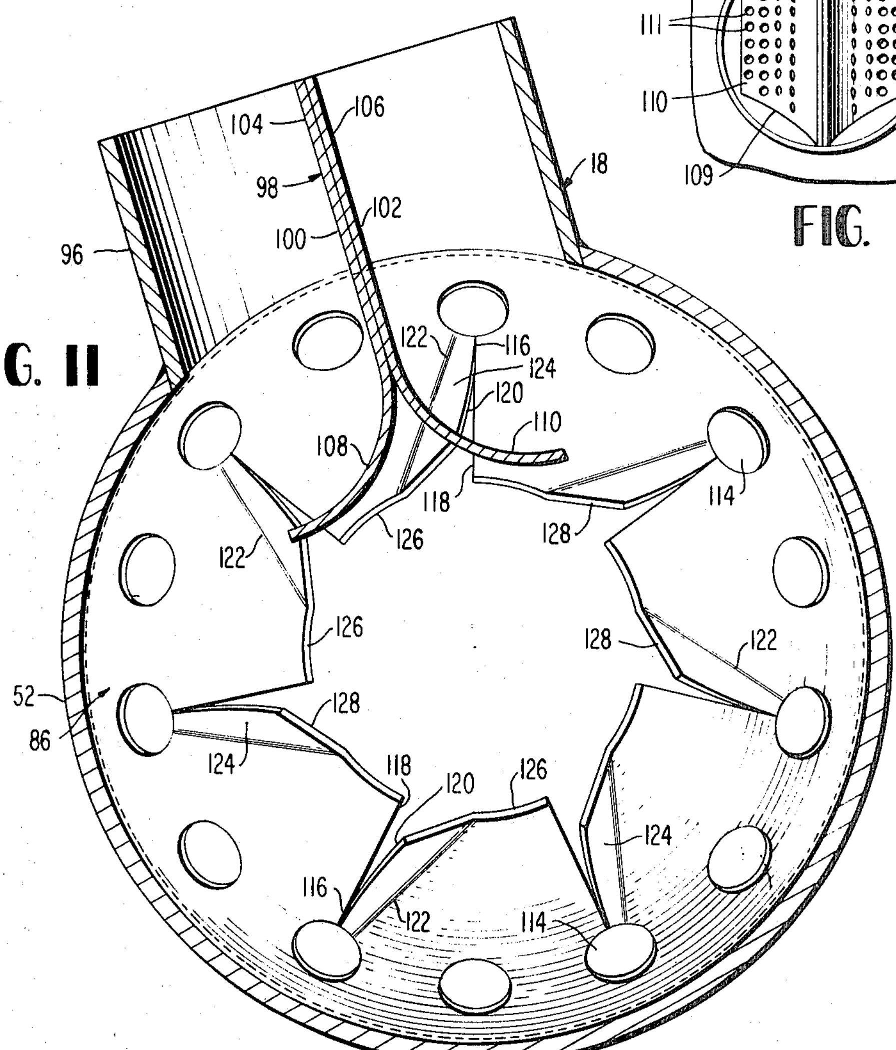


FIG. 11

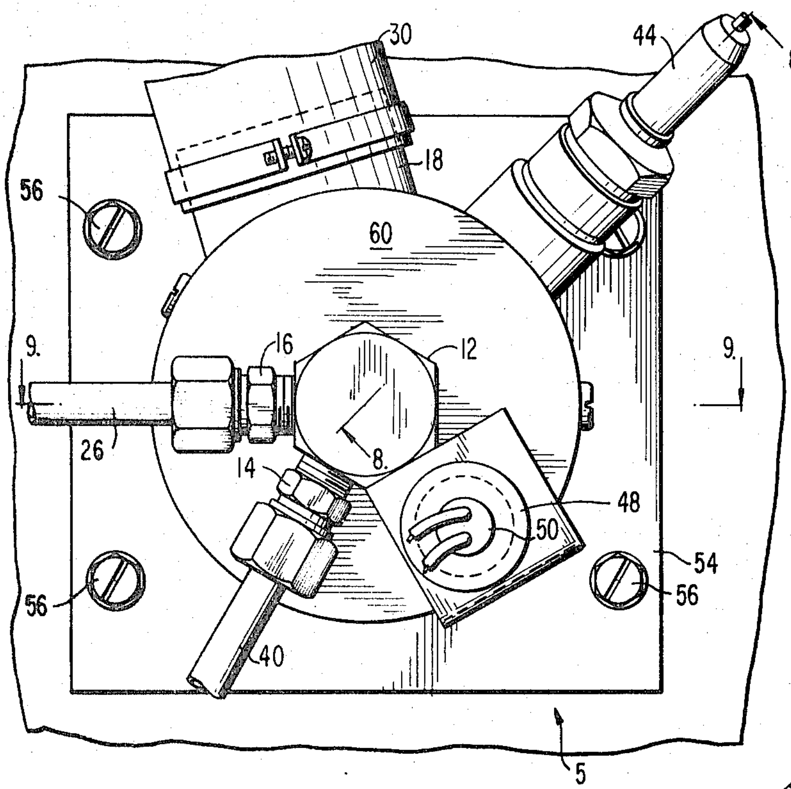


FIG. 6

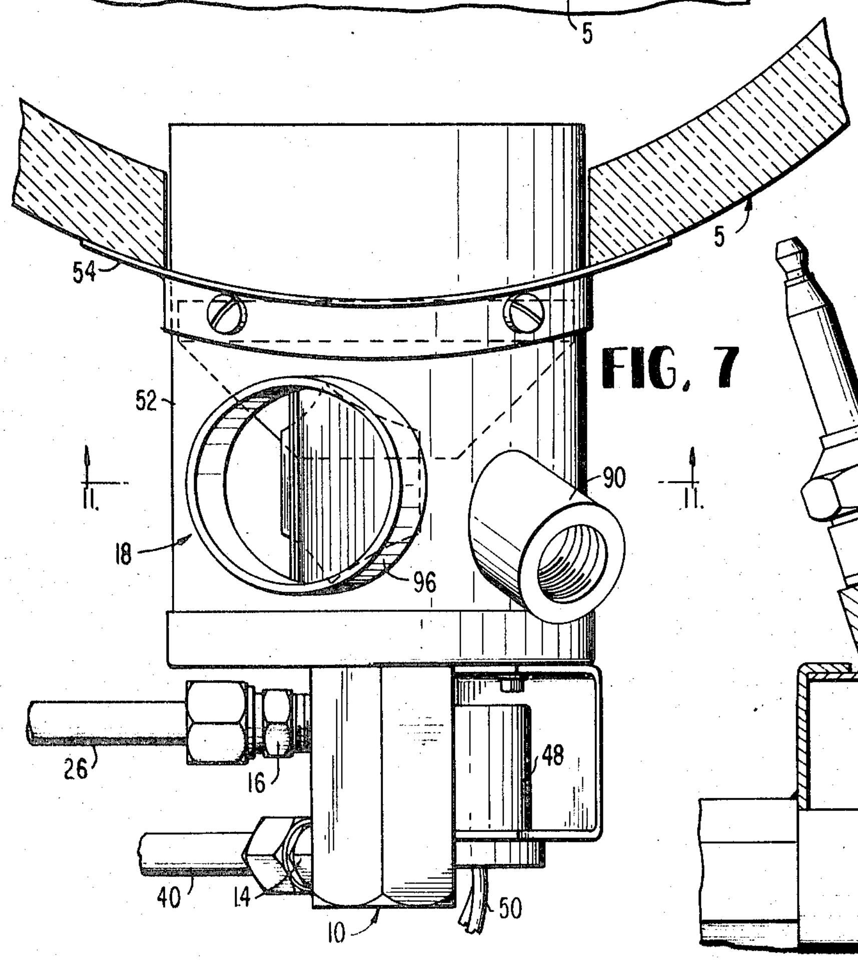


FIG. 7

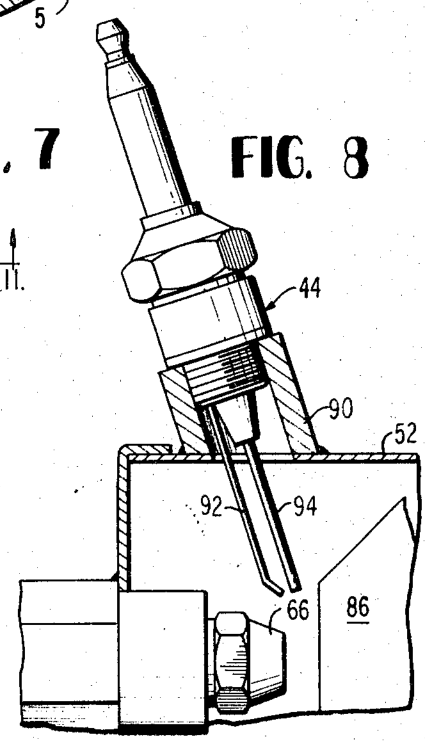


FIG. 8

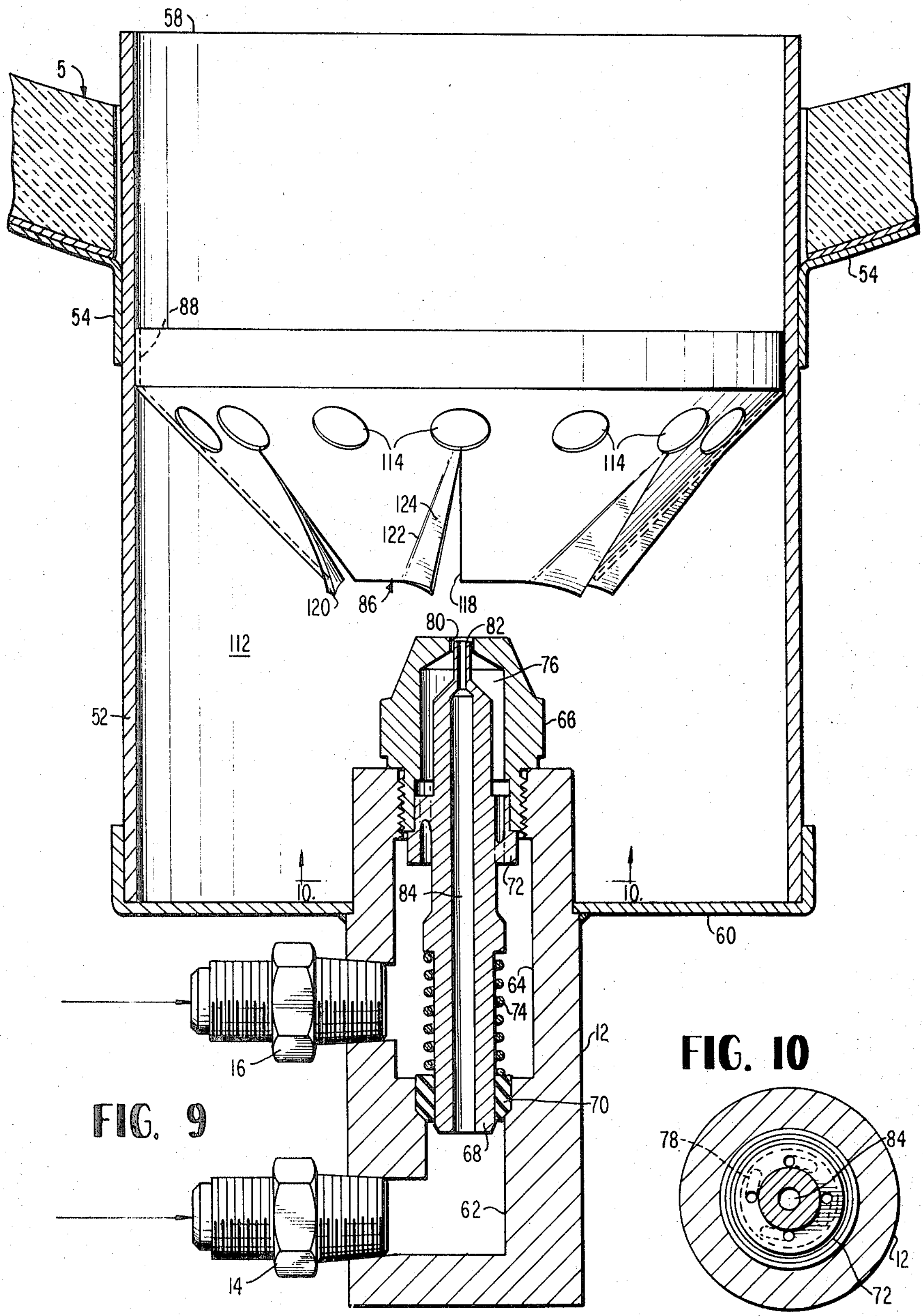

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FIG. 9

FIG. 10

FUEL BURNER

CROSS REFERENCE TO RELATED APPLICATIONS

The disclosure of this application is related to the disclosures of an application Ser. No. 128,720 of Eugene C. Briggs entitled "Portable Heater" and a joint application Ser. No. 128,726, now U.S. Pat. No. 3,666,396, of Eugene C. Briggs and William C. Wellbaum entitled "Combustion Apparatus," both filed in the U.S. Patent Office on Mar. 29, 1971.

BACKGROUND OF THE INVENTION

This invention relates to fuel burner apparatus of the type in which fuel in fluid form is projected from a nozzle and burned in a restricted combustion zone to provide heat for such applications as residential air conditioning and heating units or systems, water heaters, small steam generating systems, etc.

Nozzle type burners have heretofore been employed in various kinds of equipment and such burners have recognized advantages in the areas of structural simplicity, performance flexibility, etc. However, difficulties have been encountered in obtaining highly efficient air-fuel mixtures with such apparatus.

These difficulties are more pronounced in applications where the combustion zone is dimensionally restricted, because in these instances there is less opportunity for the occurrence of random mixing phenomena. As a result, earlier attempts to employ nozzle type burner apparatus in compact combustion equipment have often been characterized by incomplete combustion with consequent contamination of the exhaust stream and by low thermal efficiency. Difficulties also have been encountered in connection with the tendency of such equipment toward the creation of deposits on the walls of the combustion zone, which deposits give rise to random irregularities in burning performance.

Although such difficulties have existed in connection with apparatus for burning both fuel oil and gas, they have been particularly pronounced where oil has been employed as the fuel. The liquid state of this fuel is an impediment to the obtaining of an efficient air-fuel mixture in a small space. As a result, there has been a trend toward the use of gas in applications where compactness and a high degree of cleanliness in burning are required, even though the use of gas often is accompanied by complicating factors such as safety hazards and installation complexity.

SUMMARY OF THE INVENTION

This invention has as its principal object the provision of a fuel burner capable of producing a small intense flame of high combustion efficiency.

A more particular object of the invention is the provision of an oil burner in which air is caused to flow in paths which assure an efficient air-oil mixture in a small combustion zone and which protect against the impingement of incompletely burned oil particles against surfaces of the apparatus.

A burner constructed in accordance with the invention includes a cylinder member or burner tube having an open outlet end, a nozzle coaxial with the burner tube for projecting fuel toward the open outlet end of

the burner tube, a flame retention head within the burner tube and located in front of the nozzle, and means for establishing a zone of pressurized air on the nozzle side of the flame retention head. The flame retention head is a thin walled member having the general configuration of a frustum of a cone. The large end of the cone has a diameter corresponding to that of the interior of the burner tube and it is mounted against the wall of the tube. The smaller end of the coned head is disposed a short distance in front of the nozzle and is completely open and of a diameter such that the material issuing from the nozzle enters the interior of the flame retention head without contacting the walls thereof.

The interior of the flame retention head is constituted by a conical surface of revolution uninterrupted by inwardly protruding elements or portions. However, longitudinal slots are located at regularly spaced intervals about the axis of the head, and each of these slots is open to the small end of the head. The material of the head is bent outwardly at an angle along the margin of each of the slots to provide a series of vanes skewed relative to the axis of the head. With this configuration, air from the pressurized zone behind and around the flame retention head is caused to enter the interior of the head in a swirling pattern which serves to inhibit lateral flame expansion and to bring about an improved air-fuel mixture in the burning zone.

The flame retention head preferably includes additional air passages located near but spaced from its larger end. These additional air passages may be simple holes the axes of which intersect the longitudinal axis of the flame retention head. The holes preferably are spaced regularly about the circumference of the head and at least some of them may intersect the ends of the longitudinal slots remote from the small end of the head. The additional air passing through the holes is driven directly into the flame area and minimizes flame expansion so that the flame is held in close proximity to the conical head. This additional air also provides a shield for preventing impingement of raw or incompletely burned fuel against the walls of the downstream portions of the head and burner tube so as to minimize carbon deposits thereon.

The nozzle itself preferably is an aspirator nozzle of the type in which air under pressure is caused to swirl at high velocity through and out of a passage surrounding a centrally located fuel oil conduit. As the air issues from the nozzle end, it entrains oil particles and the oil-air mixture is projected toward the outlet end of the burner tube.

In constructions embodying such nozzles, it is preferred that the direction of swirl of the primary air issuing from the nozzle tip be opposite to the direction of swirl of the secondary air guided into the interior of the flame retention head by the outwardly inclined vanes at the margins of the longitudinal slots which extend to the small inlet end of the head. This counterflow arrangement promotes oil droplet breakdown and efficient mixing of the air with the dispersed oil particles.

The spacing of the burner tip from the small end of the flame retention head and the sizes of the vanes of this portion of the head also are factors which are relevant in connection with obtaining maximum performance. It is preferred that the nozzle end be spaced from the small end of the flame retention head a distance such that the visible portion of the flame is located at or a short distance from the small end of the head. The diameter of the small end of the head should be small, and the vane ends should be of substantial length and have substantial inclinations. The mass of swirling air flow achieved with such a construction is large and results in good performance.

The advantages of the novel burner of this invention are pronounced. The flame produced is a small, bright yellow flame having the appearance of a vortex, and it has been found that an oil burner constructed in accordance with the invention requires a combustion zone volume of about one-third that required in installations where conventional oil burners are employed. Moreover, the invention reduces the amounts of incompletely burned fuel and prevents the formation of carbon deposits on the walls of the apparatus.

A more complete understanding of these and other features and advantages of the invention will be gained from a consideration of the following detailed description of an embodiment illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a water chiller for an air conditioning system, which water chiller includes a fuel burner constructed in accordance with the invention.

FIG. **2** is a horizontal cross sectional view, taken along the line **2—2** in FIG. **1** and illustrating a fuel burner unit according to the invention in relation to certain other components of the equipment of FIG. **1**.

FIG. **3** is an elevational view, taken from the direction **3—3** in FIG. **2** with a vertical panel of the chiller housing being removed to reveal the components within the housing which cooperate to supply the burner with fuel and air.

FIG. **4** is a similar view taken along the line **4—4** in FIG. **3**.

FIG. **5** is a vertical cross sectional view illustrating the relationship between the fuel burner assembly and the heat receiving chamber for the generator element of the chiller of FIG. **1**.

FIG. **6** is an end elevational view of the burner assembly shown in FIGS. **2** and **5**.

FIG. **7** is a plan view of this burner assembly.

FIG. **8** is a detailed cross sectional view, taken along the line **8—8** in FIG. **6** and illustrating an igniter component of the burner assembly.

FIG. **9** is a cross sectional view taken generally along the line **9—9** in FIG. **6**, but illustrating a fuel supply to the nozzle head as being in this plane and illustrating in plan a flame retention head in the burner assembly.

FIG. **10** is a detailed cross sectional view, taken along the line **10—10** in FIG. **9** and illustrating air flow and fuel passages in the nozzle component of the burner assembly.

FIG. **11** is a cross sectional view taken along the line **11—11** in FIG. **7** to show the inlet end of the flame retention head in elevation and to illustrate an auxiliary air supply fitting in cross section.

FIG. **12** is an end view of the auxiliary air supply fitting of FIG. **11** as it appears from the outer end thereof.

DETAILED DESCRIPTION OF ILLUSTRATED EMBODIMENT

Although the invention is susceptible of being applied in a variety of environments, it is especially suited to applications where compactness and highly efficient combustion are required. The compact water chiller **1** of FIG. **1** is a particularly advantageous application, and it will be helpful to describe the invention as it is embodied in this unit.

The water chiller **1** is a small unit operating on an absorption cycle to chill water piped to and from the unit as a part of a residential air conditioning system. As is well known, such absorption cycles require the presence of a generator unit where relatively high pressures and temperatures are maintained and where an absorbed vapor such as ammonia is driven from a solution. The vapor is then condensed to a liquid and passed through an expansion valve to an evaporator where it is disposed in heat receiving relationship to the water to be chilled. The low pressure vapor then is again put into a liquid solution in an absorber, and the liquid is pumped back to the generator to complete the cycle.

As will be evident, a number of components are required for carrying out the various functions of the cycle just described. Consequently, the space available within the housing **2** of the compact unit of FIG. **1** for use in supplying the necessary heat to the generator is quite limited.

Referring now to FIG. **2**, it will be seen that the combustion apparatus for supplying heat to the generator of the chiller is made up of equipment components located near the bottom **3** of the chiller unit **1** and that these equipment components are arranged to be accessible at one side **4** of the housing **2** provided with a conventional access panel (not illustrated) which may be removed when it becomes desirable to inspect or service the equipment.

In FIGS. **2** and **5** the heat receiver for the generator of the chiller is designated generally at **5**. It includes metal housing components **6** lined with refractory material **7**. This heat receiver is in the form of a vertically oriented cylinder, and it will be understood that the main body of the generator **8** is disposed immediately above and coaxially with the heat receiver so that the heat supplied to the heat receiver is made available in an efficient way to the main heat transfer components of the generator. These heat transfer components form no part of the present invention and are represented schematically at **9** in FIG. **5**. The vertical extent of heat receiver **5** may be on the order of 6 or 7 inches.

The combustion apparatus includes two basic assemblies, a burner assembly **10** supported by the heat receiver **5** and a supply assembly **11** spaced from the burner assembly and supported on the bottom **3** of the chiller housing **2**. Fluid conduits and electrical cables connect the two assemblies together in a manner to be described more fully below.

The burner assembly **10** extends into an opening in the vertical wall of the heat receiver **5** as illustrated in FIGS. **2** and **5**. This burner assembly includes a nozzle body **12**, provided with a fuel inlet fitting **14**, a primary air inlet fitting **16**, and also a fitting **18** through which supplementary or auxiliary air may be admitted.

The supply assembly for delivering the required fluids to the fittings 14, 16 and 18 includes a motor 20 held in place by a clamp system 22 and having driven output shaft means at both ends thereof. The output at one end of the motor 20 serves to drive a primary air pump or compressor 24 of a vane type described more fully in U.S. Pat. No. 3,256,003 granted to Eugene C. Briggs on June 14, 1966. The disclosure of such patent is incorporated herein by reference and the patent may be examined in order to gain a detailed understanding of the interior construction of the compressor 24. It will suffice here to point out that the compressor 24 receives air from the interior of the casing 2 of the chiller unit 1 and delivers the compressed air to the primary air inlet fitting 16 of the burner assembly through a line or conduit 26. The compression achieved in the compressor 24 need not be high, it having been found that a pressure of about four pounds per square inch gauge ordinarily is sufficient.

The other output end of the motor 20 drives an auxiliary air blower unit indicated generally at 28 as a centrifugal pump. This unit receives air through an axial opening (not illustrated) and delivers it at an increased pressure through a peripheral outlet to a hose 30 leading to the auxiliary air inlet fitting 18 of the burner assembly.

Fuel oil is supplied from a small piston-solenoid type fuel pump 32 on the supply assembly 11. This pump includes an inlet fitting 34 to which a line from a suitable reservoir is attached. These latter elements are conventional and have not been illustrated in the drawings. The output from the pump 32 is connected to a line 36 which leads to a regulator 38, and the regulator 38 is connected to the oil inlet fitting 14 of the fuel burner by way of a line 40.

The fuel regulator 38 preferably is a demand regulator of the diaphragm valve type illustrated and described in U.S. Pat. No. 3,298,418, granted to Eugene C. Briggs on Jan. 17, 1967, the disclosure of which patent is incorporated herein by reference. This regulator 38 supplies constant fuel flow to the nozzle regardless of head variations, so long as the air system is operating properly to impose a demand for the presence of a supply of fuel within the nozzle. However, the regulator shuts off the flow when the primary air supply is interrupted, so that there is no danger of fuel being delivered to the nozzle after the conditions necessary for combustion have ceased to exist.

The electrical system for controlling the operation of the equipment may be located at 42 in FIGS. 2 and 3. These controls are conventional in nature and need not be described in detail here.

It should be noted however that the burner assembly includes an igniter component 44 connected to a cable 46 which leads into the control system and that the burner assembly also includes a detector 48 (e.g. a cadmium cell unit) which also is attached to a cable 50 leading to the control. The igniter component 44 operates to provide an ignition arc in the beginning of a burner operation cycle, and the detector 48 operates to shut down the fuel supply in the event that the flame should go out unexpectedly. The controls further serve to correlate the operations of the motor 20 and the fuel pump 32 with the requirements of the burner and the system being served by the burner.

The construction and organization of the elements of the burner assembly 10 are best illustrated in FIGS. 5–12 of the drawings.

A cylindrical member or burner tube 52 extends through a cylindrical opening in the wall of the heat receiver 5 and is attached to a mounting member 54 detachably secured to the exterior of the heat receiver 5 by such conventional means 56 as screws or the like.

The inner or outlet end 58 of the burner tube 52 is in open communication with the interior of the heat receiver 5. However, the outer end of the burner tube is closed by a member 60 having a central opening for receiving the nozzle structure.

The nozzle head or body element 12 fits closely within the central opening in the closure 60 and may be permanently secured to the closure in an appropriate manner for sealing the opening as best shown in FIG. 9. The nozzle body 12 is hollow and includes both a chamber 62 communicating with the oil inlet fitting 14 and a chamber 64 communicating with the primary air inlet fitting 16. The front end of the nozzle body 12 is provided with an internally threaded central opening for cooperation with an externally threaded rear end portion of a nozzle tip 66.

A nozzle core element 68 is disposed centrally of the assembly and fits closely within an opening at the rear end of the nozzle tip and within a seal 70 separating the oil chamber 62 from the air chamber 64. The axial position of the core 68 within the body 12 and the attached tip 66 is established by a radial collar 72 on the core and a compression spring 74 arranged to press the core forwardly until a forwardly directed face of the collar 72 abuts against the rear end of the threaded portion of the nozzle tip 66.

The front end portion of the nozzle core element 68 has an external diameter less than the diameter of the opening in the corresponding portion of the tip 66 to provide therebetween another air chamber 76. Air flows from the chamber 64 to the chamber 76 through inclined passageways 78 (FIGS. 9 and 10) through the collar portion 72. These inclined passageways serve to produce a high velocity air flow in a swirling pattern through the chamber 76 and through an orifice 80 at the outlet end of the nozzle tip 66.

The core element 68 additionally includes at its front end a tip portion 82 which protrudes into the orifice 80, and an oil passage 84 leads through the center of the core element 68 from the chamber 62 to the orifice 80. The swirling air flow from the chamber 76 out of the orifice 80 in the nozzle tip produces an aspiration effect which causes oil to flow through the passage 84. As a result, a mixture of air and atomized oil is projected forwardly from the nozzle tip toward the outlet end 58 of the burner tube 52.

A flame retention head 86 is disposed a short distance in front of the outlet end of the nozzle tip as illustrated in FIGS. 5 and 9. This head 86 is formed of heat resistant thin wall material such for example as thirty gauge stainless steel. Its shape is basically that of a frustum of a cone and it is preferred that the cone angle (i.e. inclination relative to axis) be on the order of about 45 degrees.

The small end of the coned flame retention head 86 faces toward the nozzle tip 66, while the larger end faces toward the outlet end 58 of the burner tube 52.

The diameter of the larger end of the head **86** corresponds to the internal diameter of the burner tube **52**, and an attachment ring **88** of cylindrical configuration seals this end of the head against the wall of the tube.

As indicated in FIG. **8**, the igniter component **44** is threaded into a tubular mount **90** carried by a rear portion of the burner tube **52**. This igniter component **44** includes electrodes **92** and **94** which project into the interior of the tube **52** to a location in the vicinity of the outlet end of the nozzle tip **66**. Current may be supplied to the electrodes **92** and **94** at sufficient voltage to strike an arc between these electrodes when it is desired to initiate a burning cycle.

Also mounted on a rear portion of the burner tube **52** is the auxiliary air inlet fitting **18** (FIGS. **5**, **7**, **11** and **12**). This fitting **18** is a large diameter tube **96** which mates with a correspondingly sized opening in the burner tube **52**. The axis of the tube **96** is transverse to the axis of the burner tube **52** and air flow control means **98** extend centrally through the tube **96**.

As best shown in FIGS. **11** and **12**, the air flow control means **98** is in the form of a pair of sheet members **100** and **102**. The outer ends **104** and **106** of the sheet members **100** and **102** are generally planar and extend parallel to the axis of the burner tube **52**. These outer end portions of the sheet members are disposed in abutting relationship to each other to minimize the obstruction offered thereby to the passage of auxiliary air into the burner tube **52**.

The inner end portions **108** and **110** of the sheet members **100** and **102** have special configurations for effecting distribution of the auxiliary air through the burner tube zone **112** at the rear and about the exterior of the flame retention head **86**. Each of the sheet member inner end portions **108** and **110** is curved outwardly (FIG. **11**) and each is provided with tapered front and rear edges **109** and with a multiplicity of holes **111** as illustrated in FIG. **12**. With this construction, some air is deflected in a counterclockwise direction (as viewed in FIG. **11**) by the inner end portion **108** of the sheet member **100**, some air is deflected in a clockwise direction by the inner end portion **110** of the sheet member **102**, some air passes directly through the holes **111**, and some air passes beyond the tapered front and rear edges of the deflector portions **108** and **110**.

Thus, even though in this compact system the actual inlet tube **96** is disposed on one side of the burner tube **52**, the auxiliary air admitted to the zone **112** at the rear of the burner tube **52** is distributed evenly through the zone **112**. The significance of this feature can be more fully appreciated when it is noted that, in the absence of the flow control means **98**, a large volume of cool auxiliary air flowing across the axis of the burner tube would cause wet oil to be deposited on the wall components opposite the auxiliary air inlet.

The pattern of flow of auxiliary air from the zone **112** to the interior of the flame retention head **86** is established by features of the head construction which now will be explained in detail with particular reference to FIGS. **9** and **11** of the drawings.

One set of auxiliary air openings **114** through the coned flame retention head **86** is located near the larger end of the head. These openings **114** are circular holes regularly spaced about the circumference of the head. Although there are fourteen of the holes **114** in the illustrated embodiment, it will be understood that the number of holes provided in any given instance will be determined on the basis of the air requirements for efficient combustion of fuel at the rate appropriate for the system in which the burner is used.

The head portion **86** also is provided with a second set of auxiliary air passages or slots by slitting the head longitudinally from alternate ones of the holes **114** to the small rear end of the head. Thus, there are seven of these slits **116** in the illustrated embodiment. Viewing the coned head **86** from its rear end (FIG. **11**), it will be seen with respect to each of the slits that the edge **118** thereof which trails in a counterclockwise sense lies in a longitudinal plane containing the axis of the head and is not deflected from the coned shape. However, the material adjacent the opposite marginal edge **120** is bent outwardly along a bend line **122** to provide an inclined vane **124**.

With this construction, the opposite edges **118** and **120** of the slits **116** cooperate to define forwardly converging longitudinal slots or air passage mounts for receiving the pressurized air from the zone surrounding the flame retention head **86**, and the inclined inner faces of the vanes **124** impart to the air flowing thereover a swirling pattern of motion about and along the axis of the burner tube **52**. Since the slits extend all the way to the completely open small end of the coned flame retention head **86**, air may move to the inner flow-controlling surfaces of the vanes **124** not only from the zone at the circumference of the coned head but also from the zone immediately behind the head. Thus, the swirling action is imparted to substantial masses of flowing air without any abrupt flow direction changes and in the absence of any obstructions to flow into the zones of action of the vanes. Moreover, it is to be noted that the interior of the coned head **86** is unobstructed by inward protrusions which would obstruct the spiral flow established by the vanes **124**.

An explanation of exemplary dimensional characteristics of the flame retention head will serve to further clarify the construction illustrated in the drawing. The larger diameter of this coned head **86** is 2 ¾ inches, the angle of inclination or cone angle is 45°, and the axial extent of the cone (distance between large and small ends of cone as projected onto a plane parallel to axis) is twenty-six thirty-seconds inch. The holes **114** have diameters of about nine thirty-seconds inch and have axes located about twenty-nine thirty-seconds inch forwardly of the rear end of the head **86** as measured along the sloping cone wall. The angular extent of those rear edge portions **126** of the coned head **86** which are not bent outwardly to form the vanes **124** is slightly greater than 180°. The rear end edges **128** of the vanes **124** extend outwardly at such angles that the juncture points of these edges **128** with the slit edges **120** define a circle having a diameter of about 1 15/32 inches, and both the widths and the angles of inclination of the vanes relative to the coned surface of revolution decrease as one proceeds forwardly from the rear end of the head.

SUMMARY OF BURNER OPERATION AND ADVANTAGES

In order to initiate combustion, the igniter 44 is energized to strike an arc between the igniter electrodes 92 and 94 located in the vicinity of the nozzle tip 66, air is supplied to both the primary air fitting 16 and the secondary air fitting 18, and oil is made available to the fuel fitting 14 on the nozzle body 12. After ignition has been achieved, the igniter 44 is deenergized and remains idle until it is desired to start a new burning cycle.

The primary air is driven through the inclined passages 78 in the collar portion 72 of the nozzle core 68 and swirled forwardly and clockwise about the axis of the nozzle to issue from the orifice 80 in the nozzle tip 66. This produces an aspirating effect and tiny oil particles drawn from the passage 84 of the nozzle core are mixed with the stream of air issuing from the nozzle tip.

The supplementary air distributed through the zone 112 behind the flame retention head 86 follows several paths relative to the stream issuing from the nozzle tip 66. Some of the supplementary air will of course pass directly through the open rear end of the flame retention head along with the stream issuing from the nozzle. Additional increments of supplemental air are acted upon by the vanes to produce a swirling flow having a counter clockwise direction as viewed from the rear of the retention head. This flow exerts a confining effect upon the flame in a radial sense, scours the interior surface portions of the flame retention head 86, and further improves the air-fuel mixture in the flame area. In this latter connection, it is noted that the direction of swirl imparted by the vanes 124 is opposite to the direction of swirl provided by the passages 78 in the air channel of the nozzle, thereby promoting more efficient mixing.

Substantial additional increments of supplementary air are driven through the holes 114 toward and along the central axis to further confine the flame and carry the combustion of the fuel to completion. This air flow through the holes 114 also provides a shield for the cooler metal surfaces located downstream so that these surfaces are protected against carbon deposits.

From visual observations it has been established that the flame produced is a small, bright yellow flame of a shape indicative of a vortex. This intense flame occupies a central portion of the flame retention head. Burning efficiency is further attested to by the exceptional cleanness of the exhaust gases.

Although the illustrated embodiment of the invention is particularly adapted for the burning of oil or other liquid fuel, it will be appreciated that the invention also is suitable for use in the burning of gaseous fuels. The vastly improved air-fuel mixtures achieved by the structures of the invention contribute to the efficiency of combustion of gaseous fuel in the same manner they do for liquid fuel.

It will be appreciated also that the invention may be applied in many environments other than the water chiller illustrated in the drawings. This particular application does, however, illustrate the unique compactness characteristics associated with the burner construction, and it will be appreciated that the remarkable decrease in required combustion zone volume achieved by the invention is a factor which will make it possible to utilize the fuel burner in situations where the nozzle type burners of the prior art were unsuitable.

Still other modifications and variations will suggest themselves to persons skilled in the art. It is intended therefore that the foregoing detailed description of the illustrated embodiment be considered as exemplary only and that the scope of the invention be ascertained from the following claims.

What is claimed is:

1. A fuel burner comprising:

a generally cylindrical member within which combustion may occur, said member having an inlet and open outlet end;

a fuel nozzle adjacent the member inlet and generally coaxial with said cylindrical member and having an outlet opening spaced from the outlet end of said cylindrical member;

a flame retention head having a maximum diameter generally corresponding to the diameter of the interior of said cylindrical member and including a hollow, open ended, generally conical portion having a concave interior surface uninterrupted by radial protrusions therefrom, said flame retention head being mounted within said cylindrical member with the smaller end of said conical portion facing said nozzle and being disposed in generally coaxial relationship with respect thereto; and

means for supplying air under pressure to the zone surrounding the exterior of said conical portion of said flame retention head;

said flame retention head further including means defining a first set of auxiliary air passages therethrough regularly spaced about the axis of said conical portion for admitting air from said zone to the interior of said conical portion and for guiding air flowing through said passages into a swirling pattern of motion about and along the axis of said head, each of the auxiliary air passages of said first set being formed by a slot communicating with and extending forwardly from the small open end of said conical portion, one marginal edge of the slot being located in a plane containing the axis of the flame retention head, and the opposite marginal edge of the slot being bent outwardly at an angle with respect to the first-mentioned marginal edge.

2. A fuel burner according to claim 1 wherein said conical portion of said flame retention head is additionally provided with a second set of air inlet passages formed by generally round holes therethrough, one of said holes being disposed in intersecting relation to the forward end of each of said slots.

3. A fuel burner according to claim 2 wherein the number of holes forming said second set of air passages is a multiple of the number of said slots forming said first set of air passages and wherein said holes are regularly spaced about the circumference of said conical portion.

4. An oil burner comprising:

a generally cylindrical member within which combustion may occur, said member having an open outlet end;

an aspirator nozzle generally coaxial with said cylindrical member and having an outlet opening spaced from the outlet end of said cylindrical member, said nozzle including means for directing primary air in a spiral path to said opening and an axial oil passage leading to said opening so that oil is drawn through said passage and projected forwardly from the nozzle as an atomized spray;

means for admitting auxiliary air to the portion of the interior of said cylindrical member surrounding said nozzle outlet; and

a flame retention head of thin material disposed between the outlet end of said nozzle and the outlet end of said cylindrical member, said material being formed into a generally conical section coaxial with said cylindrical member, said conical section having a large end the diameter of which corresponds to the inner diameter of said cylindrical member and a small end defining an unobstructed opening facing the outlet end of said nozzle, said head having a ring of regularly spaced holes therethrough at a location close to but spaced from the large end of said conical section and the material of said conical section being slit longitudinally from at least some of said holes to the small end of the conical section, portions of the material of said conical section each bound by an edge of one of said slits and by an inclined bend line converging toward such edge from the small end of the conical section being bent outwardly along said bend lines to form vanes, all of said vanes having inner surfaces inclined in the same direction about the axis of the head for imparting a swirling motion to auxiliary air passing along said surfaces and into the interior of the head.

5. An oil burner according to claim **4**, wherein said means in said nozzle for directing primary air in a spiral path and said vanes for imparting swirling motion to auxiliary air are so arranged that the rotational direction of auxiliary air swirling motion is opposite to the rotational direction of primary air flow.

6. A fuel burner comprising:

a generally cylindrical member within which combustion may occur, said member having an inlet and open outlet end;

a fuel nozzle adjacent said inlet and generally coaxial with said cylindrical member and having an outlet opening spaced from the outlet end of said cylindrical member;

a flame retention head having a maximum diameter generally corresponding to the diameter of the interior of said cylindrical member and including a hollow, open ended, generally conical portion having a concave interior surface uninterrupted by radial protrusions therefrom, said flame retention head being mounted within said cylindrical member with the smaller end of said conical portion defining an unobstructed opening facing said nozzle and being disposed in generally coaxial relationship with respect thereto; and

means for supplying air under pressure to a zone surrounding the exterior of said conical portion of said flame retention head and in open communication with said unobstructed opening at the smaller end of said conical portion of said flame retention head;

said flame retention head being further provided with a set of auxiliary air slots therethrough regularly spaced about the axis of said conical portion for admitting air from said zone to the interior of said conical portion, each of said slots being in open communication with and extending forwardly from the small open end of said conical portion, and vane means adjacent said slots for guiding air flowing toward the interior of said conical portion into a swirling pattern of motion about and along the axis of said head.

7. A fuel burner according to claim **6** wherein said conical portion of said flame retention head additionally includes means defining a second set of auxiliary air passages regularly spaced about the axis of said conical portion and being located near but spaced from the large end of said conical portion, said passages of said second set having axes intersecting the longitudinal axis of said head for directing air from said zone toward and along the axis of said head.

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