June 20, 1961

E. A. BURT

BURNERS

2,989,119

Filed May 17, 1956

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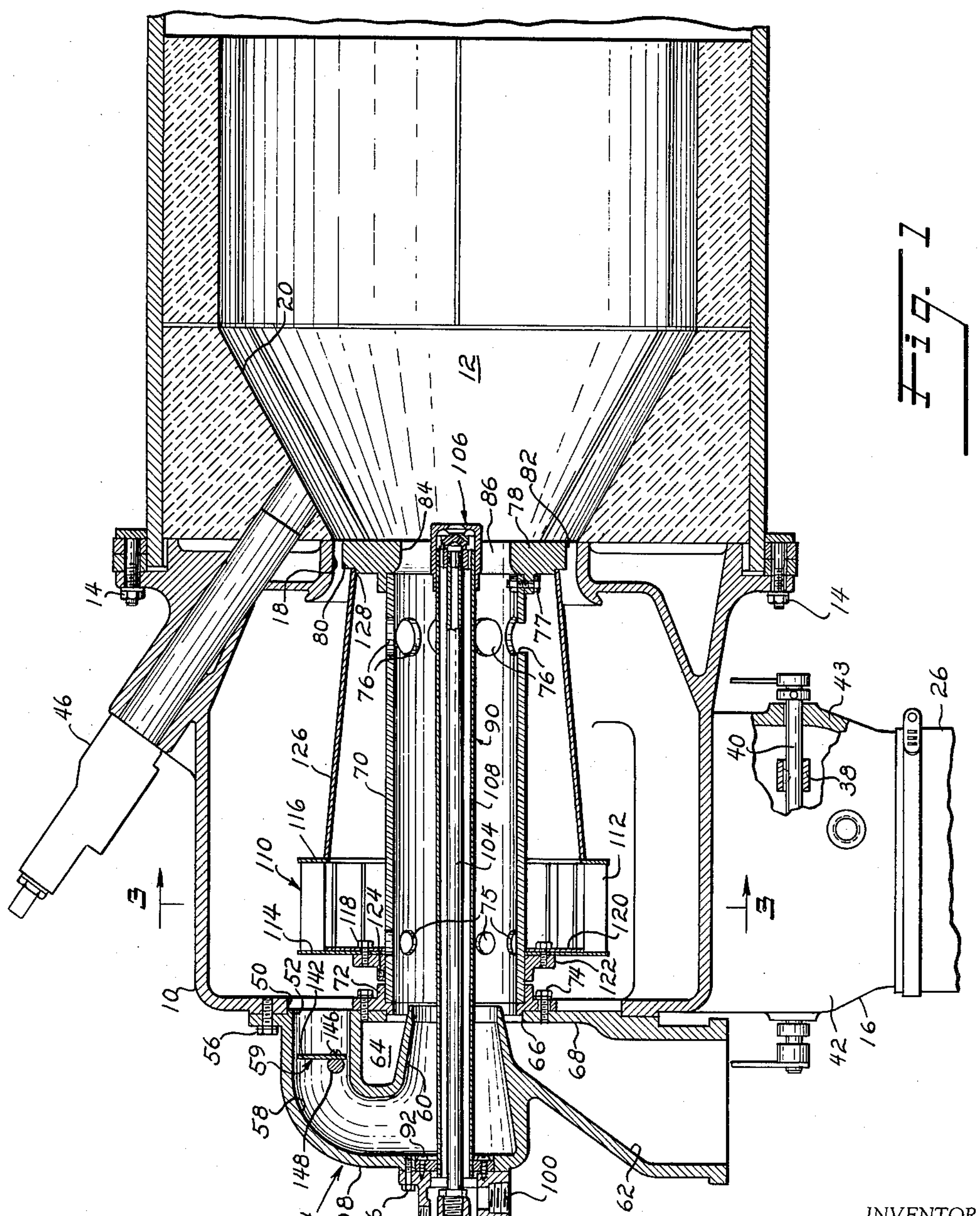

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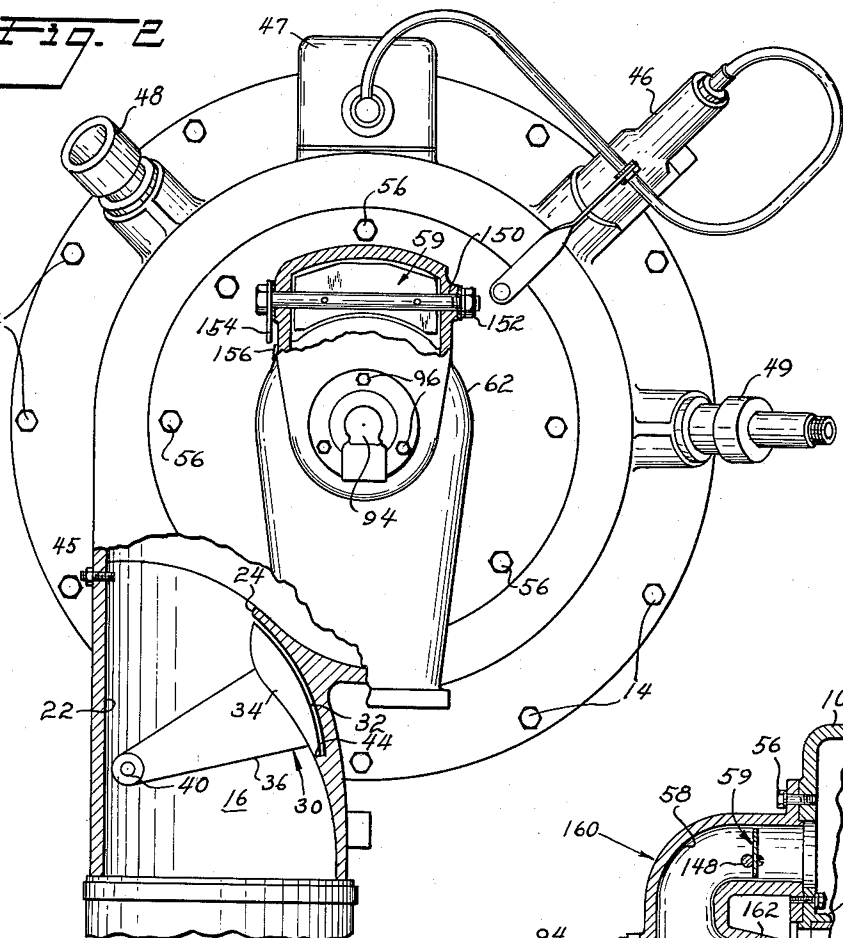
Fig. 2



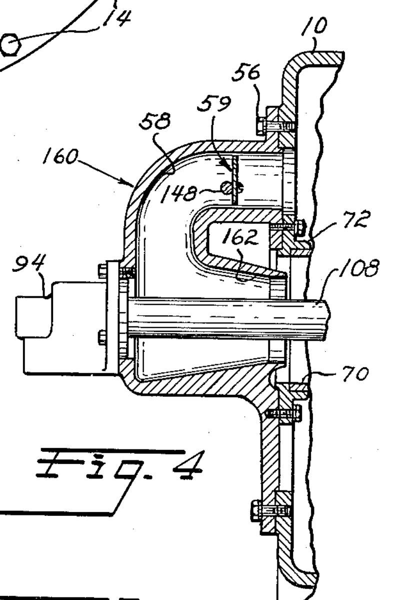


Fig. 4

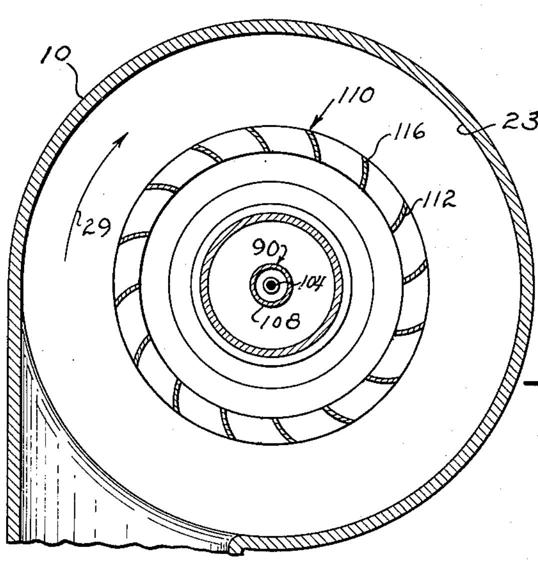


Fig. 3

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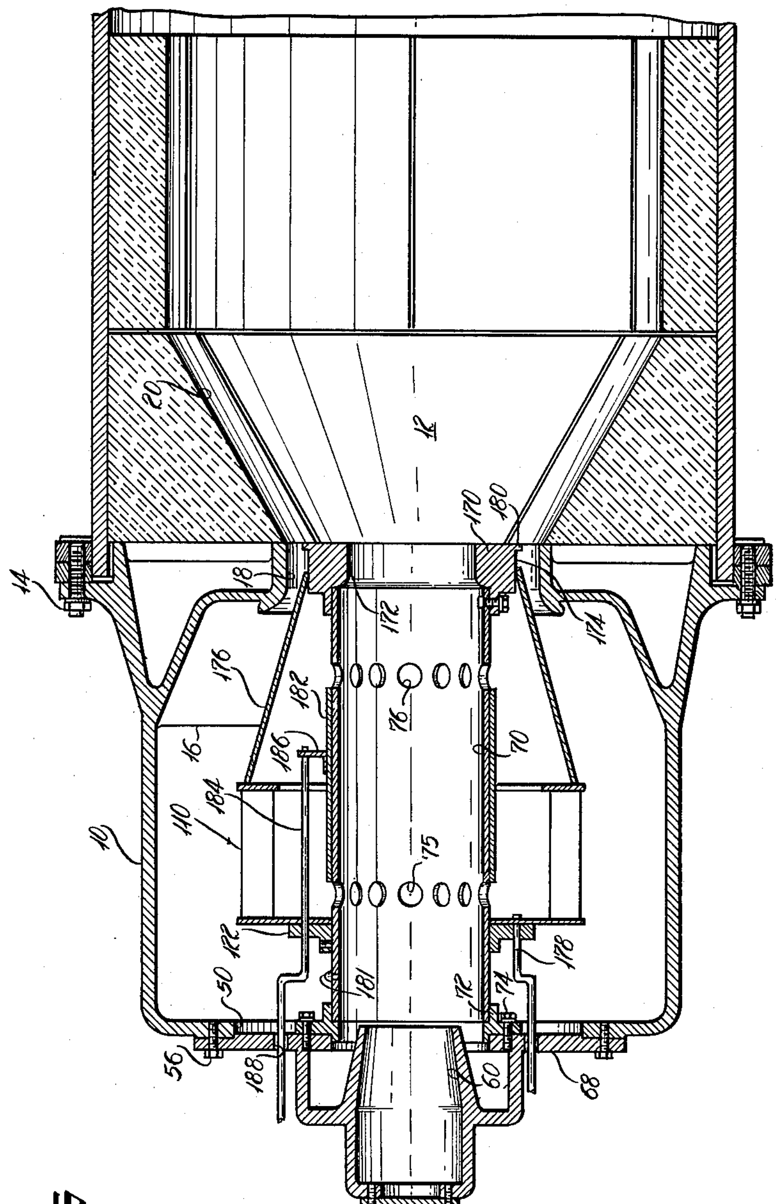

FIG-5

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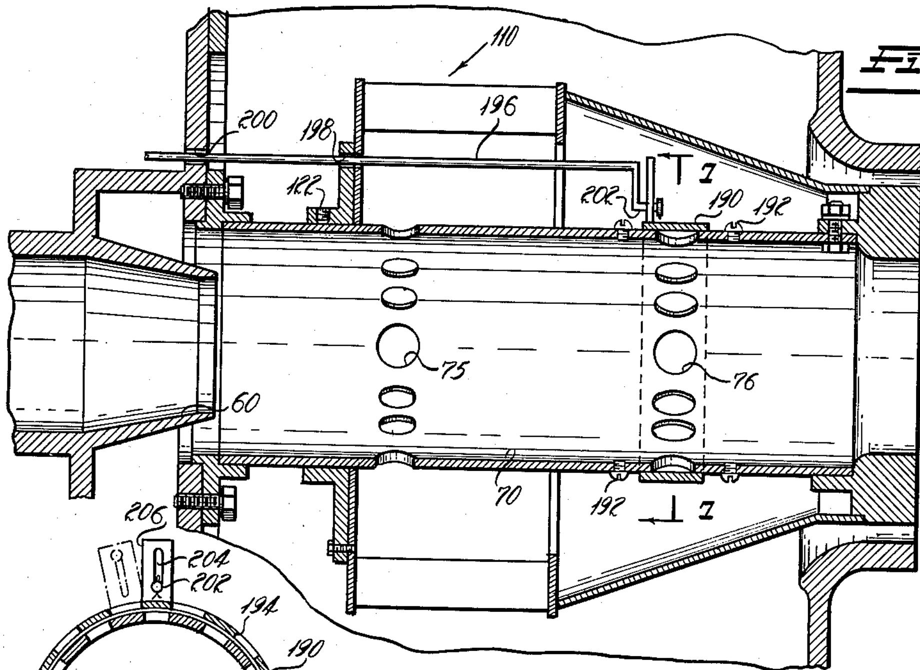

Fig. 6

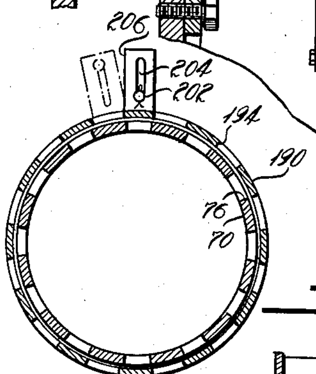

Fig. 7

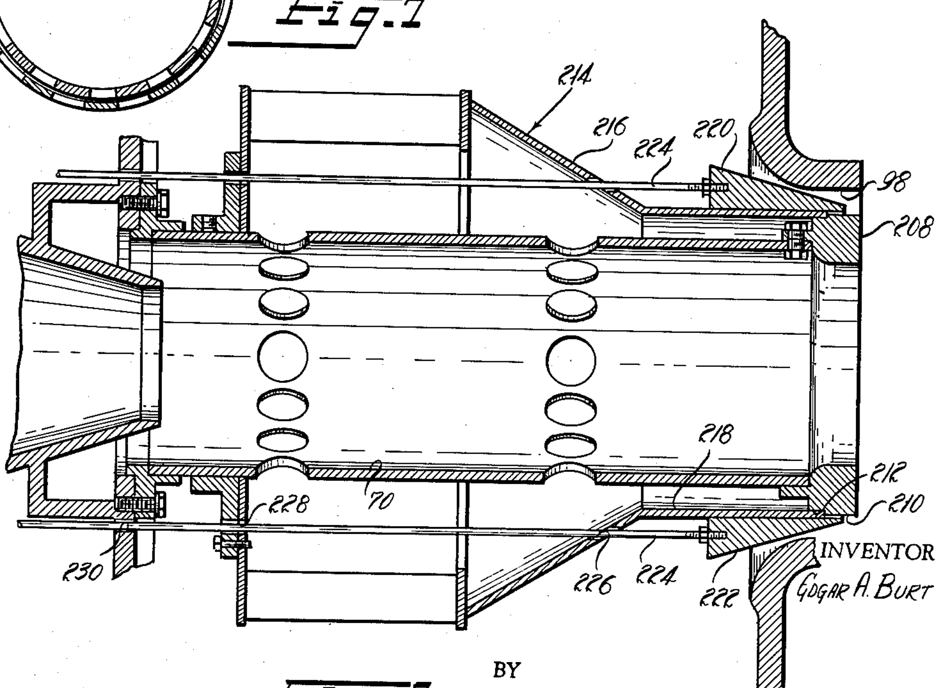

Fig. 8

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BURNERS

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5 Claims. (Cl. 158—118)

This invention relates to improvements in fuel burners and more particularly to improvements in fuel burners of the type adapted to burn either liquid or gaseous fuels for the production of steam or hot water in a boiler.

The principal purpose and object of the present invention is to provide burners having improved efficiency and which include novel means for mixing the fuel with combustion air to establish and maintain the proper fuel-air ratios and which permits substantial reductions in system pressures thus reducing the power requirements of the associated blower apparatus and reducing the overall noise level of the entire combustion apparatus.

It is generally recognized that high combustion efficiency can be obtained only if the combustion air and fuel are thoroughly and intimately mixed to form a substantially homogeneous combustion fluid in which the fuel and air are present in optimum predetermined proportions.

If the fuel-air mixture is not substantially homogeneous the desired uniform smooth combustion cannot be obtained, and, particularly where gaseous fuel is used, improper mixture of the air and gas produces frequent minor explosions which create variations in furnace pressures and altogether unsatisfactory operation which in some cases may be extremely hazardous.

It is also desirable that burners of the type with which the invention is concerned be capable of efficient operation over a wide range of heat requirements so that given sizes of burners are suitable for installation in a wide range of boiler sizes, and provide efficient operation over a wide range of fuel and air flows in a given installation.

To achieve this efficiency and maintain it over the desired range of operating conditions the invention provides means which are effective not only to promote proper fuel-air mixtures but which also permit adjustment of fuel and air flows without disturbing the combustion efficiency.

In prior attempts to satisfy these and other requirements, it has been proposed to provide air guide structures in burners effective to establish primary and secondary air streams surrounding a stream of fuel, the fuel being supplied to the burner in either liquid or gaseous form. One of the most efficient and successful prior burners of this type is disclosed in co-pending application Serial No. 234,198, filed June 29, 1951, now Patent No. 2,815,069 for Burner Aparatus. In this burner the fuel in either liquid or gaseous form is introduced into an axially directed flow of primary combustion air to form a fuel-rich combustible mixture which is surrounded by an annular envelope of secondary combustion air flowing in a helical path.

It is an important and more specific object of the invention to provide a burner which preserves the basic advantages of burners of this type and through the provision of novel means for directing, proportioning and controlling the flow of the primary and secondary air streams provides for increased combustion efficiency over a wider range of air and fuel flows than heretofore possible.

In determining the overall efficiency of burners of this type the power requirements of the blower system and other auxiliary equipment must be considered. The construction of prior burners has reflected the widespread belief that high combustion efficiency can be obtained only through the use of high pressure, high speed air supply equipment. The use of such equipment, while permitting good combustion efficiency, has disadvantages which more

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than off-set the improved combustion performance. For example the initial cost, size and maintenance problems are all substantially increased by the employment of high speed, high pressure blower units. Also the use of high pressure, high speed blower equipment substantially increases the noise level in the combustion chamber as well as in the blower unit. Often the noise level in such burners is sufficient to render the burner unsuitable for use in the heating systems of public buildings such as libraries, schools and small office buildings.

It is accordingly an additional important object of the present invention to provide improved burners which maintain high levels of combustion efficiency throughout a wide range of operating conditions despite the use of air blower equipment of reduced size which supplies air at low pressures heretofore thought to be inconsistent with high combustion efficiency.

It is a further object of the invention to provide novel valve assemblies for controlling the flow of air at two or more points in the burner to permit adjustment of the quantity and velocity of the air streams and thereby assure optimum combustion efficiency of the burner over a wide range of operating pressures and conditions and to permit utilization of fuels of varying combustion characteristics.

It is also an object of the invention to provide novel air and fuel guide structure which is effective to direct the combustion components so that the air aspirates the fuel and permits a reduction of the supply pressure of the latter.

It is an additional object to provide simplified burner constructions which may be manufactured and maintained at substantially reduced cost.

It is a further object of the present invention to provide improved burners which have increased versatility and which may be converted merely by the manipulation of fuel control valves to burn either gas or liquid fuel or may be permanently converted to burn liquid only, by the substitution of a single part.

Additional objects and advantages of the present invention will become apparent as the description proceeds in connection with the accompanying drawings in which:

FIGURE 1 is a vertical section with certain parts in elevation of a burner assembly according to the present invention adapted to burn either liquid or gaseous fuel;

FIGURE 2 is an end elevation of the burner of FIGURE 1 with parts broken away for clarity;

FIGURE 3 is a transverse vertical section taken along line 3—3 of FIGURE 1;

FIGURE 4 is a fragmentary vertical section of a modified form of the invention;

FIGURE 5 is a central horizontal section of a modified burner assembly incorporating additional valve assemblies for controlling the flow of air through the burner;

FIGURE 6 is a fragmentary view similar to FIGURE 5 showing a modified form of air control apparatus;

FIGURE 7 is a fragmentary section taken along line 7—7 of FIGURE 6 showing details of construction; and

FIGURE 8 is a fragmentary view similar to FIGURES 5 and 6 and showing a further modification of the air control apparatus.

The burner assembly embodying the present invention as shown in FIGURE 1 is adapted to burn either liquid or gaseous fuel. Fuel in either form is passed axially of the burner and by virtue of the novel air guide structure disclosed in detail below, the stream of fuel is surrounded with a primary air stream in which turbulence is produced by combining an axially flowing air stream at two spaced points with radially directed air streams.

The fuel air mixture thus produced is injected into the combustion chamber and is surrounded with secondary air flowing in a helical pattern to complete combustion. Liquid fuel, if used, is atomized and sprayed into the primary air stream in the combustion chamber. Gaseous fuel, if used, is intermixed with the primary air in a premixing chamber prior to introduction into the combustion chamber.

In a preferred form the present invention includes novel air guide structure which is effective to divide the air supplied to the burner into four separate streams, three of which are subsequently combined in a novel manner to form the primary air stream. The remaining air stream is injected separately into the combustion chamber as secondary air. The invention also contemplates novel means for controlling the proportions of the total air flow constituting the several separate air streams in a novel manner as well as for controlling the total air flow without disturbing the character or distribution of the several air streams.

In this burner structure, a housing providing a main air chamber or plenum **10** is fixed to the end of the fire or combustion chamber **12** of a boiler as by bolts **14**. Air plenum **10** is generally cylindrical in cross section, as shown in FIGURE 2, having a downwardly open air inlet port **16** and an axially open outlet port **18** through its end adjacent the combustion chamber as shown in FIGURE 1. Outlet port **18** is coaxially aligned with a frusto-conical wall **20** of the refractory lining of the combustion chamber and with the generally cylindrical contour of air plenum, **10**. The internal surface of wall **22** of the inlet port **16** is tangential to the inner cylindrical surface **23** of the air plenum **10**, the space between wall **22** and the edge **24** of the interrupted cylindrical wall of the air plenum defining the maximum possible opening of the inlet port.

Inlet port **16** is connected by a suitable flexible air duct **26** to the outlet of a blower (not shown) in a conventional manner. In this structure, the stream of incoming air is introduced under pressure at substantially constant velocity into the air plenum **10** through inlet passage **16**, forming a moving layer or film of air adjacent wall **22** of a radial thickness equal to the distance between wall **22** and edge **24**. This air stream entering the plenum **10** tangential to the cylindrical wall **23** will follow a generally circular path around the cylindrical wall **23** as indicated by the arrow **29** in FIGURE 3.

Means are provided for controlling the volume of incoming air by varying the thickness of the air stream entering the inlet along wall **22** without disturbing the tangential flow of the incoming air stream. A throttle valve, which may be adjusted to vary the size of the opening at **24**, is disclosed as a plate member **30** having an arcuate outer surface **32** and an inner surface **34** suitably curved or streamlined as shown to produce minimum turbulence of the passing air stream. Plate member **30** is suitably fixed to pivot arms **36** and **38** which are in turn fixed to a pivot shaft **40** journalled in the walls **42** and **43** of the inlet passage **16** as shown in FIGURE 1. Any suitable control linkage for positively positioning shaft **40** may be provided. Such linkage is actuated by a throttle valve control means (not shown) which will also control the quantity of fuel introduced into the burner in a conventional manner. By this valve structure, the quantity of air introduced into the air plenum may be varied in accordance with the load upon the burner without substantially modifying the input velocity of air into the air plenum at the throttle valve. The air input velocity is controlled at approximately 65 feet per second (a tolerance of +10% to −15% being permissible). Since the control means for plate member **30** forms, per se, no part of this invention, it has neither been shown nor described.

Since, as is shown in FIGURE 2, shaft **40** is parallel to wall **22**, plate member **30** may be swung toward wall **22** to reduce the opening of the inlet port **16**. Suitable stops are provided to limit the travel of plate member **30**, a shoulder **44** being formed integrally with the inlet port wall establishing the maximum open position of this inlet throttle valve while an adjustable stop **45** limits the closing of the inlet valve. Because plate member **30** moves toward wall **22**, the thickness of the air stream and thereby the quantity of incoming air may be reduced without disturbing the tangential inflow of the air stream while the input air velocity is maintained approximately constant. Since the air pressure within the air plenum **10** is greater than that within the fire chamber **12** due both to the draft of the furnace and to the air input blower, the air stream flowing into the air plenum and travelling circumferentially therearound, substantially spirals toward the outlet port **18**.

Mounted on the plenum **10** are an igniter **46** energized by a transformer **47**, an inspection window **48** and a lead sulphide fuel control cell **49**, all of which are conventional.

The main air plenum **10** at its side remote from the combustion chamber is provided with a circular aperture **50** which receives an annular shoulder **52** of a combined air and gas plenum **54**, the plenum **54** being secured to the plenum **10** by a plurality of bolts **56**. Air is led from the plenum **10** into the plenum **54** through a passage **58** containing valve assembly **59** into an air nozzle **60** formed integrally with the plenum casting. It will be noted that the nozzle **60** is coaxial with the secondary air opening **18** at the opposite end of the main air plenum **10**. Also formed integrally with the plenum **54** is a downwardly open inlet **62** for gaseous fuel which is adapted to be connected to any suitable source of fuel not shown. At its upper end the inlet connection **62** is enlarged to form an annulus **64** surrounding the nozzle **60**.

The annulus **64** communicates with the interior of the plenum **10** through a circular opening **66** formed in the wall **68** of the plenum **54** centrally of the aperture **50** in the wall of the plenum **10**. The opening **66** is coaxial with the air nozzle **60** and with the outlet opening **18**. A cylindrical mixing tube **70** is press fitted or otherwise suitably secured to a flange member **72** secured to the wall **68** of the plenum **54** by a plurality of bolts **74** to dispose the inner surface of the mixing tube **70** in substantial alignment with the opening **66**. The tube **70** is provided with rows of spaced ports **75** and **76** for a purpose to appear. The mixing tube **70** extends away from the wall **68** coaxially through the plenum **10** to a point adjacent the outlet port **18**. Secured to the opposite end of the mixing tube **70** as by bolts **77** is an air control ring **78** having an annular outer surface **80** which forms with the opening **18**, an annular secondary air nozzle **82**, the annular inner surface **84** of the ring **78** forming the primary air outlet port **86**.

The liquid fuel injector assembly, indicated generally at **90**, is rigidly positioned coaxially of the mixing tube **70** by means of bolts **92** which extend into an oil and atomizing fluid inlet fixture **94** mounted by bolts **96** to the rear wall **98** of the plenum **54**. Both the liquid fuel injector **90** and the fixture **94** may be of the form disclosed in the aforesaid application Serial No. 234,198 or may be of the form shown in application Serial No. 213,068, filed on February 28, 1951, now Patent No. 2,753,927 for Fuel Flow Control. These two elements per se form no part of the present invention and will not be described in detail.

Fixture **94** is formed with ports **100** and **102** adapted to be connected, respectively, through conduits not shown, to a source of pressurized atomizing fluid such as air or steam and to a source of liquid fuel such as fuel oil. The port **102** is in communication with a central fuel tube **104** which extends through the injector assembly **90** and terminates at its opposite end in a mixing or atomizing head **106**. The air inlet port **100** communicates with the interior of air tube **108** which forms an annular air passage about the fuel tube **104** and also terminates at its opposite end in the head **106**. As explained in detail in the above-mentioned application, the fuel injection assembly 90 is effective to inject liquid fuel into the combustion chamber 12 in the form of a fine mist in such a manner as to produce a short bushy flame. This provides efficient combustion and avoids fuel impingement on the fuel transfer surfaces or the refractory material of the furnace lining and promotes complete combustion of the fuel in a relatively short combustion chamber.

A novel air guide structure by which many of the advantages of the present invention are attained will now be described. Positioned opposite the air inlet 16 closely adjacent the rear wall of plenum 10 is a diffuser ring assembly indicated generally at 110. The diffuser assembly comprises an annular row of spaced longitudinally extending guide vanes or air scoops 112 which are welded or otherwise suitably secured at their opposite ends to annular sheet metal supports 114 and 116. Bolts 118 extend through a stiffening ring 120 into a flange ring 122 positioned on the air mixing tube 70 by means of set screws 124 so that the diffuser assembly 110 is rigidly positioned on the air mixing tube 70. The small end of a cone 126 is mounted on ledge 128 of the air control ring 78 and the large end of this cone is welded or otherwise suitably secured to the outer surface of the support ring 116. The cone 126 forms an enclosed air space about the mixing tube 70, guides the flow of secondary air toward the secondary air port 82 and imparts rigidity to the structure.

As stated above the air inlet is tangential with respect to the plenum 10 and accordingly the air introduced therethrough circulates in a spiral pattern in the plenum 10 in a clockwise direction as viewed in FIGURE 3. A portion of this air will be intercepted by the stationary vanes 112 and will be directed radially inwardly toward the premixing air tube 70. A portion of the air passing inwardly through the vanes 112 is directed through the set of first primary air mixing ports 75 having one edge located substantially in alignment with the side member 114. The remainder of the air passing through the vane structure 112 enters the mixing tube 70 through the second set of primary air mixing ports 76 adjacent the primary air outlet port 86. It will be appreciated that the division of the air flowing inwardly through the diffuser 110 is dependent upon the relative total areas of the ports 75 and 76. In a typical installation in a one hundred horsepower boiler the total area of the ports 75 is approximately one-fifth of the total area of port 76. The air streams passing radially inwardly through ports 75 and 76 mix turbulently with the main primary air stream which passes from the plenum 10 through passage 58 into the air-gas plenum 54 and is directed axially of the air premixing tube 70 through nozzle 60. The portion of the air delivered to plenum 10 and not passing through diffuser 110 or through nozzle 60 is delivered into the combustion chamber through the secondary air nozzle 82 as secondary air flowing in a helical path. The valve assembly 59 is provided in the passage 58 to control the portion of air delivered to the nozzle 60, the ports 75 and 76 and the secondary air nozzle 82. The valve assembly 59 comprises a plate 142 rigidly secured as by screws 146 to a stem 148 journalled at its opposite ends in suitable bores 150 in the side walls of the plenum assembly 54. The stem 148 may comprise a bolt held in place by a nut 152. The valve plate 142 may be locked in adjusted position by tightening the nut 152 and adjustment of the position of the plate may be effected by loosening the nut 152 and rotating the bolt 148 manually. A position indicator 154 is clamped between the head of the bolt and one of the side walls of the plenum 54 which carries suitable position indicating indicia indicated at 156.

If gaseous fuel is used it may be supplied through inlet 62 at reduced pressure because of the aspirating or eductor effect produced by the primary air nozzle 60. The air gas mixture formed in the region about the nozzle 60 is advanced through the tube 70 and is intercepted first by the radial streams flowing through the first set of supplementary primary air ports 75. It will be appreciated that since the two air streams at this point are flowing normal to each other at difference velocities and pressures, considerable turbulence and resulting mixing will occur. This action continues as the mixture passes through the tube 70 and additional turbulence and mixing is created when the mixture is intercepted by the radial streams flowing through the second set of supplemental primary air ports 76. As a result of the turbulent mixing effected in mixing tube 70 a substantialy homogeneous fuel air mixture is injected through the primary air outlet 86 into the combustion chamber 12. The homogeneous fuel rich mixture thus injected is combined with the helically flowing envelope of secondary air issuing through the nozzle 82 to initiate and maintain combustion with an efficiency heretofore unknown.

It has been found that because of the injection of a main stream of primary air through the nozzle 60 axially of the burner, combustion efficiency and the necessary thorough mixing can be effected with substantially reduced air pressures. For example in a burner according to the present invention constructed for use with a 100 horsepower boiler the pressure in plenum 10 may be maintained at from one to three inches of water below the pressure of seven and a half inches of water maintained in the best known previous designs of comparable power. Since the noise level of the burner and power requirements of the air blower are both directly proportional to the plenum pressure a substantial reduction in the size of the blower and in the noise level of the burner is effected by the present invention. These surprising advantages, which are achieved without sacrifice of combustion efficiency, substantially reduce the initial and operating costs of the apparatus and permit its installation in situations where the noise level of prior similar apparatus was objectionable.

As stated above, the apparatus shown in FIGURE 1 can be readily converted to burn liquid fuel. To accomplish this conversion it is necessary only to close the usual valves in the gas supply conduit 62 and to open the valves in the conduits leading to the ports 100 and 102 in fixture 94. While no fuel air mixing occurs upstream of the nozzle assembly 106 when liquid fuel is used nevertheless the turbulence created in the primary air stream within the premixing tube 70 greatly facilitates mixture and combustion of the fuel mist injected into the combustion chamber from the nozzle 106. All of the other advantages to be derived from a decrease in the plenum air pressure are realized when the apparatus is operated as a liquid fuel burner.

In instances where a supply of gaseous fuel is not available or it is otherwise desirable to operate only on liquid fuel a modified plenum 160 may be substituted for the gas and air plenum 54. The modified plenum 160 contains the same valve assembly 59 and a nozzle 162, the inner configuration of which is identical to the nozzle 60. The essential difference between the two plenums reside in the elimination in the plenum 160 of the gaseous fuel inlet 62 incorporated in plenum 54.

In most cases the proportioning of the primary and secondary air orifices and of the openings 75 and 76 in the primary air tube 70 together with the division of the primary and secondary air streams obtained by proper setting of the valve assembly 59 provides excellent results for most applications. However in order to increase the versatility and flexibility of the burner and to assure optimum combustion efficiency under a wide range of operating conditions including varying fuel and air pressures and variations in combustion characteristics of the fuel, the invention also comprises additional controls for varying the quantity and velocity of the air issuing through the secondary orifice and the first stage primary air issuing through the nozzle 60, the second stage primary air issuing through the ports **75** and the third stage primary issuing through the ports **76**.

FIGURE 5 illustrates a burner incorporating additional air flow control assemblies which is otherwise substantially the same as that shown in FIGURES 1 to 4. In this form of the invention the orifice ring **78** of FIGURE 1 is replaced by a ring **170**, the inner surface of which forms a primary air orifice **172** and the cylindrical outer surface **174** of which forms the inner boundary of the secondary air orifice **18**. The ring **170** is attached to the outer end of the tube **70** in the same manner as the ring **78**.

An air guide cone **176** is attached to the air guide structure **110** around the outer periphery of the latter and at its opposite end the cone **176** is slidably mounted on the outer surface **174** of the orifice ring **170**. The air guide structure **110** and the cone **176** are mounted for sliding movement axially of the primary air tube **70** and may be moved along the tube **70** by a pair of operating rods **178** (one shown) secured to the air guide structure and the mounting ring **122** and projecting outwardly through the wall **68** of the gas plenum **54** to any convenient fully accessible point. The operating rods **178** are secured to ring **122** at diametrically opposed points above and below the axis of the air tube **70**. Movement of the assembly to the right as viewed in FIGURE 5 is limited by a stop ring **180** formed on the outer surface of the orifice ring **170**. Movement in the opposite direction is limited by a stop screw **181**.

In operation, the effective size of the secondary air orifice **18** may be varied by moving the cone **176** axially of the tube **70**, movement of the cone to the right decreasing the orifice area and movement to the left increasing the effective orifice area. Such adjusting movements control both the quantity and velocity of the air flowing through the orifice **18**.

Control of the effective area of the ports **75** and **76** is obtained by a sleeve **182** telescoped over the primary air tube **70**. As shown in FIGURE 5 the length of sleeve **182** is such that in its neutral or center position shown both sets of ports **75** and **76** are fully uncovered. A pair of operating rods **184** (one shown) are rigidly secured at diametrically opposed points to a bracket **186** mounted on the sleeve **182** and extend through the air guide structure mounting ring **122** and lead to the exterior of the burner through an opening **188** in the plate **68** of the gas plenum **54**. The operating rods **184** may lead to any convenient accessible point or may if desired be attached to suitable linkage to permit remotely controlled operation. By appropriate movement of the sleeve **182** to the left or right as viewed in FIGURE 5 the effective area of the ports **75** and **76** can be varied from full open to full closed positions thus varying the velocity and quantity of the air flowing through these ports.

In practice the proper setting of the cone **176**, the sleeve **182** and the valve assembly **59** will be determined by inspection of the flame and suitable adjustment of one or more of these valves will be made to obtain the desired short bushy flame which characterizes the burner when it is operating under conditions of optimum efficiency. Generally when the burner is operating on oil the desired adjustment may be obtained by manipulation of the position of cone **176** and the valve assembly **59**, and the sleeve **82** will be left in its centered position as shown in FIGURE 5. However, when the burner is operating on gaseous fuel significant changes in the nature and efficiency of combustion may be effected by proper setting of the sleeve **182** so that the degree of turbulence within the tube **70** and the location of the point of maximum turbulence may be varied as conditions demand.

When the burner is to be operated solely or primarily on gaseous fuel, sufficient air flow control can often be obtained by varying the velocity and quantity of the first stage primary air issuing through nozzle **60** and by varying the velocity and quantity of the third stage primary air issuing through ports **76**. A burner having controls for this purpose is shown in FIGURES 6 and 7.

The basic components of the burner assembly there shown are preferably identical with the corresponding elements of the units of FIGURE 1. The effective area of the third stage primary ports **76** is controlled by a sleeve **190** telescoped over the tube **70** in encircling relation with the ports **76**. If desired screws **192** or similar stop members may be provided to limit the axial movement of the sleeve **190** while permitting its free rotation. The sleeve **190** is provided with a plurality of ports **194** equal in number, size and spacing with the ports **76**. Accordingly when the ports **194** are in register with the ports **76** full air flow is permitted through the latter. By rotation of the sleeve **190** the effective area of ports **76** may be varied fully and reduced to zero as desired. A control rod **196** is journalled in aligned openings **198** and **200** in the air guide structure mounting ring **122** and the wall **68** of the gas plenum, respectively, and extends to any desired point at the exterior of the gas plenum. At its opposite end the control rod **196** is provided with a crank arm **202** which is off-set from the axis of rotation of the rod **196** and extends through a slot **204** formed in a bracket **206** rigidly secured by any suitable means to the outer surface of the ring **190**. Accordingly, rotation of the control rod approximately 90° will move the ring **190** between positions in which the ports **76** are fully opened and fully closed. This action, when combined with the proper setting of the valve assembly **59**, will produce adequate control for many purposes.

An alternate construction for varying the effective area of the secondary air orifice **18** is shown in FIGURE 8. Apart from the air flow control device the burner is of essentially the same construction as that shown in FIGURE 1. The modified orifice ring **208** has an outer cylindrical peripheral portion **210** and a portion **212** of reduced diameter which forms a step on which the outer end of the modified air guide cone **214** is received. The modified cone is provided with a relatively sharply sloping conical surface **216** which merges into a cylindrical section **218**. Mounted for sliding movement on the cylindrical section **218** is an air control ring **220** having a cylindrical inner surface telescoped over the section **218** of the cone **214** and a frusto-conical outer surface **222** which, as shown in FIGURE 8, forms the inner periphery of the secondary air orifice **18**. Diametrically opposed control rods **224** are threaded at one end into the control ring **220** and extend away from the ring through aligned openings **226**, **228** and **230** formed in the air guide cone, the mounting ring **122**, the gas plenum wall **68**, respectively, and lead to any desired point at the exterior of the burner apparatus.

The air flow control structure of FIGURE 8, when properly used in conjunction with the butterfly valve **59**, provides excellent combustion efficiency under a wide range of operating conditions particularly in connection with the combustion of liquid fuels.

This application is a continuation-in-part of my copending application Serial No. 490,040, filed February 23, 1955 now abandoned for Burners.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

1. Fuel burner apparatus comprising an air plenum chamber having front and rear walls, means for introducing air into said plenum chamber tangentially thereof adjacent said rear wall, means forming aligned openings

in said front and rear walls, an air guide ring positioned in the opening in said front wall to define primary and secondary air orifices, a cone having a smaller end mounted on said ring radially between said orifices, air guide structure including a plurality of substantially radially directed vanes secured to the larger end of said cone, said air guide structure and said cone dividing said plenum chamber into primary and secondary air chambers communicating, respectively, with said primary and secondary air orifices and said vanes being effective to direct a portion of the air in said secondary air chamber radially into said primary air chamber, a tube extending through said primary air chamber between said ring and the opening in the rear wall of said plenum chamber, said tube having apertures to permit the entrance of said radially directed air into said tube, an air conduit connected at one end through an aperture in said rear chamber wall to said secondary air chamber, a nozzle connected to the other end of said conduit, said nozzle having an outlet opening adjacent said opening in the rear wall of said air plenum chamber and concentric therewith whereby said conduit conducts additional air from said secondary air chamber and introduces it through said nozzle into one end of said tube axially of said tube to mix with said radial streams, and means for introducing gaseous fuel into said tube in an annular stream in surrounding relation with said outlet opening of said nozzle to mix with the air issuing from said nozzle and with said radial streams.

2. Fuel burner apparatus according to claim 1 wherein said last-mentioned means comprises a gas plenum chamber carried by said air plenum chamber.

3. Fuel burner apparatus according to claim 1 together with means for controlling the quantity of air delivered to said air plenum chamber and separate means for controlling the flow of air through said conduit.

4. Fuel burner apparatus according to claim 1 together with means for adjusting the axial position of said cone to vary the size of said secondary orifice.

5. Fuel burner apparatus according to claim 1 together with means for controlling the flow of air through said apertures in said tube.

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