Feb. 7, 1967 R. E. ZINN 3,302,596

COMBUSTION DEVICE

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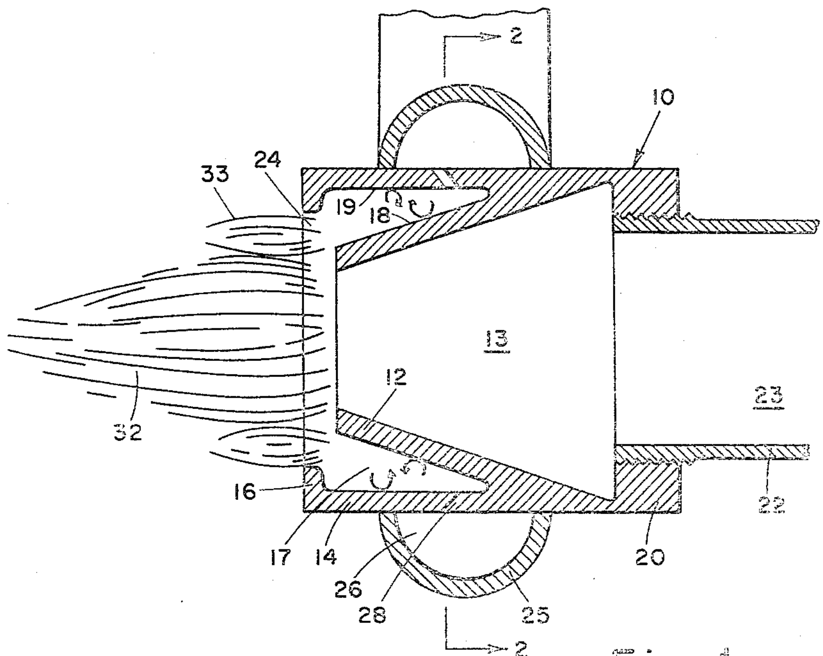

Fig. 1

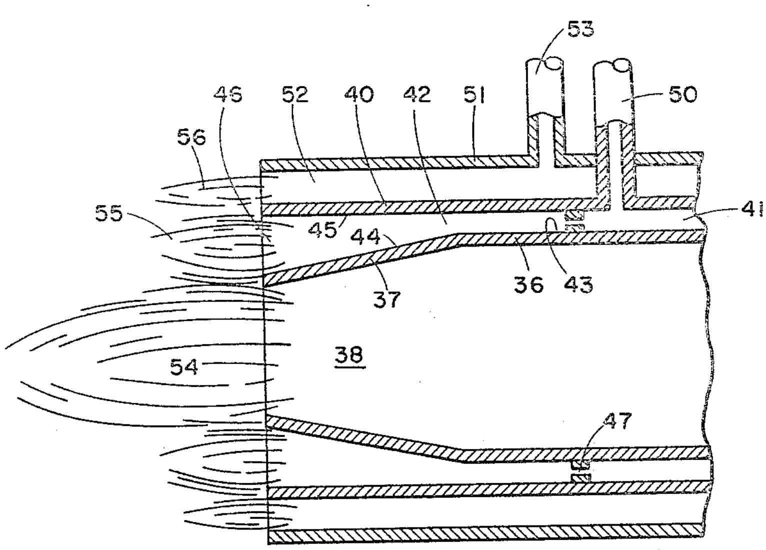

Fig. 3

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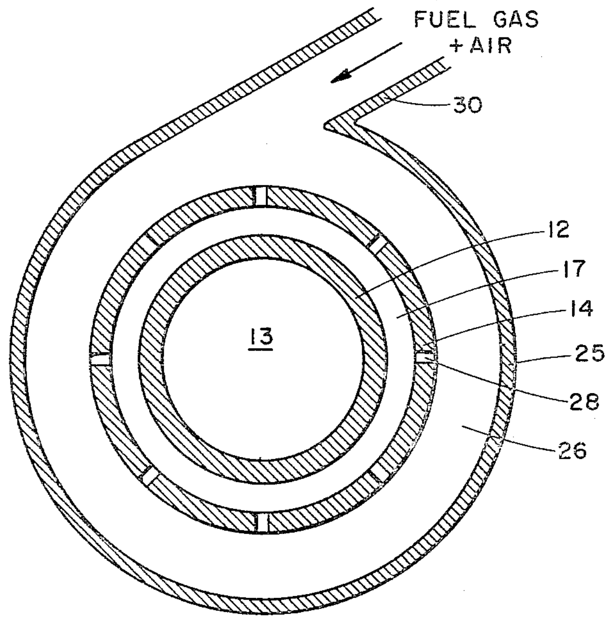

Fig. 2

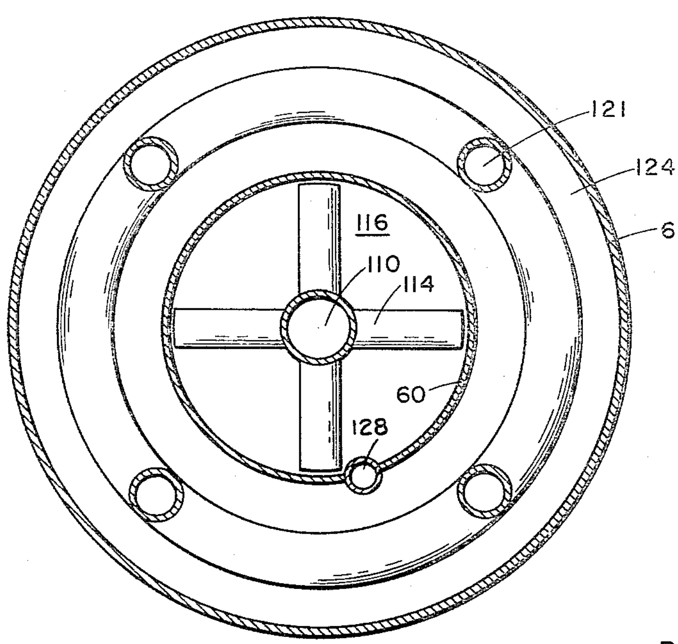

Fig. 5

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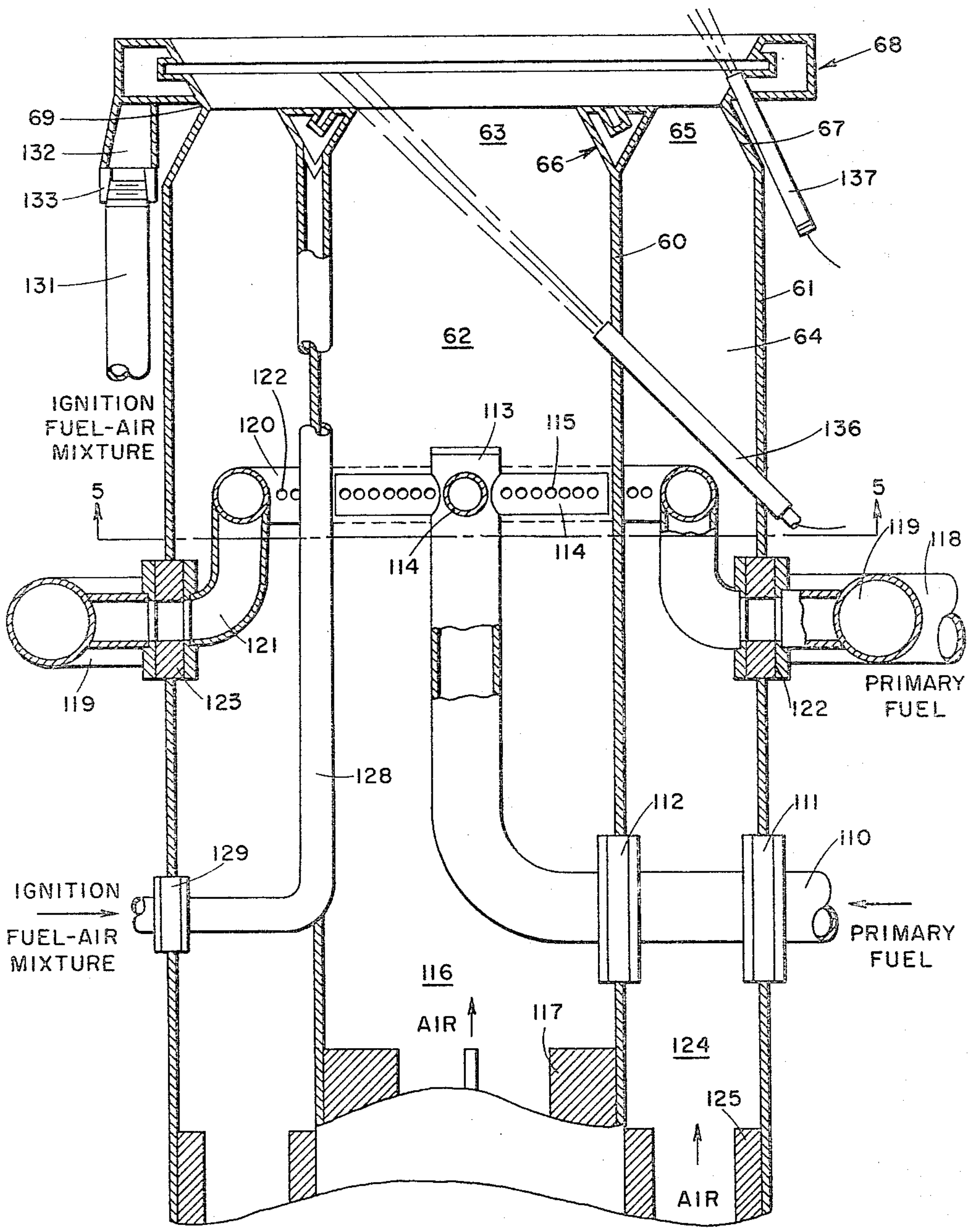

Fig. 4

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COMBUSTION DEVICE

Filed Jan. 21, 1966 4 Sheets-Sheet 4

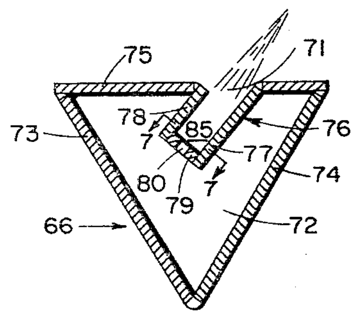

Fig. 6

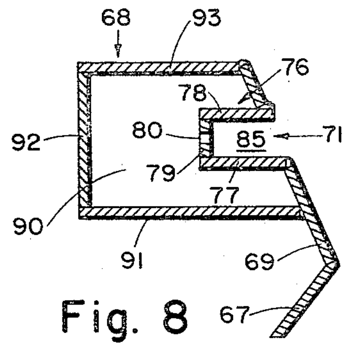

Fig. 8

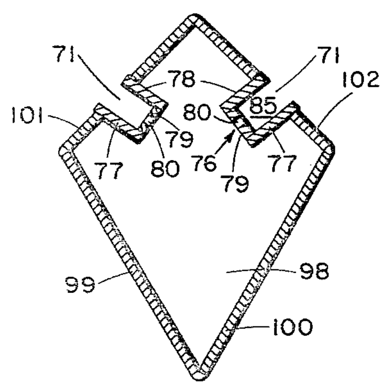

Fig. 10

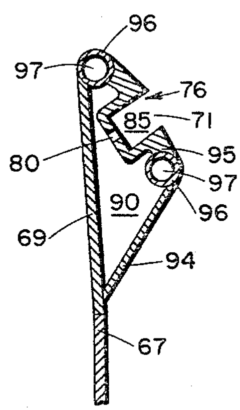

Fig. 9

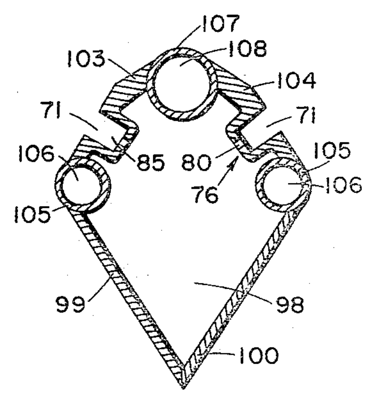

Fig. 11

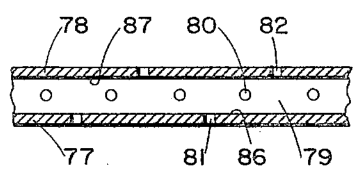

Fig. 7

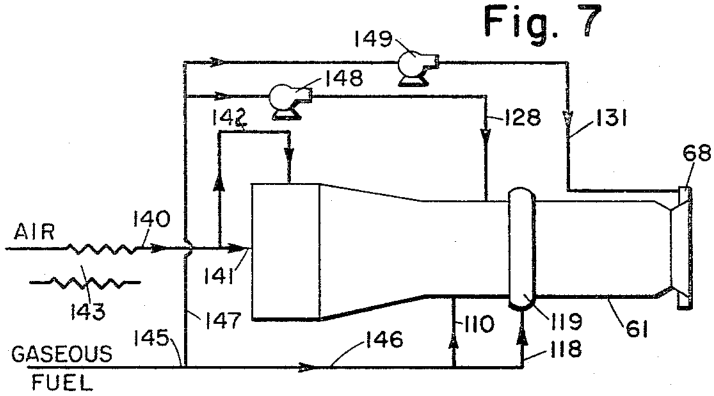

Fig. 12

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United States Patent Office

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COMBUSTION DEVICE

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Filed Jan. 21, 1966, Ser. No. 522,182
8 Claims. (Cl. 110—22)

This application is a continuation-in-part of my application Serial No. 310,311 filed September 20, 1963.

This invention relates to a combustion device and more particularly to a combustion device designed to burn fuels and fuel mixtures which are not in themselves self-propagating, or which are desired to be burned at velocities exceeding their normal flame propagation rate.

In many applications, e.g., in kilns and in furnaces for chemical processing and the like, it is necessary to develop extremely high temperatures and heat input. This can be done by burning fuels supplied at very high velocities, but this solution also presents the problem of maintaining continuous, stable flame propagation in these high-velocity fuel streams and retaining the flames at or very near the exit nozzle of the burner.

The burning of powdered coal may be taken as an example of a fuel which is normally not stable and self-propagating. It has long been known that powdered coal is a desirable fuel, and that it can be used to replace all or a portion of the more expensive fuel gas or fuel oil in combustion devices such as are employed in kilns, furnaces, etc. Powered coal burns with a higher flame emissivity and hence with a higher rate of heat transfer than gas or oil, a characteristic which makes it very desirable in some applications. However, because of the physical nature of powdered coal and due to the mechanism by which it burns, difficulties have normally been previously encountered in its use as a fuel even when used with gaseous fuels. Such difficulties have been primarily attributed to being unable to achieve rapid and stable ignition of the coal. In the combustion of pulverized coal, four phases may be said to occur, namely, the heating and drying of the coal, the gasification of the volatile materials and coking of the carbon, the combustion of the gases, and finally the combustion of the resulting coke dust. Although ignition and combustion of the volatile materials may be achieved rapidly, the ignition and combustion of the coked particles are comparatively slow. Because of these facts, it has been difficult, if not impossible, to establish a stable powdered coal flame which can be retained comparatively close to the burner outlet. In the prior art devices, the coal flame has typically been a number of diameters downstream from the mouth of the combustion nozzle, and has exhibited a tendency to travel and be unstable.

It would therefore be highly desirable to have a device in which powdered coal could be efficiently and controllably burned with fuel gas, thus materially reducing the fuel costs for any desired quantity of heat energy produced. Moreover, inasmuch as a gas flame from natural gas has a low emissivity, it would also be desirable to have a combustion device which was capable of burning a large enough percentage of coal with the natural gas so that the coal flame could increase the heat transfer capability of the flame produced.

In other instances it would be highly desirable to be able to burn gaseous or liquid fuels at velocities far exceeding the flame propagation rate associated with these mixture. It will be appreciated that such maximum propagation rates normally place an upper limit on the amount of heat output for any given size burner from any given fuel mixture.

Apparatus for achieving the stabilization of fuel mixtures which are not in themselves self-propagating or

which are delivered at velocities which would normally exceed the flame propagation rate of the mixture are known. One of the most common types of such apparatus embodies the use of a so-called flame retention nozzle. In this type of nozzle a portion of the main fuel stream is bled out through the walls of the main nozzle into a combustion zone surrounding the nozzle to provide a low velocity combustion area around the main flame. Various modifications of this basic flame retention nozzle are in use. The prior art also teaches the use of concentric nozzles which are so designed as to achieve mixing of externally-supplied air with the central main flame to improve ignition and stability. However, none of these known devices achieves the stable burning of a fuel mixture which may be formed of a wide range of powdered coal. Normally, such mixtures are not self-propagating. Moreover, the prior art devices are limited in their ability to stabilize fuel mixtures which are delivered to the nozzle at velocities greatly exceeding the normal flame propagation rate associated with the mixture.

It is therefore a primary object of this invention to provide a combustion device for burning a combustible composition to achieve a stable, non-extinguishable flame of a fuel mixture which would normally not be self-propagating, or of a fuel-mixture which may be delivered at velocities exceeding the normal flame propagation rate, or a fuel mixture combining both of these features. It is another object of this invention to provide a combustion device which is capable of delivering a heat output greater than present combustion devices of comparable size. It is a further object of this invention to provide a combustion device of the character described which is particularly useful in kilns and furnaces.

It is another primary object of this invention to provide a combustion device for burning a combination of powdered coal and fuel gas, the ratio of coal to gas being widely variable. It is another object of this invention to provide a combustion device of the character described which is capable of developing a stable flame using powdered coal. It is yet another object to provide such a device which is flexible in its performance in that the quality of emissivity and heat transfer properties may be readily controlled by adjusting the ratios of powdered coal to fuel gas which is burned. It is still another object of this invention to provide a combustion device which is capable of burning various amounts of powdered coal for uses where a natural gas flame is not desirable. Other objects of the invention will in part be obvious and will in part be apparent hereinafter.

The invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts which will be exemplified in the constructions hereinafter set forth, and the scope of the invention will be indicated in the claims.

The combustion device of this invention achieves a non-extinguishable, stable flame using a wide variety of fuels and fuel-air mixtures by providing around a primary flame an ignition ring means of a particular character. The ignition ring means uses a fuel mixture which is separate and distinct from the primary mixture. It is normally preferable, but not always necessary, that this ignition fuel mixture be formed of substantially stoichiometric proportions. The ignition ring means of the combustion device may be characterized as being comprised of chamber means communicating with an annular opening surrounding the main flame. The chamber means and the annular opening are so designed that they provide a combustion zone of low velocity directly adjacent the periphery of the primary flame. Two or more nozzles for primary flames may be used, in which case there is provided an ignition ring means for each primary flame. The same ignition ring means may be associated with two primary flames. All of these modifications are illustrated and described.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawing in which:

FIG. 1 is a longitudinal cross-sectional representation of the forward end of a combustion device illustrating an embodiment of this invention in which a single primary fuel nozzle is used;

FIG. 2 is a cross section of the combustion device of FIG. 1 taken along line 2—2;

FIG. 3 is a longitudinal cross-sectional representation of another embodiment of the combustion device in which two primary fuel nozzles are provided with a single ignition ring means;

FIG. 4 is a longitudinal cross-sectional representation of another embodiment of the combustion device in which separate ignition ring means are provided for two primary fuel nozzles;

FIG. 5 is a cross-section of the combustion device of FIG. 4 taken along line 5—5 of that figure;

FIG. 6 is a cross-sectional detailed drawing of one of the ignition ring means of the device of FIG. 4;

FIG. 7 is a cross-section of the trough-like portion of the ignition ring means of FIG. 6 taken along line 7—7 of that figure;

FIG. 8 is a cross-sectional detail of the other ignition ring means of the device of FIG. 4;

FIG. 9 is a modification of the ignition ring means of FIG. 8;

FIG. 10 is another embodiment of an ignition ring means designed to furnish an ignition ring for adjacent concentric primary fuel streams;

FIG. 11 is a modification of the ignition ring means of FIG. 10; and

FIG. 12 is a diagrammatic representation of the fuel and air lines associated with the combustion device of FIG. 4.

In order to provide a stable, continuous ignition ring around a primary flame to impart stability to the primary flame and prevent it from floating and blowing off the burner nozzle, there is provided a combustion zone of low velocity adjacent to the primary flame at the point where it exits from the nozzle. A separate fuel-air mixture, which is preferably of substantially stoichiometric proportions, is delivered to this combustion zone. As will be seen in the following description and discussion such a low-velocity combustion zone may be supplied for each of the primary fuel flames, one zone may serve two primary fuel flames, or two such zones may be associated with a single primary flame.

FIG. 1 represents an embodiment of the combustion device of this invention wherein a single ignition ring means is associated with a single primary flame. The combustion device of FIG. 1 is particularly well suited for the burning of powdered coal mixed with gaseous fuel in a wide range of proportions. In FIG. 1, the combustion device of this invention is generally represented by the numeral **10**. It will be seen to be comprised of an inner conical chamber wall **12** (which may be cylindrical) defining within it a high-velocity nozzle **13**. Surrounding the nozzle **13** is an outer chamber wall **14** which, as shown in FIG. 1, can be made integral with the conical chamber wall **12**. This outer chamber wall **14** terminates in a lip **16** which may extend beyond the annular wall and furnish a partial cover for the low-velocity ignition ring gas chamber **17** which is primarily defined by the outer surface wall **18** of conical wall **12** and the inner surface **19** of outer chamber wall **14**.

The outer chamber wall **14** terminates in a section **20** designed to be attached to a fuel and air conduit **22**. This conduit defines a fuel passage **23** through which fuel and air are introduced into the nozzle **13**. Surrounding the outer chamber wall is an annular gas manifold **26** which is connected to the low-velocity chamber **17** through a plurality of ports **28**. As will be seen in FIG. 2, conduit **30** serves as a means for introducing a separate ignition fuel mixture of gas and air into annular gas manifold **26** which in turn provides for an equal distribution of this ignition fuel mixture throughout the entire annular manifold **26**. The combustion device of this invention need not, of course, be circular in cross section.

It will be seen that the low-velocity ignition ring chamber **17** provides as its forward outlet an opening **24** which is directly adjacent and circumferentially positioned about the periphery of the main nozzle **13**. At and directly forward of this opening there exists a low-velocity combustion zone. The separate gaseous fuel-air mixture which is to be burned to form the stable continuous ignition ring is introduced into the low-velocity ignition ring gas chamber **17** through the ports **28**. In the construction shown in FIG. 1 the low-velocity combustion zone is created through the configuration of chamber **17** and its porting which forms the fluid communication with manifold **26**. It will be seen from the arrows drawn in the chamber **17** that as the gaseous fuel-air ignition mixture enters chamber **17** through the ports **28** the stream first strikes surface **18** and then surface **19**; and is set in a swirling motion. This swirling motion in turn gives rise to low-velocity eddy currents within chamber **17**. Lip **16** contributes to the intensification of these eddy currents but is not essential. Thus, the low-velocity ignition gas chamber **17** provides to a low-velocity combustion zone located at its outlet **24** an annular ring of low-velocity gaseous fuel and air which upon ignition continuously furnishes an annular ignition ring **33** around the main flame **32**.

In the case where powdered coal is used as the primary fuel and is mixed with fuel gas and air, it ignites almost instantaneously and hence it can burn as a stable coal flame at or very close to the mouth of nozzle **13**. By adjusting the ratios of the coal, fuel gas and air, it is possible to vary the performance characteristics of the combustion device, such as shown in FIG. 1, over a wide range. In practice, it has been found desirable to use a coal-gas ratio such that a substantial part of the B.t.u. output of the device is furnished from powdered coal fuel. It has been shown that the design and operating conditions can be varied to control the amount of powdered coal which can be used, or conversely the amount of fuel gas which must be mixed with the coal in the high-velocity stream to get stable combustion. The minimum amount of fuel gas required to achieve this may range from about 20% up to as much as 90 to 95% of the total B.t.u. output of the burner, depending upon operational conditions. The performance of a gas fuel burner can be improved, as previously pointed out, through the use of small amounts of coal such as to furnish between 1% and 25% of the total B.t.u. output. This quantity of coal will change the transparent or nearly colorless gas flame to a flame of high intensity with greatly increased emissivity and therefore provide increased heat transfer.

The combustion device of this invention is not as sensitive to the chemical and physical characteristics of the powdered coal as are the powdered coal combustion devices of the prior art and a wide range of coal can be used. The powdered coal should be ground sufficiently fine to be capable of being suspended in the air stream which brings it into the primary combustion chamber. This means that generally it will be ground finer than 100-mesh with a portion of it being finer than 200-mesh. A typical powdered coal suitable for burning in the combustion device of this invention would be one of which about 60% to 90% passes through a 200-mesh sieve.

FIG. 3 represents another embodiment of the combustion device of this invention. In this case, the central primary flame is supplemented by an outer annular flame, both flames being served by a single ignition ring means positioned between them. In the combustion device of

FIG. 3 the central primary combustion chamber wall **36** terminates in a conical section **37** which defines the nozzle **38**. Surrounding the inner primary combustion chamber wall **36** is a central wall **40** which, with wall **36**, defines an annular passage **41** and with conical wall **37** defines a low-velocity ignition ring gas chamber **42** comparable with low-velocity ignition ring gas chamber **17** of FIG. 1. The low-velocity ignition ring gas chamber **42** terminates at its forward end in an annular opening **46** which, like opening **24** of FIG. 1, gives rise to a low-velocity combustion zone.

As in the case of the modification of FIG. 1, the device of FIG. 3 provides the required low-velocity combustion zone to provide the ignition ring through its design and construction. The gaseous fuel and air mixture which is supplied for ignition from passage **41** must enter the low-velocity ignition gas chamber **42** through a series of constrictions **47** in annular passage **41**. The ignition fuel mixture in its passage into chamber **42** has its velocity materially reduced in by passing through these constrictions, and to a lesser extent by frictional contact with surfaces **43** and **45** of walls **36** and **40**. As the fuel mixture enters chamber **42**, eddy currents are established in this chamber and there is therefore provided the required low-velocity ignition fuel mixture to be burned at the annular opening **46**.

A conduit **50** leading into passage **41** is provided for introducing the necessary gas-air mixture into the chamber **42**. It should be noted that constrictions **47** also serve to prevent flashback as well as to contribute to the control of the velocity of the ignition fuel mixture. Surrounding these two inner chambers is a wall **51** which defines with central wall **40** an annular passage **52** into which additional primary fuel-air mixtures may be introduced such as through conduit **53**. Thus, in the combustion chamber of FIG. 3 there is provided a central primary flame **54**, an annular gas ignition ring **55**, and an outer primary flame **56** which also assumes the configuration of an annular ring around the ignition ring. The arrangement of FIG. 3 may allow for somewhat more flexibility in the type of flame obtained than the combustion device of FIG. 1, and it can be formed in multiple alternate annuli in large burner devices so long as there is an ignition ring means associated with each primary flame nozzle.

The combustion device shown in FIGS. 4 and 5 illustrates the use of separate ignition ring means associated with two primary fuel nozzles, the nozzles being concentric. The device of FIG. 4 is particularly adapted for burning gaseous fuel such as natural gas at a rate far exceeding that of the normal flame propagation rate.

The apparatus of FIG. 4 is comprised of an inner wall **60** and an outer concentric wall **61**. Within inner wall **60** there is defined a plenum chamber **62** which communicates with a central primary nozzle **63**. In like manner, the annular space defined by the walls **60** and **61** forms an annular plenum chamber **64** which communicates with an annular concentric nozzle **65**. The central conical nozzle **63** is defined by an ignition ring means **66**; and the conically-shaped annular nozzle **65** is defined by ignition ring means **66** and an inclined wall **67** which is integral with outer wall **61**. Ingition ring means **68**, which is associated with the outer annular nozzle **65**, is mounted on a flared extension **69** of the inclined wall **67**.

The ignition ring means **66** and **68** are shown in detail in FIGS. 6–8 and reference should be had to these figures in connection with the following description. Ignition ring means **66** will be seen to consist of an essentially triangularly-shaped manifold **72** which is defined by side walls **73** and **74** and an annular top ring **75**. Depending from top ring **75** is a trough **76** which defines the required low-velocity ignition ring gas chamber **85**. At opening **71** of this chamber is the low-velocity combustion zone in which the ignition gas is burned to form the stable ignition ring. This low-velocity ignition ring gas chamber **85** is defined by walls **77** and **78** and a bottom plate **79**. Gas ports **80**, **81**, and **82** are drilled in bottom **79** and in walls **77** and **78**, respectively. It will be seen from FIG. 7 that these openings are so located that ports **81** and **82** in the side walls alternate in position with each other and with ports **80** in bottom **79**. As the relatively high-velocity ignition ring fuel mixture enters the low-velocity chamber **85**, it impinges upon inner wall surfaces **86** and **87** and mixes with gas entering through ports **80** thus setting up a strong swirling pattern and establishing within the low-velocity chamber **85** the required eddy currents. Thus, the ignition ring fuel as it reaches the low-velocity combustion zone beginning at opening **71** has reached a condition which insures stable, continuous burning to provide ignition to the main fuel stream leaving nozzles **63** (see FIG. 4). Alternatively, ports may be located in only one or two sides making up chamber **85**. The essential requirement is that the position and orientation of the ports, in combination with the configuration of the chamber, are adapted to produce low-velocity eddy currents in the chamber to provide the necessary low-velocity fuel.

The ignition ring means **68** of FIG. 8 is constructed along the same lines as that of FIG. 6. In the case of FIG. 8, the ignition ring manifold **90** is defined by walls **91**, **92**, and **93** as well as by the flared extension **69**. A trough **76** like that of FIG. 6 extends into the plenum chain **90** and is constructed in the same manner as that of FIG. 6. In the combustion device of FIG. 4 this ignition ring means **68** serves to ignite the primary fuel in the outer nozzle.

FIG. 9 is a modification of the ignition ring means of FIG. 8 and provides for cooling of the ignition ring means, such as by the circulation of water through appropriate channels. In FIG. 9 like elements are referred to by like numerals in FIG. 8. It will be seen in this modification that the ignition ring manifold **90** is defined by a side wall **94** and a top wall **95** which is cast such that the ignition ring chamber **85** is an integral part of it. This trough-like chamber **85** has ports **80**, **81**, and **82** arranged in it as shown in FIG. 7. Side wall **94** is attached to the top wall **95** and top wall **95** in turn is attached to the inclined wall **69** through coils **96** which have channels **97** for the circulation of a cooling fluid such as water.

It is, however, within the scope of this invention to provide a single ignition ring means which is capable of furnishing an ignition ring for both the central and the outer main fuel streams. Such an ignition ring means is shown in FIG. 10. It will be seen that as it is used it can replace both ignition ring means **66** and **68** if it occupies essentially the same position occupied by ignition ring means **66** of FIG. 4. In the ignition ring means of FIG. 10 there is provided a diamond-shaped manifold **98** defined by walls **99**, **100**, **101**, and **102**. Depending from the upper walls **101** and **102** and extending into manifold **98** are two trough-like structures **76** which define two low-velocity ignition ring chambers; one of which opens into the central nozzle **63** and the other into the outer annular nozzle **65** (FIG. 4) to give rise to two low-velocity combustion zones. The angles at which these openings strike the fuel stream may vary over a wide range. Thus, it will be seen that the ignition ring means **68** of FIG. 8 provides an ignition ring which is at a 90° angle with the direction of the primary fuel stream while those of FIGS. 6 and 9–11 provide ignition rings directed at a somewhat smaller angle.

FIG. 11 shows a modification of the ignition ring means of FIG. 10, and like the modification of FIG. 9, it provides for fluid cooling. In FIG. 11 like components are identified by like numerals used in FIG. 10. In place of the two walls **101** and **102** of FIG. 10 there are provided walls **103** and **104** which have the trough-like structure **85** forming the ignition ring chamber integral with the walls. This chamber **85** also has the small diameter ports **80**, **81**, and **82** as shown in FIG. 7. The walls defining the manifold **98** are joined through suitable coils **105** and **107** which have channels **106** and **108** for circulating the coolant.

The primary fuel (e.g., natural gas) is fed into plenum chamber **62** through a conduit **110** which passes through walls **61** and **60** and is held in place in these walls by flanges **111** and **112**. Conduit **110** terminates in a closed header **113** and has associated with it a number of radial feeder arms **114** which have a plurality of fuel ports **115**. Air is introduced by way of the central passage **116** at a suitable velocity to sweep the gaseous fuel up through plenum chamber **62** into nozzle **63**. If the air is introduced into passage **116** tangentially or in a manner to impart a swirling motion to it, then suitable straightening vanes **117** should be located in passage **116** upstream from the point of air introduction. It is, as previously noted, within the scope of this invention to use powdered coal or a mixture of powdered coal and gaseous fuel as the combustible material in the central flame. If powdered coal is used, then the radial fuel feeder arms **114** should be replaced with any suitable device for delivering the powdered coal to the entraining air stream; or as in the case of FIG. 1, the coal may be entrained in fuel gas and air prior to its delivery to the burner.

A primary fuel gas is introduced into the annular plenum chamber **64** through conduit **118** which is connected to an annular external feeder ring **119** which in turn is in fluid communication with an internal outer annular feeder ring **120** through a series of angle-arm conduits **121**. The feeder ring **120** has fuel gas ports **122** for delivering the fuel gas to the annular chamber **64**. The connecting angle-arm conduits pass through outer wall **61** and are affixed thereto by flange **123**. Air is delivered through annular passage **124** to entrain the gaseous fuel and carry the combustion mixture to annular nozzle **65**. If the air in passage **124** has a swirling motion, then it is desirable to place straightening vanes **125** upstream from the point of air introduction into the passage **124**. If powdered coal is to be used, then the feeder ring **120** with small ports must be replaced with means suitable for delivering small solid particles into the entraining air, or the coal-fuel-air mixture may be performed outside the burner.

The ignition fuel mixture is delivered to the ignition ring means **66** (i.e., to manifold **72** (FIG. 6)) by means of means of conduit **128** which passes through wall **61** by way of flange **129** and up through a section of wall **60**. Ignition fuel is delivered to ignition ring means **68** (i.e., to manifold **90** (FIG. 8)) through conduit **131** via feed extension **132** which is connected to conduit **131** by means of a suitable adaptor ring **133**.

Finally, there is provided suitable means for continuously monitoring the burner to provide automatic cut-off of the fuel mixtures should one or more of the flames go out. These monitoring means comprise a scanning device **136** positioned to monitor the flames at the central nozzle **63** and ignition ring means **66**, and a similar scanning device **137** positioned to monitor the annular flame at annular nozzle **65** and its ignition ring means **68**. These scanning devices are commercially available and are connected by suitable means to the valves controlling the flow of fuel gas and air into the burner. Any other monitoring systems may, of course, be used.

Ignition of the primary fuel-air mixtures and the ignition ring fuel-air mixtures can be accomplished by any suitable means, i.e., a torch, an electric spark or the like.

It is also within the scope of this invention to use the ignition ring means with a fuel oil burner. As an example, the apparatus of FIG. 4 may be modified by replacing the gaseous fuel feeding system (conduit **110** and radial feeder arms **114**) by an oil spray burner nozzle of any well known design extending up the center of plenum chamber **62** in a manner to deliver atomized oil to the central area of the outlet of nozzle **63**.

FIG. 12 is a simplified diagrammatic representation of a typical combustion device constructed in accordance with this invention showing the connecting lines with the fuel supply source. A main air line **140** communicates with branch lines **141** and **142**, the former supply air into passage **116** (see FIG. 4) and the latter supplying air into passage **124**. Since it is advantageous to preheat the air prior to its mixing with an entrainment of the fuel, there is also provided means for doing this. Such means may be an out-of-contact heat exchanger **143** but it is more common to achieve preheating by direct heat transfer from combustion gases or hot air in the kiln or other apparatus with which the burner is used.

A main gaseous fuel line **145** communicates with a branch line **146** which in turn communicates with conduit **118** to introduce gaseous fuel into passage **124**. This branch line **146** also communicates with the primary fuel conduit **110** which delivers gaseous fuel to passage **116**. (See FIG. 4.) The main gaseous fuel line **145** is also joined to a branch fuel line **147** which splits and communicates with conduits **128** and **131**. Between branch conduit **147** and conduits **128** and **131** (which deliver the substantially stoichiometric fuel-air mixture to the ignition ring means) are positioned blowers **148** and **149** adapted to mix air with the gaseous fuel to provide the required ignition ring fuel-air mixture to the ignition ring manifolds.

Extensive experience in the operation of the combustion device of this invention as represented in FIG. 1 has shown it is capable of providing a stable powdered-coal flame supplemented by fuel gas. The flame does not float and because of the presence of the coal, the flame exhibits a higher emissivity and greater capability of heat transfer than a flame resulting from the burning of fuel gas or fuel oil alone. In addition to reducing the cost of B.t.u. of energy furnished, the use of powdered coal provides a type of flame more desirable in some processes, such as for example in a limestone or cement kiln where low-emissivity gas-firing produces less product per unit of heat energy.

A combustion device constructed as shown in FIG. 4 has been successfully operated to burn natural gas as gaseous fuel with air at rates up to eighty million B.t.u. per hour and to burn natural gas and fuel oil at rates up to one hundred ten million B.t.u. per hour. The ignition ring fuel mixtures used were formed of natural gas with air in essentially stoichiometric ratios, delivered to the manifolds at a controlled rate. The combustion of the primary fuel-air mixture was extremely stable, no floating or blowout being experienced.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

I claim:

1. A combustion device for burning a combustible fuel-air mixture which is not self-propagating or which is delivered at a velocity exceeding its flame propagation rate, comprising in combination

(a) nozzle means, through which said combustible fuel-air mixture is delivered, comprising a central nozzle and at least one concentric annular nozzle;

(b) ignition ring means associated with each of said nozzles, said ignition ring means comprising in combination

(1) an annular ignition ring chamber having an

annular opening directly adjacent and circumferentially about the periphery of said downstream end of said nozzle; and

(2) manifold means associated and in fluid communication with said ignition ring chamber through a multiplicity of small-diameter ports adapted to provide a separate ignition fuel-air mixture to said chamber; the position and orientation of said ports and the configuration of said ignition ring chamber being in combination adapted to produce low-velocity eddy currents in said ignition fuel-air mixture within said ignition ring chamber, whereby there is provided at said annular opening a low-velocity combustion zone so that the combustion of said ignition fuel-air mixture in said low-velocity combustion zone provides a non-extinguishable, stable ignition ring around said nozzle to stabilize the combustion of said combustible fuel-air mixture.

2. In a combustion device for burning a combustible fuel-air mixture which is not self-propagating or which is delivered at a velocity exceeding its flame propagation rate, ignition ring means associated with the downstream end of nozzle means through which said combustible fuel-air mixture is delivered, said ignition ring means comprising in combination

(a) an annular ignition ring chamber formed between the wall defining said nozzle means and a concentric surrounding cylindrical wall and having an annular opening directly adjacent and circumferentially about the periphery of said downstream end of said nozzle means; and

(b) manifold means associated and in fluid communication with said ignition ring chamber through a multiplicity of small-diameter ports adapted to provide a separate ignition fuel-air mixture to said chamber; said ports being located in said cylindrical wall thereby to cause said ignition fuel-air mixture to strike said wall defining said nozzle means; the position and orientation of said ports and the configuration of said ignition ring chamber being in combination adapted to produce low-velocity eddy currents in said ignition fuel-air mixture within said ignition ring chamber, whereby there is provided at said annular opening a low-velocity combustion zone so that the combustion of said ignition fuel-air mixture in said low-velocity combustion zone provides a non-extinguishable, stable ignition ring around said nozzle means to stabilize the combustion of said combustible fuel-air mixture.

3. In a combustion device for burning a combustible fuel-air mixture which is not self-propagating or which is delivered at a velocity exceeding its flame propagation rate, ignition ring means associated with the downstream end of nozzle means through which said combustible fuel-air mixture is delivered, said ignition ring means comprising in combination

(a) an annular ignition ring chamber having an annular opening directly adjacent and circumferentially about the periphery of said downstream end of said nozzle means;

(b) manifold means associated and in fluid communication with said ignition ring chamber through a multiplicity of small-diameter ports adapted to provide a separate ignition fuel-air mixture to said chamber; said ignition ring chamber being of a trough-like configuration surrounded by said manifold means and said small-diameter ports being located in at least one side of said trough-like configuration; the position and orientation of said ports and the configuration of said ignition ring chamber being in combination adapted to produce low-velocity eddy currents in said ignition fuel-air mixture within said ignition ring chamber, whereby there is provided at said annular opening a low-velocity combustion zone so that the combustion of said ignition fuel-air mixture in said low-velocity combustion zone provides a non-extinguishable, stable ignition ring around said nozzle means to stabilize the combustion of said combustible fuel-air mixture.

4. A combustion device in accordance with claim 3 further characterized by having channel means, adapted for circulating a fluid coolant for cooling said ignition ring means.

5. A combustion device adapted to burn a primary combustible fuel-air mixture which under normal conditions of combustion would not be capable of continuous stable combustion, comprising in combination

(a) primary fuel-air passage means;

(b) nozzle means terminating said passage means;

(c) means for delivering primary fuel and air to said passage means, comprising separate means for introducing said fuel into said passage means and means for delivering air under pressure upstream from the point of delivery of said primary fuel;

(d) ignition ring means associated with said nozzle means and comprising

(1) an annular ignition ring chamber having an annular opening directly adjacent and circumferentially about the periphery of said nozzle means; and

(2) manifold means associated and in fluid communication with said ignition ring chamber through a multiplicity of small-diameter ports adapted to provide a separate ignition fuel-air mixture to said chamber; the position and orientation of said ports and the configuration of said ignition ring chamber being in combination adapted to produce low-velocity eddy currents in said ignition fuel-air mixture within said ignition ring chamber, whereby there is provided at said annular opening a low-velocity combustion zone so that the combustion of said ignition fuel-air mixture in said low-velocity combustion zone provides a non-extinguishable, stable ignition ring around said nozzle means to stabilize the combustion of said combustible fuel-air mixture; and

(e) means for delivering said ignition ring fuel-air mixture to said manifold means.

6. A combustion device in accordance with claim 5 wherein said ignition ring chamber is of a trough-like configuration surrounded by said manifold means and said small-diameter ports are located in at least one side of said trough-like configuration.

7. A combustion device in accordance with claim 6 further characterized by having channel means, adapted for circulating a fluid coolant for cooling said ignition ring means.

8. A combustion device suitable for burning powdered coal in combination with fuel gas, comprising in combination

(a) a centrally-positioned, frusto-conical nozzle adapted to support a flame at its forward, smaller diameter end;

(b) means for delivering a mixture of powdered coal suspended in a gaseous medium containing air to said nozzle;

(c) an outer chamber wall surrounding the forward portion of said nozzle, extending beyond said nozzle and defining therewith a low-velocity combustion zone, said outer chamber wall terminating at its forward end in an inwardly directed peripheral lip, said low-velocity combustion zone being adapted to provide around said flame a separate, stable, continuous ignition ring directly adjacent to said flame;

(d) separate manifold means associated with said outer chamber wall;

(e) means for supplying to said manifold means a fuel gas-air mixture; and

(f) a plurality of ports in said outer chamber wall providing fluid communication between said manifold means and said low-velocity combustion zone.

References Cited by the Examiner

UNITED STATES PATENTS

1,105,031	7/1914	Hagemeyer.	
1,788,716	1/1931	Hepburn.	
1,938,851	12/1933	McKee	158—109
2,046,767	7/1936	Campbell	110—22
2,497,476	2/1950	Stadler.	

FOREIGN PATENTS

607,761	11/1960	Canada.
704,901	3/1954	Great Britain.

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