The present invention relates to a fuel combustion system, and more particularly, to such a system in which fuel is gasified in one region and combustion of the gases occurs in a different region.

In the prior art various fuel combustion systems have been devised for providing complete combustion of fuel, such as coal or oil. In the oil combustion systems of the prior art, air systems employ means for atomizing the oil to have complete combustion in the chamber into which the oil is dispersed. When residual oil, which is an impure and inexpensive fuel, has been used in such systems, numerous difficulties have been encountered. The high viscosity of residual oils causes the atomizing process to be much more difficult and energy consuming. Also, the ash content of residual oil travels with the fuel during the entire combustion process and interferes with the operation of the plant in forming deposits and causing corrosion and erosion in the combustion chamber and heat exchanger surfaces. In order to overcome these adverse effects in using residual oils, some prior art approaches have been to pre-atomize or pretreatment of the residual oils in an attempt to convert the fuel to a more oil-like fuel. The pretreatment of residual oils, the atomizing difficulties encountered, and the corrosion and fouling of the associated equipment are the most part offset completely the price advantage offered by use of inexpensive residual oil. Thus, it is desirable to provide a combustion system which would dispose of the adverse side effects of the prior art residual oil combustion systems in an economic manner.

The prior art oil combustion systems have not been readily convertible to a system in which other fuels, such as coal, could be employed. In prior art coal combustion systems, they have left desired a system which would eliminate moving parts and reduce heat losses.

In accordance with the present invention, a fuel combustion system which does not restrict the user to a specific type of coal or oil that may be employed. The present invention provides a new and improved combustion system wherein the corrosive and erosive trouble causing ingredients of the fuel are disposed of without interfering with the operation of the combustor. With the use of the present invention, pretreatment is not required to condition the fuel, such as residual oil. Also, when oil is used as the fuel, the present invention has eliminated prior art atomizing apparatus used to vaporize the oil prior to combustion. The present fuel combustion system has eliminated moving mechanical parts which require maintenance and replacement. Through the use of coaxially arranged volatilization and gasification chambers in the present invention, a system which is more compact in size and one which reduces heat losses is provided.

More particularly, according to the features of the present invention, a fuel combustion system is provided comprising a volatilization chamber, having upper and lower portions, in which transformation of fuel into coke is accomplished, thereby liberating combustible gases from the fuel. The present invention employs means communicating with the upper portion of the volatilization chamber for introducing fuel into the volatilization chamber. The system of the present invention is provided with a gasification chamber coaxial with the volatilization chamber and communicating with the lower portion of the volatilization chamber. Also employed is means for permitting passage of coke from the gasification chamber to the volatilization chamber. An air stream is supplied in the gasification chamber on which coke entering the gasification chamber is floated, so that the coke may be contacted by the air stream and thereby degasified releasing hot gases and forming slag. The hot gases formed in the gasification chamber are conducted through flow passage means to the volatilization chamber for heating the fuel introduced into the volatilization chamber. Vent means is provided from the volatilization chamber for removing the hot and combustible gases therefrom.

The hot and combustible gases in the vent means may be brought to a combustion burner where a second air stream is combined with the hot and combustible gases and there ignited in complete combustion.

In accordance with a further feature of the present invention, recirculating path and gas circulating means may be provided for recirculating hot and combustible gases from the vent means back into the volatilization chamber, thereby increasing the heat therein for transforming the fuel into coke and liberating combustible gases.

The fuel combustion system of the present invention performs equally well as a coal or oil combustion system to achieve the advantages mentioned above and set forth hereinafter. When the system of the present invention is used as an oil combustion system, the feeder means may comprise an oil reservoir communicating with the upper portion of the volatilization chamber and having a perforated plate with a plurality of openings as a bottom of the oil reservoir, whereby oil droplets of a desired size are introduced into the volatilization chamber. When the present invention is employed as a coal combustion system, the feeder means for introducing coal into the upper portion of the volatilization chamber may comprise a coal feeder with coal deflector for distributing the coal into the upper portion of the volatilization chamber.

For a better understanding of these and other features and advantages of the present invention, reference is made to the following description and accompanying drawings, in which:

FIG. 1 is a schematic representation, partially in section, illustrating an overall oil combustion system in accordance with a preferred form of the present invention;

FIG. 2 is a schematic fragmentary representation, partially in section, illustrating an alternative form of the feeder means for distributing the fuel, in this example coal, into the system; and

FIG. 3 is an inverted plan view of the coal deflector taken along line 3-3 of FIG. 2.

Referring now to the embodiment of the invention illustrated in FIG. 1, there is shown a fuel combustion system intended for use with a fuel such as residual oil, which is a very impure oil and, thus, an oil of varying composition. As can be seen in the schematic representation of FIG. 1, the overall system comprises a cylindrical housing of metal generally designated 10, which may be lined with a refractory material, in which volatilization, gasification and combustion of the fuel occurs. The residual oil 12 is introduced into the system through a feeder 14 which empties the residual oil 12 into reservoir 16 located in an upper portion of the housing. From the reservoir, the oil passes downwardly into a generally cylindrical volatilization chamber 20 by any appropriate feeder means which will introduce the oil in droplet form into the volatilization chamber. In this particular instance the feeder means comprises an apertured plate 22 located between oil reservoir 16 and volatilization chamber 20, the plate being provided with a plurality of similar openings (there being so that suitable size
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3 droplets will fall into the upper portion of the volatilization chamber from the openings.

In the present case the viscosity of the oil is assumed of a quality such that under moderate pressure, illustrated in FIG. 1 as atmospheric pressure, suitable size oil droplets will be formed. In other instances, for example, a rotating disc could be employed to sling the oil in suitable size droplets into the upper portion of the volatilization chamber, or the oil could be forced through the openings in open plate 22 by a pressure greater than atmospheric pressure.

As the oil droplets emerge from the open plate into the upper portion of volatilization chamber 20, they are heated by convective heat from hot carbon monoxide entering the chamber through generally radial passages 24 spaced around the central portion of volatilization chamber 20 and are heated by radiant heat from sidewalls 20a of the volatilization chamber. The heating of the residual oil droplets in the volatilization chamber liberates the volatile combustible gas component of the oil from the droplets and coke 26 is formed thereby. The coke particles formed from the oil droplets fall to the bottom 20b of volatilization chamber 20. The volatilization should be carried out in the absence of free oxygen in the volatilization chamber to avoid the formation of undesired oxides.

By the above arrangement, in introducing oil droplets of generally uniform size into the volatilization chamber, each coke particle formed from an oil droplet will be of a generally uniform size. Thus, there will be no coke dust or fine particles of coke which may be blown from the volatilization chamber with the liberated volatile combustible gases, but rather coke particles of a uniform size which readily fall to the bottom of the chamber. The coke particles accumulate on bottom 20b of the volatilization chamber forming a layer thereon. These coke particles will contain some unliberated volatile components and also the non-combustible impurities of the residual oil.

The coke particles are passed from the volatilization chamber 20 to a gasification chamber 30 where the coke will undergo partial combustion to generate hot gases, mostly carbon monoxide, and the non-combustible impurities in the coke will form slag. In this particular instance the means for permitting passage of the coke from the volatilization chamber to the gasification chamber is provided for by having the bottom 20b of the volatilization chamber formed with a conical outwardly-tapered surface, whereby the coke will move by gravity through annular opening 20c adjacent the bottom of the volatilization channel and into the gasification chamber. In this particular embodiment, the gasification chamber 30 is coaxial with the volatilization chamber and annular in form, its upper portion surrounding the lower portion of the volatilization chamber.

The coke 26 entering the gasification chamber from the volatilization chamber is suspended in the annular gasification chamber as a floating bed of coke supported by primary air stream passing upwardly through the gasification chamber. The primary air enters the housing 10 through an axial bore 32 formed upwardly through the lower central portion thereof, the lower central portion of the housing forming an upwardly extending core 33 which defines the conical sloped bottom 20b of volatilization chamber 20 and the inner sidewalls of the lower portion of the annular gasification chamber. Axial bore 32 terminates beneath bottom 20b of the volatilization chamber and has horizontally extending ports 34 directed radially outward therefrom into the gasification chamber extending annularly around core 33.

The primary air is forced into bore 32 from a suitable blower at a desired pressure. Primary air passes from bore 32 through ports 34 to gasification chamber 30 where the air proceeds upwardly to hold the coke in a floating bed. The coke in the primary air undergoes partial combustion generating carbon monoxide and forming slag, as previously stated. The hot carbon monoxide gases pass upwardly in the gasification chamber and through passages 24, located adjacent the top of the gasification chamber, into the volatilization chamber. The slag formed in the gasification chamber falls into an annular pan-like slag collector 36 located at the bottom of the gasification chamber. Openings 36a may be provided along the bottom of the slag collector and through the housing, as shown in FIG. 1, for removal of the slag from the system, as by gravity feed.

The primary air stream is regulated such that only a restricted quantity of oxygen is available to combine with the coke, and essentially only carbon monoxide will be formed. By having only partial combustion in the gasification chamber with a restricted quantity of oxygen, undesirable oxides are eliminated from the output of the system.

In the arrangement of the present invention, it is desirable that the primary air stream be kept from passing into the lower portion of the volatilization chamber through annular opening 20c. This is desired so that oxygen in the primary air stream is excluded from the volatilization chamber before the oxygen has combined with the coke. The exclusion is accomplished by maintaining the coke layer on the bottom of the volatilization chamber of sufficient height to prevent the restricted quantity of primary air from entering opening 20c. Otherwise, the primary air would start combustion chamber 20 depriving the combustion chamber 42 of combustible products and would form undesirable oxides with the coke and oil in the volatilization chamber. Also, the primary air stream is regulated such that coke particles in the floating coke bed will not be blown upward and pass into the volatilization chamber through passages 2. These coke particles are blown into the volatilization chamber.

The hot carbon monoxide gases from the gasification chamber heat the sidewalls of the volatilization chamber and heat the oil droplets and then combine with the volatile combustible gases liberated from the oil. These gases pass upwardly and out of the volatilization chamber through spaced vents 40 located around the upper portion of the volatilization chamber. Vents 40 communicate with an annular combustion chamber 42 which is coaxial with the volatilization and gasification chambers and surrounds the upper portion of the volatilization chamber and the oil reservoir. The combustion chamber is shown with its upper portion open to the atmosphere. In the combustion chamber 42 the hot carbon monoxide and combustible gases are combined with a secondary air stream and ignited to form a hot flame 44 around the housing. The secondary air is supplied from a suitable blower at a desired pressure through duct 46 to a window box 48 provided by the housing and surrounding oil reservoir 16. The secondary air in the window box passes through ports 49 into combustion chamber 42 where combustion of the gases from the volatilization chamber takes place in combination with the secondary air.

In accordance with a further feature of the present invention, a recirculating part and gas circulating means may be provided for re-circulating hot gases from the combustion chamber back to the volatilization chamber for imparting additional heat to the volatilization chamber. More specifically, bottom 20b of volatilization chamber 20 and the inner sidewalls of the lower portion of the annular gasification chamber 30 is provided from the combustion chamber downwardly adjacent the outside wall of the housing terminating in conduits 52 which communicate with passages 24 between the gasification and volatilization chambers. Passages 24 in this arrangement are venturi throats and conduits 52 each communicate with a different passage 24 at the venturi throat thereof. In this manner suction is produced at the venturi throats in passages 24, thereby drawing hot gases from the combustion chamber through channel 50 and conduits 52 to passages 24. By this arrangement, the hot gases from the combustion chamber are brought.
back into the system around the walls of and into the volatilization chamber providing additional radiant heat and convection heat, the recirculated gases passing back into the combustion chamber where they may be ignited or recirculated.

From the above it will be clear that the oil combustion system of the present invention has many advantages. In particular, the arrangement of the volatilization chamber and gasification chamber as coaxial with another provides a savings in space of the housing and provides a reduction in heat losses through a compact system. With the coaxial and annular arrangement of the chambers, the heat produced in the gasification chamber heats the walls of the volatilization chamber providing a system of increased heat for optimum operation.

It should be noted that other coaxial arrangements of the gasification and volatilization chambers may be used, such as having the gasification chamber provided as the inner chamber and the volatilization chamber as the outer annular chamber. This latter arrangement would provide the same advantages as the system shown and described in FIG. 1.

The present system is not limited to a quality of residual oil depending on the impurity content which may be used, thereby the system being low in the cost of low-cost oils. As previously stated, the present oil combustion system eliminates the atomization apparatus and saves the energy required to atomize the oil. By intentionally forming coke in the present system, impurities from the oil are eliminated from the air and are taken out of the system in the form of slag. Thus, the present system reduces air pollution by capturing the impurities in the oil and eliminating them from the place of utilization of combustible gases. In this manner the present invention protects the combustion system and equipment, which may be driven by the gases from corrosion, erosion and deposits of impurities in the equipment. In having two places of combustion of the fuel in the system, one of the gasification chamber and the other in the combustion chamber, nitrogen oxides are eliminated from the output of the system thereby preventing smog in the atmosphere caused by nitrogen oxides combining with exhaust gases from vehicles. By having incomplete combustion in the gasification chamber and forming only carbon monoxide, other harmful oxides, such as vanadium pentoxide are eliminated. These harmful oxides act as a catalyst to cause corrosion of, for example, turbine blades in a turbine system. The system provides better response time to load changes in the heat output requirement through the stored amount of highly reactive gas-generating coke at the bottom of the volatilization chamber.

While the present invention has been described with particular reference to specific embodiments where oil is employed as the fuel, with minimum of modification of the present invention, the system may operate with coal as the fuel. A schematic fragmentary representation of a coal combustor employing the novel system of the present invention is shown in FIG. 2. Corresponding parts in FIG. 2 are identified by designators corresponding to those in FIG. 1 but having the addition of primes thereto. As can be seen in FIG. 2, the system contains a similar arrangement of the volatilization chamber 20', the gasification chamber 30' and combustion chamber 42'. In this arrangement granulated coal 60 is introduced into the system from a suitable supply means through coal pipe 62 terminating in an outwardly flared portion 62a located over and communicating with volatilization chamber 20'. Within outwardly flared portion 62a of the coal pipe, a coal deflector 64 having stationary outwardly-curved helical-shaped fins 64a is located for distributing the falling coal around the upper portion of the volatilization chamber 20'. As can be seen more clearly in the inverted plan view of the coal deflector in FIG. 3, there are four vertically extending helical-shaped fins which intercept the falling coal from the coal pipe and distribute it in a volatilization chamber.

In the same manner as described in regard to FIG. 1, the coal falling into the volatilization chamber of FIG. 2 encounters convective heat from the hot carbon monoxide formed in the gasification chamber and radiant heat transferred from the sidewalls 20a' of the volatilization chamber. The coal forms coke and volatilizes combustible gases. The hot combustible gases pass from the volatilization chamber into the combustion chamber where secondary air from windbox 48', which surrounds the flared portion of the coal pipe, is added. In this particular instance, the secondary air is channeled into the windbox through air duct 65 surrounding coal pipe 62. The secondary air in windbox 48' proceeds through ports 49' into the combustion chamber 42'. Except for the use of fuel and the feeder means therefor, the system of FIG. 2 is similar in all other respects to the system in FIG. 1.

The impurities in the coal are removed in the gasification chamber in the form of slag, but if any small coke particles are carried upward with the carbon monoxide gases they may be filtered from the gases by the falling particles of coal dropping into the volatilization chamber. In this manner much of the ash formed in the output of prior art coal gasification and combustion systems may be eliminated. In addition, the system of FIG. 2 provides similar features and advantages as previously set forth in regard to FIG. 1 in saving space, reducing heat losses and concentrating heat through the coaxial arrangement of chambers. For these reasons the present coal system may find application in coal fired gas turbine systems, for example.

While the invention has been described with particular reference to specific embodiments thereof, in the interest of complete definiteness, it should be understood that it may be embodied in a large variety of forms diverse from those specifically shown and described, without departing from the scope and spirit of the invention as defined by the appended claims.

1. A fuel gasification system for gasifying combustible fuel comprising:
   a volatilization chamber for transforming fuel into coke and liberating combustible gases and having upper and lower portions;
   feeder means communicating with said upper portion of said volatilization chamber for introducing said fuel into said chamber;
   gasification chamber coaxial with said volatilization chamber and communicating with said lower portion of said volatilization chamber through a communicating passage;
   means for permitting passage of coke from said volatilization chamber into said gasification chamber;
   means for supplying an air stream in said gasification chamber on which coke entering said gasification chamber is floated so that said coke may be contacted by said air stream and thereby degasified releasing hot gases and forming slag;
   flow passage means for conducting said hot gases from said gasification chamber to said volatilization chamber so that said hot gases will assume an upward movement in said gasification chamber and impinge upon said fuel falling in said volatilization chamber;
   and
   vent means communicating with said volatilization chamber for removing said hot and combustible gases from said volatilization chamber.

2. A fuel gasification system of claim 1 in which a recirculating path and gas circulating means are provided for recirculating hot and combustible gases from said vent means back into said volatilization chamber.

3. The fuel gasification system of claim 2 in which said gas circulating means is provided by having said
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flow passage means from said gasification chamber to said volatilization chamber comprise at least one venturi throat and by having said recirculating path from said vent means include a conduit communicating with each venturi throat.

4. The fuel gasification system of claim 1 in which said air stream is limited in oxygen such that substantially only carbon monoxide is produced as said hot gases from said coke in said gasification chamber.

5. The gasification system of claim 1 in which said gasification chamber is annular in form, and said means for permitting passage of said coke from said volatilization chamber into said gasification chamber comprises a generally downwardly sloping bottom in said volatilization chamber and communicating passage, whereby said coke moves downwardly by gravity from said volatilization chamber into said gasification chamber.

6. The fuel gasification system of claim 5 in which said coke in said volatilization chamber is kept at a level that said coke effectively fills said communicating passage such that air in said air stream is prevented from passing through said communicating passage between said gasification chamber and said volatilization chamber.

7. The fuel gasification system of claim 1 in which said volatilization chamber is annular in form and said means for permitting passage of said coke from said volatilization chamber into said gasification chamber comprises a generally downwardly sloping bottom in said volatilization chamber and communicating passage, whereby said coke moves downwardly by gravity from said volatilization chamber into said gasification chamber.

8. A fuel combustion system comprising:

a volatilization chamber for transforming fuel into coke and liberating combustible gases and having upper and lower portions;

feeder means communicating with said upper portion of said volatilization chamber for introducing said fuel into said chamber;

gasification chamber coaxial with said volatilization chamber and communicatining with said lower portion of said volatilization chamber;

means for permitting passage of coke from said volatilization chamber into said gasification chamber;

means for supplying an air stream in said gasification chamber on which coke entering said gasification chamber is floated, so that said coke may be contacted by said air stream and thereby degasified releasing hot gases and forming slag;

flow passage means for conducting said hot gases from said gasification chamber to said volatilization chamber so that said hot gases will assume an upward movement in said gasification chamber and impinge upon said fuel falling in said volatilization chamber;

vent means communicating with said volatilization chamber for removing said hot and combustible gases from said volatilization chamber;

means for supplying an air stream to combine with said gases in said vent means for producing an air and combustible gas mixture; and

a combustion burner communicating with said vent means for receiving said air and combustible gas mixture.

9. An oil gasification system comprising:

a volatilization chamber for transforming oil into coke and liberating combustible gases and having upper and lower portions;

an oil reservoir communicating with said upper portion of said volatilization chamber and having means for introducing oil droplets into said upper portion of said volatilization chamber;

a gasification chamber coaxial with said volatilization chamber and communicating with said lower portion of said volatilization chamber;

means for permitting passage of coke from said volatilization chamber into said gasification chamber;

means for supplying an air stream in said gasification chamber on which coke entering said gasification chamber is floated, so that said coke may be contacted by said air stream and thereby degasified releasing hot gases and forming slag;

flow passage means for conducting said hot gases from said gasification chamber to volatilization chamber so that said hot gases will assume an upward movement in said gasification chamber and impinge upon said oil droplets falling in said volatilization chamber;

and

vent means communicating with said volatilization chamber for removing said hot and combustible gases from said volatilization chamber.

10. The oil gasification system of claim 9 in which said means for introducing oil droplets into said upper portion of said volatilization chamber comprises an apertured plate as a bottom of said oil reservoir, said apertured plate having a plurality of openings such that oil droplets of a desired size pass therethrough into said volatilization chamber.

11. A coal gasification system comprising:

a volatilization chamber for transforming coal into coke and liberating combustible gases and having upper and lower portions;

a coal feeder communicating with said upper portion of said volatilization chamber and having means for distributing coal into said upper portion of said volatilization chamber;

a gasification chamber coaxial with said volatilization chamber and communicating with said lower portion of said volatilization chamber;

means for permitting passage of coke from said volatilization chamber into said gasification chamber;

means for supplying an air stream in said gasification chamber on which coke entering said gasification chamber is floated, so that said coke may be contacted by said air stream and thereby degasified releasing hot gases and forming slag;

flow passage means for conducting said hot gases from said gasification chamber to said volatilization chamber so that said hot gases will assume an upward movement in said gasification chamber and impinge upon said coal falling in said volatilization chamber;

and

vent means communicating with said volatilization chamber for removing said hot and combustible gases from said volatilization chamber.

12. The coal gasification system of claim 11 in which said means for distributing said coal into said upper portion of said volatilization chamber comprises a coal distributor having a plurality of fins.

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