July 23, 1968 J. J. DONNELLY 3,393,964

ATOMIZATION AND BURNING OF LIQUID HYDROCARBONS WITH LPG

Filed March 2, 1965 2 Sheets-Sheet 1

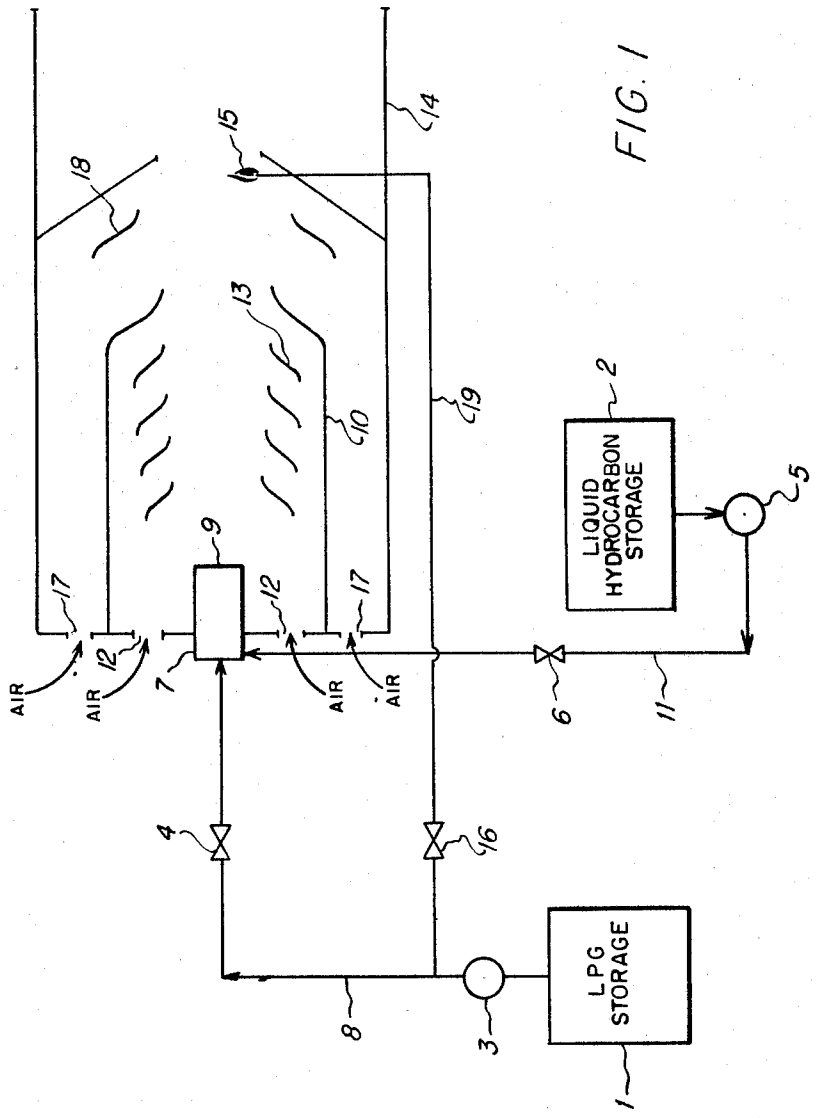


FIG. 1

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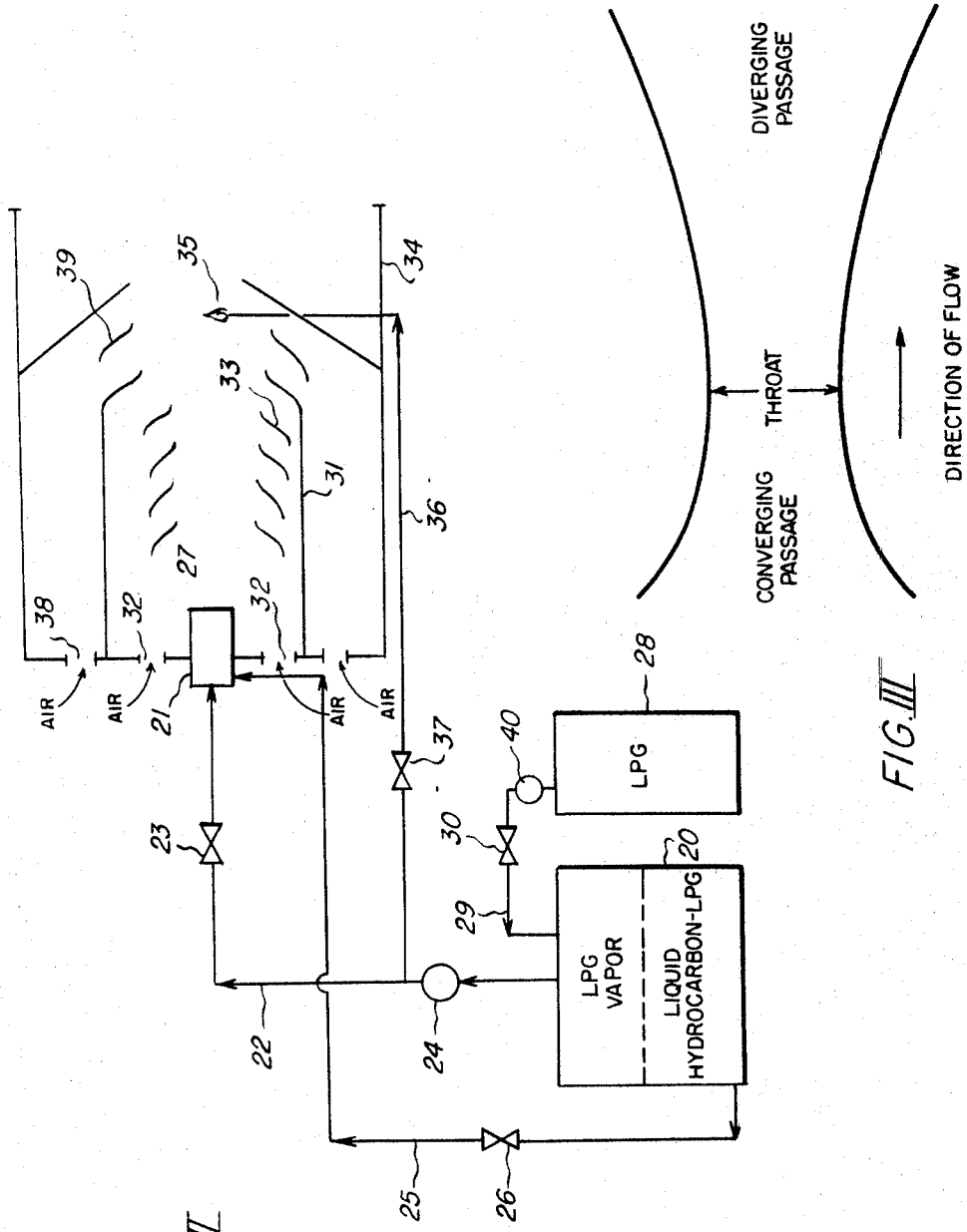


FIG. III

FIG. II

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ATOMIZATION AND BURNING OF LIQUID HYDROCARBONS WITH LPG

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10 Claims. (Cl. 431—2)

This invention relates to a process and system for atomizing combustible hydrocarbon fluids. More particularly, this invention provides a process and system for atomizing a liquid hydrocarbon in the presence of, and through the action of, a liquefiable petroleum gas. Further, the present invention provides a process for atomizing and burning a liquid hydrocarbon without the need for auxiliary gas compressors or combustion air blowers.

It is known that vaporization and combustion of liquid hydrocarbons are influenced by drop size. It is also known that vaporization and combustion rates of liquid hydrocarbons increase with a decrease in drop size since there is an increase of liquid hydrocarbon surface area per unit volume. It is also known that an increase in the combustion rates of liquid hydrocarbons can decrease the tendencies toward smoke formation and carbon deposits, and that, therefore, the burning of liquid hydrocarbon in the form of small droplets can result in clean and highly efficient combustion.

In the past it has been proposed to atomize combustible hydrocarbon liquids with liquefiable petroleum gases by first intimately contacting the two materials in a nozzle in such a manner as to cause the liquefiable petroleum gas to dissolve in the liquid hydrocarbon in an atomizing nozzle. The resultant reacted mixture is then atomized in a manner which is familiar in the art, as for example by forcing the mixture through a slit. Unfortunately, these methods for atomizing liquid hydrocarbons rely on the liquefiable petroleum gas for causing a lower viscosity of the liquid hydrocarbon upon reaction therewith in order to prevent the liquid hydrocarbon in a more convenient form for subsquent atomization rather than utilizing the energy exerted by the partial pressure of the liquefiable petroleum gas to atomize the liquid hydrocarbon. In other words, processes of the prior art are highly inefficient since energy available from the partial pressure of the liquefiable petroleum gas is not utilized to promote atomization and this energy is therefore lost.

It has also been proposed in prior processes to atomize a liquid hydrocarbon with moving air or steam in order to prevent the liquid hydrocarbon in a more convenient physical form for atomization and subsequent combustion. Such processes have found application in the firing of commercial and industrial furnaces where steam under pressure is available or where the additional cost of an air compressor is tolerable. Such processes have, however, found only limited application in domestic and small-scale commercial heating plants because they require relatively expensive equipment to supply the atomizing air at adequate pressures.

In most cases where hydrocarbon fuels are atomized for combustion purposes, electrically powered blowers are employed to supply the combustion air. The cost of the blower and its electric motor and controls adds appreciably to the initial and operating costs of the oil-burning equipment. When liquefiable LPG, at vapor pressures attainable under normal ambient conditions, is used to atomize a liquid hydrocarbon fuel, there can easily be sufficient energy in the expanded vapor to effect the induction and mixing of sufficient air for clean and efficient combustion. In the system of the present invention, the pressure energy available in LPG at normal ambient temperatures is employed to atomize a hydrocarbon fuel, induct the air necessary for combustion, and promote mixing of the air with the atomized hydrocarbon fuel and LPG vapor so that clean and efficient burning of the fuel is effected.

It is an object of the present invention to provide a process and system for atomizing liquid hydrocarbon with a liquefiable petroleum gas which is directed to an atomizing step under its own vapor or partial pressure.

It is a further object of the present invention to provide a process and system for atomizing a liquid hydrocarbon with a liquefiable petroleum gas, wherein the liquefiable petroleum gas is directed to an atomization zone in a separate stream.

It is a further object of the present invention to provide an improved process and system for burning atomized liquid hydrocarbon.

A still further object of the present invention is to provide a process and system for atomizing and burning a liquid hydrocarbon wherein the need for pumping apparatus to supply combustion air is eliminated.

Further objects of the present invention will become evident from the following detailed description.

The term "liquefiable petroleum gas" (LPG) as used herein is intended to include any normally gaseous hydrocarbon such as ethane, propane, butane, ethylene, propylene, butylene, or mixtures thereof. The term "liquid hydrocarbon" as used herein is intended to include liquid hydrocarbons boiling in the range of from about C_5 to about residuum boiling range materials, such as naphthas, kerosine, middle distillates, residual oils, residuum, or suitable mixtures thereof.

The present invention provides for a process and system for the atomization of a normally liquid hydrocarbon. A liquefiable petroleum gas in the gaseous phase is accordingly directed in a confined stream to a nozzle under its own vapor or partial pressure, and a normally liquid hydrocarbon is directed in a confined stream to the nozzle in a separate confined stream under pressure, as for example by means of a pump, gravity feed, under a gas pressure, or through an aspiration process. In the nozzle, the liquefiable petroleum gas and liquid hydrocarbon streams may be maintained as separate streams until both exit from the nozzle, or they may be brought into contact within the nozzle prior to exit therefrom. At, or prior to, the nozzle exit, the gas stream contacts the liquid stream at a velocity which is high relative to the liquid stream velocity in such a manner that the kinetic energy of the liquefiable petroleum gas is partially transferred to the liquid hydrocarbon stream to cause shearing and deformation of the liquid hydrocarbon stream. These shearing and deforming actions cause the liquid hydrocarbon stream to break up into fine droplets of small size and result in atomization thereof. When it is desired to burn the mixture of gas and atomized liquid, the mixture is introduced at high velocity into a free oxygen-containing gas such as air. The high velocity of the gas and atomized liquid mixture can be used to induct the air into the combustion space and mix it with the combustible gas-liquid stream. The resultant mixture is ignited to produce a clean and efficient flame.

In accordance with one aspect of the present invention, a liquefiable petroleum gas in the gaseous state is directed from a storage tank in a confined stream by means of its own vapor pressure to a fluid atomizing nozzle which maintains a gas stream and a liquid stream separate until it is desired to atomize the liquid stream. A normally liquid hydrocarbon is also directed under pressure in a confined stream from a separate storage tank to the nozzle in a controlled flow, as for example by a pump, by gas pressure, by aspiration, or by gravity feed. The two streams are then contacted either within

the nozzle prior to exit or are exited from the nozzle in separate streams wherein the gas stream velocity is high relative to the liquid stream velocity. In either case, the two streams are mixed to form a two-phase mixture, with the liquid hydrocarbon stream being atomized into fine droplets through the shearing and deforming actions of the liquefiable petroleum gas stream which impinges on the liquid hydrocarbon stream. The mixture is introduced at high velocity into a free oxygen-containing gas such as air. The high velocity of the gas and atomized liquid mixture can be used to induct the air into the combustion space and mix it with the combustible gas-liquid stream.

In accordance with another aspect of the present invention, a liquefiable petroleum gas and a normally liquid hydrocarbon are stored in the same storage tank with the vaporized liquefiable petroleum gas, forming an upper gas phase and a mixture of the liquefiable petroleum gas and the liquid hydrocarbon forming a lower liquid phase. The liquefiable petroleum gas in the gaseous phase is directed, under its partial pressure, in a separate stream to a two-fluid nozzle from the storage tank through a conduit which is in communication with the gas phase in the tank. The mixture of liquefiable petroleum gas and the liquid hydrocarbon is directed in a separate confined stream from the bottom portion of the storage tank to the nozzle under the force resulting from the liquefiable petroleum gas partial pressure on the liquid hydrocarbon surface in the storage tank. The liquefiable petroleum gas and the liquid mixture can be maintained as separate streams in the nozzle or they can be brought into contact within the nozzle prior to exit therefrom. At or prior to the nozzle exit, the gas stream, which is at a high velocity relative to the liquid stream velocity, and the liquid stream are mixed to form a two-phase mixture, with the liquid stream being atomized into fine droplets under the force of the liquefiable petroleum gas stream. The mixture is introduced at high velocity into a free oxygen-containing gas such as air. The high velocity of the gas and atomized liquid mixture can be used to induct the air into the combustion space and mix it with the combustible gas-liquid stream.

In accordance with another aspect of the present invention, a liquefiable petroleum gas and a liquid hydrocarbon are supplied in a manner described above to a nozzle which is capable of accelerating the liquefiable petroleum gas to supersonic velocities. The liquefiable petroleum gas in the gaseous phase is supplied to a nozzle, which is designed to expand the gas in suitable fluid-accelerating passages to convert the pressure energy of the gas to kinetic energy so that supersonic velocities are attained. The liquid hydrocarbon is introduced into the high velocity gas in a region where the gas velocity is high relative to the liquid velocity in such a manner that the kinetic energy of the petroleum gas is partially transferred to the liquid hydrocarbon stream to cause the liquid hydrocarbon stream to break up into fine droplets. When the petroleum gas is accelerated to velocities exceeding the sonic velocity, the passages can be designed to effect the formation of either interior or exterior shock waves. When the liquid hydrocarbon is injected into the moving gas in a region upstream of the shock waves, the atomization accomplished by the resultant interaction of the two streams is augmented by the subsequent passage of the comminuted liquid through the shock waves and the decelerated gases downstream of the shock waves. Following atomizing of the liquid hydrocarbon, the mixture of liquid droplets and gas still possesses a high proportion of the kinetic energy imparted to the liquifiable petroleum gas through expansion at the expense of its pressure energy. This remaining kinetic energy is sufficient to effect induction and mixing of air to permit clean and efficient burning of the liquid hydrocarbon and the liquefiable petroleum gas.

In the process of the present invention, the velocity of the expanded and accelerated liquefiable petroleum gas stream is maintained sufficiently high so that when it contacts the liquid hydrocarbon stream, the force of the impinging gas stream will cause the liquid hydrocarbon stream to be atomized. The velocity of the gas stream is regulated to cause the normally liquid hydrocarbon to be sheared into droplets having diameters usually below about 200 microns. In most cases, it is desirable to produce droplets having diameters under 50 microns, with the majority having diameters under 20 microns. The optimum droplet size will vary with the combustion system employed. Droplet size can be controlled by varying the pressure at which the liquefiable petroleum gas is supplied to the nozzle. This supply pressure can be varied by the use of a pressure-regulating valve and by changing the composition or storage temperature of the liquefiable petroleum gas. In order to produce droplets of the sizes desired for various applications, the liquefiable petroleum gas is introduced into the gas accelerating passages at pressures in the range of from about 1 p.s.i.g. to 200 p.s.i.g. When naphtha is employed as the liquid hydrocarbon and propane at an ambient temperature of 30° F. is employed as the liquefiable petroleum gas, a volume ratio of propane to naphtha of about 1 to 4 is employed in a suitable two-fluid nozzle. When the propane is at an ambient temperature of 70° F. and naphtha is employed as the liquid hydrocarbon, the volume ratio of propane to naphtha employed is about 1 to 6 in a suitable two-fluid nozzle. When an equal volume mix of propane and butane at 70° F. is employed as the liquefiable petroleum gas, and naphtha is the liquid hydrocarbon, a volume ratio of the liquefiable petroleum gas to naphtha of about 1 to 3 is employed in a suitable two-fluid nozzle.

In one embodiment of the present invention, where it is desirable to employ a low flow rate of liquid hydrocarbon to the nozzle of less than about 1 g.p.h., the liquid hydrocarbon is directed from the storage container to a constant level valve and flow regulator prior to being fed to the nozzle. The level of liquid hydrocarbon is kept constant at the constant level valve, and is supplied to the nozzle by the aspirating effect of the gaseous liquefiable petroleum gas stream at the nozzle; that is to say the velocity of the gaseous liquefiable gas stream at the nozzle exit creates a reduced pressure at this point, causing the liquid hydrocarbon to flow to the nozzle, where it is atomized by the gas stream. The level of the liquid hydrocarbon is kept at a level corresponding to the desired flow rate.

The gas stream can emerge from the nozzle so that it encloses the liquid stream and is directed inwardly toward the liquid stream emerging from the nozzle at a relatively central portion thereof. Conversely, the gas stream, as it emerges from the nozzle, can be directed outwardly from a central portion toward the periphery of the nozzle at a liquid stream emerging from a peripheral point on the nozzle. Parallel flow of the liquid and gas streams can also be used. The above-described nozzle positions of the gas and liquid streams can be employed so long as the gas stream is directed to the liquid stream at sufficiently high velocity to cause atomization of the liquid stream.

In the embodiment of the present invention, wherein it is desired to maintain a gas stream at sonic velocity or higher, the above-described storage systems can be employed, with the gas and liquid being delivered to the atomizing nozzle in separate confined streams. In the nozzle, the gas is first accelerated to the acoustic velocity in a converging section of a converging-diverging passage. Such a passage is shown in cross-section by FIGURE III. For fixed upstream conditions, the rate of discharge of a gas from a converging-diverging passage or orifice increases with a decrease in the ratio of the downstream to the upstream pressure until the velocity in the throat of the converging-diverging passage or orifice

equals the velocity of sound at the conditions existing in the throat. The ratio of the pressure in the throat to the upstream (reservoir) pressure for which the acoustic velocity is just attained is called the critical pressure ratio. The critical pressure ratio is a function of the ratio of the specific heats of the flowing gas and is usually defined by the following equation:

$$r_c=\left(\frac{2}{k+1}\right)^{\left(\frac{k}{k-1}\right)}$$

where:

r_c=critical pressure ratio
$k=C_p/C_v$
C_p=specific heat of the gas at constant pressure
C_v=specific heat of the gas at constant volume

Although this equation is for ideal gases, it is widely used with real gases with acceptable results. For normal butane $k=1.094$ at 1 atm. and 60° F. and the corresponding acoustical velocity at 60° F. is 700 ft./sec. For propane, $k=1.133$ at 1 atm. and 60° F., and the corresponding acoustical velocity is 820 ft./sec. The critical pressure ratio for propane and butane under the conditions of interest is about 0.58. When the final or discharge pressure is atmospheric, and sonic gas velocities are desired, propane and butane must be supplied to the nozzle at a vapor pressure of about 25.5 p.s.i.a. or above. A vapor pressure of 25.5 p.s.i.a. for propane is obtained at about −20° F., while a vapor pressure of 25.5 p.s.i.a. for butane is obtained at about 60° F. When it is desired to employ a mixture of propane and butane in the gas phase, the required temperature in the LPG reservoir necessary to obtain sonic gas velocity will be proportionately lower than 60° F. as the concentration of propane is increased.

After the gas has reached sonic velocity in the converging section of the nozzle passage, it is expanded to supersonic velocity in the diverging section of the nozzle passage. The gas in the diverging section of the nozzle can be over-expanded to produce interior shock waves and subsequent deceleration of the gas stream which promote further atomization of the liquid. That is to say that at a point in the diverging section of the nozzle, the gas is caused to drop to a lower pressure than the pressure at the reservoir into which the nozzle is discharging. When this is done, a shock wave forms within the nozzle and the pressure rises to conform to the external pressure. The liquid hydrocarbon is injected into the gas stream in the diverging section of the nozzle passage, wherein it is atomized. Upon passing through the shock wave and the decelerated gases, the atomized liquid hydrocarbon is further atomized into smaller droplets. After passing through the shock wave the mixture is still moving at a high velocity. The fast moving gas stream can also be underexpanded in the diverging section of the nozzle, and upon exit therefrom shock waves will be formed and the gas decelerated causing further shearing and atomization of the liquid.

In order to obtain a more complete understanding of the present invention, reference is now made to the drawings.

FIGURE I shows the system employed when the LPG and liquid hydrocarbon are stored separately.

FIGURE II shows the system employed when the LPG and liquid hydrocarbon are stored in a common container.

Referring now to FIGURE I, LPG is stored in a suitable storage tank **1**, wherein it is in both liquid and vapor phase. The LPG is directed to nozzle **7** under its own vapor pressure through conduit **8** when valve **4** and pressure regulator **3** are open. Valve **4** can be manually controlled or automatically controlled, as for example solenoid-actuated. Liquid hydrocarbon is stored in a suitable tank **2** and directed by means of pump **5** to nozzle **7** through conduit **11** when valve **6** is open. The liquid hydrocarbon can be directed to nozzle **7** by means of gravity feed, or through air aspiration effect, in which case there would be no need for pump **5**. Valve **6** can be either manually controlled or automatically controlled, either alone or in conjunction with valve **4**, as for example solenoid-actuated, and, more specifically, the solenoid-actuated valves can be controlled by a thermostat connected thereto. During operation, valve **4** is open while pressure regulator **3** controls the flow of LPG, depending upon the desired pressure in the nozzle **7**. At nozzle **7**, the LPG and liquid hydrocarbon are kept separate until atomization is desired, and they can be contacted either prior to nozzle exit **9** or at exit **9**.

Within the nozzle, the LPG can be expanded by suitably contoured fluid-accelerating passages. Dependent upon the inlet pressure and the nozzle design, the LPG can be accelerated to velocities ranging from subsonic to supersonic. When subsonic gas velocities are employed, the liquid hydrocarbon is introduced into the gas passages in the regions of highest gas velocity. When the gas is accelerated to supersonic velocities, the gas passages can be designed to cause over-expansion and shock wave formation within the passages or under-expansion and shock wave formation exterior to the passages. In this case the liquid hydrocarbon is introduced into the gas downstream of the region where critical or sonic flow is attained, but upstream of the shock wave area. The preferred point of injection is in the middle third of the region of supersonic flow. When the liquid passes through the shock wave and following decelerated gases, it is subjected to further strong disruptive forces which complete its atomization into fine droplets. When the still rapidly moving two-phase mixture of liquefiable petroleum gas and hydrocarbon droplets emerges from the atomizing nozzle, it enters an air induction and mixing section **10**. In this section the relatively high kinetic energy of the stream is partially consumed in promoting the flow of air through ports **12** into a suitable aspirating and mixing device, such as the series of ring nozzles **13** shown. Vanes can be incorporated between the ring nozzles to impart a swirling motion to the air to facilitate mixing. Upon emerging from section **10**, the air-fuel mixture enters a combustion chamber **14**, where it is ignited by an LPG pilot flame **15** wherein the LPG is conveyed through conduit **19**. Flow of gas to the pilot flame is controlled by a valve **16**. If desirable, secondary air to complete the combustion can be inducted through ports **17** into the combustion chamber **14** by means of another aspirating section **18**.

Referring now to FIGURE II, LPG and liquid hydrocarbon are stored in a suitable tank **20**, with vaporized LPG constituting the upper phase. The LPG is present in both the vapor and liquid phases. The LPG is directed to nozzle **21**, under the force of its own partial pressure, through conduit **22** when valve **23** and pressure regulator **24** are open. The liquid hydrocarbon in the lower phase of storage tank **20** is directed to nozzle **21** under the force of the LPG partial pressure, which acts on the upper surface of the liquid hydrocarbon. The liquid hydrocarbon is directed to nozzle **21** through conduit **25** when valve **26** is open. Valves **26** and **23** and pressure regulator **24** can be manually controlled or automatically controlled, as for example solenoid-actuated. Further, when automatically controlled, valves **26** and **23** can be operated alone or in conjunction. At nozzle **21**, the liquid hydrocarbon and LPG are kept separated until atomization is desired, and they can be contacted either prior to nozzle exit **27** or at exit **27**.

As the LPG in the storage tank **20** is depleted, the LPG partial pressure therein will eventually decrease to a point where the kinetic energy of the LPG stream at the nozzle will not be sufficient to atomize the liquid hydrocarbon stream. In order to prevent this loss of partial pressure, LPG can be supplied from auxiliary tank **28** through conduit **29** into storage tank **20** when valve **30** and pressure regulator **40** are open. Valve **30**

and pressure regulator 40 can be manually operated or automatically operated, as for example solenoid-actuated, and responsive to the LPG partial pressure in storage tank 20. Within the nozzle, the LPG can be expanded by suitably contoured fluid-accelerating passages, as explained for FIGURE I. When the still rapidly moving two-phase mixture of LPG and hydrocarbon droplets emerges from the atomizing nozzle, it enters an air induction and mixing section 31. In this section, the relatively high kinetic energy of the stream is partially consumed in promoting the flow of air through parts 32 into a suitable aspirating and mixing device, such as the series of ring nozzles 33. Vanes can be incorporated between the ring nozzles to impart a swirling motion to the air to facilitate mixing. Upon emerging from section 31, the air-fuel mixture enters a combustion chamber 34, where it is ignited by an LPG pilot flame 35 wherein the LPG is conveyed through conduit 36. Flow of gas to the pilot flame is controlled by valve 37. If desirable, secondary air to complete the combustion can be inducted through parts 38 into the combustion chamber 34 by means of another aspirating section 39.

The following example is intended to assist in the understanding of the invention and is not to be interpreted as imposing a limitation thereon.

EXAMPLE

In the tests described below, an LPG having a composition of 77.4 weight percent propane, 18.4 weight percent propylene, 3.1 weight percent ethane, and 1.1 weight percent ethylene was employed. A naphtha having the following characteristics was also employed:

API gravity		59.3
Distillation:		
IBP	° F.	108
10%	° F.	160
50%	° F.	255
90%	° F.	345
FBP	° F.	385
RVP lbs./sq. in.		4.4

The LPG had a lower heating value of 19,785 B.t.u./lb., while the naphtha had a lower heating value of 18,735 B.t.u./lb.

The LPG and naphtha were stored in separate storage tanks. The nozzle employed was standard Delvan-type SN aspirating nozzle rated at 0.65 g.p.h. Fuel ignition at startup was provided by a standard high voltage spark gap. Air was supplied to the atomized fuel by an external blower at the rates shown in Table 1 in order to support combustion of the fuel. The LPG was supplied to the nozzle at a reduced pressure of 4 p.s.i.g. The naphtha was supplied from a storage tank to a constant level regulator and from the constant level regulator to the nozzle by the aspirating effect of the moving LPG stream.

The burning fuel was used to heat a standard stream boiler and thermal efficiencies were calculated from the heat supplied to the boiler and the heat input based upon the lower heating ratings for LPG and naphtha shown above. The flue gas in each run was tested to determine the smoke rating and completeness of combustion. Table 1 shows the test conditions and the results obtained therefrom.

The results in the table show that high thermal efficiencies are obtained at low smoke levels by the process of the present invention. A comparison of Run E and Run D shows that smoke can be decreased by supplying more air to the burner, but with only a very slight loss in thermal efficiency.

TABLE 1

	A	B	C	D	E
Cumbustion Air, Cu. Ft./Min.	25	25	25	25	27
LPG Pressure, p.s.i.g.	4	4	4	4	4
LPG Std., Cu. Ft./Min.	.50	.50	.50	.50	.50
Naphtha Flow, GPH	.60	.63	.68	.69	.69
Flue Gas:					
Temp., ° F.	546	552	562	565	572
CO_2%	12.7	13.3	13.7	13.8	12.8
O_2%	2.6	1.9	1.2	1.1	2.5
Excess Air, percent	13.0	9.0	6.0	5.0	12.0
Smoke, Bacharach No.	0	(1)	2	2½	0
Heat Input:					
LPG, B.t.u./Hr.	67,350	67,350	67,350	67,350	67,350
Naphtha, B.t.u./Hr.	68,700	72,100	77,200	79,300	79,000
Total, B.t.u./Hr.	136,050	139,450	144,550	146,650	146,350
Heat Recovered, B.t.u./Hr.	113,800	118,200	122,500	125,200	123,900
Thermal Efficiency, percent	83.6	84.8	84.7	85.4	84.7

[1] Trace.

What I claim is:

1. The process for atomizing a liquid hydrocarbon which comprises directing a liquefiable petroleum gas in the gaseous phase in a confined stream under its own vapor pressure at storage temperature from a storage container wherein said liquefiable petroleum gas is in both gaseous phase and liquid phase to a nozzle, directing a liquid hydrocarbon to said nozzle in a separate confined stream, and mixing the liquefiable petroleum gas and the liquid hydrocarbon under pressure at the nozzle in such a manner that a portion of the liquefiable petroleum gas kinetic energy is transferred to the liquid hydrocarbon stream.

2. The process for atomizing a liquid hydrocarbon which comprises directing a liquefiable petroleum gas in the gaseous phase in a confined stream under its own vapor pressure at storage temperature from a storage container wherein said liquefiable petroleum gas is in both gaseous phase and liquid phase to a nozzle having a converging passage and a diverging passage, directing a liquid hydrocarbon to said nozzle in a separate confined stream, expanding the liquefiable petroleum gas in both the converging and diverging passages of the nozzle, and mixing the liquid hydrocarbon with the liquefiable petroleum gas in the diverging section of the nozzle in a manner to cause a portion of the liquefiable petroleum gas kinetic energy to be transferred to the liquid hydrocarbon.

3. The process of claim 1, wherein the liquefiable petroleum gas and the liquid hydrocarbon are stored separately.

4. The process of claim 2, wherein the liquefiable petroleum gas and liquid hydrocarbon are stored separately.

5. The process of claim 1, wherein the liquefiable petroleum gas and the liquid hydrocarbon are stored in contact with each other such that the liquefiable petroleum gas forms an upper gaseous phase and the liquid hydrocarbon and the liquefiable petroleum hydrocarbon form a lower liquid phase.

6. The process of claim 2, wherein the liquefiable petroleum gas and the liquid hydrocarbon are stored in contact with each other such that the liquefiable petroleum gas forms an upper gaseous phase and a mixture of liquid hydrocarbon and liquefiable petroleum gas forms a lower liquid phase.

7. The process for atomizing and burning a liquid hydrocarbon which comprises directing a liquefiable petro-

leum gas in the gaseous phase in a confined stream under its own vapor pressure at storage temperature from a storage container wherein said liquefiable petroleum gas is in both gaseous phase and liquid phase to a nozzle, directing a liquid hydrocarbon to said nozzle in a separate confined stream, mixing the liquefiable petroleum gas and the liquid hydrocarbon under pressure at the nozzle in such a manner that a portion of the liquefiable petroleum gas kinetic energy is transferred to the liquid hydrocarbon stream to atomize the same, exiting the atomized mixture from the nozzle at a kinetic energy sufficient to induct free oxygen-containing gas to the mixture, and igniting the mixture of free oxygen-containing gas, liquefiable petroleum gas, and atomized liquid hydrocarbon.

8. The process for atomizing and burning a liquid hydrocarbon which comprises directing a liquefiable petroleum gas in the gaseous phase in a confined stream under its own vapor pressure at storage temperature from a storage container wherein said liquefiable petroleum gas is in both gaseous phase and liquid phase to a nozzle having a converging section and a diverging section, directing a liquid hydrocarbon to said nozzle in a separate confined stream, expanding the liquefiable petroleum gas in the converging and diverging sections of the nozzle to accelerate said gas to supersonic velocity, mixing the liquid hydrocarbon with the liquefiable petroleum gas in the diverging section of the nozzle to atomize the liquid hydrocarbon, exiting the atomized mixture from the nozzle at a kinetic energy sufficient to induct free oxygen-containing gas therein, and igniting the mixture of free oxygen-containing gas, liquefiable petroleum gas, and atomized liquid hydrocarbon.

9. The process for atomizing a liquid hydrocarbon which comprises directing a liquefiable petroleum gas in a confined stream in the gaseous phase under its own vapor pressure at storage temperature from a storage container wherein said liquefiable petroleum gas is in both gaseous phase and liquid phase to a nozzle having a converging passage and a diverging passage, directing a liquid hydrocarbon to said nozzle in a separate confined stream, expanding the liquefiable petroleum gas to supersonic velocity in said diverging passage, introducing said liquid hydrocarbon into said gas stream to cause atomization thereof, and over-expanding said gas stream to cause interior shockwave formation and deceleration of the gas stream to cause further atomization of said liquid hydrocarbon.

10. The process for atomizing a liquid hydrocarbon which comprises directing a liquefiable petroleum gas in a confined stream in the gaseous phase under its own vapor pressure at storage temperature from a storage container wherein said liquefiable petroleum gas is in both gaseous phase and liquid phase to a nozzle having a converging passage and a diverging passage, directing a liquid hydrocarbon to said nozzle in a separate confined stream, expanding the liquefiable petroleum gas to supersonic velocity in said diverging passage, introducing said liquid hydrocarbon into said gas stream to cause atomization thereof, and under-expanding said gas stream to cause exterior shockwave formation and deceleration of the gas stream to cause further atomization of said liquid hydrocarbon.

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