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LIQUEFIED PETROLEUM GAS CONVERTER

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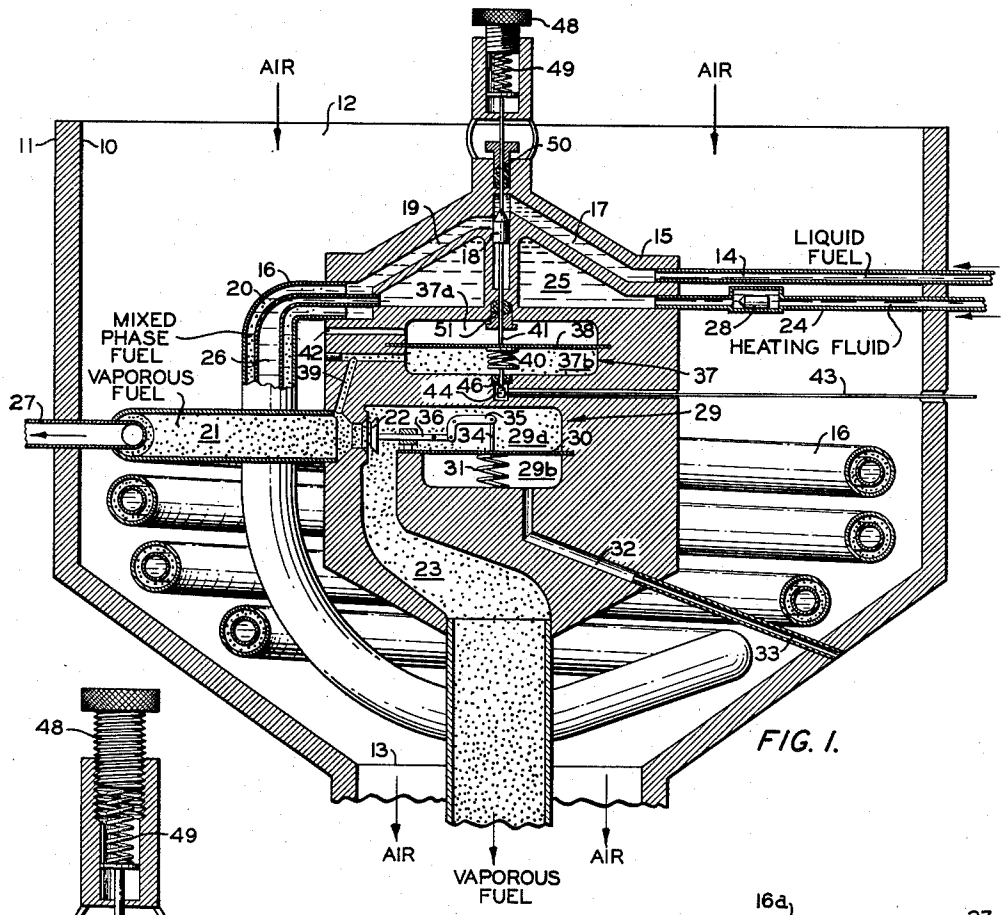


FIG. 1.

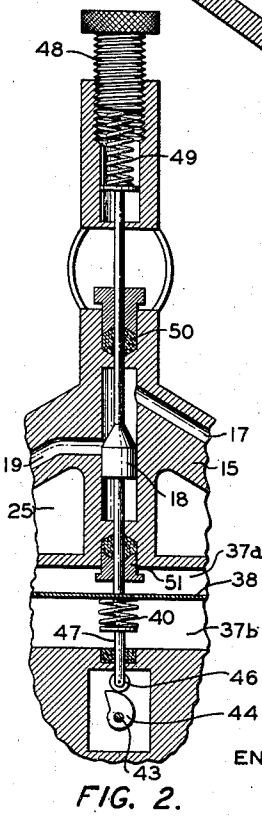


FIG. 2.

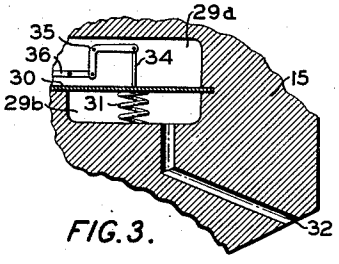


FIG. 3.

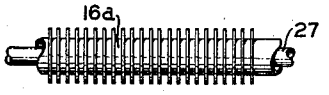


FIG. 4.

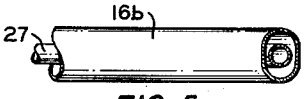


FIG. 5.

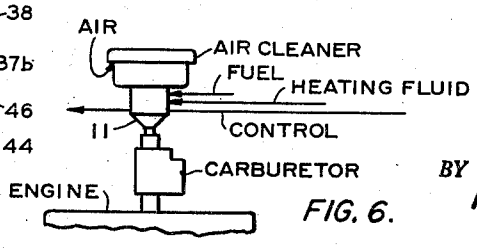


FIG. 6.

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LIQUEFIED PETROLEUM GAS CONVERTER

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6 Claims. (Cl. 62—1)

This invention relates to vaporizers for liquefied petroleum gases. In one of its more specific aspects, it relates to an apparatus for the vaporization of liquefied petroleum gas for fuel in an internal combustion engine. In another of its more specific aspects, it relates to an apparatus for vaporizing liquefied petroleum gas by utilizing the heat content of the air, used for combustion of the resulting vapor, supplemented by heat from a fluid when necessary.

Liquid hydrocarbon gases, like butane and propane, have been found to be satisfactory fuels in reciprocating internal combustion engines, including both normally aspirated and supercharged engines. This fuel is liquefied by compression and stored and carried in the liquid state under pressure and is converted to the vaporous state before use in the engine. The conversion of the fuel from the liquid state is usually effected by means of heat supplied to the liquid fuel in a heat exchange device, although a partial vaporization of the fuel is accomplished by passage of the fuel through a pressure-reduction stage such as a pressure-reducing valve. The expansion of the fuel through the pressure-reducing valve also results in the absorption of a large quantity of heat. Since the liquid fuel is seldom pure and contains water in very small amounts, ice very often accumulates in the pressure-reducing valve, unless heat is supplied at this point, and interferes with the expansion process. The heat required for the vaporization of the liquid fuel after the pressure-reduction step is usually supplied in a heat-exchange apparatus using either the hot cooling-water circulated through the engine or the exhaust gases of the engine as a source of heat.

Each of the following objects will be attained by at least one of the aspects of the invention.

It is an object of this invention to provide an apparatus for converting liquefied petroleum gas into a vaporous fuel for use in an internal combustion engine throughout a wide range of ambient air temperatures.

It is another object to provide a liquefied petroleum gas converter wherein the heat available in a fluid is provided to supplement the heat available in the air required for combustion of the fuel.

It is another object to provide a liquefied petroleum gas converter wherein the air supplied for combustion of the fuel in an internal combustion engine is cooled prior to combustion.

It is another object to provide a liquefied petroleum gas converter in which accumulations of ice in the pressure-reduction stages are prevented.

It is still another object to provide a liquefied petroleum gas converter for use in an internal combustion engine having automatic and positive means for preventing leakage of fuel when the engine is not operating.

Other objects and advantages will be apparent to one skilled in the art upon reading the disclosure of this invention, including the attached drawing wherein like elements are referred to by like numerals in the various figures.

Figure 1 is a vertical sectional view of a preferred embodiment of the invention.

Figure 2 is a detail view of the primary pressure-reducing valve of Figure 1.

Figure 3 is a sectional view of a portion of Figure 1 showing a preferred modification of the invention.

Figure 4 is a detail view of a modification of the heat-exchange tube.

Figure 5 is a detail view of a modification of the heat-exchange tube.

Figure 6 is a diagrammatic representation of the converter of the invention positioned on the carburetor of an engine.

The present invention provides an efficient and compact apparatus for the conversion of liquid hydrocarbon fuels of high vapor pressure, such as propane or butane, into a vaporous fuel for use in reciprocating internal combustion engines and the cooling of the air supplied to the engine for the combustion of the vaporous fuel by the heat absorbed in the vaporization process, to thereby increase the volumetric efficiency and reduce the octane requirement of the engine. Through use of the apparatus of the present invention, a vaporous fuel is obtained with a lower temperature than is obtained with previously known converted devices employing hot water or exhaust gases as the source of heat. The apparatus of the present invention also uses a hot circulating fluid to assure vaporization of the fuel under a broader range of ambient air temperatures than was previously obtainable and to prevent the accumulation of ice in the pressure-reduction stages of the apparatus. Because the vaporization of the liquid fuel is performed at reduced temperatures, the accumulation of gums or precipitated material in the apparatus is also decreased. In addition, the apparatus of the present invention possesses safety features which prevent the build-up of high pressures in certain parts of the converter and which prevent leakage of fuel from the converter during the periods of time the engine is not operating. The converter of this invention can be employed with either a spark ignited or a pilot-oil-ignited type internal combustion engine having either a normally aspirated or a supercharged type air-induction system.

One form of the invention for use with a normally aspirated type engine is shown in Fig. 1 of the attached drawing. The converter is located with its top attached to the air cleaner of the air-induction system. The air passes through the thermally insulated converter where it is cooled as it supplies the latent heat necessary to vaporize the liquid fuel. It then leaves the bottom of the converter and passes directly to the carburetor or manifold of the engine. The fuel enters the converter as a liquid under pressure and is reduced in pressure by passage through a primary pressure-reducing valve before passing through the heating tubes in heat exchange relationship with the air for combustion. The vaporous fuel then passes through a secondary pressure-reducing valve before flowing from the converter to the carburetor or manifold of the engine. Whenever operating conditions are encountered where the ambient temperature of the air is so low that the heat necessary for complete vaporization of the fuel is not available from the air, hot water from the engine cooling system flows into the converter and through a heating tube located concentrically within the heating tube through which the fuel flows in heat exchange relationship with the air. Also, whenever the air temperature is too low to prevent the accumulation of ice in the primary pressure-reducing valve, which is located in the air stream where the air normally prevents the accumulation of ice, hot water is admitted to the converter for reducing the formation of ice.

Referring now to Figure 1 of the drawing, **10** is the converter housing which is covered with a layer **11** of heat-insulating material to reduce heating of the air passing through the converter. Air is supplied to the

large end **12** of the converter from the air-induction system (not shown) and after being cooled by the vaporization of the liquid fuel, passes out the small end **13** of the converter directly to the carburetor or manifold of the engine (not shown). The liquid fuel under pressure flows by line **14** to the cylindrical regulator body **15** located along the vertical axis of the converter within the coil of heat exchange tube **16** which is arranged within the converter shell **10** so as to be in the path of air flow. The heat transfer between the warm air and the fuel can be improved by the attachment of radiating fins to heat exchange tube **16** designated as **16***a* in Figure 4. Within regulator body **15**, the liquid fuel flows by passage **17** to the primary pressure-reducing valve **18** where the pressure of the fuel is reduced to a pressure of, for example, about 1 to 12 p. s. i. g. before flowing by passage **19** into the annulus **20** of the concentric heat-exchange tube **16** attached to the regulator body **15**. Primary reducing valve **18** is located in the upstream section of regulator body **15** where heat is available from the incoming warm air to heat the elements of primary reducing valve **18** and prevent the accumulation of ice in the valve structure **18** and in passages **17** and **19**. The fuel is present in passage **19** in mixed phase but after passing through the complete length of the heat exchange tube **16**, is substantially converted to the vaporous phase at the outlet end of **21** of heat-exchange tube **16** attached to the downstream section of regulator body **15**. The vaporous fuel flows through secondary reducing valve **22** located in regulator body **15** into the vaporous fuel duct **23** conducting the fuel directly to the carburetor or manifold of the engine. The pressure of the vaporous fuel is reduced from a pressure of, for example, about 1 to 12 p. s. i. g. in heat exchange tube **16** to a lower pressure, for example, slightly subatmospheric pressure in fuel duct **23**.

A hot fluid, usually hot water from the cooling system of the engine, flows into the converter by line **24** and then into conical chamber **25** located in the upstream part of regulator body **15** surrounding primary reducing valve **18** and the connecting passages **17** and **19** to thus heat this section of regulator body **15** and thereby prevent the formation of ice. The hot fluid flows from conical chamber **25** into the center tube **26** of heat exchange tube **16** attached to regulator body **15**, passes through tube **16** in concurrent heat exchange relationship with the flow of fuel in the annulus **20** of tube **16**, and leaves the converter at the outlet end **21** of tube **16** by line **27**. The flow of the hot fluid to the converter takes place only when the temperature of the incoming air is insufficient to supply the heat requirement for vaporization of the liquid fuel or to prevent the accumulation of ice in the first pressure-reduction stage. The regulation of the flow of the hot fluid is provided by a thermostat **28** located in line **24** within the converter adjusted to open when the inlet air temperature becomes as low as, for example, 35° F., and to close when the air temperature becomes greater than, for example, 40° F. Many other types of temperature-sensitive regulator devices are known and can be used in place of the thermostat shown in this embodiment. Also, the regulator device can be adjusted to operate through other temperature ranges than those given above. If desired, the regulation of the flow of the hot fluid can be entirely by manual means without the use of thermostat **28**.

The flow of the vaporous fuel from the outer end **21** of heat-exchange tube **16** into vaporous fuel duct **23** through secondary pressure-reducing valve **22** provides pressure regulation for maintaining substantially constant pressure in vaporous fuel duct **23**. Reducing valve **22** also serves as a shutoff valve to prevent the leakage of fuel ino the engine when it is not in operation.

Situated adjacent to the inlet end of fuel duct **23** in regulator body **15** and directly opposite the discharge end **21** of heat exchange tube **16** is a pressure chamber **29**

in pressure communication with vaporous fuel duct **23**. Pressure chamber **29** is divided into two chambers by flexible diaphragm **30** which is spring-loaded by tension spring **31** located in lower chamber **29***b* of pressure chamber **29**. Chamber **29***b* is in pressure communication with the atmosphere by passage **32** in regulator body **15** and tube **33**, and the pressure in chamber **29***a* is the same as the pressure in the inlet end of vaporous fuel duct **23**. Movement of diaphragm **30** controls the degree of opening of valve **22** as transmitted by the mechanical linkage comprising connecting rods **34**, bell crank **35**, and valve stem **36**. With the occurrence of a momentary increase of pressure in duct **23** and, therefore, chamber **29***a*, diaphragm **30** is depressed outwardly to reduce the opening of valve **22** through the action of mechanical linkages **34**, **35** and **36**. When the engine is not in operation, tension spring **31**, acting through the mechanical linkages, keeps valve **22** shut and prevents the leakage of fuel. Upon starting the engine, the vacuum developed by the cylinders of the engine causes the pressure in chamber **29***a* to be reduced and valve **22** to open.

A pressure chamber **37** located in regulator body **15** below heating chamber **25** and divided into two pressure distinct chambers **37***a* and **37***b* by a flexible diaphragm **38**, provides means for detecting any build-up of pressure in heat-exchange tube **16** through pressure communication of chamber **37***b* with tube **16** by passage **39**. Diaphragm **38** is loaded by compression spring **40** which acts through control member **41** to force reducing valve **18** completely closed whenever the pressure in chamber **37***b* becomes a predetermined amount greater than the pressure in chamber **37***a*, which is in communication with the inlet air pressure by means of passage **42**. Thus, the opening of valve **18** is reduced whenever the flow through valve **22** is so low that the pressure increases in heat-exchange tube **16** to a dangerous value by flow through primary reducing valve **18** from the high pressure side of the valve. This safety device also prevents the build-up of pressure in heat-exchange tube **16** when valve **22** is completely closed during inoperation of the engine. This device is shown in Figure 2.

The power developed by the engine is regulated by the adjustment of the opening of primary reducing valve **18** by means of control shaft **43** extending through housing **10** of the converter into regulator body **15** and actuating cam **44** so as to vary the compression of spring **40** through roller **46** and linkage **47**. The degree of opening of valve **18** can also be regulated by means of screw control **48** so as to vary the compression of spring **49** which is compressed in opposition to spring **40**. Packing glands **50** and **51** confine the fuel pressure to the valve structure.

The apparatus of this invention requires some modifications for use with engines employing supercharged air-induction systems. In supercharging engines, the vaporous fuel in fuel duct **23** is under an elevated pressure and secondary reducing valve **22** and its mechanical linkages can be removed since this valve operates only with a reduced pressure in chamber **29***a* in comparison to the pressure in chamber **29***b*. In this modification, primary reducing valve **18** also serves for the final regulation of pressure of the vaporous fuel supplied to the engine through the movement of diaphragm **38** as detected by the changes in pressure existing at the outlet end of heat exchange tube **16** in comparison to the air pressure in the converter. Although this modification is primarily useful with a two cycle dual-fuel diesel engine, it can also be employed with a spark-ignited engine using either a supercharged or a normally aspirated air-induction system. Preferably, both pressure-reduction valves are used for normally aspirated spark-ignited engines because the pressure of the vaporous fuel in fuel duct **23** is below atmospheric pressure. In another modification employing supercharged air-induction systems, secondary reducing

valve 22 is used by removing atmospheric tube 33 so that passage 32 is connected to the discharge side of the air blower of the supercharger to provide a pressure greater than atmospheric pressure in pressure chamber 29b.

Numerous modifications of the apparatus of this invention can be devised without departing from the spirit and scope of this invention. For example, the outer shape of heat-exchange tube 16 can be elliptical instead of circular in cross section in order to reduce the pressure drop of the air flow through the heat-exchange coil. This modification is shown in Figure 5. Also, heat-exchange tube 16 can be constructed with only a portion of its length in heat-exchange relationship with inner tube 26 carrying the heating fluid in converter designs where the heat available from the air is sufficient for vaporization of the fuel. Furthermore, heat-exchange tube 16 can be arranged in the housing of the converter in other shapes besides a circular coil for improving the heat transfer between the air and the fuel.

In still another modification, the heat exchange coil can be formed by wrapping fuel line 16 around heating fluid line 26 so that fuel line 16 forms a helix with heating fluid line 26 running through the center of the helix.

Variations and modifications are possible within the scope of the disclosure of the present invention, the essence of which is the provision of a compact and efficient device, for converting liquefied petroleum gas into a vaporous fuel for an internal combustion engine, for cooling the combustion supporting air, and which provides a positive shut-off of the fuel when the engine is not in operation.

We claim:

1. A liquefied petroleum gas converter adapted for use in an internal combustion engine comprising a regulator body containing a liquid fuel passage therethrough, a first pressure-reducing valve in said passage, a heating fluid passage through said body adjacent said liquid fuel passage, means for controlling said first pressure-reducing valve in accordance with the ratio of the pressure downstream from said valve and the pressure in the inlet air duct hereinafter set forth, a vaporous fuel passage through said body, a second pressure-reducing valve in said vaporous fuel passage, and means for controlling said second pressure-reducing valve in accordance with the ratio of the pressure in said vaporous fuel passage and atmospheric pressure; a liquid fuel inlet line connected to said liquid fuel passage upstream from said first pressure-reducing valve; a heating fluid inlet line connected to a first end of said heating fluid passage; a valve in said heating fluid inlet line; a heating fluid line comprising a coil about said regulator body having one end connected to the second end of said heating fluid passage, and the other end terminating externally of said converter; a first vaporous fuel line having one end connected to said liquid fuel passage downstream from said first pressure-reducing valve, being concentrically disposed around said heating fluid line and having the other end connected to said vaporous fuel passage upstream from said second pressure-reducing valve; a second vaporous fuel line connected to said vaporous fuel passage, downstream from said second pressure reducing valve and adapted to be connected to the inlet of the internal combustion engine; and an air duct comprising a housing surrounding said regulator body and coil, open at both ends and having one end adapted to be connected to the engine inlet.

2. The converter of claim 1 wherein the first pressure-reducing valve control means is a diaphragm regulator having one side of the diaphragm in contact with the vaporous fuel downstream from the first pressure-reducing valve and the other side in contact with the inlet air; and the second pressure-reducing valve control means is a diaphragm regulator having one side of the diaphragm in contact with the vaporous fuel downstream from the second pressure-reducing valve and the other side in contact with said inlet air.

3. In an apparatus for converting liquefied petroleum gas into a vapor and feeding said vapor to an air inlet at a pressure less than inlet air pressure comprising pressure reducing means and heat supply means, the improvement comprising means for reducing the pressure of the liquefied petroleum gas to a predetermined value above inlet air pressure in indirect heat exchange relationship with the inlet air; means for passing a heated fluid in indirect heat exchange relationship with said pressure reducing means when the temperature of the inlet air reaches a predetermined minimum value; means for further reducing the pressure to a predetermined value less than inlet air pressure in indirect heat exchange relationship with the inlet air; means for passing reduced pressure gas to said means for further reducing the pressure; means for passing a heated fluid in indirect heat exchange relationship with said reduced pressure gas passing to said second named pressure reducing means when the temperature of the inlet air reaches a predetermined minimum value; and means for recovering gas from the outlet of said second named pressure reducing means at less than inlet air pressure.

4. A liquefied petroleum gas converter comprising a housing forming a conduit adapted to be connected to the carburetor of an internal combustion engine; a regulator body positioned in said housing so as to form an annulus between said housing and said regulator body for passage of air to said carburetor; a liquid fuel passageway positioned in said body; a first pressure sensitive pressure reducing valve positioned in said passageway and adapted to reduce the pressure of the fuel to a predetermined value above the pressure of the air in said annulus; a vaporous fuel passageway positioned in said body; a second pressure sensitive pressure reducing valve positioned in said vaporous fuel passageway and adapted to reduce the pressure of the vaporous fuel to a predetermined value below atmospheric pressure; a fuel conduit positioned in said annulus in heat exchange relationship with the air in said annulus having one end connected to the discharge of said first pressure reducing valve and the other end connected to the inlet of said second pressure reducing valve; and a vaporous fuel conduit means connected to the discharge of said second pressure reducing valve and adapted to supply vaporous fuel to the carburetor of an internal combustion engine.

5. An apparatus for converting a liquid fuel comprising liquefied petroleum gas from a supply maintained under superatmospheric pressure to a vapor at a pressure less than atmospheric which comprises a housing forming a conduit open at each end; a regulator body positioned in said housing so as to form an annulus between said body and said housing for passage of air therethrough; a liquid fuel passageway through said body; means for introducing liquid fuel to said passageway; a first pressure sensitive pressure reducing valve positioned in said passageway and adapted to reduce the pressure of the fuel to a selected value above the pressure of the air in said annulus; a heating fluid passageway through said body adjacent said liquid fuel passageway; a heating fluid line connecting the inlet of said heating fluid passageway to a supply of heating fluid; a temperature sensitive valve in said heating fluid line to allow flow of heating fluid when the air temperature reaches a predetermined minimum value; a heating fluid line having one end connected to the outlet of the heating fluid passageway and the other end terminating externally of the apparatus; a vaporous fuel passageway through said body; a second pressure sensitive pressure reducing valve positioned in said vaporous fuel passageway and adapted to reduce the pressure of the vaporous fuel to a predetermined value less than atmospheric pressure; a vaporous fuel line having one end connected to said liquid fuel passageway downstream from said first pressure reducing valve and the other end con-

nected to said vaporous fuel passageway upstream from said second pressure reducing valve, said vaporous fuel line adapted for indirect heat exchange with the heating fluid in said heating fluid line; and means for recovering vaporous fuel gas from the vaporous fuel passageway downstream from said second pressure reducing valve at a pressure less than atmospheric pressure.

6. A liquefied petroleum gas converter for use in an internal combustion engine comprising a regulator body containing a liquid fuel inlet line, a mixed phase fuel outlet line, a first pressure sensitive pressure-reducing valve located in said regulator body and connecting said fuel inlet line and said fuel outlet line, a heating fluid inlet line, a heating fluid outlet line, and a valve in said heating fluid inlet line; a vaporous fuel inlet line, a vaporous fuel outlet line, and a second pressure sensitive pressure-reducing valve located in said regulator body and connecting said vaporous fuel inlet line and said vaporous fuel outlet line; a coil of concentric tubes surrounding said regulator body having one end of the center tube connected to the outlet of said heating fluid line and the other end terminating outside the converter and having

one end of the outer tube connected to the mixed phase fuel outlet line and the other end connected to the vaporous fuel inlet line; and a housing surrounding said coil and regulator body and adapted to be connected to the fuel inlet of an internal combustion engine so as to comprise the air duct to said engine.

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