Eco-Friendly LPG Vaporization
by Efficient Use of Atmospheric Heat

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Abstract

Generally speaking an LPG vaporizer uses electricity or gas energy as its heat source and water or steam as its medium, however, they are a large burden for the environment. The use of electricity for vaporization can also be problematical for continuous LPG supply in emergency situations such as a power cut . To solve these problems we provide a vaporizer which does not need any fossil energy at all, including electricity. It contributes not only to environmental conservation but also to a stable LPG supply.

The ITO vaporizer utilizes the atmospheric temperature as its heat source. To utilize it more effectively, it has pipes incorporated with specially shaped fins made of aluminium alloy which has superior thermal conductivity to perform heat exchange. When we use the atmospheric temperature as our heat source, the vaporizer needs a large surface area for heat exchange and should therefore be a relatively big unit. However, by employing our Liquid Pressure Regulator which directly depressurizes and controls the liquid LPG we can decrease the liquid temperature at the vaporizer inlet (-25℃ in propane) and make the temperature difference from the atmospheric temperature large enough. Thus, we accomplish a downsizing of the vaporizer unit. The vaporizers must incorporate shut off systems to ensure that no liquid runs over to the downstream side in the case of overcapacity due to an overload, unusual weather conditions and so on. In our vaporizer, we employ a temperature triggered system to shut off the liquid at the inlet by sensing the temperature of the vaporized gas. This system resets automatically once the liquid LPG in the vaporizer is consumed and the temperature returns to the normal range. In addition, if a vapour gas bypass line is constructed at the outlet of the vaporizer, it enables a continuous supply of LPG without any interruption.

The above control features use only LPG from within the system for operation. No other energy, such as electricity, is used at all.

By utilizing atmospheric temperature as a heat source for the vaporizer, it contributes “zero” consumption of energy for vaporization and greatly lessens the environmental burden whilst producing energy and as a process will not generate any CO2 or other ‘Greenhouse’ gases. It should be noted also that the lifetime of this aluminium heat exchanger is semi-permanent and the high purity aluminium enables it to be recycled when the process is no longer required. It has been 30 years since we installed the first generation of these vaporizers and 700 units have been installed in Japan and other countries. They have contributed to energy conversion from a heavy oil or kerosene to LPG. It is now especially attractive and receiving much attention because it is possible to recoup the cost over approximately 4 years when we consider the great savings in running costs, such as electricity fees and others. With our latest developments in design and operation we are progressing to install it as a back-up system in districts where the electricity situation is not stable. Also, there are some installations where these are used as a full stand-alone vaporizer achieving an emergency back-up supply by LPG, as a decentralized distribution source of energy when the Natural Gas supply has been cut off.

By using this vaporizer, the environmental burden and running cost can become almost “zero”. In addition, it is possible to use during periods of emergency, such as disaster and as an independent device which works without other energy, including electricity. In conclusion, it contributes a ‘Green’ stable supply of LPG as a distributed source of energy.

Introduction

One of features of LPG as a distributed source of energy is that it can be transported and distributed easily and efficiently, and also be used anywhere without any geographical restrictions. Its flexibility is increased by its ability to be minimized in volume and large amounts supplied in cylinders and tanks.

To use LPG as an energy source for a small amount of LPG consumption, such as domestic usage, we use gas LPG vaporized in a cylinder/cylinders drawing vapour directly from them. In contrast, for the facilities which consume a large quantity of LPG for industrial usage, we have to install many cylinders to assure enough vaporization ability and they need a large space. In this case, we mount a vaporizer / vaporizers to decrease the number of cylinders and to install them in a smaller space. Recently, the bulk tank supply system, common in many parts of the world in which LPG is filled into a bulk tank directly by an LPG road tanker, has become widespread in Japan to increase efficiency of LPG distribution. Even in this case, sometimes the vaporization ability of LPG in a bulk tank is not enough. The installation of vaporizers to supplement this shortage is therefore also increasing.

Typically vaporizers consume electricity or gas etc. as their heat source and utilize water and steam as their medium. Consumption of these energy sources is a large burden for our environment and using electricity also brings a potential risk in that it affects LPG supply in the case of a power cut or other emergency. In addition, activities for the prevention of global warming and CO2 reduction are expanding all over the world. As one of the best solutions for these problems, we, ITO KOKI, provide a vaporizer which does not need any fossil energy, including electricity; at all and we contribute not only to environmental conservation but also to a stable LPG supply.

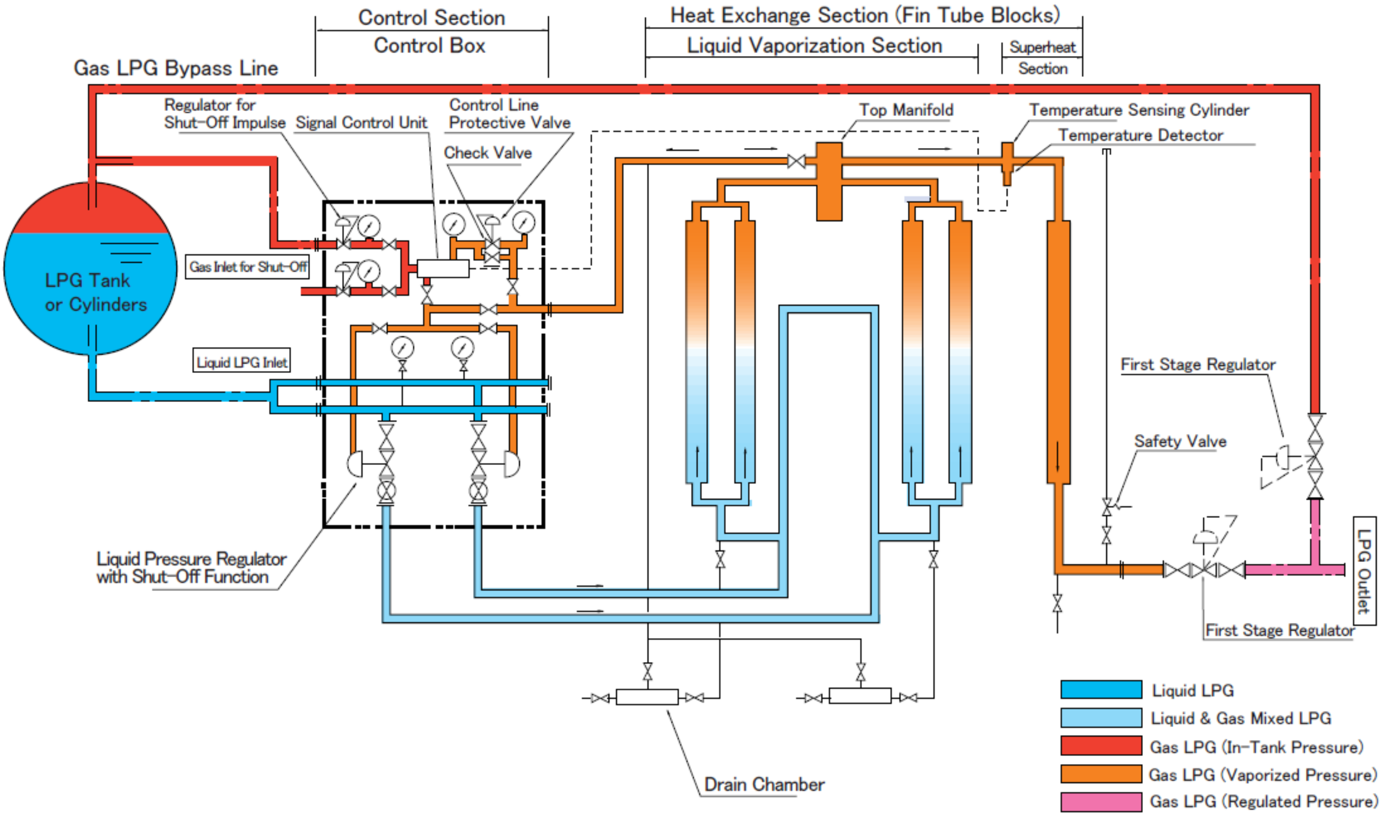
1. Basic Structure of the Vaporizer

ITO air heating type vaporizers consist of three main sections as follows:

- Firstly, the “Control Section” which controls and reduces liquid LPG and incorporates the liquid carryover protection system, which will shut off the liquid LPG if it runs over to the downstream side in case of overcapacity gas consumption due to an overload and so on.

- Secondly, the “Liquid Vaporization Section”, which vaporizes the low-temperature liquid LPG which is depressurized by heat exchanging with the atmospheric temperature.

- Lastly, the “Superheat Section”, which heats the low-temperature vaporized LPG to the level of the atmospheric temperature and passes it out for consumption.



1.1 Material for the Heat Exchange Section

To utilize the atmospheric heat efficiently as the heat source for the vaporizer, aluminium alloy, which has superior thermal conductivity; is employed as the material for the two heat exchange sections - “Liquid Vaporization Section” and “Superheat Section”. Also, since we designed the vaporizing pipes incorporating specially shaped fins, the heat exchange is performed more effectively.

In Japan, renewal of the steel fabricated heat exchange sections of the hot bath type electric vaporizer is recommended about every ten (10) years. The lifetime of this aluminium made heat exchanger is semi-permanent since the aluminium alloy has superior in corrosion resistance. In addition, since the recycling system for aluminium is very well-developed, it is easily recyclable when you eventually have to dispose of it

1.2 Vaporization Method

This vaporizer decreases the liquid LPG temperature at the vaporizer inlet by the use of Liquid Pressure Regulators which depressurize and control the liquid LPG. In other words, by depressurizing the liquid LPG at atmospheric temperature to 0.1MPa, 1 bar (gauge pressure), the temperature of the liquid LPG rapidly decreases. For example, C_3H_8 (propane) decreases to -25℃.

Moving this low-temperature gas & liquid LPG mixture to the heat exchange section makes the temperature difference from the atmospheric temperature large enough, thus we can accomplish a downsizing of the vaporizer unit. Since this air heating type vaporizer does not use a high temperature heat source we need to look at how to save space in the installation. Greater gas consumption requires more fin pipes which means the vaporizer needs a larger space for instillation. We overcome this and reduce the space by utilizing several means such as the design of the special shape fin pipes, fin pipe alignments based on ventilation efficiency and longer aluminium alloy fin pipes used for the heat exchange section – none of which affects transportation or vaporization ability.

1.3 Structure of Heat Exchange Section

The moisture in the atmosphere can build up dew condensation and form ice on the outside surface of fin pipes in the heat exchange section, caused by the heat exchange between the atmosphere and low-temperature depressurized LPG (i.e. with propane, about to -25℃). If this ice forms a hard coating on the surface of the heat exchange section the efficiency of heat exchange is drastically decreased. Continuous operation can produce this phenomenon, the efficiency deteriorates and can limit operating time. These problems are big issues for air heating type vaporisers to solve. In order to alleviate these phenomenons, we have designed the vaporizer to have a dual line structure in the vaporization section fin blocks. The control section which performs liquid decompression also has two lines. This dual line structure enables the system to change from the service side block to the reserve. The Heat exchange section is also divided into dual lines and we have made a set pressure difference between both liquid pressure regulators which are installed at each inlet.

The vaporization starts firstly from the service side block in the heat exchange section which is set at a higher pressure (the side at the higher set pressure is the service block and the other at lower set pressure is the reserve block.). When the amount of gas consumption increases the level of liquid LPG in the service block rises, the liquid LPG will flow away into the reserve block via the connection pipe between both blocks, and start to vaporize. The Service block is used preferentially and only in peak times will the reserve block be used together. So in the off-peak time when less LPG is consumed and the liquid does not flow away into reserve block, the ice formed on the reserve block is defrosted more effectively and it can reduce the efficiency deterioration. In the phase the Ice coating on the service block has been forming, by changing set pressures of the service and reserve side Liquid Pressure Regulators and changing over, the service side turns to reserve side and the ice formed on the block is defrosted, then the efficiency recovers. Moreover, we can keep a stable gas supply by changing the service side to the reserve at regular intervals according to amount of gas supply. It is easy to switch them over by moving the handles of the Liquid Pressure Regulators. In addition, it is possible to automatically switch over at a set time by installing a timer.

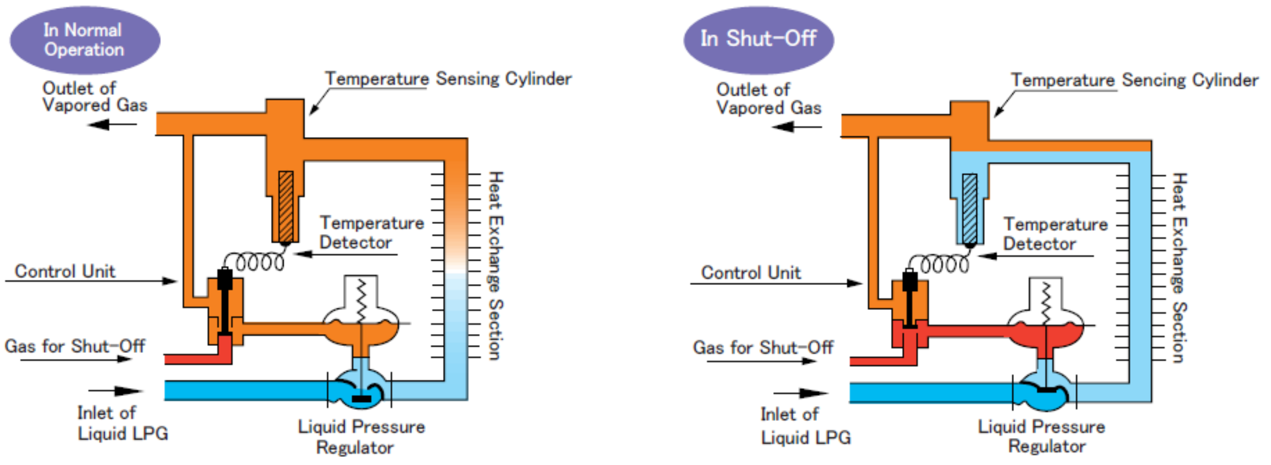
1.4 Safety System

1.4.1 Liquid Carryover Protection System

From a safety point of view, the vaporizers must incorporate shut off systems to ensure that no liquid runs over to the downstream side in the case of overcapacity due to an overload, unusual weather, and so on. This vaporizer is incorporated with a Liquid Carryover Protection System.

The system consists of the Liquid Pressure Regulator which functions also as a shut-off valve, a temperature sensing cylinder set at the outlet of the vaporization section (the inlet of the superheat section), a temperature detector which detects the temperature of the vaporized Gas in the temperature sensing cylinder, and a control unit which loads a pressure for shut-off to the liquid pressure regulator after receiving a signal (pressure) from the temperature detector.

When low-temperature liquid LPG which could not be vaporized in the liquid vaporization section due to overload, etc., flows into the temperature sensing cylinder at the outlet, the temperature detector in the cylinder responds, and sends a pressure signal to the control unit. This pressure signal drives the control unit mechanically to force the inner valve in the liquid pressure regulator to close by loading the vaporiser inlet pressure to it and this shuts off further liquid flow into the vaporization section.



When the system is activated, the gas supply is usually backed up by a gas LPG bypass line from cylinders (tank), and the liquid LPG remaining in the vaporizer is also vaporized and consumed via this gas line at the same time. Thus, this vaporizer can keep a stable gas supply without interruption. Once liquid LPG in the vaporization section is vaporized and consumed, the temperature of the temperature detector returns to the normal range, which drives the control unit again to release the shut-off status of the liquid pressure regulators.

Then, the liquid depressurize function recovers and restarts supply of liquid LPG to the liquid vaporization section. Therefore, this vaporizer can keep supplying LPG without any break. Because this vaporizer uses only gas pressure from cylinders (tank) for all the above controls, which all work without any other energy, such as electricity, it ensures a stable gas supply and safety even if a power cut etc. happens.

1.4.2 Safety Valve

This vaporizer is incorporated with a safety valve which can release LPG to a safe place and decrease the internal pressure if the pressure in the vaporizer rises more than the design pressure.

2 Additional Features

2.1 Stabilizing the Pressure in the Vaporizer at Less Than 1MPa (10 bar) during Shutdown

In Japan, there are various regulations in relation to LPG. The “High Pressure Gas Safety Act” covers when we use a product/vessel which may contain pressures of 1MPa (10 bar) or more to ensure safety. Vaporization of LPG within a vaporizer is considered as an “activity to manufacture a high pressure gas”, and the strict regulations deem that people using vaporizers to be “high pressure gas manufacturers” and this is of course a big burden for the gas consumers. However, the criteria of “consumption type vaporizers” is stipulated based on the judgement that if the vaporizer keeps the internal pressure less than 1MPa (10 bar). it may be recognized as an "activity to consume", but not an "activity to manufacture" As we have vaporizers complied with the criteria of 'consumption type vaporizer' we have succeeded in drastically reducing the burden on consumers.

We depressurize and vaporize the Liquid LPG to approximately 0.1MPa (1 bar), and also the attached cushion tank absorbs any internal pressure increase to prevent it rising up to 1MPa (10 bar) even when temperature of the liquid LPG remaining in the fin blocks of the vaporization section resumes and all liquid LPG is vaporized after gas consumption is stopped. Liquid amounts of residue in this cushion tank and its volume are minimized owing to the efficient heat exchange as we mentioned before. Thus, we offer the air heating type vaporizers with optimum design pressure considering local regulations and convenience for the users.

2.2 Hot Gas Circulation System to Expand the Range of Use in Cold Regions

Since this air heating type vaporizer performs heat exchange between the atmosphere and low-temperature LPG, -25℃ in the heat exchange section, the atmosphere moisture builds up dew condensation and ice on outside surface of the fin pipes. As the ice coating on the surface of the fin pipe builds up, ventilation to the fin tubes is obstructed and total heat transfer coefficient: [the heat transfer from the atmosphere to the surface of the fin pipe, heat conducting of inside fin pipe, and heat transfer efficiency from inside surface of fin pipe to liquid LPG combined]; decreases and then there is a decline in the vaporization ability. Usually ice coating is defrosted in part during breaks in gas consumption and the vaporizing ability is restored. However, it is difficult to defrost ice especially in cold regions due to low temperatures.

We have recently introduced a new system to use the vaporizer stably even under this situation.

The system consists of an air heating type vaporizer which is connected to the gas LPG supply line at the inlet of the vaporization section, a hot water circulation type small vaporizer which utilizes waste-heat from a factory, etc., and other valves and accessories including a flow limiter valve which limits the gas flow rate into the vaporizer etc..

Firstly we install the small vaporizer in parallel with, and set its supply pressure a little higher than, the vaporizing pressure of the air heating type vaporizer. The gas is connected to the Liquid inlet of the vaporization section of the air heating type vaporizer via the gas flow limiter valve. The hot gas generated and heated by the small vaporizer, which as mentioned is set at a little higher pressure than the vaporizing pressure of the air heating type vaporizer, flows into the heat exchange section of the air heating type vaporizer. The amount of flow is limited at a small quantity by the flow limiter valve.

Under normal situations, both this hot gas and the low-temperature liquid LPG from the air heating type vaporizer flow into the vaporization section together. However, in off-peak time, because the gas consumption quantity is small, the liquid LPG also does not flow and only the hot gas from the small vaporizer goes through the fin pipe of the vaporization section. As a result of this the ice formed on the outside surface of the fin pipes is effectively defrosted from inside. This then enables stable gas supply even in cold regions by preventing the air heating type vaporizer from decreasing its ability. As an example this system is used in the Hokkaido district in Japan where the outside temperature can decrease to minus 10 degrees Celsius.

3. Application of LPG, as a Decentralized Distribution Source of Energy with "Zero" Environmental Burden by Air Heating Type Vaporizer

Nowadays, the current main stream of LPG vaporizers are electrical and steam heating vaporizers which have more compact bodies and a lower initial cost compared with the air heating type vaporizer. However, this air heating type vaporizer is attracting attention because the total cost is lower when consideration is given to running cost[1].

It should also be noted that an installation as a back-up system in districts where the electric power conditions are not stable is also increasing. While the electricity supply in Japan was relatively stable previously, following sudden electricity shortages due to varying reasons including the latest accident of the Fukushima Daiichi Nuclear Power Station owned by the Tokyo electric power company, inquiries about air heating type vaporizer are increasing from factories and restaurants. In addition, the movement converting their energy source for equipment from a heavy oil or kerosene to gas is becoming more frequent, and we are encouraged to stimulate further demand of air heating vaporizers in cooperation with LPG distributors all over Japan. Since the first installation of the first unit in Japan 30 years ago, we have been contributing energy conversion from heavy oil or kerosene, as our 631 units in Japan and 23 in other countries of installation records shows. Our latest developments and re-designs have made these innovative installations even more effective and safe. We have re-developed and improved greatly a product which launched its first generation 30 years ago. Redeveloping, improving and innovating for the 21st century challenges.

4. Conclusion

In conclusion, by fully utilizing atmospheric temperature as a heat source for the vaporizer using all the above described technologies, this air heating type vaporizer accomplishes "zero" consumption of energy for vaporization without CO2 generation and greatly contributes to the Global LPG industry lessening the burden on the environment. In addition, these Super Ecorizers make it possible to provide a stable supply of LPG, a decentralized distribution source of energy, for emergency use at the periods of disaster as stand-alone devices which work without other energy, including electricity.

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[1] Running Cost: The thermal energy required to vaporize 1kg of LPG is approximately 100kcal. When converting to electricity, it is 0.116kW/kg (=100/860). When gas consumption per day is 1000kg, electricity consumption is 116kW/day.