Dec. 2, 1941. E. BRÄUER 2,265,110

METHOD AND APPARATUS FOR OPERATING POWER MOTORS WITH FUEL GASES OF LOW BOILING POINT

Filed Nov. 14, 1936 2 Sheets-Sheet 1

Fig. 1.

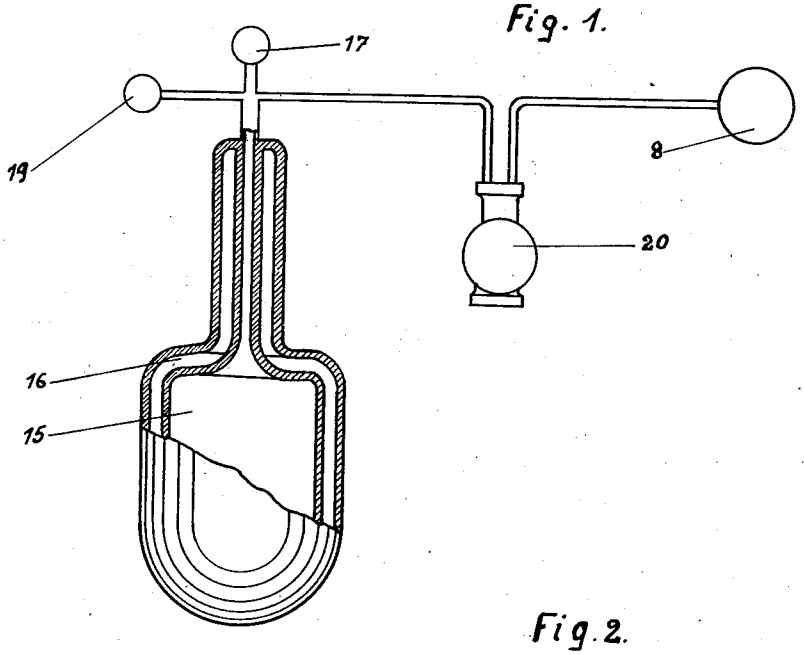
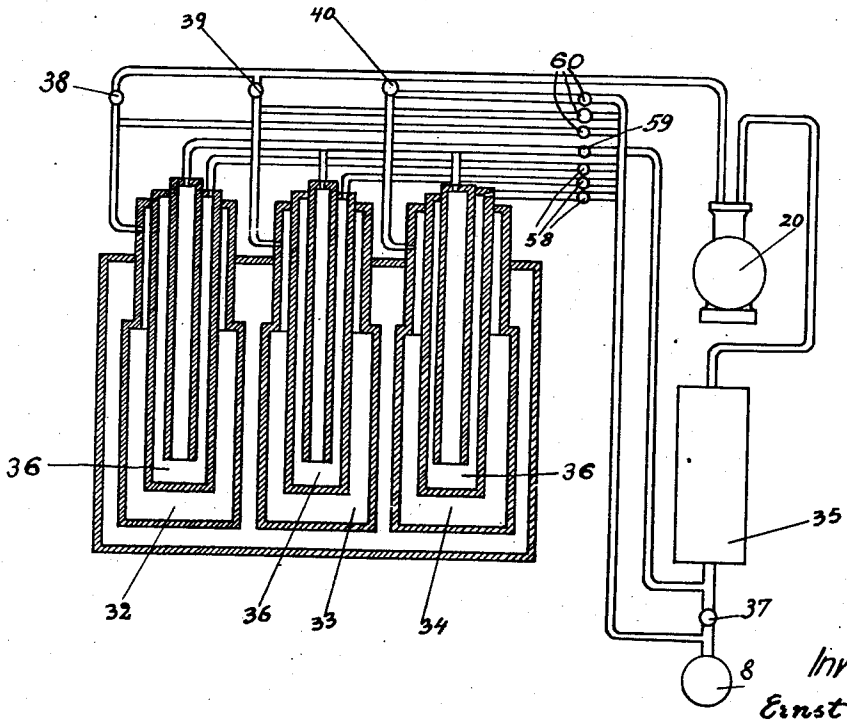


Fig. 2.



Inventor:
Ernst Bräuer
by Rudolf Hilgendorff
his Atty.

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Fig. 3.

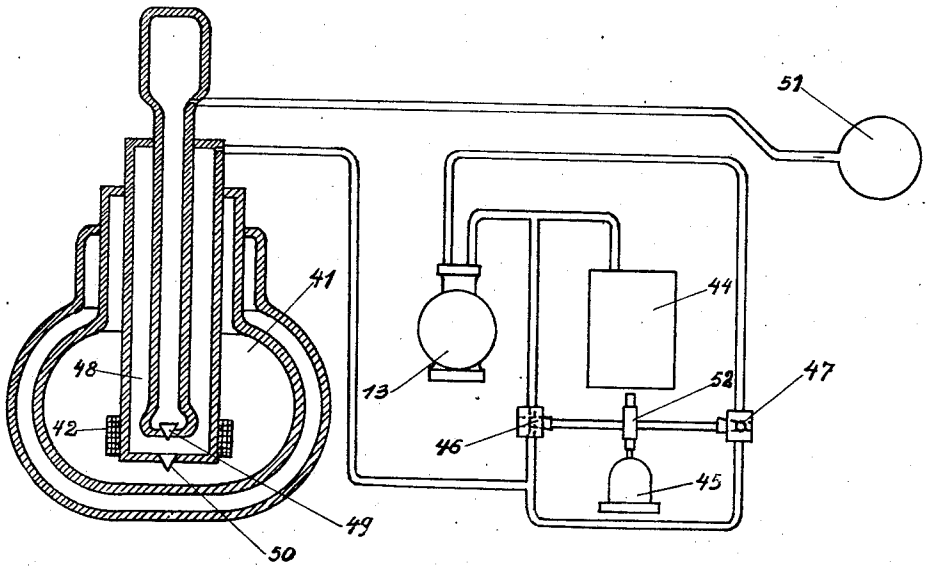
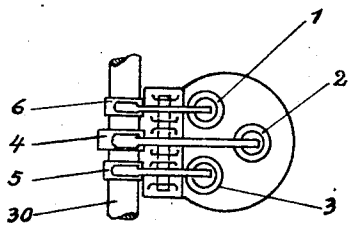
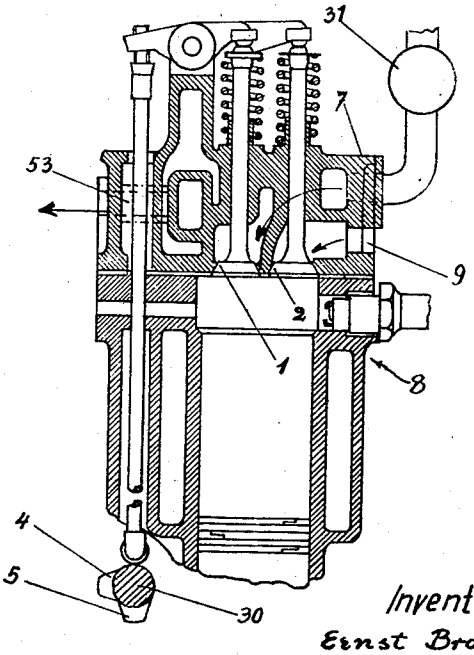


Fig. 5.

Fig. 4.





Inventor:
Ernst Bräuer
By Rudolf Hilgersdorf
his Atty.

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UNITED STATES PATENT OFFICE

2,265,110

METHOD AND APPARATUS FOR OPERATING POWER MOTORS WITH FUEL GASES OF LOW BOILING POINT

Ernst Bräuer, Vcigtsdorf, Germany

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In Germany April 5, 1933

3 Claims. (Cl. 62—1)

This invention relates to the use of fuel gases of low boiling point as fuel for engines. More particularly it has reference to means for and to a method of storing the gas and of supplying it to the motor. The invention further relates to apparatus for conditioning fuel in the application of a method of this invention.

The invention contemplates the use of fuels having low boiling points such as hydrogen, carbon monoxide, methane, and mixtures of such gases. In the following description the terms "gas" and "fuel" are intended to include any suitable fuels having a low boiling point and any suitable mixtures of such fuels. But the invention is primarily directed to gaseous fuel of a critical point of liquefaction below normal temperatures; i. e. gases which cannot assume or retain a liquid state at a normal temperature, no matter what pressure be applied.

In the past internal combustion engines have been fed with gases of low boiling point, i. e. with hydrogen, carbon monoxide, methane and so forth, and possibly with mixtures of such gases; and such gases in a liquid condition, while they were kept ready for use. In so far as I am aware, it has not been possible hitherto to retain these fuels in liquid condition, while the engine associated with the fuel tank has been idle, since the unavoidable leakage of heat into the container tends to develop dangerous pressures therein.

This invention renders it possible to feed internal combustion engines with the said gases from a supply kept in liquid or solid condition, without allowing a dangerous rise of the pressure of the fuel supply in general. More particularly no substantial rise over atmospheric pressure is to be permitted during the normal pauses in operation. Furthermore the normal working pressure of the tank is kept substantially lower than that of the atmosphere, preferably below the vapor tension of the contents at their boiling point. In this case a further lowering of the pressure by evacuation of gas will effect vaporization, and the consumption of heat due to vaporization finally lowers the temperature of the contents of the tank so far that they solidify.

This invention also makes provisions for difficulties experienced in the past with fuel storage of the kind here discussed during the pauses in operation which accompany the use of certain engines, so that a new possibility arises for operating engines on the Diesel principle with liquefied gases of the type mentioned.

One embodiment of the invention is as follows: The fuel is transported in the lowest possible subcooled liquid condition and stored in the same condition in large containers which are well insulated as regards heat. In certain cases the temperature may be lowered again by the withdrawal—e. g. pumping off—of gas. The withdrawn gas may be used in any desired manner, e. g. in heaters, furnaces, engines, or the like, it may be pressed into the network of a fuel gas supply system or it may be reliquefied.

Vehicles operating on land, air craft or water craft withdraw fuel from a storage tank into their heat insulated tanks. In spite of a heat increase the pressure in the vehicular tanks generally remains less than one atmosphere. The vehicular engines withdraw gas from the tanks, e. g. by means of the piston movement itself or by means of a gas pump. The temperature of the contents of the tank is caused to drop by the evaporation. During continuation of the operation heat must, therefore, be introduced into the tank. According to this invention, this heat is first supplied when the pressure has sunk far under one atmosphere, preferably below the vapor tension at which the fuel solidifies. In the latter case the contents of the tank are thus rendered solid. In normal operation, therefore, the application of a pre-compression of the fuel gas is necessary, i. e. a raising of its pressure to the charging pressure of the engine.

Heat may be supplied by a removal of a part of the heat insulation of the tank. Heating may also be affected by electricity, by the engine exhaust or the like. According to this invention heat may be supplied by leading the fuel gas through the tank by means of a conduit after the gas has been compressed. This offers the advantage that no condensation of moisture or carbonic acid or the like can take place at the heating surfaces. It is not objectionable if the compressed gas condenses again in the said heating conduit. There is no danger that said gas solidifies, because it is at a much higher pressure.

In a preferred embodiment of the invention the supply of heat is automatically cut in and cut off. This may for instance be effected by an electro-magnetic device which is manometrically controlled and removes and replaces a section of the heat insulation of the tank, controls an electric heating current, or operates a cock in an exhaust gas conduit or in the said conduit for the compressed fuel gas.

Apparatus by which a method of this invention may be put into practice is illustrated diagram-

matically in the accompanying drawings, in which:

Each of the schematic, partly cross-sectioned views of Figs. 1, 2 and 3 illustrates a modification of the invention.

By way of a schematic top view and of a cross-sectioned elevation Fig. 4 and Fig. 5 show details of the general arrangement for adaption of the invention to internal combustion engines.

Similar numerals refer to similar parts throughout the various views:

In Fig. 1 the tank 15 is provided with a jacket 16 for heat insulation and a pressure gauge 17. A suction pump 20 withdraws fuel from tank 15 and supplies it to an engine 8. A safety valve 19 is included in the system.

Insulation of the tank may be effected by evacuating the jacket 16.

In the embodiment of Figs. 4 and 5 the fuel gas is supplied to an internal combustion engine at a low, uniform pressure which is maintained by the reducing valve 31 even when the pressure in the tank has been raised by heating. The engine is provided with two separate intakes 7 and 9 for fuel gas and air, which are controlled by valves 1 and 2, respectively. A valve 3 is provided for the exhaust passage 53. A cam shaft 30 and cams 4, 5 and 6 control the valves and are arranged so that at the beginning of the charging stroke, pure fuel gas at low pressure is sucked in until the cylinder contains the necessary amount of fuel gas. The air supply is then released and raises the pressure in the cylinder roughly to atmospheric pressure. A good mixing of fuel gas and air for combustion may be obtained by suitable means, preferably by suitable formation of the inlet channel.

It is not necessary, that the suction means, e. g. pump 20, exclusively performs the work necessary for removing from the storage m ans, e. g. tank 15, all fuel required for the operation of an internal combustion engine. By merely warming up the tank or part thereof, fuel contained therein is raised to a pressure above that of the atmosphere, so that it flows under its own pressure to the internal combustion engine. But such a process can only be of practical usefulness, when at the same time a substantial proportion of the contents of the tank are retained at such a low temperature or pressure, that the said proportion is capable of sufficiently cooling the warmed part of the contents of the tank and of reducing them to a pressure which does not involve any danger, after the internal combustion engine has been stopped and does not require any more fuel. This is illustrated by the first embodiment shown in Fig. 2: The tank is subdivided into several part tanks or sectional compartments 32, 33, 34, which are well insulated externally, and in certain cases also in respect to each other. In most of the compartments the gas is in a subcooled fluid or solid condition. The compartment, however, from which the withdrawal takes place is heated to such a degree, that the pressure is above atmospheric pressure and the gas flows over to the internal combustion engine, and that the pump is subjected to a substantial load only at the beginning of the operation. The heating of the one of the compartments, from which the fuel is to be withdrawn, is effected in the example illustrated in the drawings by the withdrawn fuel, after such withdrawn fuel has absorbed heat, the withdrawn and heated fuel being circulated by means of a suitable conduit through or around the compartment, which is to be heated. The heating of the withdrawn fuel takes place, for instance, in the container 35, which has a surface sufficiently large to allow the passage of the desired amount of heat from the environments into the container 35. When cock 37 is closed and cock 58 opened, the fuel withdrawn by the pump 20 and warmed up in container 35 passes through the heating unit 36 depending into the compartment 33 of the tank and heats the contents of this compartment 33, so that their pressure rises above that of the atmosphere and they will flow in sufficient quantity to the internal combustion engine 8, either directly or by way of the pump. The return tube of the heating unit 36 descends to a point near the bottom thereof, so that gas arriving from container 35 is guided up around said tube in heat transfer relationship with the outer wall of the depending heating unit 36 before it returns to engine 8. Similar heating units having analogous connections are provided in the other compartments 32 and 34 which are assembled with compartment 33 in a common insulating enclosure.

During pauses or intervals between successive operations of the engine the pressure in the compartments might rise more than permissible. As a safeguard the admission of heat may suitably be checked, as for instance illustrated in the arrangement of Fig. 2. There the supply of heat ceases of itself in the stoppage of the operation, since gas no longer flows to the internal combustion engine 8. Nevertheless the vapor space of the compartment 33 should be placed into communication with the other compartments 32, 34 on each interruption of operations or in case the highest permissible pressure is exceeded. Then a portion of gas overflows from the last used compartment 33 into the other compartments and there it is condensed. The opening of cock 37 and of the connecting cocks 38, 39, 40 between the compartments can be effected automatically by the pressure in the compartments, for example by manometrically controlled switches in the circuits of electro-magnets which turn the cocks. Such control means may be of any known form and as no claim is made to these means per se, they have not been illustrated. The arrangement of Fig. 2 offers the following as instances of group operation:

(1) With the exception of cocks 60 all cocks and valves are closed: Fuel feeds directly from tanks 32, 33 and 34 to engine 8.

(2) With the exception of cocks 37, 38, 39 and 40 all valves and cocks are closed: Fuel is withdrawn by pump 20 from the tanks and passes through container 35 to engine 8.

(3) With the exception of cocks 37 and 60 all valves and cocks are open: Fuel is withdrawn by pump 20 from the tanks and passes by way of container 35 and cocks 59 through preheating units 36; and then through cocks 58 to engine 8.

A fourth modification of the invention is illustrated by Fig. 3, as follows: The tank is preferably subdivided into compartments in the manner just explained with Fig. 2. Of these only the compartment 41 is illustrated. To this compartment heat is supplied, for instance, by the electric heating coil 42, in the amount necessary to convert its solid contents into the liquid state. The fuel is withdrawn in this liquid condition. The pump 13 pumps gas out of the gas chamber of the compartment 41, and forces it into the container 44. An electromotor 45 turns the control cocks 46 and 47 by means of a worm and

worm wheel 52, so that gas enters upon the dip space 48 alternately at a higher and a lower pressure. By means of the lift valves 49 and 50, this space acts as a liquid pump and delivers liquid fuel to the engine 51:

When the cock 46 is closed and the cock 47 is open, the dip space 48 is connected with the suction side of the pump 13. The contents of the compartment 41 then flow through the valve 50 into the space 48. When, conversely, the cock 46 is opened and the cock 47 closed, the dip space 48 is connected with the pressure side of the pump 13 and the contents of the space 48 are forced through the valve 49 into the pipe of the engine 51. Of course another type of pump may be used in order to deliver the liquid from the tank 41.

The fuel is either vaporized outside of the tank before being supplied to the engine, or it is burnt in a solid injection type engine.

I claim:

1. Method of providing normally gaseous fuel for the operation of an internal combustion engine comprising insulatedly storing a supply of the gas in a non-gaseous state under partial vacuum by sub-cooling, applying heat to said supply during and for operation of the engine in order to drive off the fuel required for such operation, and establishing after such operation communication of said supply with another similar supply which is under partial vacuum in a sub-cooled state, so that a partial vacuum is restored in said first supply.

2. A tank for storing sub-cooled normally gaseous fuel in a non-gaseous state in combination with an internal combustion engine in which the fuel is to be used, comprising compartments combined in said tank and heat-insulated outwardly and relatively to each other, and a pipe system by which each of said compartments may be connected separately to said engine for operation of the engine and by which the contents of the compartments are placed into exchange relationship with each other when the engine is not in operation.

3. A tank for storing sub-cooled normally gaseous fuel in a non-gaseous state in combination with an internal combustion engine in which the fuel is to be used, comprising compartments combined in said tank and heat-insulated outwardly and relatively to each other, heating means separately applicable to each of said compartments, and a pipe system by which a heated compartment may be connected separately to said engine for operation of the engine and by which the contents of the compartments are placed into exchange relationship with each other when the engine is not in operation.

ERNST BRÄUER.