Dec. 27, 1949 H. F. KING 2,492,485

INJECTION SYSTEM FOR INTERNAL-COMBUSTION ENGINES

Filed Feb. 12, 1945 2 Sheets-Sheet 1

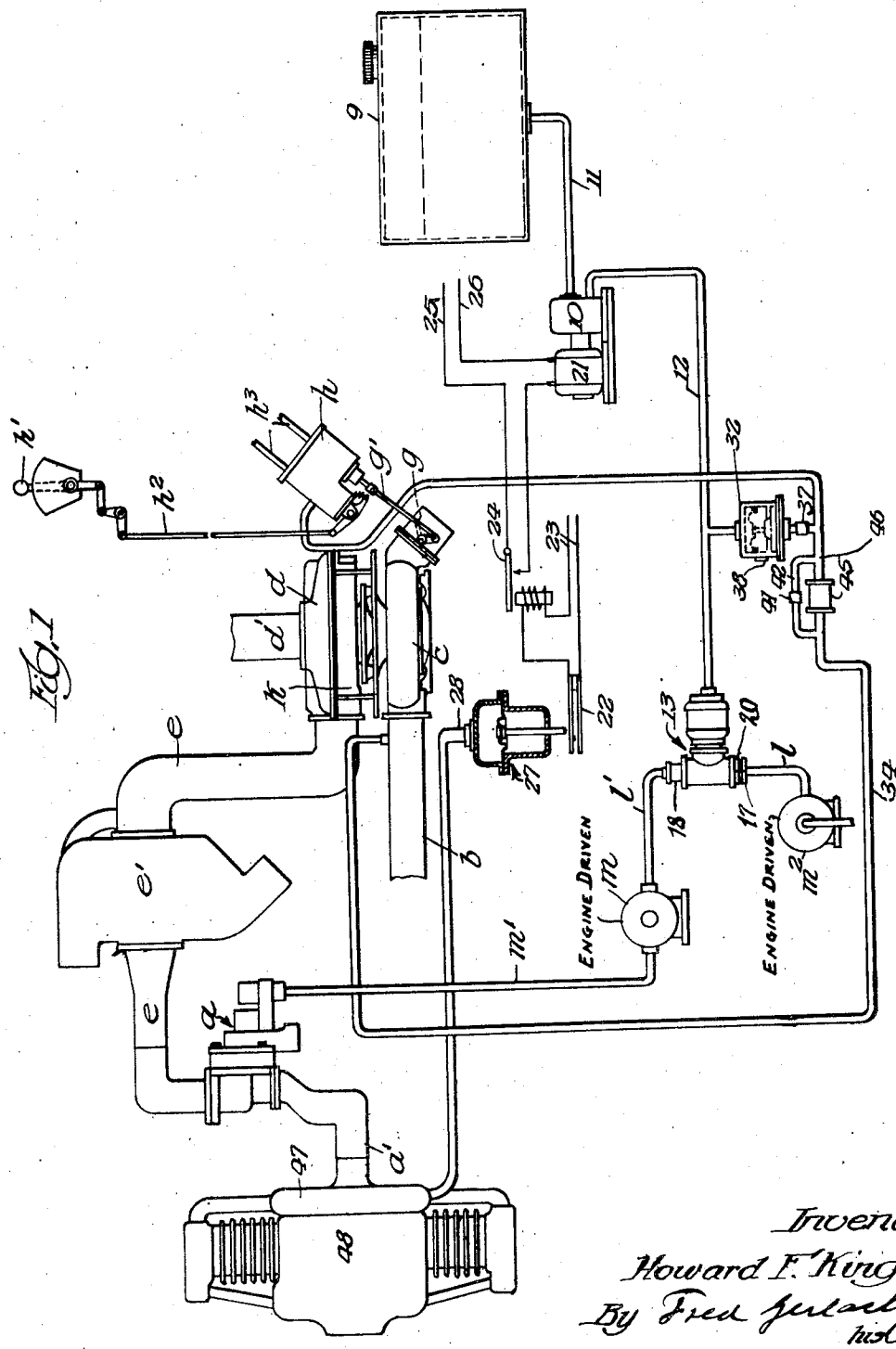

Fig. 1

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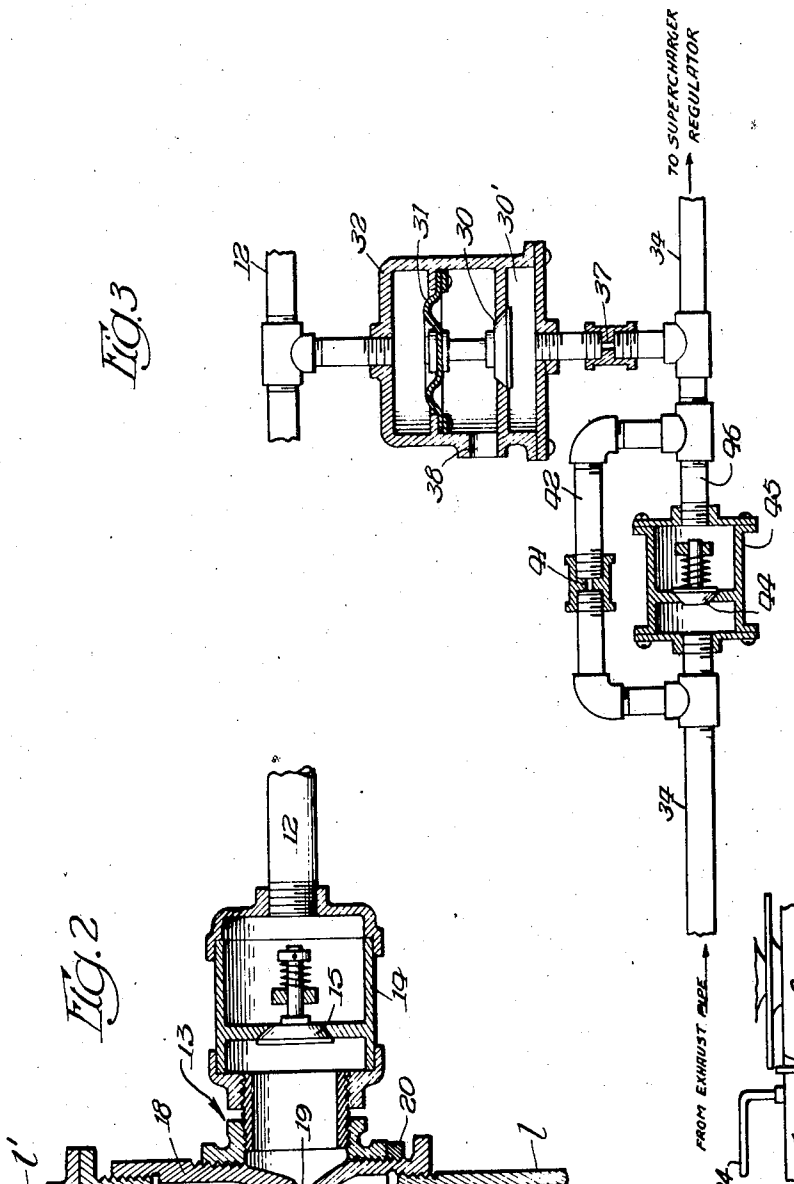

Fig. 3

Fig. 2

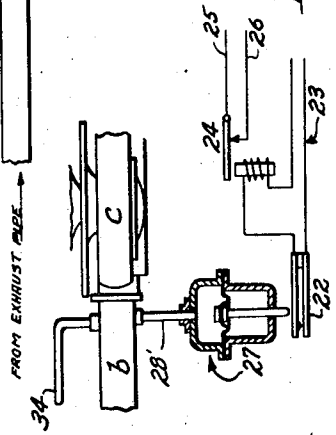

Fig. 4

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INJECTION SYSTEM FOR INTERNAL-COMBUSTION ENGINES

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17 Claims. (Cl. 60—13)

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The invention relates to apparatus for supplying a supplemental liquid, usually an anti-detonant, to the fuel delivered to internal combustion engines.

In the operating of supercharged internal combustion engines used on aircraft it has been found advantageous to inject a supplemental liquid, such as water or other anti-detonant, to the fuel delivered to the carburetor when the engine is operated at predetermined high speeds for take-off, climbing or other emergency operations.

One object of the invention is to provide an improved system for introducing the supplemental liquid into the fuel line prior to entry into the carburetor and which can be selectively controlled by the pilot through the same means used for starting and stopping the turbo-supercharger.

Another object of the invention is to provide an improved system for injecting supplemental liquid to the fuel by which said liquid will be thoroughly mixed with the fuel in transit to the carburetor.

Another object of the invention is to provide an improved injection system for supplemental liquid to the fuel which includes a reservoir which contains the liquid which is not under pressure and an automatically controlled pump for drawing the liquid from the reservoir and forcing it to the fuel for safe operation when the supplemental liquid contains an explosive constituent such as alcohol which is added to the water to lower the freezing point thereof to prevent freezing.

A still further object of the invention is to provide an improved injector system for supplemental liquid to the fuel in which the speed of the supercharger is automatically increased when the injection system becomes operative.

Other objects of the invention will appear from the detailed description.

The invention consists in the several novel features hereinafter set forth and more particularly defined by claims at the conclusion hereof.

In the drawings:

Fig. 1 is a diagrammatic view of the equipment for an internal combustion engine embodying the invention.

Fig. 2 is a section of the mixing valve for the supplemental liquid and the fuel.

Fig. 3 is a detail, partly in section, of the vent-valve and connections for bleeding pressure from a connection communicatively connected to the exhaust pressure line used for controlling the turbo-supercharger and the anti-detonant pressure pipe.

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Fig. 4 is a detail of a modification in which the diaphragm for controlling the switch for the motor which operates the pump for the detonant is controlled by the pressure in the pipe for the exhaust gases from the turbo-supercharger.

The invention is exemplified with equipment for an internal combustion engine which comprises: a carburetor *a* from which the combustible mixture is delivered to the engine cylinders in any suitable manner; a pipe *b* which is connected to the exhaust manifold or forms an extension thereof, through which exhaust gases flow from the engine cylinders; a turbo-supercharger which includes a turbine *c* driven by exhaust gases from pipe *b* and an air impeller or compressor *d* driven by said turbine; an air intake *d'* for the impeller; a duct *e* between the discharge side of impeller housing *d* and the air intake side of the carburetor; an inter-cooler *e'* included in duct *e*; a gate *g* at the discharge terminal of the turbine *c* by which the volume of the exhaust gases flowing through said turbine can be controlled for varying the speed of the impeller in housing *d* and the volume of air flowing through duct *e* to the carburetor; a supercharger-regulator *h* which is adapted to shift the gate *g* through a link and crank connection *g'* which is connected by pipes h^3 to oil under engine-system pressure for rendering the regulator responsive to such pressure; a tube **34** between the exhaust pipe *b* and the regulator *h* for rendering the regulator responsive to variations of pressure in the exhaust pipe *b*; and lever *h'* shiftable by the pilot or operator, and a connection h^2 operable by lever *h'* for rendering the regulator operative for regulated control of the speed of the turbine and rendering it inoperative because of the by-passing of the gases through the tailpipe rather than the passing thereof through the wheel of the turbine; a supply line *l* for liquid fuel to which the fuel is delivered by a booster pump m^2; an engine driven pump *m* connected to line *l'* for delivering the fuel to the carburetor *a*; and a tank or reservoir **9** for a supply of anti-detonant, such as water or other suitable mixture, for selective operation of the engine therewith when engine powers in excess of normal are desired, for example, during take-off or climbing, or emergency operations of aircraft engines.

The anti-detonant liquid may be water, or water mixed with alcohol for high altitude flying, or with a detergent. Zeolites are detergents of the type well known in the art, but other substances which readily soften hard water by reason of their base exchanging properties or hydrated

alumina silicates, both natural and synthetic, may be employed. This liquid from tank 9 is delivered to the fuel supply line l' by a suitable pump 10 which has its intake connected to draw liquid through a pipe 11 from supply tank 9 and its discharge connected by a pipe 12 to a mixing valve 13 which is connected to the fuel supply line l. The mixing valve 13, as shown, is located ahead of the carburetor to effect mixing of the anti-detonant with the fuel prior to entry into the carburetor and thereby effecting a beter distribution of the anti-detonant. Former methods for providing anti-detonant include feeding the anti-detonant directly into the intake manifold. This results in poor distribution, some cylinders getting more than others, consequently resulting in overheating. Another method was to feed directly into the cylinder intake valve ports; the system for doing so is very complicated and furthermore it is difficult to control the amount of anti-detonant that is fed to each cylinder. The pump 10 may have a capacity of 200 gallons per hour at a pressure ranging from 2 to 20 pounds. The mixing valve 13 comprises a casing-section 14 which contains a check-valve 15 for preventing the flow of fuel from line l into the pipe 12 when there is no pressure in pipe 12. The mixing valve comprises a casing-section 16, containing an annular inlet member or sleeve 17 which is coupled to the pipe l from the booster pump m^2 and an annular outlet member or sleeve which is coupled to the pipe l' between valve 13 and pump m. The contiguous ends of members 17 and 18 are annular and tapered and have an annular space 19 between them for producing a jet action by which water from casing 16 will be entrained with the stream of fuel flowing to pump m. This construction provides a valve whereby the water or anti-detonant liquid will be substantially thoroughly mixed with the liquid fuel in transit to the pump m. Member 17 is screw-threaded to casing-section 16 and to pipe l so it can be adjusted to and from member 18 for varying the area of the annular space 19 and the volume of water entrained with the fuel. A lock nut 20 is provided for securing member 17 in its adjusted position. This mixing valve insures uniform and thorough mixing and prevents the feeding of alternate slugs of water and fuel to the engine. The fuel and anti-detonant are additionally mixed in passing through the engine-driven pump m.

Pump 10 is driven by an electric motor 21 which is automatically controlled by the pressure of the charge in the intake manifold 47. The motor-operating circuit includes conductors 25, 26 and a relay operable switch 24. The coil of relay switch 24 is included in an electric circuit 23 which also includes a switch 22 for closing said circuit to actuate the relay switch 24. A pressure responsive device 27 which may be of the diaphragm type, is connected by a pipe 28 to the intake manifold 47 so that the diaphragm will be responsive to a predetermined increase in pressure in said manifold and is provided with a stem for closing switch 22 and causing the operation of motor 21 and pump 10 to deliver liquid from tank 9 to mixing valve 13. Device 27 is non-responsive to fluctuations of pressure in manifold 47 during the operation of the engine 48 at normal powers, so that it will close the circuit and cause the operation of motor 21 and pump 10 only when said pressure is selectively exceeded. When it is desired to supply water to the fuel the pilot will

shift lever h' slightly beyond its normal working range to cause the regulator h to shift gate g to increase the exhaust gas flow through the turbine c of the supercharger for increasing the speed of the supercharger. This enables the pilot to control the delivery of water to the fuel by the manipulation of the lever h' which controls the regulator h for the turbo-supercharger. In practice, an increase of pressure in the manifold 47, for example, approximately one inch mercury absolute above the normal range of pressure can be utilized to control the operation of the means for delivering the water to the fuel and this can be done by the same lever or instrumentality which is used to render the regulator operative and inoperative.

The liquid fuel is automatically leaned by the displacement of a volume of the liquid fuel with a volume of anti-detonant or water.

To cause supercharger c to operate beyond its normal speed the invention includes a bleed-valve 32 which is responsive to the pressure of water in the pipe 12 through which it flows to the mixing valve 13. The bleeding operation causes a reduction in the actuating pressure for turbo control h, which will cause supercharger c to speed up until an increase in intake manifold pressure equal to the amount of pressure drop due to the bleed action of valve 32 is obtained. The bleed valve 32 comprises a chamber 30', a vent 38, and a diaphragm 31 for moving valve 30, the diaphragm 31 being operable in response to the water pressure in the pipe 12. A metering orifice 37 is connected to the bottom of valve 32. An increase of pressure in the pipe 12 while water is flowing to the mixing valve opens a line or pipe 34 to atmosphere through the metering orifice 37 and vent 38 which pipe 34 is connected at one end of the tail pipe b of the exhaust system and to the supercharger regulator h at its other end. The pressure bled from this line is dependent upon the excess boost above maximum normal power wanted.

The means for bleeding the line comprises, in addition to the injection water operated valve 32 and the metering orifice 37 which are interposed between exhaust pressure tube 34 and the water pipe 12, a metering orifice 41 with a parallel by-passing altitude safety valve 45, serially connected into exhaust pressure tube 34. When valve 30 is opened by the pressure in pipe 12 acting against the bellows diaphragm some of the exhaust pressure in pipe 34 is bled off through metering orifice 37 into chamber 30' of valve 32 and out into the atmosphere through port 38. Before the exhaust gases in pipe 34 reach orifice 37 they are metered through a primary metering orifice 41 in by-pass pipe 42, said orifice 41 acting as a restrictor to limit the volume flow of gases into that section of pipe 34 which is connected to the supercharger regulator h, so that a relatively small bleed opening in orifice 37 will suffice to accomplish the required pressure drop before the exhaust gas pressures reach the supercharger regulator h. In order to prevent excessive supercharger speeds during high altitude operation, the by-pass altitude safety valve 45 is introduced into the bleeder system, said by-pass valve 45 comprising a housing containing a spring loaded poppet valve 44. During high altitude operation the absolute pressure in the exhaust pipe and the turbo supercharger control pipe 34 remains substantially the same as at low altitude operation; however the atmospheric back pressure acting against orifice

37 through port 38 when valve 30 is open is greatly reduced so that there is a great pressure differential between the two sides of the metering orifice 37 which results in increased bleeding off of pressure delivered to the supercharger control beyond the desired amount, thereby effecting undesirable supercharger speeds. By-pass valve 44 prevents this condition by causing spring loaded poppet 45 to open and thereby allowing additional exhaust gas to be delivered to bleed orifice 37, and thus maintaining substantially equal pressure on the supercharger regulator *h* at all altitudes.

The operation will be as follows: In the operation of the engine for aircraft at normal speeds, for example at optimum or cruising speed, the lever *h'* will be set in its normal operating position by the pilot to cause the regulator *h* to control the supercharger so that the pressure of the gases in intake manifold 47 will be insufficient to shift the diaphragm in the pressure responsive device 27, switch 22 will remain open, the relay switch 24 for the circuit for operating motor 21 will be open, the pump 10 will be idle, and no water will be pumped from tank 9 to the mixing chamber 13 or to the fuel delivered to the carburetor *a* by pump *m*. There will be no water pressure from pipe 12 against diaphragm 31 so that vent-valve 30 in casing 32 will be closed and there will be no bleeding of pressure from the pipe 34 and no increase in supercharger speed. The engine will then operate without anti-detonant or water.

During take-off, or a climb of the aircraft, the supercharger is controlled to operate above normal speed. For this purpose the pilot manually shifts lever *h'* beyond its normal operating position to control the regulator *h* to shift gate *g* for an increase of approximately one inch of mercury absolute, in the pressure of the intake manifold 47. This will increase the speed of the supercharger and the amount of air delivered to the carburetor *a*. This increase in the speed of the turbo-supercharger will produce an increase of pressure in the intake manifold 47 and pipe 28, which will act on the diaphragm of the pressure responsive device 27 to close the circuit 23 which energizes the coil of the relay switch 24 which closes the motor circuit. Motor 21 will then drive pump 10 to force water from tank 9 via pipe 12 and under pressure to the mixing valve 13 and through check valve 15 to the annular space between members 17 and 18 where the water is entrained with the liquid fuel flowing to the engine-operated pump *m*. The water will be substantially uniformly mixed with the liquid-fuel in the mixing valve to prevent the alternate feeding of slugs of fuel and water to the pump which additionally mixes the water and fuel in transit to the carburetor. The displacement with water of some of the liquid fuel passing through pipe *l* will automatically reduce the richness of the fuel air mixture.

While water under pressure is being forced to the mixing valve 13, diaphragm 31 will be operated to open vent-valve 30. Pressure will then be bled from pipe 34 which is connected to the exhaust gas in duct *b*. The amount of pressure bled from pipe 34 is dependent upon the increase in pressure developed by the engine in the exhaust pipe *b* over the normal take-off or emergency power. This venting will cause the turbo-supercharger regulator *h* to shift the gate *g* to cause the speed of the turbo-supercharger to be increased to compensate for the loss of pressure in tail pipe *b*. This bleeding of pressure will

continue until the fluid from tank 9 has been exhausted or the control lever *h'* is restored to its setting for controlling the regulator for operation of the engine at normal speed.

If the water in tank 9 becomes exhausted, the pump 10, which is of a type which will not produce pressure without the presence of liquid, will no longer produce pressure in pipe 12 and diaphragm 31 will close vent-valve 30, whereupon the bleeding of pressure from pipe 34 will cease and the engine will be operated without the addition of water to the fuel. When this bleeding stops, the speed of the supercharger will be reduced because of an increase in pressure of the regulator *h*. This reduction in speed will reduce the pressure in intake manifold 47 and cause switch 22 to stop the motor 21 and pump 10.

When the engine is to be operated within normal power ranges without the addition of water to the fuel, the pilot will set the lever *h'* for controlling the regulator *h* for the operation of the turbine *c* of the turbo-supercharger at a speed which will produce sufficient pressure in the intake manifold 47 to permit the diaphragm 27 to open switch 22 for opening the relay switch 24 and stopping the motor 21 and the pump. The pressure drop in pipe 12 resulting from the stopping of the pump will permit check valve 30 to close and discontinue the bleeding of pressure from the pipe 34, thereby cutting supercharger speed and lowering manifold pressure. The engine will then be operated without anti-detonant or water from tank 9 until the pilot again sets the supercharger regulator to produce the necessary predetermined increase in pressure in the intake manifold 47 for starting the water injection system.

The preceding specification and drawings show an embodiment of this invention as applied to anti-detonant injection means controlled by the intake manifold pressure of an engine with the supercharger being controlled by the pressure in the exhaust pipe *b*. It is to be understood that this invention may also be applied to anti-detonant injection means which are controlled by the exhaust manifold pressures of an engine. This may be accomplished by a pipe 28' which is communicatively connected to the pipe *b* through which exhaust gases flow from the engine to the casing for the diaphragm 27 so that the switch 22 which controls the operation of motor 21 and pump 10 will be responsive to exhaust manifold pressures, as shown in Fig. 4.

The embodiment of the invention as described in the specification and as shown in the accompanying drawings is preferable inasmuch as it makes the power response of the system more direct than by controlling it through the exhaust pressure.

The invention is not to be understood as restricted to the details set forth, since these may be modified within the scope of the appended claims without departing from the spirit and scope of the invention.

Having thus described the invention what I claim as new and desire to secure by Letters Patent is:

1. Apparatus for supplying a supplemental liquid to the fuel for use in operating an internal combustion engine equipped with a turbo-supercharger driven by exhaust from the engine, a regulator for the turbo-supercharger, responsive to manifold pressures, a pressure line associated with the regulator, and means for controlling the operation of the regulator, comprising: a

reservoir for the supplemental liquid; means for forcing the liquid to the fuel for delivery to the engine; means for bleeding pressure from the line to the regulator for varying the speed of the supercharger, and means responsive to the pressure of the supplemental liquid passing to the fuel for controlling the bleed-means.

2. Apparatus for supplying a supplemental liquid to the fuel for use in operating an internal combustion engine equipped with a turbo-supercharger driven by exhaust from the engine, a regulator for the turbo-supercharger, responsive to manifold pressure, a pressure line associated with the regulator, and means for controlling the operation of the regulator, comprising: a reservoir for the supplemental liquid; means for forcing the liquid to the fuel for delivery to the engine; means for bleeding pressure from the line to the regulator for varying the speed of the supercharger; and means for controlling the regulator including a vent for bleeding pressure from the exhaust, and means responsive to pressure of the supplemental liquid, passing to the fuel, for controlling the vent.

3. Apparatus for supplying a supplemental liquid to the fuel for use in operating an internal combustion engine equipped with a turbo-supercharger driven by exhaust from the engine, a regulator for the turbo-supercharger responsive to pressure of the exhaust, and means for controlling the operation of the regulator, comprising: a reservoir for the supplemental liquid; means for forcing the liquid to the fuel for delivery to the engine; means responsive to the pressure of the intake manifold for controlling the delivery of the supplemental liquid to the fuel; means for bleeding pressure from the exhaust; and means responsive to the pressure of the supplemental liquid passing to the fuel for controlling the bleed-means.

4. Apparatus for supplying a supplemental liquid to the fuel for use in operating an internal combustion engine equipped with a turbo-supercharger driven by exhaust from the engine, a regulator for the turbo-supercharger responsive to pressure of the exhaust, and means for controlling the operation of the regulator, comprising: a reservoir for the supplemental liquid; means for forcing the liquid to the fuel for delivery to the engine; means responsive to the pressure of the intake manifold for controlling the delivery of the supplemental liquid to the fuel; means for bleeding fluid from the exhaust; and means for controlling the regulator including a vent for bleeding fluid from the exhaust, and means responsive to pressure of the supplemental liquid flowing to the fuel, for controlling the vent.

5. Apparatus for supplying a supplemental liquid to the fuel for use in operating an internal combustion engine equipped with a carburetor, a turbo-supercharger driven by exhaust from the engine, a regulator for the turbo-supercharger responsive to pressure of the exhaust, and means for controlling the operation of the regulator, comprising: a reservoir for the supplemental liquid; means for forcing the liquid to the fuel for delivery to the engine; means responsive to the pressure of the intake manifold for controlling the delivery of the supplemental liquid to the fuel; a duct connected to the exhaust, a vent connected to said duct, and means responsive to the pressure of the supplemental liquid passing to the fuel, for controlling the vent.

6. Apparatus for supplying a supplemental liquid to liquid fuel for use in operating an internal combustion engine equipped with a turbo-supercharger, an exhaust pipe from the engine to the supercharger, a regulator for the supercharger connected to the exhaust duct and responsive to the pressure in said pipe, and means for controlling the operation of the regulator, comprising: means for delivering the supplemental liquid to the fuel for delivery to the engine; means controlled by a predetermined increase of the pressure of the exhaust in said duct for controlling the operation of the liquid delivery means; a duct connected and responsive to the pressure of the exhaust flowing to the regulator; a vent for bleeding fluid from the regulator duct; and means responsive to the pressure of the supplemental liquid for controlling the vent.

7. Apparatus for supplying a supplemental liquid to liquid fuel for use in operating an internal combustion engine equipped with a carburetor, a turbo-supercharger, an exhaust pipe from the engine to the supercharger, a regulator for the supercharger connected to the exhaust duct and responsive to the pressure in said pipe, and means for controlling the operation of the regulator comprising: means for delivering the supplemental liquid to the fuel for delivery to the engine; means controlled by a predetermined increase of the pressure of the exhaust for controlling the operation of the liquid delivery means; a duct connected to the exhaust flowing to the regulator and to the air being delivered to the carburetor; a vent for bleeding fluid from the duct; and means responsive to the pressure of the supplemental liquid for controlling the vent.

8. Apparatus for supplying a supplemental liquid to the fuel used in operating an internal combustion engine equipped with a turbo-supercharger driven by exhaust from the engine, and means for controlling the speed of the supercharger comprising: a reservoir for the supplemental liquid; a pump for drawing liquid from the reservoir and forcing it to the fuel; a motor for driving the pump; and means responsive to a predetermined increase in the pressure of the exhaust to the turbo-supercharger, for controlling the operation of the motor to drive the pump and the delivery of the supplemental liquid to the fuel.

9. Apparatus for supplying a supplemental liquid to the fuel used in operating an internal combustion engine equipped with a turbo-supercharger driven by exhaust from a pipe from the engine, and means for controlling the speed of the supercharger comprising: a reservoir for the supplemental liquid; a pump for drawing liquid from the reservoir and forcing it to the fuel; a motor for driving the pump; and means responsive to a predetermined increase in the pressure in said pipe for controlling the operation of the motor to drive the pump and the delivery of the liquid to the fuel.

10. Apparatus for supplying a supplemental liquid to the fuel used in operating an internal combustoin engine equipped with an exhaust duct from the engine, and means for controlling the pressure in the exhaust duct comprising: a reservoir for said liquid; a pump for drawing liquid from the pump and forcing it to the fuel; a motor for operating said pump; and fluid pressure means responsive to variations in the pressure in the exhaust from the engine for starting and stopping the motor and the pump, to control the delivery of liquid to the fuel.

11. Apparatus for supplying supplemental

liquid fuel used in operating an internal combustion engine provided with means for delivering liquid fuel under pressure for the operation of the engine comprising: a reservoir for the supplemental liquid; a pump for drawing liquid from the reservoir and forcing it to the fuel; a motor for driving said pump; a mixing valve between said pump and the fuel delivery means, and means responsive to predetermined increase in pressure of the exhaust from the engine, for controlling the operation of the motor.

12. Apparatus for supplying supplemental liquid to fuel used in operating an internal combustion engine provided with means for delivering liquid fuel under pressure for the operation of the engine comprising: a reservoir for the supplemental liquid; a pump for drawing liquid from the reservoir and forcing it to the fuel; a motor for driving said pump; a mixing valve between said pump and the fuel delivery means, said valve comprising annular inlet and discharge members with an annular gap between them through which the supplemental liquid flows to the fuel, and means responsive to a predetermined increase in pressure of the exhaust from the engine, for controlling the operation of the motor.

13. Apparatus for supplying supplemental liquid to fuel used in operating an internal combustion engine provided with means for delivering liquid fuel under pressure for the operation of the engine comprising: a reservoir for the supplemental liquid; a pump for drawing liquid from the reservoir and forcing it to the fuel; a motor for driving said pump; a mixing valve between said pump and the fuel-delivery means; means for adjusting the valve to vary the volume of liquid mixed with the fuel; and means responsive to a predetermined increase in pressure of the exhaust from the engine, for controlling the operation of the motor.

14. Apparatus for supplying supplemental liquid to fuel used in operating an internal combustion engine provided with means for delivering liquid fuel under pressure to the engine, a turbo-supercharger and an exhaust pipe from the engine to the supercharger comprising: a reservoir for the supplemental liquid; a pump for drawing supplemental liquid from the reservoir and forcing it to the fuel; a motor for driving said pump; a mixing valve between said pump and the line of fluid under pressure, and fluid pressure means for automatically controlling the operation of the motor, responsive to a predetermined increase in pressure in the exhaust pipe from the engine.

15. Apparatus for supplying supplemental liquid to fuel used in operating an internal combustion engine provided with means for delivering fuel under pressure to the engine, a turbo-supercharger, and an exhaust duct between the engine and the supercharger, comprising: a reservoir for the supplemental liquid; means for delivering liquid from the reservoir to the fuel; and means, responsive to the pressure of the liquid passing to the fuel, for bleeding exhaust from said exhaust duct and varying the speed of the turbo-supercharger.

16. Apparatus for supplying supplemental liquid to fuel used in operating an internal combustion engine provided with means for delivering fuel under pressure to the engine, a turbo-supercharger, and an exhaust duct between the engine and the supercharger comprising: a reservoir for the supplemental liquid; means for delivering liquid from the reservoir to the fuel; a connection for discharging fluid from such exhaust duct, including a vent-valve, and means responsive to the pressure of the liquid passing to the fuel for controlling said valve.

17. Apparatus for supplying supplemental liquid to fuel used in operating an internal combustion engine provided with means for delivering fuel under pressure to the engine, a turbo-supercharger, and an exhaust duct between the engine and the supercharger comprising: a reservoir for the supplemental liquid; means for delivering liquid from the reservoir to the fuel; a connection for discharging fluid from said exhaust duct including a vent-valve and a fixed leak-orifice, for controlling the discharge of exhaust fluid from the exhaust duct, and means responsive to the pressure of the liquid passing to the fuel, for controlling said valve.

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