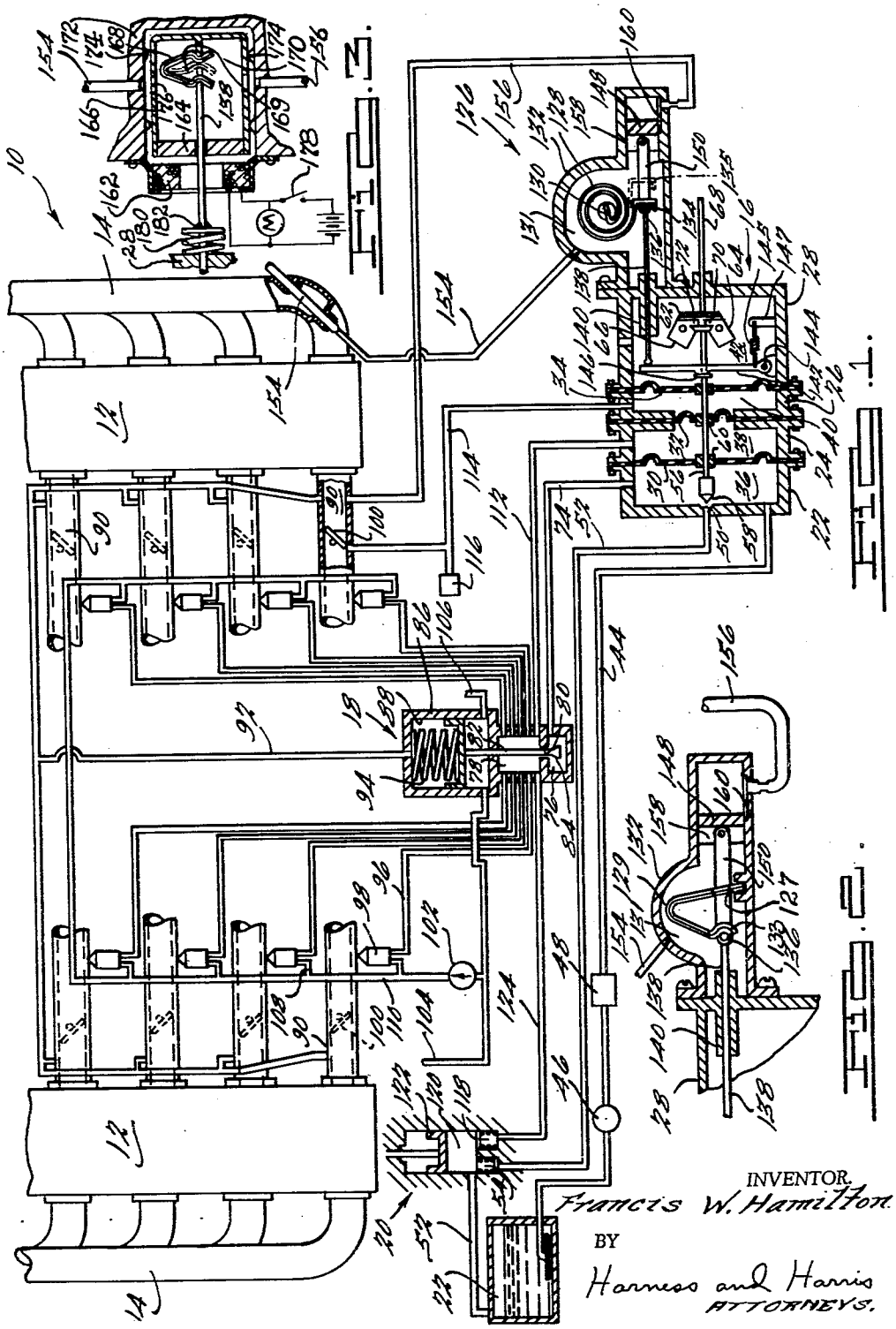
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FUEL INJECTION SYSTEM

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FUEL INJECTION SYSTEM

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This invention relates to a fuel injection system of the type disclosed in the related copending application of Thomas M. Ball et al. Serial No. 751,999 filed July 30, 1958 and assigned to applicant's assignee, and in particular relates to a cold start enrichment device for use therein.

In fuel injection systems as in other fuel systems for use on internal combustion engines, there is a need to provide some means to supplement the fuel supply to the engine under cold starting conditions which means automatically reduces its fuel supplements as the engine warms up. This additional fuel supply is necessitated for starting cold internal combustion engines due to the low vapor pressure developed by gasoline at cold engine temperatures. This low vapor pressure allows little fuel vaporization at low engine temperatures, and additional fuel is required in the combustion chamber to provide the amount of fuel vapor necessary to obtain the proper fuel-air mixture ratio for combustion.

In the fuel injection system herein presented, a bimetallic thermostatic member is connected to a shiftable fuel metering member of the fuel metering system and communicates with air that is continuously drawn through a conduit exposed to the gases within an exhaust manifold of the engine. The thermostatic member has the property of expanding at cold engine temperatures to exert a force on the said member of the fuel metering system to increase the flow of fuel to the engine. The force exerted by the cold thermostatic member on the shiftable metering member in return flow metering systems will tend to restrict the return flow of fuel to the fuel supply and in direct inlet metering systems will tend to increase the size of the fuel inlet metering orifice to enhance the flow of fuel to the engine.

An object of this invention is to provide a fuel injection system capable of delivering an enriched fuel-air mixture to a cold internal combustion engine.

Another object is to provide a device sensitive to exhaust manifold temperature for use on an internal combustion engine fuel metering system to give an additional fuel flow to said engine during cold starting conditions.

Another object is to provide a return flow fuel metering unit of a fuel injection system with a cold start enrichment device.

Another object is to provide an internal combustion engine cold start enrichment device utilizing as a sensitizing medium air drawn through a conduit and heated by the gases in an exhaust manifold.

Further objects and advantages will become apparent from the following specification and drawings, in which:

FIGURE 1 represents a view partly in cross-section of the complete fuel injection system;

FIGURE 2 represents a view partly in cross section of a variation of the bimetallic thermostatic member of FIGURE 1; and

FIGURE 3 represents a view in cross section of a variation of the cold start enrichment devices of FIGURES 1 and 2.

In FIGURE 1 is shown a fuel injection metering system for an internal combustion engine **10**, said engine having heads **12** and exhaust manifold banks **14** on each head thereof, said metering system comprising a fuel speed metering unit **16**, a fuel load metering unit **18**, an accelerator pump **20**, and a fuel supply **22**. The fuel speed

metering unit **16** is provided with four housing portions **22**, **24**, **26**, and **28** separated from each other by diaphragms **30**, **32**, and **34** respectively to provide chambers **36**, **38**, **40**, and **42**. Chamber **36** communicates with fuel supply **22** through conduit **44**. A fuel pump **46** in said conduit supplies a constant volume of fuel through filter **48** to chamber **36** during the operation of said engine regardless of the engine load or speed. A return flow metering orifice **50** in said housing portion **22** connects chamber **36** with a return flow conduit **52** which communicates with the inlet check valve **54** of accelerator pump **30**.

A return flow metering needle **56** having a tapered point **58** is secured to each of said diaphragms **30**, **32**, and **34** by suitable grommets **60**.

A flyweight support **62** pivotally supports flyweights **64** and **66** and is secured to a flexible shaft **68** which is operatively connected to the negine **10** to rotate at a speed directly proportional to engine speed. Flyweights **64** and **66** have projections **70** and **72** respectively thereon which abut the end of needle **56** as said flyweights pivot outwardly in response to rotation of shaft **68** to urge needle **56** toward orifice **50** against the force applied in the opposite direction against diaphragm **30** by the fuel in chamber **36**.

A conduit **74** connects chamber **36** to the upstream chamber **76** of the load sensor **18** which upstream chamber communicates with a downstream fuel distribution chamber **78** of the load sensor across a load metering orifice **80**. A tapered load metering needle **82** having a tapered end **84** positioned in orifice **80** is operatively connected to piston **86** reciprocably mounted in cylinder **88**, which cylinder operatively communicates with the low pressure portions of each intake manifold **90** on said engine through conduit **92**. Low pressure transmitted through conduit **92** will cause piston **86** to be drawn upwardly against the force of spring **94** to thereby urge the tapered end of needle **82** into closer proximity to the sides of orifice **80** and conversely high pressure in the intake manifolds will tend to urge needle **82** to a more open position with respect to orifice **80**. A plurality of nozzle feed conduits **96** extend from chamber **78** of the load sensor to an equal number of fuel injection nozzles **98** located upstream of the throttle valves **100** of the individual intake manifold sections **90**. The atomizing air supply to the nozzles **98** is obtained from pump **102** through intakes **104** and **106** and is transmitted to the branch air conduits **108** of said nozzles by a main air conduit **110**. Chamber **78** of the load sensor is connected to chamber **38** of the speed sensor by conduit **112** to provide an adjustment of the return flow metering needle **56** with respect to orifice **50** based on the pressure differential existing across orifice **80** of the load sensor.

An idle boost conduit **114** communicates with one of said manifold sections **90** at a point adjacent the edge of the throttle valve **100** of that section and with the chamber **40** of the speed sensor. An air bleed valve **116** in conduit **114** is provided to regulate the pressure transmitted to chamber **40** from said manifold section during idling of the engine in order to regulate thereby the speed of the engine at idling. Under normal idling conditions the pressure in chamber **40** is lower than in chamber **42** which is vented to the atmosphere and said pressure in chamber **42** tends to urge the needle **56** toward orifice **50** to retard the flow of return fuel therethrough and provide a sufficient fuel supply for idling. The requirement of this additional boost to needle **56** is due to the fact that a slow engine speed the flyweights are not flung outwardly with sufficient force to negate the frictional resistance of the needle **56** to movement.

The accelerator pump **20** having an inlet check valve **54** and an outlet check valve **118** receives fuel through

said inlet valve into chamber **120** from which the return fuel continues through the return flow conduit **52** back to the tank. The depression of the accelerator will force piston **122** of said pump **20** downwardly to force fuel through check valve **118** and through conduit **124** directly to the downstream chamber **78** of the load sensor.

Attached to portion **28** of the fuel speed metering unit **16** is a cold start enrichment device designated generally as **126**. A bimetallic thermostat coil **128** having its inner end **130** secured against movement is mounted in housing **132**. End **134** of the coil abuts a projection **136** which forms an end of booster shaft **138** slidably mounted in bushing **140**. Shaft **138** abuts at its other end an arm **142** which arm is pivotally mounted at **144** and abuts collar **146** on metering member **56**. A piston **148** carries a connecting rod **150** which is connected to end **136** of shaft **138**. Conduit **154** extends through exhaust manifold **14** and is heated by the exhaust gases therein. Groove **158** in piston **148** and groove **160** in housing **132** provide cooperating bypass passages to limit the effect of low pressure in conduit **156** on piston **148** and to prevent said piston from pulling the thermostat coil far to the right and to an ineffective position during engine warm-up. It is noted in this respect that the function of the piston is only to maintain the coil taut at all times and not to noticeably diminish the boosting effect of the coil on member **56**.

In the variation of FIGURE 2 a bimetallic thermostat member **129** has one end **127** secured against movement by projecting portions of housing **132** and has its other end **133** abutting projection **136**. This member **129** expands in the same manner as does coil **128** to exert a fuel adjusting force on member **138**.

The operation of the fuel injection metering unit **10** will be described in relation to a change in static engine operating conditions, that is constant engine speed and load. Under said static operating conditions, the combined forces exerted by flyweights **64** and **66** and the fuel in chamber **38** is balanced by the force exerted by the fuel in chamber **36** and the return flow metering member **56** is maintained stationary at a distance away from orifice **50**. In this static condition, the amount of fuel delivered to the distributing chamber **78** is constant and is equal to the constant amount of fuel being delivered to the system by the pump less the constant amount of fuel being returned to the fuel tank through the return flow conduit **52**. If this static condition represents the engine during normal driving speed, the pressure in chamber **42** has no noticeable effect on the operation of the unit and may be disregarded. It is only during idling and very low engine speeds that the pressure differential across diaphragm **34** becomes significant.

As the throttle valves **100** are moved to a more open position by the depression of the engine accelerator, an increase in manifold pressure is transmitted to the load sensor piston through conduit **92** and moves said piston down to thereby move the load metering needle **82** to a more open position with respect to the load metering orifice **80**. The pressure differential existing across said orifice is consequently decreased as more fuel is allowed to flow into chamber **78**. This decrease in pressure differential causes the flow through orifice **80** to deviate from the desirable flow which is substantially directly proportional to engine speed. To correct this condition and bring the pressure differential across said orifice up to a value where the flow of fuel therethrough is substantially directly proportional to engine speed, the fuel pressure in fuel supply pressure chamber **36** and load sensor upstream chamber **76** communicating therewith is increased. This increase in pressure is accomplished by moving the return flow metering member **56** closer to orifice **50** by the increased force transmitted by the flyweights **64** and **66** as the engine speed is increased and by the increased pressure in chamber **38** caused by the increased flow of fuel into the downstream chamber **78** of the load sensor. When the forces transmitted by said flyweights and the fuel in said chamber **38** once again balance the force transmitted in the opposite direction by the fuel in chamber **36**, the flow of fuel through orifice **80** will be substantially directly proportional to the speed of the engine and will correspond to the flow of air into the intake manifold.

Assuming that the elements of the fuel injection system as shown are in their exact positions represented during cold starting of the engine, member **56** which is normally further removed from orifice **50** than is shown in the drawing has been moved closer to orifice **50** by force supplied by the cold thermostat coil **128**. As a result of this new position of the metering member **56**, the flow of return fuel through orifice **50** is retarded and a fuel pressure increase over that during hot starting is felt in chambers **36** and **76** which pressure increase results in an increased pressure drop across orifice **80** which results in an increased fuel flow across orifice **80** into chamber **78** and to the engine through conduits **96**. As coil **128** warms up due to the air in conduit **154** being warmed by the exhaust gases in manifold **14**, said coil will gradually contract to a position shown by the dotted line **135** at which position no force is developed by coil **128** to boost member **56** toward orifice **50** and said member returns to the position it occupies during hot engine starting. It is noted that as coil **128** contracts, piston **148** will maintain it taut and will prevent loose motion of shaft **138**. Moreover, spring **145** attached to arm **142** and projection **147** within housing portion **28** constantly urges arm **142** against shaft **138** and prevents loose motion of said arm.

A secondary function of piston **148** is that of an additional accelerator fuel boost means since a sudden opening of throttle **100** will cause an increased pressure in manifold portion **90** which pressure increase will be transmitted through conduit **156** to piston **148** and cause it to move to the left with respect to FIGURES 1 and 2 of the drawing and exert a fuel boost force on member **56** through linkage **138** and **142**.

In the variation shown in FIGURE 3 member **138** slidably extends through a solenoid **162** and through face **164** of armature **166** and abuts a bimetallic thermostat element **168**. Armature **166** is slidably contained in cavity **170** of housing **172**, said cavity having spaced bearing projections **174** to allow armature **166** to slide easily. As in FIGURES 1 and 2 conduit **154** communicates with the thermostat element through suitable ports **176**, and conduit **156** connected to intake manifold conduit **90** provides a means for sucking a continuous supply of air past said element **168**.

The solenoid **162** is electrically connected into the starter circuit and is energized as long as the starter switch **178** is closed. Return spring **180** abutting housing **28** and projections **182** on member **138** performs equivalently to the spring **145** in FIGURE 1 in taking the slack out of the thermostat member.

In the operation of the device of FIGURE 3, solenoid **162** when energized by closing of switch **178** for engine starting draws armature **166** to the left and compresses element **168** if the engine is cold and if the air drawn into cavity **170** through conduit **154** is cold. The compressive force of element **168** will be transmitted to member **138** to urge metering member **56** to the left to provide a starting fuel pulse to the engine in addiiton to that provided by the cold expanded element **168**. If the engine is warm when the starting switch is closed and the air drawn into cavity **170** is warm, element **168** will be already in a compressed condition as shown by the dotted line **169** in FIGURE 3 and movement of armature **166** to the left will not cause element **168** to exert a fuel boosting force on member **138**. Independently of solenoid **162**, element **168** operates in an equivalent manner to the thermostat elements of FIGURES 1 and 2 by slowly decreasing the fuel boosting force on mem-

ber 138 as the temperature of the exhaust gases in manifold 14 increases.

I claim:

1. In a fuel metering system for an internal combustion engine having an intake and an exhaust manifold, a fuel supply conduit system, return flow fuel metering means in said conduit system, speed responsive means operatively connected with said metering means and adapted to be connected to said engine to regulate the flow of fuel thereto according to engine speed, and thermostatically operated means operatively connected to said fuel metering means and communicating with said exhaust manifold and responsive to changes in temperature of the gases within said manifold to adjust said fuel metering means to supply additional fuel to the engine under cold starting and warm up conditions.

2. A fuel injection system for an internal combustion engine comprising a fuel supply, a fuel speed metering unit having a pressure chamber communicating with said fuel supply through a fuel feed conduit and also communicating with said fuel supply through a return flow metering orifice in said fuel supply pressure chamber, a fuel load metering unit having an upstream chamber and a downstream chamber and a load metering orifice connecting said chambers, said upstream chamber communicating with said pressure chamber in said fuel speed metering unit, said downstream chamber communicating with said engine and with a metered fuel pressure chamber in said speed metering unit separated from said fuel supply pressure chamber by a flexible diaphragm, a fuel metering member carried by said flexible diaphragm and shiftable with respect to said return flow metering orifice to regulate the flow of return fuel therethrough, and thermostatically operated means operatively connected to said fuel metering member and to said exhaust manifold and responsive to changes in temperature of the gases within said manifold to shift said fuel metering unit with respect to said return flow metering orifice, said thermostatically operated means having a chamber communicating with the atmosphere through a conduit passed through said exhaust manifold, temperature responsive means in said chamber operatively associated with said metering member and adapted to exert a force on said metering member proportional to exhaust manifold temperature, and pressure responsive means in said chamber communicating with said intake manifold and abutting a portion of said temperature responsive means to maintain said temperature responsive means in a taut condition.

3. In a fuel metering system for an internal combustion engine having an intake and an exhaust manifold, a fuel supply, fuel speed metering means connected to said fuel supply and adapted to communicate with said engine intake manifold to supply fuel thereto, said metering means having a speed governor, a fuel metering orifice and a shiftable fuel metering member connected to said governor for adjusting the size of said orifice in accordance with engine speed, a load metering unit connected in series with said fuel supply and said fuel speed metering means and thermostatically operated means operatively connected to said shiftable fuel metering member and to said exhaust manifold and responsive to changes in the temperature of the gases within said manifold to shift said fuel metering member with respect to said fuel metering orifice.

4. In a fuel metering system for an internal combustion engine having an intake and an exhaust manifold, a fuel supply, a fuel metering unit connected to said fuel supply and adapted to communicate with said engine intake manifold to supply fuel thereto, said metering unit comprising a fuel metering orifice and a shiftable fuel metering member shiftable with respect to said orifice to vary the flow of fuel therethrough in accordance with engine requirements, thermostatically operated means operatively associated with said shiftable fuel metering member and responsive to changes in temperature of the gases within said exhaust manifold to shift said fuel metering member with respect to said orifice, said means having a bimetallic thermostatic coil communicating with said exhaust manifold through a conduit passed through said manifold and vented to the atmosphere, said coil being operatively linked to said metering member to shift it with respect to said orifice in response to exhaust manifold temperature changes, and means associated with said coil for continuously maintaining said coil in a taut condition.

5. In a fuel metering system for an internal combustion engine having an intake and an exhaust manifold, a fuel supply, fuel speed metering means connected to said fuel supply and adapted to communicate with said engine intake manifold to supply fuel thereto, said metering means having a speed governor, a fuel metering orifice and a shiftable fuel metering member connected to said governor for adjusting the size of said orifice in accordance with engine speed, a load metering unit connected in series with said fuel supply and said fuel speed metering means, thermostatically operated means operatively connected to said shiftable fuel metering member and to said exhaust manifold and responsive to changes in the temperature of the gases within said manifold to shift said fuel metering member with respect to said fuel metering orifice, and pressure responsive accelerator fuel boost means communicating with said intake manifold and operatively connected to said shiftable fuel metering member and said thermostatically operated means to oppose the response to low temperature exhaust gas of said thermostatically operated means at high vacuum intake manifold conditions and to exert a fuel boosting force on said shiftable fuel metering member in response to high pressure intake manifold conditions.

6. In a fuel metering system for an internal combustion engine having an intake and an exhaust manifold, a fuel supply, fuel speed metering means connected to said fuel supply and adapted to communicate with said engine intake manifold to supply fuel thereto, said metering means having a speed governor, a fuel metering orifice and a shiftable fuel metering member connected to said governor for adjusting the size of said orifice in accordance with engine speed, a load metering unit connected in series with said fuel supply and said fuel speed metering means, thermostatically operated means operatively connected to said shiftable fuel metering member and to said exhaust manifold and responsive to changes in the temperature of the gases within said manifold to shift said fuel metering member with respect to said fuel metering orifice, and pressure responsive accelerator fuel boost means communicating with said intake manifold and operatively connected to said shiftable fuel metering member and said thermostatically operated means to oppose the response to low temperature exhaust gas of said thermostatically operated means at high vacuum intake manifold conditions and to exert a fuel boosting force on said shiftable fuel metering member in response to high pressure intake manifold conditions, said accelerator fuel boost means having fluid bypass means thereon to limit the boosting force developed thereby.

7. In a fuel metering system for an internal combustion engine having an intake and an exhaust manifold, a fuel supply, fuel metering means connected to said fuel supply and adapted to be connected to said engine to regulate the flow of fuel thereto according to engine speed, thermostatically operated means operatively connected to said fuel metering means and communicating with said exhaust manifold and responsive to changes in temperature of the gases within said manifold to provide a boosting force to said fuel metering means to supply additional fuel to the engine under cold starting and warm up conditions, and solenoid operated means connected to said thermostatically operated means for increasing the boosting force thereof during cold cranking of said engine.

8. In a fuel metering system for an internal combustion engine having an intake and an exhaust manifold, a fuel supply, a fuel metering unit connected to said fuel supply and adapted to be connected to said engine to regulate the flow of fuel thereto according to engine air consumption, said metering unit comprising a fuel metering orifice and a fuel metering member shiftable with respect to said orifice to vary the flow of fuel therethrough in accordance with said engine air consumption, thermostatically operated means operatively connected to said fuel metering member and to said exhaust manifold and responsive to changes in temperature of the gases within said manifold to provide a boosting force to said fuel metering unit to supply additional fuel to the engine under cold starting and warm up conditions, and solenoid operated means connected to said thermostatically operated means for increasing the boosting force thereof during cold starting of said engine.

9. In a fuel metering system for an internal combustion engine having an intake and an exhaust manifold, a fuel supply, a fuel metering unit connected to said fuel supply and adapted to be connected to said engine to regulate the flow of fuel thereto according to engine air consumption, said metering unit comprising a fuel metering orifice and a fuel metering member shiftable with respect to said orifice to vary the flow of fuel therethrough in accordance with said engine air consumption, thermostatically operated means operatively connected to said fuel metering member and to said exhaust manifold and responsive to changes in temperature of the gases within said manifold to provide a boosting force to said fuel metering unit to supply additional fuel to the engine under cold starting and warm up conditions, solenoid operated means connected to said thermostatically operated means for increasing the boosting force thereof during cold starting of said engine, and said solenoid operated means comprising a solenoid coil and an armature, said armature abutting a portion of said thermostatically operated means to provide a force thereto in response to cranking of said engine.

10. A fuel injection system for an internal combustion engine comprising a fuel supply, a fuel speed metering unit having a pressure chamber communicating with said fuel supply through a fuel feed conduit and also communicating with said fuel supply through a return flow metering orifice in said fuel supply pressure chamber, a fuel load metering unit having an upstream chamber and a downstream chamber and a load metering orifice connecting said chambers, said upsteam chamber communicating with said pressure chamber in said fuel speed

metering unit, said downstream chamber communicating with said engine and with a metered fuel pressure chamber in said speed metering unit separated from said fuel supply pressure chamber by a flexible diaphragm, a fuel metering member carried by said flexible diaphragm and shiftable with respect to said return flow metering orifice to regulate the flow of return fuel therethrough, thermostatically operated means operatively connected to said fuel metering member and to said exhaust manifold and responsive to changes in temperature of the gases within said manifold to shift said fuel metering unit with respect to said return flow metering orifice, said thermostatically operated means having a chamber communicating with the atmosphere through a conduit passed through said exhaust manifold, temperature responsive means in said chamber operatively associated with said metering member and adapted to exert a boosting force on said metering member proportional to exhaust manifold temperature, and solenoid operated means connected to said temperature responsive means and electrically connected in the engine starting circuit for increasing said boosting force during cold starting of said engine.

11. In a fuel metering system for an internal combustion engine having an intake and an exhaust manifold, a fuel supply system, return flow fuel metering means in said supply system, speed responsive means operatively connected with said metering means and adapted to be connected to said engine to regulate the flow of fuel thereto according to engine speed, said return flow metering means comprising a fuel metering orifice and a fuel metering member shiftable with respect to said orifice, pressure responsive means adapted for connection to the engine air intake system and operably connected to said member to vary the flow of fuel to said engine in accordance with said engine air consumption, and thermostatically operated means operatively connected to said fuel metering member and to said exhaust manifold and responsive to changes in temperature of the gases within said manifold to adjust said fuel metering member to restrict the return flow and thereby supply additional fuel to the engine under cold starting and warm up conditions.

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