FUEL CONTROL MECHANISM FOR DIESEL ENGINES

Filed June 13, 1956

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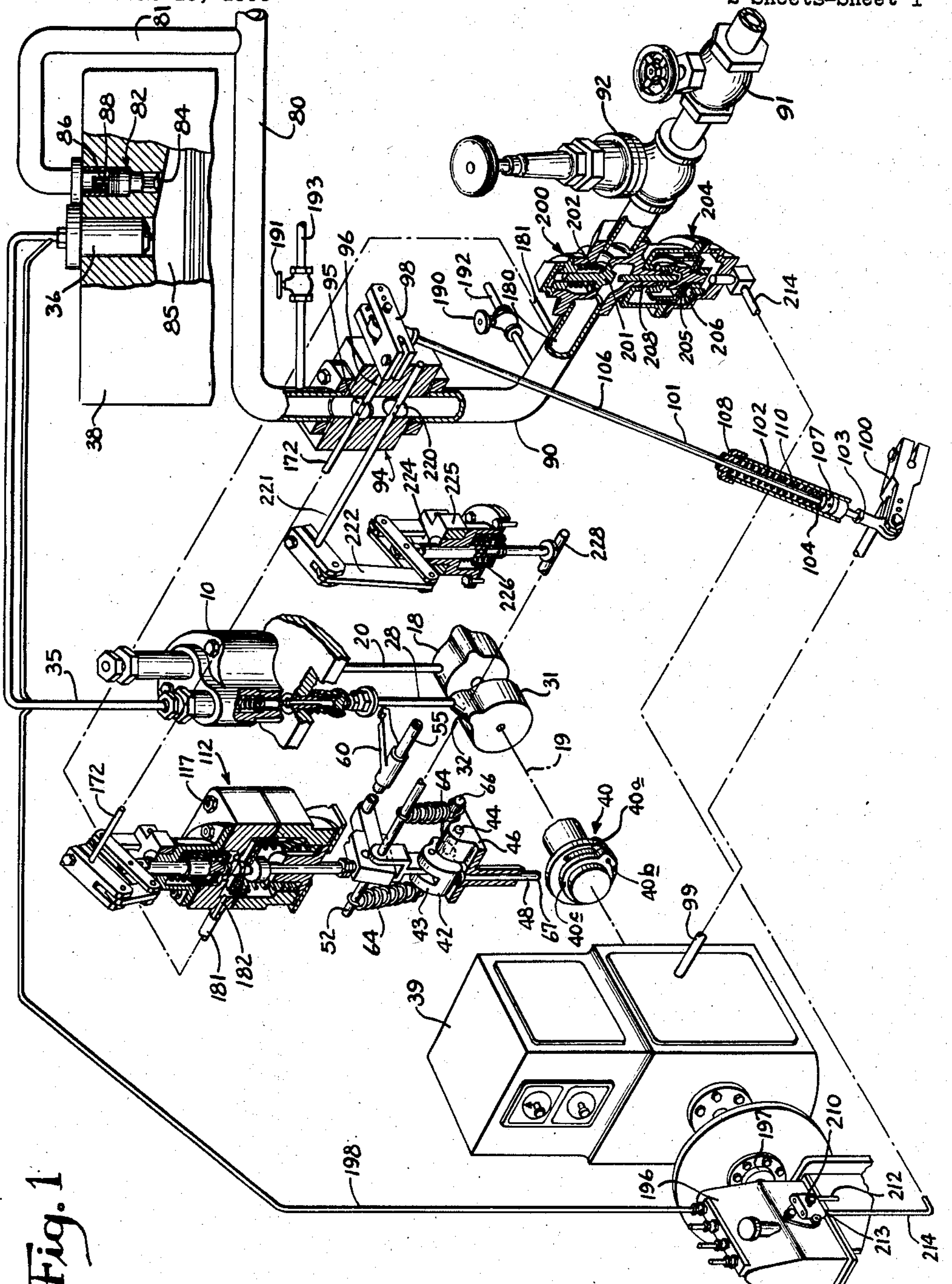

Fig. 1

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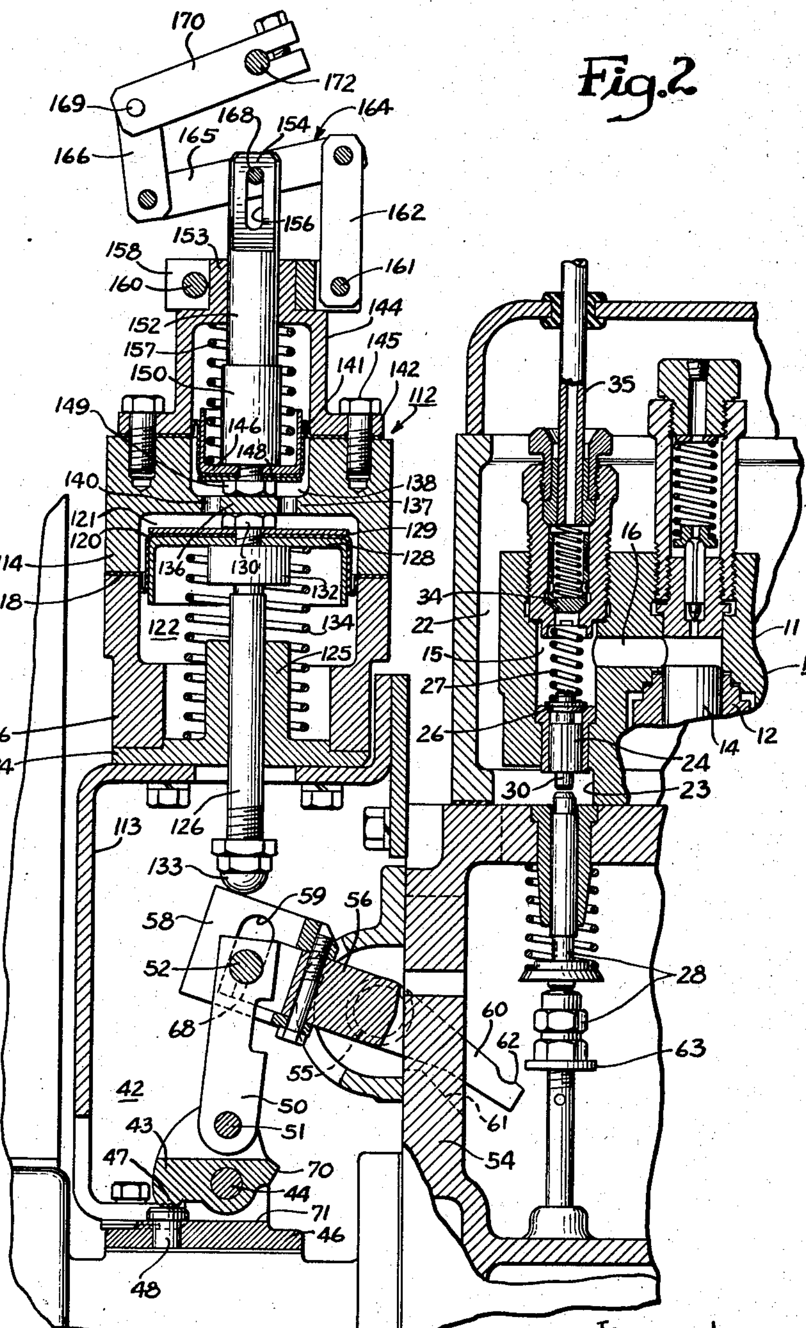
Fig. 2



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United States Patent Office

2,908,258

Patented Oct. 13, 1959

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2,908,258

FUEL CONTROL MECHANISM FOR DIESEL ENGINES

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Application June 13, 1956, Serial No. 591,117

14 Claims. (Cl. 123—27)

This invention relates to internal combustion engines, and more particularly to improved fuel control provisions for facilitating the operation of diesel engines on gaseous fuels, with gas fuel ignition by a small or pilot quantity of cylinder-compression-ignited liquid fuel.

Many diesel engines installed in localities where gaseous fuels suitable for engine operation are now readily available, may be adapted for or converted to gas fuel operation with considerable saving in fuel costs and with satisfactory power output. Accordingly, it is the primary object of the present invention to afford a fuel supply system and supply control apparatus suitable not only for factory installation in engine manufacture, but adapted in particular for application to existing diesel engines in the field, to enable operation of the engines on gas fuel with gas ignition by pilot charge of liquid fuel.

Another object of the invention is to provide fuel control apparatus for gas fuel operation of a diesel engine, which is of a character to condition the engine for normal diesel operation on liquid fuel, automatically in the event of and upon failure of gas fuel supply to the engine, or upon operator shut-off of gas supply.

These and other objects, as well as the nature and character of the system and apparatus according to the present invention, will appear from the following description of a preferred embodiment as exemplified in the accompanying drawings, wherein:

Fig. 1 is a diagrammatic view in perspective, of those parts of an engine and the fuel control apparatus which form the subject of this invention, and

Fig. 2 is an enlarged view in section, of a control mechanism forming part of the presently improved fuel control system, illustrated in association with a liquid fuel pump which is shown in part only.

As before noted, the present fuel control provisions while suitable for new engine installation, are applicable in particular to existing diesel engines in the field, for effecting and controlling operation thereof on gaseous fuel where such fuel is available for the purpose, and for conditioning the engine for liquid fuel operation, as a diesel, in the event of gas fuel supply failure or whenever it is desired to operate the engine on liquid fuel alone. A preferred embodiment of such control means is illustrated diagrammatically by Fig. 1, in application to a two-cycle diesel engine utilizing a constant stroke liquid fuel injection pump having a governor controlled inlet valve.

The injection pump (one provided for each cylinder in engines of more than one cylinder) which is indicated generally at 10 in Fig. 1 and shown more particularly in Fig. 2, comprises a pump body 11 providing a cylinder 12 therein receiving a reciprocable pump plunger 14, and a fuel admission and discharge chamber 15 communicating with the cylinder by passage 16. The plunger 14 is actuated in timed relation in the engine cycle and through a constant stroke, by a suitable cam 18 (Fig. 1) on the engine crankshaft or an extension thereof, indicated by the broken line 19, acting on the plunger through a follower rod 20 which may be spring-loaded (not shown) against the cam. Rod 20 may have a roller or other type cam-engaging follower, the showing of which is here omitted for the sake of drawing clarity. As shown in Fig. 2, the fuel pump is disposed in a liquid fuel supply reservoir 22, and has a pump body recess 23 open to the reservoir and to the pump inlet passage 24 leading to chamber 15. Fuel flow between the reservoir and chamber 15 is controlled by a fuel supply inlet or suction intake valve 26 normally urged to a closed position by spring 27, and opened by cam action. In the present engine example, cam opening of valve 26 is attained through a two-part valve-lift rod 28 in alignment with the stem 30 of valve 26 and extending to cam-follower engagement with a cam 31 (Fig. 1) which may be of any suitable construction. However, for the purpose of the present diagrammatic example, the cam is shown as having a cam lobe 32 of predetermined contour, as inclined in the axial direction and varying in effective width from one end to the other. The cam is mounted on the engine crankshaft in a manner not here shown, for rotation thereby and such as to permit axial displacement of the cam to align one or another portion of the cam lobe with the follower or lift rod 28. Thus, upon axial movement of the cam say to a given intermediate position for engagement of the corresponding portion of its lobe 32 with the valve-lift rod, the cam in rotation will effect opening of valve 26 to a certain extent and retain it in open condition for a certain time duration. Now, if the cam be axially shifted to bring the low end of the cam lobe 32 into actuating alignment with the lift rod 28, the extent and duration of valve opening will be correspondingly less, hence admitting proportionately less fuel to the chamber 15 and cylinder 12 during the pump plunger suction or intake stroke. A shift of the cam in the opposite direction, as to make the high end of the lobe effective, will result in correspondingly greater lift and duration of valve opening, thereby to admit proportionately more fuel. Consequently, the axial position of the cam determines the amount of fuel admitted to the pump for ultimate pressure delivery to the engine on the pressure stroke of the pump plunger. As here shown, pressure discharge is from the chamber 15 past a spring loaded check valve 34, to a delivery conduit 35 extending to a suitable injection valve 36 (Fig. 1) in the engine cylinder head 38. It will be appreciated, of course, that by opening the valve 26 and holding it open, the fuel pump will be thereby rendered ineffective to deliver fuel under pressure to the cylinder injection valve. Under such condition, the fuel entering chamber 15 and the pump cylinder on the plunger suction stroke, is then returned past the open valve 26 to the reservoir 22 on the pressure or upstroke of the plunger. This function of the valve 26 as a relief valve, is utilized to render the fuel pump ineffective during gas operation of the engine, or in the event of engine over-speeding when operating as a diesel, as such will appear hereinafter.

In the present example, the axially displaceable cam 31 is positioned in accordance with engine fuel requirements, through an engine operated governor 39 of suitable, well-known type, in driven connection with the engine crankshaft 19. The governor has a main output control (not shown) which is connected in cam-shift controlling relation to cam 31 by any suitable known mechanism, a showing of such mechanism being here omitted for the sake of clarity in disclosure of the essential parts of the invention, as well as because the mechanism, per se, is not important to the present invention.

The governor controlled fuel pump and liquid fuel injection provisions as hereinabove described, are in accordance with well-known practice in diesel engine operation. It is also known and usual to provide such engines with an engine over-speed control which, in the event of engine over-speeding, acts to hold open the fuel pump inlet valve **26**, and thus render the pump ineffective to deliver fuel for continued engine operation. The over-speed control then must be manually re-set in conditioning the engine for further operation. Such a control is illustrated here as comprising a fly-weight type over-speed governor device generally indicated at **40** (Fig. 1), mounted on and driven by the engine crankshaft **19**. Device **40** includes a weight element **40***a* pivoted at **40***b* to shaft-carried support **40***c* and spring-loaded (not shown). Associated with the device **40** is a manually settable trip mechanism of over-center type, shown generally at **42** in Fig. 1, which includes a trip element **43** (Fig. 2) pivoted at **44** to the frame **46** of the mechanism. The element has a nose **47** which in the set position of the trip as shown, is in contact with the head end of a trip rod **48** suitably supported and extending to a point adjacently to but clear of the periphery of the over-speed governor weight **40***a* when in normal retracted position as shown (Fig. 1). A link **50** has one end pivoted at **51** to the trip element, while its other end is formed as a bifurcate portion and supports a rod **52**. Suitably pivotally supported on a frame part **54** of the engine is a pivot or rock shaft **55** (Fig. 1), the shaft having a lever arm **56** fixed thereto and carrying a block **58** at its outer end, disposed between the furcate arms of the link **50** and receiving the rod **52** through a slot **59** in the block. The purpose of the slot **59** will appear hereinafter.

Rock shaft **55** has another lever arm **60** extending oppositely to arm **56**, but in alignment with the lift rod **28** of pump valve **26**. The arm projects through an opening indicated at **61** in the engine frame **54**, and terminates in an operating end **62** positioned for engagement with a collar **63** on lift rod **28**. A pair of trip springs **64** (Fig. 1) are provided between the rod **52** and fixed supports **66** on the base part or frame **46** of the trip mechanism, the latter supports being on the side of the trip pivot **44** opposite that containing the trip rod **48**. Since in the set position of the trip, the link pivot **51** is slightly to the left of a vertical plane through the pivot **44** of trip element **43** (as viewed in Fig. 2), while the springs **64** act on link **50** on the opposite side of such plane, the springs retain the set position of the element **43** with its nose **47** against the head of trip rod **48**. Rod **48** then is positioned to have its lower end **67** adjacently above the weight **40***a* of the over-speed cam **40**, for rod lift by the cam weight upon the occurrence of engine over-speeding. Consider for the moment the function of the trip mechanism per se, it being noted here that because of the slot **59** in block **58** (which serves a purpose later appearing), the rock shaft **55** is suitably biased (by means not shown) in the direction tending to retain the lower end **68** of block slot **59** against the link rod **52**. In the set condition of the trip, the rock shaft arm **60** will be positioned as indicated in Fig. 2, such that its end **62** is clear of the valve-lift rod collar **63**. Hence, the valve-lift rod is then free for cam actuation in normal engine operation as a diesel. Now, upon engine over-speeding for any reason, the fly-weight **40***a* of the over-speed governor **40** will be displaced outwardly under centrifugal action, and engage the end **67** of trip rod **48** to lift the latter. Upon trip rod lift, the trip element **43** is thereby pivoted to carry the link pivot **51** over-center, whereupon the springs **64** complete pivoted movement of the element to its tripped position wherein the stop projection **70** on the element abuts the frame **46** at portion **71**. The link **50** is thus lowered, and actuates rock shaft **55** to elevate its lever arm **60** into lifting engagement with the collar **63** of valve rod **28**. The extent of trip actuated lift of rod **28** is sufficient to remove the lower end of the rod from engagement by the cam **31**, and thereby to retain the fuel pump inlet valve **26** in an open position. The pump thus is rendered ineffective, until the trip is re-set. It is to be noted here that while the trip mechanism as described, is well known in the art, a part thereof is here utilized in accordance with the present invention, as a control in connection with gas operation of the engine, as such will appear presently.

Turning now to the control provisions for determining and regulating gas operation of the engine, a gas header or manifold **80** is arranged along the engine cylinders, with a branch **81** therefrom to each cylinder for delivery of gas fuel to an inlet or gas admission valve unit **82** in the cylinder head **38**. Valve unit **82** is a poppet type valve of desired construction and operating characteristics, having a valve element **84** opening inwardly of the cylinder combustion space **85**, and normally biased in the closing direction as by a spring **86** acting on the valve stem **88**. In the fuel intake cycle of the engine, when the cylinder pressure is sufficiently less than the pressure of the gas fuel then in delivery to the inlet valve, the valve opens in response to the gas pressure acting thereon in opposition to the valve closing spring **86**. Closure of the valve occurs when the cylinder pressure acting on the valve increases to a value which, together with the valve spring **86**, is greater than the opposing force of the gas pressure then acting on the open valve and tending to retain it in open position. Thus, the inlet valve operates in response to pressure differentials in the manner indicated.

Gas fuel is delivered to the header **80** by a supply conduit **90** which extends from a suitable source (not shown) of gas fuel under a source pressure predetermined for a given engine installation. In conduit **90** is a manual shut-off valve **91** and a pressure reducer or regulator valve device **92** of suitable type, the latter being set to determine the gas pressure in the portion of the conduit between the reducer valve and a gas throttle unit **94**, at a predetermined desired pressure value below the source pressure. Unit **94** provides a gas throttle valve **95**, as of the butterfly type shown, mounted on an operating shaft **96** to one end of which is secured a lever arm **98**. The throttle valve **95** is governor operated in accordance with engine fuel requirements, from the engine driven governor **39** which, pursuant to the present invention, is adapted to provide a governor output shaft **99** and a lever arm **100** on the free end thereof. Operatively connecting the governor arm **100** and the gas throttle valve arm **98** is a link structure **101** embodying a yieldable or lost-motion device **102**. The link structure includes a link element **103** pivoted to governor arm **100** and fixed to one end of a cylinder **104**, and a rod **106** pivoted to throttle valve arm **98** at one end and extending in the cylinder **104**. In the cylinder between a collar **107** fixed on the cylinder end of rod **106**, and a cylinder end cap **108**, is a compression spring **110**. This lost-motion device is provided so that when the throttle valve is held in closed position, by means hereinafter to appear, the governor may continue actuation of its lever arm **100** independently of the link rod **106**, as in governor operation during engine operation on liquid fuel, as a diesel.

Indicated generally at **112** in Fig. 1, and shown in sectional elevation in Fig. 2, is a main or primary control device which is responsive to gas pressure in the conduit **90** anterior to throttle valve **95**, and affords joint operational control over the throttle valve and the fuel pump **10**. As shown in Fig. 2, the control **112** is mounted on an engine frame supported bracket **113**, in a position adjacently above the over-speed trip mechanism **42**. In the presently preferred embodiment thereof, it provides a casing comprised of main casing members **114** and **116** secured together, as by bolts or screws **117** (Fig. 1), with the margin **118** of a flexible piston member or diaphragm **120** clamped between the parts. The diaphragm divides the interior of the casing into a pressure chamber **121** and a spring chamber **122**, the latter being closed by a bottom cap **124** secured to casing member **116** and having an internal guide boss **125** through which extends a piston rod **126**. Diaphragm backing elements **128** and **129**, together with the central portion of the diaphragm, are clamped between the piston rod head 130 and a collar 132 on the rod, while the lower-end 133 of the rod is adapted for operating engagement with the block 58 of the trip mechanism 42. Encircling the piston rod in spring chamber 122, between the cap 124 and the diaphragm backing element 128, is a compression spring 134 of predetermined capacity, which normally biases the diaphragm and rod to an initial retracted position, as shown, wherein the rod head 130 is in abutment with a stop 136 provided by a wall portion 137 of the casing member 114.

Casing member 114 provides a second pressure chamber 138 in communication with pressure chamber 121 through openings or ports 140 in wall portion 137. This chamber is closed by a flexible piston member or diaphragm 141 having its margin clamped to the casing by the ring portion 142 of a top cap member 144, the cap being secured in place as by screws 145. The diaphragm and its backing elements 146 and 148 are clamped between the head 149 and collar 150 of a piston rod 152, the latter projecting from the cap through a cap guide boss 153 and terminating in end portion 154 having an axially elongate, transverse slot 156 therein. In the cap between boss 153 and the diaphragm backing element 146 is a compression spring 157 of predetermined capacity, serving to bias the diaphragm piston and rod to an initial retracted position, as shown, wherein the rod head 149 abuts the stop wall 137. By preference, the pressure chamber 121, and hence its diaphragm piston 120, is somewhat larger than the pressure chamber 138, whereby to obtain a greater force output from the former in the function of the control as will presently appear.

Externally on the upper cap 144 is a split-collar 158 clamped to the cap boss 153, at 160, and providing a pivot support 161 for a pivoted link 162. Pivoted to the free end of link 162 is a lever arm 164 preferably comprised of a pair of parallel arms 165 loosely embracing the end portion 154 of the piston rod 152 and pivotally connected to a link 166, the arms 165 supporting substantially at the mid-length thereof, a pin 168 extending through the piston rod slot 156. Link 166 is pivotally connected at 169 to the bifurcated end of a lever arm 170, the latter being clamped on the end of a shaft 172 (Fig. 1) which is connected to or preferably provided as an extension of the gas throttle valve shaft 96. The above described connection between the throttle valve shaft 96 and the control pison rod 152 is adjusted, as through angular adjustment of the lever arm 170 in clamped connection to shaft 172, so that with the gas throttle valve 95 fully closed (Fig. 1) the pin 168 will be at the outer end of piston rod slot 156 in the initial spring-determined position of the diaphragm piston 141 as shown in Fig. 2. Since opening displacement of the throttle valve 95 as in response to governor action, is by movement of the throttle valve shaft arm 98 in the clockwise direction as viewed from the right hand side of the arm in Fig. 1, with corresponding clockwise rotation of the lever arm 170 (as viewed in Fig. 2), it will appear now that the pin 168 in contact at the upper or outer end of the piston rod slot 156 when the diaphragm piston 41 is spring-retracted to its initial position (Fig. 2), will prevent clockwise turning of arm 170 and the shaft connection to the throttle valve. Consequently, so long as the indicated spring-retracted condition of piston 141 is maintained, the throttle valve 95 will be held in closed position, against any valve-opening action of the governor 39 acting through the shaft 99, arm 100, link structure 101 including lost-motion device 102, and throttle valve arm 98. Under this condition, the governor is free to move arm 100, as permitted by the device 102 which then yields through its spring 110, it being noted here, that the diaphragm piston loading spring 157 is provided to have a materially greater force than the effective force of spring 110.

The main control device as now hereinabove described, is pressure actuated in opposition to the diaphragm piston loading springs 134 and 157, by the pressure of gas fuel in the conduit 90 at a suitable point 180 therein which is anterior to the throttle valve 95. As shown in Fig. 1, connected to conduit 90 at point 180 thereof, is a conduit 181 which extends to an inlet opening or port 182 provided in the casing member 114 of the main control 112 and opening to the pressure chamber 121. Now, conditioning of the engine for gas operation is obtained consequent to initial supply of gas fuel to conduit 90 under the desired pressure as determined by the regulator valve device 92. Assuming the engine to be then operating as a diesel, on oil fuel delivered by the injection pump 10, gas under pressure in conduit 90 is delivered to the then closed throttle valve 95 and also by way of conduit 181, to the pressure chamber 121 of control 112. The gas pressure in such chamber causes downward displacement of the diaphragm piston 120, which results through the piston rod 126 in engagement with the block 58, in downward movement of the latter as permitted by the block slot 59, without disturbing the trip-set condition of the over-speed trip link 50. In fuel gas pressure displacement of the piston 120, the block 58 is moved to a position wherein the upper end of block slot 59 contacts the rod 52, thereby turning the rock shaft 55 to a position effecting through arm 60 in engagement with the collar 63 on lift rod 28, lift of the rod 28 to an extent freeing it from cam-engagement by cam 31 and opening the fuel pump inlet valve 26. Thus, so long as gas fuel in proper volume and pressure, is present in the conduit 90 and hence in the chamber 121 of the control 112, the pressure actuated piston 120, limited in pressure displacement by the inner end of guide boss 125 serving as a stop for piston rod collar 132, will maintain the fuel pump inlet valve 26 in an open condition, thereby rendering the fuel pump inoperative to supply pressure fuel to the cylinder injection valve 36. It is to be noted here that for a given engine installation, the main control is adapted to provide the piston 120 of such size and force capacity as to assure gas pressure actuation thereof to effect hold-open lift of a single inlet valve in the instance of a one-cylinder engine, or of a plurality of pump inlet valves in the case of a multi-cylinder engine.

Gas under pressure admitted to chamber 121, enters the pressure chamber 138 through ports 140 and produces substantially simultaneously with the pressure displacement of the piston 120, displacement of the diaphragm piston 141 against its spring 157. The resulting upward movement of the piston rod 152, limited in extent by abutment of rod collar 150 with cap boss 153, elevates the slot 156 relative to the pin 168, which thus frees the linkage between the pin 168 and shaft 172. Consequently, this shaft and shaft 96 of which it is a part, are then free for rotation or angular displacement by the governor 39, in throttle valve opening control by the latter according to engine fuel requirements.

From the foregoing description of the structure and function of the main or primary control 112, it will appear now that whenever gas fuel under the desired pressure is present in conduit 90 and in supply therein to the throttle valve 95 for controlled delivery to the engine, the main control responds by gas pressure operation of its pistons to lift and hold open the inlet valves of the liquid fuel pumps 10, and to free the throttle valve 95 for governor operation thereof. Now, should the gas pressure in conduit 90 fall below a predetermined minimum value, or in the event of gas supply failure, the pistons of the main control will be spring-returned to their initial retracted positions indicated in Fig. 2. In consequence thereof, the lower piston 120 releases the pump inlet valves of the fuel pumps 10 for governor control in liquid fuel delivery to the cylinder injection valves, while the upper piston 141 acting through pin 168 and the linkage to shaft 172, rotates the latter shaft and hence the throttle valve shaft 96 to close the throttle valve 95 and maintain it closed against governor opening thereof by governor 39. With inadequate gas supply or gas failure, the engine is thus automatically conditioned for operation on liquid fuel, as a diesel.

It is to be noted here that upon gas fuel supply failure, the exhaust of residual gas pressure from the pressure chambers of the main control 112 occurs readily, through the conduit 181 to conduit 90 and therein past the throttle valve 95 to the manifold 80, and thence to the engine cylinders. Such residual exhaust may be facilitated by manual opening of the valves 190 and 191 in the respective vents 192 and 193 leading from the conduit 90 on opposite sides of the throttle valve 95, to a suitable point of gas discharge. However, the vents 192 and 193 are provided primarily for assuring positive venting of any leakage gas entering the conduit 90 past the shut-off valve 91, when the latter is or should be closed during operation of the engine on liquid fuel, as a diesel.

As hereinbefore indicated, cylinder ignition of the gas in gas fuel operation of the engine, is effected by predetermined small or pilot charges of liquid fuel compression-ignited in the engine cylinders. For this purpose, a pilot fuel injection pump unit 196 is provided and suitably mounted adjacent the governor 39, for engine crankshaft drive thereof as by the drive connection 197. The output of the pump, in metered pilot-ignition quantity, is delivered to each cylinder over a delivery conduit 198 which in the present example, is connected to the main fuel injection valve 36 for injection thereby into the cylinder. Pump unit 196 operates continuously during engine operation either on gas fuel or on liquid fuel, so that in the latter case the pilot fuel merely combines with the liquid fuel delivery from the main fuel pump 10, in cylinder injections through valve 36.

Since steady and regular ignition of the gas fuel is here obtained in positive manner by cylinder-compression-ignited liquid fuel in pilot quantity, it is important as a safety measure, to stop further gas supply to the engine promptly in the event of failure of pilot charge delivery. Accordingly, included in the gas supply conduit 90 between the pressure reducer valve 92 and the conduit point 180, is an automatic shut-off valve 200. Valve 200 may be of any suitable construction, providing a movable valve element 201 normally urged to closed position as by a spring 202. Associated with the valve is a fluid pressure operated servo-motor 204 preferably of diaphragm type, having a diaphragm piston 205 forming the movable wall of a pressure chamber 206. Carried by the piston is a rod or actuating stem 208 which extends into valve 200 in axial alignment with the valve element 201. In the absence of fluid pressure in chamber 206, the servo-motor piston 205 normally is retracted to an inactive position (as appears in Fig. 1), by the action of valve spring 202 in effecting closure of the valve element. Pressure actuation of the servo-motor to open and maintain valve 201 open, is determined by the pressure supply of liquid fuel to the pilot injection pump unit 196. As shown in Fig. 1, a suitable supply pump 210 is carried by the unit 196 in driven connection to a crankshaft driven part (not shown) of the latter, and has its intake connected by pipe 212 to a source of liquid fuel (not shown) which may be the same source supplying the main fuel pumps 10. The supply pump 210 supplies liquid fuel under pressure to the injection pump unit, and provides an outlet 213 on its pressure discharge side, which is connected by pipe 214 to the pressure chamber 206 of servo-motor 204. Thus, so long as pump 210 delivers liquid fuel to the unit 196, it will maintain the servo-motor in pressure-actuated condition holding the gas valve 201 open. On the other hand, upon liquid fuel supply failure to pump 210, the servo-motor piston 205 will be spring-retracted with closure of valve element 201, thereby cutting off further flow of gas fuel to the throttle valve 95. In this event, the main control 112 will respond to the cessation of gas supply in the conduit 90 on the engine side of valve 200, by operation as hereinbefore described, to condition the engine for liquid fuel operation. However, whether the engine then continues in operation on liquid fuel, depends upon whether the liquid fuel supply failure to supply pump 210 is accompanied by supply failure to the main fuel pump 10. In the latter case, the engine of course will cease operating. Thus, it should be now apparent that the valve 200 under pilot fuel supply control, constitutes an important safety feature in the present system.

Over-speed shut-down of the engine while operating on gas fuel, is here accomplished by an over-speed gas cut-off valve 220 included in the throttle valve unit 94 in conduit 90. In accordance with the present invention, valve 220 which is of butterfly form and mounted on an operating shaft 221, is under control of the over-speed trip mechanism 42 heretofore described. To this end, the shaft 221 is connected by lever arm linkage generally indicated at 222 in Fig. 1, to a lift rod 224 guided in a support 225. The rod is spring loaded by a spring 226, in the direction to dispose the rod in a lowered terminal position, which then effects through linkage 222 and shaft 221, closure of over-speed valve 220. Trip mechanism 42 has the rod 52 thereof, extended at 228 to underly the lower end of lift rod 224, so that in the trip-set condition of the mechanism the rod extension 228 will lift and retain rod 224 in an elevated position determining an open condition of the valve 220, this being the condition of the parts as shown in Fig. 1. Now in the event of engine over-speeding while operating on gas, the mechanism 42 will be tripped, thereby lowering rod extension 228 and allowing the spring biased rod 224 to effect closure of valve 220, with consequent cessation of engine operation. Since in gas operation, the main control 112 acts through the slotted block 58 of the trip to maintain the fuel pump inlet valve in open position, over-speed actuation of the trip element 43, link 50 and rod 52, will not disturb the already open state of the pump inlet valve, as the rod 52 is then merely displaced downwardly in block slot 59. However, upon over-speed produced cessation in engine operation and with gas supply shut-off at valve 91, the main control 112 then returns to its initial, spring-retracted condition hereinbefore described. In such condition, the piston rod 126 has its lower end 133 retracted from engagement with trip block 58, but the trip mechanism having been tripped by engine over-speeding, retains the block against upward movement until the trip is re-set.

It should be apparent, now, that given the control apparatus as herein described, such may be readily applied to existing engines in the field or factory-applied, as may be desired. When applied, the controls not only adapt the engine for operation on liquid fuel, as a diesel engine, or on gas fuel with pilot fuel ignition, but afford automatic change-over from liquid fuel operation to gas operation upon gas supply to the gas throttle valve, as well as change-over from gas to liquid fuel operation automatically in the event of gas supply failure or gas shut-off.

Having now illustrated and described a presently preferred embodiment of the invention, what it is desired to claim and secure by Letters Patent is:

1. In a fuel control system for an internal combustion engine, an engine cylinder fuel admission valve, conduit means for the delivery of gas fuel under pressure to said valve, a throttle valve in said conduit means, throttle valve actuating means responsive to engine load conditions, and control means in connection to said throttle valve adapted for holding the throttle valve in closed position, said control means operating automatically in response to gas fuel under pressure above a predetermined minimum pressure value in the conduit means anterior to

said throttle valve therein, to release the throttle valve for actuation by said actuating means.

2. In a fuel control system for an internal combustion engine, an engine cylinder fuel admission valve, conduit means for the delivery of gas fuel under pressure to said valve, a throttle valve in said conduit means, an engine driven governor and a yieldable operating connection between the governor and throttle valve, and control means connected to the throttle valve and adapted for holding the latter in closed position against governor operation thereof, said control means operating automatically in response to gas fuel under pressure above a predetermined minimum pressure value in the conduit means anterior to said throttle valve therein, to release the throttle valve for governor operation.

3. In a fuel control system for an internal combustion engine providing an engine cylinder, conduit means for cylinder delivery of gas fuel under pressure, a cylinder inlet valve controlling gas fuel admission to the cylinder, said inlet valve being biased to a closed position and opening in response to gas fuel pressure when the cylinder pressure is less than the pressure of gas fuel in supply to the inlet valve, a throttle valve in said conduit means, an engine driven governor and a yieldable operating connection between the governor and said throttle valve, and control means adapted for holding the throttle valve in closed position against governor operation thereof, said control means operating automatically in response to gas fuel under pressure above a predetermined minimum pressure value in the conduit means anterior to said throttle valve therein, to release the throttle valve for governor operation.

4. In a fuel control system for an internal combustion engine providing an engine cylinder, an inlet valve for controlling cylinder admission of gas fuel, an inlet conduit for the delivery of gas fuel under pressure to the inlet valve, a gas supply conduit connected to said inlet conduit, means for delivering liquid fuel in pilot quantity to the cylinder for ignition of gas fuel therein, a control valve in said supply conduit normally biased to a closed position, means responsive to effective operation of the liquid fuel delivering means for opening and retaining said control valve in open position, a throttle valve in the supply conduit posterior to said control valve therein, engine load responsive means for actuating said throttle valve, and control means connected to the throttle valve and adapted for holding the latter in closed position, said control means operating in response to gas fuel pressure in the supply conduit between said control valve and throttle valve, to release the throttle valve for actuation by said engine load responsive means.

5. A fuel control system for an internal combustion engine operable selectively on liquid and gas fuels, the engine providing a cylinder having a liquid fuel injection valve and a gas fuel inlet valve, said system comprising an inlet conduit for the delivery of gas fuel under pressure to said inlet valve, a gas supply conduit connected to said inlet conduit, a throttle valve in said supply conduit, an engine driven governor for actuating the throttle valve, a fuel pump for delivering liquid fuel to said injection valve, said fuel pump including an engine operated fuel supply valve effective when retained in open position, to prevent pump delivery of fuel, and control means in connection to said throttle valve and to said supply valve, effective in an initial condition thereof to retain said throttle valve in closed position and to permit engine operation of said supply valve, said control means operating in response to gas fuel pressure in the supply conduit, to release said throttle valve for governor actuation thereof and to retain said supply valve in open position.

6. In a fuel control system for an internal combustion engine operable selectively on liquid and gas fuels, supply means including a throttle valve for engine supply of gas fuel under pressure, pump means provided for supplying liquid fuel to the engine and adapted to be selectively rendered effective and ineffective, and a control common to said throttle valve and pump means, said control being effective in one control condition thereof, to retain the throttle valve in closed position and to render said pump means effective to supply liquid fuel to the engine, and said control responding to gas fuel pressure in the supply means anterior to the throttle valve, by operation to a second control condition effecting release of said throttle valve from its closed position and rendering said pump means ineffective to supply liquid fuel to the engine.

7. Control means for an internal combustion engine having conduit means including a throttle valve for engine supply of gas fuel under pressure, an engine governor in yieldable actuating connection to the throttle valve, and an engine operated liquid fuel supply pump having an engine operated fuel supply valve which is effective when retained in open position, to render the pump ineffective to supply liquid fuel, the control means comprising casing means, a pair of pistons therein forming pressure chamber means in the casing means between the pistons, a movable member in lost-motion connection to one of said pistons, connecting means between said member and said throttle valve, an operating connection between the other of said pistons and said pump supply valve, means biasing said pistons to first control positions wherein said one piston positions said member to effect through said connecting means, location and retention of the throttle valve in closed position against operation by the governor, and wherein the other piston effects through said operating connection, release of said pump supply valve for engine operation thereof, and means for admitting gas fuel under pressure from said conduit means to said pressure chamber means, said pistons responding to gas fuel pressure in the chamber means by movement to second control positions wherein said one piston releases said member for lost-motion movement to permit governor operation of said throttle valve, and said other piston effects through said operating connection, retention of said pump supply valve in an open position.

8. In a fuel control system for an internal combustion engine operable selectively on liquid fuel and on gas fuel with gas fuel ignition by liquid fuel in pilot quantity, means including a regulatable fuel injection pump for the delivery of liquid fuel to the engine, said injection pump being selectively conditionable for fuel delivery operation and conditionable for no fuel delivery thereby, conduit means for the delivery of gas fuel under pressure to the engine, pilot pump means for engine delivery of liquid fuel in predetermined pilot quantity for gas fuel ignition, a gas throttle valve in said conduit means, an engine driven governor for regulating said fuel injection pump and actuating said throttle valve, control means common to said throttle valve and fuel injection pump, effective in one control condition, to retain the throttle valve in closed position against governor opening actuation thereof and to condition the fuel injection pump for liquid fuel delivery to the engine, said control means in response to gas pressure in said conduit means anterior to the throttle valve, assuming a second control condition effecting release of said throttle valve for governor actuation and conditioning said injection pump for no fuel delivery thereby, a valve in said conduit means anterior to the throttle valve therein, liquid fuel supply means for delivering liquid fuel to said pilot pump means, and means effective in response to failure of said supply means to deliver liquid fuel to the pilot pump means, to cause closure of said valve with resultant cessation of gas fuel supply to said throttle valve.

9. In a fuel control system for an internal combustion engine operable selectively on liquid fuel and on gas fuel, and having an engine operated fuel injection pump for the delivery of liquid fuel to the engine wherein the said pump includes fuel admission valve means arranged for engine operation thereof and adapted for displacement to an open position removed from operation by the engine,

and engine operated governor for regulating said valve means; conduit means for the delivery of gas fuel under pressure to the engine, a valve unit in said conduit means providing a throttle valve and a cut-off valve therein, a throttle valve operating connection between said governor and throttle valve, settable trip means including a member settable to an initial position, operating means between said member and said cut-off valve and effective in the initial position of the member, to retain the cut-off valve in open position, engine operated means effective in response to engine speed abnormally in excess of normal maximum engine speed, to actuate said trip means with resultant displacement of said member to a second position effecting through said operating means, closure of said cut-off valve whereby to prevent flow of gas fuel through the valve unit, a pressure operated control mechanism in controlling connection to said throttle valve and effective in one control condition thereof, to position and retain said throttle valve in closed position, said control mechanism responding to gas pressure in the conduit means anterior to said valve unit therein, by operation to a second control condition effecting release of the throttle valve for governor operation thereof, and lever means including a lost-motion connection to said member of the trip means, arranged between said control mechanism and said fuel admission valve means of the injection pump and operated by the control mechanism in operation thereof to said second control condition, to effect displacement of the admission valve means to said open position removed from operation thereof by the engine.

10. In a fuel control system for an internal combustion engine operable selectively on liquid fuel and on gas fuel, means including an engine operated fuel injection pump for the delivery of liquid fuel to the engine, said pump including a pump control operable to a condition rendering the pump ineffective to deliver liquid fuel to the engine, conduit means for supplying gas fuel under pressure to the engine, first control mechanism operable in response to gas pressure in said conduit means, second control mechanism operable in response to engine speed in excess of normal maximum engine speeds, and operating means common to said control mechanisms for actuation thereby, said operating means extending to operative association with said pump control, and being effective upon actuation thereof, to operate the pump control to its said condition rendering the pump ineffective to deliver liquid fuel to the engine.

11. In a fuel control system for an internal combustion engine operable selectively on liquid fuel and on gas fuel, means including an engine operated fuel injection pump for the delivery of liquid fuel to the engine, said pump including a pump control operable to a condition rendering the pump ineffective to deliver liquid fuel to the engine, conduit means including a throttle valve for the delivery of gas fuel under pressure to the engine, an engine driven governor in operative connection to said throttle valve, first control mechanism operable from an initial condition in response to gas pressure in the conduit means, second control mechanism operable from an initial condition in response to engine speed in abnormal excess of normal maximum engine speed, operating means common to said control mechanisms for actuation thereby, said operating means extending to operative association with said said pump control and being effective upon actuation thereof, to operate the pump control to its said condition rendering the injection pump ineffective to deliver liquid fuel to the engine, and a control connection between said throttle valve and said first control mechanism, actuated by the latter in said initial condition thereof to dispose and retain the throttle valve in closed position against opening movements by the governor, said connection being effective upon gas pressure operation of the first control mechanism, to release said throttle valve for governor operation.

12. In a fuel control system as defined by claim 11, further characterized by a gas fuel cut-off valve in the said conduit means, and operating means between said cut-off valve and the said second control mechanism, effective in the said initial condition of the latter to position and retain said cut-off valve in open position, said operating connection responding to operation of the said second control mechanism from said initial condition in response to engine speed in abnormal excess of normal maximum engine speed, to effect closure of said cut-off valve.

13. In an internal combustion engine operable selectively on liquid fuel and on gas fuel, and having liquid fuel delivery means including an engine driven injection pump having a suction intake valve, an engine operated cam, a valve lift rod operable by the cam to effect alternate opening and closing of the intake valve, said lift rod being capable of lift to an elevated position out of cam engagement, for retaining the intake valve in open position and thereby rendering the injection pump ineffective to deliver liquid fuel to the engine, conduit means for engine delivery of gas fuel under pressure, a gas throttle valve in the conduit means, an engine driven governor, and a yieldable operative connection between the governor and the throttle valve; the combination therewith of a pressure operated primary control means in controlling relation to said injection pump intake valve and gas throttle valve, the control means comprising a casing, first and second pistons in the casing and forming therein pressure chamber means between the pistons, spring means normally urging the pistons to initial retracted positions, said first piston having a piston rod projecting from the casing, first lever means having a lever arm disposed for engagement by said piston rod and a second lever arm engageable with the said lift rod of the pump intake valve, said lever means in the retracted position of said first piston, normally occupying an initial position in which its said second lever arm is free of engagement with said lift rod, said second piston having a piston rod projecting from the casing, second lever means operatively carried by said casing and connected to said throttle valve, means affording a lost-motion connection between said second lever means and the piston rod of the second piston adapted for permitting operation of the second lever means relative to the piston rod, said lost-motion connection in the said retracted position of the second piston and its piston rod, being restricted by the piston rod to a condition preventing such relative operation of the second lever means and determining through the lever means, a closed condition of the throttle valve against opening displacement by the governor, and a conduit connecting said pressure chamber means of the primary control means to the said gas fuel delivery conduit means at a point thereof anterior to the said throttle valve therein, providing gas pressure delivery to the chamber means for substantially simultaneous pressure displacements of said first and second pistons from their initial retracted positions, gas pressure displacement of said first piston effecting through its piston rod, operation of said first lever means to engage its said second lever arm with said lift rod and thereby lift the rod to its said elevated position disposing and retaining the intake valve in open position rendering the injection pump ineffective to deliver liquid fuel to the engine, and said second piston in gas pressure displacement thereof, disposing its piston rod in a position releasing said lost-motion connection from said restricted condition thereof, whereby to permit operation of said second lever means relative to the piston rod of the second piston, in governor effected opening displacements of said throttle valve.

14. In a fuel control system for an internal combustion engine providing an engine cylinder having a liquid fuel injection valve and a gas fuel inlet valve, conduit means for the delivery of gas fuel under pressure to the inlet valve for cylinder admission thereby, said inlet valve being biased to a closed position and opening when the

cylinder pressure is less than the pressure of gas fuel in delivery to the valve, a throttle valve in said conduit means, an engine driven governor and a yieldable operating connection between the governor and throttle valve, means effecting a substantially constant predetermined pressure of gas supply in said conduit means anterior to the throttle valve, said throttle valve determining in accordance with governor operation thereof, the quantity and pressure of gas fuel in delivery to said inlet valve, an engine operated fuel injection pump in liquid fuel delivery connection to said injection valve, said pump having an engine timed suction intake valve capable of location and retention in an open position such as to render the pump ineffective to deliver liquid fuel to the injection valve, and a gas pressure responsive primary control effective in an initial condition, to retain said throttle valve in closed position against opening movement by the governor, said primary control operating in response to said constant predetermined gas pressure in said conduit means anterior to the throttle valve, to release said throttle valve for governor operation and to locate and retain said pump intake valve in said open position.

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