

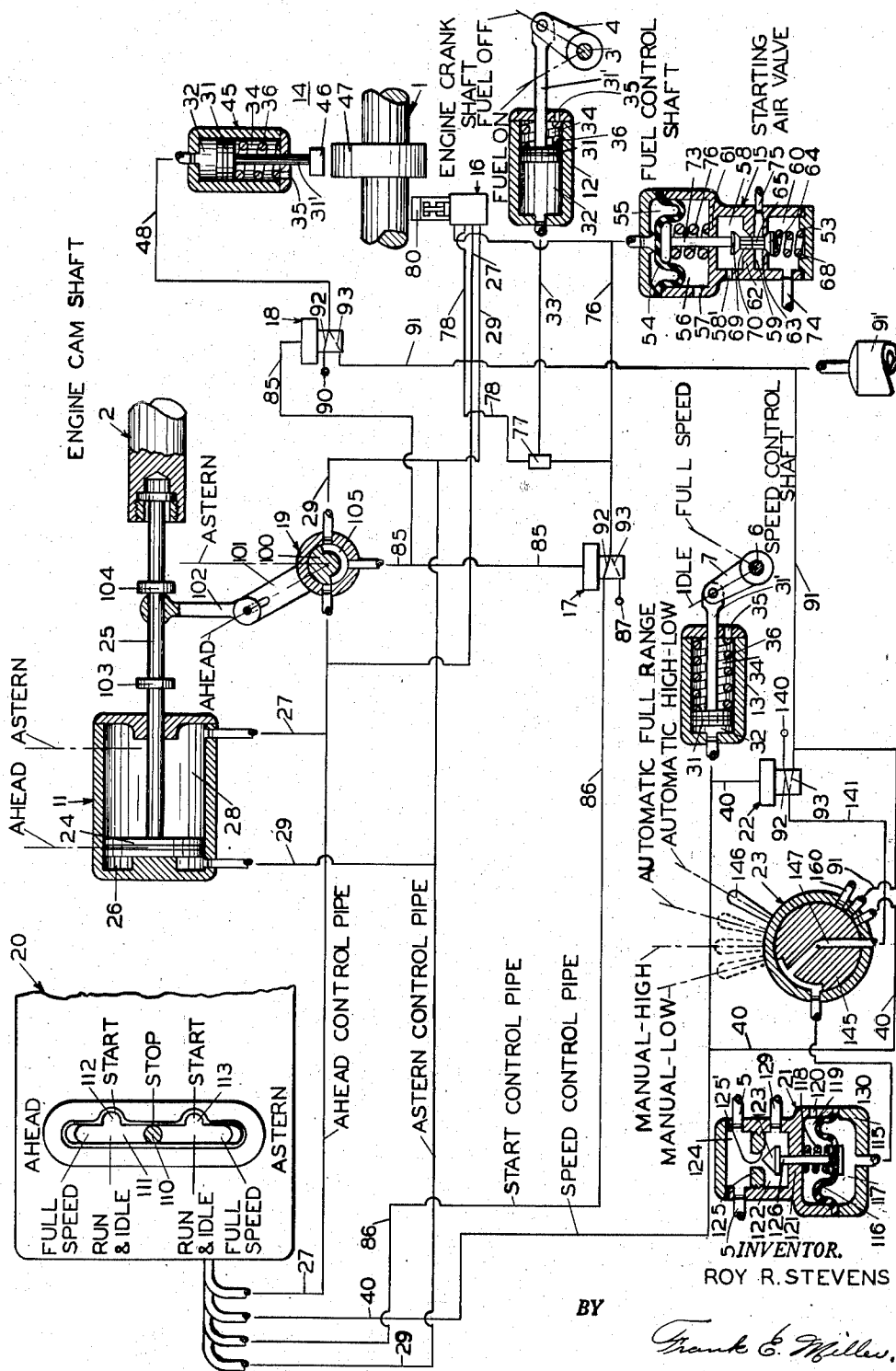
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CONTROL APPARATUS

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CONTROL APPARATUS

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This invention relates to control apparatus and more particularly to the fluid pressure type for controlling a plurality of different operations in a desired sequence, such as is required in controlling a reversible diesel engine.

The principal object of the invention is the provision of an improved fluid pressure control apparatus which is operable automatically in response to manual adjustments of a single operator's control lever to effect a plurality of different operations in a desired sequence, such for example, as are incident to effecting starting, stopping, reversing, etc. of a reversible diesel engine.

Other objects and advantages will be apparent from the following more detailed description of the invention.

In the accompanying drawing, the single figure is a diagrammatic view, mainly in section, of a fluid pressure control apparatus embodying the invention.

Description

In the drawing, the reference numeral 1 indicates a portion of one end of a crank shaft of a reversible internal combustion engine, and reference numeral 2 indicates a portion of one end of a cam shaft for said engine. The cam shaft 2 is adapted to be driven in proper phase with the crank shaft 1 in the usual manner for operating conventional engine valve mechanism (not shown) to permit the engine to be started by compressed air for operation in either direction of rotation, to, for instance, drive a ship ahead or astern. To provide for the two directions of operation, the cam shaft may have the usual forward cams (not shown) to provide for operation in one or an ahead direction and reverse cams (not shown) to provide for operation in the reverse or an astern direction. In the well known manner, the cam shaft 2 may be shiftable axially in one direction to a position for rendering forward cams effective to operate the engine's valve or timing gear, and in the opposite direction to another position for rendering reverse cams effective to operate said gear. In the drawing, the cam shaft 2 is shown in what may be considered a position to provide for operation of the engine in an ahead direction.

The reference numeral 3 indicates a fuel control shaft which is rockable through a lever 4 to control opening and closing of a fuel supply line 5 which is provided to convey fuel under pressure from a source to the fuel injectors (not shown) on the engine. In the "Fuel Off" position of shaft 3, indicated by a dot-and-dash line so titled and in which position it is shown in the drawing, the fuel supply line will be closed and no fuel will be supplied to the engine. By counterclockwise rocking movement of shaft 3 toward and to a "Fuel On" position, indicated in the drawing by

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a dot-and-dash line so titled, the fuel line may be gradually opened to allow for increase in fuel supply to the engine to a maximum amount corresponding to the above named position.

The reference numeral 6 indicates a speed control shaft which is rockable through a speed control lever 7 to different angular positions to control the speed of rotation of the engine accordingly. The speed control shaft 6 may be operatively connected to a conventional speed governor (not shown) driven by the engine and its speed setting adjusted by said shaft for governing the engine speed in the well known manner. By rocking movement of the control shaft 6 to and between an "Idle" position, indicated by a dot-and-dash line so titled in the drawing and in which position it is shown therein, and a "Full Speed" position, also so indicated, the speed of operation of the engine may be accordingly adjusted from a minimum, corresponding to the former position, and a maximum speed corresponding to the latter position.

The reference numeral 11 indicates a reversing motor for moving the engine cam shaft 2 to its two different positions; reference numeral 12 designates a fluid pressure operated fuel cut-off motor for adjusting lever 4 and reference numeral 13 designates a fluid pressure operated speed control motor for adjusting the position of the lever 7. Reference numeral 14 designates a fluid pressure operated brake for applying a braking force to oppose rotation of the engine crank shaft 1. Reference numeral 15 designates an engine starting air valve device to control supply of starting air to the starting valves of the engine (not shown). Reference numeral 16 designates a fluid pressure operated directional interlock device for interlocking control of a motor 12. Reference numeral 17 designates a fluid pressure operated relay valve device for controlling operation of the starting air valve device 15 and the directional interlock device 16. Reference numeral 18 designates a fluid pressure operated relay valve device for controlling operation of the brake 14. Reference numeral 19 designates a selector valve device operable by the motor 11 for controlling operation of the relay valve devices 17, 18. Reference numeral 20 designates an operator's control valve device for controlling operation of the apparatus aforementioned.

In addition, reference numeral 21 designates a pressure regulating valve device operable by fluid under pressure for regulating pressure of fuel in the fuel supply line 5. Reference numeral 22 designates a fluid pressure operated relay valve device for effecting a certain operating condition of control valve device 21, and reference numeral 23 designates a selector valve device for controlling different operating conditions of valve device 21.

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The reversing motor 11 may comprise a casing containing a reversing piston 24 having a piston rod 25 which extends through the casing and has an operative connection with cam shaft 2 whereby reciprocation of said piston will effect axial movement of said cam shaft. At one side of piston 24 there is a pressure chamber 26 connected to an "Astern" control pipe 29, while at the opposite side of said piston there is a pressure chamber 28 connected to an "Ahead" control pipe 27. When fluid under pressure is supplied to the "Ahead" control pipe 27 at a time when chamber 26 is open to atmosphere via pipe 29, piston 24 will be moved to the position in which it is shown in the drawing for moving the cam shaft 2 to its ahead position to provide for operation of the engine in the ahead direction. Conversely, when fluid under pressure is supplied to chamber 26 via the "Astern" control pipe 29 while chamber 28 is open to atmosphere via pipe 27, the piston 24 will be moved to its opposite extreme position to thereby move the cam shaft 2 to its astern position.

The fluid pressure fuel cut-off motor 12 may comprise a casing containing a piston 31 having a piston rod 31' which extends outwardly through said casing and is operatively connected to the lever 4 for actuating the fuel control shaft 3. At one side of piston 31 there is a pressure chamber 32 connected to a control pipe 33, while at the opposite end of said piston there is a spring chamber 34 which is open to atmosphere via a port 35. Chamber 34 contains a compression spring 36 arranged to urge piston 31 toward a position in which the shaft 3 is in its "Fuel On" position. When fluid under pressure is supplied to chamber 32 via pipe 33, piston 31 will be moved against action of spring 36 to an opposite position for rocking fuel control shaft 3 to its "Fuel Off" position in which it is shown in the drawing. Subsequent release of fluid under pressure from chamber 32 will allow spring 36 to return piston 31 to its former position for returning fuel control shaft 3 to "Fuel On" position.

The fluid pressure speed control motor 13 may be substantially similar to motor 12 and for this reason description of its construction will not be repeated. Like elements will bear the same reference numerals. The piston rod 31' of motor 13 is operatively connected to the lever 7, and chamber 32 is connected to a "Speed" control pipe 40. When fluid under pressure is vented from, or otherwise is at a minimum in pressure chamber 32 of speed control motor 13, piston 31 will be in the position in which it is shown in the drawing holding the speed control shaft 6 in its "Idle" position. Piston 31 will be moved to its opposite extreme position for rocking shaft 6 to "Full Speed" position upon supply of fluid to chamber 32 at a certain corresponding maximum pressure. Subsequent reduction in pressure in chamber 32 to its minimum value allows spring 36 to return piston 31 and the shaft 6 to "Idle" position. Piston 31 will assume any position intermediate its opposite extreme limit positions in accord with the pressure of fluid supplied to chamber 32 and, by effecting variations in said pressure, an infinite number of positions of speed control shaft 6 between "Idle" and "Full Speed" may be obtained.

The fluid pressure operated brake 14 comprises a brake cylinder device 45 which may be similar schematically to the motor 12, therefore, description of its elements will not be repeated herein and reference may be made to the previous de-

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scription. Like elements will bear the same reference numerals. In brake cylinder device 45, the piston rod 31' carries a brake shoe 46 for frictional engagement with a cylindrical brake drum 47 which is secured to rotate with the engine crank shaft 1, and the chamber 32 is connected to a brake cylinder pipe 48 for conveying fluid under pressure to and from said chamber. When fluid under pressure is released from chamber 32 in brake cylinder device 45 via pipe 48, the spring 36 will move piston 31 to its rest position in which it is shown in the drawing to withdraw the brake shoe 46 away from the drum 47, which action will hereinafter be referred to as release of the brake 14. Upon supply of fluid at adequate pressure to chamber 32, the piston 31 will move to bring the brake shoe 46 into frictional engagement with drum 47 and thereby will create a force opposing rotation of the engine crank shaft 1, which action will be referred to hereinafter as application of the brake 14. Subsequent release of fluid under pressure from chamber 32 will release the brake.

The starting air valve device 15 may comprise a casing 53 having a diaphragm 54 disposed therein and subject to pressure of fluid in a diaphragm control chamber 55 on one side and to pressure of fluid in a chamber 56 on its opposite side, which latter chamber is open to atmosphere via a port 57 in the casing. Also formed in the casing are chambers 58, 59 and 60, chamber 58 being separated from chamber 56 by a partition 61 and from chamber 59 by a partition 62. A partition 63 separates chambers 59, 60. A valve 64 is disposed in chamber 60 for controlling communication between said chamber and the chamber 59. Valve 64 may be secured to a fluid stem 65 slidably mounted in a suitable bore extending through the partition 63, a seat being formed at one end of said bore to accommodate said valve. A bias spring 68 is disposed in chamber 60, arranged to urge the valve 64 in the direction of its seat. A valve 69, similar to valve 64, is disposed in chamber 58 for controlling communication between said chamber 58 and the chamber 59. For slidably guiding the valve 69, a fluted stem 70 is provided which is slidably disposed in a suitable bore opening through partition 62. A valve seat is formed in partition 62 encircling one end of the last mentioned bore for accommodating the valve 69. Stems 65, 70 project into and meet in the chamber 59 in such a manner that action of bias spring 68 on valve 64, in urging same in the direction of its seat, at the same time, through said stems, urges valve 69 in a direction away from its respective seat. If valve 69 is seated, valve 64, consequently, will be unseated. Valve 69 is operably connected to the diaphragm 54 by means of a rod or stem 73 extending therebetween through a bore in partition 61 in which said rod is slidably disposed. A control spring 76 is provided in chamber 56, arranged to oppose deflection of the diaphragm 54 in the direction of chamber 58 as caused by pressure of fluid in chamber 55 for determining the degree of said pressure necessary to effect operation of valves 64, 69.

In operation, the device 15 will respond to a certain pressure of fluid in the control chamber 55 to close valve 69 and open valve 64 to thus connect the member 59 to the chamber 60, while at the same time closing said chamber 59 to the chamber 58. Upon a subsequent certain reduction in pressure of fluid in control chamber 55, springs 68 and 76 will close valve 64 and open

valve 69 to again connect chamber 59 to chamber 58 and to close said chamber 59 from chamber 60.

In the starting air valve device 15, chamber 60 is connected to a pipe 74 which may be connected to a source of starting air under pressure such as a reservoir (not shown). Chamber 59 is connected to a pipe 75 adapted to be connected to the engine starting valves (not shown) for conveying fluid under pressure to the engine cylinders (not shown) to start the engine rotating in a direction determined by position of cam shaft 2. Control chamber 55 is connected to a pipe 76 for conveying fluid under pressure thereto and therefrom, and chamber 58 is open to atmosphere by way of a port 58'.

A double check valve 77 of any suitable construction is provided and comprises an outlet having a connection with the pipe 33 and two opposite inlets connected to a branch of pipe 76 and to a pipe 78, respectively, the latter pipe being connected to the directional interlock device 12. Double check valve 77 is operative in the well-known manner to establish connection between whichever of the pipes 76 or 78 is pressurized and the pipe 33 and to connect the latter pipe to one, the other or both of pipes 76, 78 when both are vented to atmosphere.

The directional interlock valve device 16 may be of the type disclosed and described in detail in the copending application of Cecil S. Kelley, Serial No. 625,011, filed October 27, 1945, and assigned to the assignee of the present application. For sake of brevity, detailed description of its structure will not be repeated herein and for such description reference may be made to the above-mentioned application. Briefly, therefore, the directional interlock is operative in response to supply of fluid under pressure to pipe 76 to sense direction of rotation of the engine crank shaft 1, through actuation of a retractable shoe 80 into engagement with said shaft, and to establish communication between one or the other of the respective ahead or astern control pipes 27, 29 and the pipe 78 accordingly and to maintain such communication when fluid under pressure is vented from pipe 76, with resultant retraction of shoe 80. If the engine crank shaft 1 is turning in a direction for propelling the ship in the ahead direction when the directional interlock device is operated through supply of fluid under pressure to pipe 76, said interlock device will establish communication between the astern control pipe 29 and the pipe 78 and disestablish communication between the ahead control pipe 27 and said pipe 78. If the shaft 1 is rotating in a direction for propelling the ship astern when the interlock device 16 is operated upon supply of fluid under pressure to pipe 76, said interlock device will disestablish communication between the astern control pipe 29 and the pipe 78 and will establish communication between the latter pipe and the ahead control pipe 27. If shaft 1 is not rotating at the time fluid under pressure is supplied to pipe 76 and subsequently released therefrom, the interlock device will remain in its last directional position assumed during a previous operation when said shaft was rotating.

The relay valve devices 17, 18 schematically may be similar to the starting air valve device 15 and therefore description thereof will not be repeated herein, reference may be made to the previous description.

In relay valve device 17 its control chamber 55 is connected to a control pipe 85, its chamber

58 is connected to a "start" control pipe 86, its chamber 59 is connected to the pipe 76, and its chamber 60 is constantly open to atmosphere via a pipe 87.

In relay valve device 18, its control chamber 55 is also connected to the pipe 85, its chamber 58 is constantly open to atmosphere by way of a pipe 90, its chamber 59 is connected to the pipe 48, and its chamber 60 is connected to a fluid pressure supply pipe 91 adapted to be connected to a source of fluid under pressure such as a fluid pressure reservoir 91'.

Relay valve devices 17, 18 are operative upon supply of fluid under pressure to pipe 85 to disestablish a communication 92 and to establish a communication 93 indicated by a dash line in the drawing, and upon release of fluid under pressure from pipe 85 to disestablish communication 93 and reestablish the communication 92 indicated by a solid line in the drawing.

The selector valve device 19 may be of a rotary type comprising a rotary valve 100, having two different operating positions, and arranged to be moved to such positions through a lever 101. The lever 101 is operably connected to a link 102 which is slidable on the rod 25 between two spaced apart collars 103, 104, secured to said rod, thereby providing a lost motion connection with said rod.

When the reversing piston 24 is in its ahead position, in which it is shown in the drawing, engagement between link 102 on rod 25 and the collar 104 attached thereto will position the rotary valve 100 in valve device 19 in what may be called an ahead position, in which it is also shown in the drawing, thereby connecting the astern control pipe 29 to the pipe 85. When the reversing piston 24 and thereby rod 25 is moved to its opposite astern position, the collar 103 will engage link 102 just before the piston attains such position to actuate lever 101 to turn the rotary valve 100 to its other position, which may be called its astern position, to disconnect the astern control pipe 29 from pipe 85 and connect the ahead control pipe 27 to said pipe 85. When one of pipes 27, 29 is thereby connected to pipe 85 the other of said pipes is disconnected therefrom. A cavity 105 is provided in the rotary valve 100 through which the above defined connections are effected.

The operator's control valve device 20 may be substantially similar to that shown and described in detail in United States Patent No. 2,413,390, issued to me December 31, 1946, and assigned to the assignee of the present application, differing in the design of certain cams comprised therein and thereby effecting pressurization of the ahead and astern control pipes 27, 29 in a slightly different sequence than that in the aforementioned patent.

Briefly, the operator's control valve device 20 comprises valve means (not shown) for controlling establishment and disestablishment of pressure of fluid in the ahead, astern, and start control pipes 27, 29, 86, respectively, and for effecting variations in pressure of fluid in the speed control pipe 40. An operator's control lever 110 is provided for controlling the operation of the valve means.

The lever 110 extends through a guide slot 111 and has a "Stop" position intermediate the ends of said slot. At one side of "Stop" position indicated in the drawing by a legend "Ahead," the lever 110 has a "Run & Idle" position which is located substantially midway between "Stop" po-

sition and one end of the slot where said lever has a "Full Speed" position. Adjacent to the "Run & Idle" position the slot 11 opens to a transverse slot 112 to allow for movement of lever 110 to a "Start" position. At the opposite side of "Stop" position, indicated by the legend "Astern," the lever 110 has oppositely arranged corresponding "Run & Idle" and "Full Speed" positions and a similar "Start" position disposed opposite to "Run & Idle" in a slot 113.

In "Stop" position of lever 110, the valve means (not shown) controlled by said lever are positioned to open the speed and start control pipes 40, 86 to atmosphere and to effect pressurization of the ahead and astern control pipes 27, 29. In "Run & Idle" position at the "Ahead" side of "Stop" position, the valve means controlled by lever 110 are conditioned to effect pressurization of the ahead control pipe 27 while venting the astern control pipe 29 to atmosphere along with the start and speed control pipes 86, 40. By moving lever 110 into slot 112 the start control pipe 86 is pressurized in addition to the ahead control pipe. In "Run & Idle" position of lever 110 at the opposite or "Astern" side of "Stop" position, the astern control pipe 29 is charged with fluid under pressure while the ahead control pipe 27 is vented to atmosphere with the start, and speed control pipes 86, 40. Upon movement of lever 110 into slot 113, the start control pipe 86 is charged with fluid under pressure in addition to the astern control pipe 29.

When the lever 110 is in either of the "Run & Idle" positions, the speed control pipe 40 is open to atmosphere as above-mentioned, for rendering the speed control motor 13 effective to move the speed control lever 7 to "Idle" position in which it is shown in the drawing, while upon movement of the operator's control lever 110 to either of the "Full Speed" positions, fluid at a maximum degree of pressure is provided in the speed control pipe 40 for rendering the motor 13 effective to move the speed control lever 7 to "Full Speed" position to thereby provide for operation of the engine at maximum speed. Any desired speed or output of the engine, between idle and full speed, may be secured by suitable adjustment of the operator's control lever 110 between either of the "Run & Idle" positions and the corresponding "Full Speed" position.

While lever 110 is being positioned within the range between "Run & Idle" and "Full Speed" on the "Ahead" side of "Stop," the ahead control pipe 27 will remain charged, and conversely, while said lever is positioned within the opposite corresponding range on the "Astern" side, the astern control pipe 29 will remain charged.

The pressure regulating valve device 21 for controlling fuel pressure, as is desirable in certain types of diesel engines, may comprise a casing 115 having a flexible diaphragm 116 clamped therein. Diaphragm 116 is subject opposingly to pressure of fluid in a control chamber 117 on its one side and to the force of a control spring 118 disposed in a chamber 119 on its opposite side, chamber 119 being constantly open to atmosphere via a port 120 in casing 115. A partition 121 separates chamber 119 from a chamber 122 in which is disposed a needle valve 123, or the like, for controlling communication between a chamber 124 and said chamber 122. A partition 125 separates chambers 124, 122 and a conical shaped opening 125' is formed therein opening between said chambers for cooperation

with the valve 123 for controlling the area of flow therebetween. The valve 123 is operably connected to the diaphragm by means of a stem 126 which extends through an accommodating bore in partition 121. The chamber 124 is inserted in the fuel supply line 5 which receives fuel under pressure for supply to the engine. The chamber 122 is connected to a fuel sump (not shown) via a sump pipe 129 and may be at substantially atmospheric pressure. The control chamber 117 is connected to a pipe 130 through which variations in pressure of fluid may be effected in said chamber.

In operation of the pressure regulating valve device 21, by an increase in pressure of fluid in control chamber 117, through consequent deflection of diaphragm 116 against action of spring 118, the valve 123 is advanced toward the opening 125' which will decrease the flow area thereof between chambers 124 and 122, thus tending to prevent flow of fuel from supply pipe 5 to the sump pipe 129 and thereby maintain the pressure of the fuel in said supply pipe. A decrease in pressure of fluid in control chamber 117 will allow deflection of diaphragm 116 by spring 118 in the opposite direction to move the valve 123 further away from opening 125' and thereby increase the flow area between chambers 122, 124. By increasing the flow area, more fuel in supply pipe 5 will flow via opening 125' to the sump pipe 129, thereby reducing the pressure of such fuel in the supply pipe 5. The degree to which the pressure of fuel in supply pipe 5 is reduced below its maximum normal value will vary inversely with variation in the degree of pressure in control chamber 117.

According to a feature of the invention, the fuel pressure may be regulated manually or automatically either through a continuous range in accord with speed of the engine or at two different pressures corresponding to certain high and low ranges of speeds. Chamber 117 in valve device 21 may be connected directly to the speed control pipe 40 for the automatic continuous regulation of fuel pressure, and the relay valve device 22 provides for the automatic high and low speed regulation of fuel pressure. The selector valve device 23 provides for selection of the type of control of fuel pressure regulation as well as serving as means for effecting the manual control of high and low speed fuel pressure regulation.

When the chamber 117 in the pressure regulating valve device 21 is connected to the speed control pipe 40, the variations in pressure of fluid effected in said control pipe by manipulation of handle 110 of the operator's control valve device 20 as previously described will be experienced simultaneously in chamber 32 of speed control motor 13 and in chamber 117 in the pressure regulating device 21 to effect regulation of the pressure of the fuel supplied to the engine through adjustment in position of valve 123 as previously described in regard to operation of device 21 at the same time that motor 13 adjusts position of speed control shaft 6 as previously described. It will be appreciated from previous description that when both chamber 117 in device 21 and chamber 32 in motor 13 are connected to speed control pipe 40, an increase in control pressure in speed control pipe 40 will cause a corresponding increase in engine speed by advancing speed control lever 7 toward "Full Speed" position and a corresponding increase in pressure of fuel delivered to the engine via fuel supply line

5 by advancing valve 123 toward its seat 125'. Alternately, a decrease in control pressure in speed control pipe 40 when felt in both chamber 32 in motor 13 and chamber 117 in pressure regulating valve device 21, as when both of these chambers are connected to speed control pipe 40, will result in a corresponding decrease in engine speed through movement of speed control lever toward its "Idle" position, as will be appreciated from previous description of operation of motor 13, lever 7 and shaft 6, and a corresponding decrease in pressure of fuel supplied to the engine via fuel supply line 5 through retraction of valve 123 away from its seat 125', as will be appreciated from previous description of pressure regulating valve device 21. Thus it will be seen that with chamber 117 in pressure regulating valve device 21 connected to the speed control pipe 40, the regulation of pressure of fuel supplied to the engine will be varied automatically in accord with the speed of the engine continuously through its full range of speeds.

The relay valve device 22, as were relay valve devices 17, 18, also may be similar to the starting air valve device 15 and for detailed description thereof reference may be made to description of the former device. In relay valve device 22, the control chamber 55 is connected to the speed control pipe 40 for operating said device according to speed of the engine, the chamber 58 is constantly open to atmosphere via a pipe 140, chamber 59 is connected to a pipe 141 connected to the selector valve device 23, and the chamber 60 is connected to the fluid pressure supply pipe 91. When pressure of fluid in the speed control pipe 40 is below a certain value, corresponding to a certain upper limit for the lower speed range of operation of the engine, the relay valve device 22 will maintain pipe 141 vented to atmosphere via communication 92 and pipe 140. When pressure of fluid in the speed control pipe 40 is above the above-mentioned certain value, corresponding to a lower limit for the upper speed range of operation of the engine, the relay valve device 22 will maintain pipe 141 charged with fluid under pressure from pipe 91 via communication 93.

The selector valve device 23 may comprise a rotary valve 145 adapted to be moved to a plurality of rotary positions by means of an operator's handle 146. The rotary valve 145 comprises a port or passage 147 which is constantly in registry at its one end with the pipe 130 connected to the control chamber 117 of valve device 21. The opposite end of passage 147 registers with pipe 141 when handle 146 is in "Automatic High-Low" position, in which it is shown in the drawing and so titled; for connecting pipe 141 to pipe 130. When pipes 130, 141 are vented to atmosphere by operation of relay valve device 22 at pressures in the speed control pipe 40, corresponding to operation of the engine below a certain speed determined by such pressure through adjustment of speed control shaft 6, valve 123 in device 21 will be fully open by virtue of venting of chamber 117 via vented pipe 130, and when said pipes 130, 141 are pressurized by operation of relay valve device 22 in response to increase in pressure in speed control pipe 40 corresponding to increase in speed of the engine above a certain speed as regulated via motor 13 and speed control shaft 6 in response to such increase in pressure, said valve 123 will be closed for high fuel pressure. Handle 146 and thereby valve 145 may be moved to an "Automatic Full Range" position in which passage 147 connects to the speed con-

trol pipe 40 for thereby regulating pressure of fluid in the control chamber 117 in valve device 21 continuously with variations in speed control pressure to give continuous regulation of fuel pressure in accord with speed of operation of the engine as previously described. Handle 146 of valve device 23 also may be moved to either "Manual-Low" or to "Manual-High" positions, indicated by dot-and-dash lines in the drawing so titled. In "Manual-Low" position, passage 147 in valve 145 is in registry with a pipe 160 which opens to atmosphere for thereby venting chamber 117 in valve device 21 to atmosphere to fully open valve 123 for reducing fuel pressure corresponding to low speed operation of the engine. In "Manual-High" position of handle 146, the rotary valve 145 is positioned to bring passage 147 into registry with the supply pipe 91 to effect supply of fluid under pressure to the chamber 117 in valve device 21 to close valve 123 for high fuel pressure corresponding to high speed operation of the engine.

It will now be seen that according to one feature of the invention I have provided a relatively flexible arrangement for controlling the pressure of fuel supplied to an engine such as a diesel.

Operation of apparatus for controlling starting, stopping, and reversing of a reversible diesel engine

Let it be assumed initially that the operator's control lever 110 is in "Stop" position charging the ahead and astern control pipes 27, 29 with fluid under pressure and opening the start control pipe 35 and the speed control pipe 40 to atmosphere. Chambers 26 and 28 in the fluid pressure reversing motor 11 will thus both be charged with fluid under pressure so that the reversing piston 24 will be in a static condition for instance in the position in which it is shown in the drawing for operation of the engine in the ahead direction in which direction it may be assumed to have been previously operating. Pipe 78, hence pipe 33, will be charged with fluid under pressure via the directional interlock device 16 which may be assumed to be in its ahead position connecting the astern control pipe 29 to said pipe 78. The chamber 32 in motor 12 will therefore be charged with fluid under pressure from pipe 33 and positioned to cut off supply of fuel to the engine in which position, it is shown in the drawing. The control chamber 55 in the relay valve device 17 and control chamber 55 in relay valve device 18 will be charged with fluid under pressure via pipe 85 and the port 105 in valve device 19, which may be assumed to be in its ahead position in accord with position of the reversing piston rod 25. With pressurization of its chamber 55 relay valve device 17 will be positioned to connect the pipe 76 to atmosphere via the communication 93 and pipe 87. With pipe 76 vented to atmosphere, the directional interlock device 16 will be in a static condition with shoe 30 retracted out of contact with the engine crank shaft 1 which will not yet be rotating, and the control chamber 55 in the starting air valve device 15 consequently also will be so vented. With its chamber 55 vented to atmosphere, the starting air valve device 15 will be positioned to vent the pipe 75 connected to the engine starting valve mechanism to atmosphere. Relay valve device 18 in response to charging of its chamber 55 with fluid under pressure via pipe 35, will be positioned to connect pipe 43 to sup-

ply pipe 91 via communication 93. Chamber 32 in brake cylinder 45 therefore will be supplied with fluid under pressure from pipe 48 so that the brake 14 will be in its applied position as previously defined. Pressure chamber 32 in speed control motor 13 will be vented to atmosphere via the speed control pipe 40 so that the speed control lever 7 will be in "Idle" position to call for idling speed of the engine which is yet to be started.

Now let it be assumed that the operator desires to start the engine for operation in the same, or ahead, direction in which it last operated, as determined by position of the reversing piston 24.

The operator will then move the control lever 110 in the control valve device 29 from "Stop" position to the "Ahead" "Start" position in slot 112. This operation of lever 110 will effect a supply of fluid under pressure to the start control pipe 86 and will effect venting of fluid under pressure from the astern control pipe 29, while at the same time maintaining the ahead control pipe 27 charged with fluid under pressure and the speed control pipe 40 vented to atmosphere.

Since the reversing piston 24 was previously in its ahead position, release of fluid under pressure from chamber 26 in cylinder 11 will not change such position, so that the engine cam shaft 2 is correctly set for operation of the engine in the ahead direction. The valve device 19, therefore also remains in its ahead position.

Venting of fluid under pressure from the astern control pipe 29 results substantially at the same time in venting of fluid under pressure from the control chambers 55 in the relay valve devices 17, 18 by way of valve device 19, and from the pipe 78 connected to one end of double check valve 77 by way of the directional interlock valve device 16 which is in its head position.

In response to venting of fluid under pressure from the pipe 85, relay valve device 17 will respond to connect the start control pipe 86, which is now pressurized, via communication 92 to the pipe 76, and the relay valve device 18 simultaneously will respond to connect the brake cylinder pipe 48 to atmosphere by way of communication 92 and the pipe 90.

Supply of fluid under pressure from pipe 86 to pipe 76 will result with consequent supply to the control chamber 55 in the starting air valve device 15 which will respond to effect supply of starting air from pipe 74 to the engine by way of communication 93 and the pipe 75. Fluid under pressure supplied to pipe 76 will also flow via double check valve 77 and pipe 33 to the fuel cut-off motor 12 for maintaining fuel supply to the engine cut-off while starting, and to the directional interlock device 16 for operating same to sense the direction of rotation of said shaft 1 with shoe 89 in engagement therewith.

At the same time, release of fluid under pressure from brake cylinder pipe 48 will effect release of the brake 14 on the engine crank shaft 1 to allow for starting of the engine.

With the cam shaft 2 properly set for operation of the engine in the desired or ahead direction, supply of starting air to pipe 75 will effect starting of said engine in the ahead direction. Since the directional interlock device 16 was previously properly set in its ahead position it will not change as shaft 1 is rotated on starting air in the ahead direction.

After sufficient time is allowed for starting the

engine to turn in the proper or ahead direction, the operator will then move the lever 110 out of the "Ahead" "Start" position in recess 112 to the "Ahead" "Run & Idle" position, thereby effecting venting of the start control pipe 86 to atmosphere while the control pipes 27, 29, 40 remain conditioned as in "Ahead" "Start" position.

Venting the start control pipe 86 to atmosphere will effect simultaneous release of fluid under pressure from the control chamber in the starting air valve device 15, via pipe 76 and communication 92 in relay valve device 17, from the fuel cut-off motor 12, via pipe 33, double check valve 77 and the pipe 76 and from the directional interlock device 16 which remains in its ahead position connecting the vented astern pipe 29 to pipe 78. Upon release to fluid under pressure from the fuel cut-off motor 12 and from the control chamber in the starting air valve device 15, the fuel control lever 4 will be moved to its "Fuel On" position for effecting supply of fuel to the engine and, at the same time, the supply of starting air to the engine will be cut off. The fuel thus supplied to the engine will fire and cause the engine to run on fuel.

After the engine fires and is running on fuel, to increase the speed of operation in the ahead direction, the operator may adjust position of the lever 110 in slot 111 between its "Run & Idle" and "Full Speed" positions at the "Ahead" side of "Stop" position, as will be apparent from previous description.

From the above description, it will be noted that restarting the engine in the last direction of operation consists essentially of releasing fluid under pressure from the pipe 85 by way of the valve device 19 to effect release of the brake 14 and operation of the relay valve device 17 to connect the start control pipe 86 to the pipe 76 for supplying fluid under pressure to the directional interlock device 16 for operating same, to the fuel cut-off motor 12 for holding off supply of fuel to the engine, and to the starting air valve device 15 for effecting supply of starting air to the engine for turning same in the direction in which it was previously operating. With the engine thus being turned over by starting air in the proper direction, the lever 110 is then returned to the "Run & Idle" position to simultaneously cut off the supply of starting air to the engine and effect supply of fuel thereto, which, upon firing, continues to run the engine.

When the operator desires to stop the engine, he will move the control lever 110 to "Stop" position for supplying fluid under pressure to the astern control pipe 29 and thus to the fuel cut-off motor 12, by way of the directional interlock device 16, pipe 78, double check valve 77 and pipe 33, to effect cutting off of fuel supply to the engine through movement of lever 4 to "Fuel Off" position. At the same time, fluid under pressure from the astern control pipe 29 will flow via valve device 19 and pipe 85 to the relay valve devices 17, 18 to disconnect pipe 76 from the start pipe 86 while connecting said pipe 76 to atmospheric pipe 87, and to effect supply of fluid under pressure to the brake cylinder device 45 via pipe 48 for applying the brake 14 on the engine crank shaft 1. Thus it will be seen that the fuel is cut off to the engine and a braking force applied to the crank shaft simultaneously to effect stopping of said engine.

With the control lever 110 in "Stop" position, the apparatus will be conditioned as previously

described, i. e., with the ahead and astern control pipes 27, 29 charged with fluid under pressure and the start and speed control pipes 86, 40 vented to atmosphere. The reversing piston 24, valve device 19, and directional interlock device 16 will be in their ahead positions, the brake 14 will be applied, fuel control lever 4 will be in its "Fuel Off" position, speed control lever 7 in "Idle" position and the starting air valve device 15 will be positioned to cut off starting air to the engine, in which positions each is shown in the drawing.

Now let it be assumed that, with the engine at rest and with the reversing piston 24 in the position in which it is shown in the drawing providing for ahead operation of the engine, the operator desires to start the engine in the astern direction. To accomplish this, the operator will move lever 110 to the "Astern" "Start" position in the slot 113 to release fluid under pressure from the ahead control pipe 27 and to supply fluid under pressure to the start pipe 86 while maintaining the astern control pipe 29 charged with fluid under pressure and the speed control pipe 40 vented to atmosphere.

The fluid under pressure supplied to the start pipe 86 will be blanked off at the relay valve device 17 at this time since fluid under pressure is yet connected to the control chamber 55 of device 17 by way of port 195 in rotary valve 100 and the yet charged astern control pipe 29. The fuel control lever 4 will remain in "Fuel Off" position, since the charged astern control pipe 29 remains connected to pipe 78 via the directional interlock device 16 yet in its ahead position. Upon venting fluid under pressure from the ahead control pipe 27, the pressure of fluid in chamber 26 from the astern control pipe 29 will cause movement of the reversing piston 24 from its ahead position, in which it is shown in the drawing, to its opposite astern position for conditioning the engine for operation in the astern direction.

During initial movement of piston 24 the rod 25 attached thereto will move relative to link 102. Collar 104 moves away from link 102 as collar 103 advances. At substantially the time that the reversing piston 24 reaches its astern position, through lever 101 and by engagement of collar 103 with link 102, the rotary valve 100 will be moved to its astern position disconnecting the charged astern control pipe 29 from the pipe 85 and connecting said pipe 85 to the vented ahead control pipe 27, thereby releasing fluid under pressure from the pipe 85. According to a feature of the invention, both release of the brake 14 on the crank shaft 1 and supply of starting air to the engine are controlled by position of the reversing piston 24, both are effected simultaneously upon completion of cam reversal to condition the engine for operation in the new direction. Upon venting of fluid under pressure from the pipe 85, the relay valve device 17 will respond to connect the start control pipe 86 to the double check valve 77 to assure that fuel control lever 4 will be in "Fuel Off" position, to the directional interlock device 16 for operating same and to the starting air valve device 15 to effect supply of starting air to the engine for starting same, while at the same time, said venting of fluid under pressure from pipe 85 will cause the relay valve device 18 to effect release of fluid under pressure from the brake cylinder device 45 to release the crank shaft brake 14 to allow for starting the engine on air.

At this time, supply of starting air to the en-

gine, with the engine cam shaft in its astern position, will act to start the engine in its astern direction. The directional interlock device 16 will assume its astern position connecting the ahead pipe 27 to the pipe 78 thereby venting same to atmosphere.

After the engine is turning over on starting air, the operator may move control lever 110 to "Astern" "Run & Idle" position to vent the start pipe 86 to atmosphere, while maintaining the astern control pipe 29 charged with fluid under pressure and the ahead and speed control pipes 27, 40 open to atmosphere.

Venting of fluid under pressure from the start control pipe 86, as previously described, will effect venting of fluid under pressure from the pipe 76 by way of communication 92 in relay valve device 17. Venting of fluid under pressure from pipe 76 will release fluid under pressure from the directional interlock device 16 which will maintain its astern position connecting the vented ahead control pipe 27 to the pipe 78, from the control chamber 55 in starting air valve device 15 to cut off supply of starting air to the engine, and from the chamber 32 in the fuel control motor 12 to effect movement of lever 4 to its "Fuel On" position for supplying fuel to the engine.

Fuel thus supplied to the engine at this time will then fire and run the engine in its astern direction. By proper adjustment of the operator's control lever 110 between "Astern" "Run & Idle" position and "Astern" "Full Speed" position any desired degree of engine speed in the astern direction may be obtained.

To summarize, it will now be seen that when the operator desires to effect starting of the engine opposite to that in which it was running previously, he will then move the lever 110 from "Stop" position to the "Start" position on the side of "Stop" affording the proper direction. The reversing motor 11 will be operated to effect a shift in the engine cam shaft 2 to condition the engine for operation in the new direction. At the same time, while the cam shaft 2 is thus being shifted, both fuel and starting air are held cut off while the brake 14 is applied to shaft 1. At completion of the shift in cam shaft 2, the brake 14 is automatically released and, at the same time, starting air is supplied to the engine while the fuel is maintained cut off. With the engine being rotated in the new direction by starting air, the lever 110 may be moved from the "Start" position to the corresponding "Run & Idle" position, whereupon starting air is cut off and fuel simultaneously supplied to the engine for running same in the direction opposite to that in which it had been running previously.

When it is desired to stop the engine from operation in the astern direction, the operator will move lever 110 to "Stop" position to effect supply of fluid under pressure to the ahead control pipe 27 along with the astern control pipe 29, while the start and speed control pipes 86, 40 are vented to atmosphere. The reversing piston 24 will remain static in its astern position with both chambers 26, 29 now charged with fluid under pressure. The pipe 85 will be supplied with fluid under pressure from the now charged ahead control pipe 27, and in manner as previously described will cause simultaneously the fuel to be cut off by movement of lever 4 to "Fuel Off" position and the brake 14 to be applied on the engine crank shaft 1. The engine thereby will be stopped.

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Assume now that the engine is operating in the ahead direction, as previously described, with the operator's control lever 110 in a position between "Ahead" "Run & Idle" position and "Ahead" "Full Speed" position and that it is desired to effect a reversal in the direction of operation of the engine. The operator may then move the control lever 110 from the position it may be in at the "Ahead" side of "Stop" position directly to the opposite side of "Stop" position and into the slot 113 to the "Astern" "Start" position.

This movement of the operator's control lever 110 to the "Astern" "Start" position will release fluid under pressure from the speed control pipe 40 and thereby chamber 32 in the speed control motor 13 to permit movement of the speed control lever 7 to its "Idle" position in which it is shown in the drawing, and will also release fluid under pressure from the ahead control pipe 27 and supply fluid under pressure to the astern control pipe 29 and to the start control pipe 86. Upon release of fluid under pressure from the ahead control pipe 27, the fluid under pressure will be promptly released from the chamber 28 in the reversing motor 11 to allow pressure of fluid in chamber 28 connected to the now charged astern control pipe 29 to move the reversing piston 24 from its ahead position in which it is shown in the drawing to its opposite astern position as was previously described.

Prior to completion of the movement of the reversing piston 24 from its ahead position to its astern position, due to its lost motion connection with shaft 25, the valve device 19 will remain in its ahead position connecting the now charged astern control pipe 29 to the pipe 85. With valve device 19 yet in its ahead position fluid under pressure will then flow from the now charged astern control pipe 29 via the valve device 19 into pipe 85 to the respective control chambers 55 in the relay valve devices 17, 18. Upon supply of fluid under pressure to its control chamber, the relay valve device 17 will assume its position for cutting off the now charged start control pipe 86 from the pipe 76 and opening said pipe 76, and hence the control chamber 55 in the starting air valve device 15, to atmosphere via pipe 87 to prevent supply of starting air to the engine before the engine cam shaft 2 has been shifted to condition the engine for operation in the astern direction. The relay valve device 18, in response to supply of fluid under pressure to its control chamber, will simultaneously assume its position for effecting supply of fluid under pressure from supply pipe 91 via communication 92 to the brake cylinder pipe 48, hence to chamber 32 in brake cylinder device 45, for effecting application of brake 14 to stop rotation of the engine in the ahead direction. At the same time, the directional interlock device 16 will remain in its ahead position connecting the now charged astern control pipe 29 to the pipe 78, hence to the chamber 32 in fuel cut-off motor 12 via double check valve 77 and pipe 33 to move the fuel control lever 4 to "Fuel Off" position to allow for stopping the engine from running in its ahead direction.

At substantially the time that the reversing piston 24 reaches its astern position for effecting the proper conditioning of the engine for operation in the reverse or astern direction, through lever 191 and engagement of collar 193 with link 192, the valve device 19 will be moved to its astern position connecting the ahead control pipe 27, which is now vented to atmosphere via the control

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device 29, to the pipe 85 which will therefore also now be so vented.

Fluid under pressure in the respective control chambers 55 in relay valve devices 17, 18 will now be released to atmosphere by way of pipe 85, valve device 19 and the ahead control pipe 27.

In response of fluid under pressure from its control chamber, the relay valve device 18 will assume the position for connecting the brake cylinder pipe 48 to the pipe 99 and thereby to atmosphere via communication 92, thus releasing fluid under pressure from chamber 32 in brake cylinder device 45 for releasing the brake 14 to allow for starting the engine in the astern direction.

At the same time, in response to release of fluid under pressure from its control chamber, the relay valve device 17 will assume its position for connecting the now charged start control pipe 86 via communication 92 to the pipe 76.

Fluid under pressure from the start control pipe 86 will now flow to the pipe 15 and thereby to the opposite inlet of the double check valve 77, to the directional interlock device 16 and to the control chamber 55 in the starting air valve device 15.

Fluid under pressure thus supplied to the double check valve 77 will assure that the fuel cut-off motor 12 will maintain the fuel control lever 4 in its "Fuel Off" position regardless of the status of the pipe 78.

Fluid under pressure supplied by way of pipe 76 to the control chamber in the starting air valve device 15 will position said device to effect supply of starting air from pipe 74 to the pipe 75 for supply to the engine. Starting air thus supplied to the engine, which is now conditioned for operation in the astern direction, will complete stopping of the engine in the ahead direction if for any reason such stopping has not already been accomplished by application of brake 14, and will effect rotation of the engine in the new or astern direction.

Fluid under pressure supplied via pipe 76 to the directional interlock device 16 will operate same by bringing shoe 80 into engagement with crank shaft 1 to sense the direction of rotation of same. If the crank shaft 1 for any reason has not yet stopped rotating in the ahead direction, even though the brake 14 had been applied and starting air is being supplied to the engine opposing further rotation in the ahead direction by tending to start the engine in its astern direction, the directional interlock device 16 will remain in its ahead position connecting the now charged astern pipe 29 to the pipe 78. If the shaft 1 is rotating in its astern direction during operation of the directional interlock device 16, said device will assume its astern position and connect the pipe 78 to the now vented ahead control pipe 27.

To complete starting of the engine in the astern direction from the ahead direction, the operator may then move the control lever 110 from "Astern" "Start" in slot 113 to "Astern" "Run & Idle" in slot 111, thereby effecting venting of fluid under pressure from the start control pipe 86 to atmosphere, while maintaining the astern control pipe 29 charged with fluid under pressure and the ahead and speed control pipes 27, 40, respectively, vented to atmosphere.

The position of the reversing piston 34, valve device 19, relay valve device 17 and relay valve device 18 remain the same, since the status of the ahead and astern control pipes 27, 29 are not

changed by this last movement of the control lever 110, so that venting of fluid under pressure from the start control pipe 36 will effect venting of fluid under pressure from the pipe 76 by way of communication 32 in relay valve device 17, 5 while the brake 14 remains released.

Venting of fluid under pressure from the pipe 76 will effect release of fluid under pressure from the control chamber 55 in the starting air valve device 15, from the directional interlock device 16, and from the lower side of the double check valve 77, as it is viewed in the drawing.

Venting of fluid under pressure from the control chamber 55 of the starting air valve device 15, as will be appreciated from previous description, will cause said device to cut off supply of starting air from pipe 74 to pipe 75 hence to the engine, while at the same time venting said pipe 75 to atmosphere by way of port 58.

At the same time that the starting air is cut off, fluid under pressure vented from pipe 76 will effect retraction of shoe 33 in the directional interlock device 16 which will remain in the position which it assumed when said shoe was engaged with shaft 1, which position will be the astern position, assuming that the engine is now rotating in the astern direction as a result of the supply of starting air thereto. In its astern position, the directional interlock device 16 will connect the pipe 73 to the now vented ahead pipe 27 to release fluid under pressure from the upper side of double check valve 77, as viewed in the drawing.

With the upper side of double check valve 77 vented to atmosphere by way of the directional interlock device 16, when fluid under pressure is vented from pipe 76, as above described, the fluid under pressure in chamber 32 in the fuel cut-off motor 12 will flow via pipe 33 and said double check 77 to allow the fuel control shaft 4 to be moved to its "Fuel On" position for effecting supply of fuel to the engine simultaneously with termination of supply of starting air.

With fuel thus supplied to the engine, the engine will now fire and run in the astern direction. By movement of control lever 110 out of "Astern" "Run & Idle" to positions between said "Run & Idle" position and "Astern" "Full Speed" position, the speed control pipe 40 will be pressurized accordingly to effect adjustment of the engine speed.

If, however, for any reason, at the time that the operator's control lever 110 is moved from "Astern" "Start" to "Astern" "Run & Idle" position as just described, the engine is not yet rotating in the astern direction, the directional interlock device 16 will remain in its ahead position connecting the pipe 73 to the charged astern control pipe 27, so that when pipe 76 is vented to atmosphere via the relay valve device 17 and start control pipe 36, the fluid under pressure from pipe 73 will position double check valve 77 to prevent release of fluid under pressure from the fuel cut-off motor 12 and prevent supply of fuel to the engine until rotation of said engine is in the proper or astern direction. If such be the case, and the engine therefore is not started on fuel when the lever 110 is moved to "Astern" "Run & Idle" position from the "Astern" "Start" position, the operator will then return said lever to the former "Astern" "Start" position to again effect supply of starting air to said engine, as above described, after which he will move lever 110 back to "Astern" "Run & Idle" for assuring starting of the engine in the astern direction. 75

It will now be seen that in reversing the engine from ahead to astern, the apparatus operates in response to movement of the operator's control lever 110 from the "Ahead" side of "Stop" position to the "Astern" "Start" position in slot 113, to effect shifting of the engine cam shaft 2 from its ahead position to its astern position for conditioning the engine for operation in a reverse or astern direction, and while said cam shaft is thus being shifted the fuel supply to the engine is cut off simultaneously with application of the brake 14 on crank shaft 1 in order that the engine may be brought to a stop. At the time that the engine cam shaft 2 reaches its astern position, through adjustment of valve device 19, the brake 14 is released and at the same time starting air is supplied to the engine which acts to oppose further rotation in the ahead direction and effect turning said engine in an astern direction, while the fuel remains cut off to the engine. With the engine thus turning in an astern direction, by movement of control lever 110 out of "Astern" "Start" position in slot 113 to "Astern" "Run & Idle" position, starting air is cut off to the engine and at the same time fuel is supplied which fires and runs the engine in its astern direction. Speed adjustments of the engine may then be made by positioning lever 110 between "Astern" "Run & Idle" and "Astern" "Full Speed" as desired.

With the engine operating in the astern direction as just described, let it be assumed that the operator desires to cause operation of the engine in the ahead direction. To accomplish this he will move the control lever 110 from whatever position it may be occupying at the "Astern" side of "Stop" position to the "Ahead" "Start" position in slot 112, for effecting release of fluid under pressure from the astern control pipe 29 and from the speed control pipe 40, and for effecting supply of fluid under pressure to the ahead control pipe 27 and to the start control pipe 36.

At this time, the interlock valve device 16 is in its astern position connecting the ahead control pipe 27 to the pipe 73, so that upon supply of fluid under pressure to the previously vented ahead control pipe, fluid under pressure will flow into pipe 73, through the double check valve 77, into and through the pipe 33 to the fuel control motor 12 which will respond to move lever 4 to its fuel off position for cutting off supply of fuel to the engine, thereby allowing for stopping of same in the astern direction.

With fluid under pressure thus supplied to the ahead control pipe 27 and released from the astern control pipe 29, the chamber 28 in the reversing motor 11 will become charged with fluid under pressure and the chamber 26 therein will become void of fluid under pressure, whereupon the reversing piston 24 will be caused to move from its astern position to its ahead position for rendering the engine operable in the ahead direction.

During substantially the entire traverse of the piston 24 from its astern position to its ahead position, the valve device 19 will remain in its previously assumed astern position connecting the previously vented ahead control pipe 27 to the pipe 35, due to the lost motion connection between link 102 and the rod 25 attached to said piston, as will be understood from previous description. Therefore, at the time that fluid under pressure is supplied to the ahead control pipe 27 by the control valve device 20, fluid under pressure also will be supplied to the pipe 35, hence

to the respective control chamber in each of the relay valve devices 17, 18, by way of passage or port 105 in valve 100 in the valve device 19 and the now charged ahead control pipe 27.

Upon supply of fluid under pressure to their respective control chambers, the relay valve device 17, 18 will respond to disestablish their communication 92 and to establish their communication 93. In the relay valve device 17, disestablishment of its communication 92 disconnects the previously vented and now charged start control pipe 86 from the pipe 76, while establishment of its communication 93 connects said pipe 76 to the pipe 87 to atmosphere. Fluid under pressure from the start control pipe 86 is at this time thus prevented from reaching the control chamber in the starting air valve device 15 for effecting supply of starting air to the engine and to the directional interlock device 16 for operating same to sense direction of rotation of shaft 1. In the relay valve device 18, disestablishment of its communication 92 disconnects the brake cylinder pipe 48 from the pipe 90, hence to atmosphere, while establishment of its communication 93 connects said pipe 48 to the supply pipe 91 whereupon fluid under pressure from the latter will flow into the former and to the chamber 32 in the brake cylinder 45 to effect application of the brake 14 on the engine crank shaft 1 for stopping the engine.

With the speed control pipe 40 vented to atmosphere by the control valve device 20, the speed control motor 13 will be in its idle position for subsequent idling operation of the engine upon completion of its starting in the ahead direction.

At substantially the time that the reversing piston 24 reaches its ahead position, the collar 104 on shaft 25 will come in contact with the upper end of link 102 and cause rocking movement of lever 101, and thereby the valve 100 in valve device 19, in a counterclockwise direction, as viewed in the drawing, from its astern to its ahead position. In the ahead position of the valve 100 in valve device 19, the pipe 85 is connected to the now vented astern control pipe 29 and disconnected from the now charged ahead control pipe 27. Fluid under pressure from the respective control chambers 55 in the relay valve devices 17, 18, will then release by way of pipe 85, the valve device 19, the astern control pipe 29, and the control valve device 20 to atmosphere.

Fluid under pressure released, as above, from the control chamber in the relay valve device 18 will effect positioning of said device as previously described to release fluid under pressure from brake cylinder device 45, by establishment of communication 92 and by way of the pipe 90, thereby effecting release of the brake 14 on the crank shaft 1 to allow for rotation of the engine in the ahead direction.

At the same time, fluid under pressure released, as above, from the control chamber 55 in the relay valve device 17 will effect positioning of said device to effect supply of fluid under pressure from the now charged start control pipe 86 to the pipe 76 through establishment of communication 92. Fluid under pressure thus supplied to the pipe 76 simultaneously will flow to the double check valve 77 to assure that pipe 33 and chamber 32 in motor 12 will remain charged with fluid under pressure at this time to maintain fuel cut off to the engine, to the control chamber 55 in the relay valve device 15 to operate same to effect supply of starting air to the engine for effecting rotation of same in the ahead direction, and to the directional interlock device 16 for operating same to sense

the direction of rotation of the crank shaft 1 and assume its correspondingly adjusted position.

Upon supply of fluid under pressure, as above, to its control chamber 55, the starting air valve device 15 will effect connection between the pipe 74 and the pipe 75 and therefore between source of fluid under pressure (not shown) and the engine (not shown) for effecting rotation of the engine in its ahead direction as determined by the position of the cam shaft 2 which is now properly positioned for such rotation. If, for any reason, at the time that starting air is supplied to the engine the crank shaft 1 of said engine is still rotating in its astern direction, said starting air will oppose further rotation, thereby acting as a brake, and then start it off in its new or ahead direction.

In response to supply of fluid under pressure, as above, shoe 80 in the directional interlock device 16 is brought into contact with shaft 1 to sense the direction of rotation of same. When the shaft 1 is rotated in its ahead direction, the directional interlock device assumes its ahead position connecting the now vented astern control pipe 29 to the pipe 78, thereby venting the upper side of the double check valve 77, as viewed in the drawing, to atmosphere.

When the engine is thus caused to rotate in its ahead direction by supply of starting air thereto, the operator will effect movement of the lever 110 on the control valve device 20 out of "Astern" "Start" position in slot 113 to "Astern" "Run & Idle" position in slot 111, whereby fluid under pressure is vented to atmosphere from the start control pipe 96, while the astern control pipe 29 and speed control pipe 40 remain so vented, and the ahead control pipe 27 remains charged with fluid under pressure.

The pipe 85 will remain vented to atmosphere by way of the valve device 19 and the astern control pipe 29, so that relay valve device 17 will maintain its communication 92 established and connecting the now vented start control pipe 86, as above, to the pipe 76 and, therefore, will effect release of fluid under pressure from the directional interlock device 16, from the control chamber 55 in the starting air valve device 15, and from the lower side of double check valve 77, as viewed in the drawing, by way of the pipe 76, relay valve device 17 and pipe 86.

With the directional interlock device 16 in its ahead position and the pipe 78 therefore connected to atmosphere by way of the vented astern control pipe 29, when fluid under pressure is vented from the lower side of the double check valve 77, as above, fluid under pressure in chamber 32 in the fuel cut-off motor 12 will release to atmosphere by way of pipe 33 and said double check valve. Through action of spring 36 on piston 31, the fuel control lever 4 will be caused to assume its "Fuel On" position to effect supply of fuel to the engine for running same in the ahead direction.

Upon venting of fluid under pressure from the directional interlock device 16, shoe 80 will retract to a rest position away from shaft 1, in which it is shown in the drawing, while said device remains in its last assumed or ahead position connecting pipe 78 to the astern control pipe 29.

At the same time, upon release of fluid under pressure from the control chamber 55 in the starting air valve 15, said device will assume its position disconnecting the supply pipe 74 from the pipe 75 to the engine and connecting said pipe 75 to the port 58' to atmosphere, thereby

cutting off the supply of starting air to the engine at substantially the same time that fuel is supplied thereto.

Upon supply of fuel to the engine as above described, same will fire and effect running of the engine at idling speed in the ahead direction. To effect increase in speed and output of the engine when operating in the ahead direction, as aforesaid, the lever 110 may be moved out of "Ahead" "Run & Idle" position in slot 111 to a position or positions in the direction of "Ahead" "Full Speed" for effecting, through variation in pressure of fluid in the speed control line 40, corresponding adjustment of position of the speed control shaft 6. The status of the control pipes 27, 29, 40 will remain the same, i. e., charged, vented and vented, respectively. Consequently, all parts of the apparatus will remain in the respective positions last assumed as above described.

The engine may then be stopped when running in the ahead direction by moving the lever 110 from a position coincident or between "Ahead" "Run & Idle" and "Ahead" "Full Speed" position to "Stop" position, whereupon both the ahead and astern control pipes 27, 29 will be charged with fluid under pressure with both the start and speed control pipes 86, 40, respectively, vented to atmosphere. Parts of the apparatus will assume their respective positions, as previously described, in which they are shown in the drawing.

When the engine is stopped from running in the ahead direction, the restarting of the engine in the same or the astern direction may be accomplished by operating the apparatus in a manner which will be apparent from previous description.

Summary

It will now be seen that I have provided a control apparatus for controlling the starting, stopping and reversing of a reversible internal combustion engine which is relatively simple. Reversal of the engine is effected through movement of a single control lever from one position to a second position whereby reversal of the engine cam shaft is effected for conditioning said engine for operation in its opposite direction. At the same time, and during such cam shaft reversal, fuel supply is cut off to the engine, and a brake applied for stopping further rotation of the engine in the original direction. Upon reversal of the engine cam shaft, the brake is automatically released and starting air simultaneously supplied to oppose any additional rotation of the engine in the original direction and effect its rotation in the new direction, while the fuel remains cut off to the motor. With the engine rotating in the new direction, the control lever may be moved to a third position for simultaneously cutting off supply of starting air and supplying fuel to the engine for running same in its new direction.

The directional interlock device acts to prevent supply of fuel to the engine when the control lever is moved to its third position, as above, if for any reason the engine is not rotating in its proper new direction, thus preventing damage to the engine which otherwise might occur if such fuel were to be supplied before the engine was yet rotating in its new direction.

As hereinabove employed, the terms "Ahead" and "Astern" are synonymous with, respectively, forward and reverse, one direction and opposite direction, etc., as will be obvious.

Having now described the invention, what I

claim as new and desire to secure by Letters Patent, is:

1. An apparatus for controlling stopping of a reversible prime mover comprising two control pipes, prime mover reversing means operable by fluid under pressure from one of said pipes to a forward position and by fluid under pressure from the other pipe to a reverse position, an operator's control device having forward and reverse positions and comprising means operative in such positions to supply fluid under pressure to said one and other pipes, respectively, while venting the other pipe, braking means for said prime mover, brake control means operable by fluid under pressure to effect application of said braking means and operable upon release of fluid under pressure to release said braking means, and a valve controlling communication between said pipes and said brake control means operable by said reversing means only upon attaining the position corresponding to that of said control device to connect said brake control means to the vented one of said pipes and to disconnect said brake control means from the other pipe.

2. An apparatus for controlling stopping of a reversible prime mover comprising forward and reverse control pipes, prime mover reversing means operable to a forward position by fluid under pressure from said forward pipe upon venting said reverse pipe, and operable to a reverse position by fluid under pressure from said reverse pipe upon venting said forward pipe, an operator's control device having forward and reverse positions and also having a stop position and comprising means operative in said forward and reverse positions to supply fluid under pressure to, respectively, said forward and reverse pipes while venting the other pipe, and operative in said stop position to supply fluid under pressure to both of said pipes, structure operable by fluid under pressure to effect braking of said prime mover and operable upon release of fluid under pressure to free said prime mover for turning, and valve means operable by said reversing means upon movement into each of its positions to disconnect said structure from the one of said pipes supplied with fluid under pressure and to open communication between said structure and the other pipe.

3. An apparatus for controlling stopping, starting and fuel supply of a reversible prime mover comprising prime mover reversing means having forward and reverse positions, braking means for said prime mover, fuel control means for said prime mover, starting means for said prime mover, an operator's control device having forward and reverse positions and comprising means operable upon movement from either one of said positions to the other to effect operation of said reversing means to a corresponding position, means responsive to movement of said control device selectively to said forward and reverse positions to apply said braking means and to effect operation of said fuel control means to a fuel cut-off position, means controlled by said reversing means operable in response to positioning thereof corresponding to the position of said control device to release said braking means, to effect operation of said starting means and to maintain said fuel cut-off means in said fuel cut-off position, said operator's control device being movable to another position to terminate operation of said starting means, and means including structure responsive to direction of turning of said prime mover for effecting movement of said fuel cut-off means to a fuel cut-in position upon turn-

ing of said engine in the direction corresponding to the position of said control device and movement of said control device to said other position.

4. An apparatus for controlling starting, stopping and reversing of a reversible engine operable by fuel supplied thereto comprising in combination, fluid pressure reversing means operable upon supply of fluid under pressure to a first control pipe and venting of fluid under pressure from a second control pipe to a reversing position to condition said engine for operation in a reverse direction, fluid pressure fuel control means operable upon supply of fluid under pressure to a pressure chamber to disestablish supply of fuel to said engine and upon release of fluid under pressure from said pressure chamber to establish supply of fuel to said engine, a double check valve having one inlet, another inlet and also having an outlet which is connected to said pressure chamber, fluid pressure engine starting means rendered effective upon supply of fluid under pressure to a first control chamber and rendered ineffective upon release of fluid under pressure from said first control chamber, directional control means positioned to connect said first control pipe to said one inlet and operable to a position upon rotation of said engine in a reverse direction to disconnect said first control pipe from said one inlet and to connect said second control pipe to said one inlet, fluid pressure valve means operable in response to supply of fluid under pressure to a second control chamber to establish a first communication from said other inlet and said first control chamber to atmosphere and in response to release of fluid under pressure from said second control chamber to disestablish said first communication and to establish a second communication from said other inlet and said first control chamber to a third control pipe, fluid pressure brake means operable in response to supply of fluid under pressure to a brake cylinder chamber to effect application of a braking force to said engine and in response to release of fluid under pressure from said brake cylinder chamber to terminate said application, fluid pressure valve means operable in response to supply of fluid under pressure to a third control chamber to effect supply of fluid under pressure to said brake cylinder chamber and in response to release of fluid under pressure from said third control chamber to terminate such supply and effect release of fluid under pressure from said brake cylinder chamber, selector valve means establishing connection of said first control pipe to said second control chamber and to said third control chamber and operable to a position upon attainment of said reversing position by said reversing means to disestablish said connection and to connect said second control pipe to said second control chamber and to said third control chamber, and an operator's control device operable to a position to simultaneously effect supply of fluid under pressure to said first control pipe and to said third control pipe and release of fluid under pressure from said second control pipe and operable to a second position to effect release of fluid under pressure from said third control pipe while maintaining supply of fluid under pressure to said first control pipe and release of fluid under pressure from said second control pipe.

5. Apparatus for controlling stopping of a reversible engine comprising in combination, a source of fluid under pressure, fluid pressure engine braking means applied and released by supply and release of fluid under pressure to and

from a brake cylinder chamber, respectively, engine reversing means movable to an engine reversing position in response to supply of fluid under pressure to a pressure chamber, relay valve means responsive to supply and release of fluid under pressure to and from a control chamber to connect said brake cylinder chamber selectively to said source and to atmosphere, respectively, valve means connecting said control chamber to said pressure chamber and operable to connect said control chamber to atmosphere, means carried by said reversing means to operate said valve means immediately prior to completion of movement of said reversing means to its engine reversing position, and operator's control valve means operable to a position to effect supply of fluid under pressure to said pressure chamber.

6. Apparatus for controlling stopping of a reversible engine comprising in combination, a source of fluid under pressure, fluid pressure engine braking means applied and released by supply and release of fluid under pressure to and from a brake cylinder chamber, respectively, engine reversing means movable to forward and reverse positions in response to selective supply of fluid under pressure to forward and reverse chambers, respectively, relay valve means responsive to supply and release of fluid under pressure to and from a control chamber to connect said brake cylinder chamber selectively to said source and to atmosphere, respectively, selector valve means movable to first and second positions connecting said control chamber selectively to said forward and reverse chambers, respectively, means associated with said reversing means to cause said selector valve means to assume its second and first positions immediately prior to said reversing means attaining its forward and reverse positions, respectively, and operator's control valve means operable to forward and reverse positions to effect supply of fluid under pressure selectively to said forward and reverse chambers.

7. The combination as set forth in claim 6, including a stop position of said operator's control valve means to effect supply of fluid under pressure to both said forward and reverse chambers simultaneously.

8. An apparatus for controlling starting, stopping, and reversing of an engine, comprising in combination, a first control pipe, a second control pipe, fluid pressure engine reversing means responsive to selective supply of fluid under pressure to either said first or second control pipe to assume either a forward operation or a reverse operation position, respectively, fluid pressure fuel control means responsive to supply and release of fluid under pressure to and from a pressure chamber to disestablish and establish, respectively, supply of fuel to said engine, a double check valve having one inlet, another inlet and an outlet, said outlet having a fluid pressure connection with said pressure chamber, fluid pressure engine starting means rendered effective and ineffective by supply and release, respectively, of fluid under pressure to and from a first control chamber, directional interlock means selectively connecting said one inlet to either said second control pipe or to said first control pipe according to whether said engine is turning over in its forward or its reverse direction, respectively, a third control pipe, fluid pressure relay valve means responsive to supply and release of fluid under pressure to and from a second control

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chamber to connect selectively said other inlet and said first control chamber either to atmosphere or to said third control pipe, respectively, selector valve means operable by said engine reversing means to connect said second control chamber either to said second or to said first control pipe according to whether the engine is being conditioned for forward or reverse operation, respectively, and an operator's control valve device operable to positions to effect supply of fluid under pressure selectively to either said first control pipe or to said second control pipe and from such positions being operable to intermediate positions to effect supply of fluid under pressure also to said third control pipe and returnable to a stop position to effect supply of fluid under pressure to both said first and said second control pipes.

9. Apparatus for controlling operation of an internal combustion engine comprising in combination, a source of control fluid under pressure, an engine fuel supply pipe for conveying supply of fuel from a source of fuel under pressure to said engine, an engine speed control shaft movable to and between maximum speed and minimum speed positions for varying speed of operation of the engine accordingly, a fluid pressure speed control motor responsive to variations in pressure of fluid in a pressure chamber between maximum and minimum values to move said engine speed control shaft toward and to its maximum speed and minimum speed positions, respectively, an engine speed control pipe connected to said pressure chamber, an operator's control valve device operable manually to effect said variations in pressure of fluid in said speed control pipe, an engine fuel pressure regulating valve device having a fuel chamber open to said engine fuel supply pipe, said fuel pressure regulating device being responsive to variations in pressure of fluid in a control chamber between maximum and minimum pressures to effect variations in pressure of fuel in said fuel supply pipe between maximum and minimum fuel pressures, respectively, and means connecting said control chamber to said engine speed control pipe.

10. Apparatus for controlling operation of an internal combustion engine comprising in combination, a source of control fluid under pressure, an engine fuel supply pipe for conveying supply of fuel to said engine, an engine speed control shaft movable to and between maximum speed and minimum speed positions for varying speed of operation of the engine accordingly, a fluid pressure speed control motor responsive to variations in pressure of fluid in a pressure chamber between maximum and minimum values to move said engine speed control shaft toward and to its maximum speed and minimum speed positions respectively, an engine speed control pipe connected to said pressure chamber, an operator's control valve device operable manually to effect said variations in pressure of fluid in said speed control pipe, an engine fuel pressure regulating valve device having an inlet for connection with a source of fuel under pressure and having an outlet open to said engine fuel supply pipe, said fuel pressure regulating device being responsive to variation in pressure of fluid in a control chamber between maximum and minimum pressures to effect variations in fuel pressure from said inlet to said outlet between minimum and

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maximum fuel pressures, respectively, a relay valve device having a supply chamber connected to said source of fluid under pressure, an exhaust chamber connected to atmosphere and also having a delivery chamber, said relay valve device being responsive to increase and decrease in pressure of fluid in said speed control pipe above and below a certain value selectively to connect said delivery chamber either to said supply chamber or to said exhaust chamber, respectively, and means connecting said delivery chamber to said control chamber.

11. Apparatus for controlling operation of an internal combustion engine comprising in combination, a source of control fluid under pressure, an engine fuel supply pipe for conveying supply of fuel to said engine, an engine speed control shaft movable to and between maximum speed and minimum speed positions for varying speed of operation of the engine accordingly, a fluid pressure speed control motor responsive to variations in pressure of fluid in a pressure chamber between maximum and minimum values to move said engine speed control shaft toward and to its maximum speed and minimum speed positions respectively, an engine speed control pipe connected to said pressure chamber, an operator's control valve device operable manually to effect said variations in pressure of fluid in said speed control pipe, an engine fuel pressure regulating valve device having an inlet adapted for connection with a source of fuel under pressure and an outlet open to said engine fuel supply pipe, said fuel pressure regulating device being responsive to variations in pressure of fluid in a control chamber between maximum and minimum pressures to effect variations in fuel pressure from said inlet to said outlet between minimum and maximum fuel pressures, respectively, a relay valve device having a supply chamber connected to said source of fluid under pressure, an exhaust chamber connected to atmosphere and also having a delivery chamber, said relay valve device being responsive to increase and decrease in pressure of fluid in said speed control pipe above and below a certain value selectively to connect said delivery chamber either to said supply chamber or to said exhaust chamber, respectively, and selector valve means operable to connect said control chamber selectively to said speed control pipe, to said delivery chamber, to said source of fluid under pressure, or to atmosphere.

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