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(54) **METHOD TO CALIBRATE A FUEL INJECTION PUMP**

(57) A method (400) for calibrating a fuel injection pump (106) for a start of a fuel delivery includes calibrating a pressure gauge (200) of an air supply system (172) to a target reading by providing an air flow from the air supply system (172) to a calibration nozzle (176). The pressure gauge (200) is configured to monitor a pressure differential across a membrane (184) of the air supply system (172). The method (400) includes passing the air flow from the air supply system (172) through an air gap (160) defined by one or more bores (150,152) of the fuel injection pump (106), and monitoring a reading of the pressure gauge (200). The method (400) includes moving a plunger (140) of the fuel injection pump (106) to close, at least partly, the air gap (160) to attain the target reading on the pressure gauge (200).

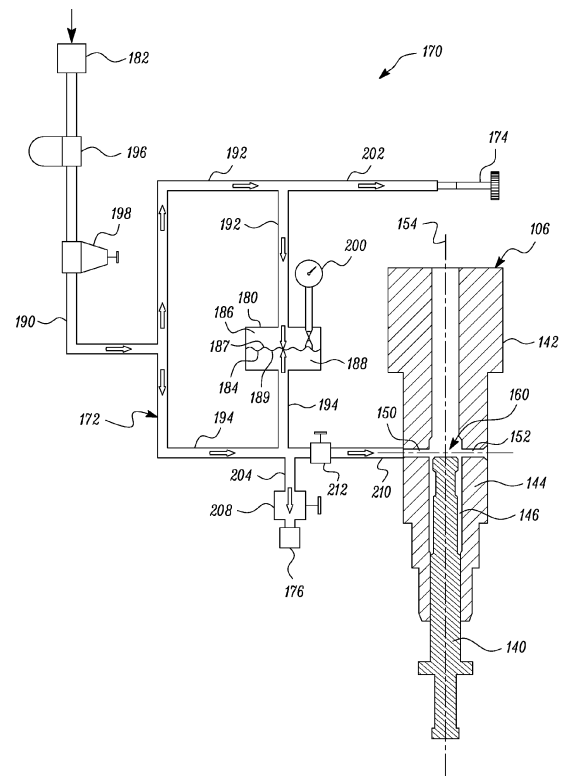


FIG. 3

Description

Technical Field

[0001] This present disclosure relates to a method and a system for calibrating fuel injection pumps for start of fuel delivery into an engine.

Background

[0002] It is a common practice for conventional fuel injection systems, applied in various power generation systems, such as engines, to be calibrated for a start of fuel delivery. Typically, a start of fuel delivery from such fuel injection pumps is calibrated in standardized environment settings, such by mounting the engine on a test bench. Moving the engine to the test bench may be tedious and time consuming. Further, such a process also involves a wastage of fuel.

[0003] Japanese patent no. JPH10220323 relates to an inspecting device for a fuel injection pump capable of accurately judging the GO/NO-GO of a clearance between a pump body and a plunger. The inspecting device comprises a supplying pump for feeding out fuel to a clearance between the outer peripheral face of a plunger and inner peripheral face of the pump body. The weight and flow rate of the fuel passing through the clearance are measured in the relative position by changing the relative position between the pump body and the plunger. The GO/NO-GO of the clearance is judged based on the measurement result.

Summary of the Invention

[0004] In one aspect, the disclosure relates to a method for calibrating a fuel injection pump for a start of a fuel delivery. The method includes calibrating a pressure gauge of an air supply system to a target reading by providing an air flow from the air supply system to a calibration nozzle. The pressure gauge is configured to monitor a pressure differential across a membrane of the air supply system. The method further includes passing the air flow from the air supply system through an air gap defined by one or more bores of the fuel injection pump, and monitoring a reading of the pressure gauge. The method also includes moving a plunger of the fuel injection pump to close, at least partly, the air gap to attain the target reading on the pressure gauge. The fuel injection pump is calibrated for the start of the fuel delivery when the target reading is attained.

[0005] In another aspect, the disclosure relates to a calibration system for calibrating a fuel injection pump for a start of a fuel delivery into a combustion chamber of an engine. The fuel injection pump includes a cylinder, a plunger, and an air gap defined by one or more bores in the cylinder and the plunger. The calibration system includes an air supply system having a housing, a membrane, and a pressure gauge. The membrane is disposed

within the housing and defines a first chamber and a second chamber within the housing. The first chamber and second chamber are configured to receive air from an air source. The pressure gauge is configured to monitor a pressure differential across the membrane. The pressure gauge is configured to be calibrated to a target reading. The air supply system is coupled to the fuel injection pump to provide an air flow through the air gap such that the second chamber is in fluid communication with the air gap. The fuel injection pump is calibrated for start of fuel delivery when the target reading of the pressure gauge is attained upon a movement of the plunger of the fuel injection pump.

Brief Description of the Drawings

[0006]

FIG. 1 is a diagrammatic view of an engine, in accordance with an aspect of the present disclosure; FIG. 2 is a diagrammatic view depicting certain components of the engine, in accordance with an aspect of the present disclosure;

FIG. 3 is a schematic view of a calibration system connected to a fuel injection pump of the engine, in accordance with an aspect of the present disclosure; and

FIG. 4 is a flowchart depicting a method to calibrate the fuel injection pump, in accordance with an aspect of the present disclosure.

Detailed Description

[0007] Referring to FIG. 1 and FIG. 2 an engine 100 is illustrated. The engine 100 may be applied in machines, such as those that are applicable in a construction industry, a mining industry, a marine industry, an agricultural industry, a transport industry, etc. In some implementations, the engine 100 may be applied in stationary power generating machines, and to machines that are applied in commercial and domestic environments.

[0008] The engine 100 includes a cylinder 102 and a piston 104 slidably disposed within the cylinder 102, and a fuel injection pump 106 configured to inject and deliver fuel into a combustion chamber 108 of the engine 100. The combustion chamber 108 is delimited by the piston 104, the cylinder 102, and a cylinder head 110 of the engine 100. The piston 104 is coupled to a connecting rod 112 that is in turn rotatably coupled to a crankshaft 114 of the engine 100, such that a reciprocal movement of the piston 104 translates into a rotary movement of the crankshaft 114. The crankshaft 114 is operatively coupled to a camshaft 116 of the engine 100 such that a rotary movement of the crankshaft 114 translates into a rotary movement of the camshaft 116. The camshaft 116 may be operatively coupled to the crankshaft 114 via a gear assembly 120. The gear assembly 120 may include a first gear 122 attached to the crankshaft 114

and a cam gearwheel 124 attached to the camshaft 116. In an embodiment, an idler gear 126 may be disposed between the first gear 122 and the cam gearwheel 124 to transfer rotation of the first gear 122 to the cam gearwheel 124, and in turn facilitate a rotation/movement of the camshaft 116.

[0009] A rotation/movement of the camshaft 116 facilitates an operation of the fuel injection pump 106, facilitating, and regulating in some cases, a fuel delivery into the combustion chamber 108 of the engine 100, for combustion. To this end, a fuel cam 130 is mounted on the camshaft 116 to operate the fuel injection pump 106. As the camshaft 116 is rotated, a lobe portion 132 of the fuel cam 130 which extends from a base circle 134 of the fuel cam 130 pushes a plunger 140 of the fuel injection pump 106 to initiate a delivery of fuel from the fuel injection pump 106 to the combustion chamber 108. A cam follower 138 may be disposed between the plunger 140 and the fuel cam 130, and contacts the fuel cam 130. As the fuel cam 130 rotates, the cam follower 138 may follow a profile of the fuel cam 130 to cause a movement of the plunger 140. Although a single cylinder is shown, the engine 100 may include multiple cylinders, and thus a configuration and working of the single cylinder, as shown, may be applicable to engines that use multiple cylinders, as well.

[0010] Referring to FIGS. 1 and 3, the fuel injection pump 106 includes a cylinder 142 having a cylindrical wall 144 defining a cylindrical bore 146, and the plunger 140 slidably disposed within the cylindrical bore 146. Further, the fuel injection pump 106 includes one or more bores, for example, a first bore 150 and a second bore 152 extending in a radial direction relative to a central axis 154 of the cylindrical bore 146. The first bore 150 and second bore 152 extend through the entire thickness of the cylindrical wall 144, and are aligned with each other. The first bore 150, the second bore 152, and the cylindrical bore 146 together define an air gap 160 with the plunger 140, above the plunger 140. The plunger 140 and/or the cam follower 138 may be biased in a downward position by a spring 162. The plunger 140 is configured to move in an upward direction when pushed by the cam follower 138 as the cam follower 138 contacts the lobe portion 132 of the fuel cam 130. Further, the fuel injection pump 106 is configured to deliver fuel into the combustion chamber 108 in response to a movement of the plunger 140 in the upward direction. The fuel injection pump 106 needs to start a delivery of the fuel into a combustion chamber 108 of the engine 100 at a desired time to initiate proper combustion and improved efficiency. To enable such a start of the fuel delivery, the fuel injection pump 106 needs to be calibrated. In certain implementation, the fuel injection pump 106 may be calibrated during an assembly of the engine 100.

[0011] To calibrate the fuel injection pump 106 for starting the fuel delivery into the combustion chamber 108 of the engine 100, a calibration system 170 (shown in FIG. 3) is utilized. The calibration system 170 is configured to

be connected with the fuel injection pump 106 to calibrate the fuel injection pump 106 for start of the fuel delivery. Referring to FIG. 3, the calibration system 170 includes an air supply system 172, a fixed nozzle 174, and a calibration nozzle 176. The fixed nozzle 174 and the calibration nozzle 176 are configured to be coupled to the air supply system 172. The air supply system 172 is configured to be coupled to the fuel injection pump 106 for calibrating the fuel injection pump 106. The air supply system 172 includes a housing 180 forming an enclosure for receiving an air from an air source 182, a membrane 184 disposed within the housing 180 and dividing the enclosure into a first chamber 186 and a second chamber 188. Therefore, the membrane 184 defines the first chamber 186 towards a first side 187 of the membrane 184, and defines the second chamber 188 towards a second side 189 of the membrane 184. The air supply system 172 may further include a supply conduit 190, a first conduit 192 coupled to supply conduit 190 and the first chamber 186, and a second conduit 194 coupled to the supply conduit 190 and the second chamber 188. The air supply system 172 is configured to be coupled to the fuel injection pump 106 to provide an air flow through the air gap 160 such that the second chamber 188 is in fluid communication with the air gap 160 for calibrating the fuel injection pump 106.

[0012] The supply conduit 190 is coupled to the air source 182 to receive an air at a pressure from the air source 182. The first conduit 192 facilitates a flow of the air received from the air source 182 via the supply conduit 190 to the first chamber 186. Similarly, the second conduit 194 facilitates a flow of the air received from the air source 182 via the supply conduit 190 to the second chamber 188. Therefore, the first chamber 186 is in fluid communication with the air source 182 via the supply conduit 190, and the first conduit 192, while the second chamber 188 is in fluid communication with the air source 182 via the supply conduit 190 and the second conduit 194.

[0013] In an embodiment, a pressure reducer 196 may be connected to the supply conduit 190 to control a pressure of air supplied from the air source 182 to the air supply system 172. Further, a control valve 198 may also be coupled to the supply conduit 190 to control an amount of air received by the air supply system 172. In an embodiment, the air source 182 may be a compressor, a pressurized air reservoir or any other similar system known in the art.

[0014] The air supply system 172 further includes a pressure gauge 200 that is configured to monitor a pressure differential across the membrane 184. Therefore, the pressure gauge 200 is used to monitor a difference in pressures of the air in the first chamber 186 and the second chamber 188. In certain implementations, the pressure gauge 200 may be a dial gauge (as shown in FIG. 3). The pressure gauge 200 may be in contact with the membrane 184 to detect the pressure differential across the membrane 184. In an embodiment, a tip of

the pressure gauge 200 which is in abutment with the membrane 184, moves in response to a movement of the membrane 184. The membrane 184 may move due to the pressure difference that may exist between the first chamber 186 and the second chamber 188. In response to the movement of the tip of the pressure gauge 200, a reading of the pressure gauge 200 may change, indicating a value of pressure differential between the first chamber 186 and the second chamber 188 (i.e. across the membrane 184).

[0015] Further, the pressure of air in the first chamber 186, and therefore, the pressure of air acting on a first side 187 of the membrane 184, may be controlled by the fixed nozzle 174. For this purpose, the fixed nozzle 174 may be fluidly coupled to the first chamber 186. The pressure in the first chamber 186 may be a function of an air gap (not shown) existing in the fixed nozzle 174. The fixed nozzle 174 may be in fluid communication with the air source 182 and the first chamber 186 via a first channel 202 of the air supply system 172. The first channel 202 may be coupled to the first conduit 192 and may facilitate an air flow (also referred to as flow of air) from the first conduit 192 to the fixed nozzle 174.

[0016] In an embodiment, the calibration nozzle 176 may be selectively fluidly coupled to air supply system 172 for controlling the pressure of air in the second chamber 188, and therefore, the pressure of air acting on the second side 189 of the membrane 184. The calibration nozzle 176 may be coupled to the air supply system 172 via a second channel 204 of the air supply system 172. The second channel 204 facilitates a flow of air from the air source 182 to the calibration nozzle 176 via the second conduit 194. Therefore, the calibration nozzle 176 may be in communication with the air source 182 and the second chamber 188 via the second channel 204. In certain scenarios, when the calibration nozzle 176 is in fluid communication with the second chamber 188 via the second channel 204, the pressure of air in the second chamber 188 may be a function of an air gap (not shown) existing in the calibration nozzle 176. In an embodiment, the air gap in the calibration nozzle 176 may be selected based on a desired air gap in the fuel injection pump 106 for a desired start of the fuel delivery from the fuel injection pump 106 into the combustion chamber 108 of the engine 100. In an embodiment, a shut-off valve 208 may be disposed in the second channel 204 upstream of the calibration nozzle 176. By operating the shut-off valve 208, a flow of air from the air source 182 to the calibration nozzle 176 may be started and/or stopped.

[0017] In an embodiment, the calibration nozzle 176 may be removably coupled to the second channel 204, and the second channel 204 may be connectable to the one of the bores 150, 152 of the fuel injection pump 106. Such a feature may enable the calibration nozzle 176 to be removed from the second channel 204 to allow the second channel 204 to be directly coupled to the fuel injection pump 106 for calibrating the fuel injection pump 106.

[0018] The calibration nozzle 176 is fluidly coupled to the second chamber 188 to control a pressure of air acting on a second side 189 of membrane 184 to calibrate the pressure gauge 200 to a target reading corresponding to a desired pressure differential across the membrane 184. The desired pressure differential and hence the target reading corresponds to a pressure differential that needs to be achieved to calibrate the fuel injection pump 106 for the start of fuel delivery into the combustion chamber 108 of the engine 100.

Industrial Applicability

[0019] Referring to FIG. 4 a method 400 for calibrating the fuel injection pump 106 for start of fuel delivery is now explained. The method 400 is explained in conjunction with FIGS. 1, 2, and 3. The method 400 includes a step 402 that includes calibration of the pressure gauge 200 to the target reading. For calibrating the pressure gauge 200, a flow of air from the air supply system 172 to the calibration nozzle 176 is enabled. To do so, according to an embodiment, the calibration nozzle 176 is coupled to the second channel 204, thereby providing the flow of air from the air source 182 to the calibration nozzle 176 through the second conduit 194 and the second channel 204. In an embodiment, the shut-off valve 208 may be actuated to enable the flow of air to the calibration nozzle 176 from the air supply system 172. Further, the air from the air source 182 enters the second chamber 188 via the second conduit 194 and pressurizes the second chamber 188. As the second chamber 188 is also in fluid communication with the calibration nozzle 176, the pressure of air inside the second chamber 188 may be a function of the air gap of the calibration nozzle 176. Owing to the air gap of the calibration nozzle 176, the air in the second chamber 188 may be at a first pressure 'P1'.

[0020] Further, the air from air source 182 enters into the first chamber 186 via the first conduit 192, and pressurize the first chamber 186. As the first chamber 186 is also in fluid communication with the fixed nozzle 174, the pressure of air inside the first chamber 186 may be a function of the air gap of the fixed nozzle 174. Owing to the air gap of the fixed nozzle 174, the air in the first chamber 186 may be at a second pressure 'P2'. Due to the pressure differential across the membrane 184, the pressure gauge 200 will show a reading that corresponds to the target reading. In this manner, the pressure gauge 200 is calibrated to the targeted reading. After calibrating the pressure gauge 200 to the target reading, the flow of the air to the calibration nozzle 176 is disabled/stopped before passing the air flow through the air gap 160 of the fuel injection pump 106. Thus, the air supply system 172 is fluidly decoupled from the calibration nozzle 176 before establishing a fluid coupling between the air supply system 172 and the fuel injection pump 106. The air supply system 170 is coupled to the fuel injection pump 106 such that the second chamber 188 is in fluid communication with the air gap 160. For fluidly decoupling the air supply

system 172 from the calibration nozzle 176, in an embodiment, the calibration nozzle 176 may be removed from the second channel 204. In such a case, the second channel 204 may be directly coupled to the first bore 150 to enable a flow of air through the air gap 160 from the air supply system 172. Alternatively, the shut-off valve 208 may be controlled to stop supply of air from the air supply system 172 to the calibration nozzle 176. In such a case, for establishing a fluid coupling between the air supply system 172 and the fuel injection pump 106, a third channel 210 of the air supply system 172 may be coupled with the first bore 150 to enable a flow of air through the air gap 160 from the air supply system 172.

[0021] Now, the method 400 moves to a step 404 that includes passing the air from the air supply system 172, through the air gap 160 of the fuel injection pump 106. In an embodiment, before passing the air through the air gap 160, the fuel cam 130 may be moved/turned to the base circle 134 such that the cam follower 138 abuts/contacts the base circle 134 of the fuel cam 130. To enable the flow of the air through the air gap 160, the air supply system 172 is coupled to the fuel injection pump 106 such that the air gap 160 is in fluid communication with the second chamber 188 and the air source 182 through the first bore 150. In an embodiment, the air supply system 172 may be coupled to the fuel injection pump 106 by coupling the second channel 204 to the first bore 150 after removing the calibration nozzle 176 from the air supply system 172. In another embodiment, the third channel 210 may be coupled to the first bore 150 to enable a flow of air provided by the air source 182 and the air supply system 172 through the air gap 160. In such a case, the flow of air to the calibration nozzle 176 may be disabled by controlling the shut-off valve 208. In an embodiment, a valve 212 may be disposed on the third channel 210 to control a flow of air from the air source 182 through the air supply system 172 to the air gap 160. Upon enabling the flow of air through the air gap 160 a reading of the pressure gauge 200 is monitored.

[0022] Thereafter, the method 400 moves to step 406. In the step 406, the plunger 140 of the fuel injection pump 106 is moved to, at least partially, close the air gap 160 to attain the target reading on the pressure gauge 200. The plunger 140 of the fuel injection pump 106 may be moved by rotating the crankshaft 114 and subsequently the camshaft 116 in a direction that corresponds to a rotation of crankshaft 114 when the engine 100 produces power. In an embodiment, a control rod of the fuel injection pump 106 may be brought a full load position before moving the crankshaft 114 and camshaft 116. Upon movement of the fuel cam 130 due to the rotation of the camshaft 116, the cam follower 138 may come in contact with the lobe portion 132, and may follow the profile of the lobe portion 132 upon further rotation of the camshaft 116. The movement of the cam follower 138 may cause the plunger 140 to move in the upward direction, causing reduction of the air gap 160 of the fuel injection pump 106. The reduction in the air gap 160 may result in an

increase in the pressure into the second chamber 188 of the air supply system 172. In so doing, a reading on the pressure gauge 200 changes and moves towards the target reading. The plunger 140 is moved in the upward direction by rotating the camshaft 116 till the reading on the pressure gauge 200 reaches the target reading. Further movement of the plunger 140 is stopped as the pressure gauge 200 attains the target reading. The position of the plunger 140 upon attaining the targeted reading corresponds to the start of fuel delivery from the fuel injection pump 106. In this manner, the fuel injection pump 106 is calibrated for the start of the fuel delivery when the target reading is attained.

[0023] In certain implementations, a graduated disc (not shown) may be mounted on the crankshaft 114 to indicate a position of the piston 104 before a top dead center (TDC) of the cylinder 102. In an implementation, the position of the piston 104 indicated by the graduated disc, upon attainment of the target reading, may differ from a designed fuel injection timing. The designed fuel injection timing may correspond to a specified position of the piston 104 before the TDC. In an exemplary embodiment, the designed fuel injection timing may correspond to a position of the piston 104 which is 10 degrees before the TDC.

[0024] When the position of the piston 104 differs from the specified position, the piston 104 may be moved to the specified position to enable a start of fuel delivery into the combustion chamber 108 at the designed fuel injection timing. For so doing, the camshaft 116 is decoupled from the crankshaft 114 so as to prevent a transfer of a motion of the piston 104/ crankshaft 114 to the camshaft 116, and subsequently to the plunger 140. In certain implementations, the decoupling of the camshaft 116 from the crankshaft 114 may be achieved by decoupling the cam gearwheel 124 from the camshaft 116. In an embodiment, decoupling of the cam gearwheel 124 from the camshaft 116 is performed by hydraulically expanding the cam gearwheel 124 attached to the camshaft 116. After decoupling the crankshaft 114 from the camshaft 116, the crankshaft 114 may be moved to move the piston 104 to the specified position before TDC. The specified position may correspond to the position of the piston 104 at the designed fuel injector timing, and therefore the start of the fuel delivery into the combustion chamber 108 of the engine 100. The specified position of the piston 104 may be indicated by the graduated disc. Upon moving and positioning the piston 104 at the specified position, the crankshaft 114 is again coupled to the camshaft 116. In this manner, the fuel injection pump 106 is calibrated for start of fuel delivery into the combustion chamber 108 of the engine 100 at the designed fuel injection timing.

[0025] In an optional embodiment, to check an accurate start of fuel delivery at the designed fuel injection timing, the piston 104 may be moved away from the specified position by rotating the crankshaft 114 in a direction opposite to the direction of a rotation of the crankshaft

114 in which the crankshaft 114 rotates when the engine 100 generates power. This results into a change in the reading of the pressure gauge 200. Thereafter, the piston 104 may be moved at the specified position by rotating the crankshaft 114 in the direction of rotation of the crankshaft 114 that results into generation of power. As the piston 104 reaches the specified position, the reading indicated by the pressure gauge 200 reaches the target reading and therefore confirms an accurate calibration of the fuel injection pump 106 for the start of the fuel delivery at the designed fuel injection timing. By using the calibration system 170 and the method 400 as explained above, the calibration of the fuel injection pump 106 for start of fuel delivery into the combustion chamber 108 of the engine 100 can be performed on an assembly line. Further, calibration system 170 and the method 400 as explained above reduces the overall time required for calibration of fuel injection pump 106 for start of fuel delivery into the combustion chamber 108 of the engine 100.

[0026] In certain implementations, an engine may include multiple cylinders. In such a case, the start of the fuel delivery from a fuel injection pump for a first cylinder is calibrated in a manner explained above. For calibrating a start of fuel delivery for the other cylinders from the corresponding fuel injection pumps, the steps 402, 404, and 406, are performed. Thereafter, shims of appropriate thickness may be utilized. In some embodiments, the engine with multiple cylinders may include a lower valve drive that may include one or more blocks to which cam followers of the fuel injection pumps are mounted. In such a case, shims may be inserted between the block and an engine block defining the cylinders of the engine. In certain implementations, the engine may be a right turning engine. In such a case, shims of greater thickness are inserted to enable a late start of delivery of fuel relative to the start of fuel delivery in the first cylinder. Alternatively, shims of reduced thickness may be inserted to enable an early start of fuel delivery relative to the start of fuel delivery into the first cylinder. In other implementations, the engine may be a left turning engine. In such a case, shims of greater thickness are inserted to enable an early start of delivery of fuel relative to the start of fuel delivery in the first cylinder. Alternatively, shims of greater thickness may be inserted to enable a late start of fuel delivery relative to the start of fuel delivery into the first cylinder.

[0027] It should be understood that the above description is intended for illustrative purposes only and is not intended to limit the scope of the present disclosure. Thus, one skilled in the art will appreciate that other aspects of the disclosure may be obtained from a study of the drawings, the disclosure, and the appended claim.

Claims

1. A method (400) for calibrating a fuel injection pump (106) for a start of a fuel delivery, the method (400)

comprising:

calibrating a pressure gauge (200) of an air supply system (172) to a target reading by providing an air flow from the air supply system (172) to a calibration nozzle (176), the pressure gauge (200) is configured to monitor a pressure differential across a membrane (184) of the air supply system (172);
 passing the air flow from the air supply system (172) through an air gap (160) defined by one or more bores (150,152) of the fuel injection pump (106), and monitoring a reading of the pressure gauge (200); and
 moving a plunger (140) of the fuel injection pump (106) to close, at least partly, the air gap (160) to attain the target reading on the pressure gauge (200), wherein the fuel injection pump (106) is calibrated for the start of the fuel delivery when the target reading is attained.

2. The method (400) of claim 1, further comprising stopping the air flow to the calibration nozzle (176) before passing the air flow through the air gap (160) of the fuel injection pump (106).
3. The method (400) of claim 1, wherein the fuel injection pump (106) is configured to deliver fuel into a combustion chamber (108) of an engine (100), wherein moving the plunger (140) includes rotating a camshaft (116) of the engine (100).
4. The method (400) of claim 1, wherein the fuel injection pump (106) is configured to deliver fuel into a combustion chamber (108) of an engine (100), the method (400) further including turning a fuel cam (130) of the engine (100) to a base circle (134) of the fuel cam (130) before passing the air flow through the air gap (160).
5. The method (400) of claim 1, wherein the fuel injection pump (106) is configured to deliver fuel into a combustion chamber (108) of an engine (100), the method (400) further including decoupling a camshaft (116) of the engine (100) from a crankshaft (114) of the engine (100) and moving a piston (104) of the engine (100) to a specified position before a top dead center (TDC) by rotating the crankshaft (114), wherein the specified position corresponds to the start of the fuel delivery.
6. The method (400) of claim 5, wherein decoupling is performed by hydraulically expanding a cam gear-wheel (124) attached to the camshaft (116).
7. The method (400) of claim 5 further including coupling the camshaft (116) with the crankshaft (114) after moving the piston (104) to the specified position

before TDC.

8. The method (400) of claim 1, wherein a fixed nozzle (174) is coupled to the air supply system (172), the fixed nozzle (174) being configured to control a pressure of air acting on a first side (187) of the membrane (184). 5

9. The method (400) of claim 1, wherein the calibration nozzle (176) is coupled to the air supply system (172), the calibration nozzle (176) being configured to control a pressure of air acting on a second side (189) of the membrane (184). 10

10. A calibration system (170) for calibrating a fuel injection pump (106) for a start of a fuel delivery into a combustion chamber (108) of an engine (100), the fuel injection pump (106) includes a cylinder (142), a plunger (140), and an air gap (160) defined by one or more bores (150,152) in the cylinder (142) and the plunger (140), the calibration system (170) comprising: 15

an air supply system (172) including: 20

a housing (180); 25

a membrane (184) disposed within the housing (180) and defining a first chamber (186) and a second chamber (188) within the housing (180), the first chamber (186) and the second chamber (188) configured to receive air from an air source (182); and 30

a pressure gauge (200) configured to monitor a pressure differential across the membrane (184), the pressure gauge (200) configured to be calibrated to a target reading, 35

wherein the air supply system (172) is coupled to the fuel injection pump (106) to provide an air flow through the air gap (160) such that the second chamber (188) is in fluid communication with the air gap (160), and 40

wherein the fuel injection pump (106) is calibrated for the start of the fuel delivery when the target reading of the pressure gauge (200) is attained upon a movement of the plunger (140) of the fuel injection pump (106). 45

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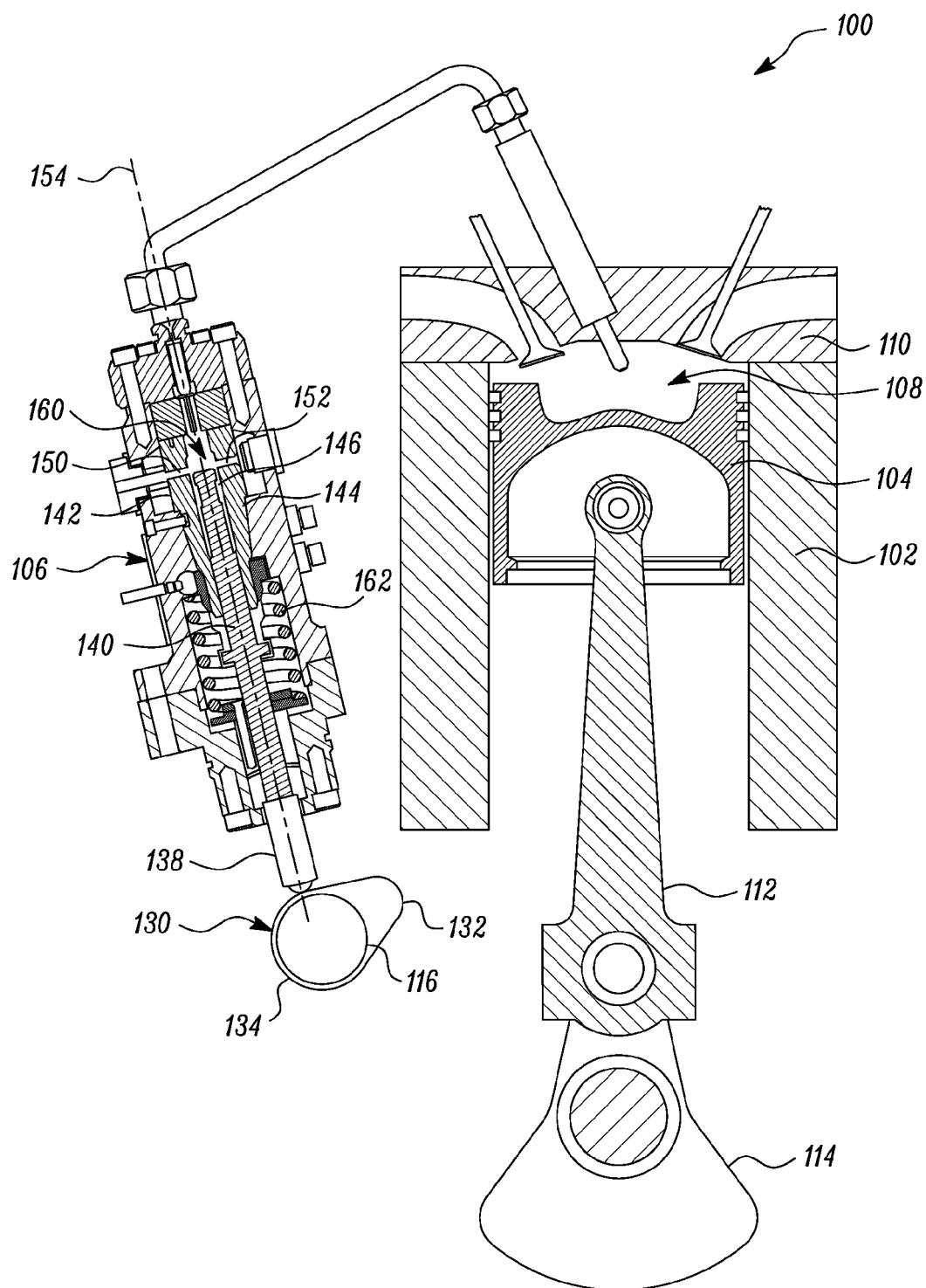


FIG. 1

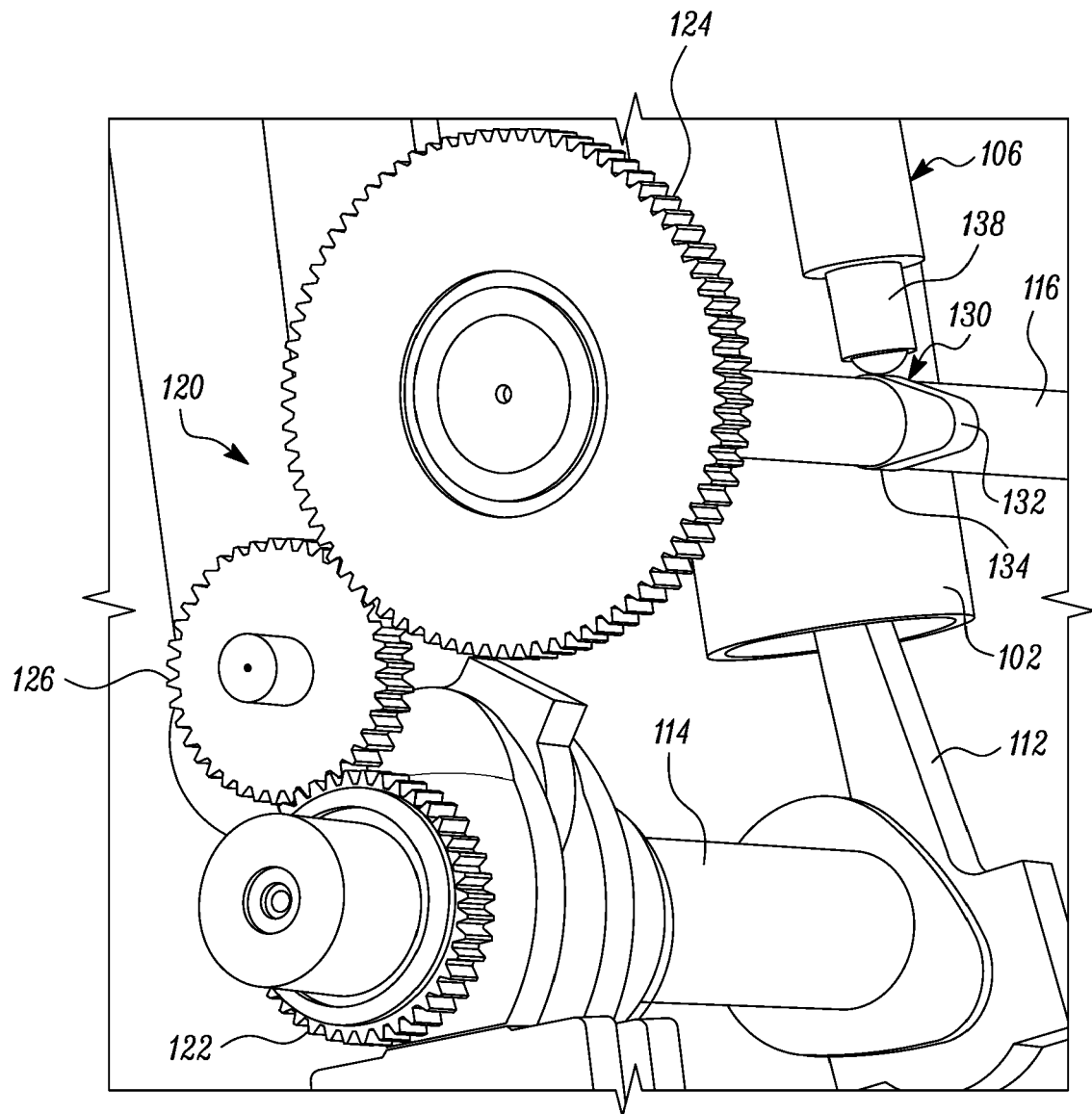


FIG. 2

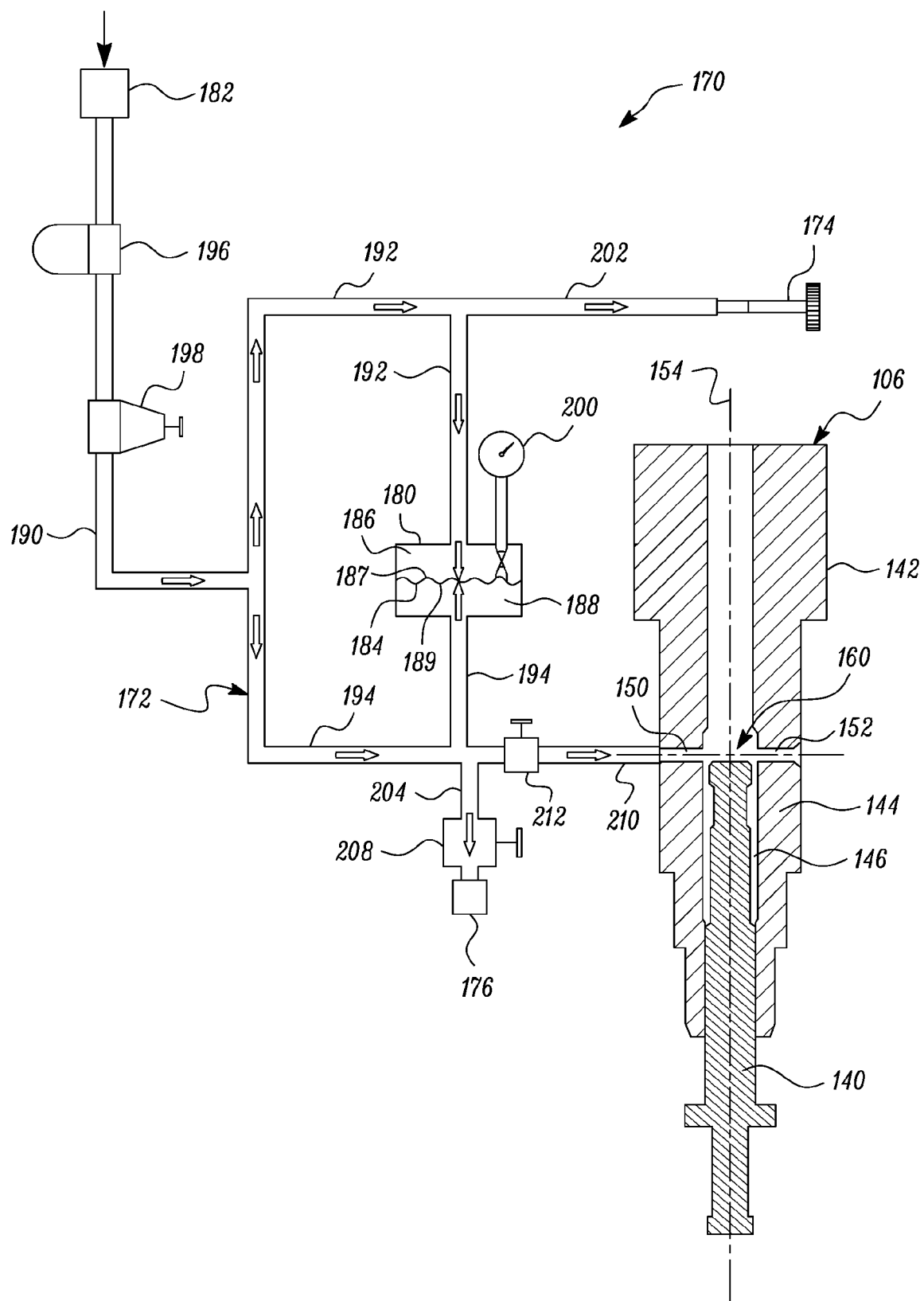


FIG. 3

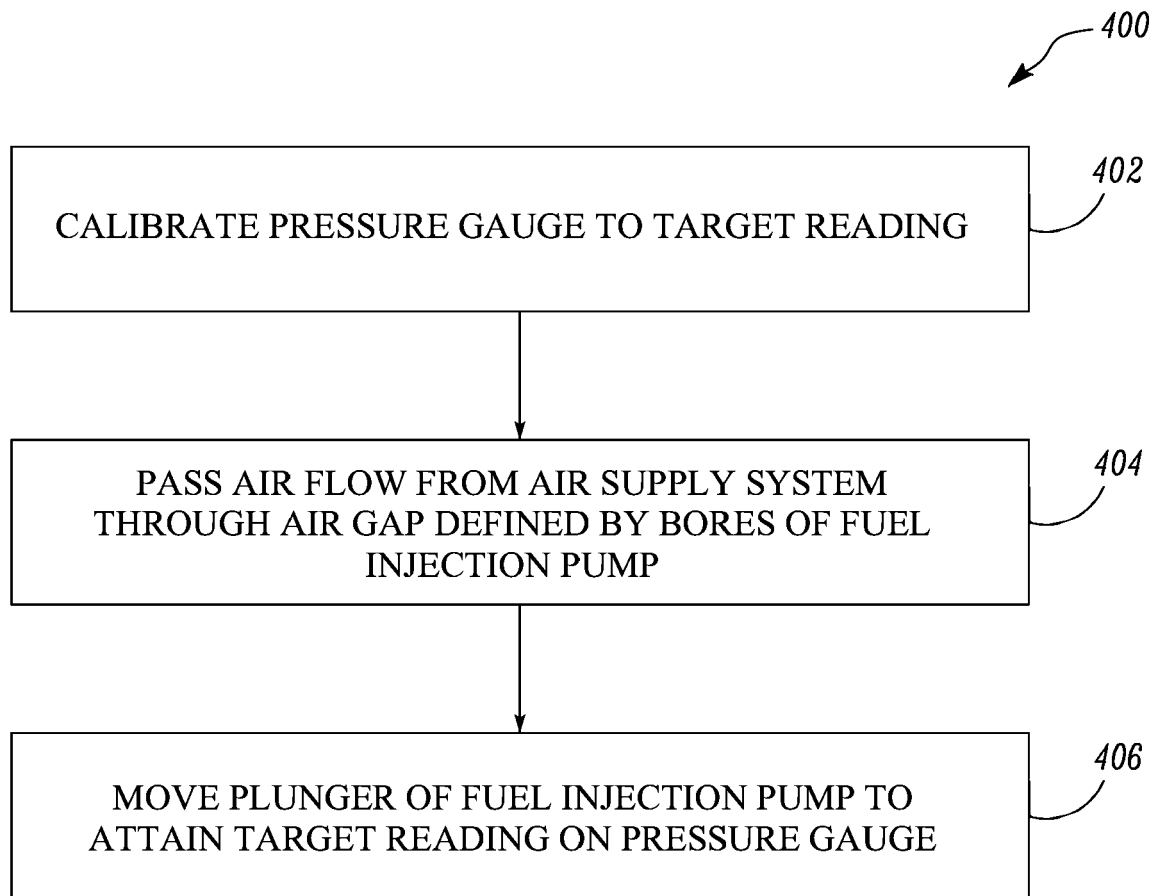


FIG. 4

REFERENCES CITED IN THE DESCRIPTION

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