(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
02 March 2023 (02.03.2023)

WIPO | PCT

(10) International Publication Number
WO 2023/028512 A1

(51) International Patent Classification:
F02M 21/02 (2006.01) *F02D 41/40* (2006.01)
F02D 3/00 (2006.01) *F02D 19/02* (2006.01)
F02D 41/34 (2006.01) *F02D 41/38* (2006.01)

(21) International Application Number:
PCT/US2022/075383

(22) International Filing Date:
24 August 2022 (24.08.2022)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
17/459,909 27 August 2021 (27.08.2021) US

(71) Applicant: **WOODWARD, INC.** [US/US]; 1081 Woodward Way, Fort Collins, Colorado 80524 (US).

(72) Inventors: **CHIERA, Domenico**; 1081 Woodward Way, Fort Collins, Colorado 80524 (US). **KARSPECK, John**; 1081 Woodward Way, Fort Collins, Colorado 80524 (US). **BUEHNER, Michael Ryan**; 1081 Woodward Way, Fort Collins, Colorado 80524 (US). **MCCREERY, Samuel James**; 1081 Woodward Way, Fort Collins, Colorado 80524 (US).

(74) Agent: **MUSSELMAN, JR., P. Weston** et al.; Fish & Richardson P.C., P.O. Box 1022, Minneapolis, Minnesota 55440-1022 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH,

WO 2023/028512 A1

(54) Title: ASYNCHRONOUS ROTARY FUEL VALVE

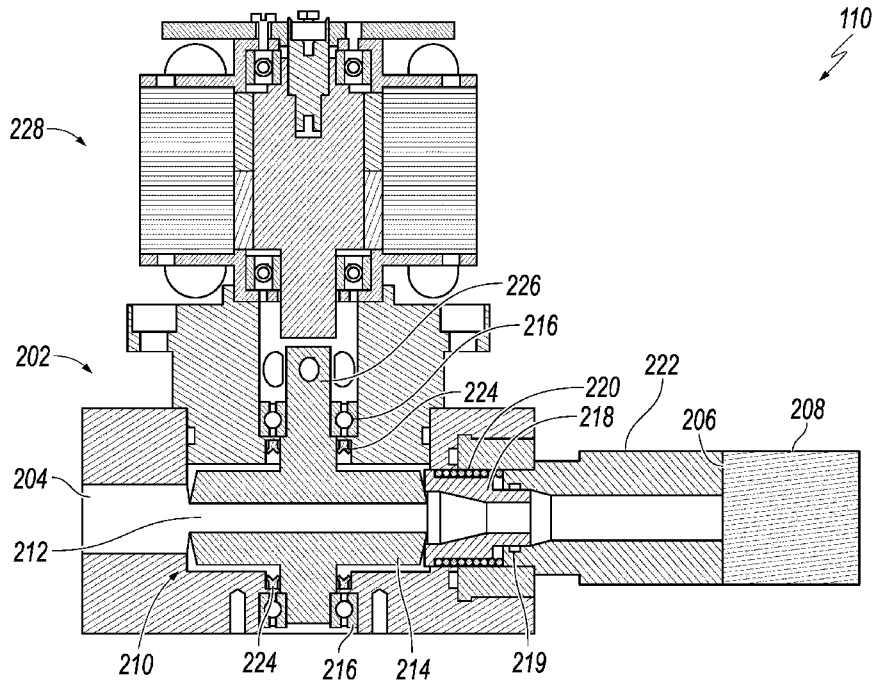


FIG. 2

(57) Abstract: A housing (202) defines a gaseous fuel inlet (204) and a gaseous fuel outlet (206). A rotor (210) defines an internal flow passage (212) therethrough that rotates with the rotor to, alternately, allow gaseous fuel flow, or to block gaseous fuel flow, between the inlet and the outlet, based on a position of the rotor. A seal (218) is biased to abut an exterior surface of the rotor. The seal is between the rotor and the outlet. An actuator is rotably coupled to the rotor. A driver (228) is configured to rotate the rotor. A controller (114) is in communication with the driver and is configured to control the driver to rotate at a rate based on an engine speed of the engine.

[Continued on next page]

TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*

ASYNCHRONOUS ROTARY FUEL VALVE

CLAIM OF PRIORITY

[0001] This application claims priority to U.S. Patent Application No. 17/459,909 filed on August 27, 2021, the entire contents of which are hereby incorporated by reference.

TECHNICAL FIELD

[0002] This disclosure relates to rotary fuel valves for internal combustion engine systems.

BACKGROUND

[0003] Internal combustion engines take a combustible mixture of air and fuel to ignite the combustible mixture within a combustion chamber (e.g., a cylinder) to produce work due to the expansion of the ignited combustible mixture. In the case of a piston/cylinder engine, the air and fuel is generally mixed within an intake manifold prior to entering the engine cylinders, though direct injection engines that mix air and fuel within the cylinder are known as well.

[0004] Fuel is added by a fuel injector or fuel admitter. Such fuel introduction can add gaseous fuel and/or atomize liquid fuel such that it is easily ignited within the ignition chamber. Fuel injectors/admitters are sized based on a desired output of the internal combustion engine and the energy density of the fuel used.

SUMMARY

[0005] This disclosure describes an asynchronous rotary fuel valve.

[0006] In a first example, a fuel admission valve for an engine comprises a housing defining a gaseous fuel inlet and a gaseous fuel outlet, a rotor defining an internal flow passage therethrough that rotates with the rotor to, alternately, allow gaseous fuel flow or to block gaseous fuel flow between the inlet and the outlet based on a position of the rotor, a seal biased to abut an exterior surface of the rotor, the seal being between the rotor and the outlet, an actuator rotably coupled to the rotor, the driver configured to rotate the rotor, and a controller in communication with the driver and configured to control the driver to rotate at a rate based on an engine speed of the engine.

[0007] In a second example, according to example 1, the controller is further configured to adjust the rotor independent of a cylinder intake valve.

[0008] In a third example, according to example 1 or 2, the controller is configured to control the rotor to rotate continuously in a single direction.

[0009] In a fourth example, according to any one of examples 1 to 3, the driver comprises a stepper motor.

[0010] In a fifth example, according to any one of examples 1 to 4, where the rotor comprises a disc with a spherically shaped circumferential edge.

[0011] In a sixth example, according to any one of examples 1 to 5, the internal flow passage comprises a non-circular opening, at ends of the internal flow passage, corresponding to a specified shape of an injector pulse.

[0012] In a seventh example, according to example 6, the non-circular profile comprises a substantially oval shape.

[0013] In an eighth example, according to example 6 or 7, the non-circular profile is asymmetric.

[0014] In a ninth example, according to any one of examples 1 to 8, the seal encircles an outlet of the internal flow passage when the internal flow passage is aligned with the gaseous fuel outlet.

[0015] In a tenth example, according to any one of examples 1 to 9, the fuel admission valve comprises a check valve in the fuel outlet.

[0016] In an eleventh example, a method comprises receiving a gaseous fuel from a pressurized gaseous fuel manifold by a gaseous fuel inlet of a fuel admission valve, regulating a flow of the gaseous fuel from the gaseous fuel inlet to a gaseous flow outlet, responsive to a fuel control signal, by a rotating rotor comprising a flow passage therethrough, the flow passage rotating with the rotor, and supplying the gaseous fuel to a manifold of an internal combustion engine by the flow outlet.

[0017] In a twelfth example, according to example 11, regulating the flow of the gaseous fuel comprises rotating the rotor by a driver, the rotor rotating at a speed that is a function of an engine speed of the internal combustion engine.

[0018] In a thirteenth example, according to example 12, rotating the rotor comprises continuously rotating the valve in a single direction.

[0019]In a fourteenth example, according to any one of examples 11 to 13, the flow is further regulated by a profile of the flow passage tuned to form a specified fuel admission rate profile.

[0020]In a fifteenth example, according to any one of examples 11 to 14, the method comprises mixing air with the gaseous fuel within the manifold, downstream of the flow outlet, prior to entering a combustion cylinder.

[0021] In a sixteenth example, an engine system comprises an internal combustion engine, an intake manifold configured to receive air from an air intake and configured to receive fuel from a fuel port, and a gaseous fuel admission valve configured to supply a gaseous fuel to an intake manifold by the fuel port, the fuel admission valve comprising a housing defining a gaseous fuel inlet and a gaseous fuel outlet, a rotor defining an internal flow passage therethrough that rotates with the rotor to allow gaseous fuel flow or to block gaseous fuel flow between the inlet and the outlet based on a position of the rotor, a seal defining a portion of an outlet flow passage, the seal biased to abut a movable surface of the rotor, the seal being between the rotor and the outlet, a driver rotably coupled to the rotor, the driver configured to rotate the rotor, and a controller configured to control the driver to rotate at a rate that is a function of an engine speed, adjust the rotor independent of the intake valve, and send an electrical signal to the driver to rotate the rotor continuously in a single direction.

[0022]In a seventeenth example, according to example 16, the intake manifold comprises a plurality of outlets, a number of outlets corresponding to a number of combustion cylinders of the internal combustion engine, where the fuel port is a first fuel port, the intake manifold comprising a plurality of fuel ports corresponding to the number of outlets, each fuel outlet comprising a fuel port, where the gaseous fuel injector is a first gaseous fuel injector, the engine system comprising a plurality of gaseous fuel injectors, a number of fuel injectors corresponding to the number of fuel ports, each of the plurality of injectors fluidically connected to a corresponding fuel port.

[0023] In an eighteenth example, according to example 16 or 17, the controller is further configured to adjust a speed of a first of the plurality of drivers based on received engine parameters.

[0024] In a nineteenth example, according to any one of examples 16 to 18, the controller is further configured to adjust a speed of a second of the plurality of drivers to be a different speed than the first of the plurality of drivers.

[0025] In a twentieth example, according to any one of examples 16 to 19, the drivers are electric motors, and the controller is configured to adjust the speed of one of the drivers by adjusting the electrical signal to one of the electric motors.

[0026]In a twenty-first example, according to any one of examples 16 to 20, the fuel admission valve is arranged to deliver fuel directly to a cylinder of an internal combustion engine.

[0027] In a twenty-second example, according to any one of examples 16 to 21, the flow passage comprises a profile defining a specified shape of an injector pulse.

[0028]An example of the subject matter described within this disclosure is a fuel admission valve for an engine. The fuel admission valve includes the following features. A housing defines a gaseous fuel inlet and a gaseous fuel outlet. A rotor defines an internal flow passage therethrough that rotates with the rotor to, alternately, allow gaseous fuel flow, or to block gaseous fuel flow, between the inlet and the outlet, based on a position of the rotor. A seal is biased to abut an exterior surface of the rotor. The seal is between the rotor and the outlet. An actuator is rotably coupled to the rotor. The driver is configured to rotate the rotor. A controller is in communication with the driver and is configured to control the driver to rotate at a rate based on an engine speed of the engine.

[0029] Aspects of the example fuel admission valve, which can be combined with the example fuel admission valve alone or in combination with other aspects, include the following. The controller is further configured to adjust the rotor independent of a cylinder intake valve.

[0030] Aspects of the example fuel admission valve, which can be combined with the example fuel admission valve alone or in combination with other aspects, include the following. The controller is configured to control the rotor to rotate continuously in a single direction.

[0031] Aspects of the example fuel admission valve, which can be combined with the example fuel admission valve alone or in combination with other aspects, include the following. The driver includes a stepper motor.

[0032] Aspects of the example fuel admission valve, which can be combined with the example fuel admission valve alone or in combination with other aspects, include the following. The rotor includes a disc with a spherically shaped circumferential edge.

[0033] Aspects of the example fuel admission valve, which can be combined with the example fuel admission valve alone or in combination with other aspects, include the following. The internal flow passage comprises a non-circular opening, at ends of the internal flow passage, corresponding to a specified shape of an injector pulse.

[0034] Aspects of the example fuel admission valve, which can be combined with the example fuel admission valve alone or in combination with other aspects, include the following. The non-circular profile comprises a substantially oval shape.

[0035] Aspects of the example fuel admission valve, which can be combined with the example fuel admission valve alone or in combination with other aspects, include the following. The non-circular profile is asymmetric.

[0036] Aspects of the example fuel admission valve, which can be combined with the example fuel admission valve alone or in combination with other aspects, include the following. The seal encircles an outlet of the internal flow passage when the internal flow passage is aligned with the gaseous fuel outlet.

[0037] Aspects of the example fuel admission valve, which can be combined with the example fuel admission valve alone or in combination with other aspects, include the following. A check valve is in the fuel outlet.

[0038] An example implementation of the subject matter described within this disclosure is a method with the following features. A gaseous fuel is received from a pressurized gaseous fuel manifold by a gaseous fuel inlet of a fuel admission valve. A flow of the gaseous fuel from the gaseous fuel inlet to a gaseous flow outlet is regulated, responsive to a fuel control signal, by a rotating rotor with a flow passage therethrough. The flow passage rotates with the rotor. The gaseous fuel is supplied to a manifold of an internal combustion engine by the flow outlet.

[0039] Aspects of the example method, which can be combined with the example method alone or in combination with other aspects, include the following. Regulating the flow of the gaseous fuel includes rotating the rotor by a driver. The rotor rotates at a speed that is a function of an engine speed of the internal combustion engine.

[0040] Aspects of the example method, which can be combined with the example method alone or in combination with other aspects, include the following. Rotating the rotor includes continuously rotating the valve in a single direction.

[0041] Aspects of the example method, which can be combined with the example method alone or in combination with other aspects, include the following. The

flow is further regulated by a profile of the flow passage tuned to form a specified fuel admission rate profile.

[0042] Aspects of the example method, which can be combined with the example method alone or in combination with other aspects, include the following. Air is mixed with the gaseous fuel within the manifold, downstream of the flow outlet, prior to entering a combustion cylinder.

[0043] An example implementation of the subject matter described within this disclosure is an engine system with the following features. An intake manifold is configured to receive air from an air intake and configured to receive fuel from a fuel port. A gaseous fuel admission valve is configured to supply a gaseous fuel to an intake manifold by the fuel port. The fuel admission valve includes a housing defining a gaseous fuel inlet and a gaseous fuel outlet. A rotor defines an internal flow passage therethrough that rotates with the rotor to allow gaseous fuel flow, or to block gaseous fuel flow, between the inlet and the outlet based on a position of the rotor. A seal defines a portion of an outlet flow passage. The seal is biased to abut a movable surface of the rotor. The seal is between the rotor and the outlet. A driver is rotably coupled to the rotor. The driver is configured to rotate the rotor. A controller is configured to control the driver to rotate at a rate that is a function of a speed of an engine. The controller is configured to adjust the rotor independent of the intake valve. The controller is configured to send an electrical signal to the driver to rotate the rotor continuously in a single direction.

[0044] Aspects of the example engine system, which can be combined with the example engine system alone or in combination with other aspects, include the following. The intake manifold includes outlets. A number of outlets corresponds to a number of combustion cylinders of the internal combustion engine. The fuel port is a first fuel port. The intake manifold includes fuel ports corresponding to the number of outlets. Each fuel outlet includes a fuel port. The gaseous fuel injector is a first gaseous fuel injector. The engine system includes multiple gaseous fuel injectors. A number of fuel injectors corresponds to the number of fuel ports. Each of the injectors fluidically connects to a corresponding fuel port.

[0045] Aspects of the example engine system, which can be combined with the example engine system alone or in combination with other aspects, include the

following. The intake manifold includes outlets. The controller is further configured to adjust a speed of a first of the plurality of drivers based on received engine parameters.

[0046] Aspects of the example engine system, which can be combined with the example engine system alone or in combination with other aspects, include the following. The intake manifold includes outlets. The controller is further configured to adjust a speed of a second of the plurality of drivers to be a different speed than the first of the plurality of drivers.

[0047] Aspects of the example engine system, which can be combined with the example engine system alone or in combination with other aspects, include the following. The intake manifold includes outlets. The drivers are electric motors. The controller is configured to adjust the speed of one of the drivers by adjusting the electrical signal to one of the electric motors.

[0048] Aspects of the example engine system, which can be combined with the example engine system alone or in combination with other aspects, include the following. The fuel admission valve is arranged to deliver fuel directly to a cylinder of an internal combustion engine.

[0049] Aspects of the example engine system, which can be combined with the example engine system alone or in combination with other aspects, include the following. The flow passage comprises a profile defining a specified shape of an injector pulse.

[0050] The details of one or more implementations are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0051] FIG. 1 is a schematic diagram of an internal combustion intake manifold.

[0052] FIG. 2 is a side cross-sectional view of an example fuel admission valve.

[0053] FIG. 3 is a side view of an example rotor and passage opening of the example fuel admission valve.

[0054] FIGS. 4A-4B is an example fuel delivery profile and a circular passage opening that provides the example fuel delivery profile.

[0055] FIG. 5 is a block diagram of an example controller that can be used with aspects of this disclosure.

[0056] FIG. 6 is a flowchart of an example method that can be used with aspects of this disclosure.

[0057] Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0058] Low energy density gaseous fuels, such as hydrogen, can be difficult for fuel injectors due to the large flow rates of gaseous fuel needed in such applications. In addition, low molar weight gaseous fuels are prone to leakage through traditional fuel admission systems. This disclosure describes a fuel admission/injection valve that includes a rotor that defines an internal flow passage therethrough that rotates with the rotor to allow gaseous fuel flow or to block gaseous fuel flow between the inlet and the outlet based on a position of the rotor. The rotor is driven by a driver rotably coupled to and configured to rotate the rotor. The rotational speed of the rotor can be adjusted and controlled by an engine controller such that the rotor rotates to meter port fuel admission/injection based on a variety of engine parameters, such as engine speed.

[0059] FIG. 1 is a schematic diagram of an internal combustion engine 101 intake manifold 102 for an internal combustion engine system 100. The intake manifold 102 is configured to receive air 104 from an air intake. Between the air intake and the port 106 to the cylinders 108 is a throttle 112. The throttle 112 regulates a flowrate of air into the intake manifold 102. The intake manifold includes multiple outlets, or ports 106. The number of ports 106 corresponds to a number of combustion cylinders 108 of the internal combustion engine 101. For example, as illustrated, the intake manifold 102 has six ports 106 corresponding to six combustion cylinders 108. While the illustrated implementation includes an in-line, six-cylinder engine, the subject matter described herein is applicable to other internal combustion engine configurations, for example, a cylinder engine with fewer or additional cylinders and/or a V-configuration, a rotary engine, or a gas-turbine.

[0060] Fuel injection/admission valves 110 are fluidically connected to the inside of the intake manifold 102 by fuel ports (not shown, underneath the fuel injection/admission valves 110). The illustrated implementation includes a port

injection arrangement. As such, there is a corresponding fuel port and fuel injection/admission valve 110 for each cylinder 108 of the engine 101.

[0061] While primarily illustrated and described in terms of port injection arrangements, other arrangements can be used without departing from this disclosure. For example, the subject matter described herein can be applied to direct injection systems. In such implementations, the fuel injection/admission valves 110 are arranged to deliver fuel directly to a corresponding cylinder 108 of an internal combustion engine. In some implementations, a single point injection system can be used. In such an implementation, a single injection/admission valve 110 can be used to supply fuel to the entire manifold. The concepts described herein are also applicable to batch and/or sequential injection applications.

[0062] Regardless of the injection/admission arrangement, the fuel injection/admission valves are coupled to, and controlled by, a controller 114. The controller 114 can be a part of the engine control unit, or it can be a stand-alone controller. Details of the controller 114 are described throughout this disclosure. In general, the controller 114 controls the fuel injection/admission valves 110 to admit fuel at the desired rate, desired duration, and at the desired time based on engine operation parameters.

[0063] FIG. 2 is a side cross-sectional view of an example fuel admission valve 110. The fuel admission valve 110 includes a housing 202 defining a gaseous fuel inlet 204 and a gaseous fuel outlet 206. The gaseous fuel inlet 204 is fluidically coupled to the intake manifold 102 (FIG. 1) as previously described. The gaseous fuel outlet 206 is fluidically connected to an intake manifold of an internal combustion engine, or directly to an inlet of an engine cylinder. In some implementations, a check valve 208 can be included at the gaseous fuel outlet 206, especially for direct injection (e.g. being directly coupled to a cylinder inlet) applications.

[0064] Housed within the housing 202 is a rotor 210 defining an internal flow passage 212 therethrough. The internal flow passage 212 rotates in unison with the rotor 210 to allow, regulate, or block gaseous fuel flow between the inlet 204 and the outlet 206 based on a position of the rotor 210. In some implementations, the flow passage 212 has a non-circular opening, or profile, at an end of the flow passage 212. Regardless of the profile/shape, the flow passage defines a specified shape of an injector pulse. That is, the profile/shape of the passage 212 helps define a specified fuel admission rate

profile during operation. Details on the passage 212 and its effect on the injector pulse are described throughout this disclosure. In some implementations, the rotor includes a disc 214 with a spherically shaped edge. Other rotor shapes can be used without departing from this disclosure. The rotor 210 is trunnion mounted; however, a floating (or overhung) rotor arrangement can be used without departing from this disclosure. The rotor 210 is supported by the housing 202 by bearings 216 at each end of the rotor. While illustrated as ball bearings, the bearings 216 can be any bearing suitable for the service, for example, journal bearings. In some implementations, the bearings can be self-lubricating bearings. In some implementations, greased bearings or actively lubricated bearings can be used.

[0065] A seal 218 defines a portion of an outlet flow passage 206. The seal 218 is biased to abut a circumferential outer surface of the rotor 210. The seal is located between the rotor 210 and the outlet 206. In some implementations, additions seals, such as an o-ring 219, can be used to maintain sealing throughout the outlet passage. The seal's placement mitigates egress of the gaseous fuel from the inlet, around the rotor, and to the outlet, ensuring that the primary gas path is through the passage 212 as the rotor 210 rotates. In some implementations, the seal has a substantially circular cross-section that surrounds an outlet of the internal flow passage 212 when the internal flow passage 212 is aligned with the gaseous fuel outlet 206. The seal 218 itself can be biased in a variety of ways, for example, by a compression spring 220. The compression spring 220 abuts a shoulder of the seal 218 at a first end and a shoulder of an outlet connector 222 at the other end. While illustrated as being biased by the compression spring 220, other biasing mechanisms, such as a tension spring, can be used without departing from this disclosure. In some implementations, the seal 218 can bias itself against the rotor. Regardless of the bias details, the seal 218 is received and/or retained within the housing 202 such that the seal is allowed to move along an axis of the outlet flow passage. The seal 218 itself can be made of a variety of materials suitable for the application, for example, the seal can include a carbon or an elastomer. In some implementations, the seal 218 can include a metallic or ceramic material with a hardness less than that of the rotor 210, for example, brass. Regardless of the material used for the seal 218, the material contacting the surface of the rotor 210 is softer than the rotor 210 itself. In some implementations, the rotor circumference has a seal surface of specified surface finish selected to facilitate sealing with the seal 218.

[0066] The housing 202 includes chevron seals 224 around the rotor shaft 226 to mitigate gas ingress into the bearings and the outside environment. While the illustrated implementation shows a single chevron seal 224 at each end of the rotor 210, additional chevron seals 224 can be stacked to improve sealing ability. Similarly, other types of dynamic seals can be used without departing from this disclosure.

[0067] A driver 228 is rotably coupled to the rotor 210 by a coupling (not shown). The driver 228 is configured to rotate the rotor. In some implementations, the driver 228 includes an electric motor. Such a motor can include any type of motor (e.g., a stepper motor, a permanent magnet motor, inductive motor, etc.) that has sufficient position sensing to allow for closed loop control of the rotor position. For example, a stepper motor can be used, or an inductive motor with an encoder or other position sensors can be used. Regardless of the driver used, the driver 228 is coupled to the controller 114 to control the driver to rotate at a rate that is a function of engine parameters interpreted by the controller 114, for example, engine speed. In some implementations, the rotor 210 is controlled by the driver 228 to rotate continuously in a single direction (i.e., without stopping, while the engine is operating). While the speed of the rotor can be adjusted during operation, the rotational speed does not go to 0. In some implementations, the speed of individual rotors associated with individual cylinders can be adjusted to individually adjust the fuel trim for each cylinder.

[0068] FIG. 3 is a side view of an example rotor and passage profile of the example fuel admission valve 110. In some implementations, the passage 212 can define a non-circular profile, for example, a lemon-shaped (or oval-shaped) profile 302. In some implementations, the non-circular profile can be asymmetric. The shape of this profile can be used to adjust the injector pulse profile. For example, an asymmetric profile can be used when opening and closing times are desired to be different.

[0069] FIGS. 4A-4B are an example fuel delivery profile 402 provided by a circular passage profile 404. The circular passage results in a fuel admission rate profile, or fuel delivery profile 402 (sometimes referred to as an injector pulse), during operation. Different passage profile shapes yield different fuel delivery profiles. In some implementations, the passage profile shape may be configured to produce a substantially square fuel delivery profile. In some implementations, the passage profile shape may be configured to produce an asymmetrical fuel delivery profile.

[0070] FIG. 5 is a block diagram of an example controller 114 that can be used with aspects of this disclosure. The controller 114 can, among other things, monitor parameters of engine system 100 and send signals to actuate and/or adjust various operating parameters of the engine system 100. As shown in FIG. 5, the controller 114, in certain instances, includes a processor 550 (e.g., implemented as one processor or multiple processors) and a non-transitory memory 552 (e.g., implemented as one memory or multiple memories) containing instructions that cause the processors 550 to perform operations described herein. The processors 550 are coupled to an input/output (I/O) interface 554 for sending and receiving communications with components in the system, including, for example, the fuel admission valves 110. In certain instances, the controller 114 can additionally communicate status with and send actuation and/or control signals to one or more of the various system components (including an actuator system, such as the throttle 112) of the engine system 100, as well as other sensors (for example, a cam angle sensor, an RPM sensor, a MAF/MAP sensor, an O_2 sensor, and other types of sensors) provided in the engine system 100. In certain instances, the controller 114 can communicate status and send actuation and control signals to one or more of the components within the engine system 100, such as fuel admission valves 110. The communications can be hard-wired, wireless, or a combination of wired and wireless. In some implementations, controllers similar to the controller 114 can be located elsewhere, such as in a control room, elsewhere on a site or within a vehicle, or even remote from the site or vehicle. In some implementations, the controller 114 can be a distributed controller with different portions located within an engine bay, or about a site or vehicle. Additional controllers can be used throughout the site or vehicle as stand-alone controllers or networked controllers without departing from this disclosure.

[0071] In operation, the controller 114 controls the driver 228 (FIG. 2) to rotate at a rate that is a function of an engine speed. That being said, the controller is also able to adjust the driver to adjust the rotor independent of the intake valve, for example, in situations where an injection pulse width is desired to be changed. To facilitate such changes, the controller 114 sends an electrical signal to the designated driver 228 to rotate the rotor continuously in a single direction, though perhaps at a variable speed.

[0072] In some implementations, the controller can also adjust fuel trims on individual cylinders. In such implementations, the controller is configured to adjust a speed of a first driver based on received engine parameters, and adjust a second driver

to be a different speed than the first driver. Such trims are often minor, but can greatly improve overall engine efficiency.

[0073] FIG. 6 is a flowchart of an example method 600 that can be used with aspects of this disclosure. In some implementations, all or part of the method 600 can be performed by the controller 114. At 602, a gaseous fuel, for example, natural gas or hydrogen, is received from a pressurized gaseous fuel manifold by a gaseous fuel inlet 204 of a fuel admission valve 110.

[0074] At 604, a flow of the gaseous fuel from the gaseous fuel inlet to a gaseous flow outlet is regulated, responsive to a fuel control signal, by a rotating rotor. The rotating rotor includes a flow passage therethrough that rotates with the rotor. In some implementations, regulating the flow of the gaseous fuel includes rotating the rotor, by a driver, at a speed that is a function of an engine speed of the internal combustion engine. In some implementations, the rotor is continuously rotated in a single direction. The flow is further regulated by a profile of the flow passage tuned to form a specified fuel admission rate profile.

[0075] At 606, the gaseous fuel is supplied to a manifold of an internal combustion engine by the flow outlet. Within the manifold, air is mixed with the gaseous fuel, downstream of the flow outlet, and prior to entering a combustion cylinder.

[0076] A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

WHAT IS CLAIMED IS:

1. A fuel admission valve for an engine, comprising:

a housing defining a gaseous fuel inlet and a gaseous fuel outlet;

a rotor defining an internal flow passage therethrough that rotates with the rotor to, alternately, allow gaseous fuel flow or to block gaseous fuel flow between the inlet and the outlet based on a position of the rotor;

a seal biased to abut an exterior surface of the rotor, the seal being between the rotor and the outlet;

an actuator rotably coupled to the rotor, the driver configured to rotate the rotor; and

a controller in communication with the driver and configured to control the driver to rotate at a rate based on an engine speed of the engine.

2. The fuel admission valve of claim 1, wherein the controller is further configured to adjust the rotor independent of a cylinder intake valve.

3. The fuel admission valve of claim 1 or 2, wherein the controller is configured to control the rotor to rotate continuously in a single direction.

4. The fuel admission valve of any one of claims 1 to 3, wherein the driver comprises a stepper motor.

5. The fuel admission valve of any one of claims 1 to 4, wherein the rotor comprises a disc with a spherically shaped circumferential edge.

6. The fuel admission valve of any one of claims 1 to 5, wherein the internal flow passage comprises a non-circular opening, at ends of the internal flow passage, corresponding to a specified shape of an injector pulse.

7. The fuel admission valve of claim 6, wherein the non-circular profile comprises a substantially oval shape.

8. The fuel admission valve of claim 6 or 7, wherein the non-circular profile is asymmetric.

9. The fuel admission valve of any one of claims 1 to 8, wherein the seal encircles an outlet of the internal flow passage when the internal flow passage is aligned with the gaseous fuel outlet.

10. The fuel admission valve of any one of claims 1 to 9, comprising a check valve in the fuel outlet.

11. A method comprising:

receiving a gaseous fuel from a pressurized gaseous fuel manifold by a gaseous fuel inlet of a fuel admission valve;

regulating a flow of the gaseous fuel from the gaseous fuel inlet to a gaseous flow outlet, responsive to a fuel control signal, by a rotating rotor comprising a flow passage therethrough, the flow passage rotating with the rotor; and

supplying the gaseous fuel to a manifold of an internal combustion engine by the flow outlet.

12. The method of claim 11, wherein regulating the flow of the gaseous fuel comprises rotating the rotor by a driver, the rotor rotating at a speed that is a function of an engine speed of the internal combustion engine.

13. The method of claim 12, wherein rotating the rotor comprises continuously rotating the valve in a single direction.

14. The method of any one of claims 11 to 13, wherein the flow is further regulated by a profile of the flow passage tuned to form a specified fuel admission rate profile.

15. The method of any one of claims 11 to 14, comprising mixing air with the gaseous fuel within the manifold, downstream of the flow outlet, prior to entering a combustion cylinder.

16. An engine system comprising:

an internal combustion engine;

an intake manifold configured to receive air from an air intake and configured to receive fuel from a fuel port; and

a gaseous fuel admission valve configured to supply a gaseous fuel to an intake manifold by the fuel port, the fuel admission valve comprising:

a housing defining a gaseous fuel inlet and a gaseous fuel outlet;

a rotor defining an internal flow passage therethrough that rotates with the rotor to allow gaseous fuel flow or to block gaseous fuel flow between the inlet and the outlet based on a position of the rotor;

a seal defining a portion of an outlet flow passage, the seal biased to abut a movable surface of the rotor, the seal being between the rotor and the outlet;

a driver rotably coupled to the rotor, the driver configured to rotate the rotor; and

a controller configured to:

control the driver to rotate at a rate that is a function of an engine speed;

adjust the rotor independent of the intake valve; and

send an electrical signal to the driver to rotate the rotor continuously in a single direction.

17. The engine system of claim 16, wherein the intake manifold comprises a plurality of outlets, a number of outlets corresponding to a number of combustion cylinders of the internal combustion engine, where the fuel port is a first fuel port, the intake manifold comprising a plurality of fuel ports corresponding to the number of outlets, each fuel outlet comprising a fuel port, where the gaseous fuel injector is a first gaseous fuel injector, the engine system comprising a plurality of gaseous fuel injectors, a number of fuel

injectors corresponding to the number of fuel ports, each of the plurality of injectors fluidically connected to a corresponding fuel port.

18. The system of claim 16 or 17, wherein the controller is further configured to:
adjust a speed of a first of the plurality of drivers based on received engine parameters.

19. The system of any one of claims 16 to 18, wherein the controller is further configured to adjust a speed of a second of the plurality of drivers to be a different speed than the first of the plurality of drivers.

20. The system of any one of claims 16 to 19, wherein the drivers are electric motors, and the controller is configured to adjust the speed of one of the drivers by adjusting the electrical signal to one of the electric motors.

21. The system of any one of claims 16 to 20, wherein the fuel admission valve is arranged to deliver fuel directly to a cylinder of an internal combustion engine.

22. The engine system of any one of claims 16 to 21, wherein the flow passage comprises a profile defining a specified shape of an injector pulse.

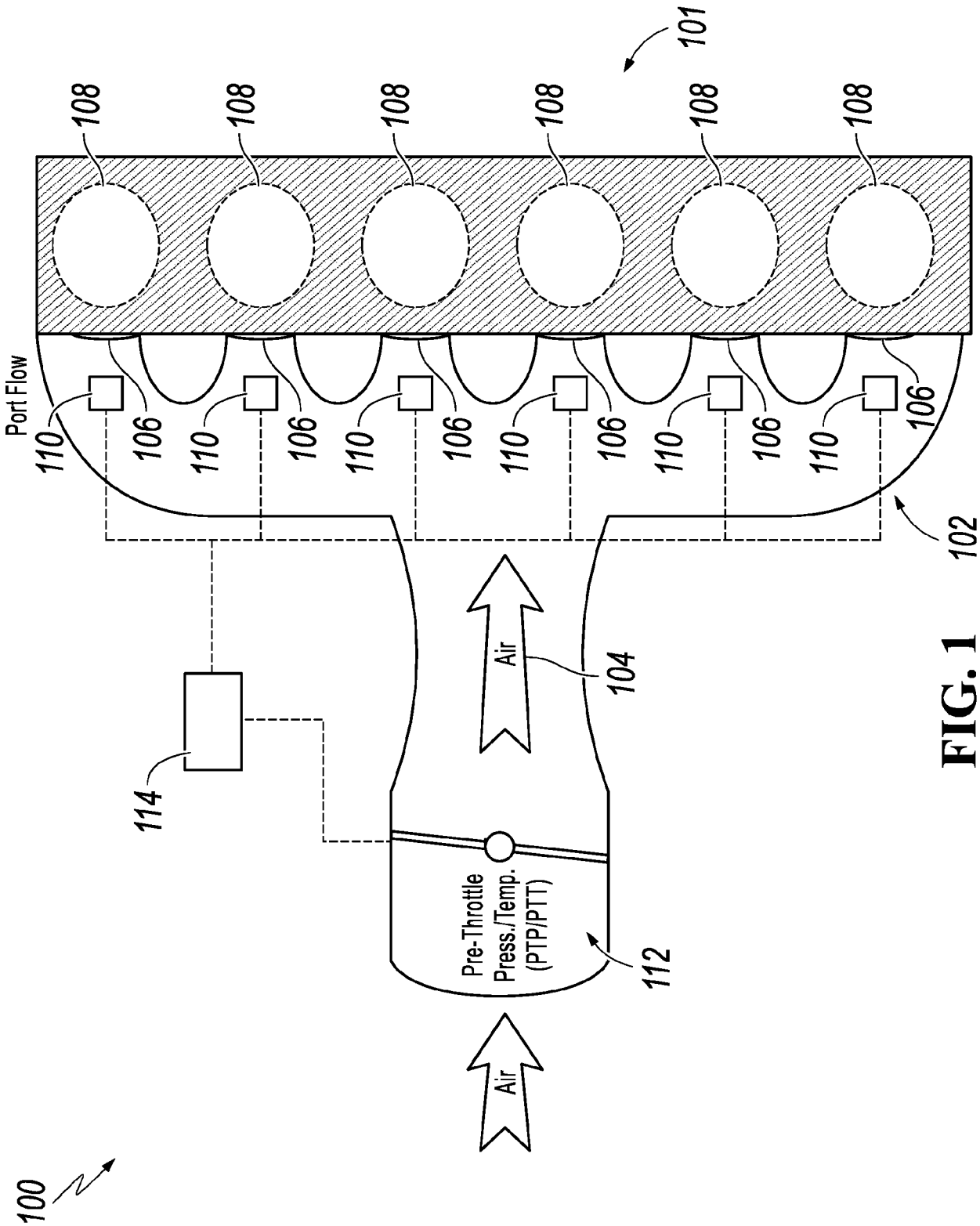

101
108
108
108
108
108
108
Port Flow
110
106
110
106
110
106
110
106
110
106
110
106
102
Air
104
114
Pre-Throttle
Press./Temp.
(PTP/PTT)
112
Air
100

FIG. 1

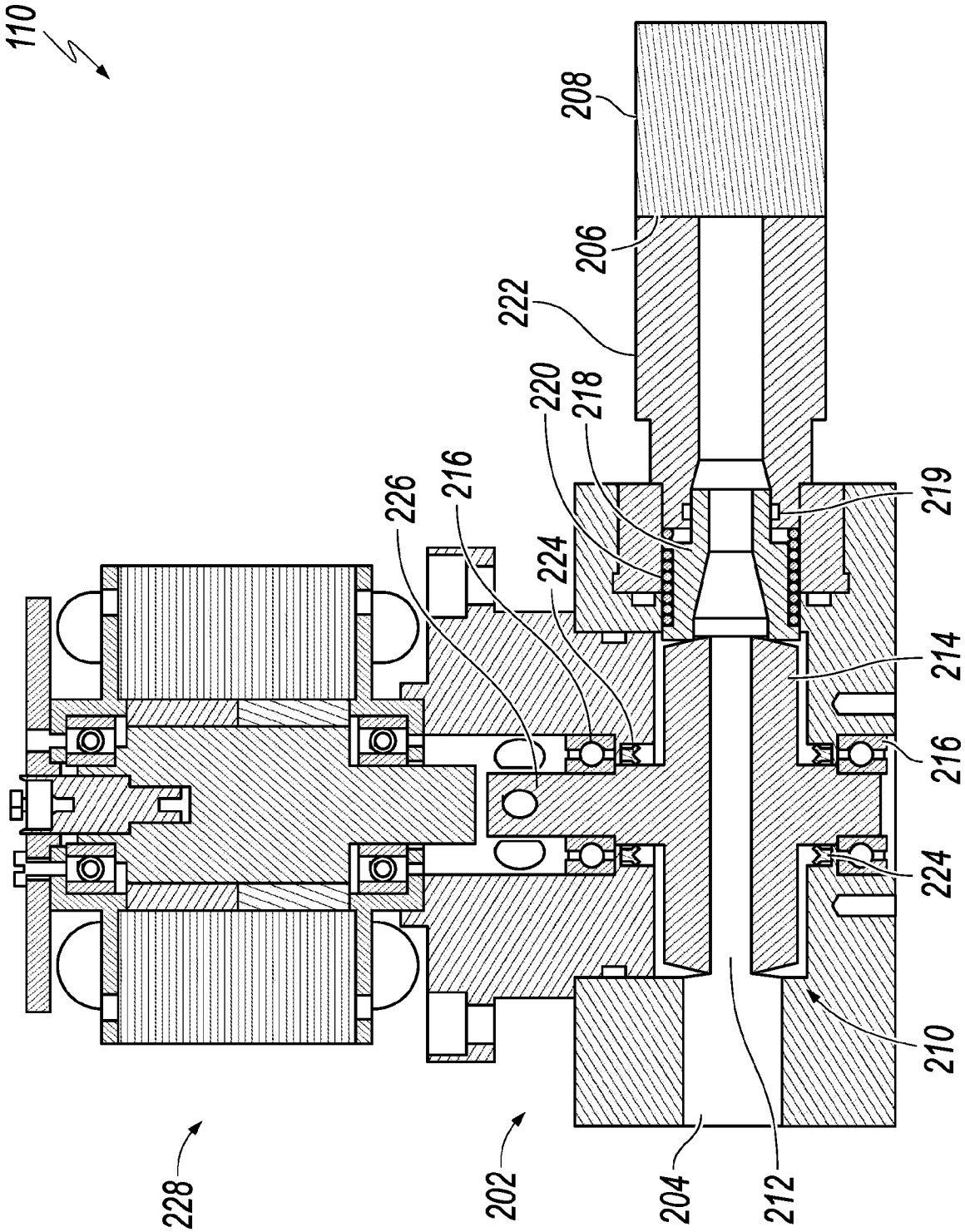

110
208
206
222
220
218
219
216
226
224
214
216
224
210
228
202
204
212

FIG. 2

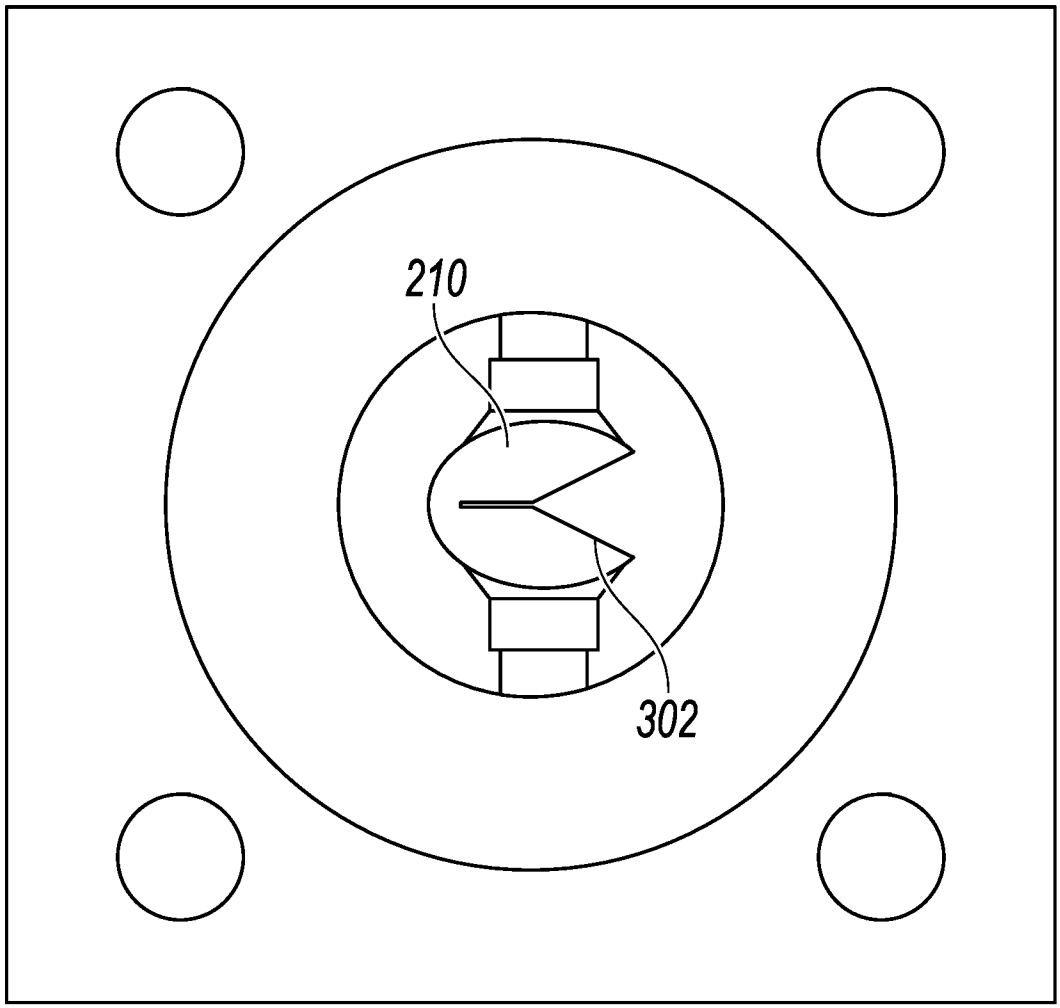


FIG. 3

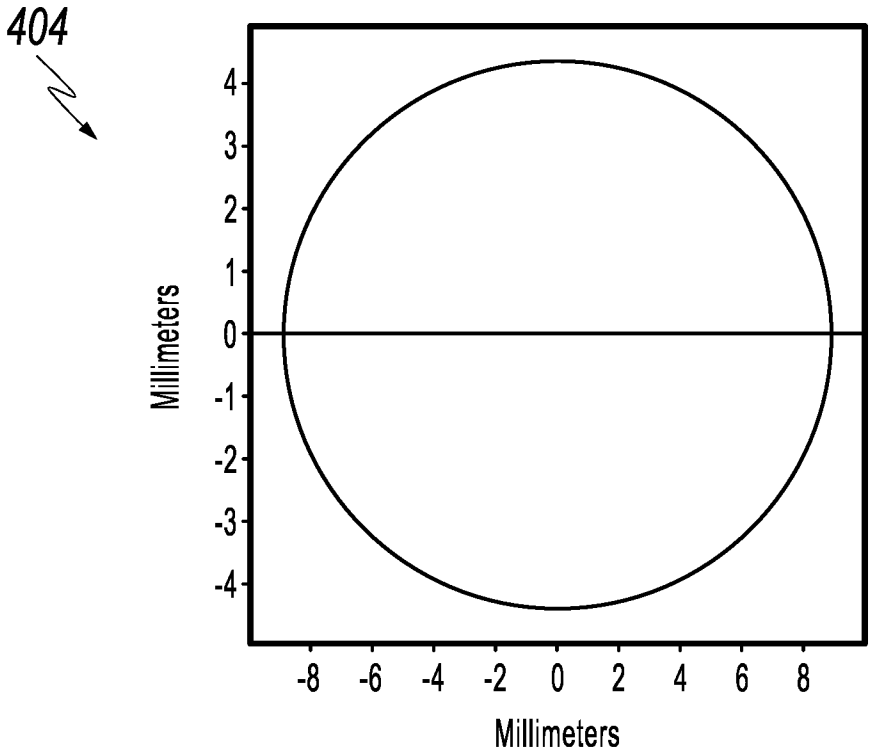

404
4
3
2
1
0
-1
-2
-3
-4
Millimeters
-8
-6
-4
-2
0
2
4
6
8
Millimeters

FIG. 4A

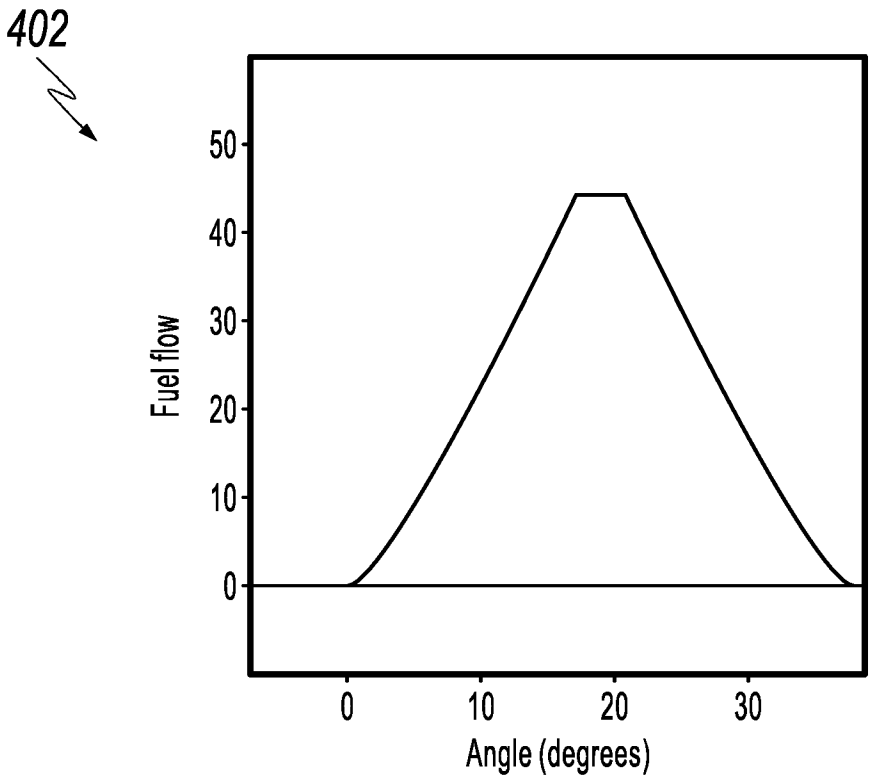

402
50
40
30
20
10
0
Fuel flow
0
10
20
30
Angle (degrees)

FIG. 4B

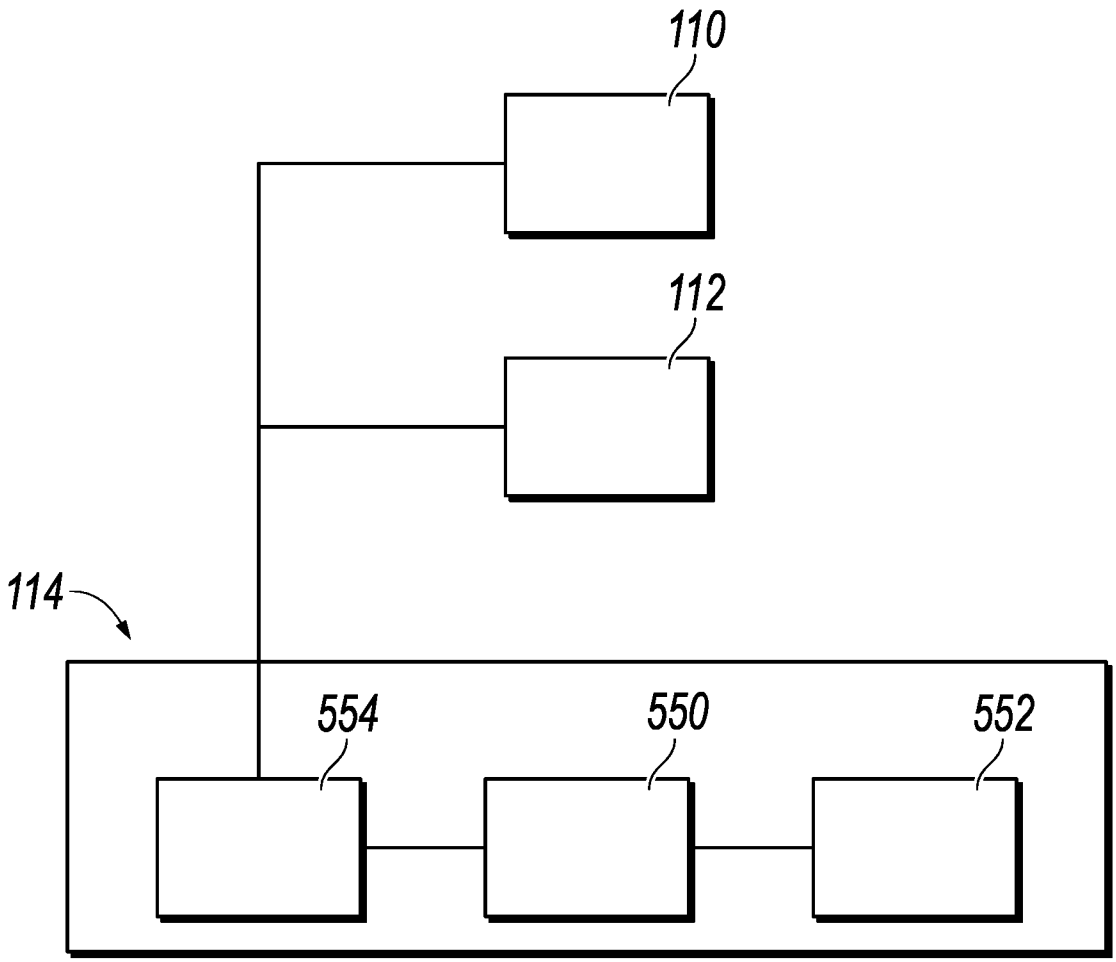


FIG. 5

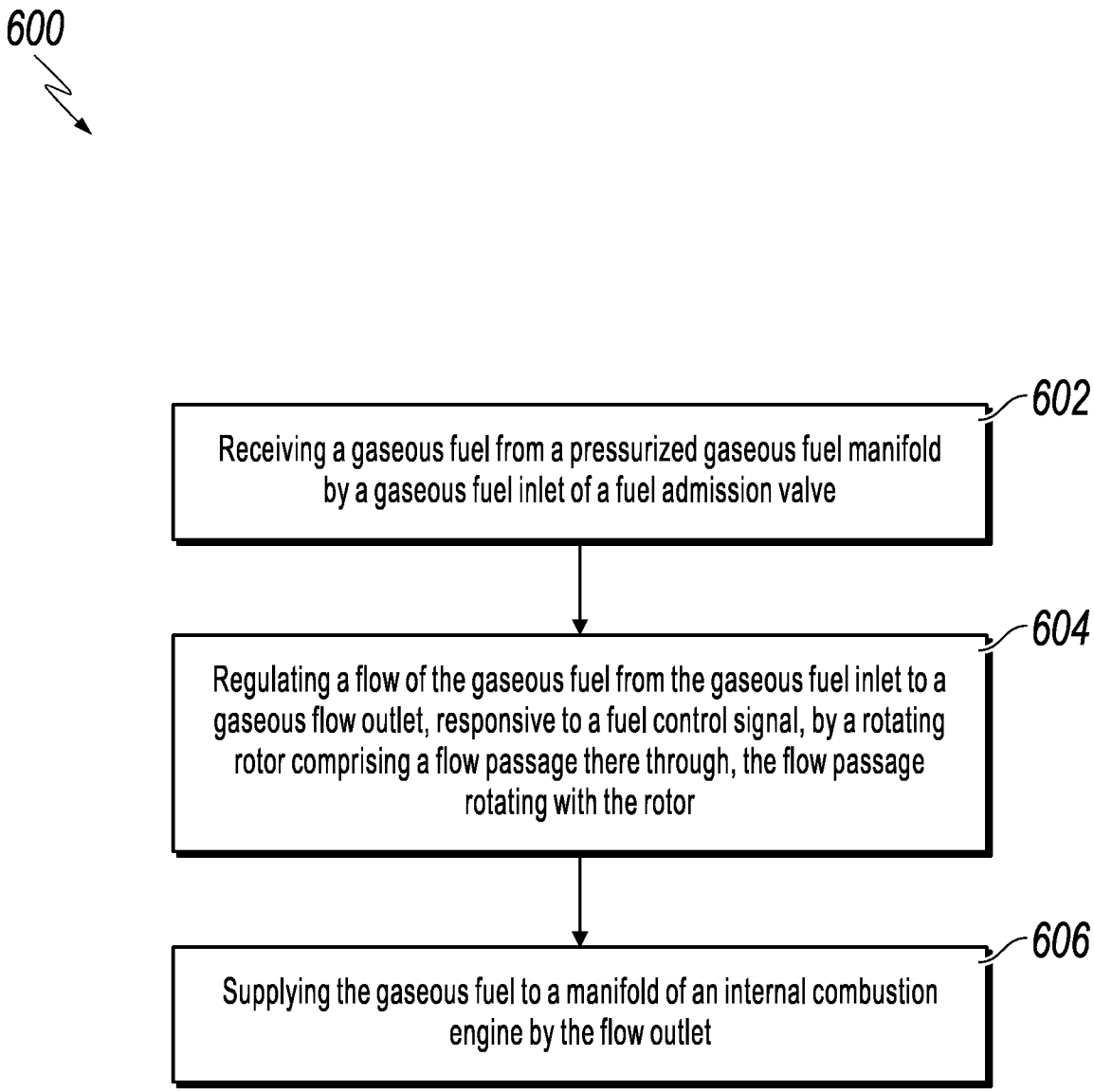

600
602
Receiving a gaseous fuel from a pressurized gaseous fuel manifold by a gaseous fuel inlet of a fuel admission valve
604
Regulating a flow of the gaseous fuel from the gaseous fuel inlet to a gaseous flow outlet, responsive to a fuel control signal, by a rotating rotor comprising a flow passage there through, the flow passage rotating with the rotor
606
Supplying the gaseous fuel to a manifold of an internal combustion engine by the flow outlet

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2022/075383

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02M21/02 F02D3/00 F02D41/34 F02D41/40 F02D19/02
ADD. F02D41/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02M F02D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	EP 0 106 699 A2 (OXIN U K LTD [GB]) 25 April 1984 (1984-04-25) pages 4,6,7; figures 2-4	1,2,4, 6-12,14, 15 3,13, 16-22
	----- US 6 360 719 B1 (UITENBROEK PAUL [DE]) 26 March 2002 (2002-03-26) the whole document	1-4,6-22
	----- US 6 055 953 A (MOTOREN WERKE MANNHEIM AG [DE]) 2 May 2000 (2000-05-02) abstract; figures	1,2,4, 9-12 3,13, 16-22
	----- US 5 448 971 A (BLUNDELL DAVID W [GB] ET AL) 12 September 1995 (1995-09-12) abstract; figures	1-4,6-22
	----- -/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 November 2022	06/12/2022

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Godrie, Pierre

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2022/075383

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 01/42628 A1 (QATTAN JAMAL UMAR [US]) 14 June 2001 (2001-06-14) abstract; figures 3-7	5

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2022/075383

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0106699 A2	25-04-1984	NONE	
US 6360719 B1	26-03-2002	AR 019898 A1	20-03-2002
		AT 228611 T	15-12-2002
		AT 288028 T	15-02-2005
		AU 4907199 A	01-02-2000
		BR 9911911 A	27-03-2001
		DE 19830575 A1	13-01-2000
		EP 1095210 A1	02-05-2001
		EP 1236875 A2	04-09-2002
		ES 2183579 T3	16-03-2003
		ES 2236392 T3	16-07-2005
		JP 5464607 B2	09-04-2014
		JP 2002520536 A	09-07-2002
		JP 2012092842 A	17-05-2012
		US 6360719 B1	26-03-2002
		US RE39852 E	25-09-2007
		WO 0003131 A1	20-01-2000
US 6055953 A	02-05-2000	AT 199963 T	15-04-2001
		DE 19634299 A1	26-02-1998
		EP 0829627 A2	18-03-1998
		ES 2155229 T3	01-05-2001
		US 6055953 A	02-05-2000
US 5448971 A	12-09-1995	NONE	
WO 0142628 A1	14-06-2001	AU 2256301 A	18-06-2001
		US 2001029918 A1	18-10-2001
		WO 0142628 A1	14-06-2001