



(51) International Patent Classification:

F02M 55/02 (2006.01)

(21) International Application Number:

PCT/US2021/042924

(22) International Filing Date:

23 July 2021 (23.07.2021)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

63/055,973

24 July 2020 (24.07.2020)

US

(71) Applicant: CUMMINS INC. [US/US]; 500 Jackson Street, Columbus, Indiana 47201 (US).

(72) Inventors; and

(71) Applicants: VINCENT, Jacques L. [GB/GB]; Flat 6, 61 Lower Hillmorton, Rugby Warwickshire CV21 3TD (GB). ARUMUGAM, Raghuvaram [GB/GB]; 52 Jubilee Way, Countesthorpe Leicestershire LE8 5UB (GB).

(72) Inventors: RICHARDS, Kieran J.; 73 Old Forge Drive, West Haddon Northamptonshire NN6 7ET (GB).

GLOVER, Brandon; 23 Main Street, Wolsten Warwickshire CV8 3HH (GB). DENOYELLE, Vincent; 29 Main Street, Long Lawford Warwickshire CV23 9AZ (GB). PIL-LAI, Deepak; 3661 Premier Drive, Columbus, Indiana 47203 (US).

(74) Agent: CAGE, Darnell M.; Faegre Drinker Biddle & Reath LLP, 300 N. Meridian Street, Suite 2500, Indianapolis, Indiana 46204 (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, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, 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, 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,

(54) Title: MODULAR AND SCALABLE COMMON RAIL FUEL SYSTEM ARCHITECTURE

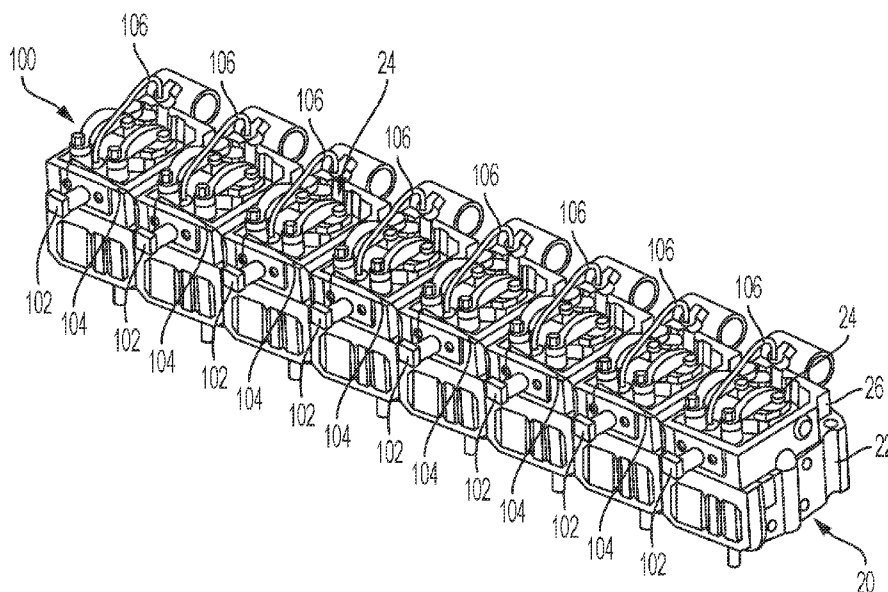


FIG. 1

(57) Abstract: A connection member for a fuel system comprising a body having an inlet configured to receive fuel, a first outlet fluidly coupled to the inlet and configured to release fuel from the body, a second outlet fluidly coupled to the inlet and configured to be fluidly coupled to a fuel injector, and a fuel path fluidly coupling the inlet, the first outlet, and the second outlet, the fuel path including an accumulator volume.



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))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

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

MODULAR AND SCALABLE COMMON RAIL FUEL SYSTEM ARCHITECTURE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority to U.S. Provisional Patent Application Serial No. 63/055,973, filed on July 24, 2020, and entitled “MODULAR AND SCALABLE COMMON RAIL FUEL SYSTEM ARCHITECTURE,” the complete disclosure of which is expressly incorporated by reference herein.

TECHNICAL FIELD OF THE DISCLOSURE

[0002] The present disclosure relates generally to systems for injecting fuel into an internal combustion engine.

BACKGROUND OF THE DISCLOSURE

[0003] In an internal combustion engine, fuel is provided to the engine via a fuel injection system. The fuel injection system directs fuel housed in a fuel pump through injector lines that are coupled to the fuel injectors. The fuel injectors are coupled, either directly or indirectly, to cylinders in the engine. The fuel is mixed with air (either in the cylinder or outside of the cylinder), and is ignited within the cylinder to power the engine. Internal combustion engines are offered in a variety of different sizes and can vary in the arrangement of the cylinders (e.g., an inline arrangement or a v-arrangement) and the number of cylinders in the arrangement.

[0004] In certain fuel systems used with internal combustion engines, an accumulator volume of fuel may be placed in the injector such that the injector acts as a mini accumulator, or the accumulator volume may be placed in a fuel rail. However, having the accumulator volume in the injector results in unique injectors that are taller and/or more expensive than standard injectors, while having the accumulator volume in the fuel rail results in a need for additional space for packaging the fuel rail. Thus, a fuel system is needed that places the accumulator volume outside of the injector to allow traditional fuel injectors to be used, but also outside of a fuel rail so that the system does not have to include a fuel rail.

SUMMARY OF THE DISCLOSURE

[0005] In one embodiment of the present disclosure, a connection member for a fuel system is provided. The connection member comprises a body having an inlet configured to receive fuel, first outlet fluidly coupled to the inlet and configured to release fuel from the body, a second outlet fluidly coupled to the inlet and configured to be fluidly coupled to a fuel injector, and a fuel path fluidly coupling the inlet, the first outlet, and the second outlet, the fuel path including an accumulator volume.

[0006] In another embodiment of the present disclosure, a fuel distribution system is provided. The fuel distribution system comprises at least one connection member having an inlet, a first outlet, and a second outlet, a first outer fuel line fluidly coupled to the inlet of the at least one connection member, a second outer fuel line fluidly coupled to the first outlet of the at least one connection member, and an inner fuel line fluidly coupled to the second outlet of the connection member.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Advantages and features of the embodiments of this disclosure will become more apparent from the following detailed description of exemplary embodiments when viewed in conjunction with the accompanying drawings, wherein:

[0008] FIG. 1 shows a perspective view of an embodiment of a fuel distribution system of the present disclosure coupled to an engine, where the fuel distribution system includes a plurality of connection members, a plurality of outer fuel lines, and a plurality of inner fuel lines;

[0009] FIG. 2 shows a schematic diagram of the embodiment of the fuel distribution system of FIG. 1 in an end-to-end series configuration coupled to an engine, where the fuel distribution system further includes a high-pressure fuel pump, a pressure limiting valve, and a fuel tank, where the pressure limiting valve is positioned at a back end of the fuel distribution system;

[0010] FIG. 3 shows a schematic diagram of the embodiment of the fuel distribution system of FIG. 2, where the pressure limiting valve is positioned at a front end of the fuel distribution system;

[0011] FIG. 4 shows a schematic diagram of another embodiment of a fuel distribution system of the present disclosure in a central feed or split configuration coupled to an engine,

where the fuel distribution system includes a high-pressure fuel pump, a plurality of connection members, a plurality of outer fuel lines, a plurality of inner fuel lines, a pressure limiting valve, a junction block, and a fuel tank;

[0012] FIG. 5A shows a schematic diagram of a first embodiment of the junction block of FIG. 4;

[0013] FIG. 5B shows a schematic diagram of a second embodiment of the junction block of FIG. 4;

[0014] FIG. 6A shows a front right perspective view of an embodiment of a connection member of the fuel distribution system of FIG. 1;

[0015] FIG. 6B shows a front left perspective view of the connection member of FIG. 6A;

[0016] FIG. 6C shows a left side elevational view of the connection member of FIG. 6A;

[0017] FIG. 7 shows a semi-transparent front left perspective view of the connection member of FIG. 6A;

[0018] FIG. 8A shows a cross-sectional view of the connection member of FIG. 6A taken along line 8A-8A of FIG. 7;

[0019] FIG. 8B shows a cross-sectional view of the connection member of FIG. 6A taken along line 8B-8B of FIG. 7;

[0020] FIG. 9 shows a cross-sectional view of another embodiment of a connection member of present disclosure;

[0021] FIG. 10 shows a cross-sectional view of one of the connection members and one of the inner fuel lines coupled to one of the injectors of the engine of FIG. 1; and

[0022] FIG. 11 shows a more detailed cross-sectional view of the inner fuel line and the injector of FIG. 10.

[0023] Corresponding reference characters indicate corresponding parts throughout the several views. Although the drawings represent embodiments of the present disclosure, the drawings are not necessarily to scale and certain features may be exaggerated in order to better illustrate and explain the present disclosure. The exemplifications set out herein illustrate embodiments of the disclosure, in one form, and such exemplifications are not to be construed as limiting the scope of the disclosure in any manner.

DETAILED DESCRIPTION OF THE DRAWINGS

[0024] Referring to FIGS. 1-4, a fuel distribution system 100 of the present disclosure is shown coupled to an engine 20 having a plurality of cylinders (not shown) covered by cylinder heads 22 and a plurality of fuel injectors 24 providing fuel to the cylinders through cylinder heads 22. In the exemplary embodiments shown in FIGS. 1-4, engine 20 includes six cylinders. However, in various embodiments, the number of cylinders of engine 20 may include 4, 6, 12, 18 or any other number of cylinders. Furthermore, in various embodiments, the cylinders may each be individually covered by an individual cylinder head, while in other various embodiments, two or more cylinders may be covered by a single cylinder head that spans over the two or more cylinders.

[0025] Fuel distribution system 100 generally includes a high-pressure (“HP”) fuel pump 110, a pressure limiting valve (“PLV”) 112, a fuel source or tank 114, a plurality of connection members 102 each coupled to a rocker housing 26 (FIG. 1) coupled to cylinder head 22 of engine 20, a plurality of outer fuel lines 104 fluidly coupling connection members 102 to each other and/or to high-pressure (“HP”) fuel pump 110 and/or fuel source 114 (FIG. 2), and a plurality of inner fuel lines 106 fluidly coupling connection members 102 to fuel injectors 24 of engine 20. In various embodiments, inner fuel lines 106 may be coupled to fuel injectors 24 via an injector joint 107 (i.e., a nut or other coupler) (FIGS. 10 and 11). Injector joint 107 may include a single or multiple O-rings 105 for sealing purposes (FIG. 11). Inner fuel lines 106 and/or outer fuel lines 104 may be double-walled fuel lines that include a main channel 108 and a fuel leakage passage 109 surrounding main channel 108 (FIG. 11).

[0026] With reference to FIGS. 2 and 3, in various embodiments, connection members 102 are coupled in series or end-to-end such that HP fuel pump 110 is coupled to a first of connection members 102 at one end or the other of fuel distribution system 100 which is then coupled in series to the other connection members 102. When connection members 102 are coupled in series, PLV 112 may be coupled at either end of fuel distribution system 100 and fluidly coupled to fuel source 114 and/or fuel pump 110. For instance, as shown in FIG. 2, PLV 112 may be coupled to the last of connection members 102 in the chain of connection members 102 between the last of connection members 102 and fuel source 114. When PLV 112 is coupled downstream of the last of connection members 102, fuel source 114 may be positioned between PLV 112 and fuel pump 110. Alternatively, as shown in FIG. 3, PLV 112 may be

coupled upstream of the first of connection members 102 in the chain of connection members 102 between fuel pump 110 and the first of connection members 102. When PLV 112 is coupled upstream of the first of connection members 102, PLV 112 may be coupled directly to both fuel pump 110 and fuel source 114.

[0027] Referring now to FIG. 4, in other various embodiments, connection members 102 are coupled to HP fuel pump 110 at a central feed or in a split configuration such that HP fuel pump 110 is fluidly coupled between two of the middle connection members 102 which are then coupled in series to the connection members 102 to one side of each of the middle connection members 102. When connection members 102 are coupled to HP fuel pump 110 at the central feed or in the split configuration, the pressure drop between injectors 24 is lower than a pressure drop between injectors 24 when connection members 102 are coupled to HP fuel pump 110 in series or end-to-end. PLV 112 is generally coupled to connection members 102 and fuel pump 110 through a junction block 111. PLV 112 may alternatively be placed in other various positions relative to fuel distribution system 100 and engine 20. For instance, PLV 112 may be positioned between two rocker lever housings 26, cylinder heads 22 and/or connection members 102.

[0028] With reference to FIGS. 5A and 5B, junction block 111 generally includes an inlet 120 fluidly coupled to fuel pump 110, a first outlet 122 fluidly coupled to PLV 112, and second and third outlets 124 and 126, respectively, fluidly coupled to connection members 102. In various embodiments, junction block 111 may include an inlet channel 130 that splits into two outlet channels 132 and 134 extending to second and third outlets 124 and 126 with a first outlet channel 136 that tees into inlet channel 130 prior to inlet channel 130 splitting into outlet channels 132 and 134 and extends to first outlet 122. In other various embodiments, junction block 111' may include an inlet channel 130' that tees into a longitudinal channel 138 that extends from a first side 140 of junction block 111' to a second side 142 of junction block 111', and two outlet channels 132' and 134' that extend from longitudinal channel 138 to second and third outlets 124' and 126'. A first end 150 of longitudinal channel 138 includes a plug 152, while a second end 154 of longitudinal channel 138 extends to first outlet 122'.

[0029] Referring now to FIGS. 6A-C, 7, 8A-B, and 9, connection member 102, 102* will be described in further detail. Connection member 102, 102* includes a body 200, 200* having an inlet 202, 202* configured to be fluidly coupled with outer fuel line 104 from an upstream

connection member 102, 102* or HP fuel pump 110 or PLV 112, a first outlet 204, 204* configured to be fluidly coupled with outer fuel line 104 coupled to a downstream connection member 102, 102* or PLV 112, and a second outlet 206, 206* configured to be fluidly coupled to inner fuel line 106, which is fluidly coupling connection member 102, 102* to fuel injector 24 (FIG. 10). In various embodiments, inlet 202 is positioned between first outlet 204 and second outlet 206 (FIGS. 6-8), while in other various embodiments, first outlet 204* is positioned between inlet 202* and second outlet 206* (FIG. 9).

[0030] Connection member 102 may further include first and second grooves 208 and 210 configured to receive a sealing member for sealing a connection between connection member 102 and rocker housing 26/cylinder head 22, and/or a clamping plate 212 configured to assist in retention of connection member 102 within rocker housing 26/cylinder head 22. In various embodiments, clamping plate 212 is positioned between inlet 202 and second outlet 206, while first and second grooves 208 and 210 are positioned between clamping plate 212 and second outlet 206. Connection member 102 may also or alternatively include a retention groove 214 (Fig. 6B) configured to retain a wire harness clip (not shown). In various embodiments, retention groove 214 is positioned adjacent second outlet 206.

[0031] With reference to FIGS. 7-9, connection member 102, 102* further includes a fuel path/accumulator volume 216, 216* fluidly coupling inlet 202, 202*, first outlet 204, 204*, and second outlet 206, 206*, and a fuel leak path 240 fluidly coupled to inlet 202, 202*, first outlet 204, 204*, and/or second outlet 206, 206*. Fuel path/accumulator volume 216, 216* includes a first portion 218, 218* having a first diameter d_1 , d_1^* and a second portion 220, 220* having a second diameter d_2 , d_2^* . In various embodiments, for example the embodiment shown in FIGS. 6-8, first portion 218 extends from first outlet 204, adjacent an outer end 222 of body 200, past both inlet 202 and second outlet 206, and second portion 220 extends between second outlet 206 and inner end 224 of body 200. In other various embodiments, for example the embodiment shown in FIG. 9, first portion 218* may extend from inlet 202* adjacent outer end 222 of connection member 102* just past first outlet 204*, while second portion 220* extends from adjacent first outlet 204* down past second outlet 206* adjacent inner end 224 of connection member 102*. In various embodiments, fuel path/volume 216, 216* includes a first plug 226, 226* in an outlet 228, 228* of fuel path/volume 216, 216* positioned at inner end 224 and/or a second plug 230 in an outlet 232 of fuel path/volume 216* positioned at outer end 222. Fuel

path/volume 216* may also include a control orifice 234 between first portion 218* and second portion 220*, where control orifice 234 is positioned downstream of inlet 202* and first outlet 204* and closer to inner end 224 than inlet 202* and first outlet 204*.

[0032] Referring to FIGS. 7 and 8B, connection member 102 further includes fuel leak path 240 fluidly coupled to inlet 202, first outlet 204 and/or second outlet 206. Fuel leak path 240 generally includes a main fuel leak channel 242 extending from second outlet 206 to outer end 222 and a second outlet channel 244 fluidly coupling second outlet 206 to main fuel leak channel 242. Main fuel leak channel 242 generally includes a first outlet 246 in outer end 222 of body 200 and a second outlet 248 positioned along a bottom surface of body 200. First outlet 246 generally includes a plug (not shown) such that fuel leakage exits main fuel leak channel 242 through second outlet 248. In various embodiments, fuel leak path 240 further includes an inlet leak channel 250 and a first outlet leak channel 252. Inlet leak channel 250 and first outlet leak channel 252 may each separately fluidly couple inlet 202 and/or first outlet 204 to main fuel leak channel 242 or include a separate outlet (not shown) along an outer surface of body 200.

[0033] With reference now to FIGS. 10 and 11, the flow of fuel will be described. Fuel is provided to a first connection member 102 through outer fuel line 104 from HP fuel pump 110. As fuel enters connection member 102 through inlet 202, fuel fills fuel path/accumulator volume 216. Excess fuel is provided to connection member 102 is passed to first outlet 204 and passed to subsequent downstream connection members 102 through a separate outer fuel line 104'. When fuel is needed in fuel injector 24, fuel within accumulator volume 216 is passed through second outlet 206 into main channel 108 of inner fuel line 106 to fuel injector 24. Any fuel leakage between fuel injector 24 and/or inner fuel line 106 is passed through passage 109 (FIG. 11) back to second outlet 206 and into fuel leak path 240 (FIGS. 7 and 8B) to be collected or vented in a controlled manner. In addition, any fuel leakage around inlet 202 and first outlet 204 is passed through inlet leak channel 250 and first outlet leak channel 252 to be collected or vented in a controlled manner.

[0034] The various embodiments of the system described herein provide benefits that can be applied to internal combustion engines in both inline configurations and v-configurations. The modular system allows the fuel system to be integrated on to existing engines. The multiple wall design can reduce the risk of fuel spray from an injector connection when the connection is on the hot side of the engine. Leaking fuel at the cold side connection routes the fuel away from hot

components and reduces the risk of the leaking fuel contacting hot areas. The leaking fuel can either be vented in a controlled manner or collected. Various embodiments of the system can reduce both the total cost of ownership and engine repair time.

[0035] While various embodiments of the disclosure have been shown and described, it is understood that these embodiments are not limited thereto. The embodiments may be changed, modified and further applied by those skilled in the art. Therefore, these embodiments are not limited to the detail shown and described previously, but also include all such changes and modifications.

[0036] Furthermore, the connecting lines shown in the various figures contained herein are intended to represent exemplary functional relationships and/or physical couplings between the various elements. It should be noted that many alternative or additional functional relationships or physical connections may be present in a practical system. However, the benefits, advantages, solutions to problems, and any elements that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as critical, required, or essential features or elements. The scope is accordingly to be limited by nothing other than the appended claims, in which reference to an element in the singular is not intended to mean “one and only one” unless explicitly so stated, but rather “one or more.” Moreover, where a phrase similar to “at least one of A, B, or C” is used in the claims, it is intended that the phrase be interpreted to mean that A alone may be present in an embodiment, B alone may be present in an embodiment, C alone may be present in an embodiment, or that any combination of the elements A, B or C may be present in a single embodiment; for example, A and B, A and C, B and C, or A and B and C.

[0037] In the detailed description herein, references to “one embodiment,” “an embodiment,” “an example embodiment,” etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art with the benefit of the present disclosure to affect such feature, structure, or characteristic in connection with other embodiments whether or not

explicitly described. After reading the description, it will be apparent to one skilled in the relevant art(s) how to implement the disclosure in alternative embodiments.

[0038] Furthermore, no element, component, or method step in the present disclosure is intended to be dedicated to the public regardless of whether the element, component, or method step is explicitly recited in the claims. No claim element herein is to be construed under the provisions of 35 U.S.C. § 112(f), unless the element is expressly recited using the phrase “means for.” As used herein, the terms “comprises,” “comprising,” or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus.

WHAT IS CLAIMED IS:

1. A connection member for a fuel system including a fuel injector comprising:
 - a body having
 - an inlet configured to receive fuel;
 - a first outlet fluidly coupled to the inlet and configured to release fuel from the body;
 - a second outlet fluidly coupled to the inlet and configured to be fluidly coupled to the fuel injector; and
 - a fuel path fluidly coupling the inlet, the first outlet, and the second outlet, the fuel path including an accumulator volume.
2. The connection member of claim 1, wherein the inlet is positioned between the first outlet and the second outlet.
3. The connection member of claim 1, wherein the first outlet is positioned between the inlet and the second outlet.
4. The connection member of claim 1, further comprising: a fuel leak path having at least one fuel leak channel fluidly coupled to at least one of the inlet, the first outlet, and the second outlet.
5. The connection member of claim 4, wherein the at least one fuel leak channel of the fuel leak path includes a main leak channel, an inlet leak channel, a first outlet leak channel, and a second outlet leak channel, at least one of the inlet leak channel, the first outlet leak channel, and the second outlet leak channel being fluidly coupled to the main leak channel.
6. The connection member of claim 5, wherein each of the inlet leak channel, the first outlet leak channel, and the second outlet leak channel are fluidly coupled to the main leak channel.

7. The connection member of claim 1, wherein the fuel path includes a first portion having a first diameter and a second portion having a second diameter, the second diameter being greater than the first diameter.
8. The connection member of claim 7, wherein the first portion extends from adjacent a first end of the connection member past the second outlet.
9. The connection member of claim 7, wherein the first portion extends past the inlet and the first outlet and ends prior to reaching the second outlet.
10. The connection member of claim 1, further comprising a clamping plate positioned between the inlet and the second outlet, and at least one channel positioned between the clamping plate and the second outlet.
11. The connection member of claim 1, further comprising a groove adjacent the second outlet, the groove configured for retaining a wiring harness clip.
12. A fuel distribution system comprising:
 - at least one connection member having an inlet, a first outlet, and a second outlet;
 - a first outer fuel line fluidly coupled to the inlet of the at least one connection member;
 - a second outer fuel line fluidly coupled to the first outlet of the at least one connection member; and
 - an inner fuel line fluidly coupled to the second outlet of the connection member.
13. The fuel distribution system of claim 12, wherein at least one of the first outer fuel line, the second outer fuel line, and the inner fuel line include a first wall defining a main channel of the line and a second wall defining a passage extending between the first wall and the second wall.
14. The fuel distribution system of claim 12, wherein the inlet and the first outlet are configured to be positioned outside of a cylinder of an engine.

15. The fuel distribution system of claim 12 further comprising a high-pressure fuel pump fluidly coupled to the at least one connection member and a pressure limiting valve fluidly coupled to the at least one connection member.
16. The fuel distribution system of claim 15, wherein the high-pressure fuel pump is coupled to the first outer fuel line and the pressure limiting valve is coupled to the second outer fuel line.
17. The fuel distribution system of claim 15, wherein the at least one connection member includes a first connection member and a second connection member, the second outer fuel line fluidly coupled to an inlet of the second connection member, a third outer fuel line fluidly coupled to a first outlet of the second connection member, the high-pressure fuel pump coupled to the first connection member via the first outer fuel line and the first outlet of the second connection member coupled to the pressure limiting valve via the third outer fuel line.
18. The fuel distribution system of claim 15, wherein the at least one connection member includes a first connection member and a second connection member, the high-pressure fuel pump fluidly coupled to the first connection member via the first outer fuel line and the high-pressure fuel pump fluidly coupled to an inlet of the second connection member via a third outer fuel line.
19. The fuel distribution system of claim 18, wherein the pressure limiting valve is coupled to the first connection member and the second connection member through the high-pressure fuel pump.
20. The fuel distribution system of claim 15, wherein the at least one connection member includes a first connection member and a second connection member, and the pressure limiting valve is positioned between the first connection member and the second connection member.

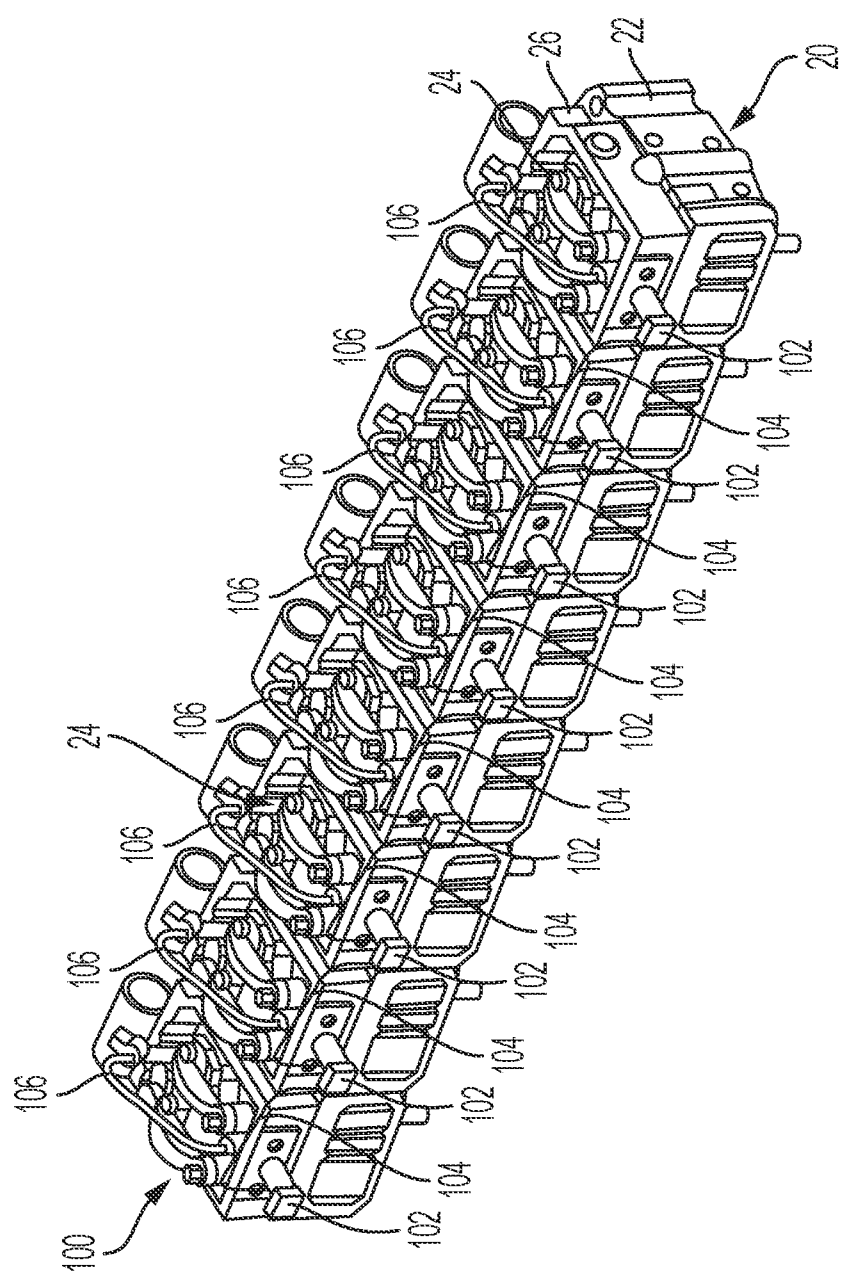


FIG. 1

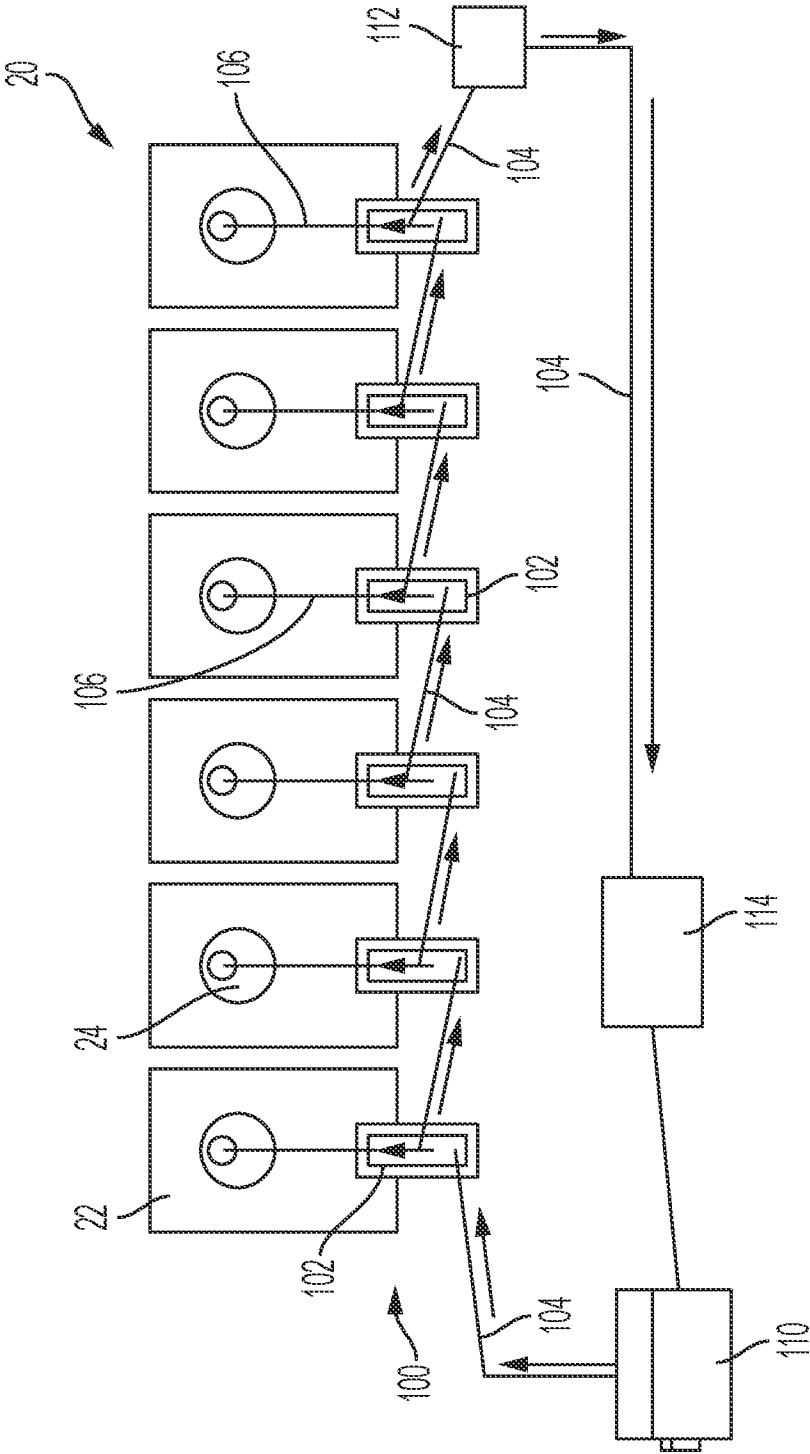


FIG. 2

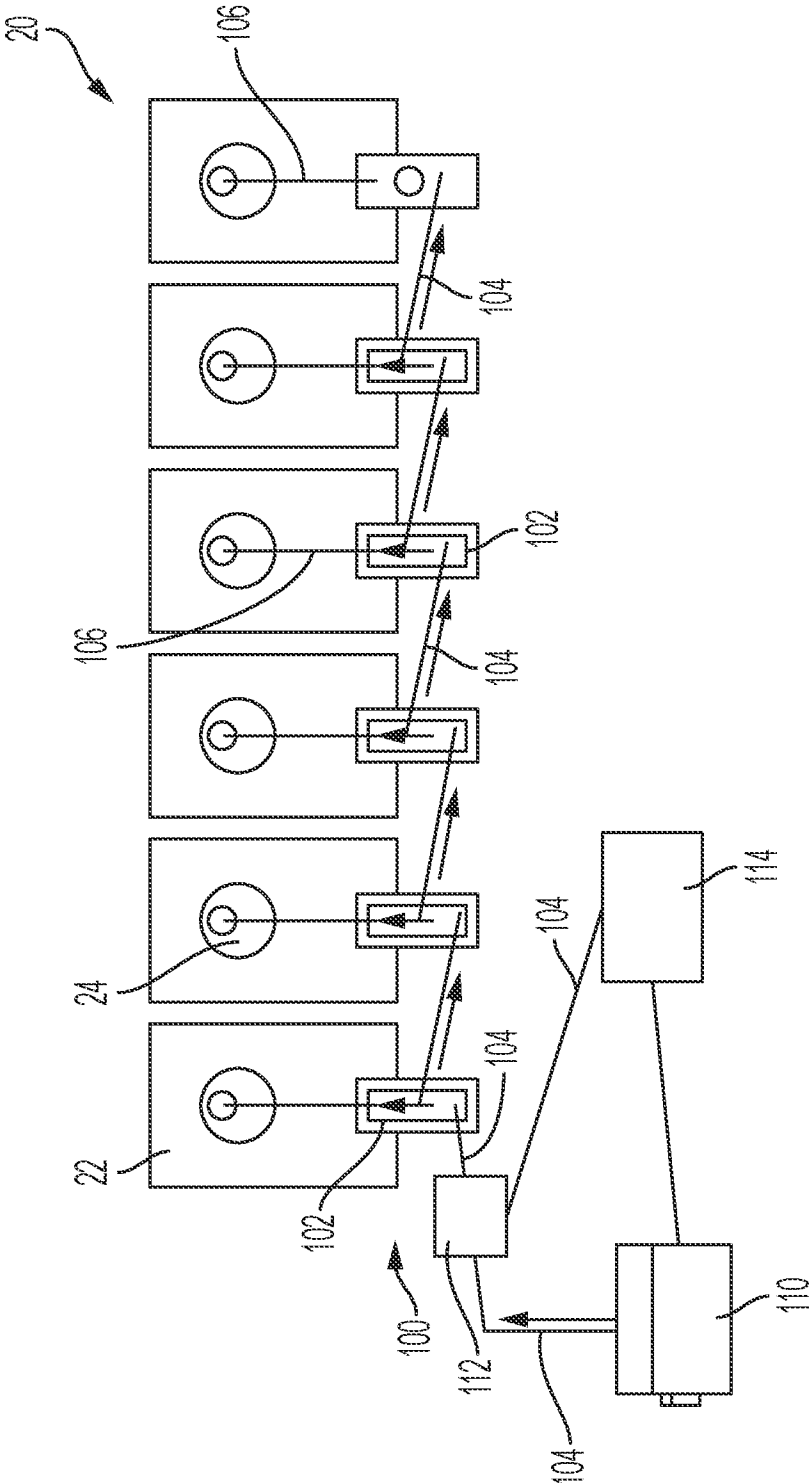
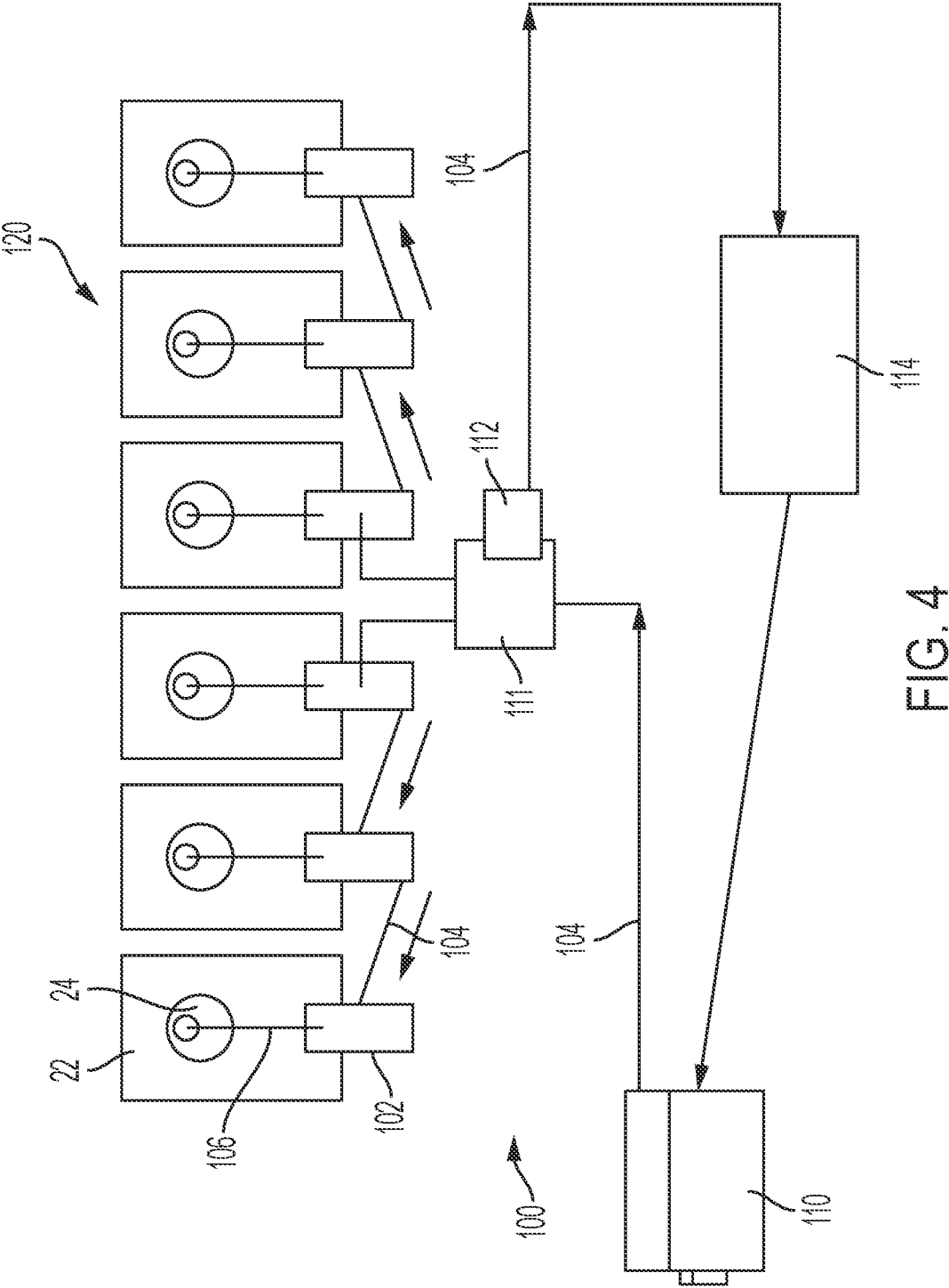


FIG. 3



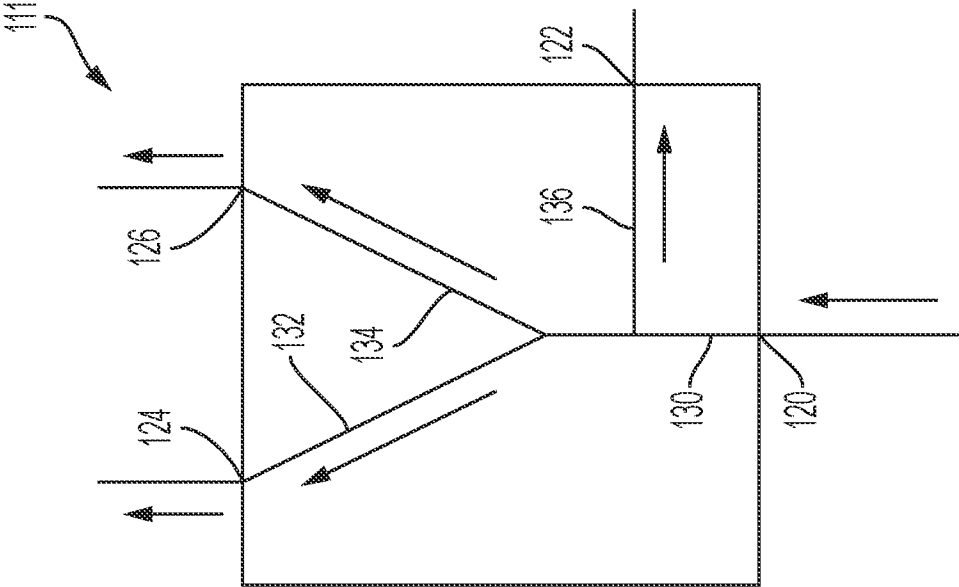


FIG. 5A

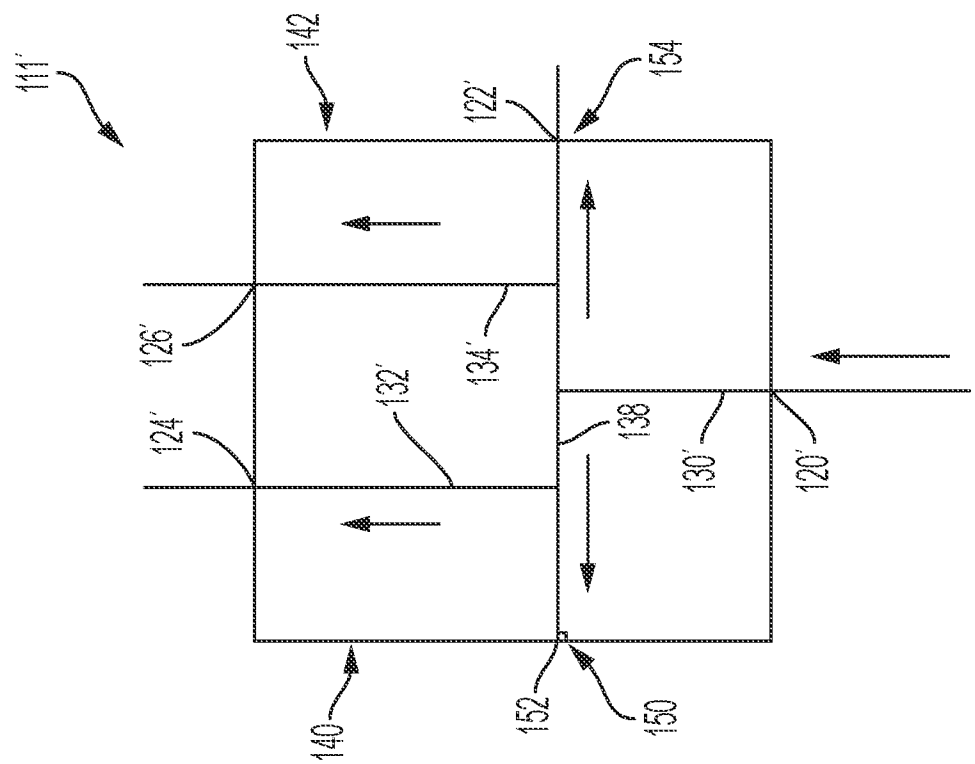


FIG. 5B

7/12

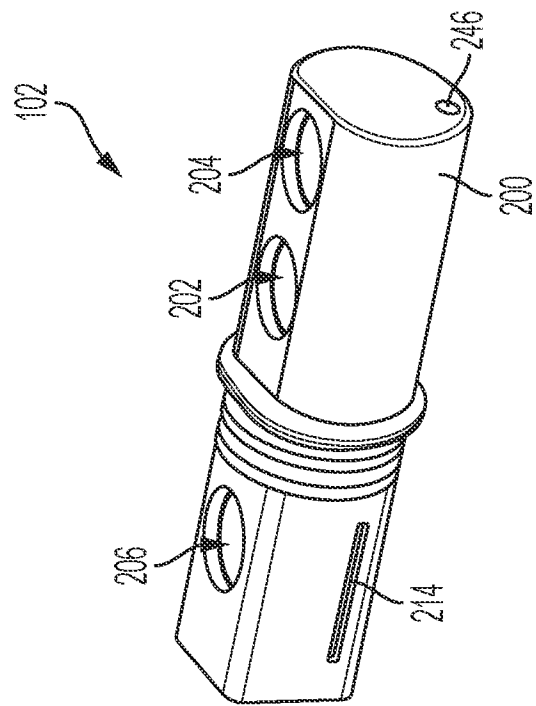


FIG. 6B

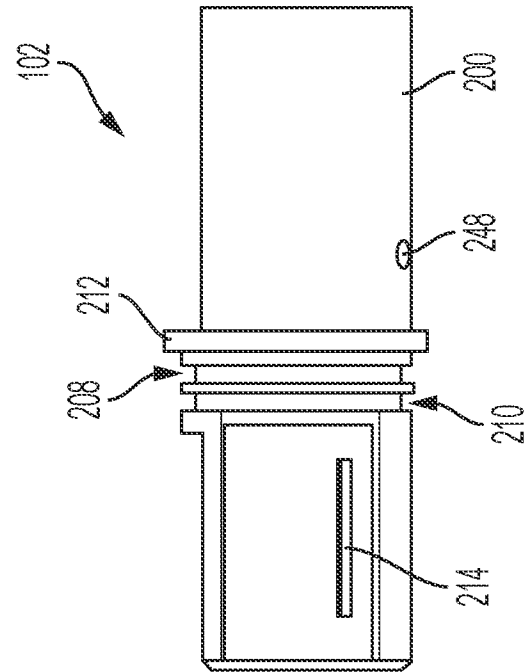


FIG. 6C

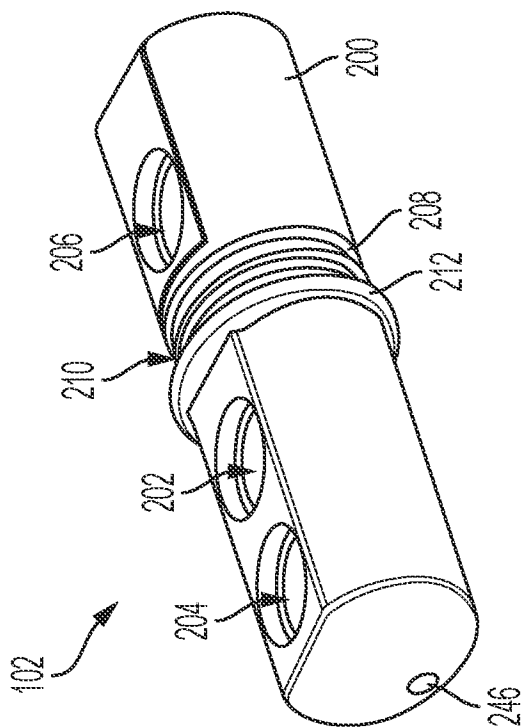


FIG. 6A

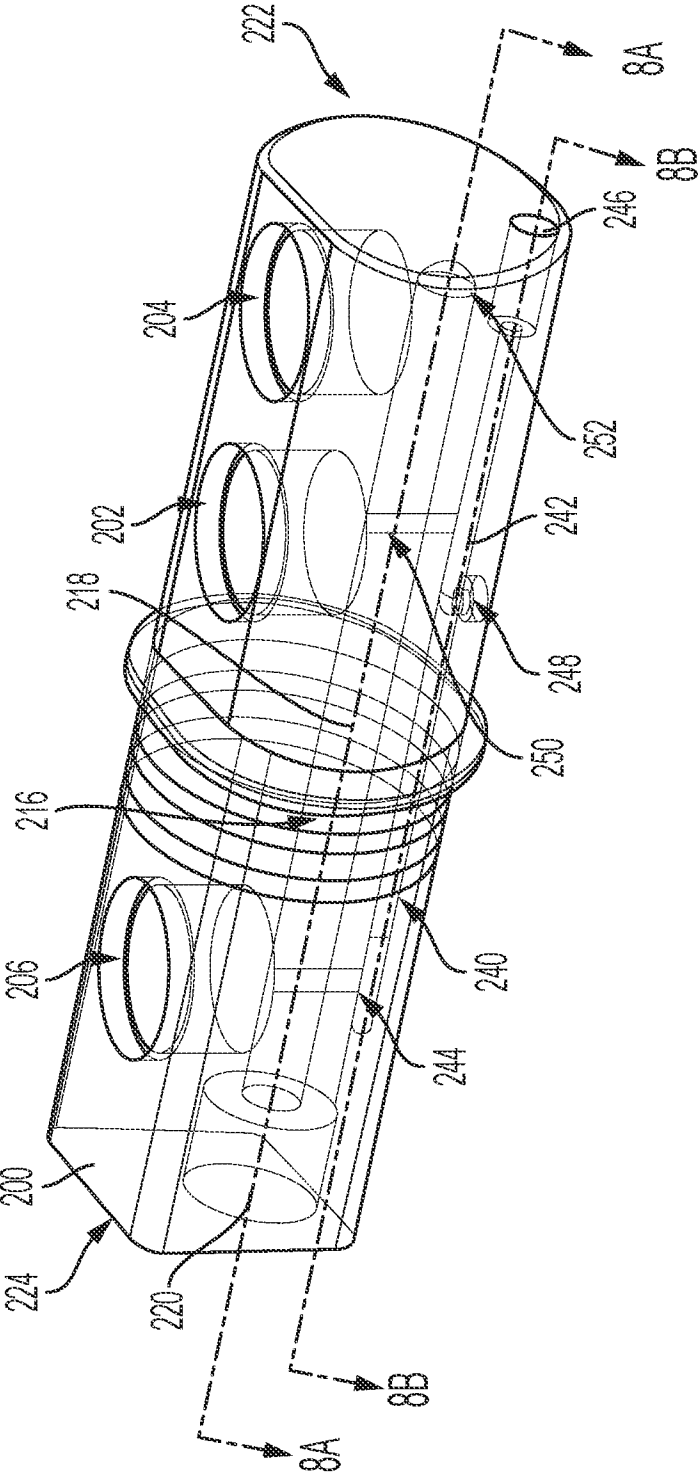
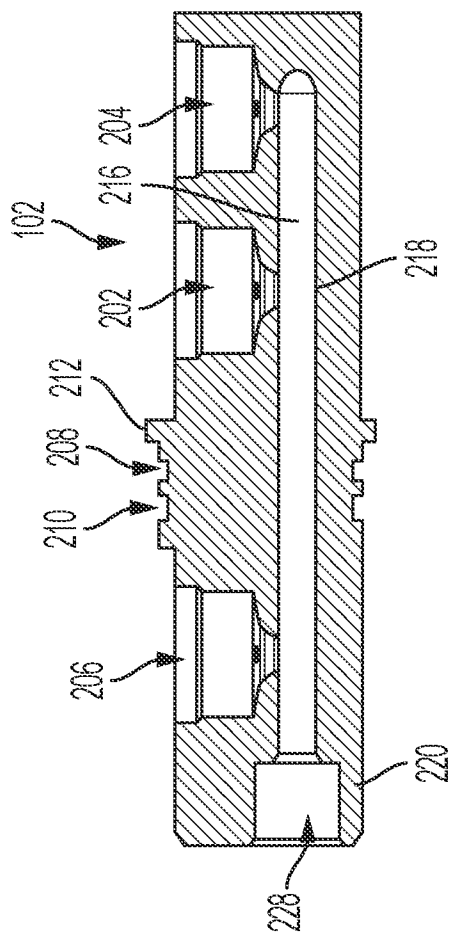
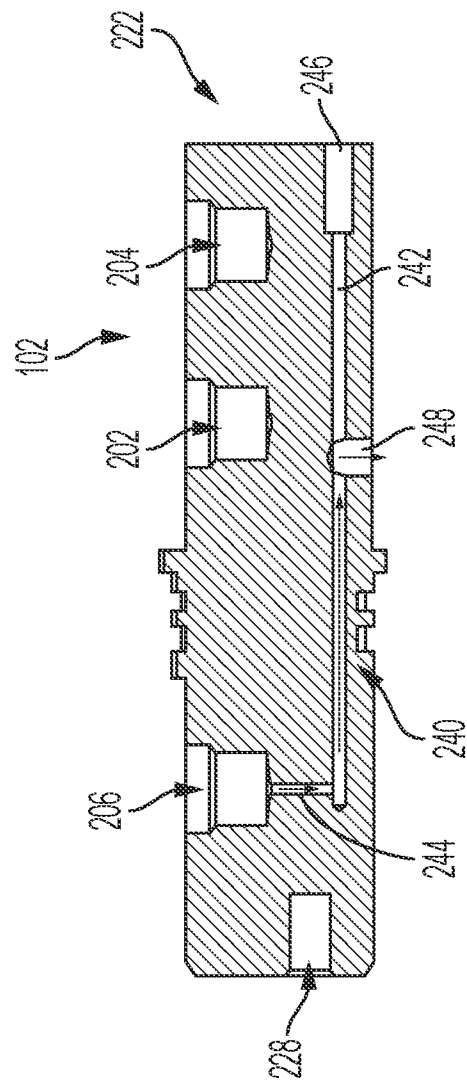


FIG. 7



AGLE



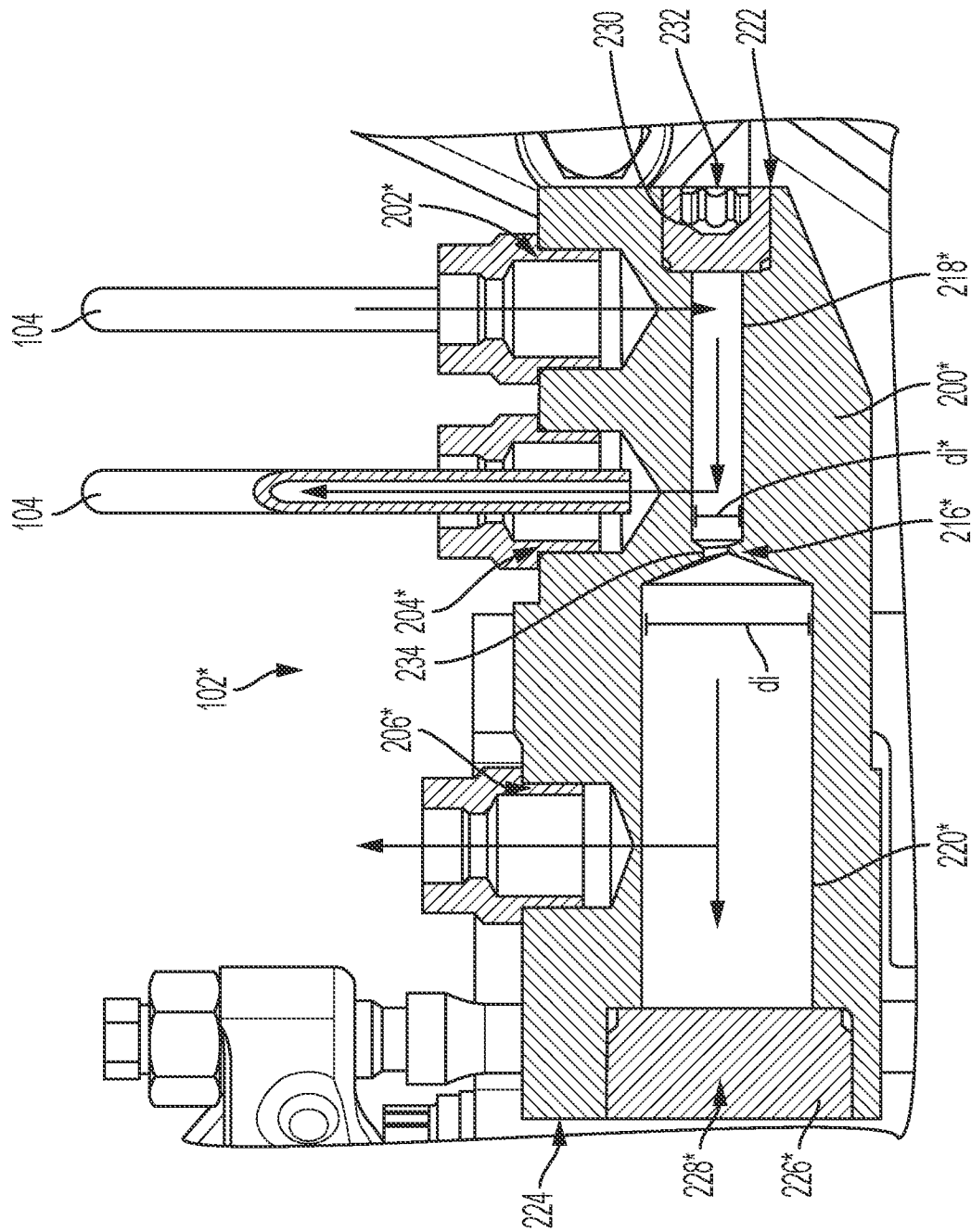


FIG. 9

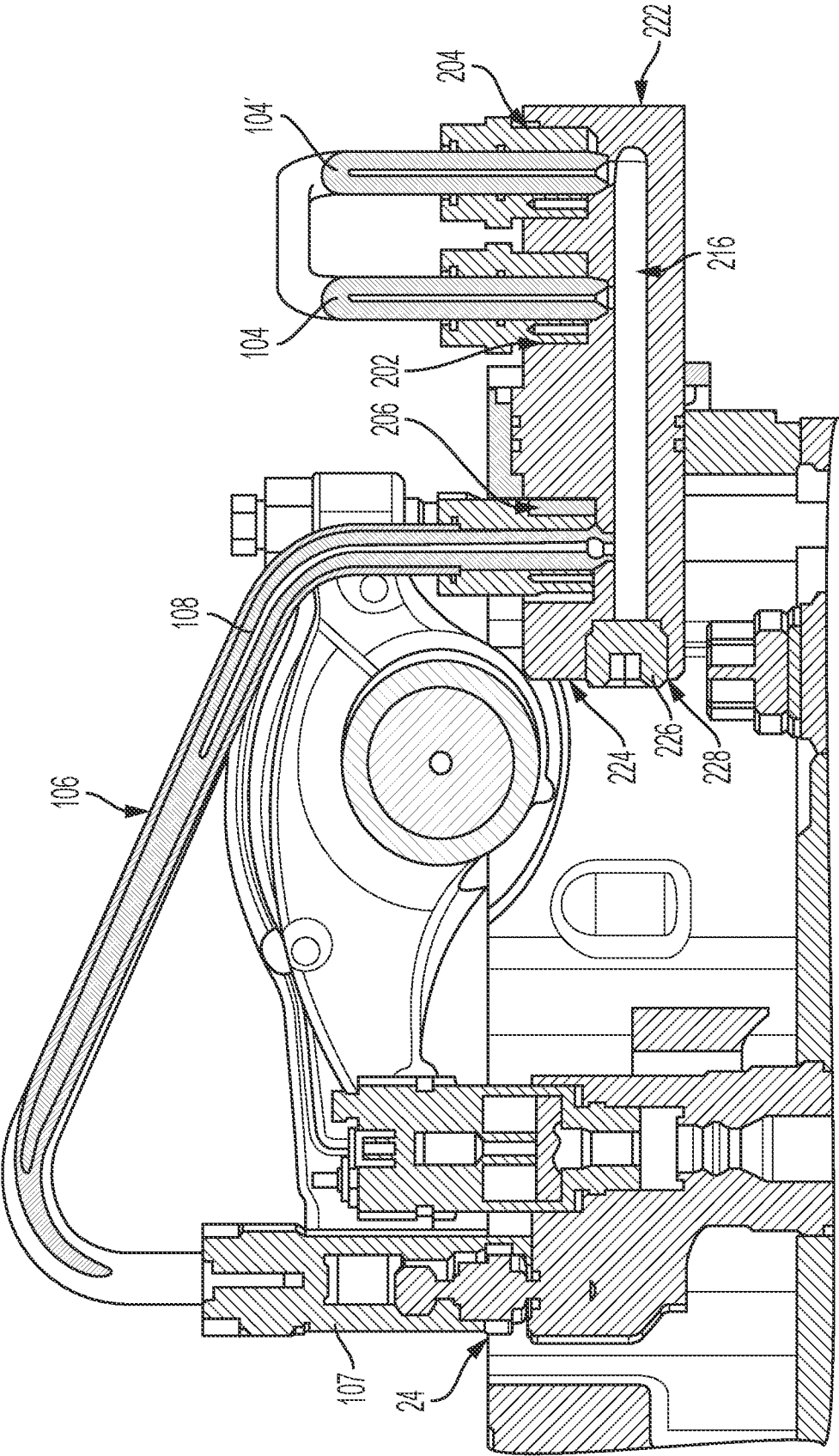


FIG. 10

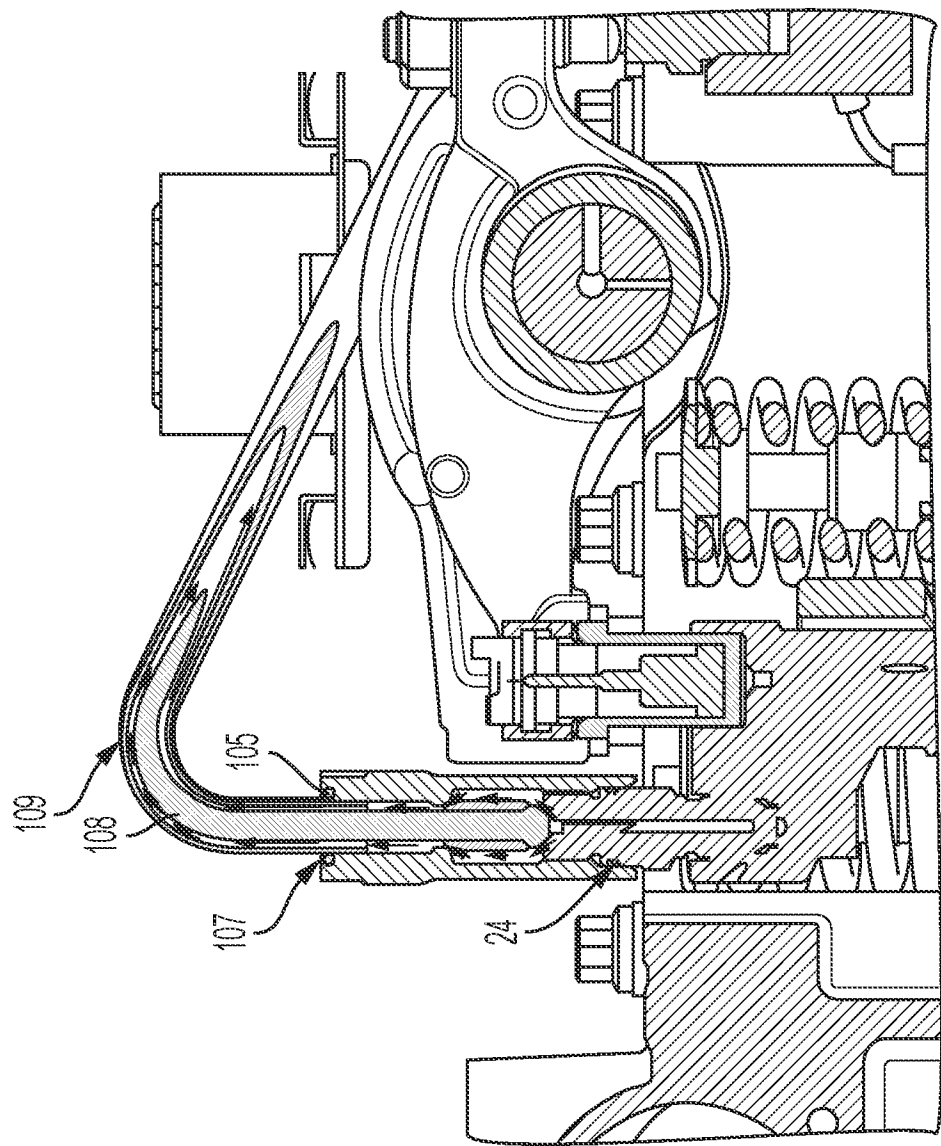


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 21/42924

A. CLASSIFICATION OF SUBJECT MATTER

IPC - F02M 55/02 (2021.01)

CPC - F02M 55/002; F02M 55/02; F02M 55/025; F02M 63/0225; F02M 69/04; F02M 69/465; F02M 69/50; F02M 2200/40

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)

See Search History document

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

See Search History document

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X — A	US 5,832,906 A (DOUVILLE et al.) 10 November 1998 (10.11.1998), entire document, especially Fig 1, 2; col 4, ln 28-40; col 7, ln 56-64; col 8, ln 3-9, ln 13-17, ln 30-39, ln 48-53; col 9, ln 29-31; col 9, ln 64 to col 10, ln 1	1-4, 7-9, 12, 14 5, 6, 13
X — Y — A	US 7,827,962 B2 (WEIZENAUER et al.) 09 November 2010 (09.11.2010), entire document, especially Fig 1, 2, 3.1, 3.2; col 1, ln 13-14, ln 55-58; col 2, ln 7-17; col 4, ln 33-38, ln 46-61; col 5, ln 8-22, ln 47-56; col 6, ln 4-8	1, 3, 7, 12, 14-16, 18 10, 11 13, 17, 19, 20
Y	US 2019/0178213 A1 (PHILLIPS et al.) 13 June 2019 (13.06.2019), Fig 1a, 1b; para [0030], [0031]-[0032], [0035]	10
Y	US 2005/0103110 A1 (ERNSBERGER et al.) 19 May 2005 (19.05.2005), Fig 1-8; para [0005], [0032], [0034], [0048]	11
A	US 6,418,910 B1 (NALLY et al.) 16 July 2002 (16.07.2002), entire document	1-20
A	US 2016/0177901 A1 (DICKEN et al.) 23 June 2016 (23.06.2016), entire document	1-20
A	US 7,827,967 B2 (BEARDMORE) 09 November 2010 (09.11.2010), Fig 2; col 5, ln 11-34	4-6
A	WO 2016/071046 A1 (DELPHI INTERNATIONAL OPERATIONS LUXEMBOURG S.A.R.L. 12 May 2016 (12.05.2016), Fig 1; pg. 4, ln 2-9	4-6

☐ Further documents are listed in the continuation of Box C.☐ 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

"D" document cited by the applicant in the international application

"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

27 September 2021 (27.09.2021)

Date of mailing of the international search report

OCT 29 2021

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-8300

Authorized officer

Karl Rodriguez

Telephone No. PCT Helpdesk: 571-272-4300