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2207/DEL/2014 4 August 2014 (04.08.2014) IN(71) Applicant: **EATON CORPORATION** [US/US]; 1000
Eaton Boulevard, Cleveland, Ohio 44122 (US).(72) Inventors: **MILLS, Vaughn Kevin**; 14196 Fairway Drive,
Chelsea, Michigan 48118 (US). **BHURKE, Pritam**; Prime
Rose-A, Sukhwani Campus, Vallabh Nagar, Pimpri, Pune
411018 (IN). **DINNI, Ravikumar**; Flat no C2-302,
Woodsville, Phase 1, GAT no 97, Bhoradewadi, Pune
412105 (IN). **GOUD, Shivaprasad**; Flat no02, Creative
Rainbow Apartment, Sec 06, plot no 39, Santanagar,
Moshi 411025 (IN).(74) Agents: **COLANTONI, Krystyna** et al.; Mei & Mark
LLP, P.O. Box 65981, Washington, District of Columbia
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(54) Title: FUEL TANK LIQUID VAPOR DISCRIMINATOR WITH INTEGRATED OVER-PRESSURE AND MAKE-UP AIR VALVES

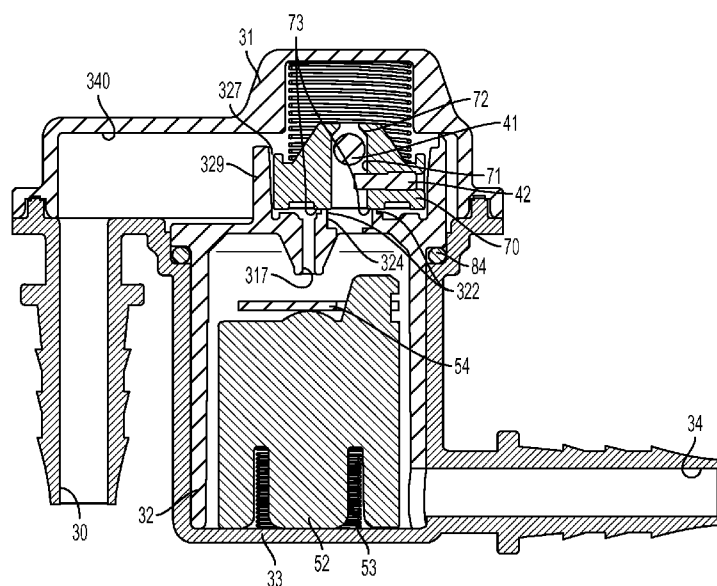


FIG. 4

(57) Abstract: A valve assembly (23, 100) comprises a roll-over valve (50, 150) configured for fluid exchange through a float sleeve and through an orifice. A lower housing (82, 33, 180) is connected to the roll-over valve (50, 150) and comprises a fluid vent (330, 827, 151) connected to drain fluid by passing the fluid through the float sleeve. An upper housing (31, 81, 181) is sealed against the lower housing. The upper housing comprises a fluid pathway (30, 340, 819, 185), biases an over-pressure seal towards the lower housing to block fluid flow between the fluid pathway and the fluid vent, and receives a make-up air valve. The make-up seal is biased to block fluid flow between the fluid pathway and the fluid vent. A liquid trap (324, 815, 170) connects the over-pressure relief valve and the make-up air valve to the fluid vent (330, 827, 151).

**FUEL TANK LIQUID VAPOR DISCRIMINATOR WITH INTEGRATED OVER-PRESSURE
AND MAKE-UP AIR VALVES**

Field

[001] This application relates to fuel system safety and emissions mechanisms. More specifically, the application provides an integrated over-pressure relief and make-up air valve in combination with a liquid vapor discriminator.

Background

[002] Current fuel system designs include piecemeal connections between various valves, resulting in multiple failure points and leak paths. The piecing together of various parts also results in inefficient use of space and system redundancies for such parts as liquid return lines and connections. The assembly and mounting process for the various parts is also complex because the parts are dispersed across the motive device.

[003] Some fuel tank designs include pressure relief in the inlet cap in the form of a vent to the atmosphere. This pollutes the environment and permits evaporation of fuel from the tank. The current designs do not permit pressure relief to be filtered in an environmentally friendly way. Current designs also do not permit concurrent vacuum relief, pressure relief, and roll-over liquid protection. Nor do the current designs package the concurrent functions in an integrated assembly.

SUMMARY

[004] The systems and methods disclosed herein improve the art by way of integrating one or both of an over-pressure relief valve and a make-up air valve with contemporaneous liquid blocking from a roll-over valve. Environmental concerns are addressed by way of a liquid vapor discriminator in line with a charcoal canister (EVAP canister). Integrating the functions in a single valve housing results in a simplified system layout and reduced number of total components. Further improvements integrate a fuel-fill sleeve with at least an over-pressure relief valve and a roll-over valve.

[005] A valve assembly comprises a roll-over valve comprising a float, a roll-over spring, a roll-over sealing member, a float sleeve and an orifice. The roll-over valve is configured for fluid exchange through the float sleeve and through the orifice, and is configured for the float to rise in liquid to abut the sealing member against the orifice. An over-pressure relief valve comprises an over-pressure seal, an over-pressure seat and an over-pressure spring biasing the over-pressure seal towards the over-pressure seat. A make-up air valve comprises a make-up seal selectively biased against a make-up seat. A lower housing is connected to the roll-over valve and comprises a fluid vent connected to

drain fluid by passing the fluid through the float sleeve. An upper housing is sealed against the lower housing. The upper housing comprises a fluid pathway, biases the over-pressure seal towards the lower housing to block fluid flow between the fluid pathway and the fluid vent, and receives the make-up air valve. The make-up seal is biased to block fluid flow between the fluid pathway and the fluid vent. A liquid trap connects the over-pressure relief valve and the make-up air valve to the fluid vent.

[006] Another fuel system comprises a fuel tank interface comprising at least one tank recess. a mid-plate or a tank post is affixed to the at least one tank recess. The valve assembly abuts the fuel tank interface. A lid plate is mounted to the mid-plate or to the tank post to secure the valve assembly to the fuel tank interface. A hinged fuel tank lid is mounted to the lid plate. The fuel tank lid comprises at least a lid seal for sealing against the tube.

[007] Another integrated valve assembly comprises a lower housing, comprising a valve seat, a hollow cylinder, and a fluid pathway at least partially surrounding the hollow cylinder. A liquid trap is in fluid communication with the fluid pathway. A fluid vent connects to drain fluid from the liquid trap. An upper housing is sealed against the lower housing. The upper housing comprises a hollow cylindrical tube formed through the upper housing. The tube is fitted within the hollow cylinder. A roll-over valve comprises a float, a roll-over spring, a roll-over sealing member, a float sleeve and an orifice. The roll-over valve is configured for fluid exchange through the float sleeve and through the orifice, and is configured for the float to rise in liquid to abut the sealing member against the orifice. The roll-over valve is positioned to receive fluid from the liquid trap and to direct received fluid to the fluid vent. An over-pressure relief valve comprises an over-pressure seal, an over-pressure seat and an over-pressure spring biasing the over-pressure seal towards the valve seat.

[008] A method for drop-down installation of an integrated valve assembly in a fuel tank, comprises affixing a mid-plate to a tank with a fuel tank interface. An integrated valve assembly is placed into the fuel tank interface, the placing comprising tilting the integrated valve assembly to first introduce a roll-over valve of the integrated valve assembly into the fuel tank interface, aligning a port of the integrated valve assembly with a port gap of the fuel tank interface, and leveling the integrated valve assembly with the fuel tank interface such that the port protrudes through the port gap. An upper housing of the integrated valve assembly is parallel with the fuel tank interface. A lid plate is placed on top of the integrated valve assembly and the lid plate secures the integrated valve assembly to the mid-plate. A fuel tank lid is attached to the lid plate.

[009] Additional objects and advantages will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by

practice of the disclosure. The objects and advantages will also be realized and attained by means of the elements and combinations particularly pointed out in the appended claims.

[010] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the claimed invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[011] Figure 1 is a schematic of a prior art fuel system.

[012] Figures 2A-2D are schematics of exemplary fuel systems comprising a roll-over valve (ROV), an over-pressure relief valve (OPR), and a make-up air valve (MUA).

[013] Figure 3A shows a valve assembly where the MUA can draw make-up air from the canister port.

[014] Figure 3B shows a valve assembly where the MUA can draw make-up air from an alternate vent.

[015] Figure 4 shows an alternative valve assembly where the MUA can draw make-up air from the canister port.

[016] Figures 5A-5C show an alternative valve assembly and first through third flow paths.

[017] Figure 6 shows another valve assembly with alternative porting.

[018] Figures 7A-7C show flow paths for an alternative integrated valve assembly.

[019] Figures 8A & 8B are alternative views of the integrated valve assembly of Figure 7A.

[020] Figure 9 is another cross-section of an integrated valve assembly.

[021] Figure 10A is an exploded view of an integrated valve assembly.

[022] Figures 10B & 10C are exploded views of a fuel tank incorporating an integrated valve assembly and a fuel tank lid 113.

[023] Figures 11A-11D illustrate placing an integrated valve assembly into a fuel tank interface.

[024] Figure 12 is a cross-section of an integrated valve assembly including a fuel tank lid.

[025] Figures 13A & 13B show an alternative integrated valve assembly including a fuel tank lid.

[026] Figure 14 is a cross-section of the example of Figures 13A & 13B.

[027] Figure 15 is a flow chart of a method of assembling an integrated valve assembly in a fuel tank.

DETAILED DESCRIPTION

[028] Reference will now be made in detail to the examples, which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. Directional references such as “left” and “right” are for ease of reference to the figures.

[029] Emissions and safety regulations are beneficial for protecting consumers and the environment. However, compliance with regulations requires the addition of parts to existing systems. Instead of a piecemeal addition of those parts, and instead of introducing multiple leak paths through T-connectors and hose lines, applicant proposes integration of parts for ease of compliance. By packaging multiple functions together, it is easier to find space on the end-user machine.

[030] At times, applicant references “make-up air or “air,” and this should be understood to mean intake or fresh air. But, make-up air can further include gaseous matter from the fuel tank or from the combustion process or both. Mixtures of fresh air and combustion waste can form make-up air, such as by including extracted matter from the charcoal canister. Fluid can comprise one or both of liquids or vapors, and the vapors can comprise air or fuel vapors.

[031] As shown in Figure 1, a prior art fuel tank 10 can include an inlet cap 13 that includes pressure relief. The pressure relief allows fuel vapors to exit the tank 10 should the fuel 12 evaporate and expand beyond predetermined limits. Liquid fuel 12 can be drawn from the tank to a carburetor 14 and then to the engine 15 for combustion via liquid fuel line 11. This layout is typical of many two-wheel vehicles such as motorcycles and mopeds.

[032] In order to provide greater safety and protection for two-wheel vehicles, such as motorcycles and mopeds, and for three or four wheel vehicles such as all-terrain vehicles (ATV), automobiles and other powered devices having a fuel tank, such as tractors and lawn-mowers, Applicant proposes the system architectures shown in Figures 2A-2D.

[033] In Figure 2A, a fuel tank 20 comprises an inlet cap 24 and an internally mounted valve assembly 23 that can be, for example, flush mounted or drop-in assembled to the fuel tank 20. The inlet cap 24 can, but no longer requires, an independent ROV because over-pressure in the tank can now be relieved via the valve assembly 23. The valve assembly can include a liquid trap to return sloshed liquid fuel or condensed fuel vapor to the tank 20. Valve assembly 23 can comprise, as alternative internals, the components of Figures 3A-6. To permit internal mounting of the valve assembly, where roll-over protection is located inside the fuel tank, the nozzles of Figures 3A-6 can be removed, repositioned, or modified to permit drop-in assembly of the valve assembly 23 in to the fuel tank 20.

[034] As shown in Figures 7A-14 and Figure 2D, the valve assembly can be integrated with the inlet cap to form an alternative internally mounted integrated valve assembly. The inlet cap 24 in Figure 2D can thus further comprise refueling components, such as fuel fill shut off mechanisms. A vapor fuel line 21 connects between the valve assembly 23 and a canister 25, such as a charcoal or EVAP canister. The canister 25 connects the vapor fuel line 21 to a purge valve 26, which is either “blind” (mechanical) or controlled via vehicle electronics. The vapor fuel line 21 also connects to the carburetor 27. The carburetor 27 has a liquid fuel line 11 to the tank 20 and to the engine 28. The liquid fuel line 11 allows for extracting fuel 22 from the tank 20 for combustion in the engine. Purge valve 26 may alternatively be omitted: For example, the canister 25 can be plumbed to a vacuum source line at the carburetor 27 with a metered orifice to provide vacuum flow across the canister 25 during engine 28 operation.

[035] Because of the complexities of mounting and maintaining an internal valve, Figures 2B and 2C propose externally mounted valve systems that connect the valve assembly exteriorly to the fuel tank 20. Instead of individual hose lines, T-connectors, and mounting brackets to attached singular ROV, OPR, OVR, and liquid trap, the integrated alternatives of Figures 3A-6 are mounted outside of the fuel tank 20. The fuel tank 20 comprises the inlet cap 24 mounted to the tank or distanced from the tank by a refueling neck. Vapor fuel line 21 connects to the tank and to the external valve assembly 23. The valve assembly 23 is connected to the fuel tank via appropriate nozzles and liquid and vapor fuel lines 11, 21. A liquid fuel line 11 connects the fuel 22 to the carburetor 27, which supplies fuel 22 to the engine 28. Purge valve 26 may alternatively be omitted, as discussed above.

[036] In Figures 2A-2D, alternatives are possible, such as direct injection of fuel to the engine, or such as use of an inlet manifold, thus omitting or supplementing carburetor 27. Additional parts, such as a fuel pump or in-tank fuel sender, or such as a liquid return line from the valve assembly 23 to the fuel tank 20, are omitted for clarity. It is to be understood that, in the externally mounted configurations, liquid fuel can enter the vapor line from the fuel tank to the valve assembly, and the liquid can return to the tank or be directed to the combustion process by appropriate liquid traps and line connections. The liquid redirection can be used in the internally mounted configurations, though the valve assemblies include gravimetric return of liquid to the tank. While a canister port and a fuel tank port are used in the examples for brevity, the valve assemblies 23 can be connected via their ports to a variety of liquid or vapor processing mechanisms, for example, one or more of a carburetor, intake manifold, fuel shut-off mechanism, high pressure vapor line, low pressure vapor line, fuel sender, a liquid trap, or a filter such as a charcoal filter or EVAP canister.

[037] The valve assembly 23 comprises a make-up air valve (MUA) 40, which is a one-way valve. MUA 40 permits air or other gasses to enter the fuel tank 20 to make-up for fuel 22 extracted for combustion and can also be used for over vacuum relief when fuel vapors condense. An over-pressure relief (OPR) valve 60 is connected to the vapor fuel line 21 to permit outgassing when the vapors in the line exceed a first predetermined pressure. The OPR 60 “cracks” (opens) to release excess pressure, but is biased closed below the predetermined pressure. A roll-over valve (ROV) 50 is also present to prevent liquid fuel 22 from entering the canister 25 in the event that the fuel tank 20 is tipped or in the event liquid otherwise accumulates in the vapor fuel line 21. During normal operation, for example when a vehicle is upright and liquid has not entered ROV 50, ROV 50 is in a default open position that permits equalization of pressure between the fuel tank 20 and canister 25. MUA 40 and OPR 60 are biased in closed positions and open, respectively, when there is an under-pressure or over-pressure condition in fuel tank 20 that is not otherwise remedied by vapor flow through ROV 50. The MUA 40 and OPR 60 are designed to prevent liquid fuel from exiting through the valve assembly 23 but for exceeding the seal set point of the OPR 60.

[038] The canister 25 can be further connected in several alternative ways. As shown in Figure 2B, canister can be connected to an air supply 29, which can be the atmosphere. The canister can also connect to an exhaust gas conduit to filter engine exhaust. Since it is beneficial to the environment to filter any over-pressure relief gasses, the canister is connected to the valve assembly 23. A liquid fuel trap is used to prevent liquid fuel from contaminating the canister 25. To assist with exhaust vapor consumption, the MUA 40 can also be connected to the canister 25, as shown in Figure 2C.

[039] Figure 3A illustrates a valve assembly 23 including an integrated OPR 60, MUA 40, and ROV 50. A port 30 connects to the canister 25, which is preferably a charcoal or EVAP or like filter. The port 34 can be omitted when internally mounting the valve assembly, and the hole 330 fluidly communicates with the fuel tank 20. The port 34 can also be connected to the tank 20 via an appropriate line connection. It is beneficial to use gravity to drain fuel 22 back to the fuel tank 20 via port 34. But, when valve assembly is externally mounted, the port 34 connects to the fuel tank 20 to direct fuel 22 back to fuel tank 20. Ports 30 and 34 are connected to the valve assembly, for example, by integrally molding them to the housing halves, by snap-fit, press-fit or weld, and with or without one or more o-rings. The OPR 60 is physically integrated with MUA 40 using a movable substructure 70. MUA 40 is located within OPR 60 and actuated by ball 41. An upper spring 61 is biased against an upper housing 31 and a movable substructure 70. A first recess 311 surrounds upper spring 61 and guides it. Float sleeve 32 includes an intermediate recess 325 for seating and guiding movable substructure 70. The movable substructure 70 is illustrated as a cylindrical body with an internal passage 71 for sliding movement of ball 41. A seat 72

comprises a taper in the internal passage 71 to seat the ball 41 and seal the internal passage 71 against the passage of vapors. A recess 75 seats the upper spring 61. An outer cylindrical lip 77 guides the movable substructure 70 in the intermediate recess 325 and prevents lateral motion of the upper spring 61.

[040] If vapor pressure from the tank 20 via port 34 exceeds a first predetermined value, the pressure exceeds the upper spring 61 spring force and the movable substructure 70 raises up, thereby venting to the vapor fuel line 21 between lower tessellations 73 of the substructure 70 and upper ridges 322 of float sleeve 32. This provides over-pressure relief to prevent fuel tank rupture during conditions such as high heat fuel vapor expansion or a collision to the fuel tank. Unlike prior designs, the over-pressure relief is provided regardless of whether the ROV 50 is activated, because the ROV sealing member 54 does not seal against the passageway 324 to the integrated OPR and OVR valve. Thus roll-over protection is provided simultaneously with over-pressure and over-vacuum relief. Should a user lean their vehicle in a way that triggers the sealing of the ROV 50, the user continues to benefit from OVR and OPR protections. While a small amount of fuel could exit the OPR 60 during an event such as a collision or overheating of an overturned fuel tank, the instantaneous pressure relief possible through OPR 60 prevents a much larger fuel leak that would occur with fuel tank rupture. The location of the integrated OPR 60 and MUA 40 parallel to the passageway 317 from the ROV 50 permits gravitational return of liquid fuel to the tank 20 when the OVR float 52 moves away from the passageway 317. Thus, it is possible to omit or to use a liquid trap between the canister 25 and the valve assembly 23 so that any liquid released during over-pressure relief can drain back to the tank 20 without contaminating the canister 25 and without need to adjust the set points of the MUA 40 or OPR 60.

[041] When a vacuum occurs in the fuel tank 20, such as by fuel extraction for combustion or by fuel tank cooling, the make-up valve ball 41 activates. That is, the ball 41 in the movable substructure 70 moves away from the tapered ball seat 72 to let make-up air or other gasses pass to the fuel tank 20. Alternatively to a ball shape, ball 41 can be replaced with a disc or sheet. In this embodiment, the make-up air is drawn through port 30 from the canister and in to the fuel tank 20. Unlike prior designs, MUA 40 also activates regardless of whether ROV 50 is activated or not. That is, when liquid lifts float 52 and raises sealing member 54 to block passageway 317 thus activating and closing ROV 50, make-up air can still enter the tank through passageway 324. Thus, valve assembly 23 prevents fuel tank collapse in conditions such as when a user tilts the vehicle to park or service it. Because MUA 40 is biased closed in the presence of liquid or vapor fuel, no liquid fuel exits through MUA 40 in a tilted or roll-over condition. One-way flow is assured because

only a vacuum condition below a second predetermined pressure value will open MUA 40 for flow into the fuel tank.

[042] ROV 50 includes a float 52 in a lower housing 33. A float sleeve 32 is seated in lower housing 33 and guides the float 52 along float recess 326. Float sleeve 32 provides further recesses and coupling surfaces to integrate the ROV, OPR, and MUA via one or more of press fits, snap fits, and weld-ready seams. Lower housing 33 includes a floor 333. If a roll-over event occurs, a spring 53 is biased against the floor 333 to push the float 52 and affiliated sealing member 54 upwards to prevent fluid from crossing through passageway 317 and out through chamber 340. ROV 50 is normally open because the weight of the float 52 overcomes the force exerted by spring 53, but in the case of sufficient liquid ingress, the buoyancy of float 52 assists the spring 53 in raising the float 52. The sealing member 54 alternatively can be a sealing ring, a flexible strip, or tape.

[043] As show in in Figure 3A, valve assembly 23 comprises MUA 40 internal to OPR 60. The operational components share a first recess 311 in upper housing 31 and an intermediate recess 325 in float sleeve 32. The housing sleeve integrates the vapor passage 324 in the intermediate recess 325, and the float sleeve 32 receives the float 52 of the ROV 50 in a float recess 326. The lower housing 33 receives and surrounds the float sleeve 32 and provides a floor 333 for ROV spring 53. By integrating the upper housing 31, float sleeve 32 and lower housing 33 in to a one-piece construction via such mechanisms as press fit, snap fit, and/or ultrasonic welding, OEM and user integration is simplified, and a unified assembly provides multiple functions to an otherwise crowded fuel system. O-rings and other seals are preferably included to improve vapor seal and reduce vapor leak paths.

[044] Figure 3B illustrates an alternative valve assembly 23. A wall 328 separates chamber 340 from integrated OPR 60. The wall 328 abuts outer cylindrical lip 77, as illustrated, or is molded to abut upper housing 31. ROV 50 activates as above. However, OPR 60 provides emergency relief and vents excess pressure via vent 350. While an instantaneous fluid expulsion is possible, or a fuel vapor expulsion is possible, the fuel tank is protected against rupture. Also as above, MUA 40 is biased closed, but a vacuum condition at port 34 draws ball 41 away from ball seat 72 and make-up air can be drawn through vent 350 to relieve the vacuum. Alternatively, vent 350 includes a liquid trap, filter material, or porting or is directly vented to atmosphere.

[045] Figure 4 illustrates another valve assembly 23. O-ring 84 provides a seal between lower housing 33 and float sleeve 32. A pin 42 in the movable substructure 70 prevents the ball from falling out of the internal passage 71 and limits the mobility of the ball 41. Ports 30 and 34 are molded to lower housing 33. Also illustrated is an alternative location for passageway 317. Should the float 52 and seal 54 remain lowered, vapor can escape between gaps in lower tessellations 73 of the movable substructure 70 and upper

ridges 322 of float sleeve 32. Vapor reaches port 30 by passing between wall 329 in float sleeve 32 and movable substructure 70 and a gap 327 between wall 329 and cap 31. But if the passageway 317 is sealed by seal 54, pressure can lift movable substructure 70 to break the seal at tessellations 73.

[046] Figure 5A shows an alternative housing arrangement and tank venting during normal vehicle operation. In this example, porting is machined in to an upper housing 81 and a lower housing 82, and the halves are sealed together with the cooperation of o-rings 84 or other gasket materials in appropriate glands 85. Plug 83 seals a machining port 819 to prevent vapor passage out of upper housing 81. Plug 83 can alternatively be replaced with a nozzle for directing flow to more than one location. Nozzles 86, 87 are also connected with appropriate o-rings or other seals for connectivity for liquid or vapor flow. While barbed nozzles are illustrated, other valve stems can be used, such as quick-connect. The nozzles may alternatively be co-formed with respective upper housing 81 and lower housing 82, such as by molding.

[047] Flow paths are shown using arrows in Figures 5A-5C. Figure 5A depicts the release of vapors from fuel tank 20 through the first flow path in a normal condition—i.e., when ROV 50 is open. Vapor enters nozzle 86 from the fuel tank 20, and vent along pathway 827 to pass through the open liquid/vapor discriminator ROV 50, to port 819, and to the canister port 87. Similar to Figure 3A, float 52 rests towards or against a lower seat 824 when no liquid is present. The lower seat 824 also biases a float spring 53 to lift the float 52 in the presence of liquid. A float sleeve 51 is seated in the lower recess 823 of the lower housing 82. Sealing member 54, which can be a ring, tape, or other seal, rests against the float 52 and does not block upper orifice 55 of float sleeve 51. The fuel vapors pass through the upper orifice 55 in to ROV porting 817 in the upper housing 81, then the vapors exit nozzle 87 to, for example, canister. In Figures 4 & 5A, the ROV, make-up air and OPR valves are not activated and are biased closed.

[048] Upper housing 81 comprises an upper recess 811 for receiving a portion of the combined make-up and over-vacuum relief valve. The upper recess 811 includes an upper seat 812 for seating upper spring 61. The movable substructure 70 projects in to the upper recess 811 when the movable substructure 70 is lifted by appropriate vapor pressure, as shown in Figure 5B.

[049] Figure 5B illustrates the flow of vapors through the second flow path of valve assembly 23 wherein the over-pressure relief function and the roll-over protection function are contemporaneous. Fuel vapors enter port 86 and vent in to pathway 827. Vapors rise in to pathway 825 and exceed a first predetermined amount of vapor pressure, which overwhelms upper spring 61 of OPR valve 60. The movable substructure 70 lifts to unseal, and vapors traverse gaps between the tessellations 73, 64 between the base of the

movable substructure 70 and the insert 62. Alternatively, insert 62 can be omitted and tessellations 64 can be formed directly in lower housing 82. The vapors traverse a gap between a sidewall of the insert 62 and the movable substructure 70 and exit an OPR port 815 in upper housing 81. Vapors are then directed as above to nozzle 87.

[050] The movable substructure 70 includes OPR tessellations 73 for sealing against a vapor leak path with lower insert surface tessellations 64. The lower insert 62 is otherwise cup-shaped to seat in OPR recess 822 via press fit and to seal against the OPR recess 822 to prevent vapor leak paths. OPR O-ring 88 seats in OPR gland 89 to assist with the vapor sealing. The lower insert 62 is seated around a portion of the movable substructure 70, and the movable substructure 70 can reciprocate in a common portion between the OPR recess 822 and the upper recess 811.

[051] Movable substructure 70 includes internal passage 7 and a tapered ball seat 72 for providing a vapor seal with make-up air ball 41. Upper spring 61 surrounds an upper, semi-conical portion of the movable substructure 70. And, lip 79 of substructure 70 prevents lateral motion of upper spring 61.

[052] In Figure 5B, ROV 50 is activated, and consequently the first flow path is closed: The float 52 is illustrated in the activated position, such that the ROV spring 53 beneath the ROV float 52 is extended and sealing member 54 rises up to block upper orifice 55 of float sleeve 51. Should liquid traverse the combined MUA/OVR valve, the liquid can collect in OPR port 815, which functions as a liquid trap to return fluid to pathways 825 and 817. Should the liquid overwhelm the OPR port 815, the liquid cannot reach the canister nozzle 87 without encountering an opportunity to drain through the ROV 50 via ROV porting 817 and back to tank via vent pathway 827. Thus, ROV porting 817 functions as a liquid trap within the valve assembly. As above, over-pressure and over vacuum relief are available to the fuel tank despite active roll-over protection at ROV 50. Since both MUA 40 and OPR 60 are biased closed, roll-over fluid cannot exit the valve absent an extreme condition, such as overheating of the fuel tank or an impact to the fuel tank. And, over vacuum relief is afforded without fuel leakage, even in the roll-over condition, because air flow will be drawn in to the tank, but flow out of the tank will seat ball 41 against tapered ball seat 72. Thus, the fuel tank is protected against collapse and rupture.

[053] In Figure 5C, a third flow path includes reverse flow for make-up air entering port 87 and exiting port 86. ROV 50 is closed. The reverse flow of gasses from, for example, canister 25 to MUA 40 provides selective make-up air to the fuel tank 20. Thus, when fuel 22 is extracted from the fuel tank 20, a vacuum occurs in the fuel tank 20 and this second predetermined pressure draws the ball 41 in the movable substructure 70 downward to open a vapor passageway. When the vacuum is alleviated, the ball rises up

from vapor pressure to return to a position blocking the passageway. Liquid ingress from the tank can also lift ball 41 back in to place.

[054] Figure 6 illustrates another integrated assembly. An alternative vent 850 is included in upper housing 81. Instead of venting to canister via nozzle 87, over-pressure vapors from OPR 60 vent to alternative vent 850, and make-up air from MUA 40 is drawn through alternative vent 850. A nozzle can be included at vent 850 to direct expelled liquid or vapors to, for example, a filter or a liquid or vapor trap, or the vent 850 can be directly exposed to atmosphere. Upper housing 81 is machined to permit venting of fuel vapors during normal operation to, for example, canister 25 via nozzle 87, but wall 813 separates vent 850 from the canister flow path, and fluid or vapor flow to the canister port 87 is not possible when the ROV 50 is closed. A modified machining port 819 connects to nozzle 87. Machining port 819 can be closed via plug 83 with o-rings. Optionally, an additional machining port 831 can be included and plugged via additional plug 830. Alternatively, the valve assembly 23 can be simplified by placing nozzle 87 at the location of additional plug 830 and omitting machining ports 819 from upper housing 81. The three ports extending from ROV port 817 and the vent 850 permit fuel vapors to be directed to a larger number of vapor processing mechanisms.

[055] As above for Figures 3A-4, the OPR, OVR, and ROV functions of the examples of Figures 5A-6 are integrated in to a single, housed assembly. Press fit, snap fit, welding or other methods are implemented to deter unwanted leakage out of the assembly and to unify the assembly. The parallel layout of Figures 5A-6 permits integration of ROV porting 817 and orifice 55 in to upper housing 81, such as by molding or machining, to eliminate float sleeve 51. This simplifies manufacture and complements integration of insert 62 in to lower housing 82.

[056] In carburetor fuel injected 2-wheeler architecture, it is possible to externally mount the valve assembly 23. Being externally mounted to the vehicle, outside of the fuel tank, these valves are serviceable. However, this type of arrangement is associated with aesthetic, safety, and canister protection challenges. Such an external mounted valve connects with the help of several hose lines and thus may result in more emissions to the environment through these lines. By integrating three valves in to one package, the number of line connections are reduced over the prior art and the number of externally mounted parts are reduced over the prior art. This makes the serviceable valve assembly easier for a vehicle supplier to integrate and safer for the user and for the environment.

[057] With reference to Figure 2D, the functionality of valve assembly 23, as depicted, for example, in Figures 3A-6 can be integrated into a vehicle fuel cap receiving assembly, such as with integrated valve assembly 100 of Figures 7A-14. Safety, canister protection, aesthetics, and multiple hose line connection issues are addressed in the

internally mounted system including integrated valve assembly 100. In addition to ROV functionality, integrated valve assembly 100 traps and drains sloshing liquid, and performs over-pressure relief and under-pressure relief. Several hose connections are eliminated with this design. The integrated valve assembly 100 is a modular solution that overcomes packaging constraints when installing a valve into an existing tank by reducing the overall footprint for the valves. Modularity is enhanced because valve features, such as spring pressures, ROV layout, and valve seal type can be customized for the end user without re-tooling the fuel tank 20. This is particularly beneficial to 2-wheeler vehicles, which comprise a compact assembly and limited size fuel tank. It also addresses product manufacturing challenges that arise when a ROV is affixed directly to a fuel tank. The integrated valve assembly 100, by integrating the fuel cap with liquid trap, ROV, MUA, and OPR, greatly simplifies manufacture of fuel tank access and user safety devices.

[058] While integrated valve assembly 100 is described for use with All-Terrain Vehicles (ATVs), motorcycles, mopeds, and scooters, other vehicles such as automobiles, SUVs, and trucks can also benefit from integrated valve assembly 100 when the fuel-fill neck is lengthened, integrated with, or connected to, the integrated assembly 100 to account for differences in the distance between the fuel cap and the fuel tank.

[059] Figure 7A is a cross-section of integrated valve assembly 100, which illustrates vapor flow to canister 25 when ROV 150 is open. That is, Figure 7A depicts the flow of vapors through the first flow path of integrated valve assembly 100. In addition to ROV 150, integrated valve assembly 100 includes OPR valve 160, MUA 140, lower housing 180, upper housing 181, and port 130. Preferably, lower housing 180 and upper housing 181 are each integrally molded. A fueling neck is a cylindrical fuel receiving tube 187 that forms the innermost portion of upper housing 181, and comprises a tapered fuel funnel 189 at the uppermost portion of tube 187. Lower housing 180 includes a hollow cylindrical portion 188 to receive cylindrical fuel receiving tube 187 of upper housing 181. Upper housing 181 is fitted within lower housing 180. Lower housing 180 includes receptacle 186 to receive ROV 150.

[060] The first, second and third flow paths proceed through receptacle 186. The first flow path proceeds through the base of an installed ROV 150 when it is open, such as through vents 1590. The second and third flow paths proceed through second flow path opening 151 in upper housing 181 and through upper vents 159 of ROV 150. Second flow path opening 151 is a vent formed through a wall of receptacle 186 of lower housing 180.

[061] The integrated valve assembly 100 is configured to be installed underneath the fuel tank lid 113. This conceals the safety devices from the user experience and permits a vehicle manufacturer to retain design features of the fuel tank lid 113. Integrated valve assembly 100 is preferably located at a topmost position of the tank 20, such as illustrated

in Figure 2D, which ensures it does not submerge into the fuel but for a roll-over condition. Sloshed fuel drains back into the fuel tank 20 after being captured in a liquid trap 170. When fuel tank lid 113 is opened, fuel 22 can be introduced into the fuel tank through the center space of fuel funnel 189 and cylindrical fuel receiving tube 187. While not illustrated, the integrated valve assembly 100 can interface with or further integrate refueling features, such as nozzle shut-off mechanisms. Or, the diameters of the fuel funnel 189 and cylindrical fuel receiving tube 187 are selected to trigger the shut-off mechanism of a fuel dispensing nozzle.

[062] As depicted in Figure 7A, a recess 185 that is roughly ring shaped is formed between upper housing 181 and lower housing 180 to circulate fuel or vapors around the exterior of cylindrical fuel receiving tube 187. OPR valve 160 is formed from and within upper housing 181. MUA 140 is formed from and between the surfaces of upper housing 181 and lower housing 180. The recess 185 is illustrated with a stepped-down portion beneath the MUA 140 to include a liquid trap 170. The liquid trap 170 connects with a notch or other step-down beneath OPR 160 to permit fluid drain between the upper housing 180 and the lower housing 181 so that fluid can drain to receptacle 186 and out ROV150. The liquid trap 170 can also be designed with a slant to gravitationally direct liquid fuel away from MUA 140 and towards ROV 150. Fluid and vapor can circumscribe the cylindrical fuel receiving tube 187 using the ring-shaped recess 185 and the liquid trap 170. Under normal operating conditions or when the vehicle is tilted on, for example, a kickstand, minimal liquid is able to enter the second flow path opening 151 and the ROV is able to perform its function of preventing corking of downstream valves and preventing flooding of the vapor path. Leakage of fuel during a roll-over condition is also prevented because the ROV150, OPR 160 and MUA 140 do not permit fuel to leave the tank. This is an improvement over prior art designs that permit free access between the tank and tank lid by way of open vents.

[063] Figure 7B is a cross-section of integrated valve assembly 100, which illustrates vapor flow to the atmosphere through the second flow path. This occurs, for example, when vents 1590 of ROV 150 are covered by fuel or the fluid connection from port 130 to canister 25 is undermined, thereby closing off the first flow path. In these circumstances, integrated valve assembly 100 relieves the over-pressure condition through second flow path opening 151, upper vents 159, orifice 555, and OPR valve 160, as shown in Figs. 8A and 9B.

[064] Figure 7C illustrates air being drawn from the atmosphere through the third flow path. This occurs, for example, when ROV 150 is closed or the fluid connection from port 130 to canister 25 is undermined, thereby closing off the first flow path. In these circumstances, integrated valve assembly 100 relieves the under-pressure condition by

sucking in air through MUA valve 160 into recess 185. Such make-up air is drawn through upper vents 159 and through second flow path opening 151, or through orifice 555 and vents 159.

[065] Figures 8A & 8B depict an example of the relative positioning and circumferential distribution of MUA 150, OPR 160, ROV 150, and port 130. The circumferential distribution about the cylindrical fuel receiving tube 187 can be adjusted for design purposes, though maximizing the distance between second flow path opening 151 and port 130 permits the most room for gravitational drain of liquid fuel. Fingers and grooves for snap-fittings are also illustrated.

[066] Figure 9 is a cross-section view of the integrated valve assembly 100. MUA 140 is a one-way valve and comprises MUA seal 141, MUA spring 142, MUA orifice 143, MUA seat 144, MUA pin 145, and MUA neck 146. MUA seal 141 is preferably a disc or a ball. MUA spring 142 is biased to press MUA seal 141 towards MUA pin 145, which is part of lower housing 180. MUA seal 141 is guided by MUA neck 146. MUA neck 146, MUA seat 144 and MUA orifice 143 are formed within upper housing 181. Under normal and over-pressure conditions, MUA spring 142 holds MUA seal 141 against MUA seat 144 and prevents flow through MUA orifice 143. However, in under-pressure conditions sufficient to overcome the force exerted by MUA spring 142, MUA seal 141 moves from MUA seat 144 towards MUA pin 155 within MUA neck 146. Thus, MUA 140 permits air to flow into integrated valve assembly 100 through MUA orifice 143 and into the tank through the third flow path.

[067] OPR 160 is a one-way valve and comprises OPR seal 161, OPR spring 162, OPR cap 163, OPR orifice 164, OPR seat 165, and OPR neck 167. OPR seal 161 is preferably a disc or a ball. OPR spring 162 is biased against OPR cap 163 and OPR seal 161. OPR cap 163 can be welded onto or press-fit into OPR neck 167, which is formed by upper housing 181. Grooves or slots can be included in one or both of the OPR neck 176 or OPR cap 163 to facilitate flow between ribs in one or both of OPR cap 163 and OPR neck 167. Both OPR seat 165 and OPR orifice 164 are formed by upper housing 181. In normal and under-pressure conditions, OPR spring 162 holds OPR seal 161 against OPR seat 165 and prevents any flow through OPR orifice 164. However, in over-pressure conditions sufficient to overcome the force exerted by OPR spring 162, OPR seal 161 moves towards OPR pin 166 of OPR cap 163. OPR 160 permits vapor to escape from integrated valve assembly 100 via the second flow path and into the atmosphere through OPR orifice 164 and between OPR cap 163 and OPR neck 167.

[068] ROV 150 is installed into receptacle 186 of lower housing 180 such as by the barbed coupling in Figure 9, or the barbs and grooves of Figures 12 & 14, or by welding, press-fitting, or like means. To seal the ROV 150 against the receptacle 186, o-rings can

also be used or a snap ring 1833. ROV 150 operates similarly to ROV 50. ROV 150 can additionally include ROV cap 1550, which permits the flow of vapors into lower housing 180 and the ring-shaped recess 185 between lower housing 180 and upper housing 181. ROV 150 optionally includes disc 156 to aide in pressure regulation. Liquid fuel can lift float 52 to lift seal 54 to close orifice 555, thereby closing first flow path of ROV 150. Blocking orifice 555 also blocks liquid and vapor passage through upper vents 159 and second flow path opening 151.

[069] The recess 185 between lower housing 180 and upper housing 181 is sealed by top o-ring 182 and bottom o-ring 183. Top o-ring 182 also prevents the leakage of liquid fuel and fuel vapors to the atmosphere, as well as ingress of water into fuel tank 20. Bottom o-ring 183 also prevents fuel from entering into liquid trap 170 in a roll-over condition.

[070] ROV cap 1550 further includes a notch 171 near orifice 555 of ROV 150 that permits liquid to drain from liquid trap 170 into fuel tank 20 through ROV 150. Fuel 22 that exits fuel tank 20 along with fuel vapors or because of condensation or sloshing can be trapped and accumulated by liquid trap 170. Liquid trap 170 works by using gravity to collect fluid that makes its way into recess 185. When ROV 150 is open, fluid drains through notch 171, around disk 156, through orifice 555, and ultimately back into tank 20 around float 52. Further features of the ROV 150 include holes 1590 in the sides and or base for regulating fluid movement in to and out of float sleeve 510.

[071] Figure 10A depicts an alternative circumferential distribution of the port 130, ROV 150, MUA 150, and OPR 160 around the cylindrical fuel receiving tube 187. The exploded view also illustrates how assembly can be simplified via a drop down method with modular parts.

[072] Over-pressure relief valve 160 can be assembled by placing over-pressure relief seal 161 and over-pressure relief spring 162 into over-pressure relief neck 167. Over-pressure relief cap 163 is affixed to the neck 167 by, for example, welding, snap fitting, or press-fitting. Make-up air valve 140 can be assembled by placing make-up air seal 141 and make-up air spring 142 in make-up air neck 146. Upper housing 181 and lower housing 180 can be attached by placing cylindrical fuel receiving tube 187 of upper housing 181 within hollow cylindrical portion 188 of lower housing 180. During this drop down assembly step, make-up air neck 146 engages with pin 145 of lower housing 180. Top o-ring 182 and bottom o-ring 183 are placed between the housings to seal recess 185. Then, the upper and lower housings can be affixed together by, for example, welding, snap-fitting, or press-fitting. ROV 150 can be installed within receptacle 186 and affixed by, for example, welding, snap-fitting, or press-fitting. Outer o-ring 184 is affixed around the lower housing to provide a seal with the tank interface 194.

[073] Figure 10B illustrates the fuel tank lid 113 and its relationship to the integrated valve assembly 100 and fuel tank 20. Figure 15 is flow chart illustrating an exemplary method of installing integrated valve assembly 100, consistent with Figures 10B and 10C. Installation is simplified via a drop down method with modular parts. The fuel tank 20 can comprise a fuel tank interface 194, as illustrated in Figure 10B, or a stepped tank recess, as illustrated in Figure 10C. The fuel tank can be stamped, molded, or otherwise formed to include the tank interface 194 or tank recesses 1981, 1982. The remainder of the fuel tank is not shown for clarity.

[074] Integrated valve assembly 100 can be connected to fuel tank 20 with a fuel tank interface 194 by first welding a mid-plate 193 to the fuel tank interface 194, as in step S10. Mid-plate includes mounting features, such as threaded holes 190, for receiving mounting elements such as threaded bushings 196. Alternatively, in step S11, the mid-plate is welded in to the tank recess 198. Steps S11 and S10 can be omitted when the fuel tank includes mounting features such as interface posts 195 or holes. Alternative mounting elements can comprise, for example, rivets, snap-pins, barbed pins, or screws.

[075] Integrated valve assembly 100 can be placed within fuel tank, as in step S12, so that the integrated valve assembly 100 seats against a step, recess or lip. A technique for this placement is discussed below with respect to Figures 11A-11D, and comprises a tilted drop-in method. Port 130 is attached to a vapor fuel line 21, which is preferably a hose, for connection to canister or other vapor processing mechanism prior to installing the integrated valve assembly 100, or, prior to fully sealing the fuel tank 20, such as when a side panel or access port is included on the fuel tank 20.

[076] A lid plate 191 is then dropped down upon integrated valve assembly 100, as in step S13. Lid plate 191 is attached via a bushing 1960, which can be a screw interface, as in step S14. Bushing 1960 engages hole 1900 in the mid-plate or alternatively threads in to a fuel tank interface post 195.

[077] Fuel tank lid 113 is dropped down upon lid plate 191, as in step S15, and is attached with mounting elements such as bushings 196, as in step S16. Fuel tank lid 113, when closed, abuts a lid seal 121 against the fuel funnel 189 to seal fuel tank 20. At the same time, fuel tank lid 113 permits MUA 140 and OPR 160 to vent to the atmosphere through, for example, lid gap 114. MUA 140 and OPR 160 crack points can be set to limit actuation to safety requirements to restrict vapor flow to the atmosphere. Environmental and user protections are gained because vapors do not continuously vent to atmosphere to give the tank over pressure or over vacuum relief, and no electrical actuation is required to provide the safety features.

[078] Figures 11A-11D illustrate a method of placing integrated valve assembly 100 in to a fuel tank interface 194, which is shown as a stamped recess. Due to the

protrusion of ROV 150 and receptacle 186, the footprint of integrated valve assembly 100 is larger than the opening of fuel tank interface 194. As shown in Figure 11A, integrated valve assembly 100 is such that the ROV 150 is first introduced into the interface 194. Then, port 130 of the valve is aligned with port gap 197 and the valve can be gradually leveled, as shown in Figures 11B-11D. At the conclusion of this placing method, the top of upper housing 181 should be parallel with the top of fuel tank interface 194. A fuel tank interface post 195 is also shown, and hole 1910 of lid plate aligns with post 195 to clamp the valve assembly in place via a mounting element, such as a threaded bushing 196 or a screw.

[079] Figure 12 is a cross section of an integrated valve assembly 100 installed in fuel tank interface 194 and includes a hinged 117 fuel tank lid 113. Tank lid comprises a hinged lid body 119, which surrounds a lid lock recess 120. Lid lock recess 120 can be covered by a hinged 116 flap 115. An optional keyed lock barrel or unlatching mechanism seats in the lid lock recess 120 and actuates a lid locking mechanism 118. The lid locking mechanism 118 catches against a step 1890 on fuel funnel 189 to lock the lid seal 121 against the fuel funnel. A mechanism seat 123 can be included to support the locking mechanism 118. The mechanism seat 123 can be coupled to the hinged lid body 119 and can orient the lid seal 121. Alternatively, lid seal 121 can couple directly to the hinged lid body 119, and a catch mechanism between the fuel tank 20 and the tank lid 113 can procure force to seal the tank.

[080] Lid seal 121 passes through lid plate 191 when the lid 113 is opened and closed. Lid body 119 can be moved about lid hinge 117 to allow fuel tank access when lid locking mechanism 118 is released. Fuel in tank 20 is prevented from directly accessing the atmosphere by lid seal 121, which provides an air-tight seal with fuel funnel 189 of cylindrical fuel receiving tube 187 of upper housing 181. However, vapors released through OPR 160 can access the atmosphere through the hollow space surrounded by lid plate 191 and through lid gap 114 within lid body 119, as shown via flow arrow. A vacuum to MUA 140 reverses the arrow, and air is drawn from the atmosphere through lid gap 114 and through the space of lid plate 191.

[081] Figures 13A-14 illustrate an alternative integrated valve assembly 200. The circumferential distribution of the port 130, ROV 150, and valve 260 is biased to one side of the fuel receiving tube 187. Liquid trap 170 and ring-shaped recess 1850 for vapor circulation are also biased to one side, permitting a more compact footprint compared to Figure 12. Valve 260 can be one of MUA 140, OPR 160, or combined MUA and OPR as integrated in movable substructure 70 of Figures 3A & 4-5C. Thus, either a one-way valve or the integration of two one-way valves have direct access to the fuel tank at valve 260.

[082] OPR 160 can be placed at valve 260 and MUA 140 can be omitted because it can be placed downstream at, for example, the canister to permit purge of the canister

when make-up air is required. Alternatively, the OPR 160 can be connected via port 130 to the integrated valve assembly 200 while MUA 140 is placed at valve 260. Valve 260 permits pressure exchange directly from the tank 20 to the liquid trap 170. If the seal 54 blocks flow through orifice 555, tank safety is provided. As in the above examples, upper housing 181 and lower housing 180 come together to enclose valve 260. A snap fit via fingers 1801 is possible to join the upper and lower housing, with O-rings 1830 & 1831 used to prevent leak paths. However, the liquid trap 170 permits return of liquid fuel through ROV 150, as above.

[083] Figure 14 also depicts a stepped fuel tank interface 194 with no port gap 197. The installation method of Figure 14 utilizes a tilt method, similar to Figures 11A-11D, to introduce the integrated valve assembly 200 in to the tank 20 and to level. But, the port 130 is placed in the tank 20 without alignment to a port gap 197. Figure 14 does not include a fuel tank interface post 195, instead relying on the mid-plate 193 for mounting element connectivity. A funnel lip 1891 on upper housing seats in tank recess 1981. An o-ring 1832 seals a leak path. A mounting sleeve 192 provides a seal abutment 1921 for lid seal 121. Lid locking mechanism 118 locks against edge 1922 of mounting sleeve, and is, as above, locked and unlocked by a mechanism seated in lock recess 120. Lid plate 191 and fuel tank lid 113 are secured to mid-plate 193 as above, but mid-plate is welded to recess 1982 of fuel tank 20. Environmental pollution through lid gap 114 is limited to splashed fuel caught in mounting sleeve 192. With port 130 connected to, for example, the canister, released fuel vapors are filtered by canister to limit pollution.

[084] Other implementations will be apparent to those skilled in the art from consideration of the specification and practice of the disclosure. It is intended that the specification be considered as exemplary only, with the true scope of the invention being indicated by the following claims.

WHAT IS CLAIMED IS:

1. A valve assembly (23, 100) comprising:
a roll-over valve (50, 150) comprising a float (52), a roll-over spring (53), a roll-over sealing member (54), a float sleeve (32, 51, 510) and an orifice (55, 317, 555), the roll-over valve configured for fluid exchange through the float sleeve and through the orifice, and for the float to rise in liquid to abut the sealing member against the orifice;
an over-pressure relief valve (60, 160) comprising an over-pressure seal (62, 73, 161), an over-pressure seat (64, 165, 322) and an over-pressure spring (61, 162) biasing the over-pressure seal towards the over-pressure seat;
a make-up air valve (40, 140) comprising a make-up seal (41, 141) selectively biased against a make-up seat (72, 144);
a lower housing (82, 33, 180) connected to the roll-over valve (50, 150) and comprising a fluid vent (330, 827, 151) connected to drain fluid by passing the fluid through the float sleeve;
an upper housing (31, 81, 181) sealed against the lower housing, the upper housing further comprising a fluid pathway (30, 340, 819, 185), the upper housing biasing the over-pressure seal towards the lower housing to block fluid flow between the fluid pathway and the fluid vent, and the upper housing receiving the make-up air valve, the make-up seal biased to block fluid flow between the fluid pathway and the fluid vent; and
a liquid trap (324, 815, 170) connected to the over-pressure relief valve, the make-up air valve, and the fluid vent (330, 827, 151).
2. The valve assembly (23, 100) of claim 1, further comprising a second liquid trap (317, 817) connected to the roll-over valve to pass the fluid through the float sleeve (32, 51).
3. The valve assembly (23, 100) of claim 2, wherein the over pressure relief valve provides over-pressure relief at a first predetermined pressure through the fluid pathway (30, 340, 819) when the roll-over sealing member blocks fluid flow through the second liquid trap (317, 817).
4. The valve assembly (23, 100) of claim 1,
wherein the lower housing comprises a tessellated surface (64),
wherein the over-pressure relief valve (60) comprises a movable substructure (70) and the movable substructure comprises a tessellated lower surface (73),
wherein the over-pressure spring (61) biases the tessellated lower surface (73) against the tessellated surface in a first substructure position, and
wherein, when the tessellated lower surface is exposed to a first predetermined pressure greater than the spring force of the upper spring (61), the lower surface of the movable

- substructure lifts from the first substructure position to a second substructure position to open fluid flow between the fluid pathway and the fluid vent.
5. The valve assembly (23, 100) of claim 4, wherein the lower housing comprises an insert (62) in an over-pressure recess 822, and the tessellated surface (64) is on the insert (62).
6. The valve assembly (23, 100) of claim 1, wherein the float sleeve comprises a tessellated surface (322), wherein the over-pressure relief valve (60) comprises a movable substructure (70) and the movable substructure comprises a tessellated lower surface (73), wherein the over-pressure spring (61) biases the tessellated lower surface (73) against the tessellated surface in a first substructure position, and wherein, when the tessellated lower surface is exposed to a first predetermined pressure greater than the spring force of the upper spring (61), the lower surface of the movable substructure lifts from the first substructure position to a second substructure position to open fluid flow between the fluid pathway and the fluid vent.
7. The valve assembly (23, 100) of claim 4 or 6, wherein the movable substructure (70) comprises a hollow internal passage (71) and a taper (72) forming the make-up seat (72), and wherein the make-up seal (41) is movable between a first seal position sealing against the make-up seat and a second seal position opening the passageway and resting the seal against the pin.
8. The valve assembly (23, 100) of claim 7, wherein the movable substructure further comprises a spring recess 75 surrounding the internal passage, a pin (42) extending in to the internal passage, and a lip (77, 79) guiding the over-pressure spring (61).
9. The valve assembly of any of claims 1-4, or 6, wherein the upper housing (31) further comprises:
a vent (350, 850) fluidly connected to the over-pressure relief valve (60) and to the make-up air valve (40); and
a wall (328, 813) separating the over-pressure relief valve (60) and the make-up air valve (40) from the fluid pathway (340, 819).
10. The valve assembly of claim 1, further comprising:
a hollow cylinder (188) formed through the lower housing; and
a hollow cylindrical tube (187) formed through the upper housing, the tube (187) fitted within the hollow cylinder (188),
wherein the liquid trap 170 and the fluid pathway (185) at least partially surround the hollow cylinder (188).
11. The valve assembly of claim 10, further comprising a port (130) integrated with the lower housing (180), wherein the port (130), the make-up air valve (140), the over-pressure

relief valve (160), and the roll-over valve are circumferentially distributed around the hollow cylinder and the tube.

12. The valve assembly of claim 10, further comprising a fuel funnel (189) adjoining the tube.

13. The valve assembly of claim 12, further comprising a lock step (1890) between the fuel funnel and the tube.

14. The valve assembly of claim 12 or 13, further comprising a lid seal (121) abutting the fuel funnel (189) to seal fluid from flowing through the tube (187).

15. The valve assembly of claim 14, further comprising a hinged fuel tank lid (113) attached to the lid seal to open and close fluid flow through the tube.

16. The valve assembly of claim 14, wherein the lid seal (121) does not obstruct over pressure relief through the over-pressure relief valve nor obstruct vacuum relief through the make-up air valve.

17. The valve assembly of claim 10, further comprising holes (159) in the float sleeve (510), the holes aligned to fluidly communicate between the orifice (555) and the fluid vent (151).

18. The valve assembly of claim 10, wherein the over-pressure relief valve further comprises an over-pressure neck (167) extending from the over-pressure seat (165), and a cap (163) fixed to the neck to bias the over-pressure spring (162).

19. The valve assembly of claim 18, wherein one of the over-pressure neck and the over-pressure cap is ribbed.

20. The valve assembly of claim 10, wherein the upper housing further comprises a make-up neck (146) extending from the make-up seat (144), and wherein the lower housing further comprises a make-up pin for restricting travel of the make-up seal 141 in the make-up neck (146).

21. The valve assembly of claim 10, further comprising a receptacle (186) in the lower housing, wherein the roll-over valve is one of press-fit, snap-fit, or welded in the receptacle.

22. A fuel system comprising:

a fuel tank interface comprising at least one tank recess (198, 1981, 1982);

a mid-plate (193) or a tank post (195) affixed to the at least one tank recess;

the valve assembly of claim 10 abutting the fuel tank interface;

a lid plate (191) mounted to the mid-plate or to the tank post to secure the valve assembly of claim 10 to the fuel tank interface; and

a hinged fuel tank lid mounted to the lid plate, the fuel tank lid comprising at least a lid seal (118) for sealing against the tube.

23. An integrated valve assembly (200) comprising

a lower housing (180) comprising:

- a hollow cylinder (188);
 - a fluid pathway (185) at least partially surrounding the hollow cylinder (188);
 - a liquid trap (170) in fluid communication with the fluid pathway;
 - a fluid vent (151) connected to drain fluid from the liquid trap; and
 - a valve seat (260);
- an upper housing (181) sealed against the lower housing, the upper housing further comprising a hollow cylindrical tube (187) formed through the upper housing, the tube (187) fitted within the hollow cylinder (188);
- a roll-over valve (150) comprising a float (52), a roll-over spring (53), a roll-over sealing member (54), a float sleeve (510) and an orifice (555), the roll-over valve configured for fluid exchange through the float sleeve and through the orifice, and configured for the float to rise in liquid to abut the sealing member against the orifice, and the roll-over valve positioned to receive fluid from the liquid trap and to direct received fluid to the fluid vent;
- an over-pressure relief valve (60, 160) comprising an over-pressure seal (62, 73, 161), an over-pressure seat (64, 165, 322) and an over-pressure spring (61, 162) biasing the over-pressure seal towards the valve seat (260).
24. A method for drop-down installation of an integrated valve assembly (100) in a fuel tank (20), comprising:
- affixing a mid-plate (193) to a tank with a fuel tank interface (194);
 - placing an integrated valve assembly (100) into the fuel tank interface comprising:
 - tilting the integrated valve assembly to first introduce a roll-over valve (150) of the integrated valve assembly into the fuel tank interface;
 - aligning a port (130) of the integrated valve assembly with a port gap (197) of the fuel tank interface; and
 - leveling the integrated valve assembly with the fuel tank interface such that the port protrudes through the port gap and an upper housing (181) of the integrated valve assembly is parallel with the fuel tank interface;
 - placing a lid plate on top of the integrated valve assembly;
 - mounting the lid plate to secure the integrated valve assembly to the mid-plate; and
 - attaching a fuel tank lid to the lid plate.

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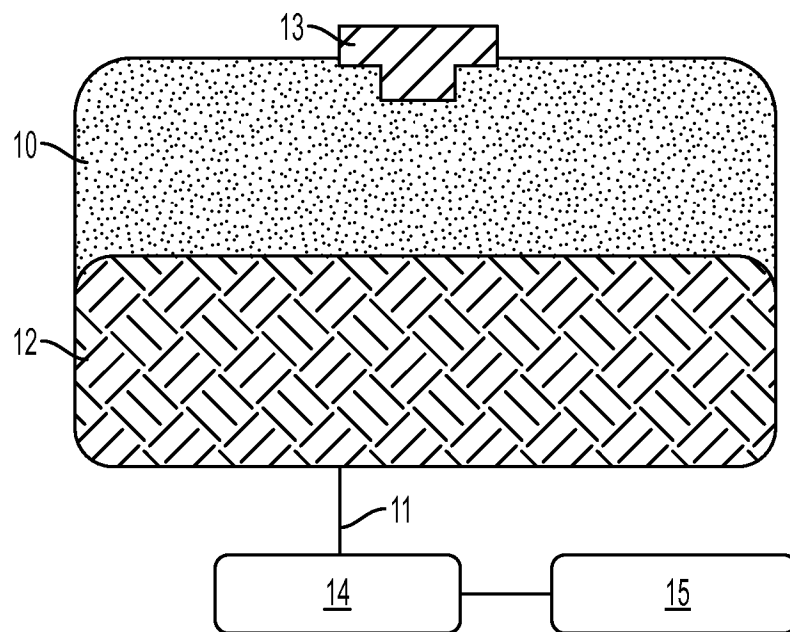


FIG. 1
PRIOR ART

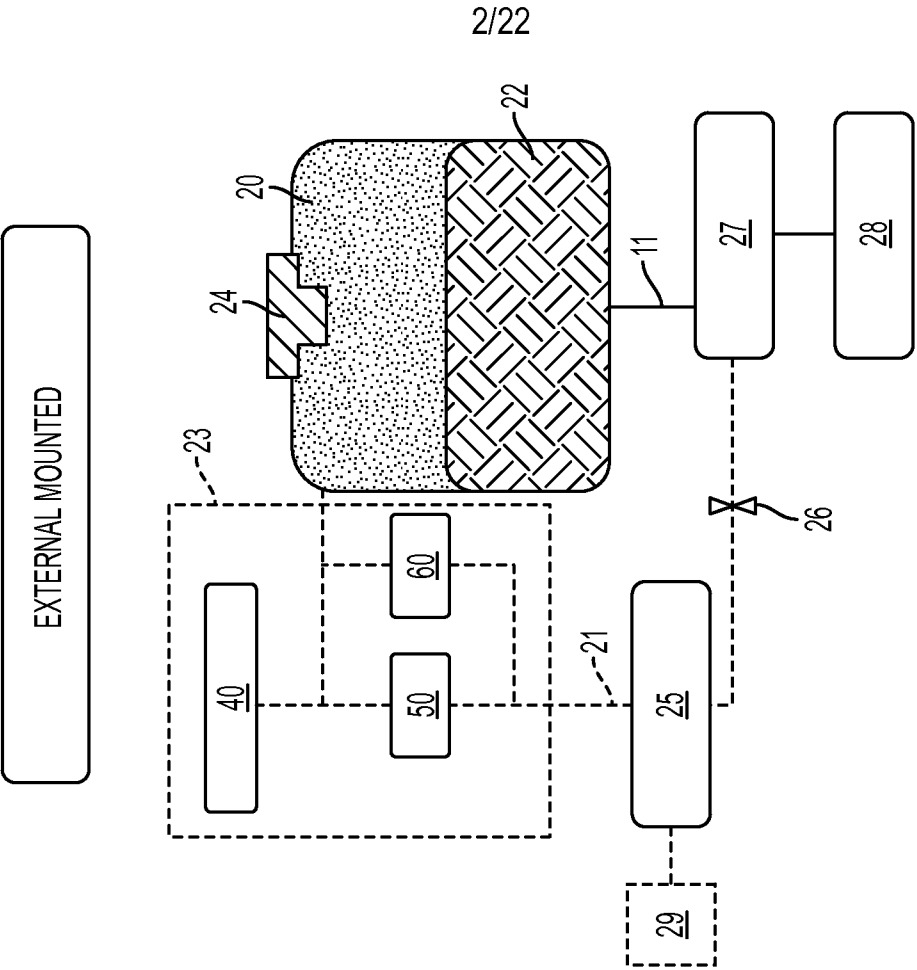


FIG. 2B

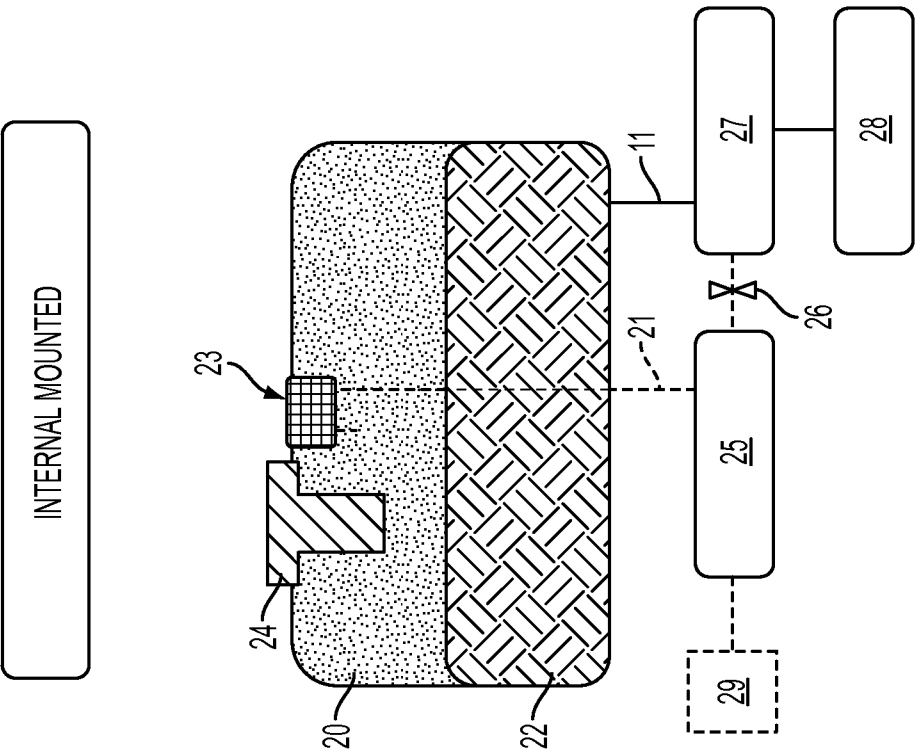


FIG. 2A

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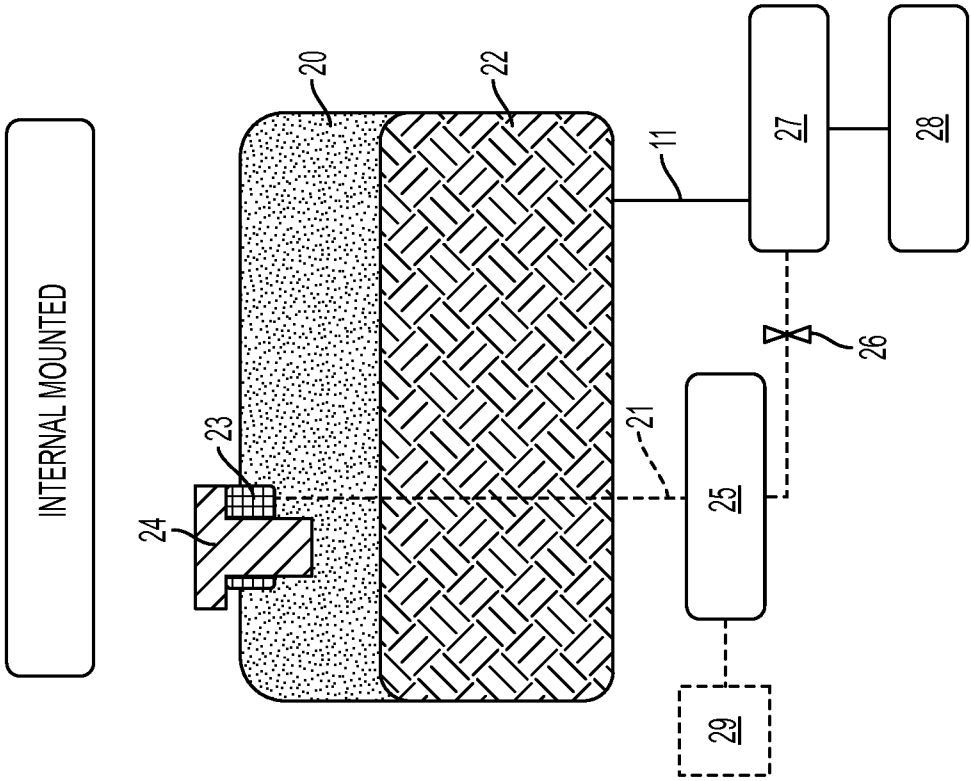


FIG. 2D

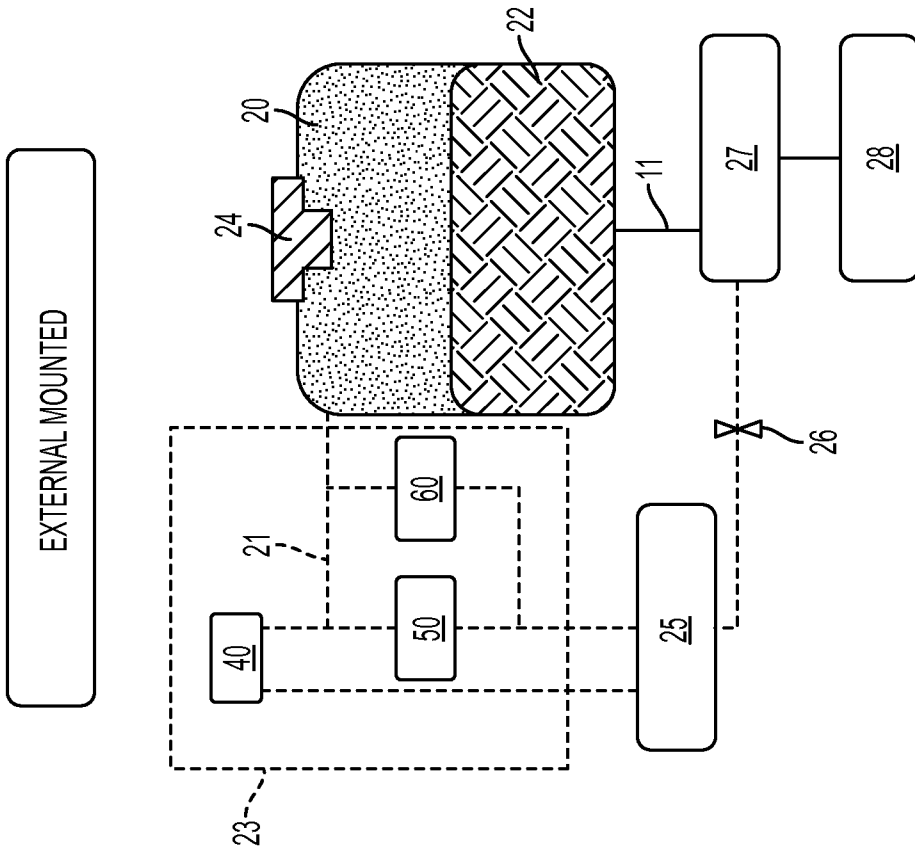


FIG. 2C

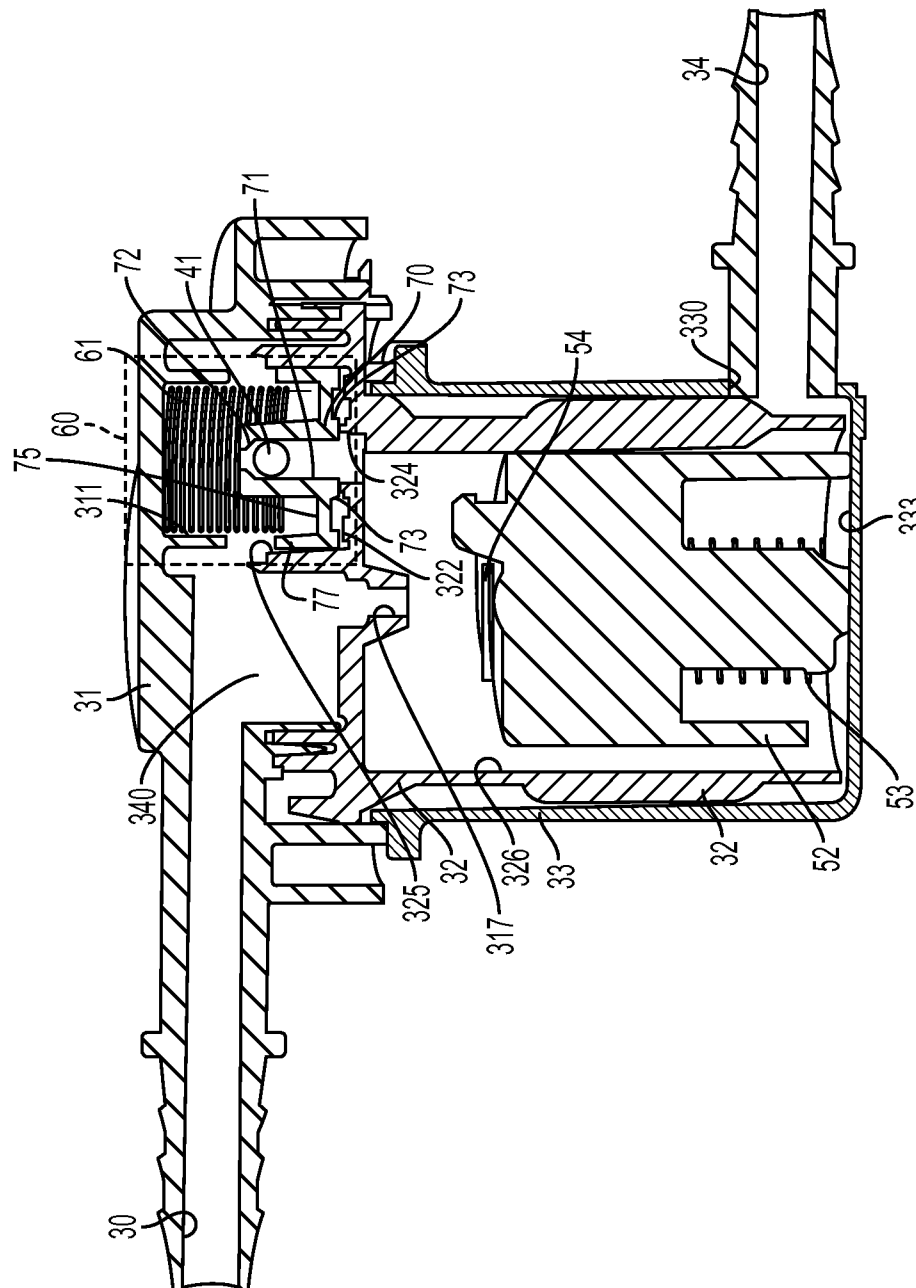


FIG. 3A

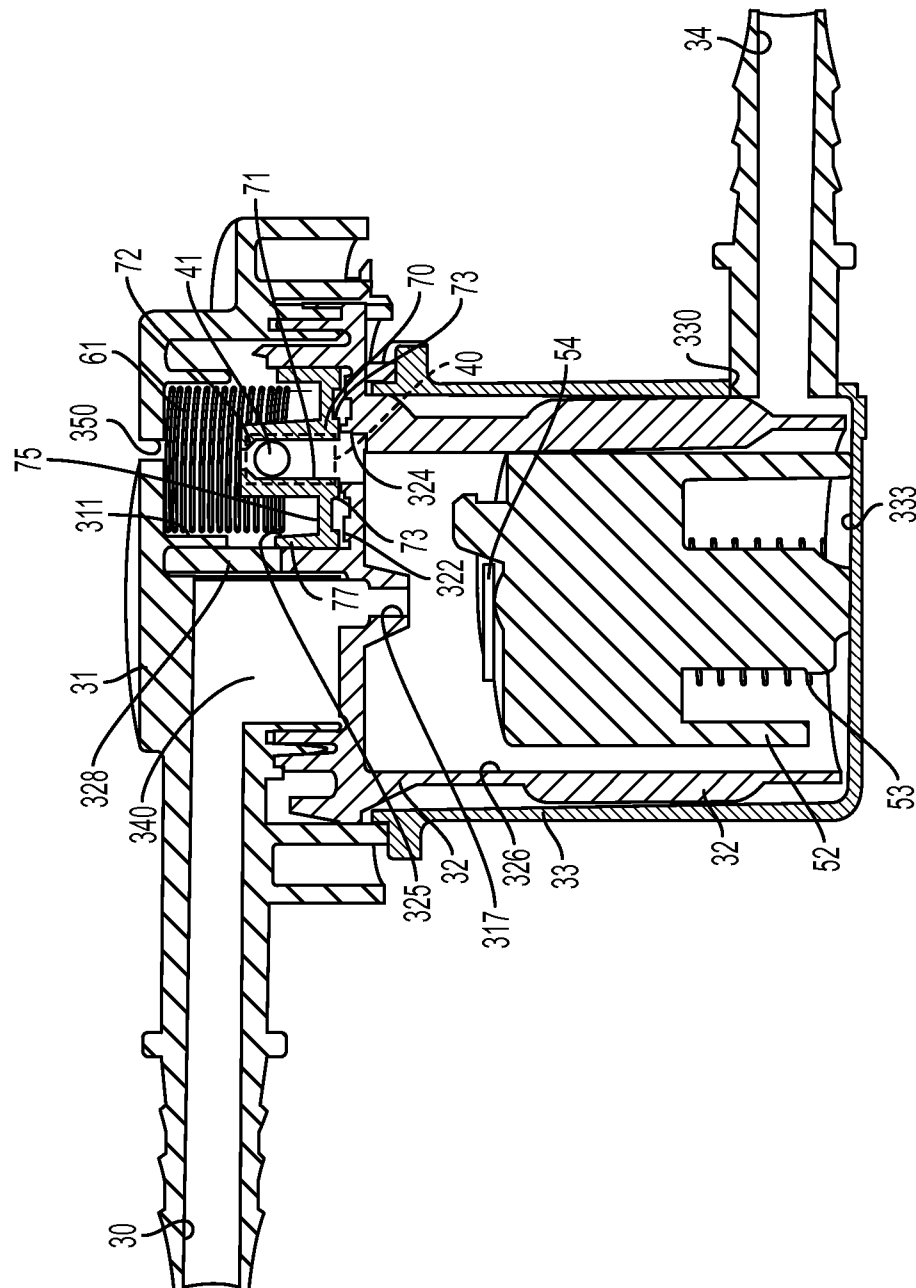


FIG. 3B

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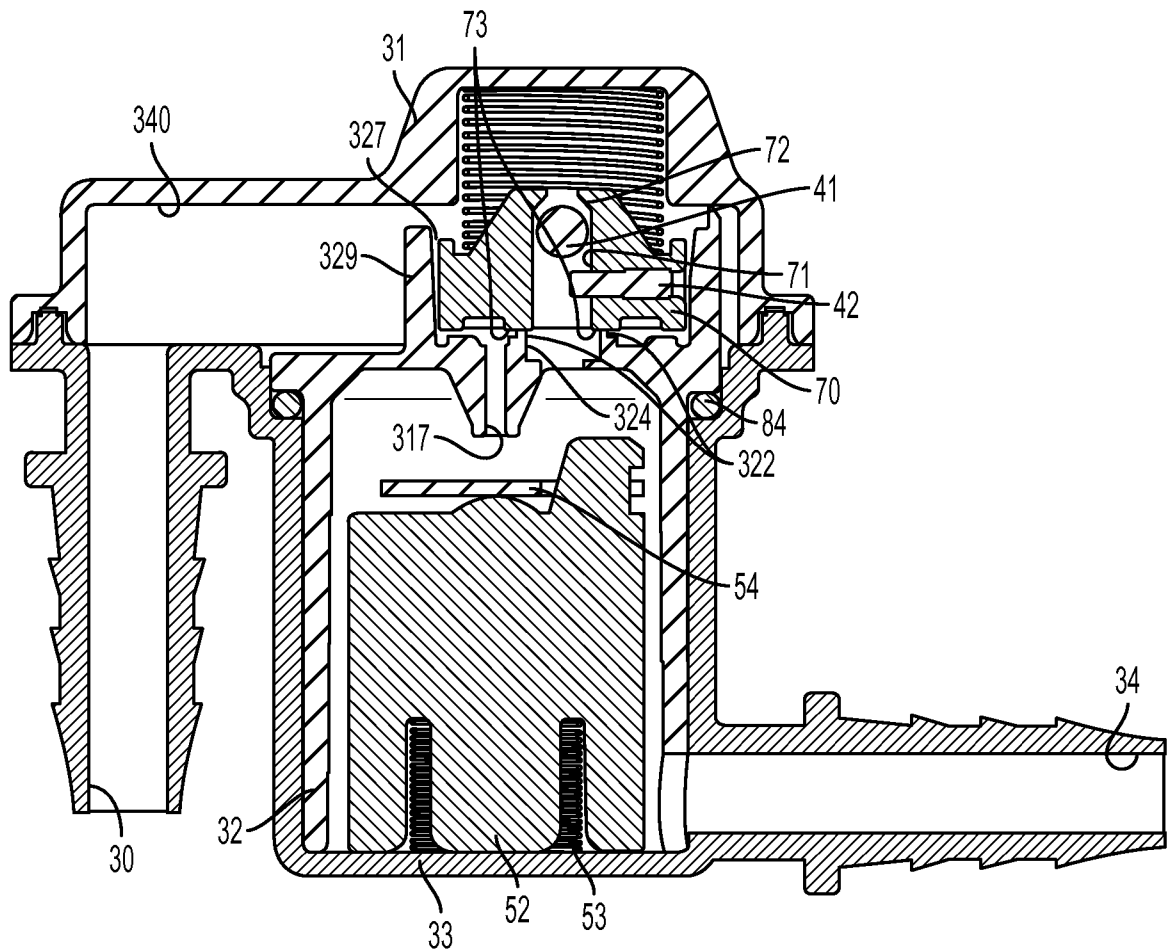
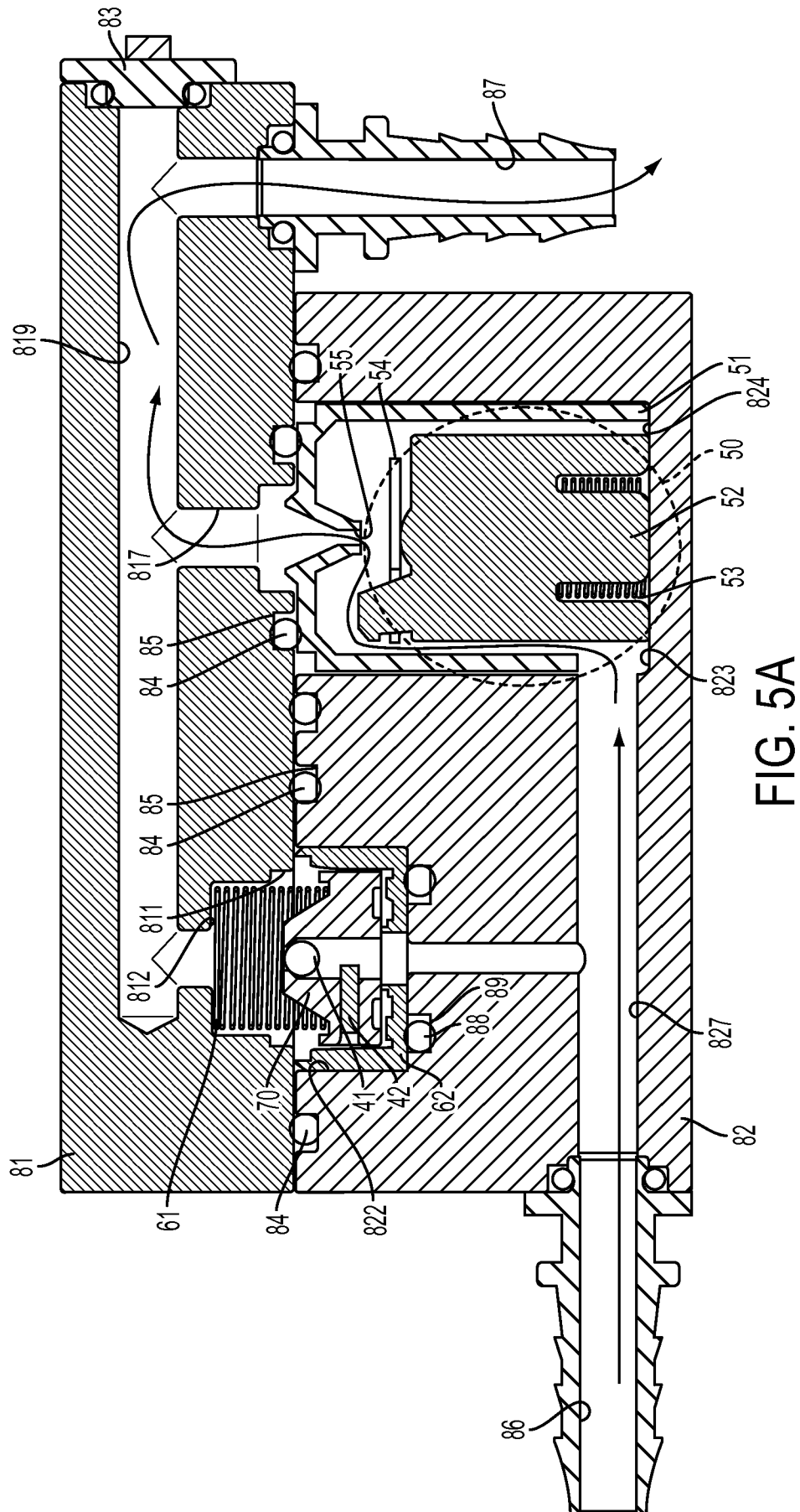


FIG. 4

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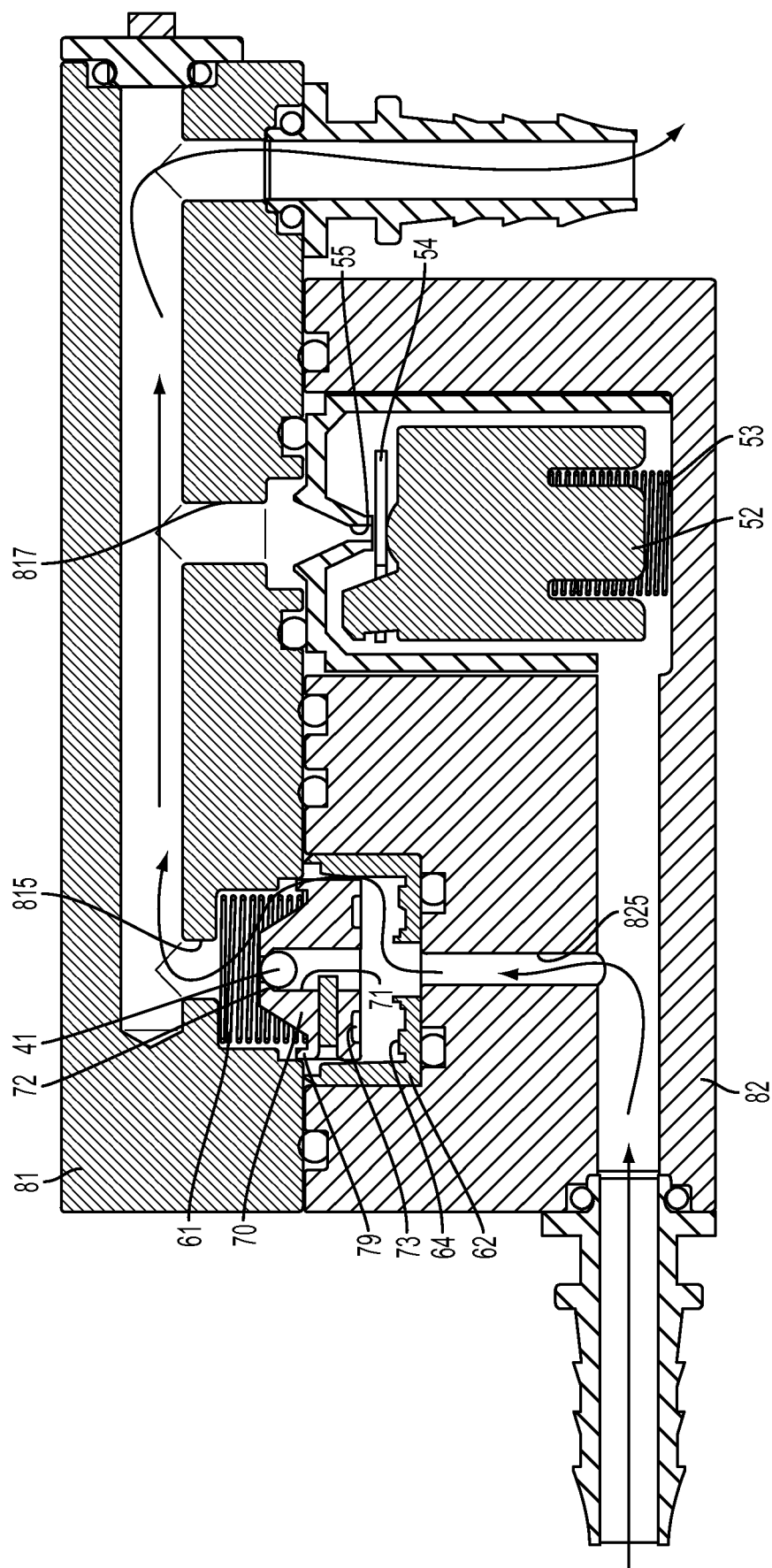


FIG. 5B

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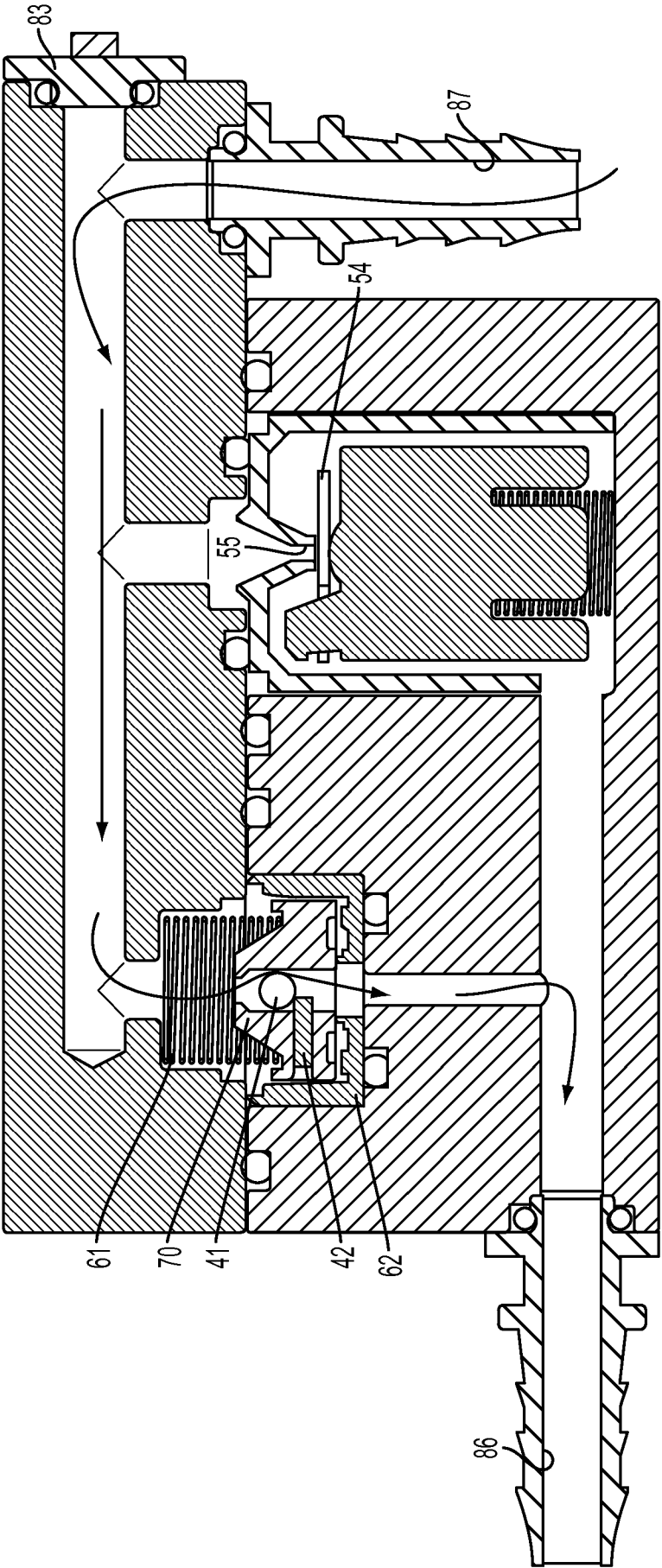


FIG. 5C

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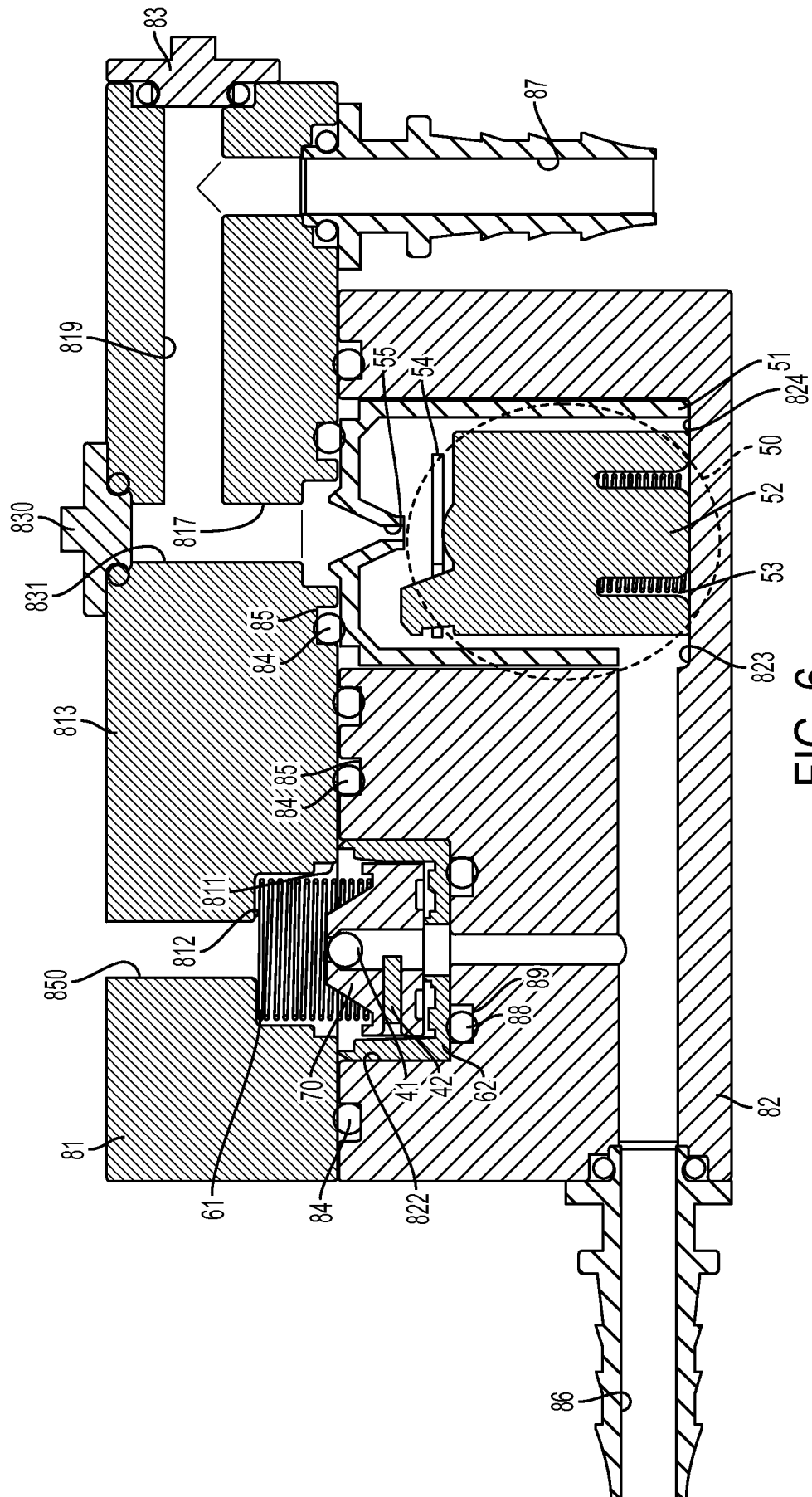


FIG. 6

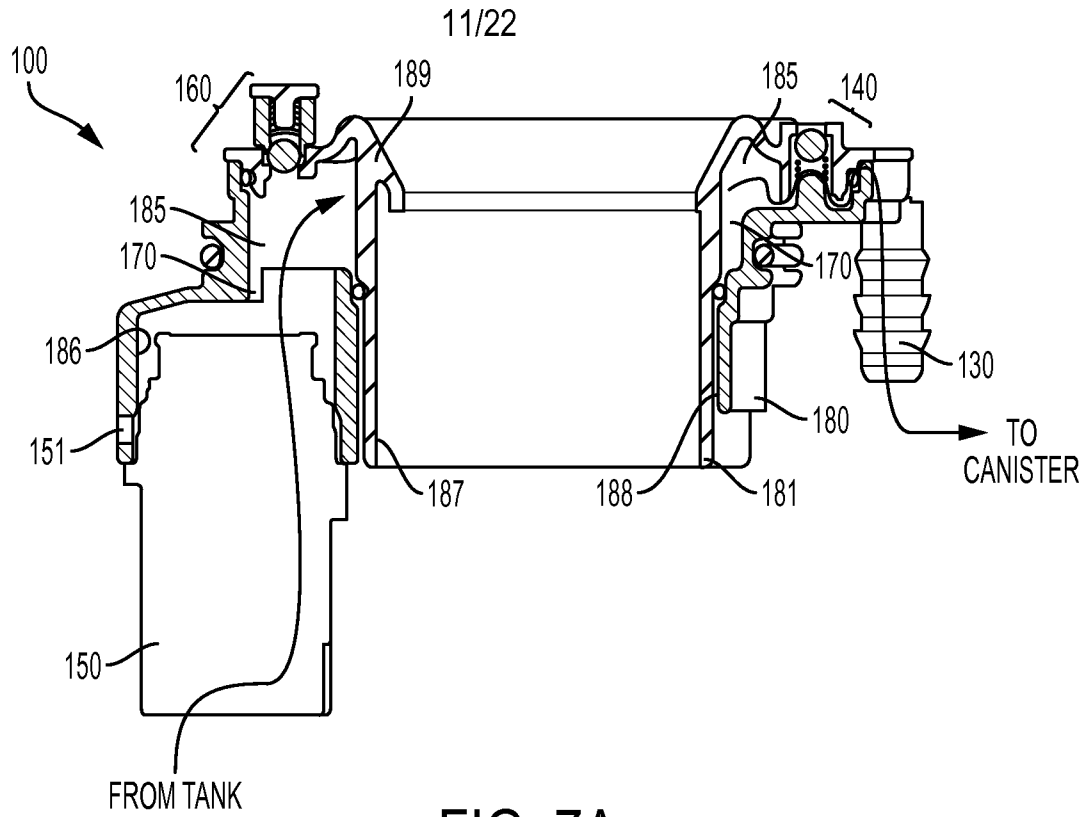


FIG. 7A

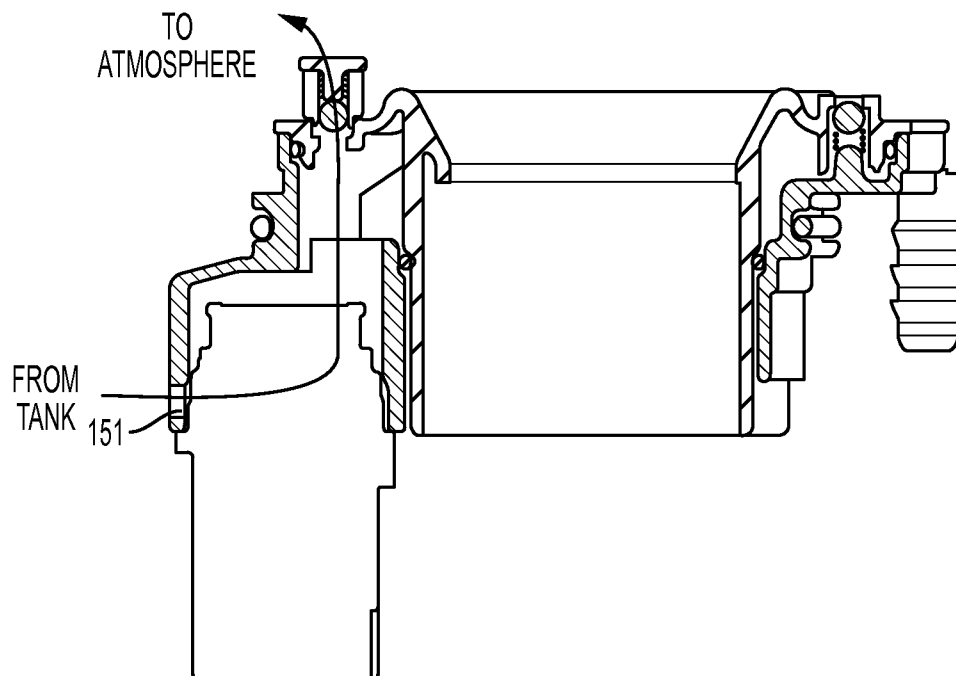


FIG. 7B

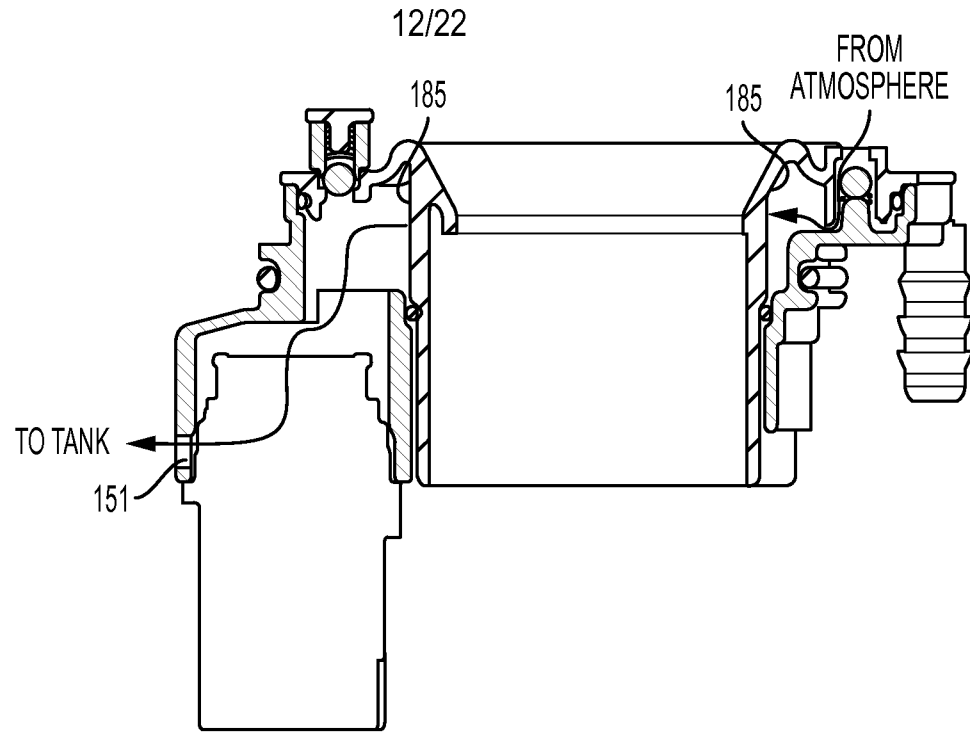


FIG. 7C

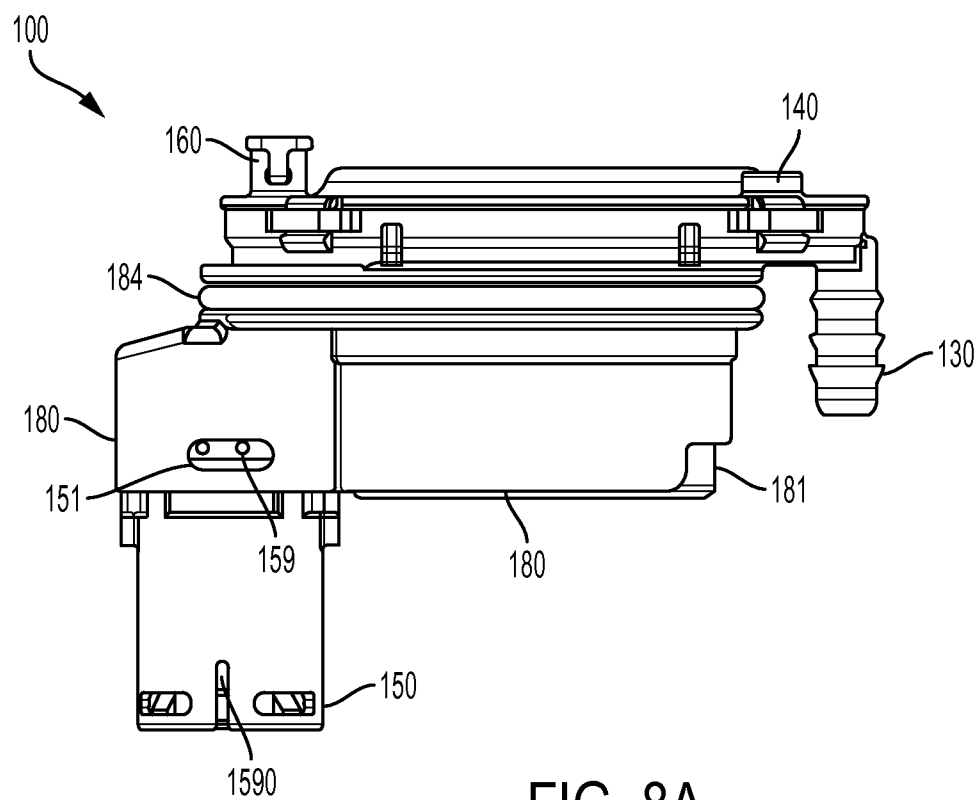


FIG. 8A

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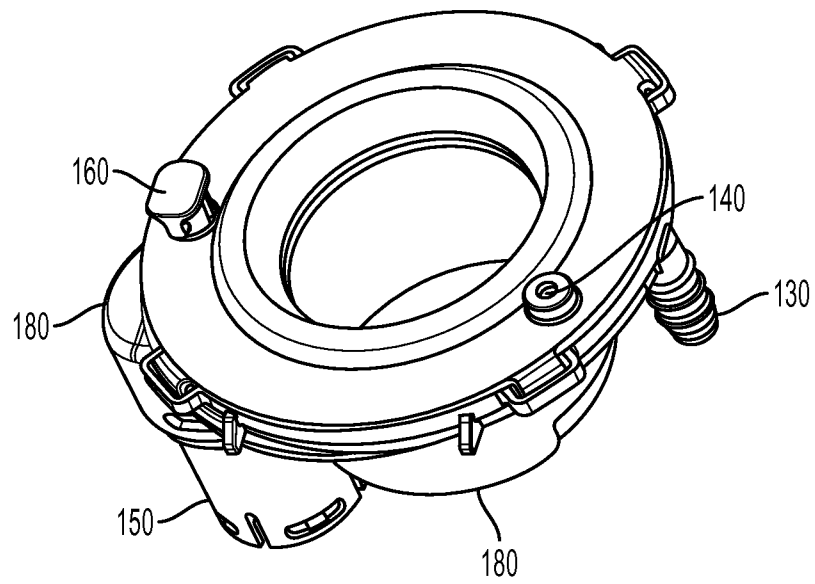


FIG. 8B

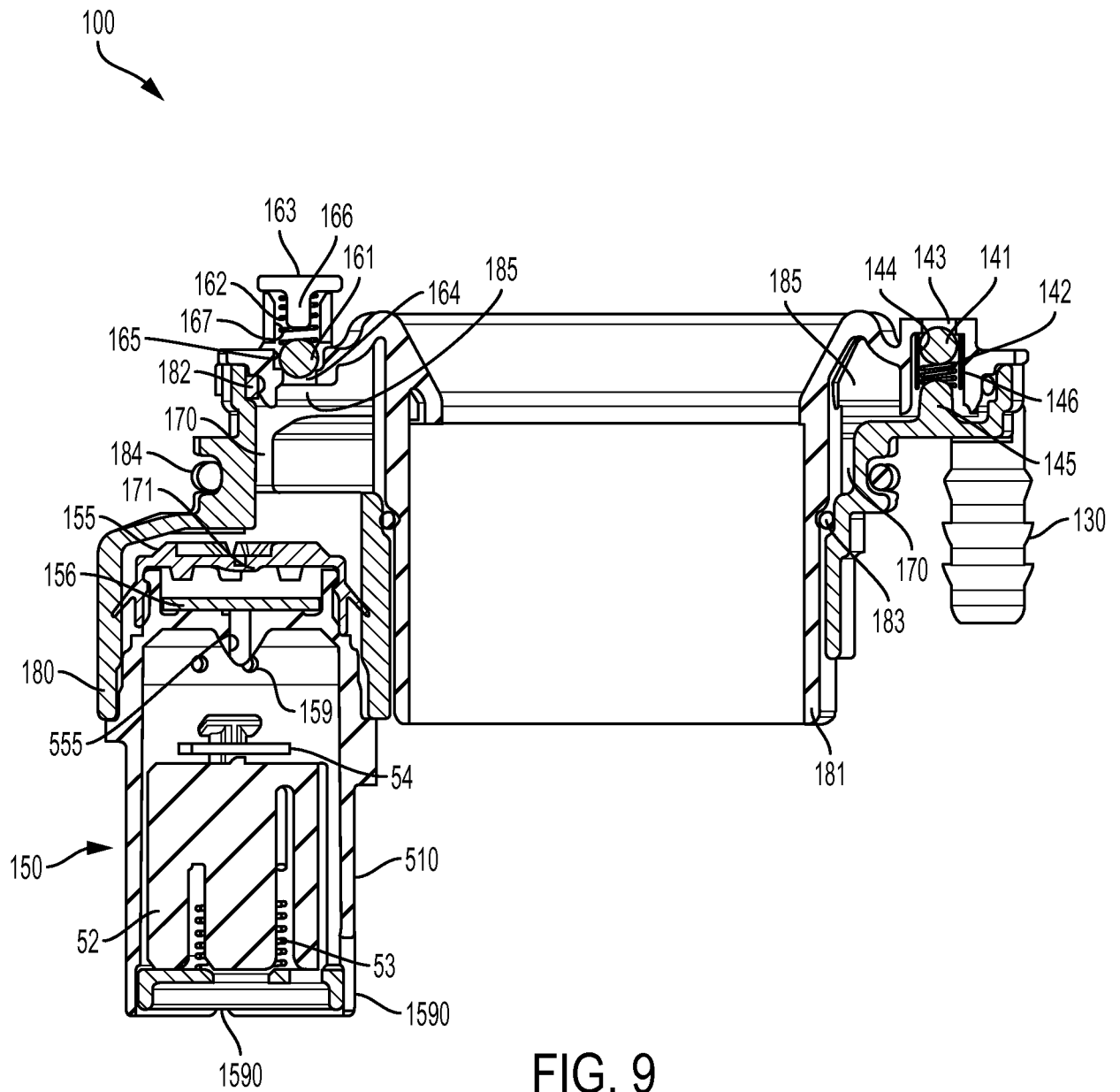


FIG. 9

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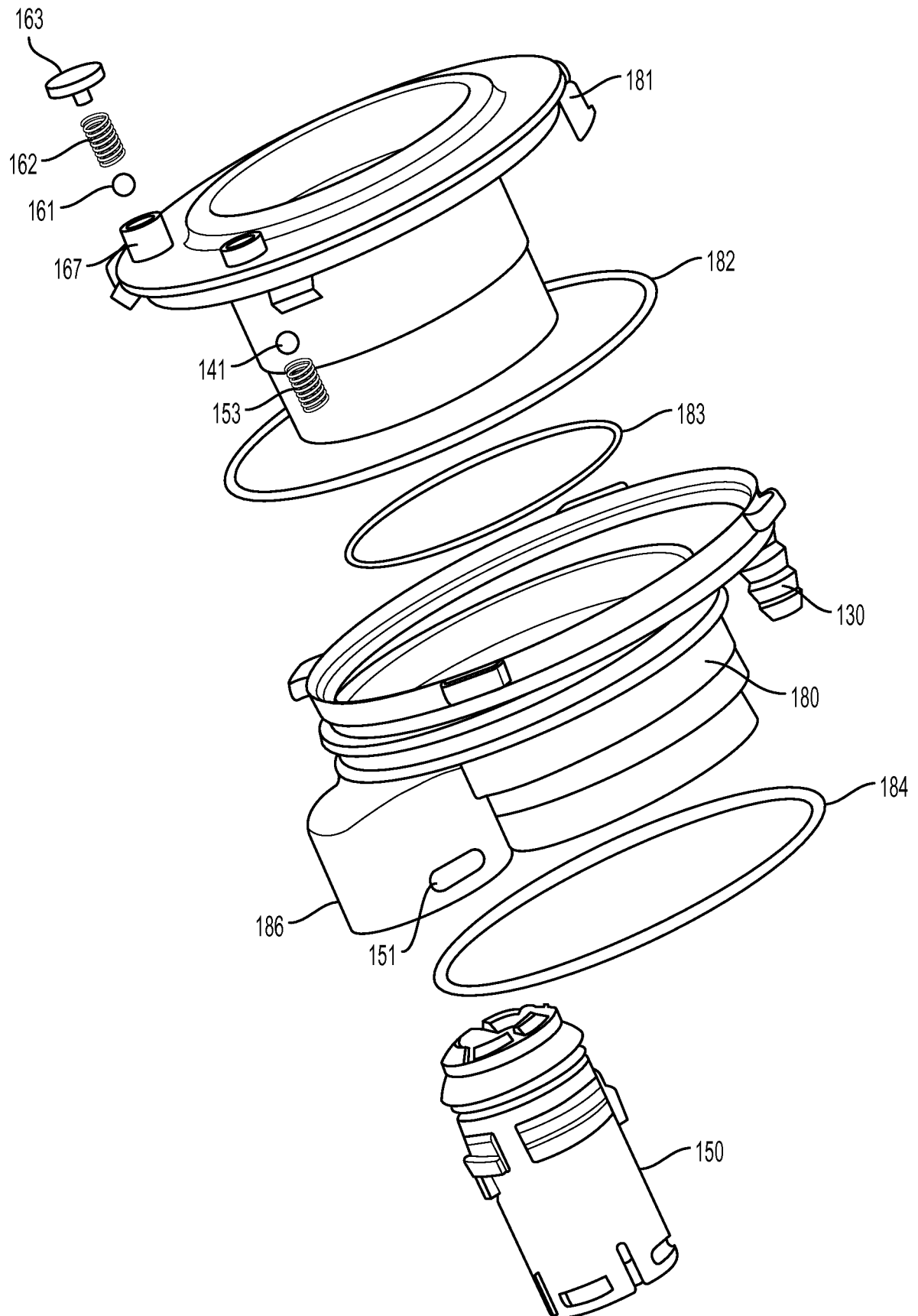


FIG. 10A

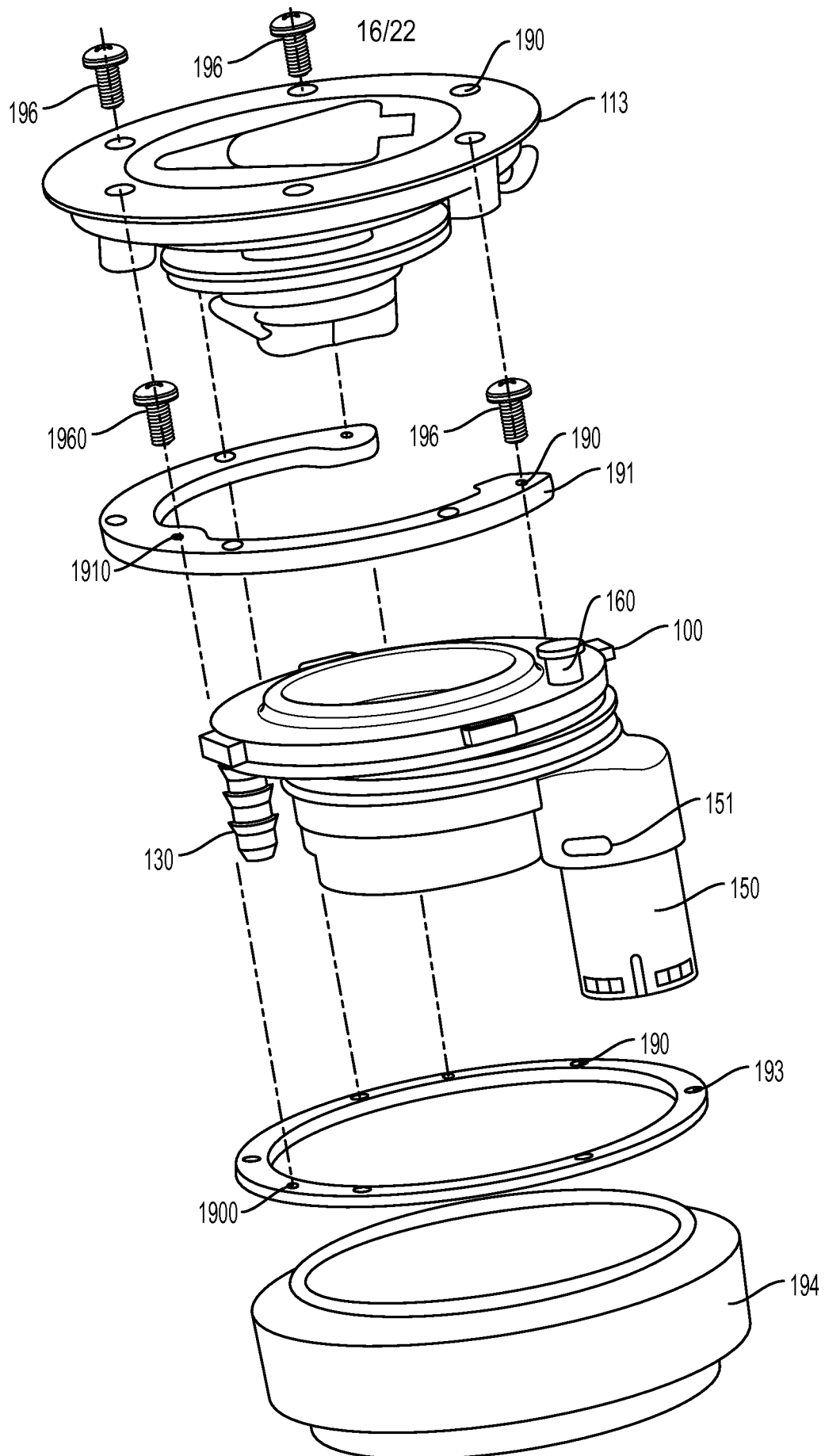


FIG. 10B

SUBSTITUTE SHEET (RULE 26)

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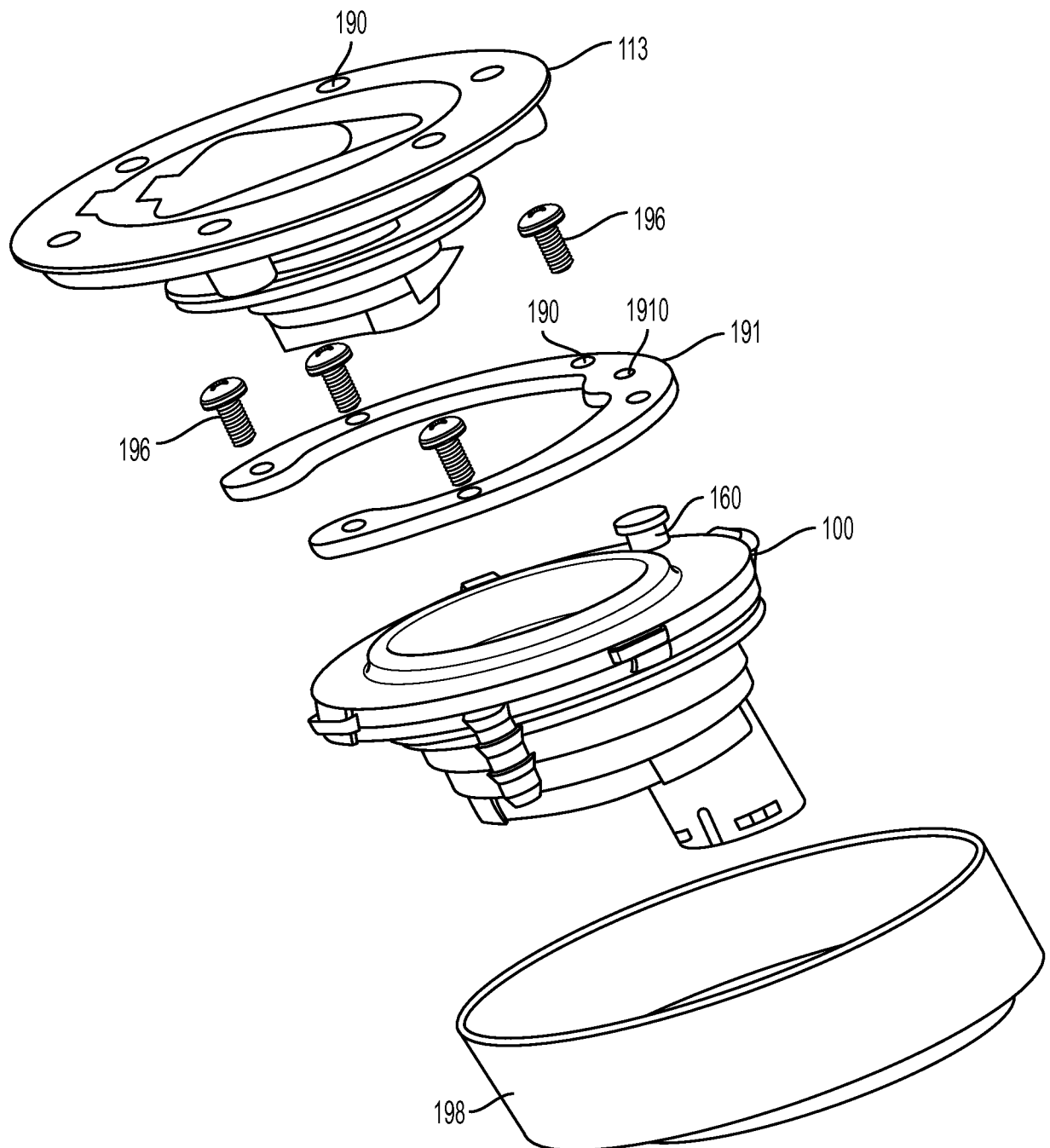


FIG. 10C

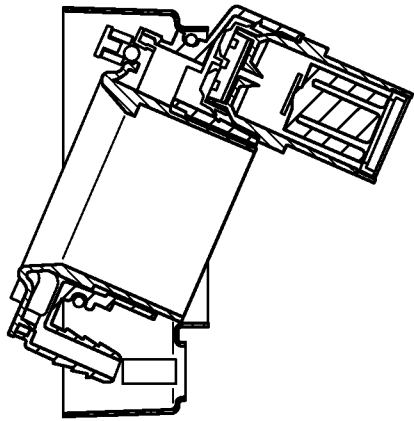


FIG. 11B

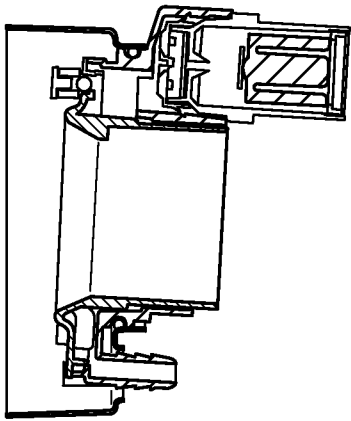


FIG. 11D

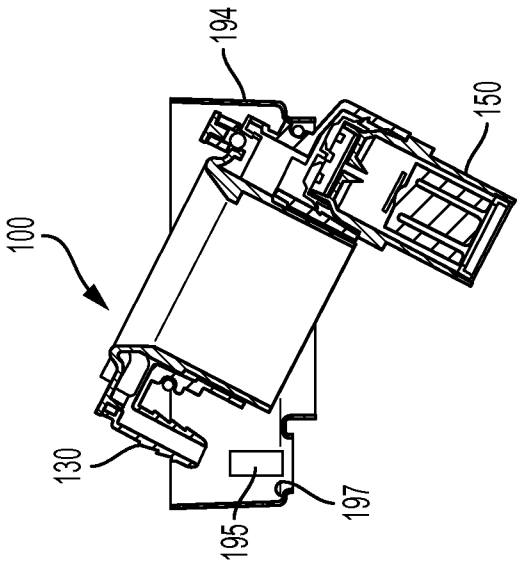


FIG. 11A

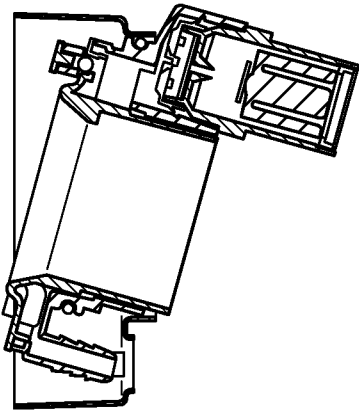


FIG. 11C

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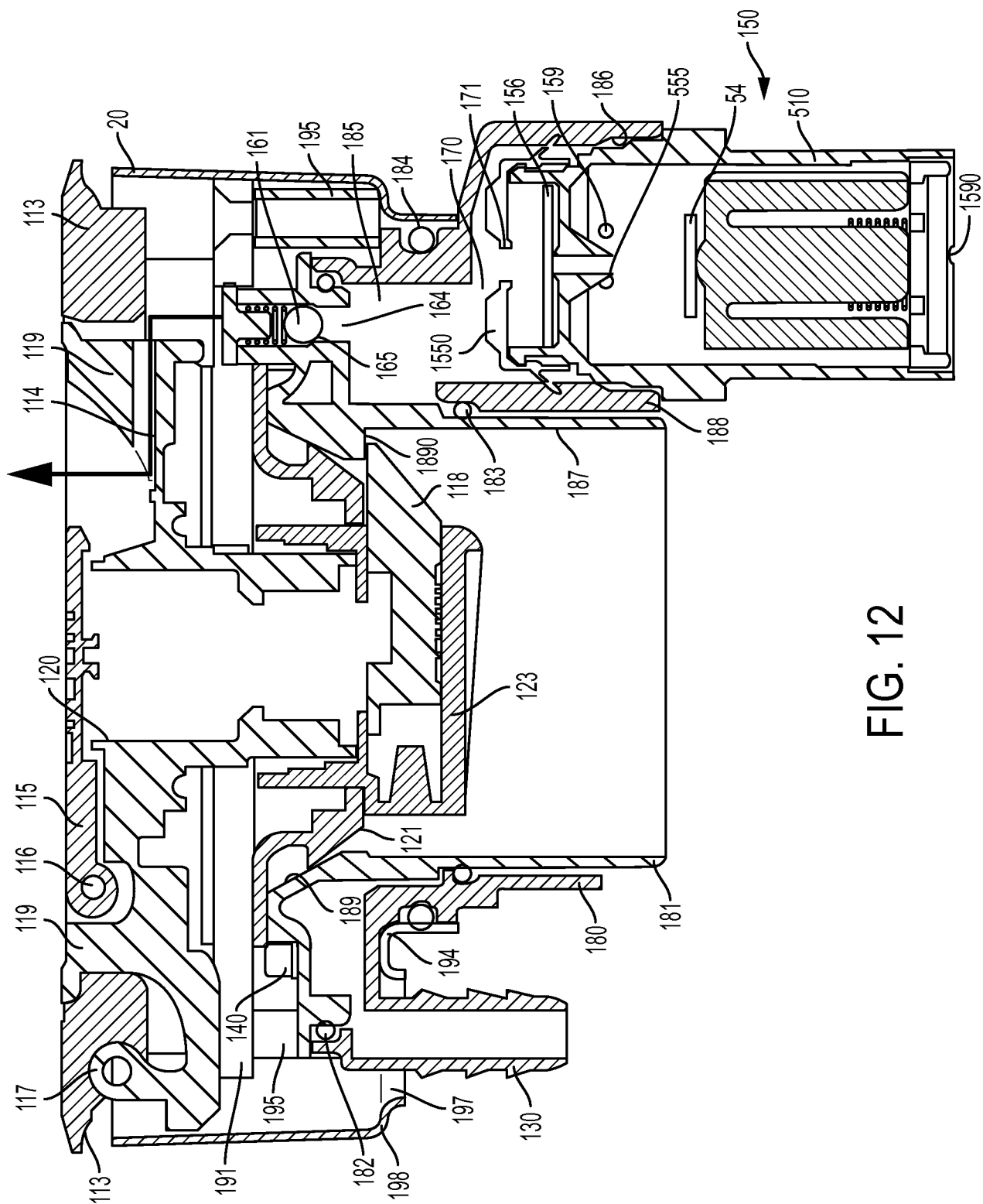


FIG. 12

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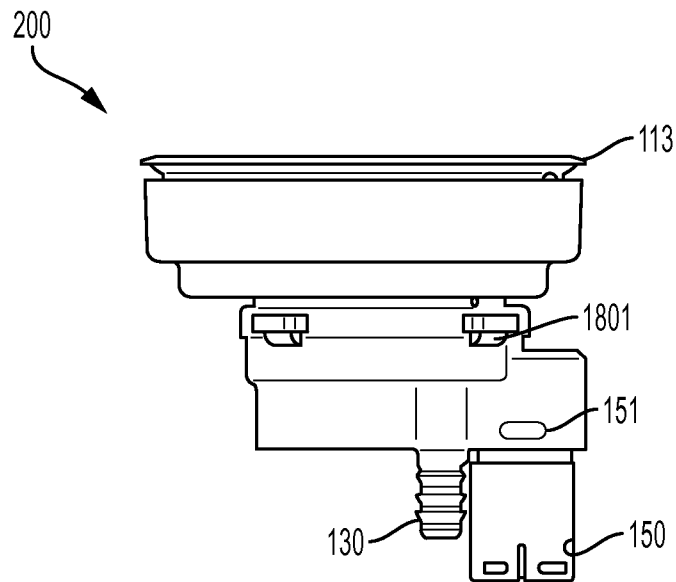


FIG. 13A

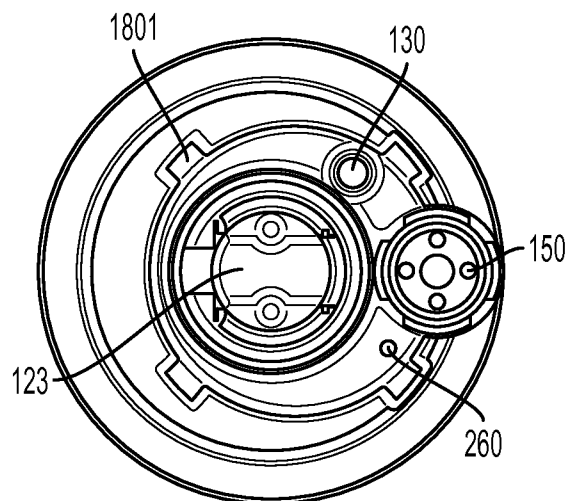


FIG. 13B

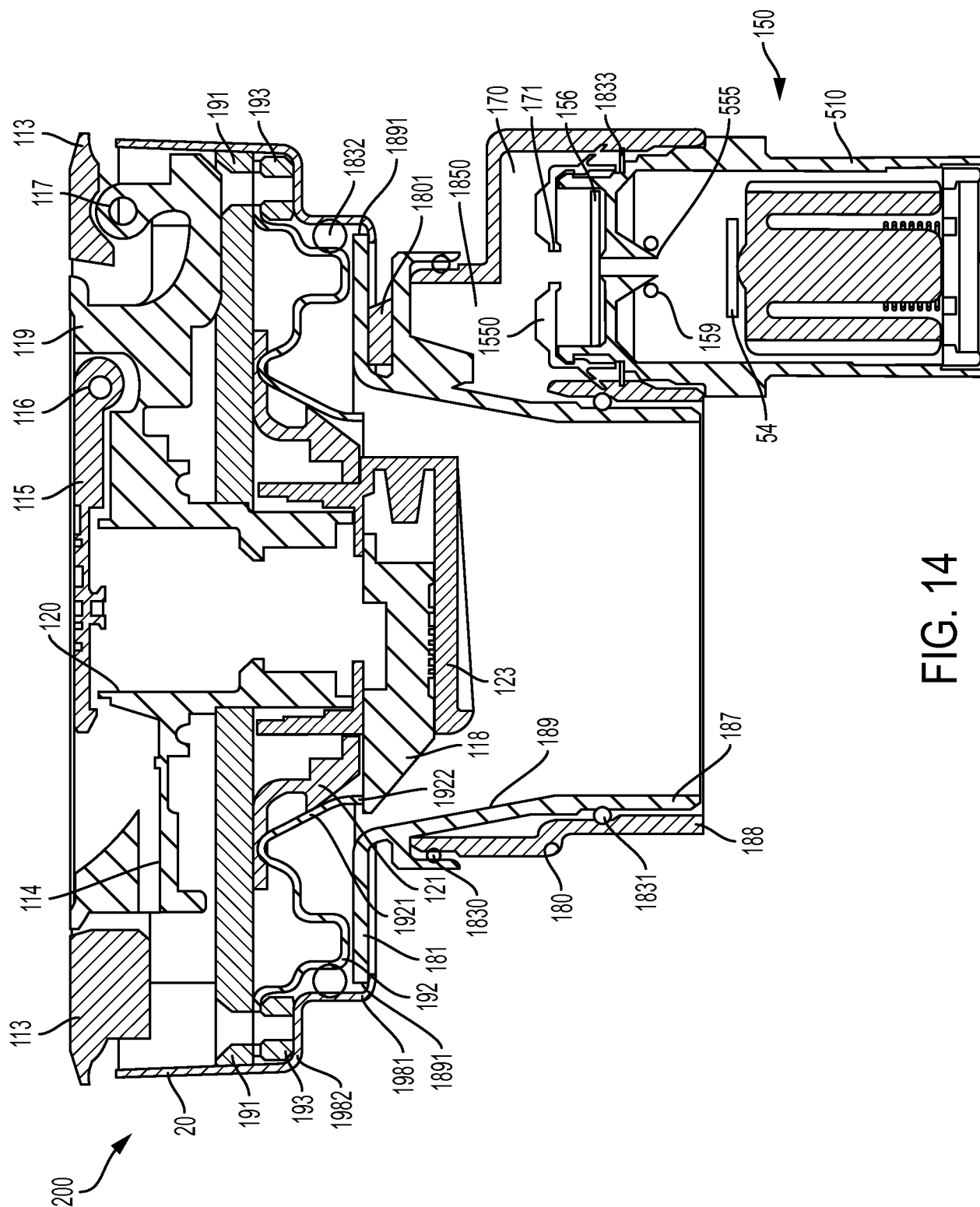


FIG. 14

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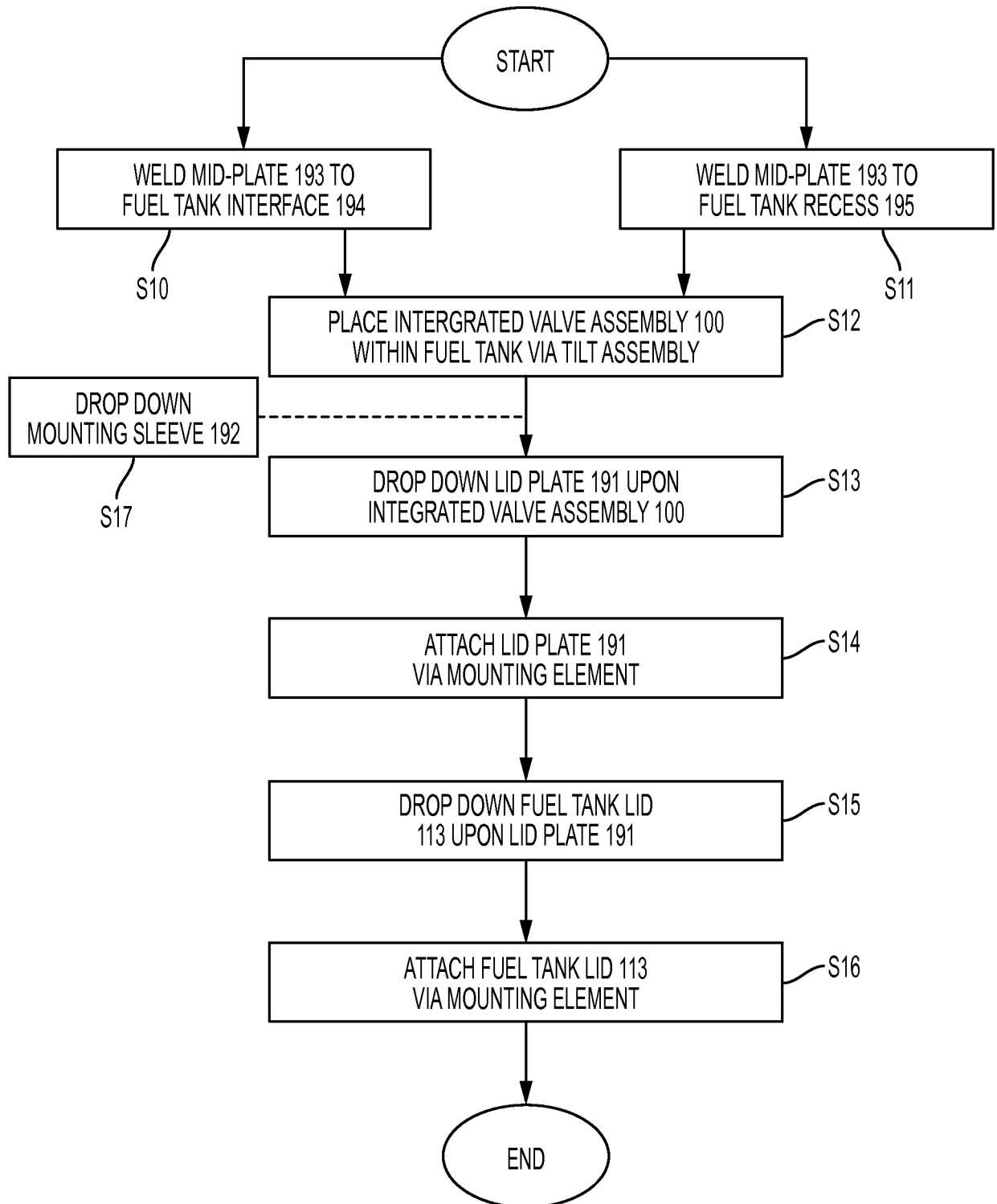


FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/017397**A. CLASSIFICATION OF SUBJECT MATTER****F02M 25/08(2006.01)i, F02M 37/00(2006.01)i**

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

B. FIELDS SEARCHEDMinimum documentation searched (classification system followed by classification symbols)
F02M 25/08; F16K 17/36; F16K 24/04; F16K 17/18; F02M 1/00; F02M 37/00; B60K 15/035Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility modelsElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: valve, roll-over, float, pressure relief valve, housing, seal, block, fuel tank, and canister**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010-0282335 A1 (MILLS, VAUGHN K.) 11 November 2010 See abstract; paragraphs [0016]-[0033] and figures 1-5.	1-7,9
Y		8
A		10-24
Y	US 5666989 A (ROETKER, JOHN J.) 16 September 1997 See abstract; column 6, lines 19-36 and figure 3.	8
A	US 2003-0230288 A1 (KING et al.) 18 December 2003 See abstract; claims 1, 7 and figure 5.	1-24
A	JP 2012-180791 A (KYOSAN DENKI CO., LTD.) 20 September 2012 See abstract; paragraphs [0006]-[0016] and figure 1.	1-24
A	KR 10-0774244 B1 (SSANGYONG MOTOR COMPANY) 07 November 2007 See abstract and figure 3.	1-24



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

04 June 2015 (04.06.2015)

Date of mailing of the international search report

05 June 2015 (05.06.2015)

Name and mailing address of the ISA/KR

International Application Division
Korean Intellectual Property Office
189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City, 302-701,
Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

HWANG, Chan Yoon

Telephone No. +82-42-481-3347



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/017397

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 5666989 A	16/09/1997	None	
US 2003-0230288 A1	18/12/2003	US 6675779 B2	13/01/2004
JP 2012-180791 A	20/09/2012	None	
KR 10-0774244 B1	07/11/2007	None	