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(54) **Title:** ELECTRONIC PLUMBING FIXTURE FITTING WITH ELECTRONIC VALVE INCLUDING PISTON AND SEAT, SENSOR MOUNTED ON ELECTRONIC BOARD, AND FLOW MODULE

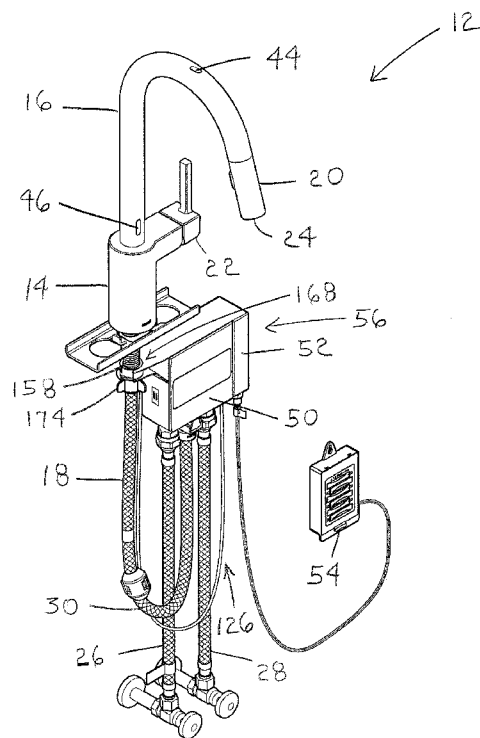


Figure 2

(57) **Abstract:** The present invention provides an electronic plumbing fixture fitting with an electronic valve including a piston and a seat, a sensor mounted on an electronic board, and a flow module, such as an electronic faucet with an electronic valve including a piston and a seat, a sensor mounted on an electronic board, and a flow module.



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**ELECTRONIC PLUMBING FIXTURE FITTING WITH
ELECTRONIC VALVE INCLUDING PISTON AND SEAT,
SENSOR MOUNTED ON ELECTRONIC BOARD, AND FLOW MODULE**

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Nos. 62/105,174, 62/105,175, and 62/105,176, filed January 19, 2015, the entire disclosures of which are hereby incorporated by reference.

FIELD

[0002] The present invention relates generally to an electronic plumbing fixture fitting with an electronic valve including a piston and a seat, a sensor mounted on an electronic board, and a flow module, such as an electronic faucet with an electronic valve including a piston and a seat, a sensor mounted on an electronic board, and a flow module.

BACKGROUND

[0003] Electronic plumbing fixture fittings, such as electronic faucets, are well known. Such electronic plumbing fixture fittings are used in residential and commercial applications, such as in kitchens, bathrooms, and various other locations.

SUMMARY

[0004] The present invention provides an electronic plumbing fixture fitting with an electronic valve including a piston and a seat, a sensor mounted on an electronic board, and a flow module.

[0005] In an exemplary embodiment, the electronic plumbing fixture fitting comprises a discharge outlet and an electronic valve. The discharge outlet is operable to deliver water. The electronic valve is operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated. The electronic valve includes a piston and a seat. The piston includes a body and a nose. The seat includes a body. The body of the seat includes a central opening extending therethrough. The electronic valve has a sealing zone. The sealing zone is a region where a sealing member on one of the piston and the seat interfaces with the other of the piston and the seat. The electronic valve has a flow control zone. At any given position of the piston relative to the seat, the flow control zone is a region where a portion of the piston interfaces with a portion of the seat. The sealing zone is separate from the flow control zone.

[0006] In an exemplary embodiment, the electronic plumbing fixture fitting comprises a discharge outlet and an electronic valve. The discharge outlet is operable to deliver water. The electronic valve is operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated. The electronic valve includes a piston and a seat. The piston includes a body and a nose. The nose of the piston includes a conical portion and a cylindrical portion. The seat includes a body. The body of the seat includes a central opening extending therethrough. The central opening includes an inlet portion, a conical portion, and a cylindrical

portion. The nose of the piston is operable to be received in and move in and out of the central opening in the seat.

[0007] In an exemplary embodiment, the electronic plumbing fixture fitting comprises a discharge outlet and an electronic valve. The discharge outlet is operable to deliver water. The electronic valve is operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated. The electronic valve includes a piston and a seat. The piston includes a body and a nose. The nose of the piston includes a dome-shaped portion. The seat includes a body. The body of the seat includes a central opening extending therethrough. The central opening includes an inlet portion and a rounded portion. The nose of the piston is operable to be received in and move in and out of the central opening in the seat.

[0008] In an exemplary embodiment, the electronic plumbing fixture fitting comprises a discharge outlet, an electronic valve, a sensor, an electronic control, and a cable. The discharge outlet is operable to deliver water. The discharge outlet is located above a mounting surface for the fitting. The electronic valve is operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated. The sensor is operable to send a signal when the sensor is triggered. The sensor is mounted on an electronic board. The sensor is located above the mounting surface. The electronic control is operable to receive the signal from the sensor when the sensor is triggered and, in response, send a signal to the electronic valve to activate the electronic valve. At least a portion of the electronic control is located above the mounting surface. The cable is operable to electrically connect the sensor to the electronic control. At least a portion of the cable is operable to electrically connect the sensor to the portion of the

electronic control located above the mounting surface. The electronic board and the portion of the cable operable to electrically connect the sensor to the portion of the electronic control located above the mounting surface are integrally formed.

[0009] In an exemplary embodiment, the electronic plumbing fixture fitting comprises a discharge outlet, an electronic valve, a first sensor, a second sensor, an electronic control, a first cable, and a second cable. The discharge outlet is operable to deliver water. The discharge outlet is located above a mounting surface for the fitting. The electronic valve is operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated. The first sensor is operable to send a first signal when the first sensor is triggered. The first sensor is mounted on a first electronic board. The first sensor is located above the mounting surface. The second sensor is operable to send a second signal when the second sensor is triggered. The second sensor is mounted on a second electronic board. The second sensor is located above the mounting surface. The electronic control is operable to receive the first signal from the first sensor when the first sensor is triggered and, in response, send a first signal to the electronic valve to activate the electronic valve. The electronic control is operable to receive the second signal from the second sensor when the second sensor is triggered and, in response, send a second signal to the electronic valve to activate the electronic valve. At least a portion of the electronic control is located above the mounting surface. The first cable is operable to electrically connect the first sensor to the second sensor. The first cable is located above the mounting surface. The second cable is operable to electrically connect the second sensor to the electronic control. At least a portion of the second cable is operable to electrically connect the second sensor to the portion of the electronic control located above the mounting surface. The

first electronic board, the second electronic board, the first cable, and at least the portion of the second cable operable to electrically connect the second sensor to the portion of the electronic control located above the mounting surface are integrally formed.

[0010] In an exemplary embodiment, the electronic plumbing fixture fitting comprises a discharge outlet, an electronic valve, a first sensor, a second sensor, an electronic control, a first cable, and a second cable. The discharge outlet is operable to deliver water. The discharge outlet is located above a mounting surface for the fitting. The electronic valve is operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated. The first sensor is operable to send a first signal when the first sensor is triggered. The first sensor is mounted on a first electronic board. The first sensor is located above the mounting surface. The second sensor is operable to send a second signal when the second sensor is triggered. The second sensor is mounted on a second electronic board. The second sensor is located above the mounting surface. The electronic control is operable to receive the first signal from the first sensor when the first sensor is triggered and, in response, send a first signal to the electronic valve to activate the electronic valve. The electronic control is operable to receive the second signal from the second sensor when the second sensor is triggered and, in response, send a second signal to the electronic valve to activate the electronic valve. The first cable is operable to electrically connect the first sensor to the second sensor. The first cable is located above the mounting surface. The second cable is operable to electrically connect the second sensor to the electronic control. At least a portion of the second cable is located above the mounting surface. The first electronic board, the second electronic board, and the first cable are integrally formed.

[0011] In an exemplary embodiment, the electronic plumbing fixture fitting comprises a housing, a mounting shank, an electronic valve, a flow module, and a wand hose. The housing is operable to mount above a mounting surface. The housing includes a spout and a wand. The wand is operable to pull away from the spout. The wand includes a discharge outlet operable to deliver water. The mounting shank is operable to extend downwardly from the housing. The mounting shank is operable to extend through and below the mounting surface. The mounting shank is operable to extend behind a sink mounted in the mounting surface. The electronic valve is operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated. The electronic valve is located inside the flow module. The flow module includes a bracket, a hot water inlet, a hot water passage, a cold water inlet, a cold water passage, a mixed water outlet, and a mixed water passage. The bracket includes a mounting portion. The mounting portion is operable to connect to the mounting shank. The hot water inlet is operable to receive hot water from a hot water supply. The hot water passage is operable to fluidly connect the hot water inlet and the electronic valve. The cold water inlet is operable to receive cold water from a cold water supply. The cold water passage is operable to fluidly connect the cold water inlet and the electronic valve. The mixed water outlet is operable to discharge mixed water to the discharge outlet. The mixed water passage is operable to fluidly connect the electronic valve and the mixed water outlet. The wand hose is operable to fluidly connect the mixed water outlet and the wand. The wand hose extends below the mounting surface and through the mounting surface and the spout. The flow module is operable to mount below the mounting surface and on the mounting shank.

[0012] In an exemplary embodiment, the electronic plumbing fixture fitting comprises a housing, a mounting shank, an electronic valve, a flow module, and a wand hose. The housing is operable to mount above a mounting surface. The housing includes a spout and a wand. The wand is operable to pull away from the spout. The wand includes a discharge outlet operable to deliver water. The mounting shank is operable to extend downwardly from the housing. The mounting shank is operable to extend through and below the mounting surface. The mounting shank is operable to extend behind a sink mounted in the mounting surface. The electronic valve is operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated. The electronic valve is located inside the flow module. The flow module includes a bracket, a hot water inlet, a hot water passage, a cold water inlet, a cold water passage, a mixed water outlet, and a mixed water passage. The bracket includes a mounting portion. The mounting portion is operable to connect to the mounting shank. The mounting portion includes a generally C-shaped clip that is operable to connect to the mounting shank. The hot water inlet is operable to receive hot water from a hot water supply. The hot water passage is operable to fluidly connect the hot water inlet and the electronic valve. The cold water inlet is operable to receive cold water from a cold water supply. The cold water passage is operable to fluidly connect the cold water inlet and the electronic valve. The mixed water outlet is operable to discharge mixed water to the discharge outlet. The mixed water passage is operable to fluidly connect the electronic valve and the mixed water outlet. The wand hose is operable to fluidly connect the mixed water outlet and the wand. The wand hose extends below the mounting surface and through the mounting surface and the spout. The flow module is operable to mount below the mounting surface and on the mounting shank.

[0013] In an exemplary embodiment, the electronic plumbing fixture fitting comprises a housing, a mounting shank, an electronic valve, a flow module, and a wand hose. The housing is operable to mount above a mounting surface. The housing includes a spout and a wand. The wand is operable to pull away from the spout. The wand includes a discharge outlet operable to deliver water. The mounting shank is operable to extend downwardly from the housing. The mounting shank is operable to extend through and below the mounting surface. The mounting shank is operable to extend behind a sink mounted in the mounting surface. The electronic valve is operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated. The electronic valve is located inside the flow module. The flow module includes a top side, a bottom side, a bracket, a hot water inlet, a hot water passage, a cold water inlet, a cold water passage, a mixed water outlet, and a mixed water passage. The top side is opposite the bottom side. The bracket extends from the top side of the flow module. The bracket includes a mounting portion. The mounting portion is operable to connect to the mounting shank. The mounting portion includes a generally C-shaped clip that is operable to connect to the mounting shank. The hot water inlet is operable to receive hot water from a hot water supply. The hot water inlet is located in the bottom side of the flow module. The hot water passage is operable to fluidly connect the hot water inlet and the electronic valve. The cold water inlet is operable to receive cold water from a cold water supply. The cold water inlet is located in the bottom side of the flow module. The cold water passage is operable to fluidly connect the cold water inlet and the electronic valve. The mixed water outlet is operable to discharge mixed water to the discharge outlet. The mixed water outlet is located in the bottom side of the flow module. The mixed water passage is operable to fluidly connect the electronic

valve and the mixed water outlet. The wand hose is operable to fluidly connect the mixed water outlet and the wand. The wand hose extends below the mounting surface and through the mounting surface and the spout. The flow module is operable to mount below the mounting surface and on the mounting shank.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Figure 1 is a schematic illustration of an electronic plumbing fixture fitting according to an exemplary embodiment of the present invention;

[0015] Figure 2 is a perspective view of an electronic faucet according to an exemplary embodiment of the present invention;

[0016] Figures 3a and 3b include views of an electronic mixing valve, including a hot water electronic valve, a cold water electronic valve, and a housing, according to an exemplary embodiment of the present invention - Figure 3a is an exploded perspective view, and Figure 3b is a central cross-sectional view;

[0017] Figures 4a-4f include views of the hot/cold water electronic valve of Figures 3a and 3b, including a piston and a seat, according to an exemplary embodiment of the present invention - Figure 4a is a perspective view, Figure 4b is an exploded perspective view, Figure 4c is a front view, Figure 4d is a top view, Figure 4e is a bottom view, and Figure 4f is a central cross-sectional view;

[0018] Figures 5a-5g include views of the housing of Figures 3a and 3b, according to an exemplary embodiment of the present invention - Figure 5a is a perspective view, Figure 5b is a front view, Figure 5c is a left view, Figure 5d is a right view, Figure 5e is a top view, Figure 5f is a bottom view, and Figure 5g is a central cross-sectional view;

[0019] Figures 6a-6e include views of the piston of Figures 4a-4f, including a body and a nose, according to an exemplary embodiment of the present invention - Figure 6a is a perspective view, Figure 6b is a front view, Figure 6c is a left view, Figure 6d is a central cross-sectional view, and Figure 6e is a detailed front view of the nose;

[0020] Figures 7a-7e include views of the seat of Figures 4a-4f, including a body and projections, according to an exemplary embodiment of the present invention - Figure 7a is a perspective view, Figure 7b is a front view, Figure 7c is a top view, Figure 7d is a central cross-sectional view, and Figure 7e is a detailed central cross-sectional view of a portion of the body;

[0021] Figures 8a-8e include central cross-sectional views of the piston and the seat of Figures 6a-6e and 7a-7e during various phases of operation of the hot/cold water electronic valve of Figures 4a-4f incorporating the piston and the seat of Figures 6a-6e and 7a-7e - Figure 8a shows a completely closed position, Figure 8b shows a cracked open position, Figure 8c shows an open position in which flow begins to increase, Figure 8d shows a half open position, and Figure 8e shows a completely open position;

[0022] Figures 9a-9d include views of another embodiment of a piston, including a body and a nose, according to another exemplary embodiment of the present invention - Figure 9a is a perspective view, Figure 9b is a front view, Figure 9c is a left view, and Figure 9d is a central cross-sectional view;

[0023] Figures 10a-10d include views of another embodiment of a seat, including a body and projections, according to another exemplary embodiment of the present invention - Figure 10a is a perspective view, Figure 10b is a front view, Figure 10c is a top view, and Figure 10d is a central cross-sectional view;

[0024] Figures 11a-11e include central cross-sectional views of the piston and the seat of Figures 9a-9d and 10a-10d during various phases of operation of the hot/cold water electronic valve of Figures 4a-4f incorporating the piston and the seat of Figures 9a-9d and 10a-10d - Figure 11a shows a completely closed position, Figure 11b shows a cracked open position, Figure 11c shows an open position in which flow begins to increase, Figure 11d shows a half open position, and Figure 11e shows a completely open position;

[0025] Figures 12a and 12b include flow rate data for the hot/cold water electronic valve of Figures 4a-4f incorporating the piston and the seat of Figures 6a-6e and 7a-7e - Figure 12a is a graph showing the flow rate data, and Figure 12b is a chart showing the flow rate data;

[0026] Figures 13a and 13b include flow rate data for the hot/cold water electronic valve of Figures 4a-4f incorporating the piston and the seat of Figures 9a-9d and 10a-10d - Figure 13a is a graph showing the flow rate data, and Figure 13b is a chart showing the flow rate data;

[0027] Figure 14a-14c include views of portions of the electronic faucet of Figure 2, including electronic boards and cables and a mounting shank, according to an exemplary embodiment of the present invention - Figure 14a is an exploded perspective view, Figure 14b is an assembled perspective view, and Figure 14c is an exploded perspective view;

[0028] Figures 15a-15d include views of the electronic boards and the cables of Figures 14a-14c according to an exemplary embodiment of the present invention - Figure 15a is a top view, Figure 15b is a bottom view, Figure 15c is a side view, and Figure 15d is a detailed view of the circled section of Figure 15b;

[0029] Figures 16a-16c include views of a flow module according to an exemplary embodiment of the present invention - Figure 16a is a top perspective view, Figure 16b is a bottom perspective view, and Figure 16c is an exploded bottom perspective view;

[0030] Figures 17a-17d include additional views of the flow module of Figures 16a-16c - Figure 17a is a front view, Figure 17b is a cross-sectional view taken along the line 17b-17b in Figure 17a, Figure 17c is a cross-sectional view taken along the line 17c-17c in Figure 17a, and Figure 17d is a cross-sectional view taken along the line 17d-17d in Figure 17a;

[0031] Figures 18a-18d include further views of the flow module of Figures 16a-16c - Figure 18a is a top view, Figure 18b is a left side view, Figure 18c is a right side view, and Figure 18d is a cross-sectional view taken along the line 18d-18d in Figure 18a; and

[0032] Figures 19a and 19b include views of the flow module of Figures 16a-18d mounted on the mounting shank of Figure 14a - Figure 19a is a bottom perspective view, and Figure 19b is a front view.

DETAILED DESCRIPTION

[0033] The present invention provides an electronic plumbing fixture fitting. In an exemplary embodiment, the electronic plumbing fixture fitting is an electronic faucet. However, one of ordinary skill in the art will appreciate that the electronic plumbing fixture fitting could be an electronic showering system, an electronic showerhead, an electronic handheld shower, an electronic body spray, an electronic side spray, or any other electronic plumbing fixture fitting.

[0034] An exemplary embodiment of an electronic plumbing fixture fitting 10, such as an electronic faucet 12, is illustrated in Figure 1. An exemplary embodiment of the electronic faucet 12 is illustrated in Figure 2.

[0035] In the illustrated embodiment, as best shown in Figure 2, the faucet 12 includes a hub 14, a spout 16, a flexible hose 18, a wand 20, and a handle 22. An upstream end of the hub 14 is connected to a mounting surface (such as a counter or sink). An upstream end of the spout 16 is connected to a downstream end of the hub 14. The spout 16 is operable to rotate relative to

the hub 14. The flexible hose 18 extends through the hub 14 and the spout 16 and is operable to move within the hub 14 and the spout 16. An upstream end of the wand 20 is mounted in a downstream end of the spout 16 and is connected to a downstream end of the flexible hose 18. A downstream end of the wand 20 includes a discharge outlet 24 through which water is delivered from the faucet 12. The wand 20 is operable to be pulled away from the spout 16. The handle 22 covers a side opening in the hub 14 and is operable to be moved relative to the hub 14. Although the faucet 12 has been described as having a rotatable spout 16, a pull-out or pull-down wand 20, and a handle 22 mounted on the hub 14, one of ordinary skill in the art will appreciate that the spout 16 could be fixed relative to the hub 14, the faucet 12 may not include a wand 20, the handle 22 may be mounted on other locations on the faucet 12 or remote from the faucet 12, the faucet 12 could include more than one handle 22, the handle 22 may be any mechanical actuation device or user interface, and/or the faucet 12 may not include a handle 22.

[0036] Additionally, in the illustrated embodiment, as best shown in Figure 1, the fitting 10 includes a hot water line 26, a cold water line 28, a mixed water line 30, and an electronic mixing valve 32. The electronic mixing valve 32 includes a hot water electronic valve 34 and a cold water electronic valve 36. An upstream end of the hot water line 26 connects to a hot water supply 38, and an upstream end of the cold water line 28 connects to a cold water supply 40. A downstream end of the hot water line 26 connects to the electronic mixing valve 32, and more specifically, the hot water electronic valve 34. A downstream end of the cold water line 28 connects to the electronic mixing valve 32 and, more specifically, the cold water electronic valve 36. An upstream end of the mixed water line 30 connects to the electronic mixing valve 32. A downstream end of the mixed water line 30 connects to the discharge outlet 24. In the illustrated embodiments, at least a portion of the mixed water line 30 is the flexible hose 18. As stated

above, the downstream end of the flexible hose 18 connects to the upstream end of the wand 20. Although the faucet 12 has been described as including a hot water electronic valve 34 and a cold water electronic valve 36, one of ordinary skill in the art will appreciate that the faucet 12 could include one or more electronic valves and/or the faucet 12 could include one or more mechanical valves in series or in parallel with the electronic valve(s).

[0037] In an exemplary embodiment, the hot water electronic valve 34 and the cold water electronic valve 36 are proportional valves and, more specifically, stepper motor actuated valves. However, one of ordinary skill in the art will appreciate that, in some embodiments, the electronic valves could be any type of electronic valves.

[0038] Further, in the illustrated embodiments, as best shown in Figures 1 and 2, the fitting 10 includes an activation sensor 42, such as a toggle sensor 44 and a presence sensor 46 of the faucet 12.

[0039] In an exemplary embodiment, the toggle sensor 44 is a proximity sensor and, in particular, an infrared sensor. The toggle sensor 44 is also referred to as a latching sensor and a sustained-flow sensor. In the illustrated embodiment, the toggle sensor 44 is mounted on an apex of the spout 16. The toggle sensor 44 defines a toggle zone. In an exemplary embodiment, the toggle sensor 44 is operable to activate the hot water electronic valve 34 and the cold water electronic valve 36 when an object enters the toggle zone and to deactivate the hot water electronic valve 34 and the cold water electronic valve 36 when the object exits and reenters the toggle zone. As used herein, an “object” can be any portion of a user’s body or any item used by the user to trigger the toggle sensor 44. In an exemplary embodiment, the toggle zone extends generally upwardly from the toggle sensor 44. Additionally, in an exemplary embodiment, the toggle zone has a generally cone-like shape.

[0040] In an exemplary embodiment, the presence sensor 46 is a proximity sensor, and, in particular, an infrared sensor. The presence sensor 46 is also referred to as a quick-strike sensor. In the illustrated embodiment, the presence sensor 46 is mounted on the upstream end of the spout 16. The presence sensor 46 defines a presence zone. In an exemplary embodiment, the presence sensor 46 is operable to activate the hot water electronic valve 34 and the cold water electronic valve 36 when an object enters the presence zone and to deactivate the hot water electronic valve 34 and the cold water electronic valve 36 when the object exits the presence zone. Again, as used herein, an “object” can be any portion of a user’s body or any item used by the user to trigger the presence sensor 46. In an exemplary embodiment, the presence zone extends generally horizontally from the presence sensor 46. Additionally, in an exemplary embodiment, the presence zone has a generally cone-like shape.

[0041] As described above, the toggle sensor 44 and the presence sensor 46 are proximity sensors and, in particular, infrared sensors. Proximity sensors are sensors that detect the presence of an object without any physical contact. However, one of ordinary skill in the art will appreciate that the toggle sensor 44 and the presence sensor 46 could be any type of electronic sensors that can be triggered, including, but not limited to, other proximity sensors, touch sensors, and image sensors. Exemplary electronic sensors include, but are not limited to, electromagnetic radiation sensors (such as optical sensors and radar sensors), capacitance sensors, inductance sensors, piezo-electric sensors, and multi-pixel optical sensors (such as camera sensors). Moreover, the toggle sensor 44 and the presence sensor 46 may not be the same type of sensor. As further described above, the toggle sensor 44 is mounted on the apex of the spout 16 and the presence sensor 46 is mounted on the upstream end of the spout 16. However, one of ordinary skill in the art will appreciate that the toggle sensor 44 and the

presence sensor 46 could be mounted in any location on the faucet 12 or in a location remote from the faucet 12. Furthermore, the toggle sensor 44 and the presence sensor 46 may be located in close proximity to each other or fairly remote from each other.

[0042] Similarly, as described above, the sensors are a toggle sensor 44 and a presence sensor 46. However, one of ordinary skill in the art will appreciate that the toggle sensor 44 and the presence sensor 46 could be any type of sensors that provide information useful in determining whether to activate or deactivate the hot water electronic valve 34 and the cold water electronic valve 36, including, but not limited to, flow sensors, pressure sensors, temperature sensors, and position sensors. Moreover, the toggle sensor 44 and the presence sensor 46 may be the same type of sensor.

[0043] Further, in the illustrated embodiment, as best shown in Figure 1, the fitting 10 includes a parameter sensor 48. In an exemplary embodiment, the parameter sensor 48 is operable to detect movement of the handle 22 and to provide information to set at least one parameter of water flowing through the hot water electronic valve 34 and the cold water electronic valve 36 based on the movement of the handle 22. The parameter sensor 48 is operable to detect movement of the handle 22 either directly or indirectly. In an exemplary embodiment, based on the movement of the handle 22, the parameter sensor 48 provides information to set a temperature and/or a volume of water flowing through the hot water electronic valve 34 and the cold water electronic valve 36.

[0044] In the illustrated embodiments, the handle 22 operates as it would with a standard faucet. In other words, the handle 22 can be moved between various positions to indicate a desired temperature and volume of water discharged from the faucet 12.

[0045] More specifically, with regard to the temperature of water, the handle 22 can be rotated about a longitudinal axis of the side opening in the hub 14. At one extent of a range of rotation, the position of the handle 22 indicates all hot water (a full hot position). At the other extent of the range of rotation, the position of the handle 22 indicates all cold water (a full cold position). In between the extents of the range of rotation, the position of the handle 22 indicates a mix of hot and cold water (mixed temperature positions) with hotter temperature water as the position nears the full hot extent of the range of rotation and colder temperature water as the position nears the full cold extent of the range of rotation.

[0046] With regard to the volume of water, the handle 22 can be moved toward and away from the side opening in the hub 14. At one extent of a range of movement, the position of the handle 22 indicates no volume of water (a full closed position). At the other extent of the range of movement, the position of the handle 22 indicates full volume of water (a full open position). In between the extents of the range of movement, the position of the handle 22 indicates an intermediate volume of water (less than full open positions) with reduced volume water as the position nears the full closed extent of the range of movement and increased volume water as the position nears the full open extent of the range of movement.

[0047] Additionally, in the illustrated embodiment, as best shown in Figure 2, the electronic faucet 12 includes a flow module 50, an electronics module 52, and a power module 54. The flow module 50 includes a number of inlets and outlets and a number of flow passages. These inlets/outlets and flow passages enable the easy management of the flow between the incoming supplies (i.e., the hot water supply 38 and the cold water supply 40) and the wand 20. In the illustrated embodiment, the hot water electronic valve 34 and the cold water electronic valve 36 are located inside the flow module 50. The electronics module 52 includes a number of

electronic components. These components enable the activation and deactivation of the hot water electronic valve 34 and the cold water electronic valve 36. In the illustrated embodiment, the electronics module 52 is connected to the flow module 50. The power module 54 provides electrical power to electronic components of the faucet 12.

[0048] Further, in the illustrated embodiment, as best shown in Figure 1, the fitting 10 includes an electronic control 56. The electronic control 56 receives information (such as signals) from the toggle sensor 44 and the presence sensor 46 to activate and deactivate the hot water electronic valve 34 and the cold water electronic valve 36. Moreover, the electronic control 56 receives information (such as signals) from the parameter sensor 48 to set parameters (such as the temperature and the volume) of water flowing through the hot water electronic valve 34 and the cold water electronic valve 36. In an exemplary embodiment, at least a portion of the electronic control 56 is located inside the electronics module 52. Although the fitting 10 has been described as having a separate electronic control 56, one of ordinary skill in the art will appreciate that the electronic control 56 could be incorporated into the toggle sensor 44, the presence sensor 46, and/or the parameter sensor 48.

[0049] In an exemplary embodiment, as best shown in Figures 3a-3b and 5a-5g, the electronic mixing valve 32 includes the hot water electronic valve 34, the cold water electronic valve 36, and a housing 58. The housing 58 includes a hot water inlet 60, a cold water inlet 62, a hot water electronic valve chamber 64, a cold water electronic valve chamber 66, a mixing chamber 68, and an outlet 70. The hot water electronic valve 34 is operable to be received in the hot water electronic valve chamber 64, and the cold water electronic valve 36 is operable to be received in the cold water electronic valve chamber 66.

[0050] In an exemplary embodiment, the hot water electronic valve 34 and the cold water electronic valve 36 are the same type of valve, i.e., a proportional valve and, more specifically, a stepper motor actuated valve. The following description of the electronic valve applies to both the hot water electronic valve 34 and the cold water electronic valve 36.

[0051] In an exemplary embodiment, as best shown in Figures 3a-5g, the hot/cold water electronic valve 34/36 includes a stepper motor 72, an upper housing 74, a lower housing 76h/76c, a piston 78, a seat 80, and various sealing members 82, such as O-rings. The motor 72 includes a shaft 84.

[0052] In an exemplary embodiment, as best shown in Figures 5a-5g, the lower housing 76h/76c of the hot/cold water electronic valve 34/36 is integral with the housing 58 of the electronic mixing valve 32. However, one of ordinary skill in the art will appreciate that the lower housing 76h/76c of the hot/cold water electronic valve 34/36 could be separate from the housing 58 of the electronic mixing valve 32.

[0053] In an exemplary embodiment, as best shown in Figures 6a-6e, the piston 78 includes a body 86 and a nose 88. In the illustrated embodiment, the body 86 is generally cylindrical shaped. More specifically, the body 86 is a hexagonal prism. The body 86 includes a recess 90 that is operable to receive a portion of the shaft 84. In the illustrated embodiment, the nose 88 includes a sealing member groove 92, a first conical portion 94, a cylindrical portion 96, and a second conical portion 98. The sealing member groove 92 is operable to receive the sealing member 82, such as an O-ring. Although the nose 88 of the piston 78 has been described as including specific portions, one of ordinary skill in the art will appreciate that the nose 88 of the piston 78 does not need to include each of these portions. For example, the nose 88 of the piston 78 may not include a second conical portion 98.

[0054] In an exemplary embodiment, as best shown in Figures 7a-7e, the seat 80 includes a body 100 and a plurality of projections 102 extending therefrom. In the illustrated embodiment, the body 100 is generally cylindrical shaped. In the illustrated embodiment, the seat 80 includes four projections 102 extending from the body 100. The projections 102 are operable to connect the seat 80 to the lower housing 76h/76c. The body 100 includes a central opening 104 extending therethrough. In the illustrated embodiment, the central opening 104 in the body 100 includes an inlet portion 106, a first cylindrical portion 108, a conical portion 110, a second cylindrical portion 112, and an outlet portion 114. The nose 88 of the piston 78 is operable to be received in and move in and out of the central opening 104 in the seat 80. Although the central opening 104 in the seat 80 has been described as including specific portions, one of ordinary skill in the art will appreciate that the central opening 104 in the seat 80 does not need to include each of these portions. For example, the central opening 104 in the seat 80 may not include a first cylindrical portion 112 and an outlet portion 114.

[0055] The conical portion 110 of the seat 80 has an angle 116, and the second conical portion 98 of the piston 78 has an angle 118. As best shown in Figure 7d, the angle 116 of the conical portion 110 of the seat 80 is an angle between: (1) a central longitudinal axis of the seat 80, and (2) a line extending along the conical portion 110 of the seat 80. The central longitudinal axis of the seat 80 and the line extending along the conical portion 110 of the seat 80 extend in a common plane. As best shown in Figure 6d, the angle 118 of the second conical portion 98 of the piston 78 is an angle between: (1) a central longitudinal axis of the piston 78, and (2) a line extending along the second conical portion 98 of the piston 78. The central longitudinal axis of the piston 78 and the line extending along the second conical portion 98 of the piston 78 extend in a common plane. In an exemplary embodiment, the angle 116 of the conical portion 110 of

the seat 80 is less than the angle 118 of the second conical portion 98 of the piston 78. In the illustrated embodiment, the angle 116 of the conical portion 110 of the seat 80 is approximately twenty-two and one-half degrees (22.5°). In the illustrated embodiment, the angle 118 of the second conical portion 98 of the piston 78 is approximately thirty degrees (30°).

[0056] The inlet portion 106 of the seat 80 has an angle 120. As best shown in Figure 7d, the angle 120 of the inlet portion 106 of the seat 80 is an angle between: (1) the central longitudinal axis of the seat 80, and (2) a line extending along the inlet portion 106 of the seat 80. The central longitudinal axis of the seat 80 and the line extending along the inlet portion 106 of the seat 80 extend in a common plane. In an exemplary embodiment, the angle 120 of the inlet portion 106 of the seat 80 is between approximately twenty-five degrees and seventy-five degrees (25° - 75°). In an exemplary embodiment, the angle 120 of the inlet portion 106 of the seat 80 is between approximately thirty-five degrees and fifty-five degrees (35° - 55°). In an exemplary embodiment, the angle 120 of the inlet portion 106 of the seat 80 is between approximately forty degrees and fifty degrees (40° - 50°). In the illustrated embodiment, the angle 120 of the inlet portion 106 of the seat 80 is approximately forty-five degrees (45°).

[0057] In an exemplary embodiment, a geometry of the nose 88 of the piston 78 generally corresponds to a geometry of the central opening 104 in the seat 80. More specifically, in the illustrated embodiment, as best shown in Figures 8a-8e, a geometry of the first conical portion 94 and the cylindrical portion 96 of the piston 78 generally corresponds to a geometry of the conical portion 110 and the second cylindrical portion 112 of the seat 80. Even more specifically, opposing surfaces of the first conical portion 94 and the cylindrical portion 96 of the piston 78 and the conical portion 110 and the second cylindrical portion 112 of the seat 80 are generally parallel.

[0058] During operation of the hot/cold water electronic valve 34/36 including the piston 78 and the seat 80, as best shown in Figures 8a-8e, the hot/cold water electronic valve 34/36 moves from a completely closed position to a completely open position. In the completely closed position, no fluid flows through the hot/cold water electronic valve 34/36. In the completely open position, a maximum amount of fluid flows through the hot/cold water electronic valve 34/36. Between the completely closed position and the completely open position, an increasing amount of fluid flows through the hot/cold water electronic valve 34/36.

[0059] In the completely closed position, the sealing member 82 on the piston 78 is in sealing contact with the inlet portion 106 of the seat 80. Additionally, the first conical portion 94 and the cylindrical portion 96 of the piston 78 interface with the conical portion 110 and the second cylindrical portion 112 of the seat 80. As a result of the sealing contact between the sealing member 82 on the piston 78 and the inlet portion 106 of the seat 80, no fluid flows through the hot/cold water electronic valve 34/36.

[0060] As the piston 78 starts to move out of the seat 80, the sealing member 82 on the piston 78 loses sealing contact with the inlet portion 106 of the seat 80. Additionally, the first conical portion 94 and the cylindrical portion 96 of the piston 78 move away from the conical portion 110 and the second cylindrical portion 112 of the seat 80. As a result of the sealing member 82 on the piston 78 losing sealing contact with the inlet portion 106 of the seat 80, fluid starts to flow through the hot/cold water electronic valve 34/36.

[0061] As the piston 78 moves further out of the seat 80, the sealing member 82 on the piston 78 moves further away from the inlet portion 106 of the seat 80. Additionally, the first conical portion 94 and the cylindrical portion 96 of the piston 78 move further away from the

conical portion 110 and the second cylindrical portion 112 of the seat 80. As a result, an increasing amount of fluid flows through the hot/cold water electronic valve 34/36.

[0062] In the completely open position, the sealing member 82 on the piston 78 is furthest away from the inlet portion 106 of the seat 80. Additionally, the first conical portion 94 and the cylindrical portion 96 of the piston 78 are furthest away from the conical portion 110 and the second cylindrical portion 112 of the seat 80. As a result, the maximum amount of fluid flows through the hot/cold water electronic valve 34/36.

[0063] In the illustrated embodiment, as best shown in Figures 8a-8e, the hot/cold water electronic valve 34/36 has a sealing zone SZ. The sealing zone SZ is static. The sealing zone SZ is a region where the sealing member 82 on the piston 78 interfaces with the inlet portion 106 of the seat 80. More specifically, the sealing zone SZ is the region where the sealing member 82 on the piston 78 is in contact with the inlet portion 106 of the seat 80. As stated above, when the sealing member 82 on the piston 78 is in contact with the inlet portion 106 of the seat 80, the hot/cold water electronic valve 34/36 is sealed and no fluid flows through the hot/cold water electronic valve 34/36. When the sealing member 82 on the piston 78 is not in contact with the inlet portion 106 of the seat 80, the hot/cold water electronic valve 34/36 is not sealed and a varying amount of fluid flows through the hot/cold water electronic valve 34/36 (depending on the position of the piston 78 relative to the seat 80).

[0064] In the illustrated embodiment, as best shown in Figures 8a-8e, the hot/cold water electronic valve 34/36 also has a flow control zone FCZ. The flow control zone FCZ is dynamic. At any given position of the piston 78 relative to the seat 80, the flow control zone FCZ is a region where the downstream end of the cylindrical portion 96 of the piston 78 interfaces with the seat 80. More specifically, the flow control zone FCZ is the region where the downstream

end of the cylindrical portion 96 of the piston 78 is at a minimum distance from the seat 80. In the completely closed position, the downstream end of the cylindrical portion 96 of the piston 78 interfaces with the downstream end of the second cylindrical portion 112 of the seat 80. As the hot/cold water electronic valve 34/36 opens, the downstream end of the cylindrical portion 96 of the piston 78 interfaces with the second cylindrical portion 112 of the seat 80 and then the conical portion 110 of the seat 80. In the completely open position, the downstream end of the cylindrical portion 96 of the piston 78 interfaces with the conical portion 110 of the seat 80.

[0065] In an exemplary embodiment, as best shown in Figures 8a-8e, the sealing zone SZ is separate from the flow control zone FCZ. In an exemplary embodiment, as best shown in Figures 8a-8e, the sealing zone SZ is upstream of the flow control zone. More specifically, when the hot/cold water electronic valve 34/36 is completely closed, the sealing zone SZ is separate from and upstream of the flow control zone FCZ1 (see Figure 8a); as the hot/cold water electronic valve 34/36 opens, the sealing zone SZ is separate from and upstream of the flow control zone FCZ2 (see Figure 8b); as the hot/cold water electronic valve 34/36 further opens, the sealing zone SZ is separate from and upstream of the flow control zone FCZ3 (the flow control zone FCZ3 moves upstream along the second cylindrical portion 112 and then the conical portion 110 of the seat 80 as the hot/cold water electronic valve 34/36 further opens) (see Figures 8c and 8d); and when the hot/cold water electronic valve 34/36 is completely open, the sealing zone SZ is separate from and upstream of the flow control zone FCZ4 (see Figure 8e).

[0066] Although the hot/cold water electronic valve 34/36 has been described as having a sealing zone SZ where the sealing member 82 on the piston 78 interfaces with the inlet portion 106 of the seat 80, one of ordinary skill in the art will appreciate that the sealing member 82 could be on the seat 80 and interface with the nose 88 of the piston 78. Additionally, although

the hot/cold water electronic valve 34/36 has been described as including a sealing member 82, such as an O-ring, in the sealing member groove 92 on the piston 78, one of ordinary skill in the art will appreciate that the sealing member 82 could be integrally formed with the piston 78 (or the seat 80 if the sealing member 82 is on the seat 80). Further, one of ordinary skill in the art will appreciate that the piston 78 (or the seat 80 if the sealing member 82 is on the seat 80) does not need to include a sealing member groove 92.

[0067] In an exemplary embodiment, the hot/cold water electronic valve 34/36 including the piston 78 and the seat 80 has a sealing zone. The sealing zone is static. The sealing zone is a region where a sealing member 82 on one of the piston 78 and the seat 80 interfaces with the other of the piston 78 and the seat 80. More specifically, the sealing zone is the region where the sealing member 82 on one of the piston 78 and the seat 80 is in contact with the other of the piston 78 and the seat 80. When the sealing member 82 on one of the piston 78 and the seat 80 is in contact with the other of the piston 78 and the seat 80, the hot/cold water electronic valve 34/36 is sealed and no fluid flows through the hot/cold water electronic valve 34/36. When the sealing member 82 on one of the piston 78 and the seat 80 is not in contact with the other of the piston 78 and the seat 80, the hot/cold water electronic valve 34/36 is not sealed and a varying amount of fluid flows through the hot/cold water electronic valve 34/36 (depending on the position of the piston 78 relative to the seat 80).

[0068] In an exemplary embodiment, the hot/cold water electronic valve 34/36 including the piston 78 and the seat 80 has a flow control zone. The flow control zone is dynamic. At any given position of the piston 78 relative to the seat 80, the flow control zone is a region where a portion of the piston 78 interfaces with a portion of the seat 80. More specifically, the flow control zone is the region where the portion of the piston 78 is at a minimum distance from the

portion of the seat 80. Even more specifically, the flow control zone is the region where a distance between the portion of the piston 78 and the portion of the seat 80 is less than a distance between any other portion of the piston 78 and any other portion of the seat 80.

[0069] In another exemplary embodiment, as best shown in Figures 9a-9d, the piston 78' includes a body 86' and a nose 88'. In the illustrated embodiment, the body 86' is generally cylindrical shaped. More specifically, the body 86' is a hexagonal prism. The body 86' includes a recess 90' that is operable to receive a portion of the shaft 84. In the illustrated embodiment, the nose 88' includes a sealing member groove 92' and a dome-shaped portion 122. The sealing member groove 92' is operable to receive the sealing member 82, such as an O-ring.

[0070] In another exemplary embodiment, as best shown in Figures 10a-10d, the seat 80' includes a body 100' and a plurality of projections 102' extending therefrom. In the illustrated embodiment, the body 100' is generally cylindrical shaped. In the illustrated embodiment, the seat 80' includes four projections 102' extending from the body 100'. The projections 102' are operable to connect the seat 80' to the lower housing 76h/76c. The body 100' includes a central opening 104' extending therethrough. In the illustrated embodiment, the central opening 104' in the body 100' includes an inlet portion 106', a rounded portion 124, and an outlet portion 114'. The nose 88' of the piston 78' is operable to be received in and move in and out of the central opening 104' in the seat 80'. Although the central opening 104' in the seat 80' has been described as including specific portions, one of ordinary skill in the art will appreciate that the central opening 104' in the seat 80' does not need to include each of these portions. For example, the central opening 104' in the seat 80' may not include an outlet portion 114'.

[0071] During operation of the hot/cold water electronic valve 34/36 including the piston 78' and the seat 80', as best shown in Figures 11a-11e, the hot/cold water electronic valve 34/36

moves from a completely closed position to a completely open position. In the completely closed position, no fluid flows through the hot/cold water electronic valve 34/36. In the completely open position, a maximum amount of fluid flows through the hot/cold water electronic valve 34/36. Between the completely closed position and the completely open position, an increasing amount of fluid flows through the hot/cold water electronic valve 34/36.

[0072] In the completely closed position, the sealing member 82 on the piston 78' is in sealing contact with the inlet portion 106' of the seat 80'. Additionally, the dome-shaped portion 122 of the piston 78' interfaces with the rounded portion 124 of the seat 80'. As a result of the sealing contact between the sealing member 82 on the piston 78' and the inlet portion 106' of the seat 80', no fluid flows through the hot/cold water electronic valve 34/36.

[0073] As the piston 78' starts to move out of the seat 80', the sealing member 82 on the piston 78' loses sealing contact with the inlet portion 106' of the seat 80'. Additionally, the dome-shaped portion 122 of the piston 78' moves along the rounded portion 124 of the seat 80'. As a result of the sealing member 82 on the piston 78' losing sealing contact with the inlet portion 106' of the seat 80', fluid starts to flow through the hot/cold water electronic valve 34/36.

[0074] As the piston 78' moves further out of the seat 80', the sealing member 82 on the piston 78' moves further away from the inlet portion 106' of the seat 80'. Additionally, the dome-shaped portion 122 of the piston 78' moves further away from the rounded portion 124 of the seat 80'. As a result, an increasing amount of fluid flows through the hot/cold water electronic valve 34/36.

[0075] In the completely open position, the sealing member 82 on the piston 78' is furthest away from the inlet portion 106' of the seat 80'. Additionally, the dome-shaped portion

122 of the piston 78' is furthest away from the rounded portion 124 of the seat 80'. As a result, the maximum amount of fluid flows through the hot/cold water electronic valve 34/36.

[0076] In the illustrated embodiment, as best shown in Figures 11a-11e, the hot/cold water electronic valve 34/36 has a sealing zone SZ. The sealing zone SZ is static. The sealing zone SZ is a region where the sealing member 82 on the piston 78' interfaces with the inlet portion 106' of the seat 80'. More specifically, the sealing zone SZ is the region where the sealing member 82 on the piston 78' is in contact with the inlet portion 106' of the seat 80'. As stated above, when the sealing member 82 on the piston 78' is in contact with the inlet portion 106' of the seat 80', the hot/cold water electronic valve 34/36 is sealed and no fluid flows through the hot/cold water electronic valve 34/36. When the sealing member 82 on the piston 78' is not in contact with the inlet portion 106' of the seat 80', the hot/cold water electronic valve 34/36 is not sealed and a varying amount of fluid flows through the hot/cold water electronic valve 34/36 (depending on the position of the piston 78' relative to the seat 80').

[0077] In the illustrated embodiment, as best shown in Figures 11a-11e, the hot/cold water electronic valve 34/36 also has a flow control zone FCZ. The flow control zone is dynamic. At any given position of the piston 78' relative to the seat 80', the flow control zone FCZ is a region where the dome-shaped portion 122 of the piston 78' interfaces with the seat 80'. More specifically, the flow control zone FCZ is the region where the dome-shaped portion 122 of the piston 78' is at a minimum distance from the seat 80'. In the completely closed position, the dome-shaped portion 122 of the piston 78' interfaces with the rounded portion 124 of the seat 80'. As the hot/cold water electronic valve 34/36 opens, the dome-shaped portion 122 of the piston 78' moves along the rounded portion 124 of the seat 80'. In the completely open position,

the dome-shaped portion 122 of the piston 78' is furthest away from the rounded portion 124 of the seat 80'.

[0078] In an exemplary embodiment, as best shown in Figures 11a-11e, the sealing zone SZ is separate from the flow control zone FCZ. In an exemplary embodiment, as best shown in Figures 11a-11e, the sealing zone SZ is upstream of the flow control zone FCZ. More specifically, when the hot/cold water electronic valve 34/36 is completely closed, the sealing zone SZ is separate from and upstream of the flow control zone FCZ1 (see Figure 11a); as the hot/cold water electronic valve 34/36 opens, the sealing zone SZ is separate from and upstream of the flow control zone FCZ2 (see Figure 11b); as the hot/cold water electronic valve 34/36 further opens, the sealing zone SZ is separate from and upstream of the flow control zone FCZ3 (the flow control zone FCZ3 moves upstream along the rounded portion 124 of the seat 80' as the hot/cold water electronic valve 34/36 further opens) (see Figures 11c and 11d); and when the hot/cold water electronic valve 34/36 is completely open, the sealing zone SZ is separate from and upstream of the flow control zone FCZ4 (see Figure 11e).

[0079] Although the hot/cold water electronic valve 34/36 has been described as having a sealing zone SZ where the sealing member 82 on the piston 78' interfaces with the inlet portion 106' of the seat 80', one of ordinary skill in the art will appreciate that the sealing member 82 could be on the seat 80' and interface with the nose 88' of the piston 78'. Additionally, although the hot/cold water electronic valve 34/36 has been described as including a sealing member 82, such as an O-ring, in the sealing member groove 92' on the piston 78', one of ordinary skill in the art will appreciate that the sealing member 82 could be integrally formed with the piston 78' (or the seat 80' if the sealing member 82 is on the seat 80'). Further, one of ordinary skill in the

art will appreciate that the piston 78' (or the seat 80' if the sealing member 82 is on the seat 80') does not need to include a sealing member groove 92'.

[0080] In an exemplary embodiment, the hot/cold water electronic valve 34/36 including the piston 78' and the seat 80' has a sealing zone. The sealing zone is static. The sealing zone is a region where a sealing member 82 on one of the piston 78' and the seat 80' interfaces with the other of the piston 78' and the seat 80'. More specifically, the sealing zone is the region where the sealing member 82 on one of the piston 78' and the seat 80' is in contact with the other of the piston 78' and the seat 80'. When the sealing member 82 on one of the piston 78' and the seat 80' is in contact with the other of the piston 78' and the seat 80', the hot/cold water electronic valve 34/36 is sealed and no fluid flows through the hot/cold water electronic valve 34/36. When the sealing member 82 on one of the piston 78' and the seat 80' is not in contact with the other of the piston 78' and the seat 80', the hot/cold water electronic valve 34/36 is not sealed and a varying amount of fluid flows through the hot/cold water electronic valve 34/36 (depending on the position of the piston 78' relative to the seat 80').

[0081] In an exemplary embodiment, the hot/cold water electronic valve 34/36 including the piston 78' and the seat 80' has a flow control zone. The flow control zone is dynamic. At any given position of the piston 78' relative to the seat 80', the flow control zone is a region where a portion of the piston 78' interfaces with a portion of the seat 80'. More specifically, the flow control zone is the region where the portion of the piston 78' is at a minimum distance from the portion of the seat 80'. Even more specifically, the flow control zone is the region where a distance between the portion of the piston 78' and the portion of the seat 80' is less than a distance between any other portion of the piston 78' and any other portion of the seat 80'.

[0082] Although the electronic plumbing fixture fitting 10 has been described as including an electronic mixing valve 32 and the electronic mixing valve 32 has been described as including a hot water electronic valve 34 and a cold water electronic valve 36, one of ordinary skill in the art will appreciate that the electronic valve could be used as a shutoff valve in addition to or in place of the mixing valve. Additionally, when the electronic valve is used as a shutoff valve, the seat 80/80' could be integrated into the valve housing.

[0083] During operation of the hot/cold water electronic valve 34/36 including the piston 78 and the seat 80, as best shown in Figures 12a and 12b, a flow rate through the hot/cold water electronic valve 34/36 generally increases with each step of the motor 72. In this embodiment, a maximum number of steps provided by the motor 72 is eighty (80) steps. As a result, a first twenty-five percent (25%) of the maximum number of steps provided by the motor 72 is a first twenty (20) steps. With a supply line pressure of approximately forty-five pounds per square inch (45 psi) and no restriction on the flow downstream of the valve, a maximum flow rate through the hot/cold water electronic valve 34/36 at the maximum number of steps is approximately one and one-half gallons per minute (1.5 gpm). As a result, twenty-five percent (25%) of the maximum flow rate provided by the hot/cold water electronic valve 34/36 is approximately three-hundred seventy-five thousandths gallons per minute (0.375 gpm), twenty percent (20%) of the maximum flow rate provided by the hot/cold water electronic valve 34/36 is approximately three-tenths gallons per minute (0.3 gpm), and fifteen percent (15%) of the maximum flow rate provided by the hot/cold water electronic valve 34/36 is approximately two-hundred twenty-five thousandths gallons per minute (0.225 gpm).

[0084] During operation of the hot/cold water electronic valve 34/36 including the piston 78 and the seat 80, with a supply line pressure of approximately forty-five pounds per square

inch (45 psi) and no restriction on the flow downstream of the valve, for the first twenty-five percent (25%) of the maximum number of steps provided by the motor 72, the flow rate through the hot/cold water electronic valve 34/36 does not exceed approximately twenty-five percent (25%) of the maximum flow rate provided by the hot/cold water electronic valve 34/36. In another exemplary embodiment, with a supply line pressure of approximately forty-five pounds per square inch (45 psi) and no restriction on the flow downstream of the valve, for the first twenty-five percent (25%) of the maximum number of steps provided by the motor 72, the flow rate through the hot/cold water electronic valve 34/36 does not exceed approximately twenty percent (20%) of the maximum flow rate provided by the hot/cold water electronic valve 34/36. In another exemplary embodiment, with a supply line pressure of approximately forty-five pounds per square inch (45 psi) and no restriction on the flow downstream of the valve, for the first twenty-five percent (25%) of the maximum number of steps provided by the motor 72, the flow rate through the hot/cold water electronic valve 34/36 does not exceed approximately fifteen percent (15%) of the maximum flow rate provided by the hot/cold water electronic valve 34/36.

[0085] During operation of the hot/cold water electronic valve 34/36 including the piston 78 and the seat 80, with a supply line pressure of approximately forty-five pounds per square inch (45 psi) and no restriction on the flow downstream of the valve, for the first twenty-five percent (25%) of the maximum number of steps provided by the motor 72, the flow rate through the hot/cold water electronic valve 34/36 does not exceed approximately six tenths gallons per minute (0.6 gpm). In another exemplary embodiment, with a supply line pressure of approximately forty-five pounds per square inch (45 psi) and no restriction on the flow downstream of the valve, for the first twenty-five percent (25%) of the maximum number of

steps provided by the motor 72, the flow rate through the hot/cold water electronic valve 34/36 does not exceed approximately five tenths gallons per minute (0.5 gpm). In another exemplary embodiment, with a supply line pressure of approximately forty-five pounds per square inch (45 psi) and no restriction on the flow downstream of the valve, for the first twenty-five percent (25%) of the maximum number of steps provided by the motor 72, the flow rate through the hot/cold water electronic valve 34/36 does not exceed approximately four tenths gallons per minute (0.4 gpm). In another exemplary embodiment, with a supply line pressure of approximately forty-five pounds per square inch (45 psi) and no restriction on the flow downstream of the valve, for the first twenty-five percent (25%) of the maximum number of steps provided by the motor 72, the flow rate through the hot/cold water electronic valve 34/36 does not exceed approximately three tenths gallons per minute (0.3 gpm). In another exemplary embodiment, with a supply line pressure of approximately forty-five pounds per square inch (45 psi) and no restriction on the flow downstream of the valve, for the first twenty-five percent (25%) of the maximum number of steps provided by the motor 72, the flow rate through the hot/cold water electronic valve 34/36 does not exceed approximately two tenths gallons per minute (0.2 gpm).

[0086] During operation of the hot/cold water electronic valve 34/36 including the piston 78' and the seat 80', as best shown in Figures 13a and 13b, a flow rate through the hot/cold water electronic valve 34/36 generally increases with each step of the motor 72. In this embodiment, a maximum number of steps provided by the motor 72 is two-hundred fifty (250) steps. As a result, a middle seventy percent (70%) of the maximum number of steps provided by the motor 72 is a middle one-hundred seventy-five (175) steps (from step 38 to step 210 which will be approximated as step 40 to step 215 for purposes of any flow rate calculations). With a supply

line pressure of approximately forty-five pounds per square inch (45 psi) and no restriction on the flow downstream of the valve, a maximum flow rate through the hot/cold water electronic valve 34/36 at the maximum number of steps is approximately nine and one-half gallons per minute (9.5 gpm).

[0087] During operation of the hot/cold water electronic valve 34/36 including the piston 78' and the seat 80', with a supply line pressure of approximately forty-five pounds per square inch (45 psi) and no restriction on the flow downstream of the valve, for the middle seventy percent (70%) of the maximum number of steps provided by the motor 72, an average rate of change in the flow rate through the hot/cold water electronic valve 34/36 is in a range of approximately ten thousandths gallons per minute per step (0.010 gpm/step) and sixteen hundredths gallons per minute per step (0.16 gpm/step). In another exemplary embodiment, with a supply line pressure of approximately forty-five pounds per square inch (45 psi) and no restriction on the flow downstream of the valve, for the middle seventy percent (70%) of the maximum number of steps provided by the motor 72, the average rate of change in the flow rate through the hot/cold water electronic valve 34/36 is in a range of approximately twenty thousandths gallons per minute per step (0.020 gpm/step) and eighty thousandths gallons per minute per step (0.080 gpm/step). In the illustrated embodiment, with a supply line pressure of approximately forty-five pounds per square inch (45 psi) and no restriction on the flow downstream of the valve, for the middle seventy percent (70%) of the maximum number of steps provided by the motor 72, the average rate of change in the flow rate through the hot/cold water electronic valve 34/36 is approximately forty-two thousandths gallons per minute per step (0.042 gpm/step).

[0088] As best shown in Figures 14a-14c and 15a-15d, the toggle sensor 44, the presence sensor 46, and the electronic control 56 are electrically connected via cables 126. The toggle sensor 44 is operable to send a signal to the electronic control 56 when the toggle sensor 44 is triggered. The electronic control 56 is operable to receive the signal from the toggle sensor 44 when the toggle sensor 44 is triggered and, in response, send a signal to the hot/cold water electronic valve 34/36 to activate the hot/cold water electronic valve 34/36. The presence sensor 46 is operable to send a signal to the electronic control 56 when the presence sensor 46 is triggered. The electronic control 56 is operable to receive the signal from the presence sensor 46 when the presence sensor 46 is triggered and, in response, send a signal to the hot/cold water electronic valve 34/36 to activate the hot/cold water electronic valve 34/36.

[0089] In an exemplary embodiment, the toggle sensor 44 is located above the mounting surface. As stated above, in the illustrated embodiment, the toggle sensor 44 is mounted on the apex of the spout 16. In an exemplary embodiment, the toggle sensor 44 is mounted on a first electronic board 128. Additionally, the toggle sensor 44 is mechanically and electrically connected to the presence sensor 46. In the illustrated embodiment, a first cable 126a is operable to mechanically and electrically connect the toggle sensor 44 to the presence sensor 46 and mechanically support the toggle sensor 44. In an exemplary embodiment, the first cable 126a is located above the mounting surface. Further, in an exemplary embodiment, the toggle sensor 44 has mounting structure associated with it. In the illustrated embodiment, the toggle sensor 44 has a bracket 130 and adhesive 132 that maintain the toggle sensor 44 in position on the apex of the spout.

[0090] In an exemplary embodiment, the presence sensor 46 is located above the mounting surface. As stated above, in the illustrated embodiment, the presence sensor 46 is

mounted on the upstream end of the spout 16. In an exemplary embodiment, the presence sensor 46 is mounted on a second electronic board 134. Additionally, the presence sensor 46 is mechanically and electrically connected to the electronic control 56. In the illustrated embodiment, a second cable 126b is operable to mechanically and electrically connect the presence sensor 46 to the electronic control 56 and mechanically support the presence sensor 46. In an exemplary embodiment, the second cable 126b is located above the mounting surface. In an exemplary embodiment, at least a portion of the second cable 126b is located above the mounting surface. Further, in an exemplary embodiment, the presence sensor 46 has mounting structure associated with it. In the illustrated embodiment, the presence sensor 46 has adhesive 136 that maintains the presence sensor 46 in position on the upstream end of the spout.

[0091] In an exemplary embodiment, at least a portion of the electronic control 56 is located above the mounting surface. In an exemplary embodiment, the portion of the electronic control 56 located above the mounting surface includes a control module 138. In the illustrated embodiment, the control module 138 is located in a portion of the hub 14 to which the handle 22 is mounted. An exemplary embodiment of an electronic faucet with an electronic control associated with a handle is disclosed in U.S. Patent App. No. 13/889,186 filed on May 7, 2013, which was published as U.S. Patent App. Pub. No. 2013/0291978 A1 on November 7, 2013, and which issued as U.S. Patent No. 9,212,473 B2 on December 15, 2015, for Electronic Plumbing Fixture Fitting, the entire disclosures of which are hereby incorporated by reference. In an exemplary embodiment, the control module 138 is operable to receive the signal from the toggle sensor 44 or the presence sensor 46 when the toggle sensor 44 or the presence sensor 46 is triggered and, in response, send the signal to the hot/cold water electronic valve 34/36 to activate the hot/cold water electronic valve 34/36. In an exemplary embodiment, the second cable 126b

is operable to electrically connect the presence sensor 46 to the portion of the electronic control 56 located above the mounting surface. In the illustrated embodiment, the second cable 126b is operable to electrically connect the presence sensor 46 to the control module 138.

[0092] In an exemplary embodiment, at least a portion of the electronic control 56 is located below the mounting surface. In an exemplary embodiment, the portion of the electronic control 56 located below the mounting surface includes the electronics module 52. In the illustrated embodiment, the electronics module 52 is connected to the flow module 50. In an exemplary embodiment, the electronics module 52 is operable to receive the signal from the toggle sensor 44 or the presence sensor 46 when the toggle sensor 44 or the presence sensor 46 is triggered and, in response, send the signal to the hot/cold water electronic valve 34/36 to activate the hot/cold water electronic valve 34/36. In an exemplary embodiment, at least a portion of the cable 126, such as the second cable 126b, is operable to directly electrically connect the presence sensor 46 to the portion of the electronic control 56 located below the mounting surface. In an exemplary embodiment, at least a portion of the cable 126, such as the second cable 126b, is operable to directly electrically connect the presence sensor 46 to the electronics module 52. In an exemplary embodiment, at least a portion of the cable 126 is operable to indirectly electrically connect the presence sensor 46 to the portion of the electronic control 56 located below the mounting surface. In the illustrated embodiment, a third cable 126c is operable to indirectly electrically connect the presence sensor 46 to the electronics module 52 via the second cable 126b and the control module 138.

[0093] In an exemplary embodiment, at least a portion of the electronic control 56 is located above the mounting surface, and at least a portion of the electronic control 56 is located below the mounting surface. In an exemplary embodiment, the portion of the electronic control

56 located above the mounting surface is the control module 138, and the portion of the electronic control 56 located below the mounting surface is the electronics module 52. In an exemplary embodiment, at least one of the control module 138 and the electronics module 52 is operable to receive the signal from the toggle sensor 44 or the presence sensor 46 when the toggle sensor 44 or the presence sensor 46 is triggered and, in response, send the signal to the hot/cold water electronic valve 34/36 to activate the hot/cold water electronic valve 34/36. In an exemplary embodiment, the second cable 126b is operable to electrically connect the presence sensor 46 to the portion of the electronic control 56 located above the mounting surface, and at least a portion of the cable 126, such as the second cable 126b and/or the third cable 126c, is operable to electrically connect the presence sensor 46 to the portion of the electronic control 56 located below the mounting surface. In the illustrated embodiment, the second cable 126b is operable to electrically connect the presence sensor 46 to the control module 138, and at least a portion of the cable 126, such as the second cable 126b and/or the third cable 126c, is operable to electrically connect the presence sensor 46 to the electronics module 52.

[0094] In the illustrated embodiment, the first electronic board 128 is a first flexible printed circuit board (PCB). In an exemplary embodiment, the toggle sensor 44 is surface mounted on the first flexible PCB. In the illustrated embodiment, at least a portion of the first flexible PCB is attached to a stiffener 140 that provides mechanical support. Additionally, in the illustrated embodiment, the first cable 126a operable to electrically connect the toggle sensor 44 to the presence sensor 46 is a second flexible printed circuit board (PCB). In the illustrated embodiment, at least a portion of the second flexible PCB is attached to a stiffener 140 that provides mechanical support.

[0095] In the illustrated embodiment, the second electronic board 134 is a third flexible printed circuit board (PCB). In an exemplary embodiment, the presence sensor 46 is surface mounted on the third flexible PCB. In the illustrated embodiment, at least a portion of the third flexible PCB is attached to a stiffener 140 that provides mechanical support. Additionally, in the illustrated embodiment, the second cable 126b operable to electrically connect the presence sensor 46 to the control module 138 is a fourth flexible printed circuit board (PCB). In the illustrated embodiment, at least a portion of the fourth flexible PCB is attached to a stiffener 140 that provides mechanical support.

[0096] In the illustrated embodiment, the third cable 126c operable to indirectly electrically connect the presence sensor 46 to the electronics module 52 is a communications wire.

[0097] In an exemplary embodiment, the first electronic board 128 on which the toggle sensor 44 is mounted, the first cable 126a operable to electrically connect the toggle sensor 44 to the presence sensor 46, and the second electronic board 134 on which the presence sensor 46 is mounted are integrally formed. In an exemplary embodiment, the first electronic board 128 on which the toggle sensor 44 is mounted, the first cable 126a operable to electrically connect the toggle sensor 44 to the presence sensor 46, the second electronic board 134 on which the presence sensor 46 is mounted, and the second cable 126b operable to electrically connect the presence sensor 46 to any portion of the electronic control 56 located above the mounting surface are integrally formed. In an exemplary embodiment, the first electronic board 128 on which the toggle sensor 44 is mounted, the first cable 126a operable to electrically connect the toggle sensor 44 to the presence sensor 46, the second electronic board 134 on which the presence sensor 46 is mounted, and at least the portion of the second cable 126b located above the

mounting surface are integrally formed. In the illustrated embodiment, the first flexible PCB on which the toggle sensor 44 is mounted, the second flexible PCB operable to electrically connect the toggle sensor 44 to the presence sensor 46, the third flexible PCB on which the presence sensor 46 is mounted, and the fourth flexible PCB operable to electrically connect the presence sensor 46 to the control module 138 are integrally formed. As a result, all of the sensors and the mechanical and electrical connections between the sensors and any portion of the electronic control 56 that is located above the mounting surface for the fitting do not include any separate connectors.

[0098] As stated above, the flow module 50 includes a number of inlets and outlets and a number of flow passages. These inlets/outlets and flow passages enable the easy management of the flow between the incoming supplies (i.e., the hot water supply 38 and the cold water supply 40) and the wand 20. In the illustrated embodiment, the electronic mixing valve 32, including the hot water electronic valve 34, the cold water electronic valve 36, and the housing 58, is located inside the flow module 50.

[0099] In an exemplary embodiment, as best shown in Figures 16a-18d, the flow module 50 includes the following inlets:

[00100] 1. a hot water inlet 142 operable to receive hot water from the hot water supply 38 - in the illustrated embodiment, the hot water inlet 142 of the flow module 50 includes the hot water inlet 60 of the housing 58 - as illustrated, the hot water inlet 142 fluidly connects to the hot water line 26, and

[00101] 2. a cold water inlet 144 operable to receive cold water from the cold water supply 40 - in the illustrated embodiment, the cold water inlet 144 of the flow module 50

includes the cold water inlet 62 of the housing 58 - as illustrated, the cold water inlet 144 fluidly connects to the cold water line 28.

[00102] Additionally, the flow module 50 includes the following outlet:

[00103] 1. a mixed water outlet 146 operable to discharge mixed water from the hot water electronic valve 34 and the cold water electronic valve 36 to the discharge outlet 24 - in the illustrated embodiment, the mixed water outlet 146 of the flow module 50 includes the outlet 70 of the housing 58 - as illustrated, the mixed water outlet 146 fluidly connects to the mixed water line 30 (also referred to as the flexible or wand hose 18).

[00104] Further, the flow module 50 includes the following flow passages:

[00105] 1. a hot water passage 148 operable to fluidly connect the hot water inlet 142 and the hot water electronic valve 134,

[00106] 2. a cold water passage 150 operable to fluidly connect the cold water inlet 144 and the cold water electronic valve 136, and

[00107] 3. a mixed water passage 152 operable to fluidly connect the hot water electronic valve 134, the cold water electronic valve 136, and the mixed water outlet 146.

[00108] In the illustrated embodiment, the flow module 50 includes a top side 154 and a bottom side 156. The top side 154 is opposite the bottom side 156.

[00109] In the illustrated embodiment, the hot water inlet 142, the cold water inlet 144, and the mixed water outlet 146 are located in the bottom side 156 of the flow module 50.

[00110] In an exemplary embodiment, as best shown in Figure 14a, the electronic faucet 12 includes a mounting shank 158. The mounting shank 158 extends downwardly from the hub 14. The mounting shank 158 extends through and below the mounting surface (such as the counter or sink). Additionally, the mounting shank 158 extends behind the sink. In the

illustrated embodiment, the mounting shank 158 has a hollow interior 160. In the illustrated embodiment, the mounting shank 158 has a threaded exterior 162. In the illustrated embodiment, the mounting shank has an inlet 164 and an outlet 166. In the illustrated embodiment, the outlet 166 of the mounting shank extends into the hub 14. Although the mounting shank 158 has been illustrated as having a hollow interior 160, one of ordinary skill in the art will appreciate that the mounting shank 158 could be solid. Additionally, although the mounting shank 158 has been illustrated as having a threaded exterior 162, one of ordinary skill in the art will appreciate that the mounting shank 158 could have a non-threaded exterior, such as a smooth exterior.

[00111] In an exemplary embodiment, the flow module 50 includes a bracket 168 extending therefrom. In the illustrated embodiment, the bracket 168 extends from the top side 154 of the flow module 50. In an exemplary embodiment, the bracket 168 includes a mounting portion 170. The mounting portion 170 is operable to connect to the mounting shank 158. In the illustrated embodiment, the mounting portion 170 includes a generally C-shaped clip 172 that enables the mounting portion 170 to connect to the mounting shank 158. In the illustrated embodiment, a nut 174 is operable to thread onto the mounting shank 158 and secure the generally C-shaped clip 172 to the mounting shank 158. Although the mounting portion 170 has been illustrated as including a generally C-shaped clip 172, one of ordinary skill in the art will appreciate that the mounting portion 170 could include any structure that enables the mounting portion 170 to connect to the mounting shank 158. For example, the mounting portion 170 could include a smooth bore that enables the mounting portion 170 to connect to the mounting shank 158 or a threaded bore that enables the mounting portion 170 to thread onto the mounting shank 158. Additionally, although the electronic faucet 12 has been illustrated as including a nut 174,

one of ordinary skill in the art will appreciate that any type of fastener could be used to secure the mounting portion 170 to the mounting shank 158 or a separate fastener may not be needed to secure the mounting portion 170 to the mounting shank 158.

[00112] In an exemplary embodiment, as best shown in Figures 19a and 19b, the flow module 50 is operable to mount below the mounting surface (such as the counter or sink (and more specifically, a top of the sink)). In an exemplary embodiment, the flow module 50 is operable to mount at least partially behind the sink. In an exemplary embodiment, the flow module 50 is operable to mount substantially behind the sink. In an exemplary embodiment, at least thirty percent (30%) of the flow module 50 is operable to mount behind the sink. In an exemplary embodiment, the flow module 50 is operable to mount completely behind the sink. As a result, the flow module 50 can be mounted away from other items under the mounting surface and/or utilize space under the mounting surface that would otherwise not be utilized.

[00113] As used herein, “behind the sink” means a location behind a vertical plane that extends along a rear wall of the sink, regardless of whether the location is above or below a bottom wall of the sink. Walls of the sink and locations relative to walls of the sink are defined relative to a user of the sink when the user is standing at the sink operating the electronic faucet 12 in a normal mode of operation. In the normal mode of operation, (1) a front wall is a wall of the sink closest to the user, (2) the rear wall is a wall of the sink furthest from the user, (3) side walls are two (2) walls of the sink joining the front wall to the rear wall, (4) the bottom wall is a wall of the sink joining bottom edges of the front wall, the rear wall, and the side walls, and (5) the location behind the vertical plane that extends along the rear wall of the sink is a location on a side of the vertical plane that is furthest from the user.

[00114] In an exemplary embodiment, the bracket 168 positions the wand hose 18 between the mixed water outlet 146 and the inlet 164 of the mounting shank 158 such that a portion of the wand hose 18 extends in a loop between the hose bracket 168 and the inlet 164 of the mounting shank 158. As a result, the bracket 168 ensures that the wand hose 18 is properly aligned relative to the hub 14 and the spout 16 through which the wand hose 18 extends and moves. When the wand hose 18 is properly aligned relative to the hub 14 and the spout 16, the wand 20 can be easily pulled away from and returned to the spout 16.

[00115] One of ordinary skill in the art will now appreciate that the present invention provides an electronic plumbing fixture fitting with an electronic valve including a piston and a seat, a sensor mounted on an electronic board, and a flow module, such as an electronic faucet with an electronic valve including a piston and a seat, a sensor mounted on an electronic board, and a flow module. Although the present invention has been shown and described with reference to particular embodiments, equivalent alterations and modifications will occur to those skilled in the art upon reading and understanding this specification. The present invention includes all such equivalent alterations and modifications and is limited only by the scope of the following claims in light of their full scope of equivalents.

What is claimed is:

1. An electronic plumbing fixture fitting, comprising:
 - a discharge outlet, the discharge outlet being operable to deliver water; and
 - an electronic valve, the electronic valve being operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated, the electronic valve including a piston and a seat;
 - the piston including a body and a nose;
 - the seat including a body, the body including a central opening extending therethrough;
 - the electronic valve having a sealing zone, the sealing zone being a region where a sealing member on one of the piston and the seat interfaces with the other of the piston and the seat;
 - the electronic valve having a flow control zone, at any given position of the piston relative to the seat, the flow control zone being a region where a portion of the piston interfaces with a portion of the seat;
 - wherein the sealing zone is separate from the flow control zone.
2. The electronic plumbing fixture fitting of claim 1, wherein the sealing zone is upstream of the flow control zone.
3. The electronic plumbing fixture fitting of claim 1, wherein the sealing zone is static.

4. The electronic plumbing fixture fitting of claim 1, wherein the flow control zone is dynamic.
5. The electronic plumbing fixture fitting of claim 1, wherein the sealing zone is the region where the sealing member on one of the piston and the seat is in contact with the other of the piston and the seat.
6. The electronic plumbing fixture fitting of claim 1, wherein the flow control zone is the region where the portion of the piston is at a minimum distance from the portion of the seat.
7. The electronic plumbing fixture fitting of claim 1, wherein the flow control zone is the region where a distance between the portion of the piston and the portion of the seat is less than a distance between any other portion of the piston and any other portion of the seat.
8. An electronic plumbing fixture fitting, comprising:
 - a discharge outlet, the discharge outlet being operable to deliver water; and
 - an electronic valve, the electronic valve being operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated, the electronic valve including a piston and a seat;
 - the piston including a body and a nose, the nose including a conical portion and a cylindrical portion;

the seat including a body, the body including a central opening extending therethrough, the central opening including an inlet portion, a conical portion, and a cylindrical portion;

wherein the nose of the piston is operable to be received in and move in and out of the central opening in the seat.

9. The electronic plumbing fixture fitting of claim 8, wherein a geometry of the nose of the piston generally corresponds to a geometry of the central opening in the seat.

10. The electronic plumbing fixture fitting of claim 8, wherein a geometry of the conical portion and the cylindrical portion of the piston generally corresponds to a geometry of the conical portion and the cylindrical portion of the seat.

11. The electronic plumbing fixture fitting of claim 8, wherein opposing surfaces of the conical portion and the cylindrical portion of the piston and the conical portion and the cylindrical portion of the seat are generally parallel.

12. The electronic plumbing fixture fitting of claim 8, wherein:

the conical portion of the seat has an angle;

the conical portion of the piston has an angle; and

the angle of the conical portion of the seat is less than the angle of the conical portion of the piston.

13. The electronic plumbing fixture fitting of claim 8, wherein:
the inlet portion of the seat has an angle; and
the angle of the inlet portion of the seat is between approximately twenty-five degrees and seventy-five degrees.
14. The electronic plumbing fixture fitting of claim 8, wherein, with a supply line pressure of approximately forty-five pounds per square inch and no restriction on flow downstream of the electronic valve, for a first twenty-five percent of a maximum number of steps provided by a motor of the electronic valve, a flow rate through the electronic valve does not exceed approximately six tenths gallons per minute.
15. The electronic plumbing fixture fitting of claim 8, wherein:
the electronic valve has a sealing zone, the sealing zone being a region where a sealing member on one of the piston and the seat interfaces with the other of the piston and the seat;
the electronic valve has a flow control zone, at any given position of the piston relative to the seat, the flow control zone being a region where a downstream end of the cylindrical portion of the piston interfaces with the seat; and
the sealing zone is separate from the flow control zone.
16. The electronic plumbing fixture fitting of claim 15, wherein the sealing zone is upstream of the flow control zone.

17. An electronic plumbing fixture fitting, comprising:
- a discharge outlet, the discharge outlet being operable to deliver water; and
 - an electronic valve, the electronic valve being operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated, the electronic valve including a piston and a seat;
 - the piston including a body and a nose, the nose including a dome-shaped portion;
 - the seat including a body, the body including a central opening extending therethrough, the central opening including an inlet portion and a rounded portion;
 - wherein the nose of the piston is operable to be received in and move in and out of the central opening in the seat.
18. The electronic plumbing fixture fitting of claim 17, wherein, with a supply line pressure of approximately forty-five pounds per square inch and no restriction on flow downstream of the electronic valve, for a middle seventy percent of a maximum number of steps provided by a motor of the electronic valve, an average rate of change in a flow rate through the electronic valve is in a range of approximately ten thousandths gallons per minute per step and sixteen hundredths gallons per minute per step.
19. The electronic plumbing fixture fitting of claim 17, wherein:
- the electronic valve has a sealing zone, the sealing zone being a region where a sealing member on one of the piston and the seat interfaces with the other of the piston and the seat;

the electronic valve has a flow control zone, at any given position of the piston relative to the seat, the flow control zone being a region where the dome-shaped portion of the piston interfaces with the seat; and

the sealing zone is separate from the flow control zone.

20. The electronic plumbing fixture fitting of claim 19, wherein the sealing zone is upstream of the flow control zone.

21. An electronic plumbing fixture fitting, comprising:

a discharge outlet, the discharge outlet being operable to deliver water, the discharge outlet being located above a mounting surface for the fitting;

an electronic valve, the electronic valve being operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated;

a sensor, the sensor being operable to send a signal when the sensor is triggered, the sensor being mounted on an electronic board, the sensor being located above the mounting surface;

an electronic control, the electronic control being operable to receive the signal from the sensor when the sensor is triggered and, in response, send a signal to the electronic valve to activate the electronic valve, at least a portion of the electronic control being located above the mounting surface; and

a cable, the cable being operable to electrically connect the sensor to the electronic control, at least a portion of the cable being operable to electrically connect the sensor to the portion of the electronic control located above the mounting surface;

wherein the electronic board and the portion of the cable operable to electrically connect the sensor to the portion of the electronic control located above the mounting surface are integrally formed.

22. The electronic plumbing fixture fitting of claim 21, wherein:

the electronic control includes a control module;

the control module is operable to receive the signal from the sensor when the sensor is triggered and, in response, send the signal to the electronic valve to activate the electronic valve;

the control module is located above the mounting surface; and

the cable is operable to electrically connect the sensor to the control module.

23. The electronic plumbing fixture fitting of claim 21, wherein:

the electronic control includes an electronics module;

the electronics module is operable to receive the signal from the sensor when the sensor is triggered and, in response, send the signal to the electronic valve to activate the electronic valve;

the electronics module is located below the mounting surface; and

the cable is operable to electrically connect the sensor to the electronics module.

24. The electronic plumbing fixture fitting of claim 21, wherein:
- the electronic control includes a control module and an electronics module;
 - at least one of the control module and the electronics module is operable to receive the signal from the sensor when the sensor is triggered and, in response, send the signal to the electronic valve to activate the electronic valve;
 - the control module is located above the mounting surface;
 - the electronics module is located below the mounting surface; and
 - the cable is operable to electrically connect the sensor to the control module and the electronics module.
25. The electronic plumbing fixture fitting of claim 21, wherein the electronic board is a flexible printed circuit board.
26. The electronic plumbing fixture fitting of claim 25, wherein at least a portion of the flexible printed circuit board is attached to a stiffener.
27. The electronic plumbing fixture fitting of claim 21, wherein the portion of the cable operable to electrically connect the sensor to the portion of the electronic control located above the mounting surface is a flexible printed circuit board.
28. The electronic plumbing fixture fitting of claim 27, wherein at least a portion of the flexible printed circuit board is attached to a stiffener.

29. An electronic plumbing fixture fitting, comprising:

a discharge outlet, the discharge outlet being operable to deliver water, the discharge outlet being located above a mounting surface for the fitting;

an electronic valve, the electronic valve being operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated;

a first sensor, the first sensor being operable to send a first signal when the first sensor is triggered, the first sensor being mounted on a first electronic board, the first sensor being located above the mounting surface;

a second sensor, the second sensor being operable to send a second signal when the second sensor is triggered, the second sensor being mounted on a second electronic board, the second sensor being located above the mounting surface;

an electronic control, the electronic control being operable to receive the first signal from the first sensor when the first sensor is triggered and, in response, send a first signal to the electronic valve to activate the electronic valve, the electronic control being operable to receive the second signal from the second sensor when the second sensor is triggered and, in response, send a second signal to the electronic valve to activate the electronic valve, at least a portion of the electronic control being located above the mounting surface;

a first cable, the first cable being operable to electrically connect the first sensor to the second sensor, the first cable being located above the mounting surface; and

a second cable, the second cable being operable to electrically connect the second sensor to the electronic control, at least a portion of the second cable being operable to electrically

connect the second sensor to the portion of the electronic control located above the mounting surface;

wherein the first electronic board, the second electronic board, the first cable, and at least the portion of the second cable operable to electrically connect the second sensor to the portion of the electronic control located above the mounting surface are integrally formed.

30. The electronic plumbing fixture fitting of claim 29, wherein:

the electronic control includes a control module;

the control module is operable to receive the first signal from the first sensor when the first sensor is triggered and, in response, send the first signal to the electronic valve to activate the electronic valve, the control module is operable to receive the second signal from the second sensor when the second sensor is triggered and, in response, send the second signal to the electronic valve to active the electronic valve;

the control module is located above the mounting surface; and

the second cable is operable to electrically connect the second sensor to the control module.

31. The electronic plumbing fixture fitting of claim 29, wherein:

the electronic control includes an electronics module;

the electronics module is operable to receive the first signal from the first sensor when the first sensor is triggered and, in response, send the first signal to the electronic valve to activate the electronic valve, the electronics module is operable to receive the second signal from

the second sensor when the second sensor is triggered and, in response, send the second signal to the electronic valve to active the electronic valve;

the electronics module is located below the mounting surface; and

the second cable is operable to electrically connect the second sensor to the electronics module.

32. The electronic plumbing fixture fitting of claim 29, wherein:

the electronic control includes a control module and an electronics module;

at least one of the control module and the electronics module is operable to receive the first signal from the first sensor when the first sensor is triggered and, in response, send the first signal to the electronic valve to activate the electronic valve, at least one of the control module and the electronics module is operable to receive the second signal from the second sensor when the second sensor is triggered and, in response, send the second signal to the electronic valve to active the electronic valve;

the control module is located above the mounting surface;

the electronics module is located below the mounting surface; and

the second cable is operable to electrically connect the second sensor to the control module and the electronics module.

33. The electronic plumbing fixture fitting of claim 29, wherein the first electronic board is a first flexible printed circuit board, and the first cable is a second flexible printed circuit board.

34. The electronic plumbing fixture fitting of claim 33, wherein at least a portion of the first flexible printed circuit board is attached to a stiffener, and at least a portion of the second flexible printed circuit board is attached to a stiffener.

35. The electronic plumbing fixture fitting of claim 29, wherein the second electronic board is a third flexible printed circuit board, and the portion of the second cable operable to electrically connect the second sensor to the portion of the electronic control located above the mounting surface is a fourth flexible printed circuit board.

36. The electronic plumbing fixture fitting of claim 35, wherein at least a portion of the third flexible printed circuit board is attached to a stiffener, and at least a portion of the fourth flexible printed circuit board is attached to a stiffener.

37. An electronic plumbing fixture fitting, comprising:

a discharge outlet, the discharge outlet being operable to deliver water, the discharge outlet being located above a mounting surface for the fitting;

an electronic valve, the electronic valve being operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated;

a first sensor, the first sensor being operable to send a first signal when the first sensor is triggered, the first sensor being mounted on a first electronic board, the first sensor being located above the mounting surface;

a second sensor, the second sensor being operable to send a second signal when the second sensor is triggered, the second sensor being mounted on a second electronic board, the second sensor being located above the mounting surface;

an electronic control, the electronic control being operable to receive the first signal from the first sensor when the first sensor is triggered and, in response, send a first signal to the electronic valve to activate the electronic valve, the electronic control being operable to receive the second signal from the second sensor when the second sensor is triggered and, in response, send a second signal to the electronic valve to activate the electronic valve;

a first cable, the first cable being operable to electrically connect the first sensor to the second sensor, the first cable being located above the mounting surface; and

a second cable, the second cable being operable to electrically connect the second sensor to the electronic control, at least a portion of the second cable being located above the mounting surface;

wherein the first electronic board, the second electronic board, and the first cable are integrally formed.

38. The electronic plumbing fixture fitting of claim 37, wherein:

the electronic control is located above the mounting surface; and

the second cable is integrally formed with the first electronic board, the second electronic board, and the first cable.

39. The electronic plumbing fixture fitting of claim 37, wherein:

the electronic control is located below the mounting surface; and

at least the portion of the second cable located above the mounting surface is integrally formed with the first electronic board, the second electronic board, and the first cable.

40. The electronic plumbing fixture fitting of claim 37, wherein:

at least a portion of the electronic control is located above the mounting surface;

at least a portion of the electronic control is located below the mounting surface;

at least a portion of the second cable is operable to electrically connect the second sensor to the portion of the electronic control located above the mounting surface; and

at least the portion of the second cable operable to electrically connect the second sensor to the portion of the electronic control located above the mounting surface is integrally formed with the first electronic board, the second electronic board, and the first cable.

41. An electronic plumbing fixture fitting, comprising:

a housing, the housing being operable to mount above a mounting surface, the housing including a spout and a wand, the wand being operable to pull away from the spout, the wand including a discharge outlet operable to deliver water;

a mounting shank, the mounting shank being operable to extend downwardly from the housing, the mounting shank being operable to extend through and below the mounting surface, the mounting shank being operable to extend behind a sink mounted in the mounting surface;

an electronic valve, the electronic valve being operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated;

a flow module, the electronic valve being located inside the flow module, the flow module including:

a bracket, the bracket including a mounting portion, the mounting portion being operable to connect to the mounting shank,

a hot water inlet operable to receive hot water from a hot water supply,

a hot water passage operable to fluidly connect the hot water inlet and the electronic valve,

a cold water inlet operable to receive cold water from a cold water supply,

a cold water passage operable to fluidly connect the cold water inlet and the electronic valve,

a mixed water outlet operable to discharge mixed water to the discharge outlet, and

a mixed water passage operable to fluidly connect the electronic valve and the mixed water outlet; and

a wand hose, the wand hose being operable to fluidly connect the mixed water outlet and the wand, the wand hose extending below the mounting surface and through the mounting surface and the spout;

wherein the flow module is operable to mount below the mounting surface and on the mounting shank.

42. The electronic plumbing fixture fitting of claim 41, wherein the flow module is operable to mount at least partially behind the sink.

43. The electronic plumbing fixture fitting of claim 41, wherein the flow module is operable to mount substantially behind the sink.

44. The electronic plumbing fixture fitting of claim 41, wherein at least thirty percent of the flow module is operable to mount behind the sink.

45. The electronic plumbing fixture fitting of claim 41, wherein the flow module is operable to mount completely behind the sink.

46. The electronic plumbing fixture fitting of claim 41, further including:

a sensor, the sensor being operable to send a signal when the electronic valve is to be activated; and

an electronics module, the electronics module being operable to receive the signal from the sensor when the electronic valve is to be activated and, in response, send a signal to the electronic valve to activate the electronic valve, the electronics module being operable to connect to the flow module.

47. An electronic plumbing fixture fitting, comprising:

a housing, the housing being operable to mount above a mounting surface, the housing including a spout and a wand, the wand being operable to pull away from the spout, the wand including a discharge outlet operable to deliver water;

a mounting shank, the mounting shank being operable to extend downwardly from the housing, the mounting shank being operable to extend through and below the mounting surface, the mounting shank being operable to extend behind a sink mounted in the mounting surface;

an electronic valve, the electronic valve being operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated;

a flow module, the electronic valve being located inside the flow module, the flow module including:

a bracket, the bracket including a mounting portion, the mounting portion being operable to connect to the mounting shank, the mounting portion including a generally C-shaped clip that is operable to connect to the mounting shank,

a hot water inlet operable to receive hot water from a hot water supply,

a hot water passage operable to fluidly connect the hot water inlet and the electronic valve,

a cold water inlet operable to receive cold water from a cold water supply,

a cold water passage operable to fluidly connect the cold water inlet and the electronic valve,

a mixed water outlet operable to discharge mixed water to the discharge outlet,
and

a mixed water passage operable to fluidly connect the electronic valve and the mixed water outlet; and

a wand hose, the wand hose being operable to fluidly connect the mixed water outlet and the wand, the wand hose extending below the mounting surface and through the mounting surface and the spout;

wherein the flow module is operable to mount below the mounting surface and on the mounting shank.

48. The electronic plumbing fixture fitting of claim 47, wherein the flow module is operable to mount at least partially behind the sink.

49. The electronic plumbing fixture fitting of claim 47, wherein the flow module is operable to mount substantially behind the sink.

50. The electronic plumbing fixture fitting of claim 47, wherein at least thirty percent of the flow module is operable to mount behind the sink.

51. The electronic plumbing fixture fitting of claim 47, wherein the flow module is operable to mount completely behind the sink.

52. The electronic plumbing fixture fitting of claim 47, wherein:

the flow module includes a top side and a bottom side, the top side being opposite the bottom side;

the bracket extends from the top side of the flow module; and

the hot water inlet, the cold water inlet, and the mixed water outlet are located in the bottom side of the flow module.

53. The electronic plumbing fixture fitting of claim 47, further including:

a sensor, the sensor being operable to send a signal when the electronic valve is to be activated; and

an electronics module, the electronics module being operable to receive the signal from the sensor when the electronic valve is to be activated and, in response, send a signal to the electronic valve to activate the electronic valve, the electronics module being operable to connect to the flow module.

54. An electronic plumbing fixture fitting, comprising:

a housing, the housing being operable to mount above a mounting surface, the housing including a spout and a wand, the wand being operable to pull away from the spout, the wand including a discharge outlet operable to deliver water;

a mounting shank, the mounting shank being operable to extend downwardly from the housing, the mounting shank being operable to extend through and below the mounting surface, the mounting shank being operable to extend behind a sink mounted in the mounting surface;

an electronic valve, the electronic valve being operable to permit flow of water through the discharge outlet when the electronic valve is activated and to not permit flow of water through the discharge outlet when the electronic valve is deactivated;

a flow module, the electronic valve being located inside the flow module, the flow module including:

a top side and a bottom side, the top side being opposite the bottom side;

a bracket, the bracket extending from the top side of the flow module, the bracket including a mounting portion, the mounting portion being operable to connect to the mounting shank,

a hot water inlet operable to receive hot water from a hot water supply, the hot water inlet being located in the bottom side of the flow module,

a hot water passage operable to fluidly connect the hot water inlet and the electronic valve,

a cold water inlet operable to receive cold water from a cold water supply, the cold water inlet being located in the bottom side of the flow module,

a cold water passage operable to fluidly connect the cold water inlet and the electronic valve,

a mixed water outlet operable to discharge mixed water to the discharge outlet, the mixed water outlet being located in the bottom side of the flow module, and

a mixed water passage operable to fluidly connect the electronic valve and the mixed water outlet; and

a wand hose, the wand hose being operable to fluidly connect the mixed water outlet and the wand, the wand hose extending below the mounting surface and through the mounting surface and the spout;

wherein the flow module is operable to mount below the mounting surface and on the mounting shank.

55. The electronic plumbing fixture fitting of claim 54, wherein the flow module is operable to mount at least partially behind the sink.

56. The electronic plumbing fixture fitting of claim 54, wherein the flow module is operable to mount substantially behind the sink.

57. The electronic plumbing fixture fitting of claim 54, wherein at least thirty percent of the flow module is operable to mount behind the sink.

58. The electronic plumbing fixture fitting of claim 54, wherein the flow module is operable to mount completely behind the sink.

59. The electronic plumbing fixture fitting of claim 54, wherein the mounting portion of the bracket include a generally C-shaped clip that is operable to connect to the mounting shank.

60. The electronic plumbing fixture fitting of claim 54, further including:

a sensor, the sensor being operable to send a signal when the electronic valve is to be activated; and

an electronics module, the electronics module being operable to receive the signal from the sensor when the electronic valve is to be activated and, in response, send a signal to the electronic valve to activate the electronic valve, the electronics module being operable to connect to the flow module.

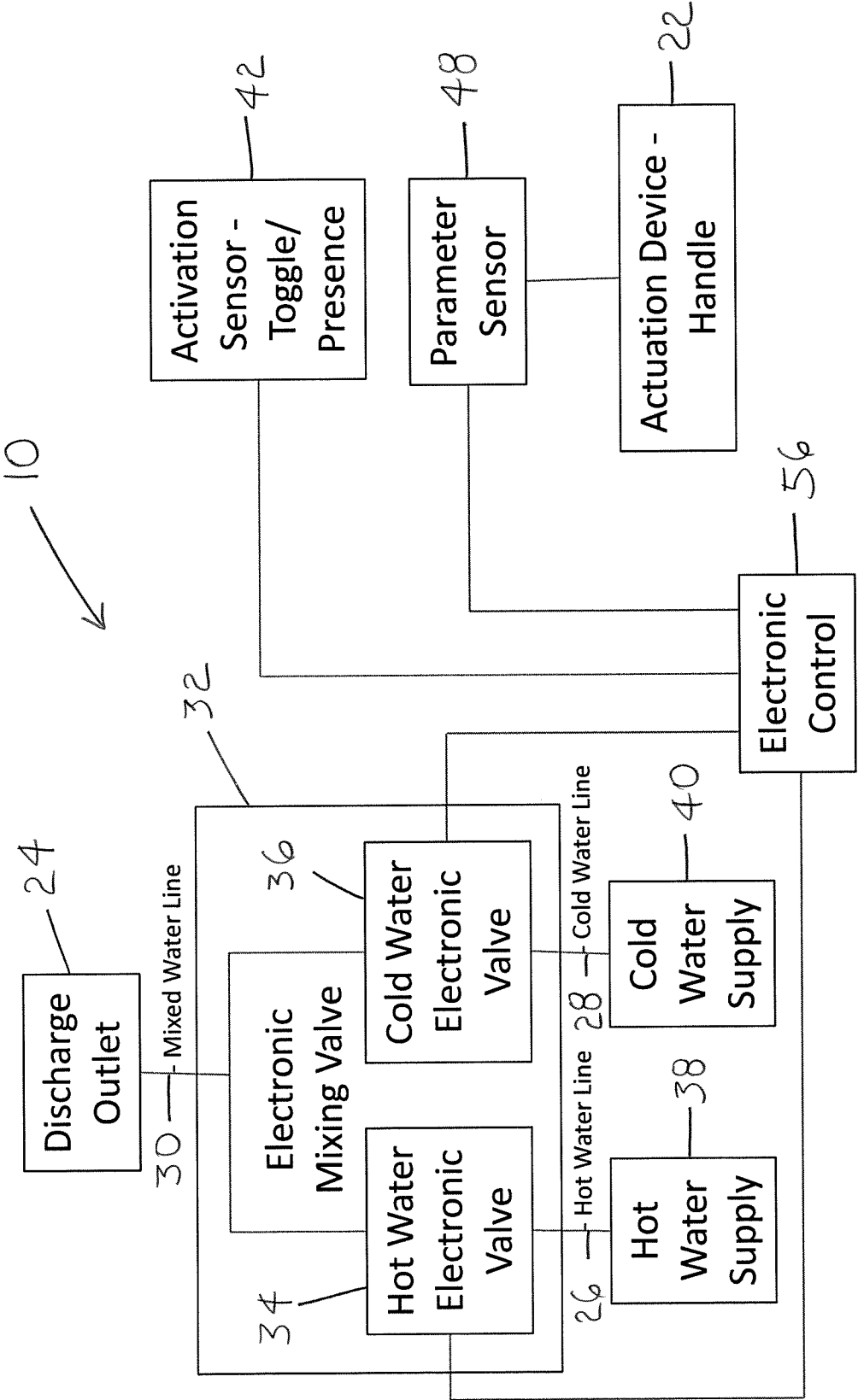


Figure 1

2/46

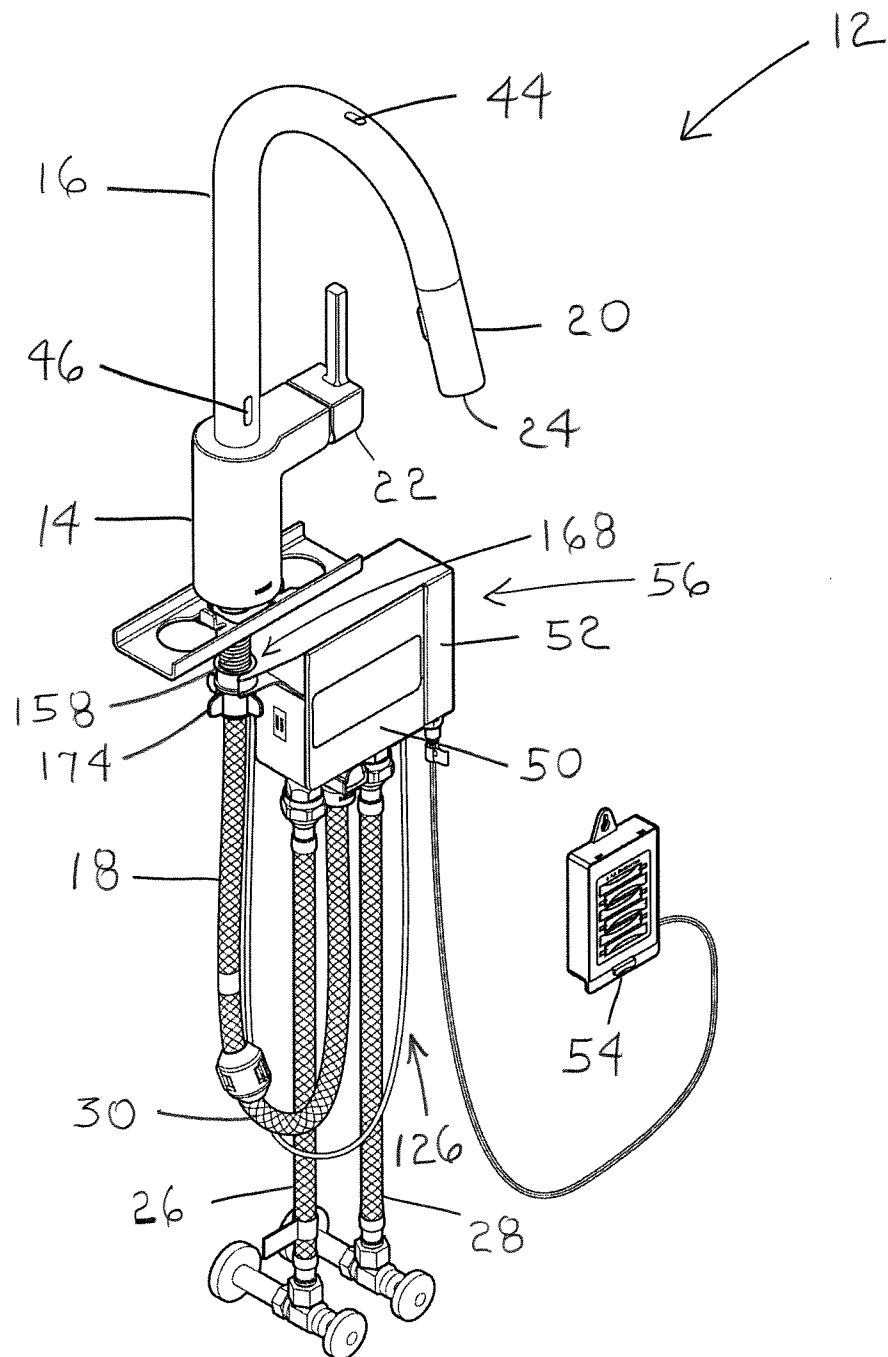


Figure 2

3/46

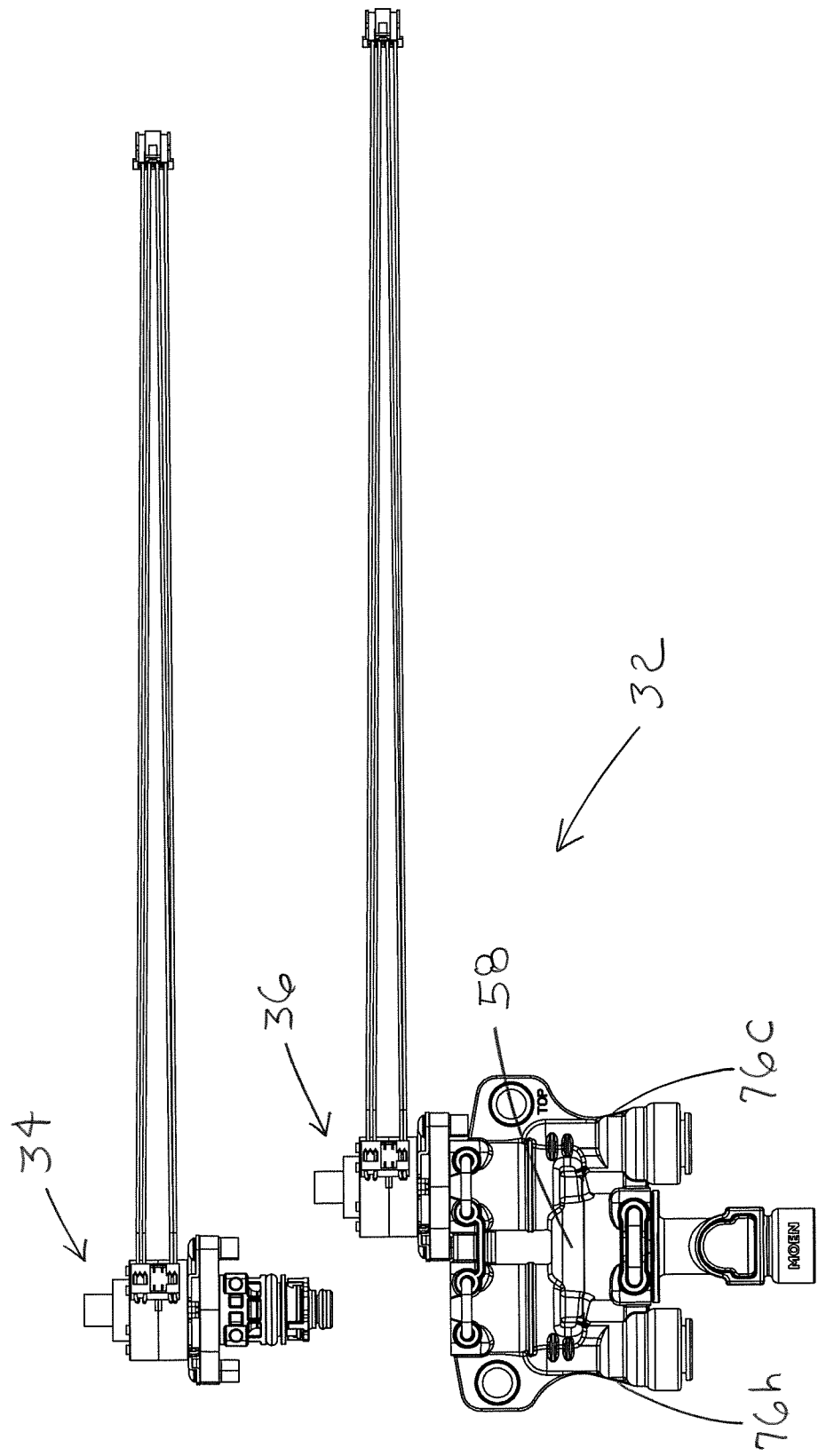


Figure 3a

4/46

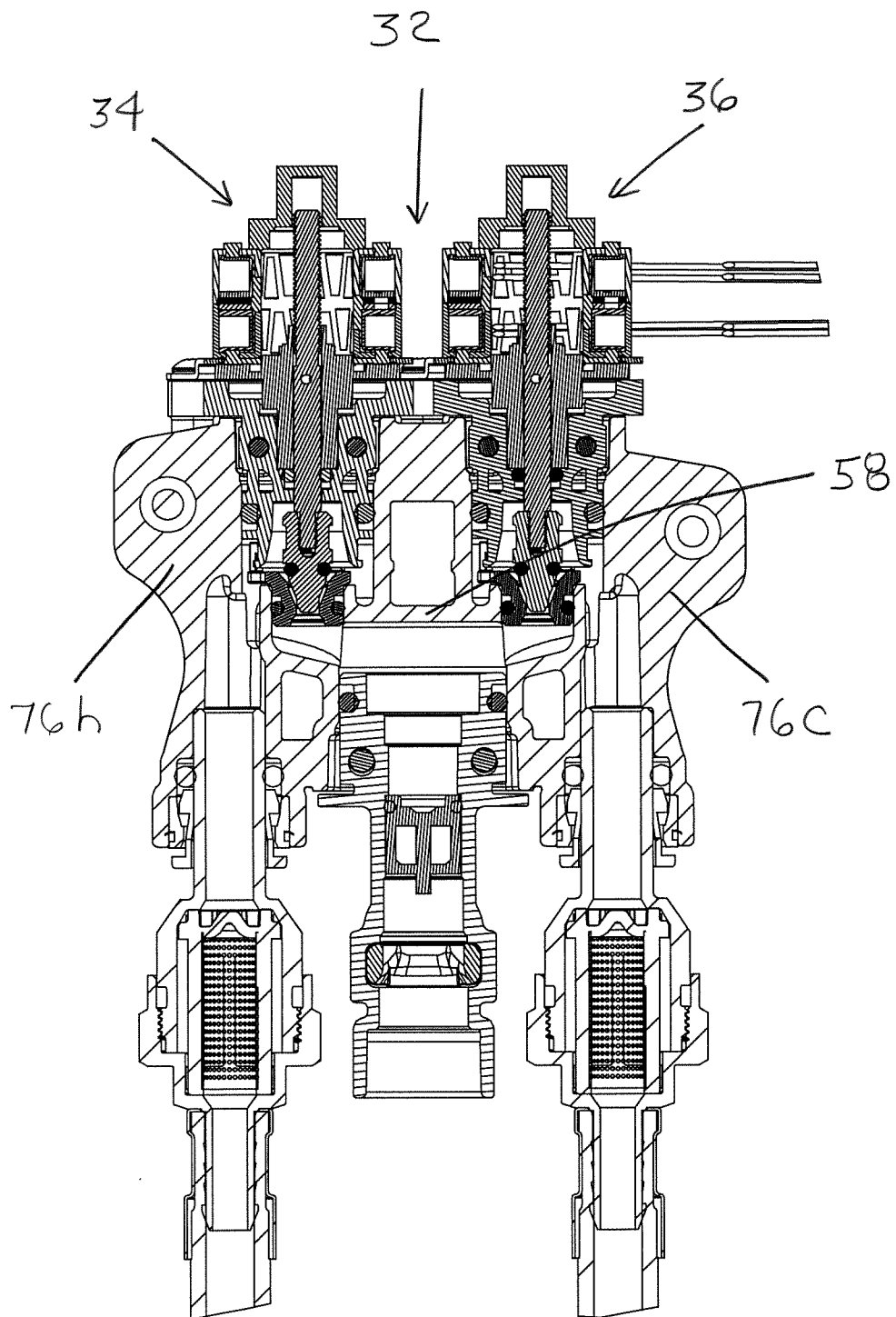


Figure 3b

5/46

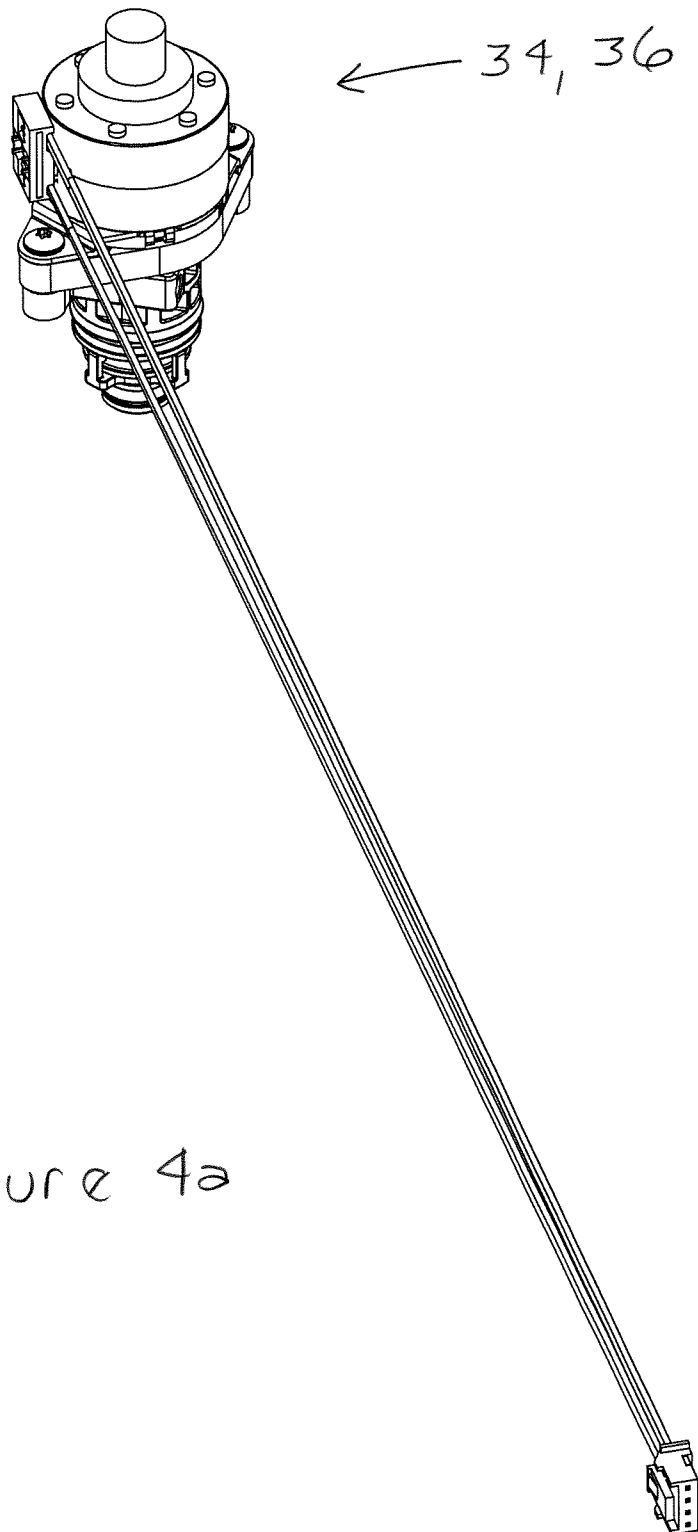


Figure 4a

6/46

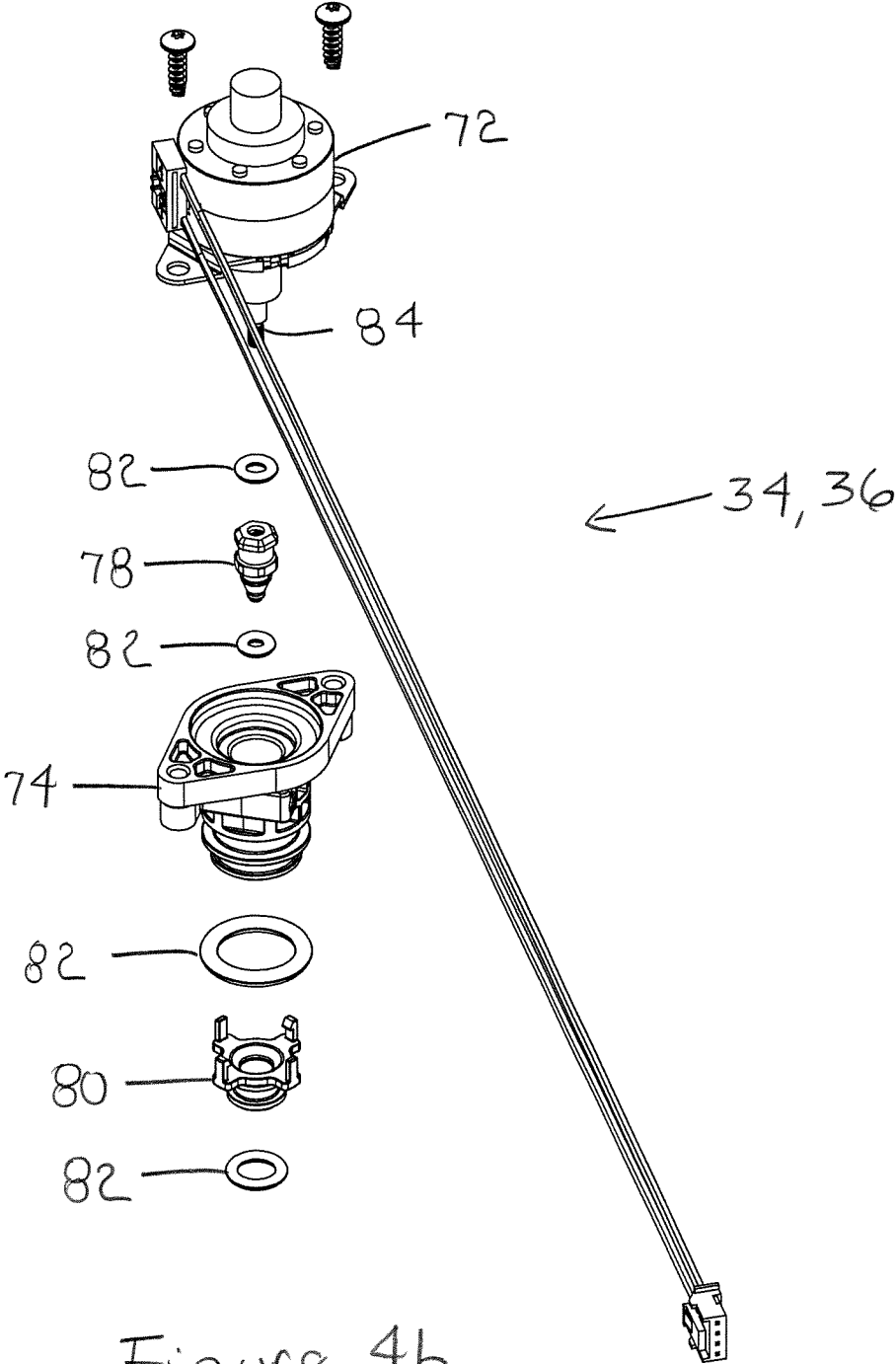


Figure 4b

7/46

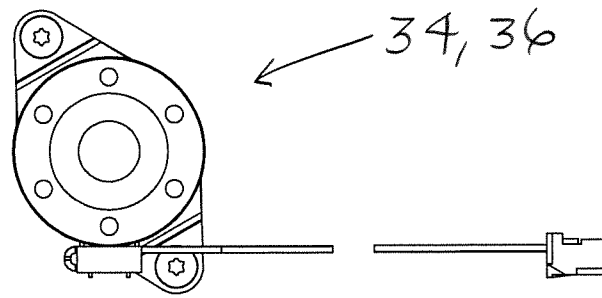


Figure 4d

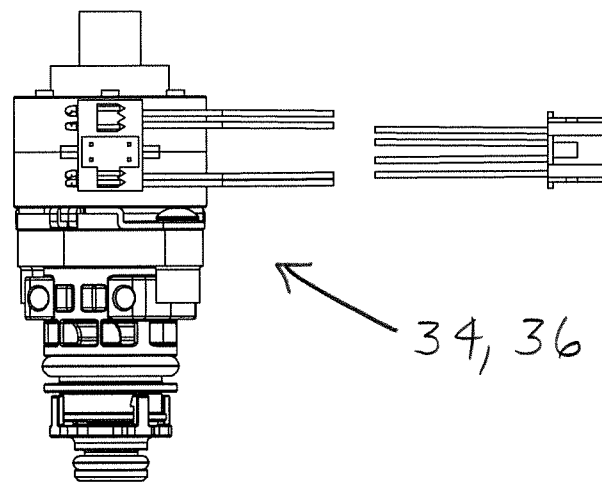


Figure 4c

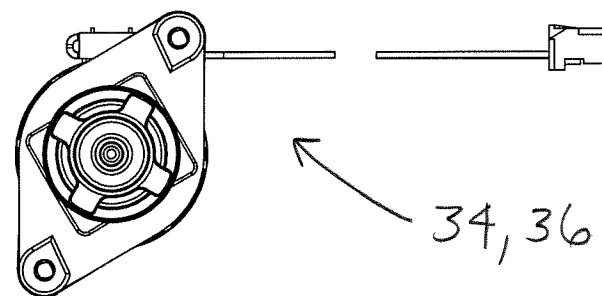


Figure 4e

8/46

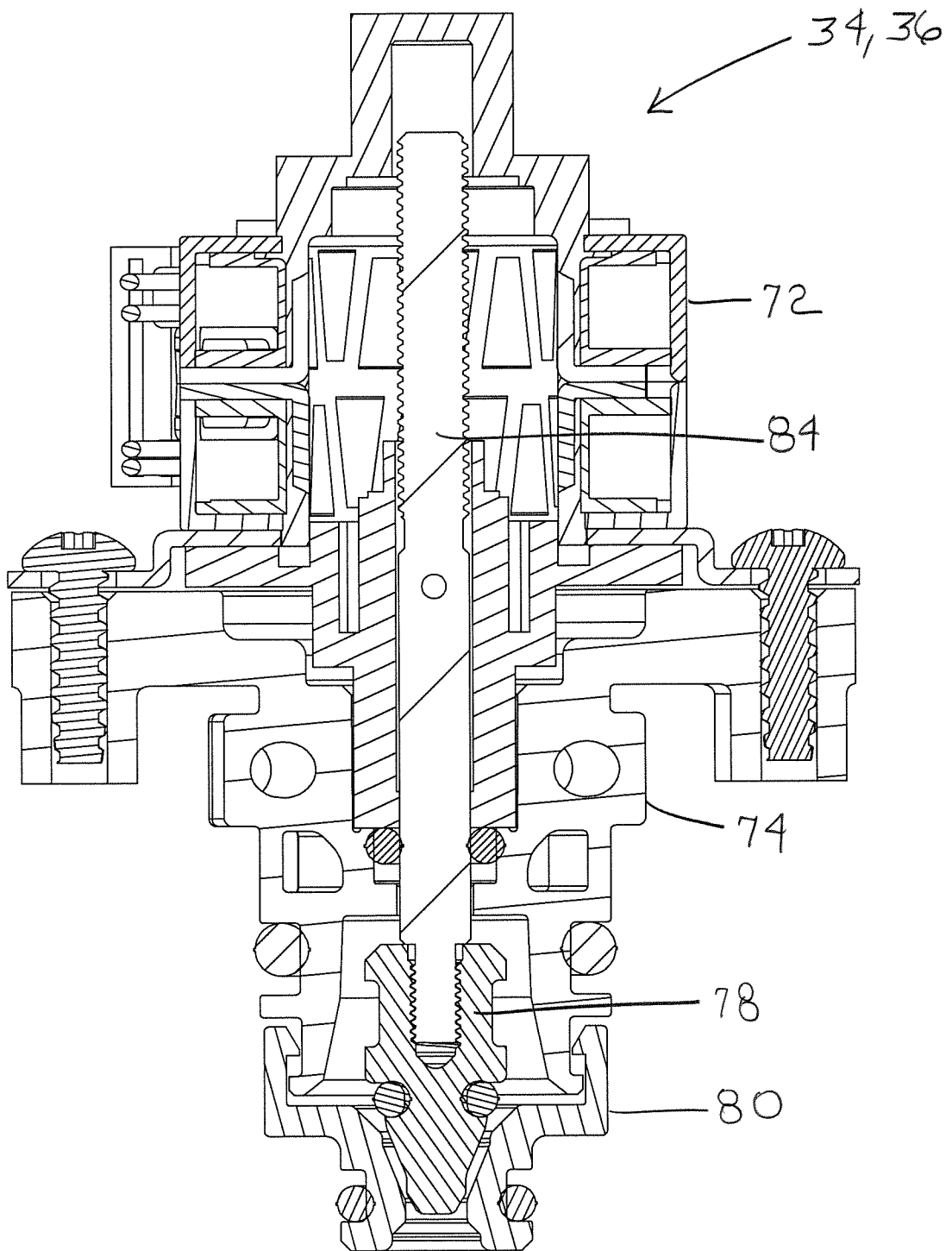


Figure 4f

9/46

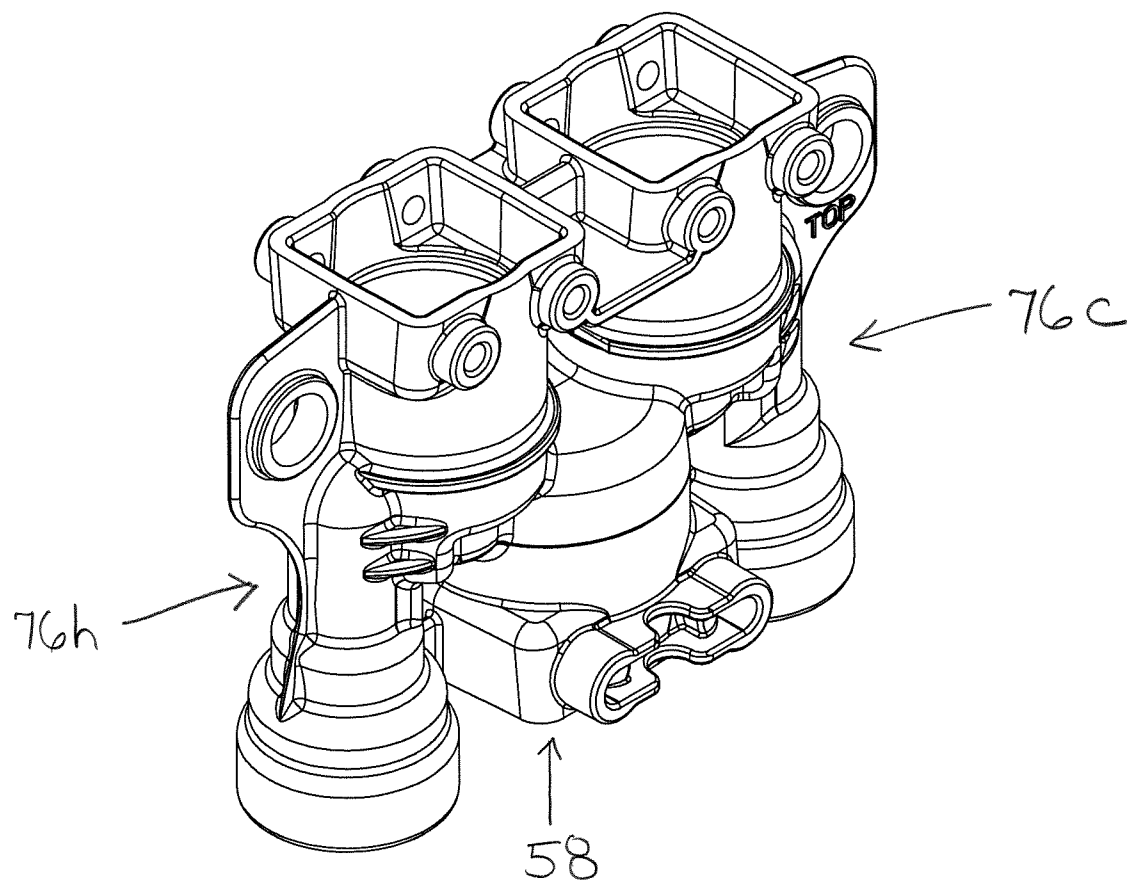


Figure 5a

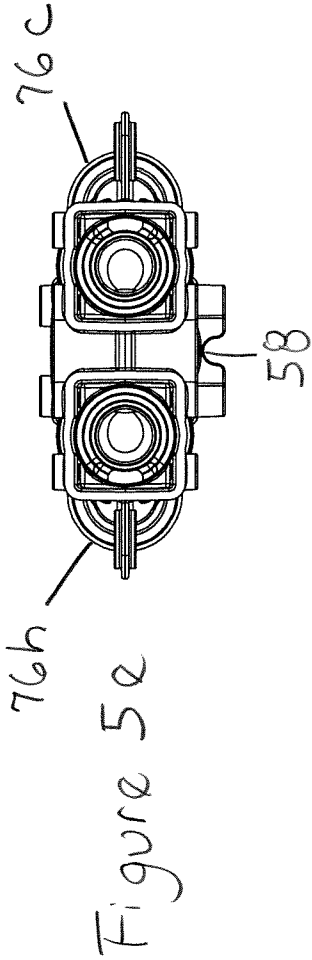


Figure 5c

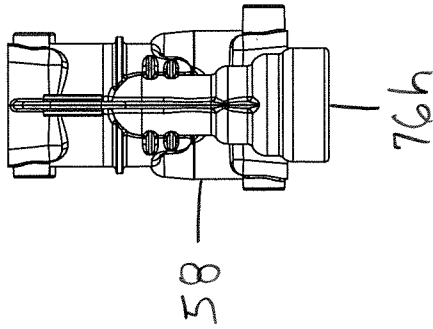


Figure 5b

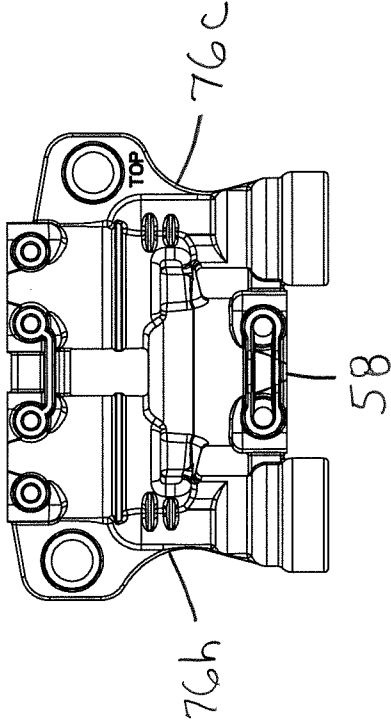
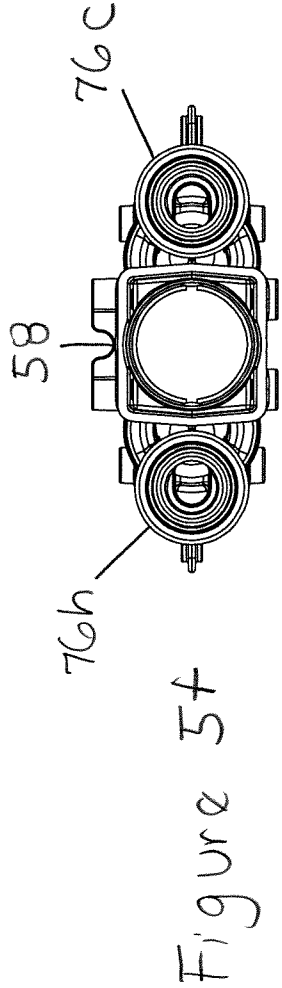
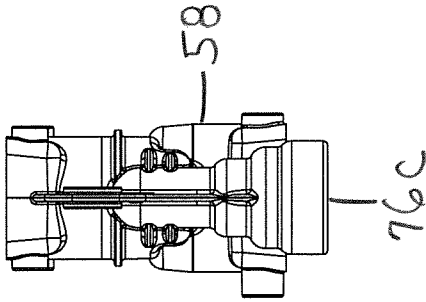
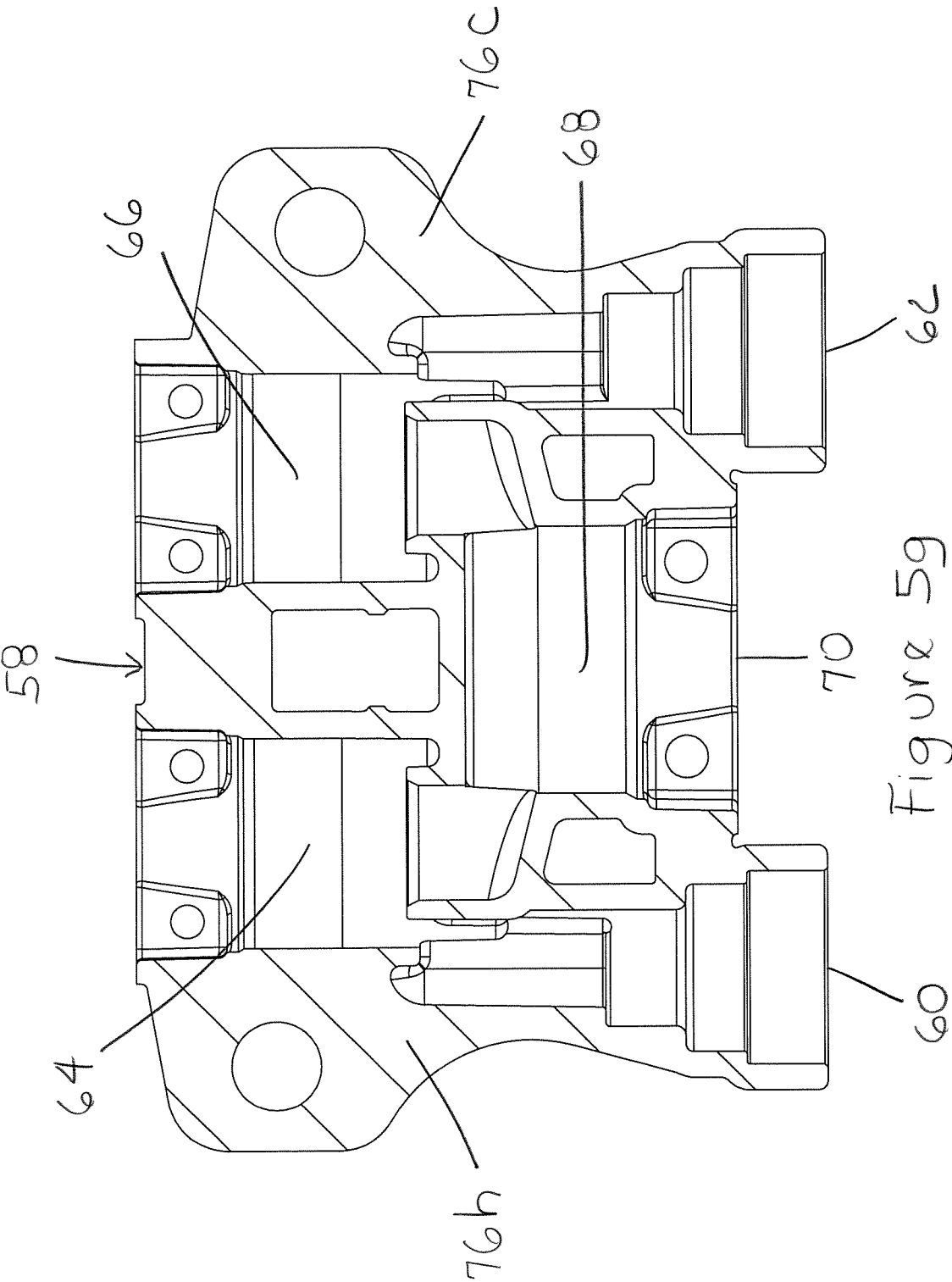
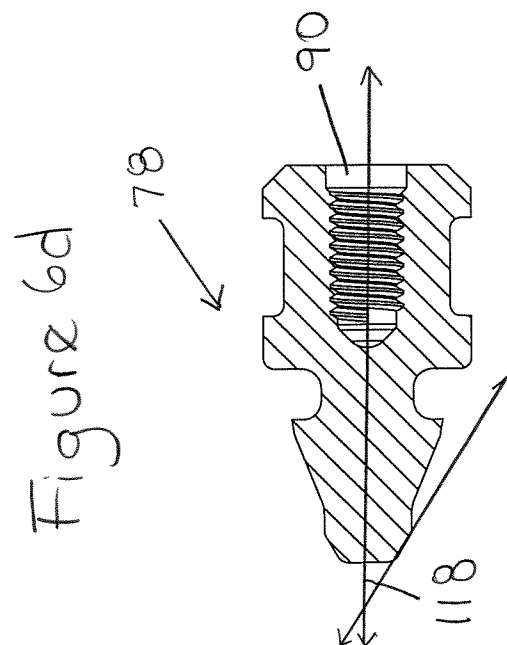
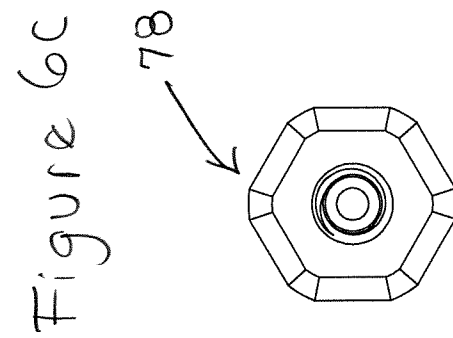
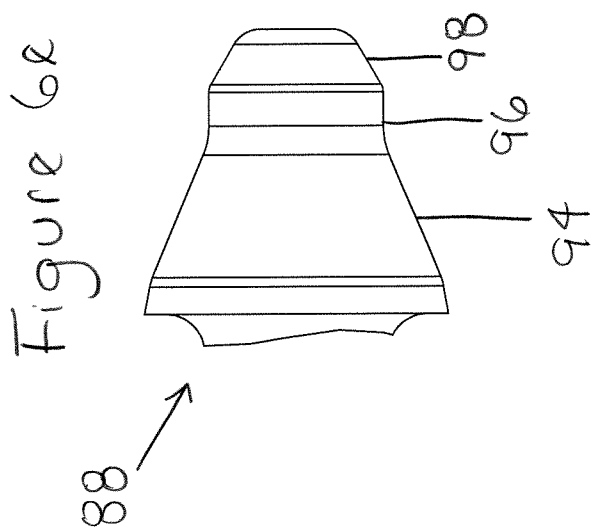
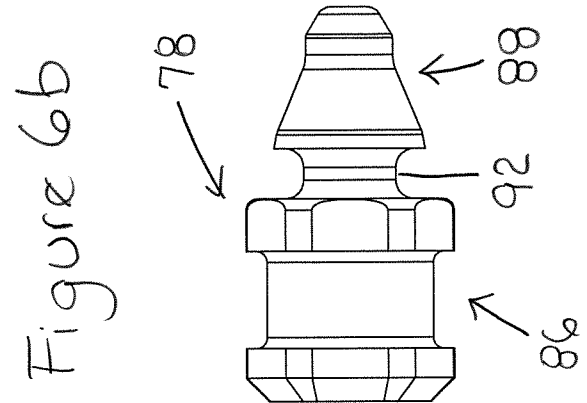
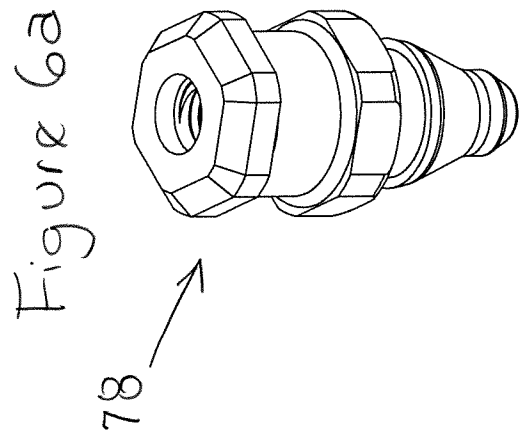


Figure 5d





12/46



13/46

Figure 7a

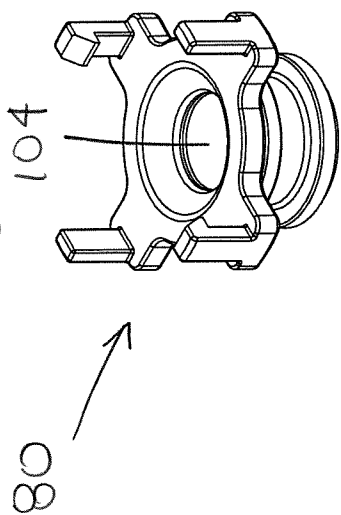


Figure 7b

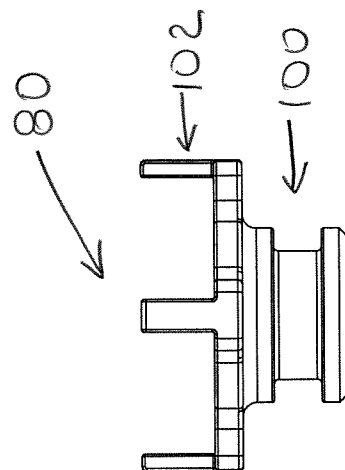


Figure 7c

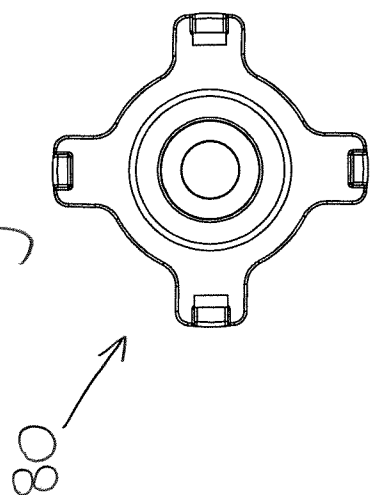


Figure 7d

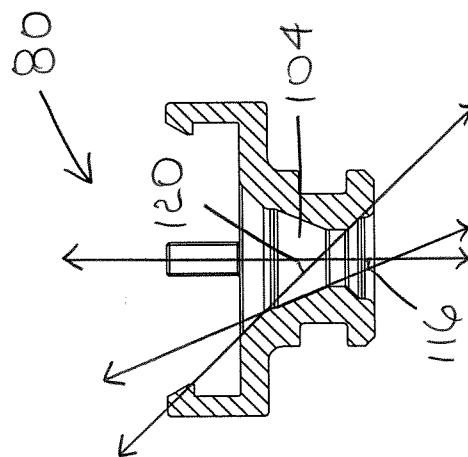
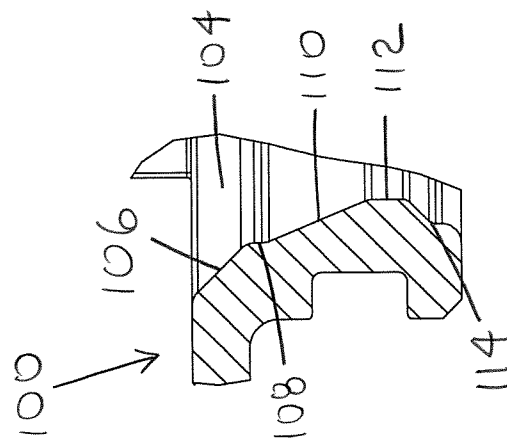
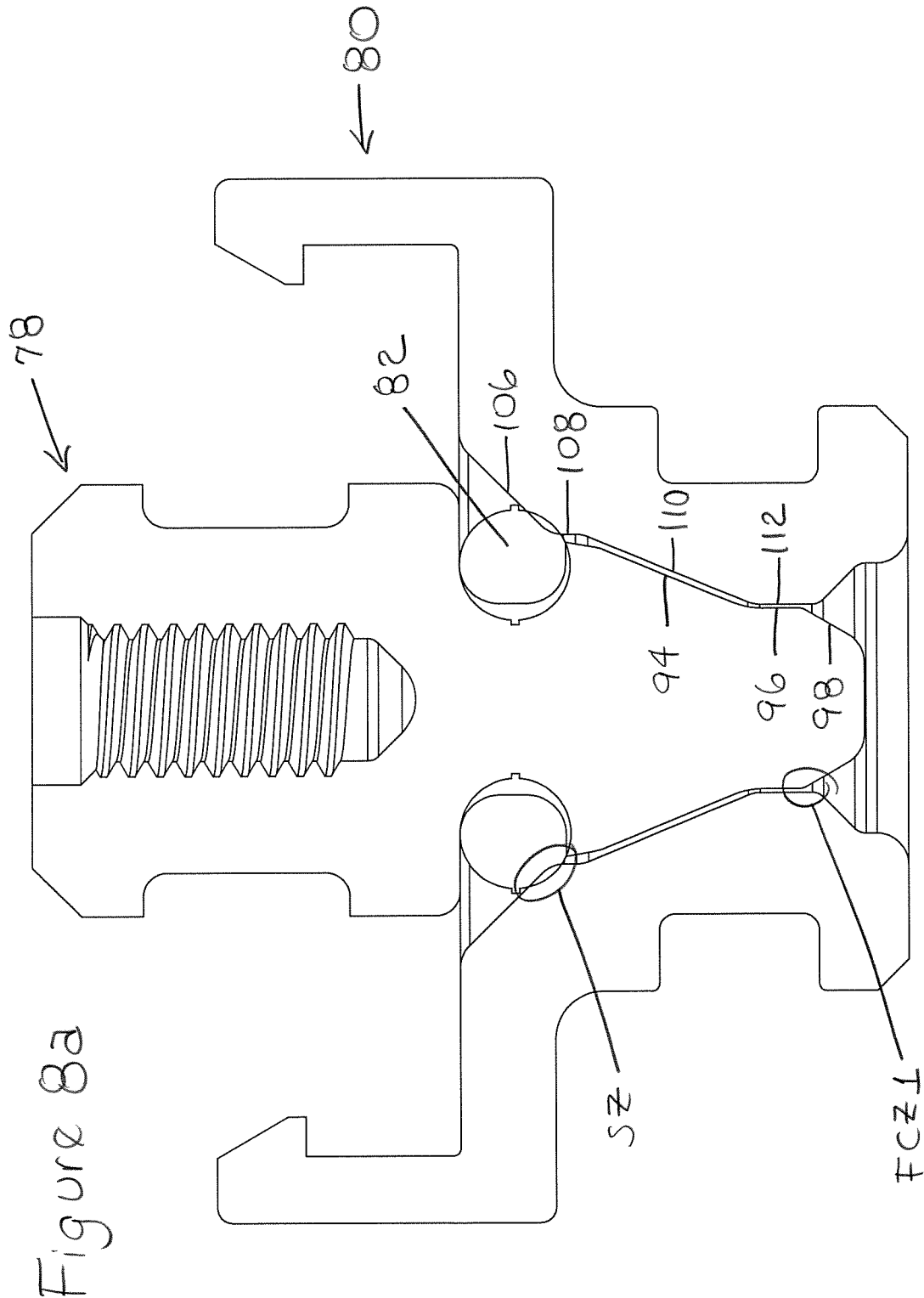


Figure 7e





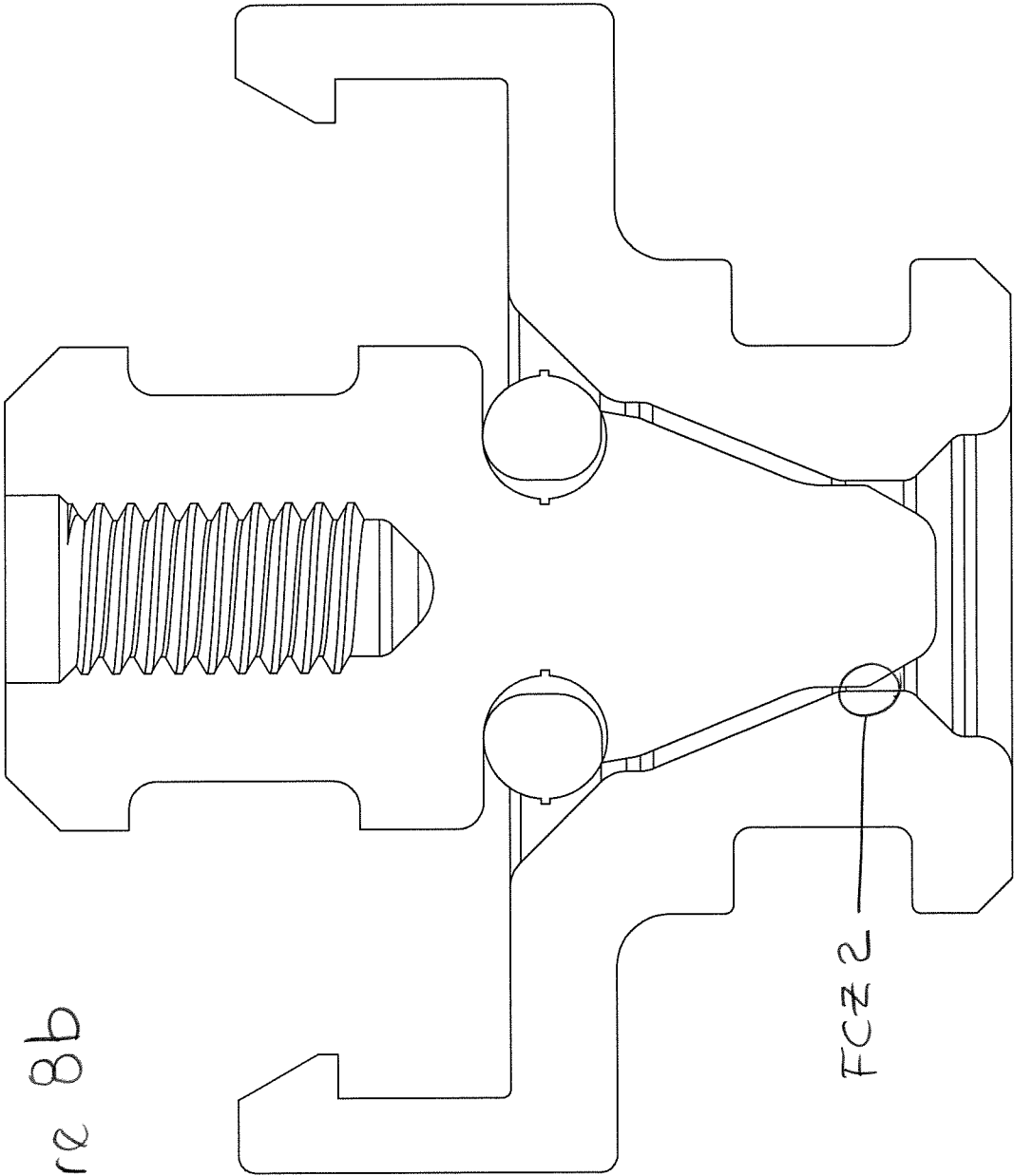


Figure 8b

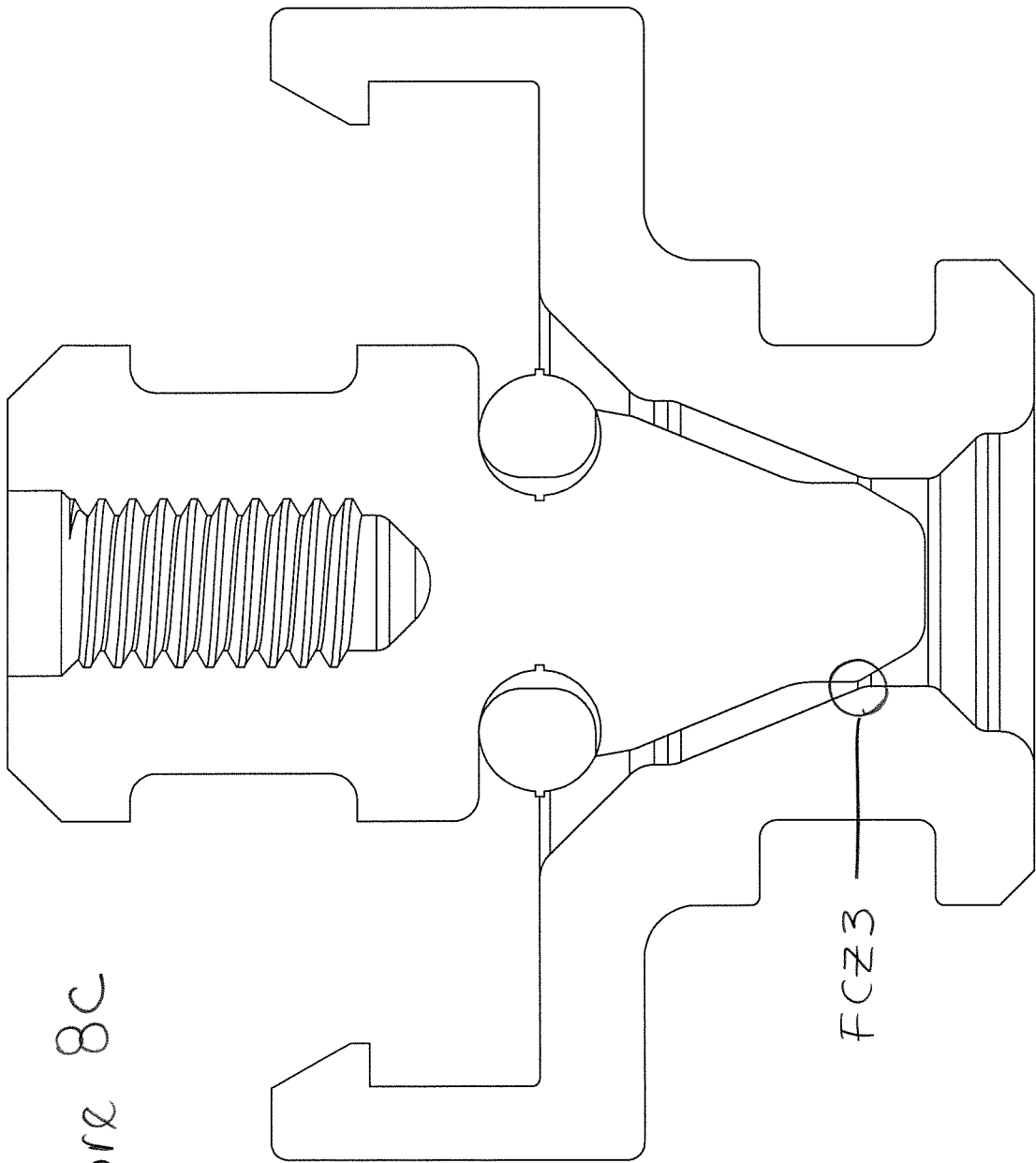


Figure 8c

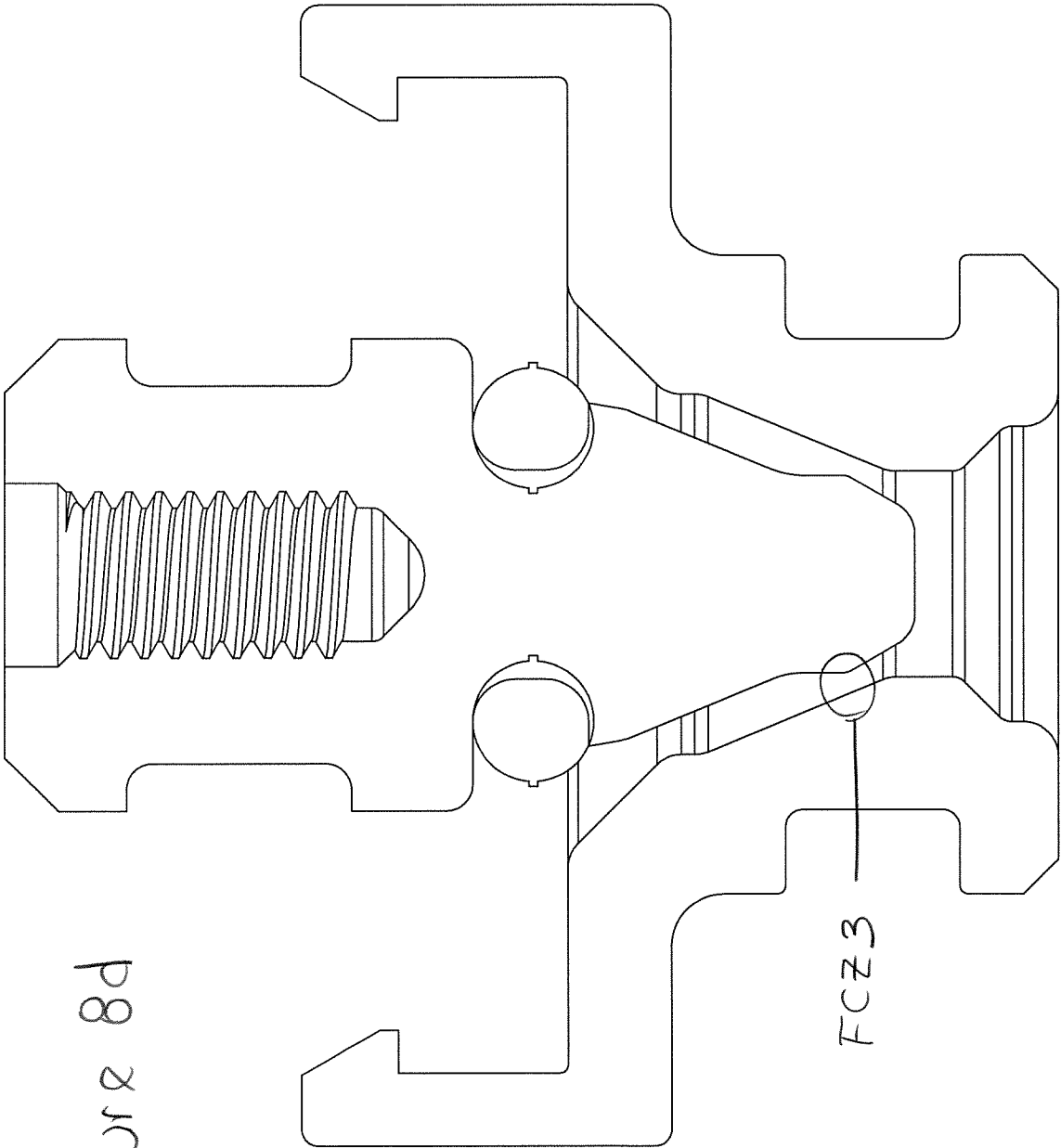


Figure 8d

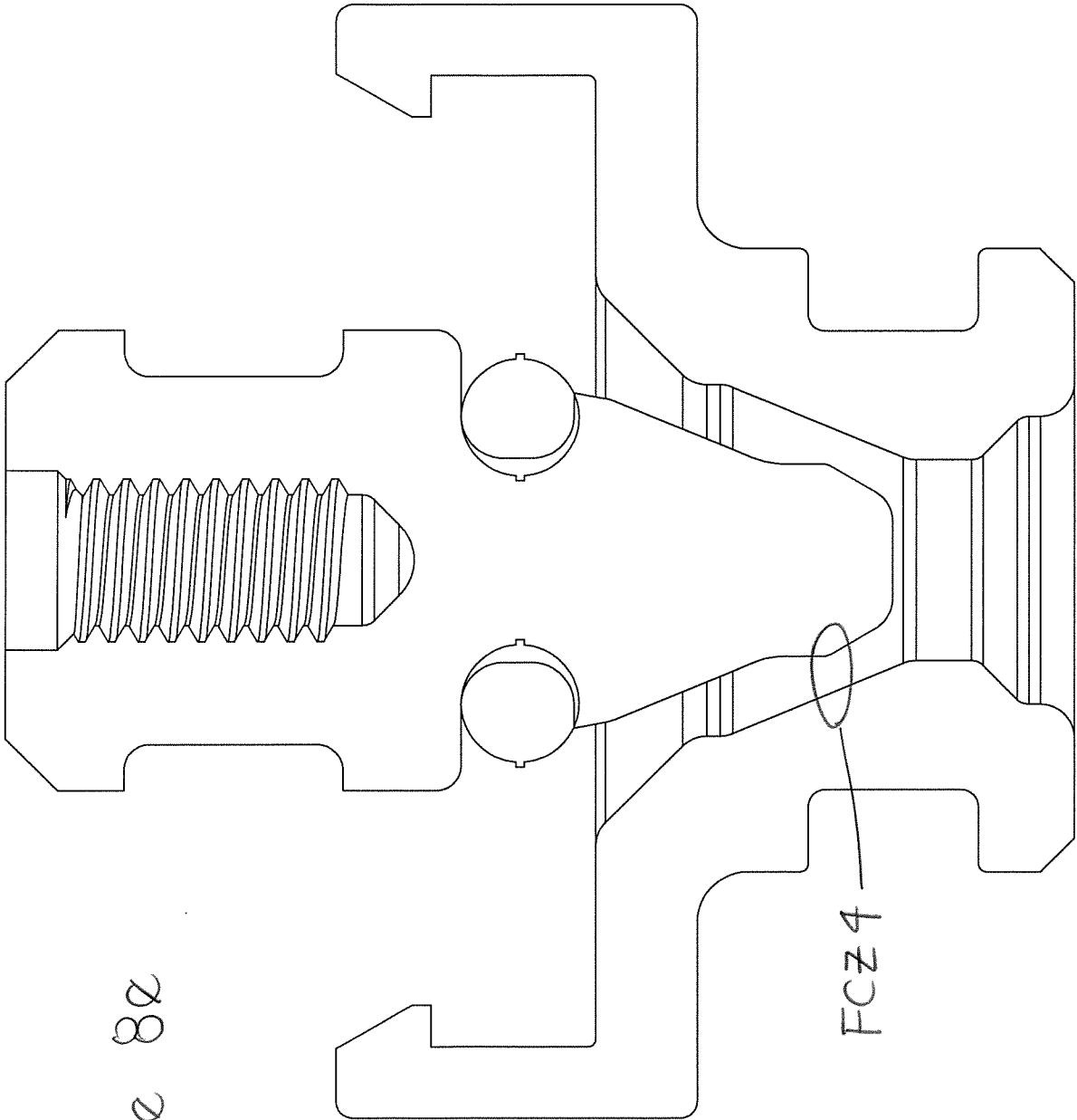


Figure 8a

78' Figure 9a

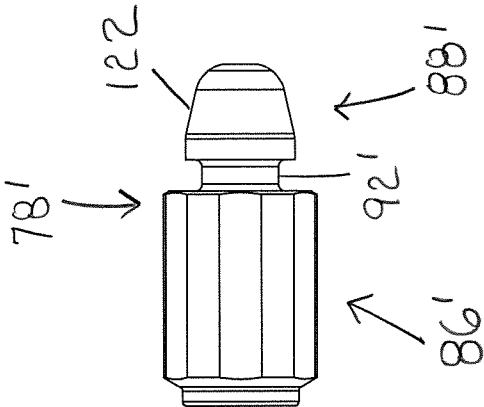
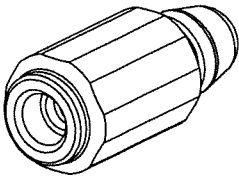


Figure 9b

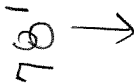


Figure 9c

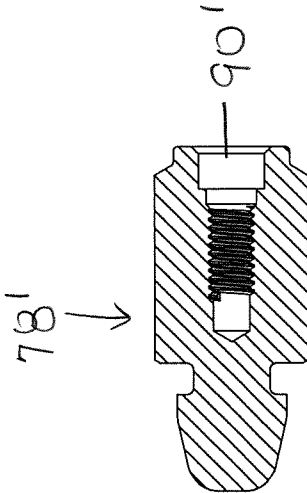
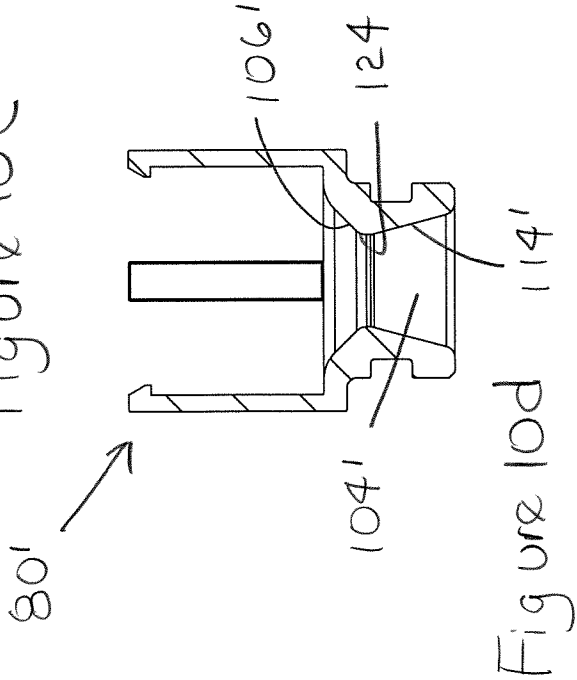
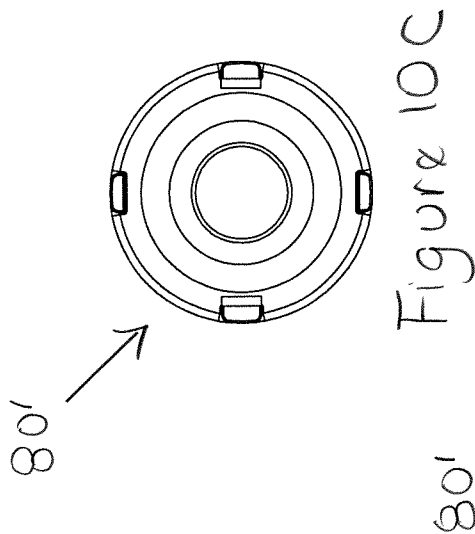
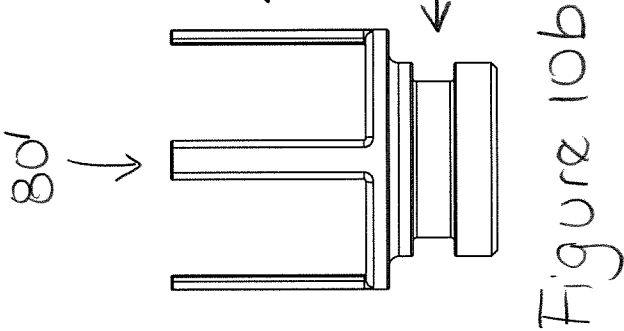
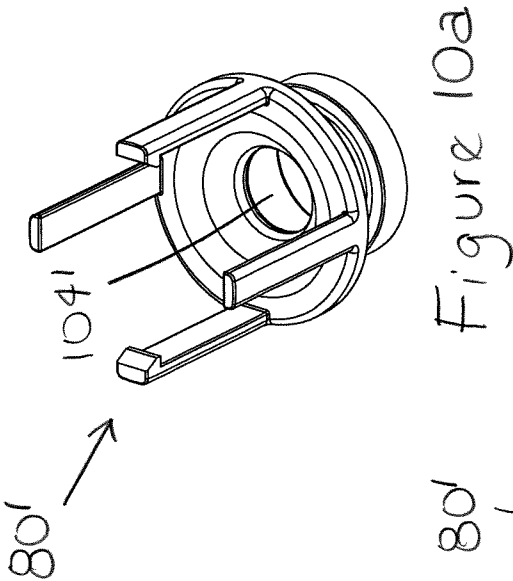


Figure 9d



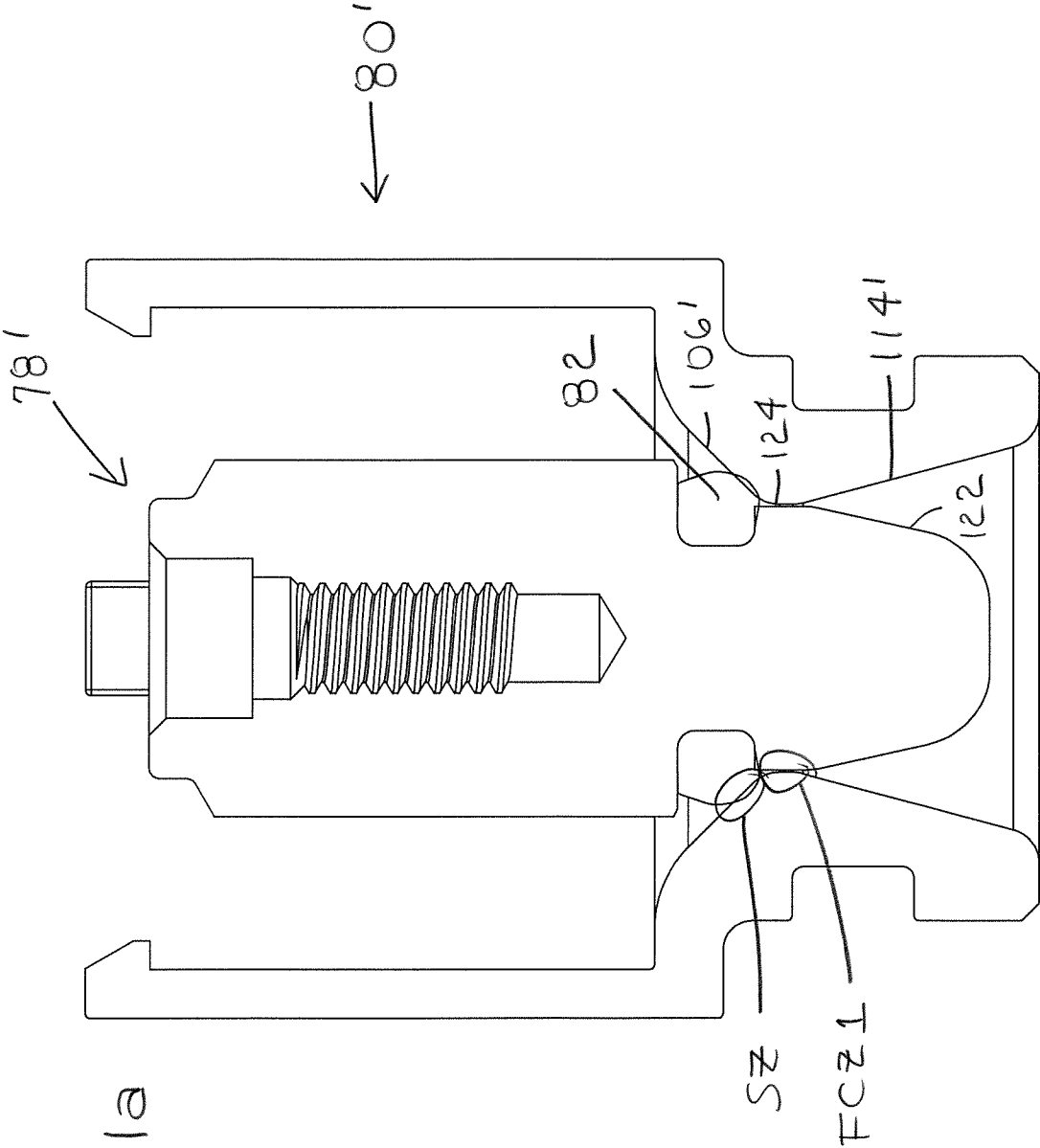


Figure 11a

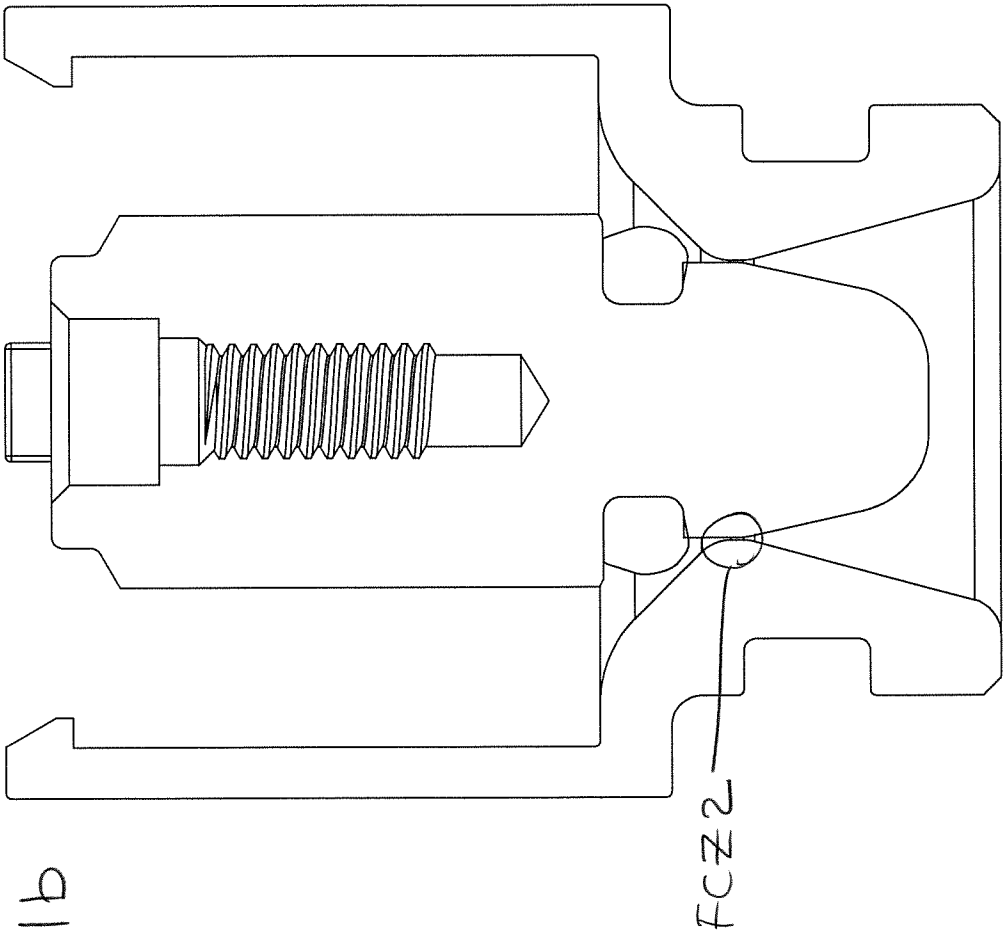


Figure 11b

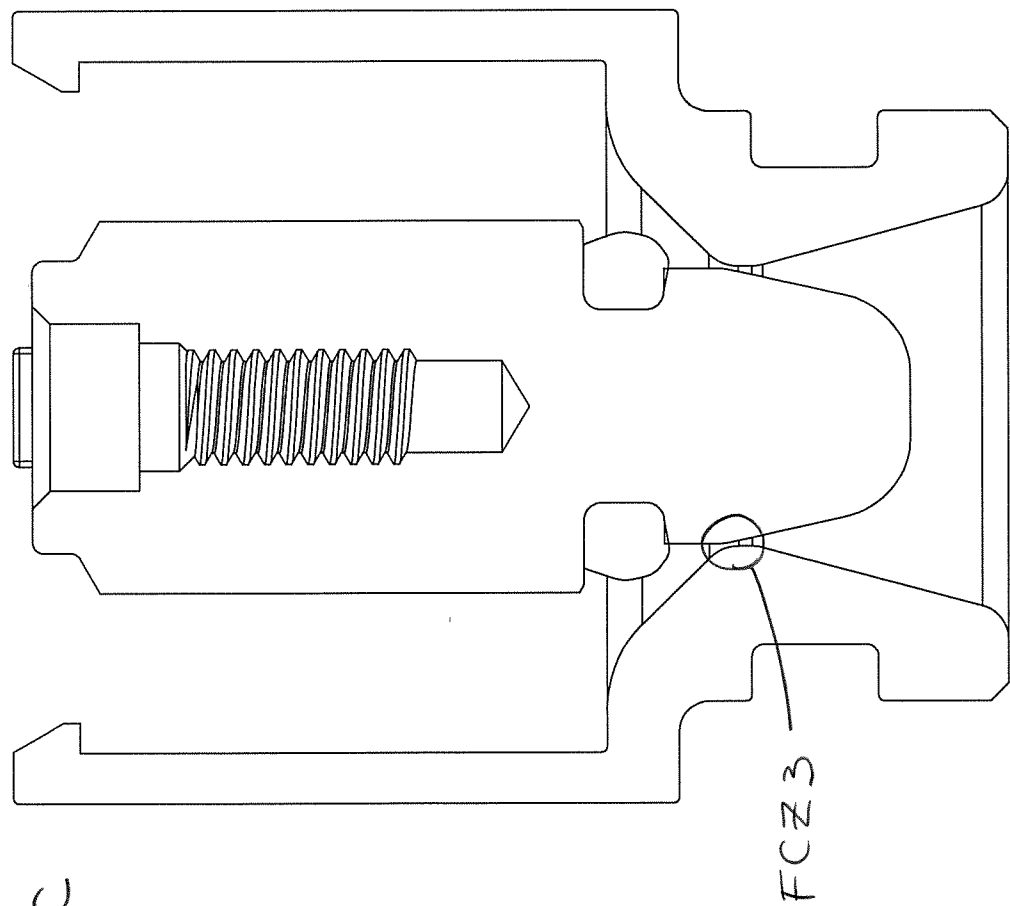


Figure 11c

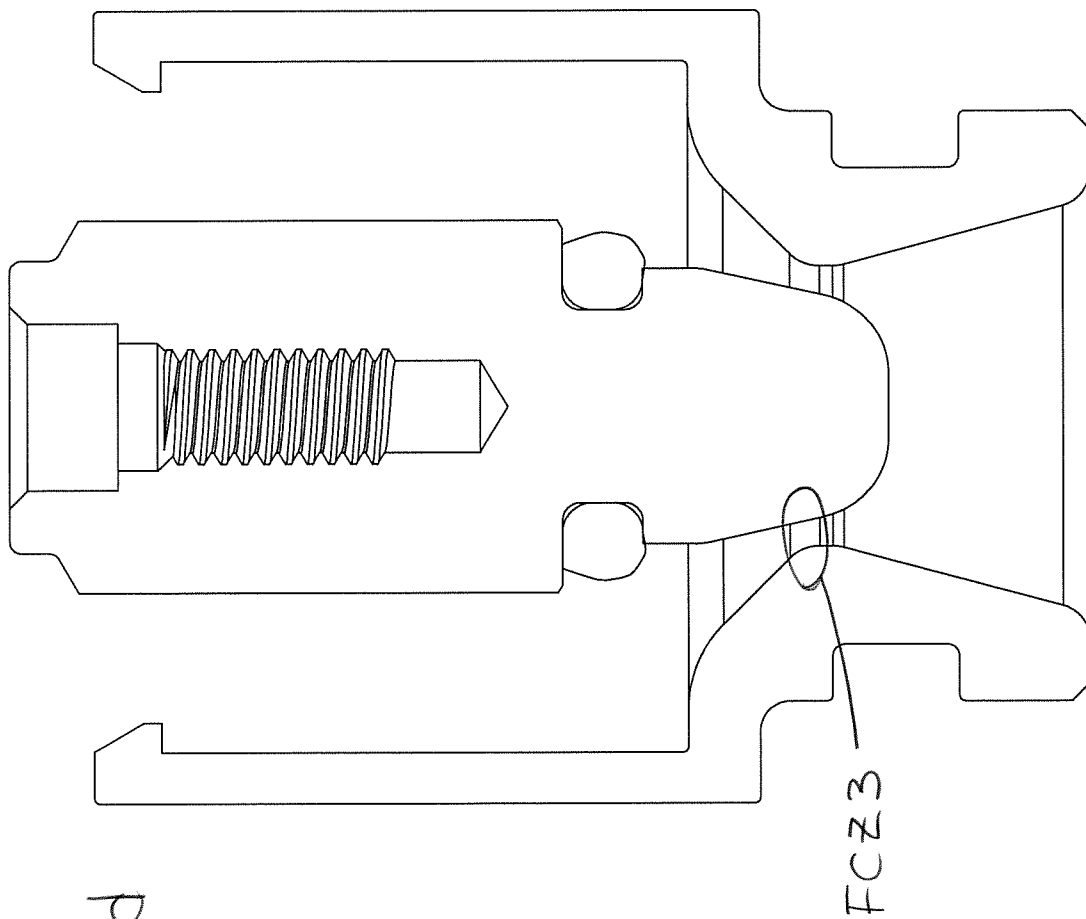


Figure 11d

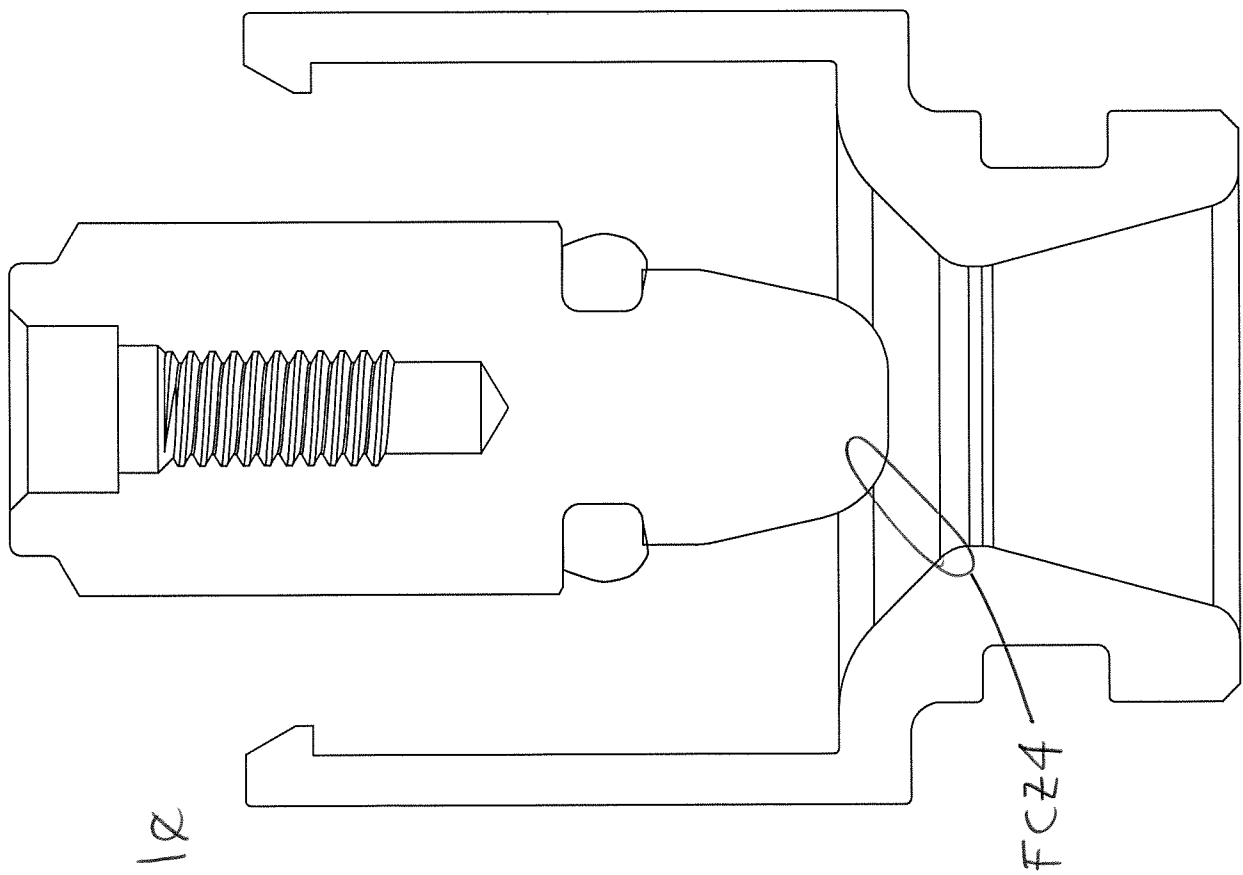
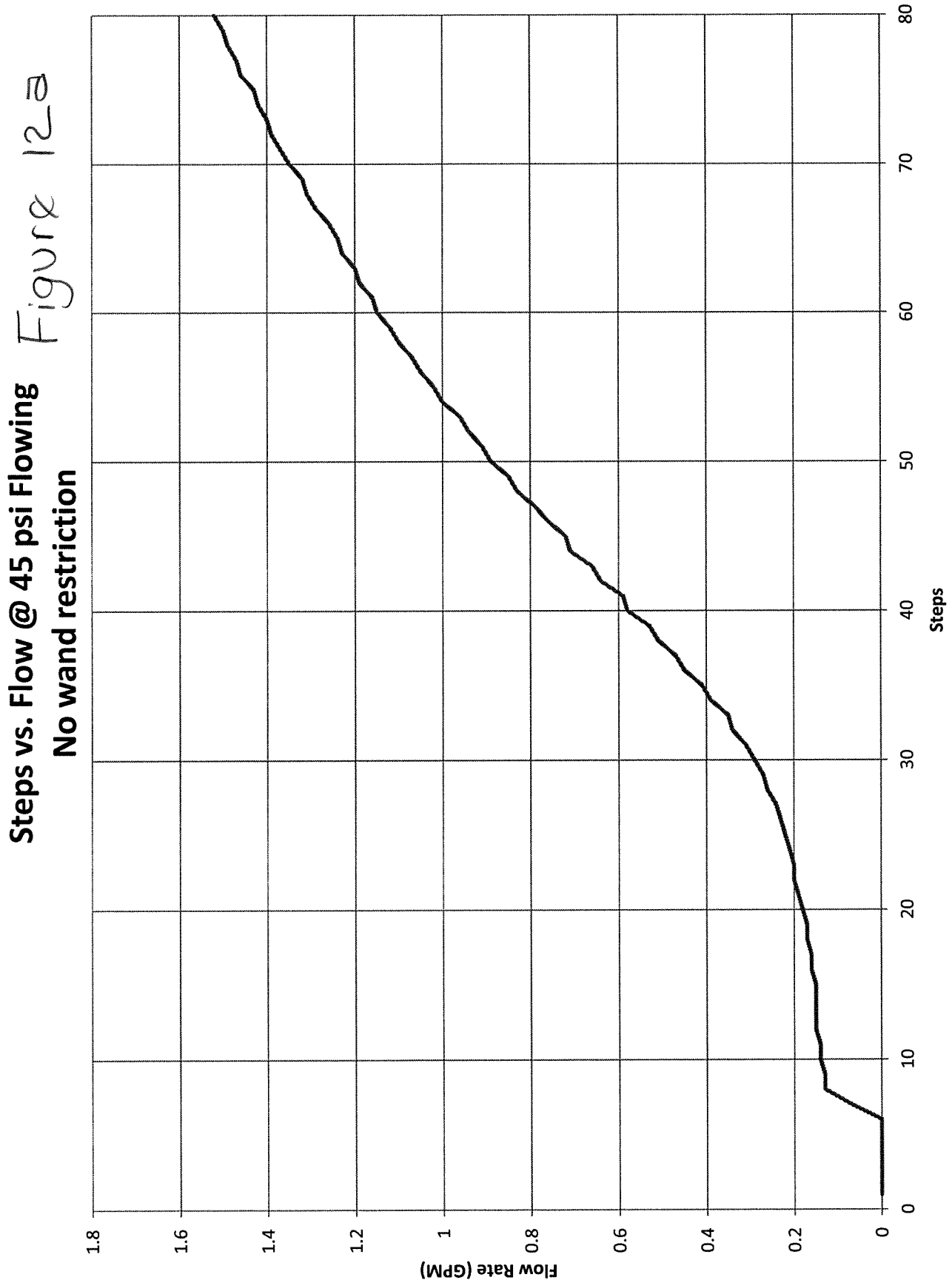


Figure 11e

26/46



27/46

Step	Flow Rate (GPM)
0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	0.07
8	0.13
9	0.13
10	0.14
11	0.14
12	0.15
13	0.15
14	0.15
15	0.15
16	0.16
17	0.16
18	0.17
19	0.17
20	0.18
21	0.19
22	0.2
23	0.2
24	0.21
25	0.22
26	0.23
27	0.24
28	0.26
29	0.27
30	0.29
31	0.31
32	0.34
33	0.35
34	0.39
35	0.41
36	0.45
37	0.47
38	0.51
39	0.53
40	0.58

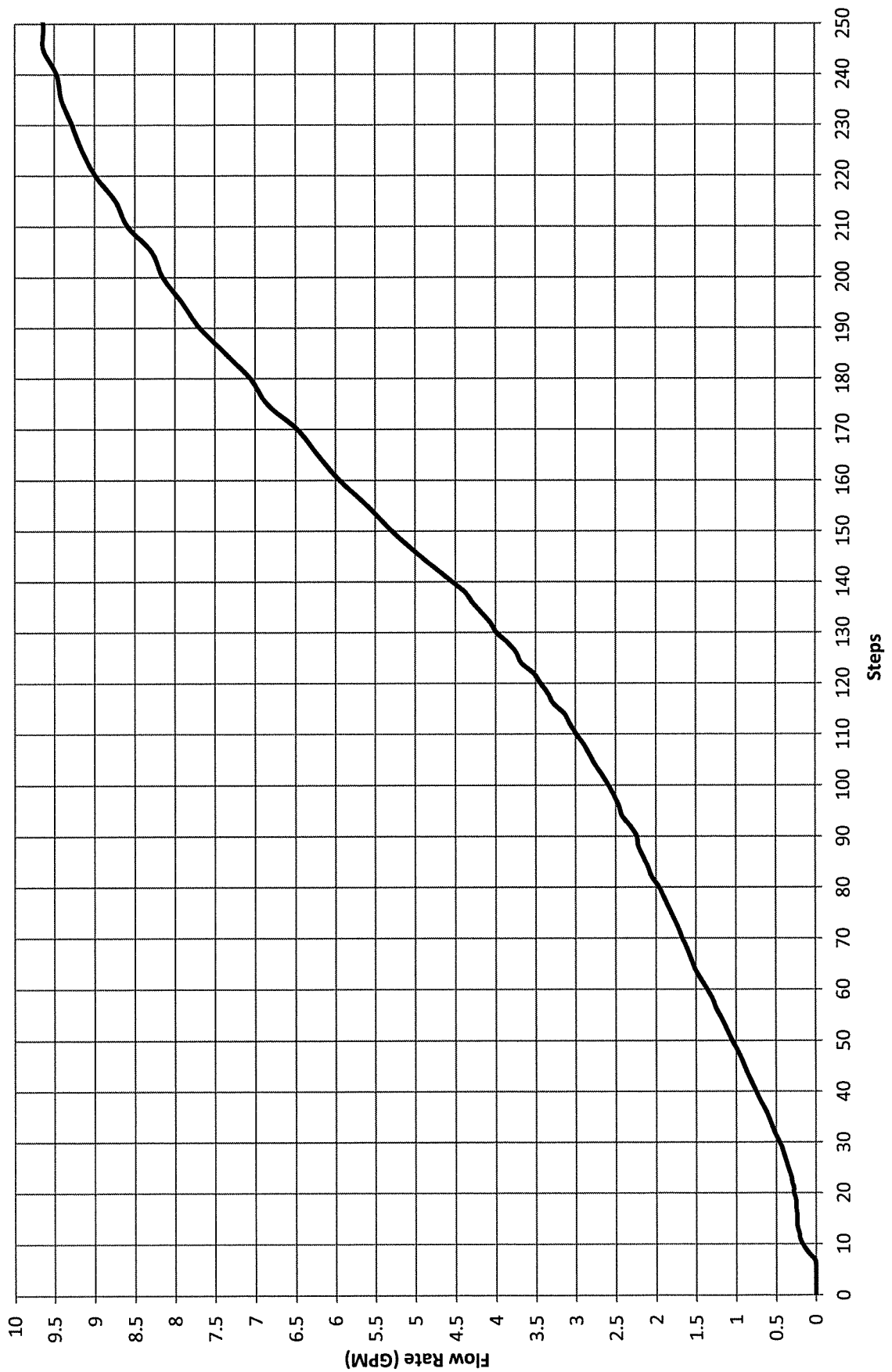
Figure 12b

Step	Flow Rate (GPM)
41	0.59
42	0.64
43	0.66
44	0.71
45	0.72
46	0.76
47	0.79
48	0.83
49	0.85
50	0.89
51	0.91
52	0.94
53	0.96
54	1
55	1.02
56	1.05
57	1.07
58	1.1
59	1.12
60	1.15
61	1.16
62	1.19
63	1.2
64	1.23
65	1.24
66	1.26
67	1.29
68	1.31
69	1.32
70	1.35
71	1.37
72	1.39
73	1.4
74	1.42
75	1.43
76	1.46
77	1.47
78	1.49
79	1.5
80	1.52

28/46

Steps vs. Flow @ 45 psi Flowing
No wand restriction

Figure 13a



29/46

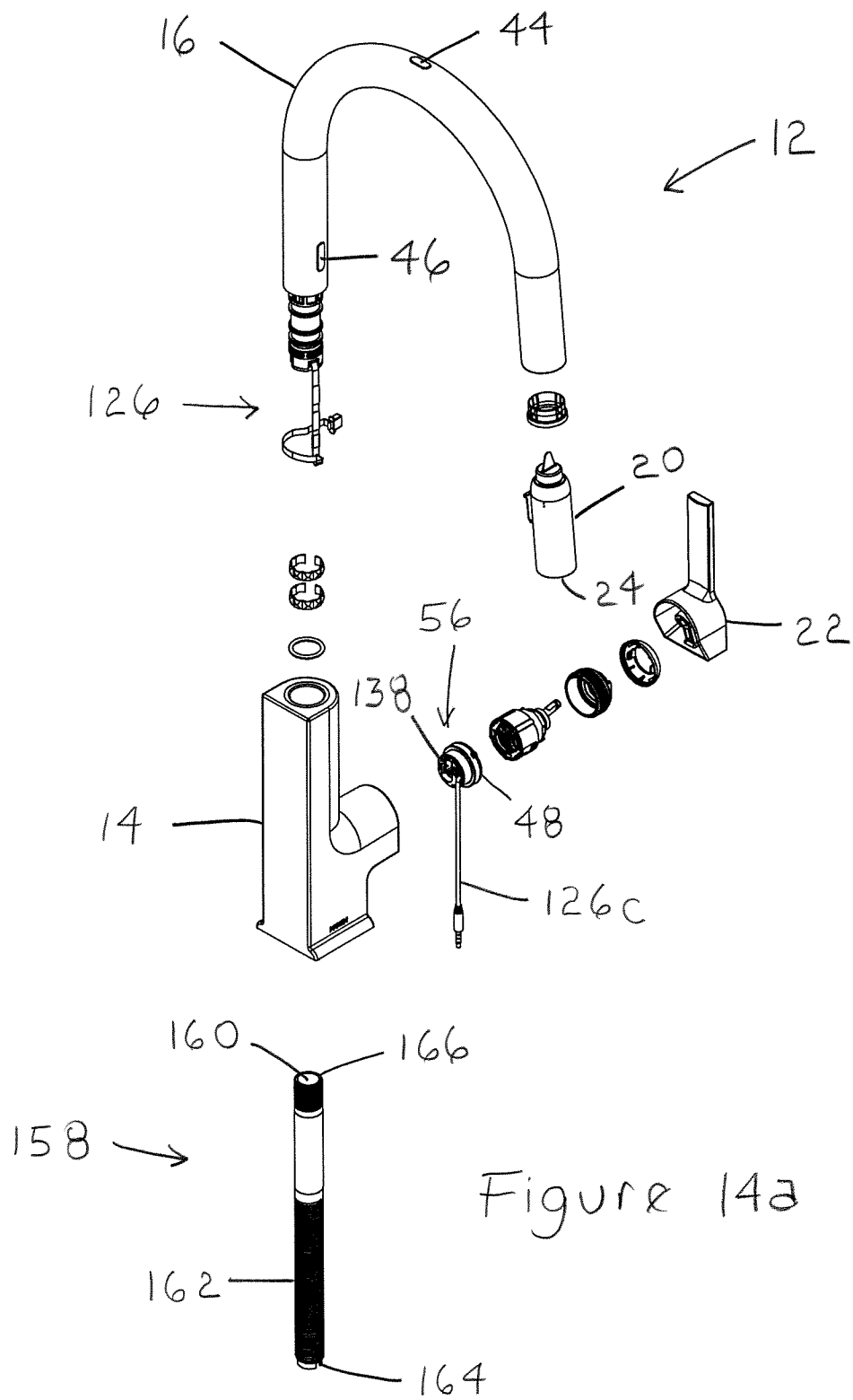
Step	Flow Rate (GPM)
0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	0.02
8	0.08
9	0.13
10	0.17
11	0.2
12	0.21
13	0.23
14	0.24
15	0.24
16	0.24
17	0.25
18	0.25
19	0.26
20	0.28
21	0.28
22	0.3
23	0.31
24	0.33
25	0.35
26	0.37
27	0.39
28	0.41
29	0.43
30	0.46
32	0.52
34	0.57
36	0.62
38	0.69
40	0.75
42	0.81
44	0.87
46	0.92
48	0.98
50	1.05

Step	Flow Rate (GPM)
52	1.11
54	1.17
56	1.24
58	1.29
60	1.36
62	1.44
64	1.51
66	1.56
68	1.61
70	1.67
72	1.72
74	1.78
76	1.84
78	1.9
80	1.96
82	2.05
84	2.1
86	2.16
88	2.22
90	2.24
92	2.32
94	2.42
96	2.46
98	2.52
100	2.59
102	2.67
104	2.76
106	2.83
108	2.9
110	2.99
112	3.07
114	3.14
116	3.28
118	3.35
120	3.44
122	3.53
124	3.68
126	3.74
128	3.85
130	3.99
132	4.07

Step	Flow Rate (GPM)
134	4.18
136	4.29
138	4.38
140	4.54
145	4.93
150	5.29
155	5.6
160	5.95
165	6.22
170	6.48
175	6.85
180	7.06
185	7.37
190	7.69
195	7.91
200	8.15
205	8.29
210	8.59
215	8.74
220	8.99
225	9.16
230	9.28
235	9.41
240	9.47
245	9.64
250	9.64

Figure 13b

30/46



31/46

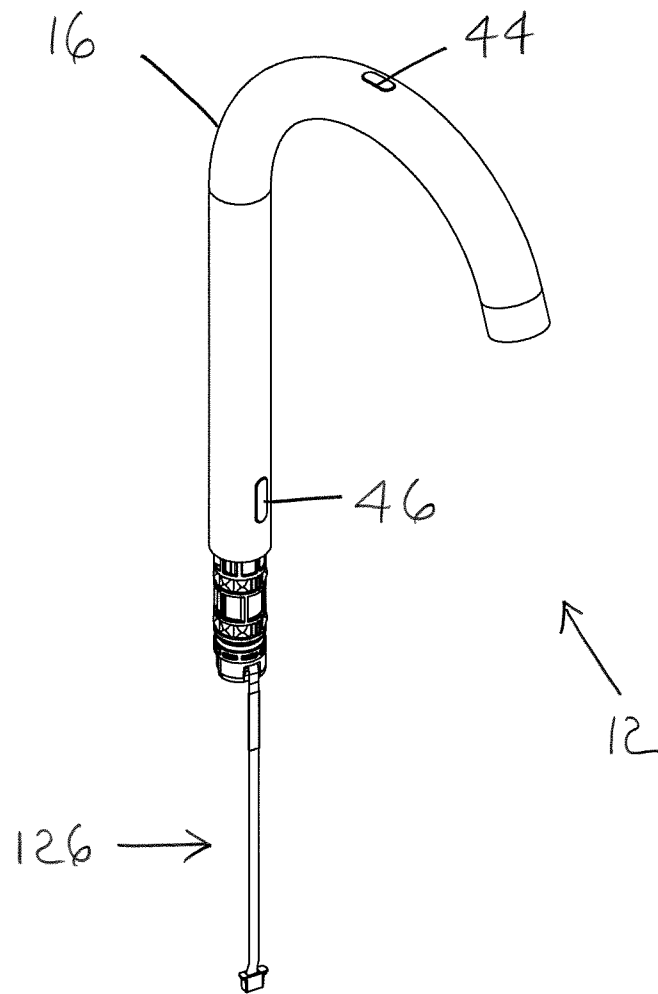


Figure 14b

32/46

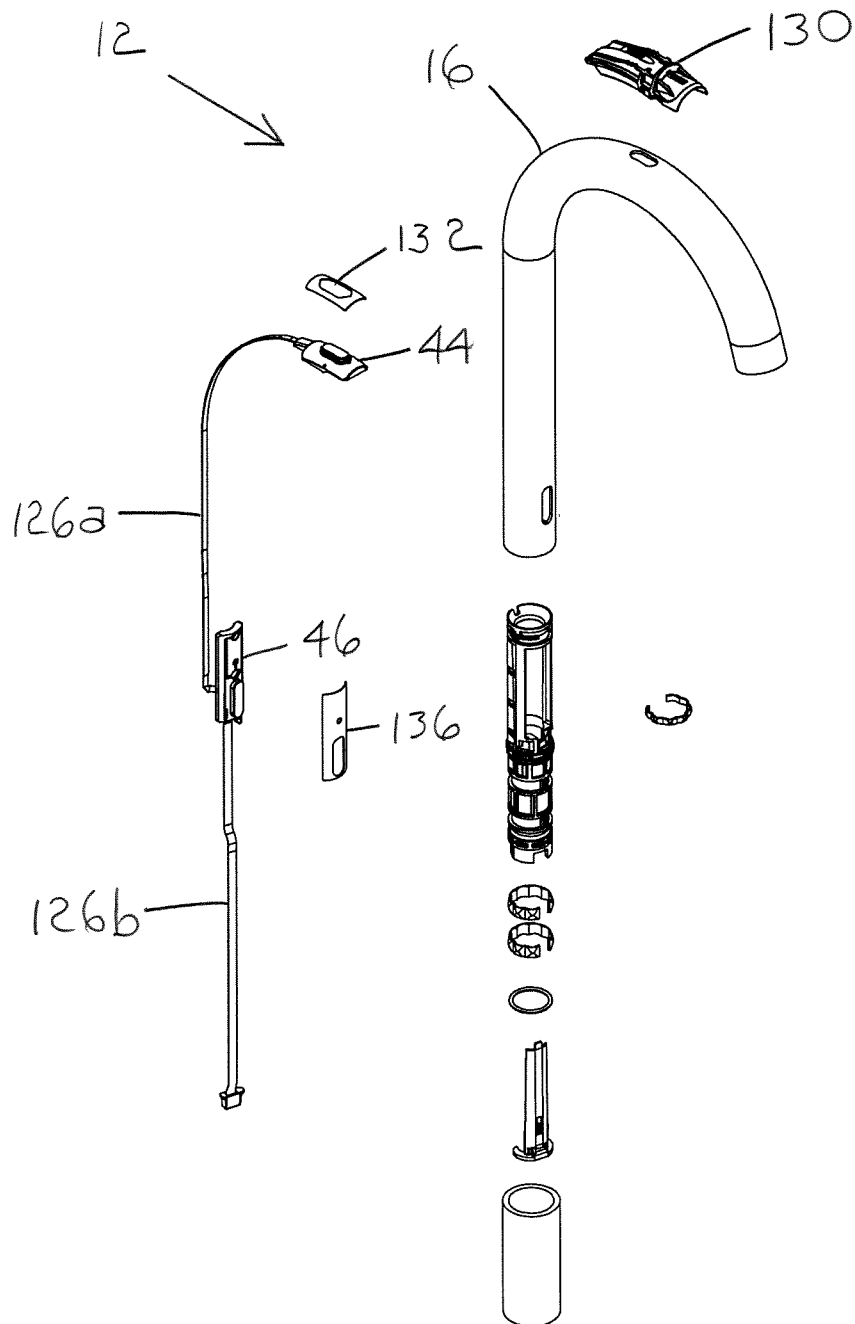


Figure 14c

Figure 15b

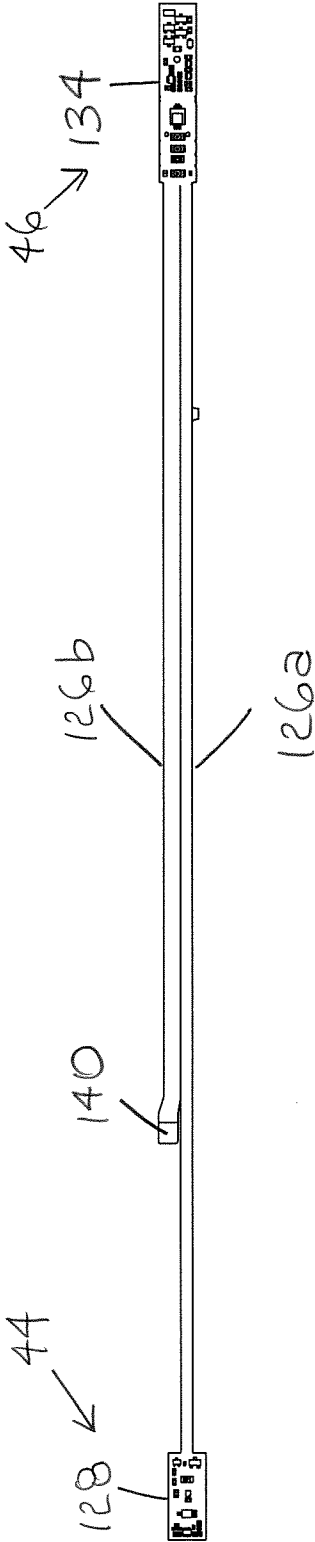
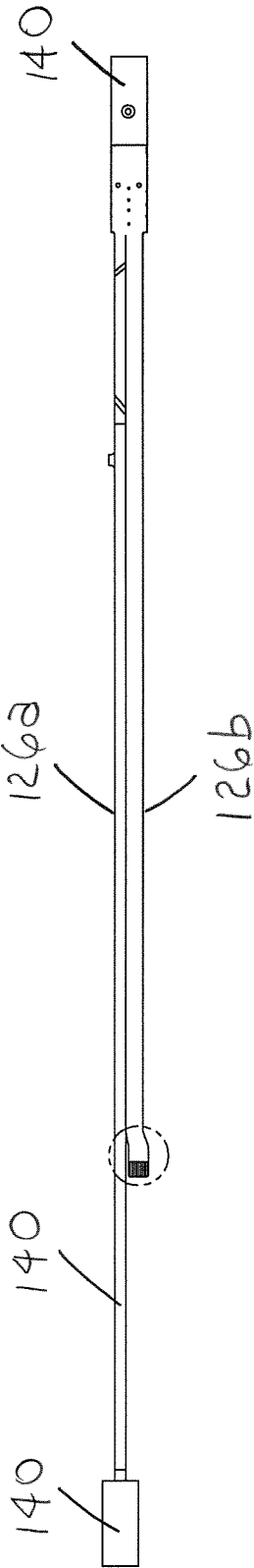


Figure 15a

Figure 15c

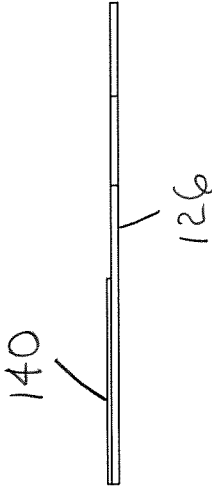
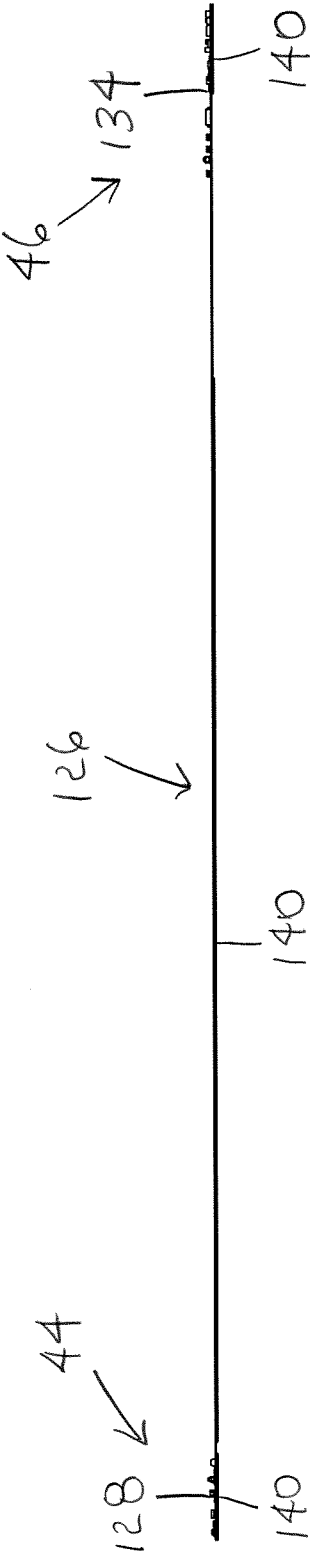


Figure 15d

35/46

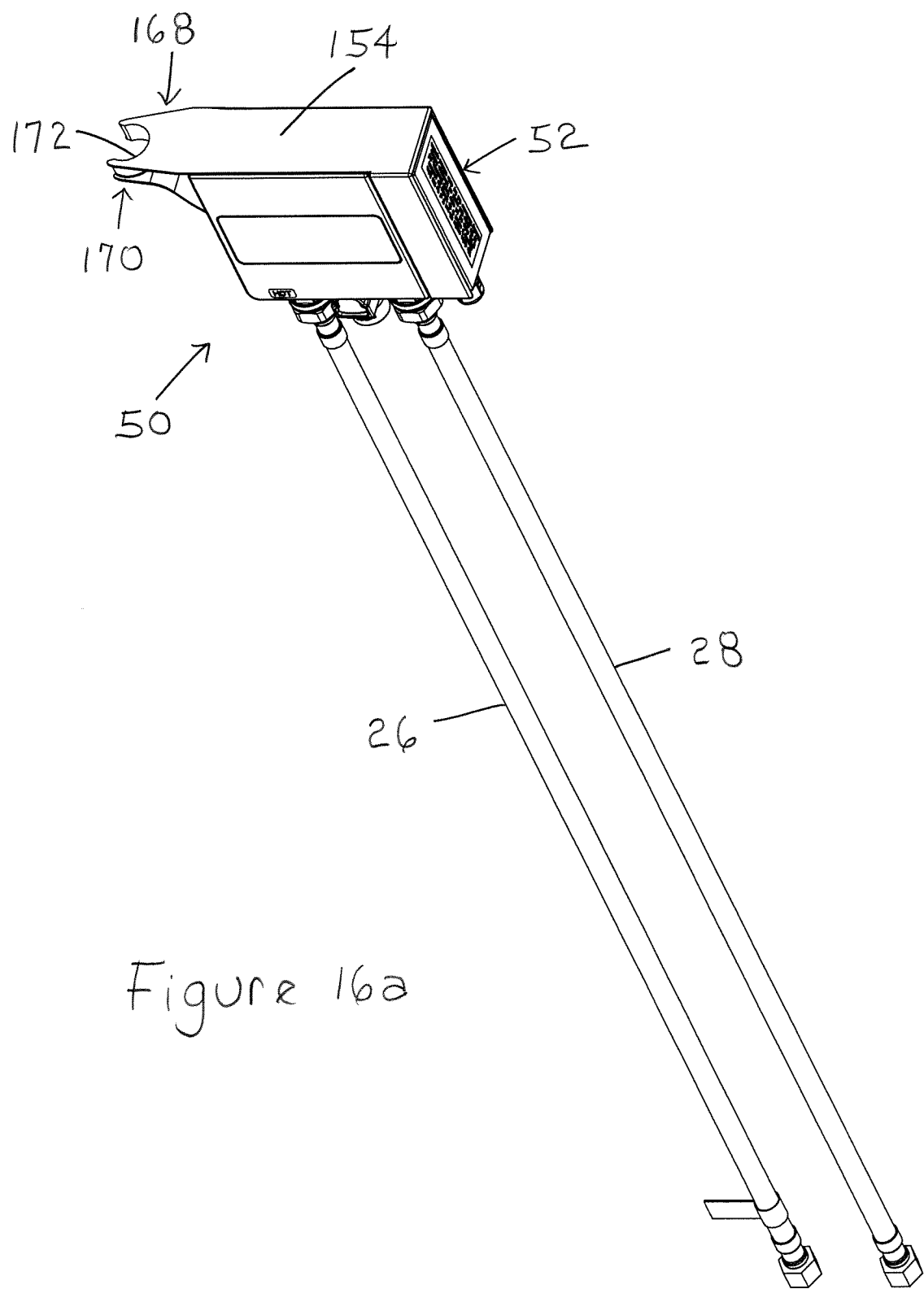


Figure 16a

36/46

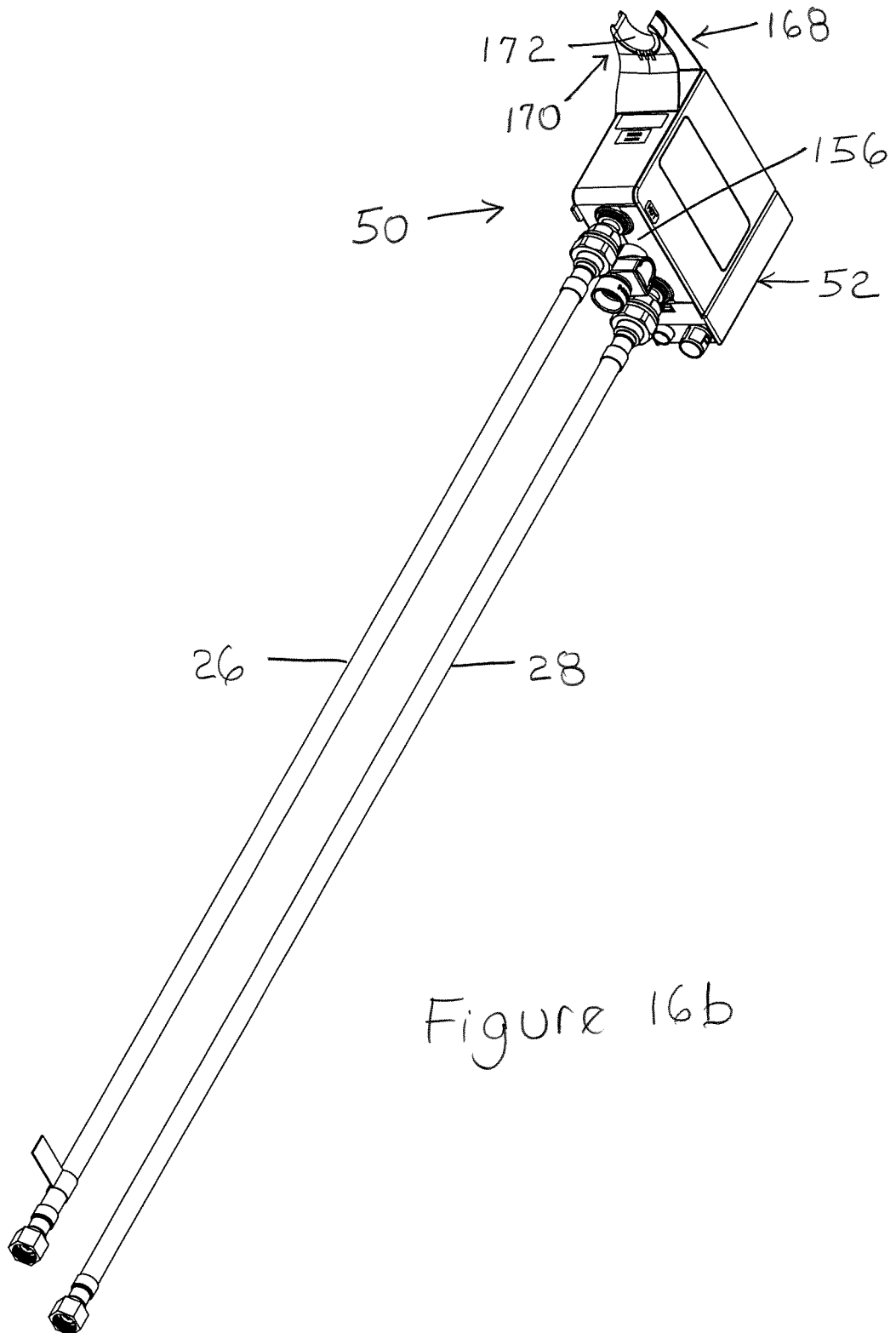


Figure 16b

37/46

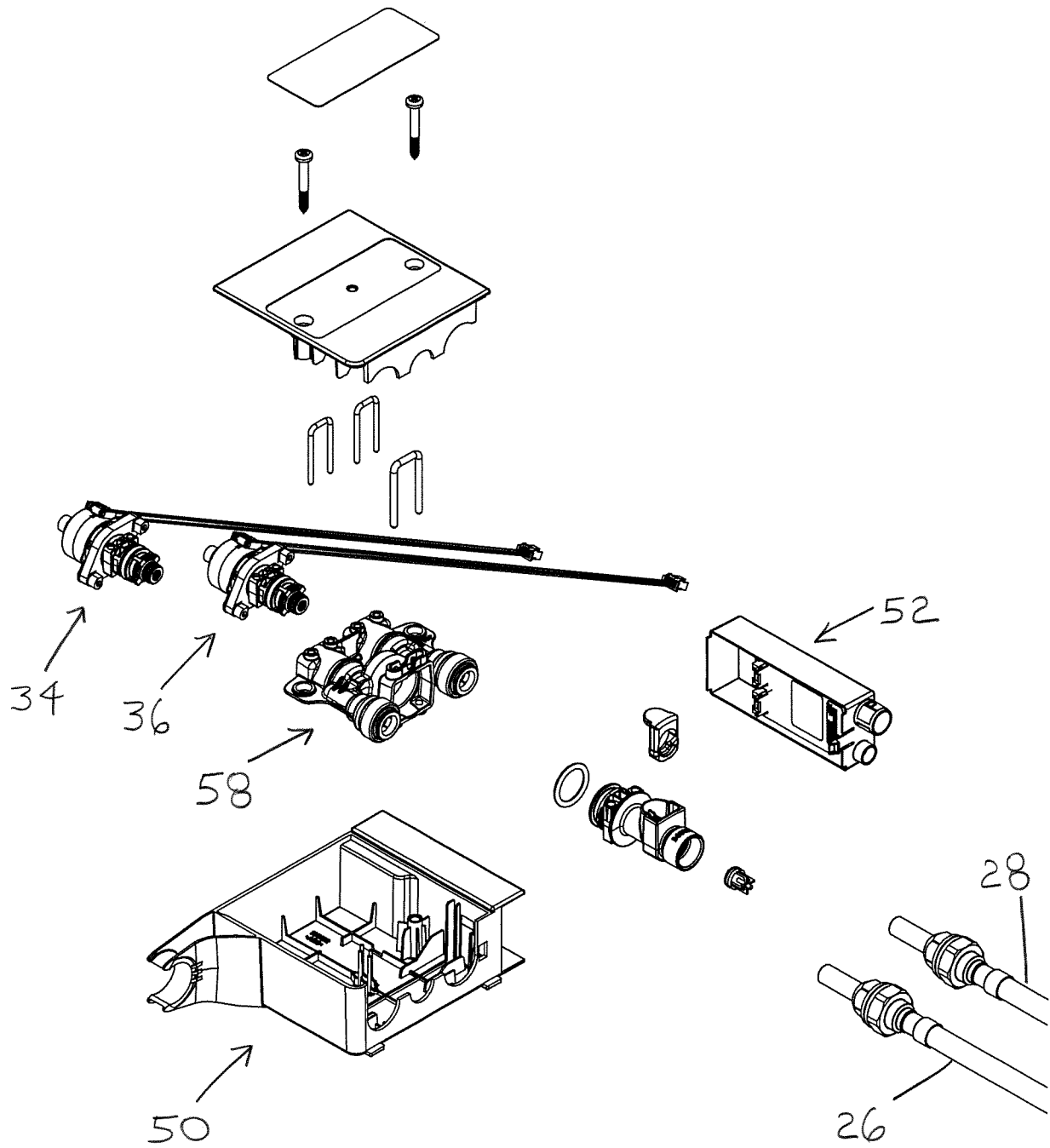
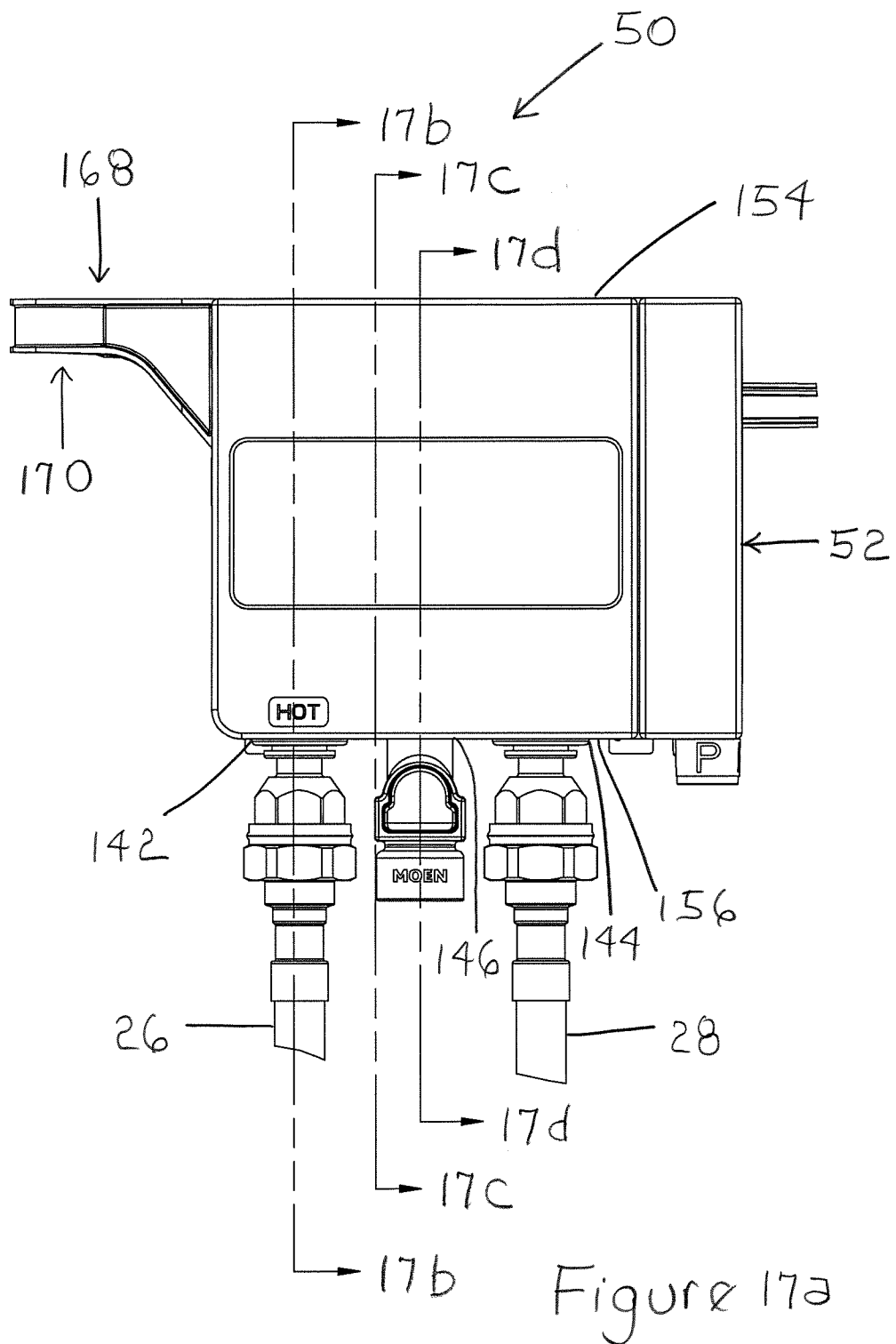


Figure 16c

38/46



39/46

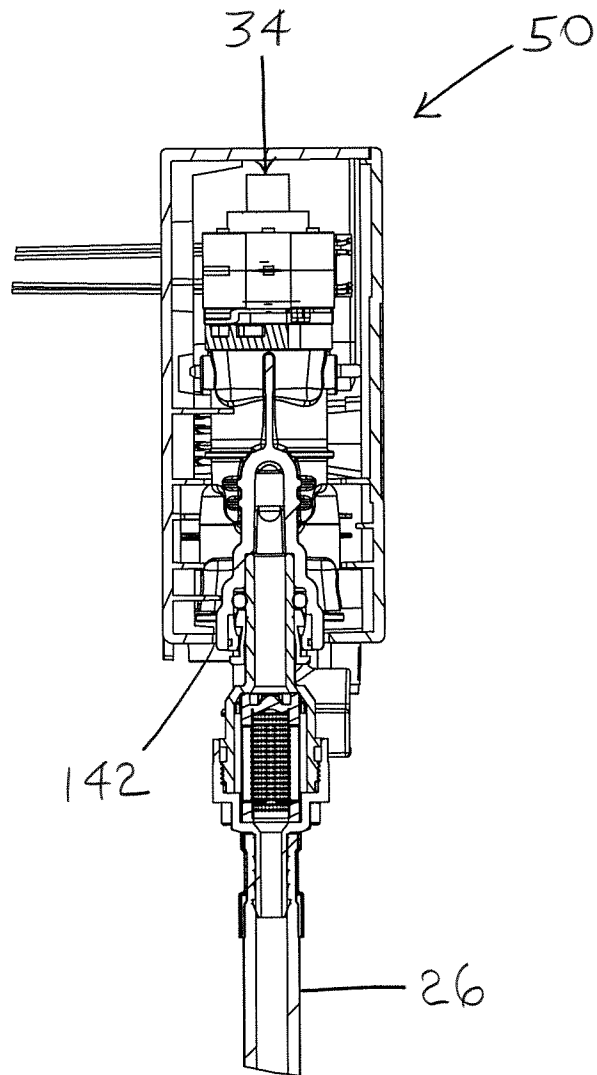


Figure 17b

40/46

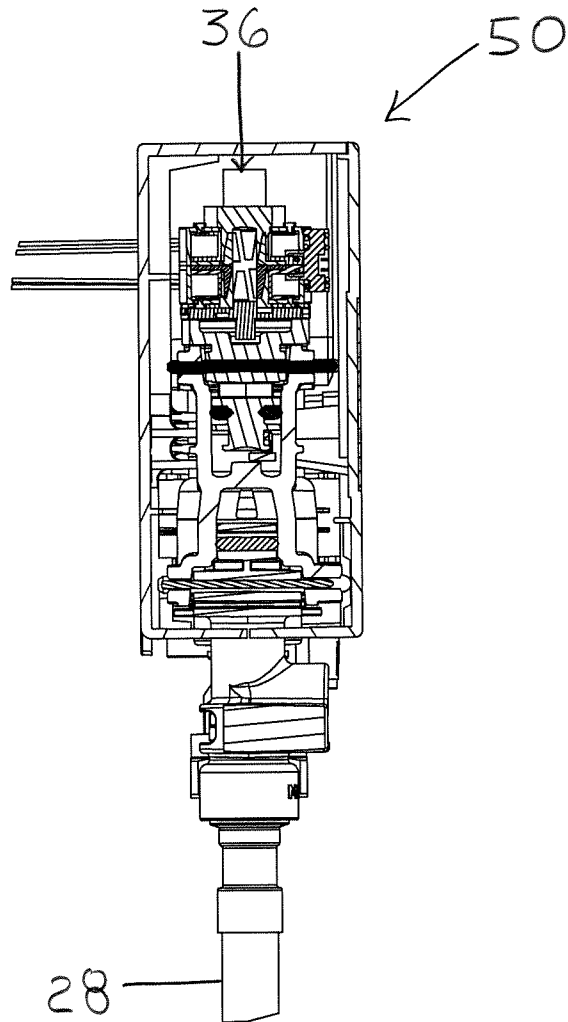


Figure 17c

41/46

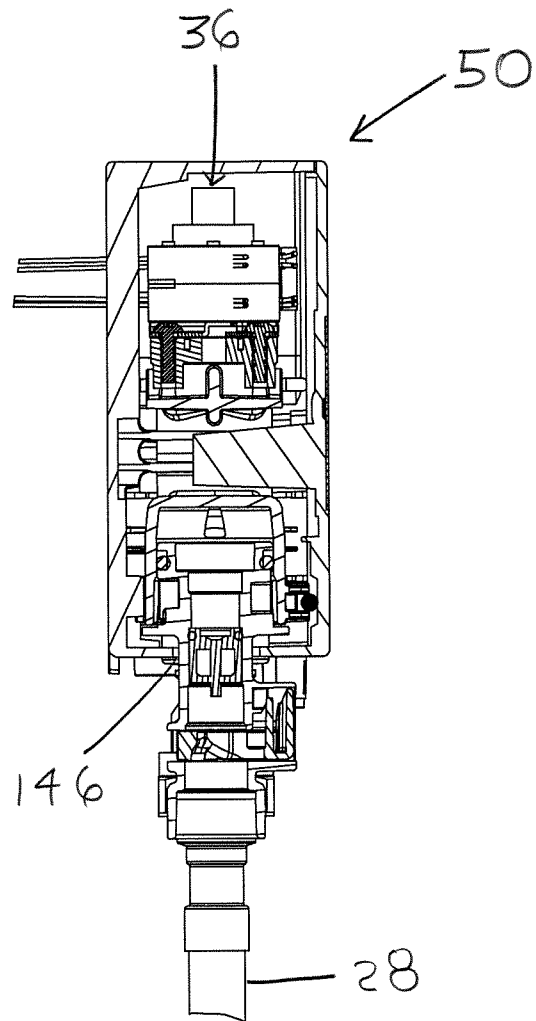


Figure 17d

42/46

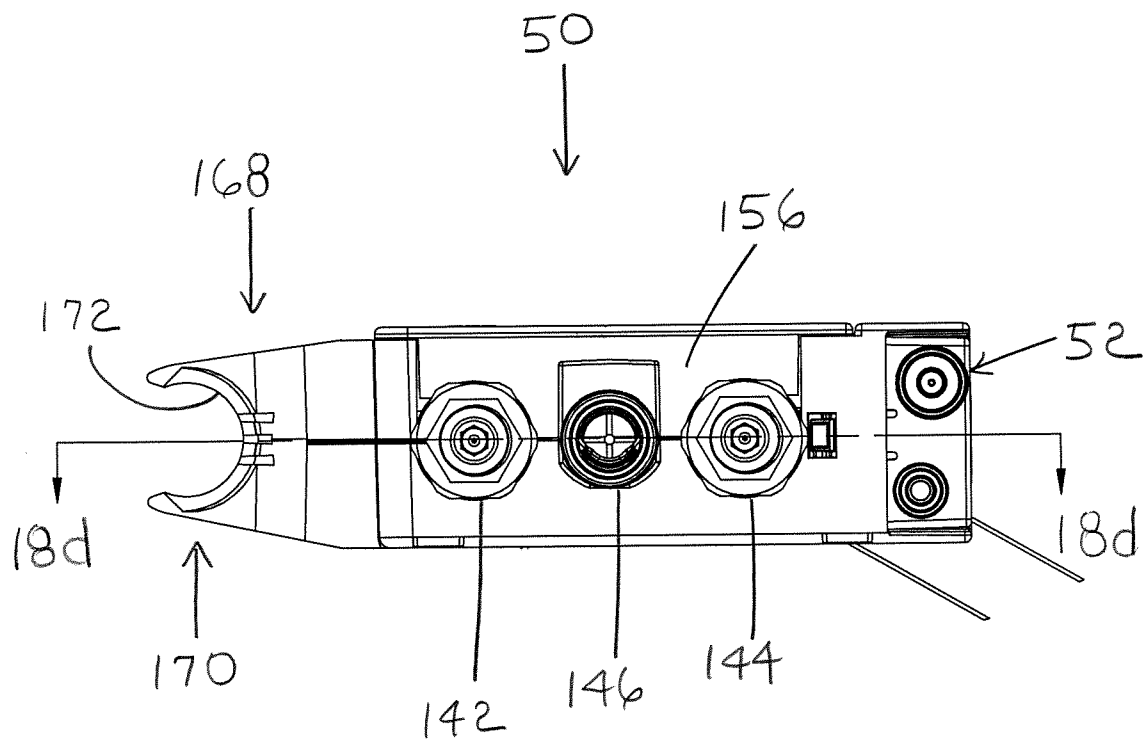


Figure 18a

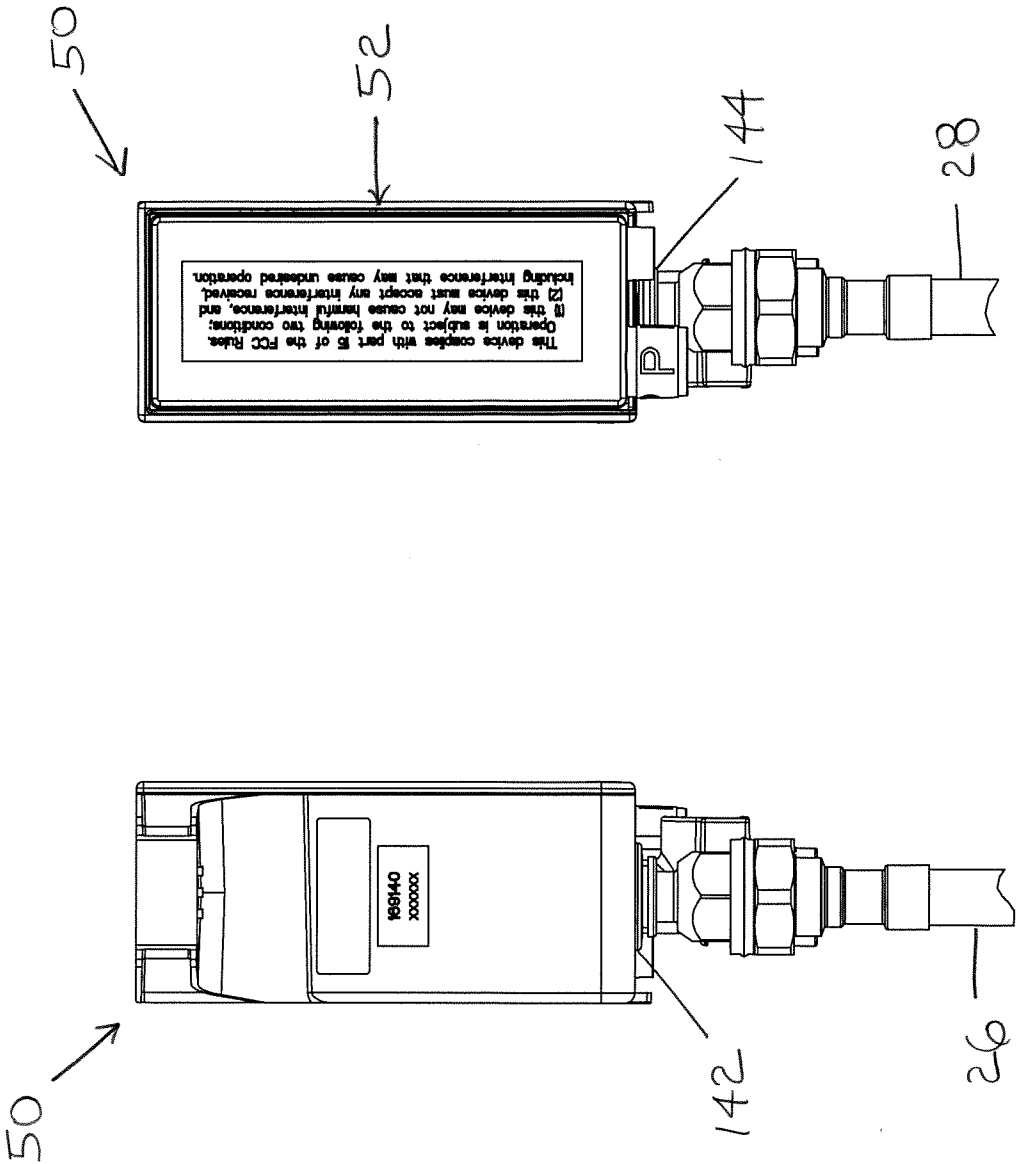


Figure 18c

Figure 18b

44/46

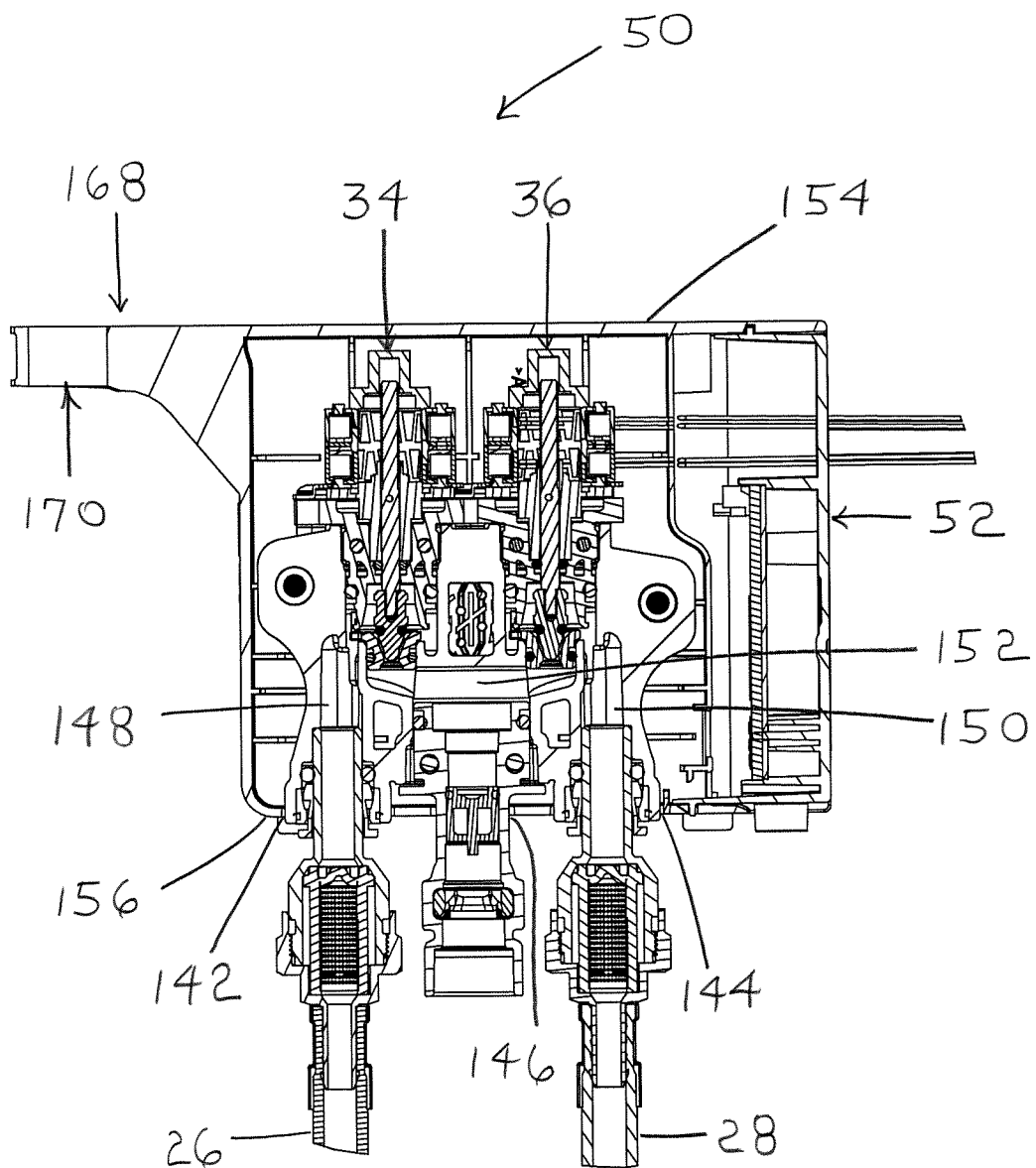


Figure 18d

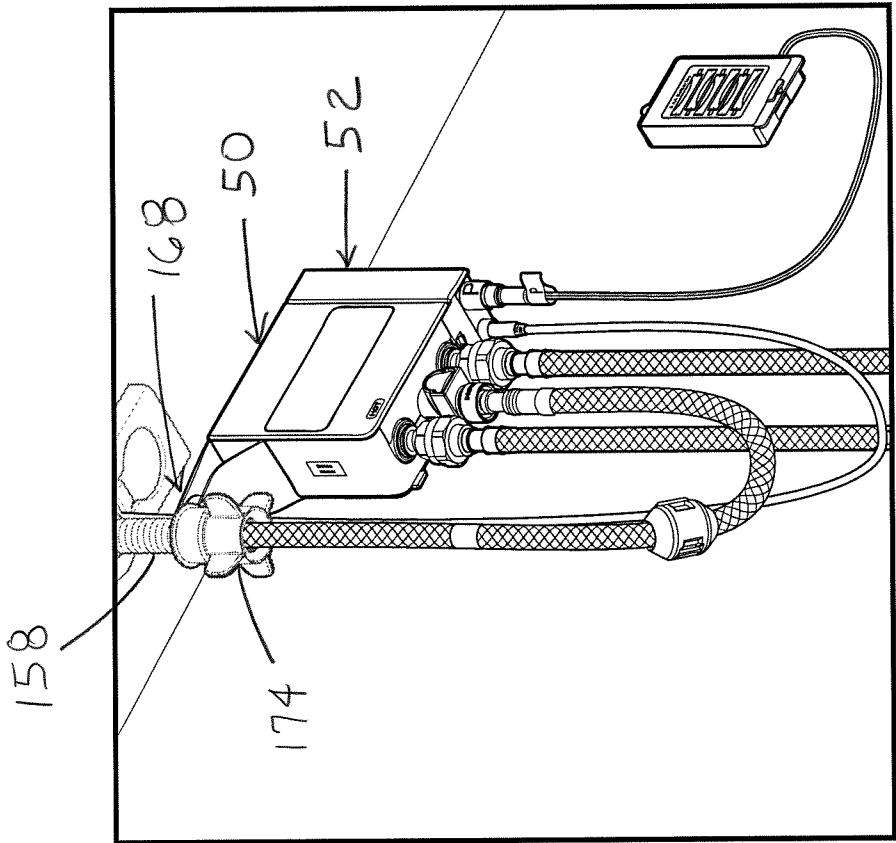


Figure 19a

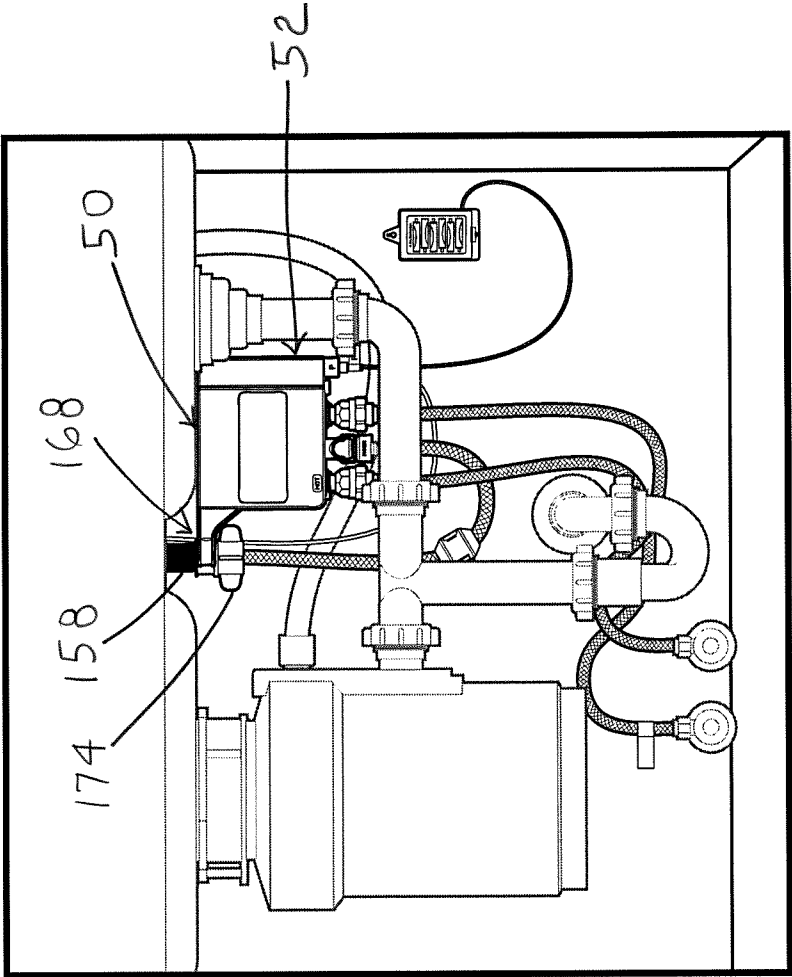


Figure 19b