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Multi-way valve with dual actuators

Abstract

A multi-way valve adapted to control a flow of fluid to different thermal fluid circuits includes a valve housing, a valve flow controller, and sealing systems. The valve flow controller is arranged in the valve housing to control flow through the valve housing. The sealing systems are configured to seal between the valve housing and the valve flow controller.

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Background/Summary

PRIORITY CLAIM (1) This application claims priority to and the benefit of U.S. Provisional Patent Application No. 63/438,111, filed 10 Jan. 2023, the disclosure of which is now expressly incorporated herein by reference.

TECHNICAL FIELD
(1) The present disclosure relates to multi-way valves, and particularly to multi-way valves for controlling the flow of heating and/or cooling fluid to various thermal fluid circuits in a vehicle. More particularly, the present disclosure relates to an electro mechanical multi-way valve.
BACKGROUND
(2) Multi-way valves are used for controlling the flow of fluid to various thermal fluid circuits in a vehicle. However, there is a need for multi-way valves with an increased number of possible flow paths and improved sealing.
SUMMARY
(3) The present disclosure provides a multi-way valve that controls the flow of heating and/or cooling fluid to different thermal fluid circuits in a vehicle with improved sealing. The multi-way valve may include a valve housing and a valve flow controller positioned in the housing to control the flow of fluid through the valve housing. The flow of heating and/or cooling fluid may be controlled to direct fluid to different thermal fluid circuits in a vehicle.
(4) According to an aspect of the present disclosure, the valve housing may include a valve housing body coupled to a manifold of the thermal fluid circuits, a first housing end cover, and a second housing end cover. The valve housing body may be shaped to define a first valve cavity, a second valve cavity in fluid communication with the first valve cavity, and a plurality of apertures that open into the first and second valve cavities. The first housing end cover may be coupled to the first end of the valve housing to close a first end opening to the first valve cavity. The second end cover may be coupled to the second end of the valve housing to close a second end opening to the second valve cavity.
(5) According to an aspect of the present disclosure, the valve flow controller may include a first valve rotor arranged in the first valve cavity of the valve housing body and a second valve rotor

arranged in the second valve cavity of the valve housing body. The first valve rotor and the second valve rotor may each be configured to rotate relative to the valve housing body about a valve axis. The first and second valve rotors may cooperate to define a plurality of flow paths in the valve housing when the first and second valves are rotated about the valve axis to control the flow of fluid through the valve housing.

(6) According to an aspect of the present disclosure, the valve flow controller of the multi-way valve may further include actuators each coupled to the respective valve rotors to control rotation of the valve rotors about the respective rotor axis. The actuators may rotate the first and second valve rotor to different predetermined positions relative to the valve housing to establish different flow paths through the housing.

(7) According to an aspect of the present disclosure, the multi-way valve may further include a first sealing system configured to form a seal engagement between the first valve rotor and the valve housing body of the valve housing. The first sealing system may include a first seal that extends circumferentially partway around the valve axis and is located between the first valve rotor and the valve housing body.

(8) According to an aspect of the present disclosure, the first sealing system may further include a first biasing assembly configured to apply a radial force on the first valve rotor when the first valve rotor is in preselected positions relative to the valve housing body. The first biasing assembly may selectively apply the radial force to the first valve rotor to urge the first valve rotor into a predetermined level of engagement with the first seal when the first valve rotor is in one of the different preselected positions.

(9) According to an aspect of the present disclosure, the multi-way valve may further include a second sealing system configured to form a seal engagement between the second valve rotor and the valve housing body of the valve housing. The second sealing system may include a second seal that is located in a connecting aperture formed in the valve housing body.

(10) According to an aspect of the present disclosure, the second sealing system may further include a second biasing assembly configured to apply an axial force on the second valve rotor when the second valve rotor is in preselected positions relative to the valve housing body. The second biasing assembly may selectively apply the axial force to the second valve rotor to urge the second valve rotor into a predetermined level of engagement with the second seal when the second valve rotor is in one of the different preselected positions.

(11) With the multi-way valve of the present disclosure, a multi-way valve with an increased number of flow paths and improved sealing is provided. The first valve rotor and the second valve rotor rotate about the same axis and cooperate to define the increased number of flow paths. This arrangement improves sealing between the plurality of apertures in the valve housing body and the plurality of chambers in the first valve rotor not only because the flow path is less complicated, but the first and second sealing systems also uses less material for the seals and reduces the friction on the valve rotors. The increased engagement of the valve rotors with the corresponding seals also improves sealing between the valve rotors and the valve housing body and reduces leakage therebetween. This increased engagement of the each valve rotor with the corresponding seal applied only at preselected positions also reduces the amount of torque needed to rotate the valve rotors between various positions and reduces wear on the seals themselves.

(12) Additional features of the present disclosure will become apparent to those skilled in the art upon consideration of illustrative embodiments exemplifying the best mode of carrying out the disclosure as presently perceived.

Description

BRIEF DESCRIPTIONS OF THE DRAWINGS

(1) The detailed description particularly refers to the accompanying figures in which:

(2) FIG. **1** is a perspective diagrammatic view of a multi-way valve configured to control the flow of fluid to various thermal fluid circuits in a vehicle;

(3) FIG. **2** is an exploded view of the multi-way valve of FIG. **1** showing the multi-way valve includes a valve housing, a valve flow controller having first and second valve rotors configured to be arranged in a corresponding cavity of the valve housing to control a flow of fluid through the valve housing and first and second actuators coupled to the respective valve rotor to independently control rotation thereof, and first and second sealing systems each having seals configured to seal between one of the first and second valve rotors of the valve flow controller and the valve housing;

(4) FIG. **3** is an exploded view of the multi-way valve of FIG. **1** showing the valve housing includes a valve housing body shaped to define a first valve cavity and a second valve cavity in fluid communication with the first valve cavity, a first housing end cover configured to be coupled to a first end of the valve housing to close a first end opening to the first valve cavity, and a second end cover configured to be coupled to a second end of the valve housing spaced apart axially from the first end of the valve housing relative to a valve axis to close a second end opening to the second valve cavity, and further showing the valve flow controller includes the first valve rotor—also referred to as a main valve rotor—configured to be arranged in the first valve cavity, the second valve rotor—also referred to as a throttle valve rotor—configured to be arranged in the second valve cavity of the valve housing body, and the first and second actuators each coupled to one of the main and throttle valve rotors to independently rotate the main and throttle rotors relative to the valve housing body about the valve axis to define a plurality of flow paths to control the flow of fluid through the valve housing;

(5) FIG. **4** is an exploded view of the valve housing body and the valve flow controller included in the multi-way valve of FIG. **2** with a portion of the valve housing broken away to show the valve housing body includes an annular outer wall that extends around the valve axis to define a hollow space, a partition wall located in the hollow space of the annular outer wall to divide the hollow space into the first valve cavity and the second valve cavity and defines a connecting aperture that connects the first and second valve cavities, and a housing base that extends from the outer wall to defined a plurality of apertures that open into the first and second valve cavities, and further showing the first biasing assembly includes a ridge that extends radially inward from the annular outer wall into the first cavity to engage the first valve rotor;

(6) FIG. **5** is a perspective view of the main valve rotor included in the valve flow controller of the multi-way valve of FIG. **1** showing the main valve rotor includes a valve rotor body and a first valve shaft that extends axially from the valve rotor body to a terminal end configured to be couple to the first actuator, and further showing the valve rotor body includes a first valve rotor drum that extends circumferentially about the valve axis, a plurality of circumferential flow divider walls that extend circumferentially at least partway around the first valve rotor drum, and a plurality of axial flow divider walls that extend axially along the first valve rotor drum between the circumferential flow divider walls to form a plurality of chambers as shown in FIGS. **6**A-**6**D;

(7) FIG. **5**A is a detail view of FIG. **5** showing the first sealing system includes a first biasing assembly having protrusions formed on the main valve rotor that each extend radially outward from the first valve rotor body to selectively engage the ridge on the valve housing body as suggested in FIGS. **27-28**A as the first valve rotor rotates about the valve axis to the different predetermined positions to form the first biasing assembly configured to selectively apply a radial force on the first valve rotor to urge the first valve rotor into engagement with the seal located in the valve housing body when the first valve rotor is in one of the different predetermined positions to improve sealing between the first valve rotor and the valve housing body;

(8) FIG. **6**A is an elevation view of the main valve rotor of FIG. **5** showing the different chambers

defined by the different circumferential and axial flow divider walls that each extend radially outward away from the first valve rotor drum;
(9) FIG. **6**B is an elevation view of the main valve rotor in FIG. **6**A rotated 90 degrees about the valve axis compared to FIG. **6**A to show different chambers defined by the different circumferential and axial flow divider walls that each extend radially outward away from the first valve rotor drum;
(10) FIG. **6**C is an elevation view of the main valve rotor in FIG. **6**B rotated 90 degrees about the valve axis compared to FIG. **6**B to show different chambers defined by the different circumferential and axial flow divider walls that each extend radially outward away from the first valve rotor drum;
(11) FIG. **6**D is an elevation view of the main valve rotor in FIG. **6**C rotated 90 degrees about the valve axis compared to FIG. **6**C to show different chambers defined by the different circumferential and axial flow divider walls that each extend radially outward away from the first valve rotor drum;
(12) FIG. **7** is a perspective view of the throttle valve rotor and the second end cover included in the multi-way valve of FIG. **2** showing the throttle valve rotor includes a second valve rotor plate formed to include a second rotor through hole that extends axially through the second valve rotor relative to the second rotor axis and a plurality of second valve rotor walls that extend axially away from the second valve rotor plate to define a plurality of second valve ports, and further showing the second sealing system includes cam ramps formed on an axially facing surface of the second housing cover of the valve housing and cam surfaces formed on each of the second valve rotor walls of the second valve rotor that selectively engage the cam ramps on the second housing end cover as suggested in FIGS. **25-26**A as the second valve rotor rotates about the valve axis to the different predetermined positions to form a second biasing assembly configured to selectively apply an axial force on the second valve rotor to urge the second valve rotor into engagement with the seal located in the partition wall of the valve housing body when the second valve rotor is in one of the different predetermined positions to improve sealing between the second valve rotor and the first valve rotor;
(13) FIG. **8** is an elevation view of the throttle valve rotor of FIG. **7** showing the cam surfaces included in the second biasing assembly each form a high point that when aligned with the cam ramps on the second housing end cover apply the axis force to the second valve rotor, and further showing each of the cam surfaces is formed on the terminal ends of each second valve rotor wall such that the high point of each cam surface is not equally spaced apart around the valve axis;
(14) FIG. **9** is an elevation view of the second end cover of FIG. **7** showing the camp ramps are equally spaced apart around the valve axis and each of the cam ramps forms a high point that engages with the high point on the cam surfaces to apply the axial force;
(15) FIG. **10** is a table showing the different modes of the multi-way valve of FIG. **1** and the different flow paths created at each of the different modes A-E;
(16) FIG. **10**A is a bottom view of the multi-way valve in mode A or mode B**1** as shown in FIG. **10** in which the main valve rotor is in a MAIN VALVE ROTOR FIRST position as shown in FIG. **15** and the throttle valve rotor is in a THROTTLE VALVE ROTOR FIRST position as shown in FIG. **11**;
(17) FIG. **10**B is a bottom view of the multi-way valve in mode B**2** or mode C as shown in FIG. **10** in which the main valve rotor stays in the MAIN VALVE ROTOR FIRST position and the throttle valve rotor has rotated to a THROTTLE VALVE ROTOR SECOND position as shown in FIG. **12**;
(18) FIG. **10**C is a bottom view of the multi-way valve in mode B**3** as shown in FIG. **10** in which the main valve rotor stays in the MAIN VALVE ROTOR FIRST position, while the throttle valve rotor has rotated to a THROTTLE configuration as shown in FIG. **13**;
(19) FIG. **10**D is a bottom view of the multi-way valve in mode D as shown in FIG. **10** in which the throttle valve rotor stays in the THROTTLE VALVE ROTOR FIRST position, while the main valve rotor moves to a MAIN VALVE ROTOR SECOND position as shown in FIG. **17**;
(20) FIG. **10**E is a bottom view of the multi-way valve in mode E as shown in FIG. **10** in which the main valve rotor moves to a MAIN VALVE ROTOR THIRD position as shown in FIG. **19**, while

the throttle valve rotor **40** is in the THROTTLE configuration;
(21) FIG. **11** is a cross-sectional view of the multi-way valve of FIG. **10**A showing the throttle valve rotor is in the THROTTLE VALVE ROTOR FIRST position in which the connecting aperture is blocked by the throttle valve rotor and the sixth aperture and the seventh aperture formed in the valve housing body are in fluid communication with the second valve cavity and with each other;
(22) FIG. **12** is a cross-sectional view of the multi-way valve of FIG. **10**B showing the throttle valve rotor is in the THROTTLE VALVE ROTOR SECOND position in which the throttle valve rotor covers the sixth aperture and the hole formed in the throttle valve rotor is aligned with the connecting aperture so that the first valve cavity is in fluid communication with the seventh aperture;
(23) FIG. **13** is a cross-sectional view of the multi-way valve of FIG. **10**C showing the throttle valve rotor is in the THROTTLE configuration in which the second rotor through hole formed in the throttle valve rotor remains aligned with the connecting aperture so that the first valve cavity is in fluid communication with both the sixth aperture and the seventh aperture formed in the valve housing body;
(24) FIG. **14** is a cross-sectional view of the multi-way valve showing the throttle valve rotor in a THROTTLE VALVE ROTOR THIRD position in which the connecting aperture is blocked by the throttle valve rotor so that the second valve cavity is isolated from the first valve cavity, and the sixth and seventh apertures are covered blocking flow between the sixth and seventh apertures and the second valve cavity;
(25) FIG. **15** is a cross-sectional view of the multi-way valve of FIG. **10**A showing the main valve rotor in the MAIN VALVE ROTOR FIRST position in which one of the chambers surrounds the third aperture and the fifth aperture to connect the third and fifth apertures in fluid communication as shown in FIG. **16**A, while another one of the chambers surrounds the fourth aperture to block off the fourth aperture as shown in FIG. **16**C;
(26) FIG. **16**A is a cross-sectional view of the multi-way valve of FIG. **15** taken at a first axial location along the valve axis showing the main valve rotor in the MAIN VALVE ROTOR FIRST position in which one of the chambers defined by the main valve rotor surrounds the third aperture and the fifth aperture to connect the third and fifth apertures in fluid communication with each other while isolating the third and fifth apertures from the other apertures;
(27) FIG. **16**B is a cross-sectional view of the multi-way valve of FIG. **15** taken at a second axial location along the valve axis showing the main valve rotor in the MAIN VALVE ROTOR FIRST position in which one of the circumferential flow divider walls blocks flow from the third and fifth apertures to the first, second, and fourth apertures;
(28) FIG. **16**C is a cross-sectional view of the multi-way valve of FIG. **15** taken at a third axial location along the valve axis showing the main valve rotor in the MAIN VALVE ROTOR FIRST position in which one of the chambers surrounds the fourth aperture to block off the fourth aperture and the chamber surrounding the second aperture has an opening so that the second aperture in fluid communication with the first aperture, i.e. the first valve cavity;
(29) FIG. **17** is a cross-sectional view of the multi-way valve of FIG. **10**D showing the main valve rotor in the MAIN VALVE ROTOR SECOND position in which the main valve rotor has rotated so that the main valve rotor connects the second aperture and the third aperture, connects the first aperture and the fourth aperture, and blocks the fifth aperture to form another flow path, and further showing one of the chambers surrounds the second and third apertures to connect the second and third apertures in fluid communication as shown in FIGS. **18**A-**18**C, while another one of the chambers surrounds the fifth aperture to block off the fifth aperture as shown in FIG. **18**C;
(30) FIG. **18**A is a cross-sectional view of the multi-way valve of FIG. **17** taken at the first axial location along the valve axis showing the main valve rotor in the MAIN VALVE ROTOR SECOND position in which the third and fifth apertures are surrounded by different chambers so

that one of the axial flow divider walls blocks the flow of fluid therebetween while also blocking off the fifth aperture;

(31) FIG. **18**B is a cross-sectional view of the multi-way valve of FIG. **17** taken at the second axial location along the valve axis showing the main valve rotor in the MAIN VALVE ROTOR SECOND position in which the chamber surrounding the third aperture extends axially so that the second and third apertures are connected in fluid communication;

(32) FIG. **18**C is a cross-sectional view of the multi-way valve of FIG. **17** taken at the third axial location along the valve axis showing the main valve rotor in the MAIN VALVE ROTOR SECOND position in which the same chamber surrounding the third aperture surrounds the second aperture and the chamber surrounding the fourth aperture has an opening so that the fourth aperture in fluid communication with the first aperture, i.e. the first valve cavity;

(33) FIG. **19** is a cross-sectional view of the multi-way valve of FIG. **10**E showing the main valve rotor in the MAIN VALVE ROTOR THIRD position in which the main valve rotor has rotated so that the main valve rotor connects all the apertures in fluid communication, further showing the chamber that surrounds the second aperture, the third aperture, the fourth aperture, and the fifth aperture and has an opening so that the apertures are in fluid communication with the first aperture, i.e. the first valve cavity, as shown in FIGS. **20**A-**20**C;

(34) FIG. **20**A is a cross-sectional view of the multi-way valve of FIG. **19** taken at the first axial location along the valve axis showing the main valve rotor in the MAIN VALVE ROTOR THIRD position in which the chamber that surrounds both the third and fifth apertures has an opening so that the apertures are in fluid communication with the first aperture;

(35) FIG. **20**B is a cross-sectional view of the multi-way valve of FIG. **19** taken at the second axial location along the valve axis showing the main valve rotor in the MAIN VALVE ROTOR THIRD position in which the chamber extends axially so that the third and fifth apertures are connected in fluid communication with the second and fourth aperture;

(36) FIG. **20**C is a cross-sectional view of the multi-way valve of FIG. **19** taken at the third axial location along the valve axis showing the main valve rotor in the MAIN VALVE ROTOR THIRD position in which the same chamber surrounding the third and fifth apertures extends to the second and fourth apertures so that all the apertures are in fluid communication;

(37) FIG. **21** is a cross-sectional view of the multi-way valve in another possible position similar to the MAIN VALVE ROTOR FIRST position such that the same apertures are in fluid communication as in FIG. **15**;

(38) FIG. **22**A is a cross-sectional view of the multi-way valve of FIG. **21** taken at the first axial location along the valve axis showing one of the chambers defined by the main valve rotor surrounds the third aperture and the fifth aperture to connect the third and fifth apertures in fluid communication with each other while isolating the third and fifth apertures from the other apertures;

(39) FIG. **22**B is a cross-sectional view of the multi-way valve of FIG. **21** taken at the second axial location along the valve axis showing one of the circumferential flow divider walls blocks flow from the third and fifth apertures to the first, second, and fourth apertures;

(40) FIG. **22**C is a cross-sectional view of the multi-way valve of FIG. **21** taken at the third axial location along the valve axis showing one of the chambers surrounds the fourth aperture to block off the fourth aperture and the chamber surrounding the second aperture has an opening so that the second aperture in fluid communication with the first aperture, i.e. the first valve cavity;

(41) FIG. **23** is a cross-sectional view of the multi-way valve in another possible position similar to the MAIN VALVE ROTOR FIRST position such that the same apertures are in fluid communication as in FIG. **15**;

(42) FIG. **24**A is a cross-sectional view of the multi-way valve of FIG. **23** taken at the first axial location along the valve axis showing one of the chambers defined by the main valve rotor surrounds the third aperture and the fifth aperture to connect the third and fifth apertures in fluid

communication with each other while isolating the third and fifth apertures from the other apertures;
(43) FIG. **24**B is a cross-sectional view of the multi-way valve of FIG. **23** taken at the second axial location along the valve axis showing one of the circumferential flow divider walls blocks flow from the third and fifth apertures to the first, second, and fourth apertures;
(44) FIG. **24**C is a cross-sectional view of the multi-way valve of FIG. **23** taken at the third axial location along the valve axis showing one of the chambers surrounds the fourth aperture to block off the fourth aperture and the chamber surrounding the second aperture has an opening so that the second aperture in fluid communication with the first aperture, i.e. the first valve cavity;
(45) FIG. **25** is a cross-sectional view of a portion of the multi-way valve of FIG. **1** showing the second biasing assembly has not yet applied the axial force to the throttle valve rotor;
(46) FIG. **25**A is a detail view of FIG. **25** showing one of the cam surfaces on the throttle valve rotor is spaced apart from the corresponding cam ramp so that the axial force is not applied to the throttle valve rotor by the second biasing assembly to reduce friction on the throttle valve rotor;
(47) FIG. **26** is a cross-sectional view similar to FIG. **25** showing the throttle valve rotor has rotated about the valve axis to one of the predetermined positions to cause the second biasing assembly to apply the axial force to the throttle valve rotor to urge the throttle valve rotor axially toward the partition wall of the valve housing and into engagement with the second seal to increase friction therebetween;
(48) FIG. **26**A is a detail view of FIG. **26** showing the cam surface on the throttle valve rotor is aligned with the corresponding cam ramp so that the axial force is applied to the throttle valve rotor by the second biasing assembly to increase friction on the throttle valve rotor and improve sealing;
(49) FIG. **27** is a cross-sectional view of the multi-way valve of FIG. **1** showing the first biasing assembly has not yet applied the radial force to the main valve rotor;
(50) FIG. **27**A is a detail view of FIG. **27** showing one of the protrusions formed on the main valve rotor is spaced apart from the ridge formed on the valve housing body so that the radial force is not applied to the main valve rotor by the first biasing assembly to reduce friction on the main valve rotor;
(51) FIG. **28** is a cross-sectional view similar to FIG. **27** showing the main valve rotor has rotated about the valve axis to one of the predetermined positions to cause the first biasing assembly to apply the radial force to the main valve rotor to urge the main valve rotor radially outward toward the valve housing body and into engagement with the first seal to increase friction therebetween; and
(52) FIG. **28**A is a detail view of FIG. **28** showing the protrusion on the main valve rotor is aligned with the ridge formed on the valve housing body so that the radial force is applied to the main valve rotor by the first biasing assembly to increase friction on the main valve rotor and improve sealing.

DETAILED DESCRIPTION

(53) An illustrative multi-way valve **10** configured to control the flow of fluid to various thermal fluid circuits in a vehicle is shown in FIG. **1**. The multi-way valve **10** includes a valve housing **12**, a valve flow controller **14**, a first sealing system **16**, and a second sealing system **18** as shown in FIGS. **2** and **3**. The valve flow controller **14** is arranged in the valve housing **12** to control flow through the valve housing **12**. The sealing system **16** is configured to seal between the valve housing **12** and the valve flow controller **14**.
(54) The valve flow controller **14** includes a first valve rotor **38** arranged in a first valve cavity **26** formed by the valve housing **12**, a second valve rotor **40** arranged in a second valve cavity **28** formed by the valve housing **12**, and first and second actuators **27**, **29** as shown in FIGS. **2** and **3**. The first valve rotor **38** and the second valve rotor **40** are both configured to rotate relative to the valve housing **12** about a valve axis **19**. Each actuator **27**, **29** is coupled to one of the valve rotors **38**, **40** to drive rotation of the corresponding valve rotor **38**, **40**.

(55) The first and second valve rotors **38**, **40** cooperate to define a plurality of flow paths through the valve housing **12** as shown in FIGS. **10**A-**10**E. As the first and second valve rotors **38**, **40** are rotated about the valve axis **19** to different set positions as shown in FIGS. **11-24**C, the first and second valve rotors **38**, **40** form the different flow paths to control a flow of fluid through the valve housing **12** to different thermal fluid circuits.
(56) The different modes of the multi-way valve **10** are shown in FIG. **10**. The first and second valve rotors **38**, **40** are in different predetermined positions in each of the different modes A-E to form the different flow paths through the valve housing **12**. The multi-way valve **10** and/or each of the actuators **27**, **29** may include a control unit that is preprogrammed with the different modes A-E.
(57) By axially stacking the first valve rotor **38** and the second valve rotor **40**, the overall size of the multi-way valve **10** is reduced compared to other multi-way valves. Each actuator **27**, **29** is coupled to one of the valve rotors **38**, **40** to drive rotation thereof.
(58) Other multi-way valves may have more complex passageways through the valve housing, which complicates sealing and increases the pressure drop as the fluid has to make more turns/changes direction more. The complex passageways may increase the potential for leaks across the different passageways. These valves may incorporate seals to seal between the passageways, but adding seals may require the actuator to have an increased torque capability to overcome the friction of the seals between the different components.
(59) Moreover, adding more seals increases the overall manufacturing cost of the multi-way valve. Some valves may use a Teflon material for the seals. This may make manufacturing a multi-way valve expensive, especially as other valves have complex passageways with large, complex seals that may need large amounts of Teflon material.
(60) The multi-way valve **10** of the present disclosure includes the first valve rotor **38** axially stacked with the second valve rotor **40** to reduce the amount of sealing material and improve sealing. Additionally, the arrangement of the first valve rotor **38** and the second valve rotor **40** reduces the contract surface area of the seals **72**, **76**, thereby reducing the friction on the first valve rotor **38** and the second valve rotor **40**.
(61) Turning again to the valve housing **12**, the valve housing includes a valve housing body **20**, a first housing end cover **22**, and a second housing end cover **24** as shown in FIGS. **2-4**. The valve housing body **20** is formed to include the first valve cavity **26**, the second valve cavity **28** in fluid communication with the first valve cavity **26**, and a plurality of apertures **36**A-G that open into the first and second valve cavities **26**, **28**. The first housing end cover **22** is coupled to a first end **20**A of the valve housing body **20** to close a first end opening **26**O to the first valve cavity **26**. The second housing end cover **24** is coupled to a second end **20**B of the valve housing body **20** to close a second end opening **28**O to the second valve cavity **28**. The second end **20**B is spaced apart axially from the first end **20**A of the valve housing body **20** relative to the valve axis **19**.
(62) In some embodiments, the valve housing **12** may further include any one of a quick connect, push lock, barb, pipe, port, etc. that define the housing apertures **36**A-G. In some embodiments, any outlet aperture may be defined by one of a quick connect, push lock, barb, pipe, port, etc.
(63) The valve housing body **20** includes an annular outer wall **30**, a partition wall **32**, and a housing base **34** as shown in Figs. FIGS. **2-4**. The annular outer wall **30** extends around the valve axis **19** to define a hollow space. The partition wall **32** is located in the hollow space of the annular outer wall **30** to divide the hollow space into the first valve cavity **26** and the second valve cavity **28**. The housing base **34** extends away from the outer wall **30** and is formed to define the plurality of apertures **36**A-G that open in the first and second valve cavities **26**, **28**.
(64) The partition wall **32** is formed to include a connecting aperture **32**A as shown in FIGS. **3** and **4**. The connecting aperture **32**A extends axially through the partition wall **32** so that the first valve cavity **26** is in fluid communication with the second valve cavity **28** through the connecting aperture **32**A. The connecting aperture **32**A extends circumferentially partway about the valve axis

19.
(65) In the illustrative embodiment, the valve housing body **20** is also formed to include a first rod **33** and a second rod **35** as shown in FIGS. **4**, **15**, **17**, **19**, **21**, and **23**. The first rod **33** extends axially away from the partition wall **32** into the first valve cavity **26** and the second rod **35** extends axially away from the partition wall **32** into the second valve cavity **28**. The first rod **33** and the second rod **35** are both aligned with the valve axis **19**. The first rod **33** extends into the first valve rotor **38** to provide support for one end of the first valve rotor **38**. The second rod **35** extends into the second valve rotor **40** to provide support for one end of the second valve rotor **40**. In the illustrative embodiment, the connecting aperture **32**A is located radially outward of the first and second rods **33**, **35**.
(66) The plurality of housing apertures **36**A-G includes a first aperture **36**A, a second aperture **36**B, a third aperture **36**C, a fourth aperture **36**D, a fifth aperture **36**E, a sixth aperture **36**F, and a seventh aperture **36**G as shown in FIGS. **10**A-E. The first aperture **36**A, the second aperture **36**B, the third aperture **36**C, the fourth aperture **36**D, and the fifth aperture **36**E open into the first valve cavity **26**. The sixth aperture **36**F and the seventh aperture **36**G open into the second valve cavity **28**.
(67) In the illustrative embodiment, a first seal **72** included in the first sealing system **16** is located radially between the first valve rotor **38** and the annular outer wall **30** of the valve housing body **20** as shown in FIGS. **15-24**C. The first seal **72** extends around the second aperture **36**B, the third aperture **36**C, the fourth aperture **36**D, and the first aperture **36**E. A second seal **76** included in the second sealing system **18** is located in the connecting aperture **32**A.
(68) In the illustrative embodiment, the first seal **72** is a wraparound type seal. In the illustrative embodiment, the second seal **76** is press-fit seal. In some embodiments, the seals **72**, **76** may be over molded. In some embodiments, the seals **72**, **76** may be o-rings. In other embodiments, the seals **72**, **76** may be any other suitable seal.
(69) The first housing end cover **22** includes a cover plate **22**P that extends circumferentially around the valve axis **19** and flanges **22**F that each extend axially from the cover plate **22**P, and a through hole **22**H as shown in FIG. **3**. The cover plate **22**P couples to the first end **20**A of the valve housing body **20**. In the illustrative embodiment, an outer edge of the cover plate **22**P forms a lip **22**L that extends around the first end **20**A of the valve housing body **20** to couple the first housing end cover **22** to the valve housing body **20**. Each flange **22**F extends circumferentially at least partway around the valve axis **19** and extends axially away from the cover plate **22**P into the first valve cavity **26**. The cover plate **22**P is also formed to include a hole **22**H that extends axially therethrough and receives a portion of the first valve rotor **38**.
(70) Each flange **22**F engages the first valve rotor **38** as shown in FIG. **15**. In the illustrative embodiment, the flanges **22**F are spaced apart circumferentially from each other so as to form apertures **22**A circumferentially therebetween.
(71) The second housing end cover **24** includes a cover plate **24**P that extends circumferentially around the valve axis **19** as shown in FIGS. **3** and **4**. The cover plate **24**P couples to the second end **20**B of the valve housing body **20**. In the illustrative embodiment, an outer edge of the cover plate **24**P forms a lip **24**L that extends around the second end **20**B of the valve housing body **20** to couple the second housing end cover **24** to the valve housing body **20**. The cover plate **24**P is also formed to include a hole **24**H that extends axially therethrough and receives a portion of the second valve rotor **40**.
(72) The valve flow controller **14** includes the first valve rotor **38**, also referred to as the main valve rotor **38**, and the second valve rotor **40**, also referred to as the throttle valve rotor **40**. The main valve rotor **38** is arranged in the first valve cavity **26** of the valve housing body **20** and the throttle valve rotor **40** is arranged in the second valve cavity **28** of the valve housing body **20**. The main valve rotor **38** and the throttle valve rotor **40** are configured to rotate relative to the valve housing body **20** about the valve axis **19**.
(73) The first and second valve rotors **38**, **40** cooperate to define a plurality of flow paths through

the valve housing body **20**. As the first and second valve rotors **38**, **40** are rotated about the valve axis **19** to different set positions, the first and second valve rotors **38**, **40** form different flow paths to control the flow of fluid through the housing apertures **36**A-G of the valve housing body **20**.

(74) The first valve rotor **38** includes a first valve rotor body **44** and a first valve rotor shaft **46** that extends axially from the first valve rotor body **44** as shown in FIGS. **5-6**D. The first valve rotor shaft **46** extends axially through the first housing end cover **22** of the valve housing **12** to a terminal end **46**E. The terminal end **46**E is located outside of the first housing end cover **22** in the illustrative embodiment to couple to the actuator **27**.

(75) The first valve rotor shaft **46** is hollow in the illustrative embodiment as shown in FIGS. **15**, **17**, **19**, **21**, and **23**. The first rod **33** extends axially from the partition wall **32** into the first valve rotor shaft **46** to support the first valve rotor **38** relative to the valve housing body **20**.

(76) The first valve rotor body **44** includes a first valve rotor drum **48**, a plurality of circumferential flow divider walls **50**A-C, and a plurality of axial flow dividers walls **52**A-K as shown in FIGS. **6**A-D. The first valve rotor drum **48** extends circumferentially about the valve axis **19** and is hollow to define a rotor drum cavity **54**. The plurality of circumferential flow divider walls **50**A-C are spaced apart axially along the first valve rotor drum **48**. Each of the circumferential flow dividers walls **50**A-C extend radially outward from and circumferentially at least partway around the first valve rotor drum **48**. The plurality of axial flow divider walls **52**A-K are spaced apart circumferentially around the first valve rotor drum **48**. The plurality of axial flow divider walls **52**A-K extend axially between the plurality of circumferential flow divider walls **50** to define a plurality of chambers **56**.

(77) In the illustrative embodiment, the first valve rotor shaft **46** extends axially from the first valve rotor body **44** through the rotor drum cavity **54** as shown in FIGS. **15**, **17**, **19**, **21**, and **23**. The first valve rotor body **44** include a plurality of supports **45** that extend radially inward from the first valve rotor drum **48** to the first valve rotor shaft **46** to support the first valve rotor shaft **46**.

(78) The plurality of circumferential flow divider walls **50**A-C includes a first circumferential flow divider wall **50**A, a second circumferential flow divider wall **50**B, and a third circumferential flow divider wall **50**C as shown in FIGS. **6**A-**6**D. The first circumferential flow divider wall **50**A extends radially outward from and circumferentially all the way around the first valve rotor drum **48** at a first axial end **51** of the first valve rotor drum **48**. The second circumferential flow divider wall **50**B extends radially outward from and circumferentially all the way around the first valve rotor drum **48** at a second axial end **53** of the first valve rotor drum **48**. The third circumferential flow divider wall **50**C extends radially outward from and circumferentially only partway around the first valve rotor drum **48** axially between the first and second circumferential flow divider walls **50**A, **50**B.

(79) The plurality of axial flow divider walls **52**A-K includes at least ten different axial flow divider walls **52**A-K spaced apart circumferentially around the first valve rotor drum **48** as shown in FIGS. **6**A-D. Most of the plurality of axial flow divider walls **52**A-K extend axially between the first and second axial ends **51**, **53** of the first valve rotor drum **48** and interconnect the first and second circumferential flow divider walls **50**A, **50**B. Other axial flow divider walls **52**D, **52**F, **52**H only extend axially partway along the first valve rotor drum **48** between the first and third circumferential flow divider walls **50**A, **50**C.

(80) The different chambers **56**A-M are defined between the different circumferential flow divider walls **50**A-C and axial flow divider walls **52**A-K as shown in FIGS. **6**A-D. The plurality of chambers **56**A-M includes at least thirteen different chambers **56**A-M that range in size.

(81) In the illustrative embodiment, the first valve rotor drum **48** is formed to include openings **58**B, **58**E, **58**H, **58**J, **58**M as shown in FIGS. **6**A-D. The openings **58**B, **58**E, **58**H, **58**J, **58**M extend through the first valve rotor drum **48** and open into the rotor drum cavity **54**. Each of the openings **58**B, **58**E, **58**H, **58**J, **58**M corresponds to one of the chambers **56**B, **56**E, **56**H, **56**J, **56**M. Each of the chambers **56**B, **56**E, **56**H, **56**J, **56**M is in fluid communication with the rotor drum cavity **54**

through the openings **58**B, **58**E, **58**H, **58**J, **58**M.

(82) As the first valve rotor **38** rotates, the first valve rotor body **44** controls the flow to each aperture **36**A, **36**B, **36**C, **36**D, **36**E formed in the valve housing body **20** as shown in FIGS. **15-24**C. The first valve rotor body **44** controls the flow to each aperture **36**A, **36**B, **36**C, **36**D, **36**E by aligning different chambers **56**A-M with the different apertures **36**A, **36**B, **36**C, **36**D, **36**E in the different predetermined positions. This controls which apertures **36**A, **36**B, **36**C, **36**D, **36**E are in fluid communication with the rotor drum cavity **54** or with one of the other apertures **36**A, **36**B, **36**C, **36**D, **36**E.

(83) The first aperture **36**A is always in fluid communication with the rotor drum cavity **54** in the illustrative embodiment. The fluid flows to/from the first aperture **36**A through the apertures **22**A formed in the first housing end cover **22** and into the rotor drum cavity **54**.

(84) In some positions, portions of the first valve rotor body **44** surrounds one of the other apertures **36**B, **36**C, **36**D, **36**E formed in the valve housing body **20** to block the flow of fluid therethrough. Some of the chambers **56**A-M are sized to cover only the one aperture **36**B, **36**C, **36**D, **36**E in certain predetermined positions so that the flow of fluid is blocked from flowing into/out of the rotor drum cavity **54** or is blocked from flowing between apertures **36**B, **36**C, **36**D, **36**E.

(85) The second valve rotor **40** includes a second valve rotor plate **60**, a second valve shaft **62**, and a plurality of second valve rotor walls **64**, **66**, **68** as shown in FIGS. **7** and **8**. The second valve rotor plate **60** extends circumferentially about the valve axis **19**. The second valve shaft **62** extends axially away from the second valve rotor plate **60** to a terminal end **62**E. The second valve shaft **62** extends through the second housing end cover **24** to so that the terminal end **62**E is located outside of the second housing end cover **24**. Each of the second valve rotor walls **64**, **66**, **68** extend axially away from the second valve rotor plate **60** in the same direction as the second valve shaft **62**. The second valve rotor walls **64**, **66**, **68** are spaced apart circumferentially to define a plurality of second valve rotor ports **65**, **67**, **69**.

(86) In the illustrative embodiment, the second valve shaft **62** is hollow as shown in FIGS. **15**, **17**, **19**, **21**, and **23**. The second rod **35** extends axially from the partition wall **32** into the second valve shaft **62** to support the second valve rotor **40** relative to the valve housing body **20**.

(87) The second valve rotor plate **60** is formed to define a second rotor through hole **70** as shown in FIGS. **7** and **8**. The second rotor through hole **70** extends axially through the second valve rotor plate **60** relative to the valve axis **19** so that the flow of fluid is able to flow axially through the second valve rotor **40** parallel to the valve axis **19**. The second rotor through hole **70** extends circumferentially partway about the valve axis **19** in the illustrative embodiment.

(88) Each of the second valve rotor walls **64**, **66**, **68** extends axially away from the second valve rotor plate **60** to a terminal end **64**E, **66**E, **68**E as shown in FIGS. **7** and **8**. The terminal ends **64**E, **66**E, **68**E of each of the second valve rotor walls **64**, **66**, **68** is spaced apart axially from the terminal end **62**E of the second valve shaft **62** such that the second valve rotor walls **64**, **66**, **68** do not extend past the second housing end cover **24**.

(89) As the second valve rotor **40** rotates, the second valve rotor plate **60** controls the flow of fluid through the connecting aperture **32**A, while the second valve rotor walls **64**, **66**, **68** vary the amount of fluid flowing through the apertures **36**F, **36**G formed in the valve housing body **20** as shown in FIGS. **11-14**. The different valve rotor walls **64**, **66**, **68** partially open, fully open, or close the apertures **36**F, **36**G in the different predetermined positions to control the flow of fluid therethrough. In some positions, a portion of the second valve rotor plate **60** covers the connecting aperture **32**A to block the flow of fluid therethrough.

(90) The different modes of the multi-way valve **10** are shown in FIG. **10**. The first mode (mode A) and the second mode (mode B**1**) are shown in FIG. **10**A. The third mode (mode B**2**) and the fifth mode (mode C) are shown in FIG. **10**B. The fourth mode (mode B**3**) is shown in FIG. **10**C. The sixth mode (mode D) is shown in FIG. **10**D. The seventh mode (mode E) is shown in FIG. **10**E.

(91) In modes A and B**1**, the main valve rotor **38** is in a MAIN VALVE ROTOR FIRST position as shown in FIGS. **15-16**C and the throttle valve rotor **40** is in a THROTTLE VALVE ROTOR FIRST position as shown in FIG. **11**. In the MAIN VALVE ROTOR FIRST position, the main valve rotor **38** connects the first aperture **36**A to the second aperture **36**B, connects the third aperture **36**C and the fifth aperture **36**E, and blocks the fourth aperture **36**D to form the first flow path. One of the chambers **56**I surrounds the third aperture **36**C and the fifth aperture **36**E to connect the third and fifth apertures, **36**C, **36**E in fluid communication. Another one of the chambers **56**G surrounds the fourth aperture **36**D to block the flow of fluid to the fourth aperture **36**D.
(92) In the THROTTLE VALVE ROTOR FIRST position, the throttle valve rotor **40** covers the connecting aperture **32**A to block flow between the first and second valve cavities **26**, **28** through the connecting aperture **32**A formed in the partition wall **32** and connects the sixth aperture **36**F and the seventh aperture **36**G. The second valve rotor ports **65**, **67** align with the sixth and seventh apertures **36**F, **36**G to allow the flow of fluid between the sixth aperture **36**F and the seventh aperture **36**G.
(93) In mode B**2**, the main valve rotor **38** stays in the MAIN VALVE ROTOR FIRST position, while the throttle valve rotor **40** moves to a THROTTLE VALVE ROTOR SECOND position as shown in FIG. **12**. In the THROTTLE VALVE ROTOR SECOND position, the throttle valve rotor **40** has rotated about the valve axis **19** to uncover the connecting aperture **32**A to align the hole **70** with the connecting aperture **32**A. This allows flow between the first and second valve cavities **26**, **28** through the connecting aperture **32**A formed in the partition wall **32** and the hole **70**. Simultaneously, one of the second valve rotor walls **64** covers the sixth aperture **36**F to block flow through the sixth aperture **36**F, while one of the second valve rotor ports **69** aligns with the seventh aperture **36**G. In this way, the seventh aperture **36**G is in fluid communication with the first aperture **36**A.
(94) In mode B**3**, the main valve rotor **38** stays in the MAIN VALVE ROTOR FIRST position and the throttle valve rotor **40** moves to a THROTTLE configuration as shown in FIG. **13**. In the THROTTLE configuration, the throttle valve rotor **40** has rotated to uncover the sixth aperture **36**F, while keeping the hole **70** formed in the throttle valve rotor **40** aligned with the connecting aperture **32**A. In the THROTTLE configuration, the second valve rotor port **69** aligns with both the sixth aperture **36**F and the seventh aperture **36**G to allow the flow of fluid therethrough. However, in the THROTTLE configuration, the throttle valve rotor **40** can rotate about the valve axis **19** to vary, or throttle, the flow through the sixth and seventh apertures **36**F, **36**G. The second valve rotor walls **64**, **68** may block a portion of the corresponding aperture **36**F, **36**G to vary the flow therethrough.
(95) In mode C, the main valve rotor **38** is in the MAIN VALVE ROTOR FIRST position and the throttle valve rotor **40** is in the THROTTLE VALVE ROTOR SECOND position. However, the direction of the flow between the third aperture **36**C and the fifth aperture **36**E may have reversed as suggested in FIG. **10**.
(96) In mode D, the throttle valve rotor **40** is in the THROTTLE VALVE ROTOR FIRST position, while the main valve rotor **38** moves to a MAIN VALVE ROTOR SECOND position as shown in FIG. **17-18**C. In the MAIN VALVE ROTOR SECOND position, the main valve rotor **38** has rotated to connect the second aperture **36**B and the third aperture **36**C, to connect the first aperture **36**A and the fourth aperture **36**D, to block the fifth aperture **36**E. One of the chambers **56**L surrounds the second and third apertures **36**B, **36**C to connect the second and third apertures **36**B, **36**C in fluid communication. Another one of the chambers **56**K surrounds the fifth aperture **36**E to block the flow of fluid to the fifth aperture **36**E.
(97) In mode E, the main valve rotor **38** moves to a MAIN VALVE ROTOR THIRD position as shown in FIGS. **19-20**C, while the throttle valve rotor **40** is in the THROTTLE configuration. In the MAIN VALVE ROTOR THIRD position, the main valve rotor **38** has rotated to connect all the apertures **36**A-G. One of the chambers **56**M surrounds the second aperture **36**B, the third aperture **36**C, the fourth aperture **36**D, and the fifth aperture **36**E and the chamber **56**M has the opening **58**

so that the apertures **36**B-E are in fluid communication with the first aperture **36**A.

(98) The multi-way valve **10** and/or each of the actuators **27**, **29** may include the control unit configured to direct the actuators **27**, **29** to move each of the valve rotors **38**, **40** to the different predetermined positions in each of the different modes A-E. Based on where the vehicle needs fluid, the control unit would direct the actuators **27**, **29** to move each of the valve rotors **38**, **40** to one of the positions for the desired mode.

(99) The first and second sealing systems **16**, **18** help seal between the valve housing **12** and the first and second valve rotors **38**, **40** in the different predetermined positions as shown in FIGS. **25-28**A. The first sealing system **16** seals between the valve housing body **20** and the first valve rotor **38**. The second sealing system **18** seals between the partition wall **32** of the valve housing body **20** and the second valve rotor **40**.

(100) The first sealing system **16** includes the first seal **72** and a first biasing assembly **74** as shown in FIGS. **27-28**A. The first seal **72** is located radially between the first valve rotor **38** and the valve housing body **20**. The first seal **72** extends axially between the first and second ends **51**, **53** of the first valve rotor **38** and extends circumferentially partway about the valve axis **19**. The first biasing assembly **74** is configured to selectively apply a radial force FR on the first valve rotor **38** to urge the first valve rotor **38** toward the base **34** of the valve housing body **20** when the first valve rotor **38** is in one of the plurality of different predetermined positions so as to increase sealing between the first valve rotor **38** and the valve housing body **20**. This radial force FR is applied to urge the first valve rotor **38** into engagement with the first seal **72** when the first valve rotor **38** is in one of the plurality of different predetermined positions to improve sealing between the first valve rotor **38** and the valve housing body **20**.

(101) The first seal **72** surrounds each of the plurality of apertures **36**B, **36**C, **36**D, **36**E formed in the valve housing body **20**. In the illustrative embodiment, the first seal **72** includes holes that align with the apertures **36**B, **36**C, **36**D, **36**E in the valve housing body **20** as shown in FIGS. **15-24**C.

(102) The first biasing assembly **74** selectively applies the radial force FR to increase friction between the first valve rotor **38** and the first seal **72** at the different predetermined positions, but removes the radial force FR when the first valve rotor **38** rotates to reduce the friction between the first valve rotor **38** and the first valve seal **72**. In this way, the torque needed to rotate the first valve rotor **38** is reduced and the wear on the first seal **72** is reduced.

(103) Similarly, the second sealing system **18** includes a second seal **76** and a second biasing assembly **78** as shown in FIGS. **25-26**A. The second seal **76** is located in the connecting aperture **32**A formed in the partition wall **32** of the valve housing body **20** to engage an axially facing surface **60**S of the second valve rotor **40**. In the illustrative embodiment, the second seal **76** is press fit into the connecting aperture **32**A formed in the partition wall **32** of the valve housing body **20** to engage an axially facing surface **60**S of the second valve rotor **40**. The second biasing assembly **78** is configured to selectively apply an axial force FA on the second valve rotor **40** to urge the second valve rotor **40** toward the partition wall **32** of the valve housing body **20** when the second valve rotor **40** is in one of the plurality of different predetermined positions so as to increase sealing between the second valve rotor **40** and the valve housing body **20**. The axial force FA is applied to urge the second valve rotor **40** into engagement with the second seal **76** when the second valve rotor **40** is in one of the plurality of different predetermined positions to improve sealing between the second valve rotor **40** and the partition wall **32** of the valve housing body **20**.

(104) The second biasing assembly **78** selectively applies the axial force FA to increase friction between the second valve rotor **40** and the seals at the different predetermined positions, but removes the axial force FA when the second valve rotor **40** rotates to reduce the friction between the second valve rotor **40** and the second seal **76**. In this way, the torque needed to rotate the second valve rotor **40** is reduced and the wear on the second seal **76** is reduced.

(105) In the illustrative embodiment, the first and second seals **72**, **76** comprise a Teflon material. In some embodiments, the seals may be made of another suitable material.

(106) In other multi-way seals, large amounts of Teflon material may be used to seal the different passages, which can make manufacturing the multi-way valve expensive. Therefore, by reducing the amount of friction on the first and second seals **72**, **76** during rotation of the first and second valve rotors **38**, **40**, wear on the first and second seals **72**, **76** is reduced. This reduces the need to replace the first and second seals **72**, **76** as well and reduces the cost of repairing the multi-way valve **10**. In other embodiments, the seals may be made of another suitable material.
(107) Turning again to the first sealing system **16**, the biasing assembly **74** includes a ridge **80** and a plurality of protrusions **82** as shown in FIGS. **27-28**A. The ridge **80** extends radially inward from and axially along the annular outer wall **30** of the valve housing body **20**. The ridge **80** extends radially inward from the annular outer wall **30** opposite the apertures **36**A-E. The plurality of protrusions **82** extend radially outward from the first valve rotor **38** and are configured to engage the ridge **80** on the valve housing body **20** as the first valve rotor **38** rotates about the valve axis **19** to the plurality of different predetermined positions.
(108) In the illustrative embodiment, the protrusions **82** are located at the intersection of the third circumferential flow divider wall **50**C and the different axial flow divider walls **52**A-K. The protrusions **82** are spaced apart circumferentially around the first valve rotor body **44**. In the illustrative embodiment, the protrusions **82** are spaced apart at about 72 degree intervals around the first valve rotor **38**.
(109) The ridge **80** is fixed to the valve housing body **20**. Each of the protrusions **82** on the first valve rotor **38** rides against the ridge **80** as the first valve rotor **38** is rotated and applies downward radial force FR to the first valve rotor **38** when aligned with the ridge **80** on the valve housing body **20**. This radial force FR generates a contact pressure between the first valve rotor **38** and the elastomer seal **72**. The increased contact pressure and resulting increase in friction are only generated when the ridge **80** is aligned with one of the protrusions **82** on the first valve rotor **38**. This reduces friction and torque on the actuator **29** during movement between seal points.
(110) In some embodiments, the ridge **80** and the protrusions **82** may be interchangeable. The ridge **80** and the protrusions **82** may be interchangeable such that the ridge **80** is formed on the first valve rotor **38** and the protrusion **82** is formed on the valve housing body **20**.
(111) Turning again to the second sealing system **18**, the second biasing assembly **78** includes cam ramps **86** and a plurality of cam surfaces **88**, **90**, **92** as shown in FIGS. **7**, **8**, and **25-26**A. The cam ramps **86** are formed on an axially facing **24**S surface of the second housing end cover **24** of the valve housing body **20**. The cam ramps **86** are equally spaced apart circumferentially about the valve axis **19**. Each cam surface **88**, **90**, **92** is formed on one of the second valve rotor walls **64**, **66**, **68**. The cam surfaces **88**, **90**, **92** are configured to engage the cam ramps **86** on the second housing end cover **24** as the second valve rotor **40** rotates about the valve axis **19** to the plurality of different predetermined positions.
(112) In this way, the raised portions **88**P, **90**P, **92**P of each of the cam surfaces **88**, **90**, **92** engages one of the cam ramps **86** in each of the different predetermined positions to cause the axial force FA to be applied to the second valve rotor **40**. Then as the second valve rotor **40** rotates about the valve axis **19**, the raised portions **88**P, **90**P, **92**P of the cam surfaces **88**, **90**, **92** disengage the cam ramps **86** so that the axial force FA is removed and the torque needed to rotate the second valve rotor **40** is reduced.
(113) The cam ramps **86** are fixed on the second housing end cover **24**. The cam surfaces **88**, **90**, **92** on the second valve rotor **40** rides against the cam ramps **86** in a circular manner and applies downward axial force FA to the second valve rotor **40** when aligned with the high point **88**P, **90**P, **92**P of the cam surfaces **88**, **90**, **92**. This force FA generates a contact pressure between the underside of the second valve rotor **40** and the elastomer seal **76** press-fit into the partition wall **32** of the valve housing body **20**. The increased contact pressure and resulting increase in friction are only generated when each high point **88**P, **90**P, **92**P of the cam surfaces **88**, **90**, **92** is aligned with a

cam ramp **86**. This reduces friction and torque on the actuator **29** during movement between seal points.

Claims

1. A multi-way valve comprising a valve housing coupled to a manifold of thermal fluid circuits, the valve housing including a valve housing body, a first housing end cover coupled to a first end of the valve housing body, and a second housing end cover coupled to a second end of the valve housing spaced apart axially from the first end of the valve housing relative to a valve axis, the valve housing body shaped to define a first valve cavity, a second valve cavity in fluid communication with the first valve cavity, and a plurality of apertures that open into the first and second valve cavities, the first housing end cover coupled to the first end of the valve housing to close a first end opening to the first valve cavity, and the second housing end cover coupled to the second end of the valve housing to close a second end opening to the second valve cavity, and a valve flow controller includes a first valve rotor arranged in the first valve cavity of the valve housing body and configured to rotate relative to the valve housing body about the valve axis, a second valve rotor arranged in the second valve cavity of the valve housing body and configured to rotate relative to the valve housing body about the valve axis, a first actuator coupled to the first valve rotor to drive rotation of the first valve rotor about the valve axis, and a second actuator coupled to the second valve rotor to drive rotation of the second valve rotor about the valve axis, wherein the first and second valve rotors cooperate to define a plurality of flow paths when the first and second valve rotors are rotated about the valve axis to a plurality of different predetermined positions to control a flow of fluid through the valve housing, and wherein the valve housing body includes an annular outer wall that extends around the valve axis to define a hollow space, a partition wall located in the hollow space of the annular outer wall to divide the hollow space into the first valve cavity and the second valve cavity, and a housing base that extends from the annular outer wall and formed to define the plurality of apertures, and wherein the partition wall is formed to include a connecting aperture in fluid communication with the first valve cavity and the second valve cavity of the valve housing body.
2. The multi-way valve of claim 1, wherein the first valve rotor includes a first valve rotor body and a first valve rotor shaft that extends axially from the first valve rotor body through the first housing end cover of the valve housing to a terminal end located outside of the first housing end cover of the valve housing and coupled to the first actuator.
3. The multi-way valve of claim 2, wherein the first valve rotor body of the first valve rotor includes a first valve rotor drum that extends circumferentially about the valve axis, a plurality of circumferential flow divider walls spaced apart axially along the first valve rotor drum that extend radially outward from and circumferentially at least partway around the first valve rotor drum, and a plurality of axial flow divider walls that extend axially between the plurality of circumferential flow divider walls to define a plurality of chambers therebetween.
4. The multi-way valve of claim 2, wherein the second valve rotor includes a second valve rotor plate, a plurality of second valve rotor walls that extend axially away from the second valve rotor plate and spaced apart circumferentially to define a plurality of second valve ports, and a second valve shaft that extends axially from the second valve rotor plate through the second housing end cover of the valve housing to a terminal end located outside the second housing end cover and coupled to the second actuator, and wherein the second valve rotor plate is formed to include a second rotor through hole that extends axially through the second valve rotor relative to the valve axis so that the flow of fluid is able to flow axially through the second valve rotor parallel to the valve axis.
5. The multi-way valve of claim 1, further comprising a first sealing system configured to seal between the first valve rotor and the valve housing body, the first sealing system including a first

seal located radially between the first valve rotor and the valve housing body that surrounds each of the plurality of apertures formed in the valve housing body.
6. The multi-way valve of claim 5, wherein the first sealing system further includes first biasing means for applying a radial force on the first valve rotor to urge the first valve rotor into engagement with the first seal when the first valve rotor is in one of the plurality of different predetermined positions to improve sealing between the first valve rotor and the valve housing body and for removing the radial force on the first valve rotor to reduce friction between the first valve rotor and the first seal when the first valve rotor is rotated about the valve axis from one position to another position included in the plurality of different predetermined positions.
7. The multi-way valve of claim 6, wherein the first biasing means includes a ridge that extends radially inward from and axially along the annular outer wall of the valve housing and a plurality of protrusions that extend radially outward from the first valve rotor and configured to engage the ridge on the valve housing body as the first valve rotor rotates about the valve axis to the plurality of different predetermined positions.
8. The multi-way valve of claim 5, further comprising a second sealing system configured to seal between the second valve rotor and the valve housing body, the second sealing system including a second seal is located in the connecting aperture formed in the partition wall of the valve housing body to engage an axially facing surface of the second valve rotor.
9. The multi-way valve of claim 8, wherein the second sealing system further includes second biasing means for applying an axial force on the second valve rotor to urge the second valve rotor into engagement with the second seal when the second valve rotor is in one of the plurality of different predetermined positions to improve sealing between the second valve rotor and the partition wall of the valve housing body and for removing the axial force on the second valve rotor to reduce friction between the second valve rotor and the second seal when the second valve rotor is rotated about the valve axis from one position to another position included in the plurality of different predetermined positions.
10. The multi-way valve of claim 9, wherein the second biasing means includes cam ramps on an axially facing surface of the second housing end cover of the valve housing and a plurality of cam surfaces on the second valve rotor configured to engage the cam ramps on the second housing end cover as the second valve rotor rotates about the valve axis to the plurality of different predetermined positions.
11. The multi-way valve of claim 5, the first sealing system further comprising a first biasing assembly configured to selectively apply a radial force on the first valve rotor to urge the first valve rotor into engagement with the first seal when the first valve rotor is in one of the plurality of different predetermined positions to improve sealing between the first valve rotor and the valve housing body.
12. The multi-way valve of claim 11, wherein the first biasing assembly includes a ridge that extends radially inward from and axially along the annular outer wall of the valve housing and a plurality of protrusions that extend radially outward from the first valve rotor and configured to engage the ridge on the valve housing body as the first valve rotor rotates about the valve axis to the plurality of different predetermined positions.
13. The multi-way valve of claim 12, further comprising a second sealing system configured to seal between the second valve rotor and the valve housing body, the second sealing system including a second seal is located in the connecting aperture formed in the partition wall of the valve housing body to engage an axially facing surface of the second valve rotor and a second biasing assembly configured to selectively apply an axial force on the second valve rotor to urge the second valve rotor into engagement with the second seal when the second valve rotor is in one of the plurality of different predetermined positions to improve sealing between the second valve rotor and the partition wall of the valve housing body.
14. The multi-way valve of claim 13, wherein the second biasing assembly includes cam ramps on

an axially facing surface of the second housing end cover of the valve housing and a plurality of cam surfaces on the second valve rotor configured to engage the cam ramps on the second housing end cover as the second valve rotor rotates about the valve axis to the plurality of different predetermined positions.

15. A multi-way valve comprising a valve housing coupled to a manifold of thermal fluid circuits, the valve housing including a valve housing body, a first housing end cover coupled to a first end of the valve housing body, and a second housing end cover coupled to a second end of the valve housing spaced apart axially from the first end of the valve housing relative to a valve axis, the valve housing body shaped to define a first valve cavity, a second valve cavity in fluid communication with the first valve cavity, and a plurality of apertures that open into the first and second valve cavities, the first housing end cover coupled to the first end of the valve housing to close a first end opening to the first valve cavity, and the second housing end cover coupled to the second end of the valve housing to close a second end opening to the second valve cavity, and a valve flow controller includes a first valve rotor arranged in the first valve cavity of the valve housing body and configured to rotate relative to the valve housing body about the valve axis, a second valve rotor arranged in the second valve cavity of the valve housing body and configured to rotate relative to the valve housing body about the valve axis, a first actuator coupled to the first valve rotor to drive rotation of the first valve rotor about the valve axis, and a second actuator coupled to the second valve rotor to drive rotation of the second valve rotor about the valve axis, wherein the first and second valve rotors cooperate to define a plurality of flow paths when the first and second valve rotors are rotated about the valve axis to a plurality of different predetermined positions to control a flow of fluid through the valve housing, and wherein the multi-way valve further comprises a first sealing system configured to seal between the first valve rotor and the valve housing body, the first sealing system including a first biasing assembly configured to selectively apply a radial force on the first valve rotor to urge the first valve rotor toward the plurality of apertures formed in the valve housing body when the first valve rotor is in one of the plurality of different predetermined positions to increase sealing between the first valve rotor and the valve housing body.

16. The multi-way valve of claim 15, wherein the first sealing system further includes a first seal located radially between the first valve rotor and the valve housing body that surrounds each of the plurality of apertures formed in the valve housing body.

17. The multi-way valve of claim 15, wherein the first biasing assembly includes a ridge that extends radially inward from and axially along an annular outer wall of the valve housing and a plurality of protrusions that extend radially outward from the first valve rotor and configured to engage the ridge on the valve housing body as the first valve rotor rotates about the valve axis to the plurality of different predetermined positions.

18. The multi-way valve of claim 15, wherein the multi-way valve further comprises a second sealing system configured to seal between the second valve rotor and the valve housing body, the second sealing system including a second biasing assembly configured to selectively apply an axial force on the second valve rotor to urge the second valve rotor toward the first valve rotor when the second valve rotor is in one of the plurality of different predetermined positions to increase sealing between the second valve rotor and the valve housing body.

19. The multi-way valve of claim 18, wherein the second biasing assembly includes cam ramps on an axially facing surface of the second housing end cover of the valve housing and a plurality of cam surfaces on the second valve rotor configured to engage the cam ramps on the second housing end cover as the second valve rotor rotates about the valve axis to the plurality of different predetermined positions.

20. A multi-way valve comprising a valve housing that extends axially along a valve axis, the valve housing formed to include a first valve cavity and a second valve cavity in fluid communication with the first valve cavity, a valve flow controller includes a first valve rotor arranged in the first

valve cavity of the valve housing and configured to rotate relative to the valve housing about the valve axis, a second valve rotor arranged in the second valve cavity of the valve housing and configured to rotate relative to the valve housing about the valve axis, a first actuator coupled to the first valve rotor to drive rotation of the first valve rotor about the valve axis, and a second actuator coupled to the second valve rotor to drive rotation of the second valve rotor about the valve axis, and the first and second valve rotors cooperate to define a plurality of flow paths when the first and second valve rotors are rotated about the valve axis to a plurality of different predetermined positions to control a flow of fluid through the valve housing, and a first sealing system configured to seal between the first valve rotor and the valve housing in the first valve cavity, the first sealing system including a first biasing assembly configured to selectively apply a radial force on the first valve rotor to urge the first valve rotor toward a plurality of apertures formed in the valve housing when the first valve rotor is in one of the plurality of different predetermined positions to increase sealing between the first valve rotor and the valve housing.
21. The multi-way valve of claim 20, wherein the first sealing system further includes a first seal located radially between the first valve rotor and the valve housing that surrounds each of the plurality of apertures formed in the valve housing.
22. The multi-way valve of claim 21, wherein the first biasing assembly includes a ridge that extends radially inward from and axially along the valve housing opposite the first seal and a plurality of protrusions that extend radially outward from the first valve rotor and configured to engage the ridge on the valve housing as the first valve rotor rotates about the valve axis to the plurality of different predetermined positions.
23. The multi-way valve of claim 20, wherein the multi-way valve further comprises a second sealing system configured to seal between the second valve rotor and the valve housing, the second sealing system including a second biasing assembly configured to selectively apply an axial force on the second valve rotor to urge the second valve rotor toward the first valve rotor when the second valve rotor is in one of the plurality of different predetermined positions to increase sealing between the second valve rotor and the valve housing.
24. The multi-way valve of claim 23, wherein the second sealing system further includes a second seal located axially between the second valve rotor and the valve housing.
25. The multi-way valve of claim 23, wherein the second biasing assembly includes cam ramps on an axially facing surface of the valve housing and a plurality of cam surfaces on the second valve rotor configured to engage the cam ramps on the valve housing as the second valve rotor rotates about the valve axis to the plurality of different predetermined positions.
26. The multi-way valve of claim 20, wherein the valve housing including a valve housing body shaped to define the first valve cavity and the second valve cavity, a first housing end cover coupled to a first end of the valve housing to close off the first valve cavity, and a second housing end cover coupled to a second end of the valve housing spaced apart axially from the first end of the valve housing relative to the valve axis to close off the second valve cavity, and wherein the valve housing body includes an annular outer wall that extends around the valve axis to define a hollow space, a partition wall located in the hollow space of the annular outer wall to divide the hollow space into the first valve cavity and the second valve cavity, and a housing base that extends from the annular outer wall and formed to define the plurality of apertures, and wherein the multi-way valve further comprises a second sealing system configured to seal between the second valve rotor and the valve housing body, the second sealing system including a second seal located in a connecting aperture formed in the partition wall of the valve housing body.
27. The multi-way valve of claim 26, wherein the first valve rotor includes a first valve rotor body and a first valve rotor shaft that extends axially from the first valve rotor body through the first housing end cover of the valve housing to a terminal end located outside of the first housing end cover of the valve housing and coupled to the first actuator.
28. The multi-way valve of claim 27, wherein the first valve rotor body of the first valve rotor

includes a first valve rotor drum that extends circumferentially about the valve axis, a plurality of circumferential flow divider walls spaced apart axially along the first valve rotor drum that extend radially outward from and circumferentially at least partway around the first valve rotor drum, and a plurality of axial flow divider walls that extend axially between the plurality of circumferential flow divider walls to define a plurality of chambers therebetween.

29. The multi-way valve of claim 26, wherein the second valve rotor includes a second valve rotor plate, a plurality of second valve rotor walls that extend axially away from the second valve rotor plate and spaced apart circumferentially to define a plurality of second valve ports, and a second valve shaft that extends axially from the second valve rotor plate through the second housing end cover included in the valve housing to a terminal end located outside the second housing end cover and coupled to the second actuator, and wherein the second valve rotor plate is formed to include a second rotor through hole that extends axially through the second valve rotor relative to the valve axis so that the flow of fluid is able to flow axially through the second valve rotor parallel to the valve axis.