

CONNECTION SYSTEM AND METHOD

RELATED APPLICATIONS

- [0001] This application claims priority to United States Provisional Patent Application No. 61/708,470, entitled "Modular Filter With Tension Members," filed October 1, 2012, United States Provisional Patent Application No. 61/775,051, entitled "Modular Filter With Tension Members and Manifold for Modular Filters," filed March 8, 2013, United States Provisional Patent Application No. 61/813,983, entitled "Manifold for Modular Filters, Modular Filter Cassettes and Connection Systems," filed April 19, 2013, United States Provisional Patent Application No. 61/826,880, entitled "Modular Filter with Tension Members," filed May 23, 2013 and United States Provisional Patent Application No. 61/835,884, entitled "Manifold for Modular Filters, Modular Filter Cassettes and Connection Systems," filed June 17, 2013, each of which is fully incorporated herein by reference for all purposes.

TECHNICAL FIELD

- [0002] This disclosure relates to connection systems for fluid connections. Even more particularly, some embodiments this disclosure relates to connection systems for deformable materials. Even more particularly, some embodiments relate to fluid connections for use with semiconductor manufacturing fluids.

BACKGROUND

- [0003] Semiconductor manufacturing processes are highly sensitive to contamination. Therefore, materials that contact the process fluids are often formed from polymers that are non-reactive with process fluid. In many cases, however, these materials are relatively deformable and may exhibit significant creep at higher temperatures. Consequently, it is difficult to provide fluid connections that do not leak.
- [0004] Some filtration systems rely on threaded connections. In these systems, the other fitting includes external fitting threads, while the other fitting includes a screw cap with inner threads. The screw cap is screwed onto the filter so that the fittings seal together. However, the loosening of fittings following temperature excursions is a common problem in the semiconductor industry.
- [0005] This problem is particularly an issue when the fittings are made of a material that is deformable, such as perfluoroalkoxy polymer (PFA). Existing PFA fittings typically use

relatively fine v-shaped threads (such as Unified or metric screw threads). The threads are designed to create a substantial amount of contact between screw cap and filter fitting through multiple rotations of the screw cap. Buttress threads and the like are avoided because such threads have less surface contact compared to a Unified screw thread or a metric screw thread (for example) of the same relative size and pitch and, therefore, are more likely to loosen.

- [0006] Traditional threaded fittings have several other shortcomings. As one example, traditional threaded fittings do not provide a quick connect mechanism to simultaneously seal multiple ports. Each fitting must be connected separately. This leads to another problem in that a user must have adequate room to manipulate the individual fittings. Another deficiency is that such fittings often use o-rings, which increase the likelihood of contamination. Another shortcoming is that the fittings are not easily manipulated by robots.

SUMMARY

- [0007] Embodiments of a connection system that can be used in a variety of applications, including in semiconductor manufacturing applications, are described. One embodiment provides a connection system comprising a connection housing, a first fitting and a connection nut. The connection housing can define a connection housing first opening having a first set of connection housing inner threads. The connection nut can be disposed in the connection housing first opening and be rotatable around the first fitting.
- [0008] The connection nut can comprise a set of first connection nut external threads and a set of first connection nut internal threads. The set of first connection nut internal threads are multi-start threads configured to engage a set of second fitting external threads on a second fitting. The connection nut internal threads can be configured to create a seal between the first fitting and second fitting with less than 360 degrees of rotation. In some embodiments, less than 360 degrees of rotation may result in at least 360 degrees or more of thread engagement and in other embodiments may result in less than the 360 degrees of thread engagement. The thread engagement may provide a circumferential axial sealing force (e.g., an axial sealing force of at least 360 degrees or, in some cases, less than 360 degrees).
- [0009] The set of first connection nut external threads engage the first set of connection housing inner threads. The set of first connection nut external threads and the first set of connection housing inner threads may be single start threads configured to create a friction force that prevents counter rotation of the first connection nut under the axial sealing force. According to another embodiment, the connection nut does not include external nut threads, but is

retained in the connection housing from moving axially while still being able to rotate. In one embodiment, the connection nut internal threads and second fitting external threads are multi-start threads and the connection nut external threads are single start threads with a finer pitch.

- [0010] According to one embodiment, the set of first connection nut internal threads can comprise multi-start threads. For example, in one embodiment, the multi-start threads can comprise a first thread running 120-180 degrees from a first start, a second thread running 120-180 degrees from a second start and a third thread running 120-180 degrees from a third start. Other embodiments may include other numbers of starts and the threads may run less than 120 degrees and greater than 180 degrees. According to one embodiment, the multi-start threads are buttress threads. In one embodiment, the connection nut internal threads have a load flank angle of 0-5 degrees and a relief flank angle of 25-35 degrees.
- [0011] The connection system and fitting may include alignment features to help ensure that the fitting external threads and connection nut internal threads are properly aligned. In one embodiment, the alignment features of the fitting may include an alignment rib. The gear arm, or other rotation member, may include a slot to receive the rib. The alignment rib and slot may be configured so that the rotation member must be rotated to a certain angle (e.g., corresponding to a position in which the threads are aligned) before the alignment rib can enter the slot. The alignment rib and slot may be helical.
- [0012] A connection nut and port fitting can include features to ensure proper engagement between the connection nut and port fitting. A connection nut can comprise a first set of alignment features and the port fitting can comprise a set of complementary alignment features. The first set of alignment features can be spaced from a start of the set of connection nut internal threads a distance such that the set of connection nut internal threads cannot engage the fitting external threads unless the first set of alignment features mate with the corresponding alignment features of the fitting (and in some cases pass by so that the connection nut may rotate).
- [0013] According to one embodiment, for example, connection nut may include a set of inner projections spaced from a start of the connection nut internal threads, while a port fitting can comprise a port rib spaced from the port fitting external threads that includes a set of notches. The inner projections and port rib can be spaced so that the nut internal threads cannot engage the port fitting external threads unless the inner protrusion passes through the alignment notch. In some cases, the alignment features can be configured so that only certain cassettes fit in certain manifolds (or in particular positions within a manifold) (e.g., to

ensure proper cassettes are used for certain applications). For example, the notch sets and inner projections can be altered in geometry, spacing, or other aspect for different fittings/connection nuts.

- [0014] A connection system can further include a third fitting defining a third fitting flow passage and a second connection nut that includes a set of external threads and is rotatable about the third fitting. The second connection nut can comprise a set of second connection nut internal threads, wherein the set of second connection nut internal threads are multi-start threads configured to engage a set of fourth fitting external threads on a fourth fitting to create a 360 degree axial sealing force on the fourth fitting with less than 360 degrees of rotation to seal the fourth fitting to the third fitting and create a continuous flow passage. The second connection nut may be disposed in the same connection housing as the first connection nut or in second connection housing. The second connection nut may also comprise a set of alignment features such as inner projections.
- [0015] A connection system can include a gear assembly operatively coupling the first connection nut to the second connection nut such that the first connection nut and second connection nut rotate simultaneously. A rotation member can be operatively coupled to the gear assembly such that rotation of the rotation member rotates the first connection nut and the second connection nut. The rotation member, in one embodiment, comprises a gear arm having gear teeth. The gear arm may be operatively coupled to the first connection nut and second connection nut by one or more gears. In one embodiment, the gear arm is directly coupled to the first connection nut and operatively coupled to the second connection nut. The gear arm may further comprise a main arm portion extending forward. The arm portion can comprise a slot positioned to receive a radial rib extending from the first port fitting as the arm portion rotates. The slot and rib may be helical.
- [0016] A drive shaft can be received in a drive shaft passage of the gear arm. The drive shaft can be translatable in the drive shaft passage from a fully retracted position to a fully inserted position. The drive shaft may be rotatable through a range of angular positions about a pivot point. In one embodiment, in a first set of selected angular positions the drive shaft cannot be translated to the fully inserted position and in a selected angular position the drive shaft can be translated to the fully inserted position to lock rotation of the gear arm. In the first set of angular positions, a first end of the drive shaft may overlaps a front surface of the connection housing, while in the selected angular position, the first end of the drive shaft may be aligned with a feature into which the first end of the drive shaft can be inserted.

- [0017] A method for connecting a first fluid fitting and a second fluid fitting, can include aligning multi-start inner connection nut threads of a connection nut with external fitting threads of the second fluid fitting, wherein the connection nut is rotatable about the first fluid fitting in a connection housing and has connection nut external threads that engage connection housing inner threads; rotating the connection nut less than 360 degrees (in some cases less than 180 degrees, including less than 135 degrees) to seal the first fluid fitting to the second fluid fitting. Less than 360 degrees of rotation (and in some cases less than 180 degrees of rotation) can result in at least 360 degrees of threaded engagement. In other embodiments, the amount of threaded engagement may be less than 360 degrees, while a sufficient sealing force is still applied. The method may further include rotating a plurality of connection nuts simultaneously to create a plurality of seals.
- [0018] The connection system and fitting may include alignment features to help ensure that the fitting external threads and connection nut internal threads are properly aligned. In one embodiment, the alignment features of the fitting may include an alignment rib. The gear arm, or other rotation member, may include a slot to receive the rib. The alignment rib and slot may be configured so that the rotation member must be rotated to a certain angle (e.g., corresponding to a position in which the threads are aligned) before the alignment rib can enter the slot. The alignment rib and slot may be helical.
- [0019] The connection nut may include alignment features. In one embodiment, the connection nut may include a first set of alignment features and a fitting may include a second set of alignment features. Aligning the inner connection nut threads of the connection nut with external fitting threads of the second fluid fitting may include aligning the first set of alignment features and the second set of alignment features. According to one embodiment, the first set of alignment features can comprise a set of inner projections and the second set of alignment features can comprise a set of notches that align with the inner projection. The second set of alignment features may be disposed on an alignment rib.
- [0020] In some cases, the alignment features can be configured so that only certain fittings can fit with certain connection systems (e.g., to ensure proper cassettes are used for certain applications). For example, the notch sets and inner projections can be altered in geometry, spacing, or other aspect for different fittings/connection nuts.
- [0021] Embodiments can provide a quick connect mechanism for fluid fittings and, in some embodiments, a quick connect system that allows multiple fittings to be sealed simultaneously. In some cases, the quick connect system can allow a user to seal ports even when the ports are located to the rear of a purification cassette away from the user.

Furthermore, the quick connection can be o-ringless, improving contamination control and providing more reliable higher temperature operation.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0022] The drawings accompanying and forming part of this specification are included to depict certain aspects of embodiments of the invention. A clearer impression of the invention, and of the components and operation of systems provided with the invention, will become more readily apparent by referring to the exemplary, and therefore nonlimiting, embodiments illustrated in the drawings, wherein identical reference numerals designate the same components. Note that the features illustrated in the drawings are not necessarily drawn to scale.
- [0023] FIGURES 1A-1B are diagrammatic representations of one embodiment of a connection system in a non-engaged and an engaged state.
- [0024] FIGURE 2 is a diagrammatic representation of another embodiment of a connection system.
- [0025] FIGURE 3 is a diagrammatic representation of one embodiment of a connection nut.
- [0026] FIGURE 4A is a diagrammatic representation of one embodiment of a connection nut.
- [0027] FIGURE 4B is a diagrammatic representation of one embodiment of a connection nut and fitting.
- [0028] FIGURES 5A-5B are diagrammatic representations of another embodiment of a connection system.
- [0029] FIGURE 6 is a diagrammatic representation of one embodiment of a connection housing.
- [0030] FIGURES 7A-7B are diagrammatic representations of one embodiment of a drive system.
- [0031] FIGURES 8A-8C are diagrammatic representations of one embodiment of an end cap having fittings.
- [0032] FIGURE 9 is a diagrammatic representation of one embodiment of an alignment opening.
- [0033] FIGURES 10A-10C are diagrammatic representations of another embodiment of a drive system.
- [0034] FIGURES 11A-11B are diagrammatic representations of one embodiment of cassette having fittings.

- [0035] FIGURE 12 is a diagrammatic representation of a view of one embodiment of connection system.
- [0036] FIGURE 13 is a diagrammatic representation of one embodiment of a view of a connection system and end cap.
- [0037] FIGURE 14 is a diagrammatic representation of one embodiment of a connection system with stand-alone fittings.
- [0038] FIGURE 15 is a diagrammatic representation of a view of one embodiment of a connection system with stand-alone fittings.
- [0039] FIGURE 16 is a diagrammatic representation of one embodiment of a connection system with stand-alone fittings.
- [0040] FIGURE 17 is a diagrammatic representation of a view of one embodiment of a view of a connection system with stand-alone fittings.

DESCRIPTION

- [0041] Connection systems and the various features and advantageous details thereof are explained more fully with reference to the nonlimiting embodiments that are illustrated in the accompanying drawings and detailed in the following description. Descriptions of well-known starting materials, processing techniques, components and equipment are omitted so as not to unnecessarily obscure the invention in detail. It should be understood, however, that the detailed description and the specific examples, while indicating preferred embodiments, are given by way of illustration only and not by way of limitation. Various substitutions, modifications, additions and/or rearrangements within the spirit and/or scope of the underlying concept will become apparent to those skilled in the art from this disclosure.
- [0042] As used herein, the terms “comprises,” “comprising,” “includes,” “including,” “has,” “having” or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, article, or apparatus that comprises a list of elements is not necessarily limited only those elements but may include other elements not expressly listed or inherent to such process, article, or apparatus. Further, unless expressly stated to the contrary, “or” refers to an inclusive or and not to an exclusive or. For example, a condition A or B is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

- [0043] Additionally, any examples or illustrations given herein are not to be regarded in any way as restrictions on, limits to, or express definitions of, any term or terms with which they are utilized. Instead, these examples or illustrations are to be regarded as being described with respect to one particular embodiment and as illustrative only. Those of ordinary skill in the art will appreciate that any term or terms with which these examples or illustrations are utilized will encompass other embodiments which may or may not be given therewith or elsewhere in the specification and all such embodiments are intended to be included within the scope of that term or terms. Language designating such nonlimiting examples and illustrations includes, but is not limited to: "for example," "for instance," "e.g.," "in one embodiment." Furthermore, while certain items may be referred to as "first," "second," "third," "fourth," etc. (e.g., a first sidewall, second sidewall) it would be understood that such terms are used for explanation and any one of multiple such items may be considered the "first," "second," etc.
- [0044] Many fittings that can withstand higher pressures must be rotated several times in order to complete a seal. Such connections are difficult to use, especially in cramped spaces, and do not facilitate filter changes by robots. Therefore, a new fluid connection is needed. To this end, embodiments described herein provide a quick connect connection that can be utilized in a variety of applications, including in semiconductor manufacturing systems. The quick connect connection can provide o-ringless sealing. The o-ringless design can reduce contamination and provide more reliable high temperature operation. The quick connect connection can further provide features to prevent insertion errors or incorrect seating.
- [0045] FIGURES 1A and 1B are diagrammatic representations of one embodiment of an example connection system 100. Connection system 100 comprises a connection housing 102 defining a nut receiving area, a connection nut 110 disposed in the nut receiving area, a first fitting 112, at least partially received by the nut, and a second fitting 114. First fitting 112 provides a fluid flow passage open to the end of first fitting 112 proximate to connection nut 110 and second fitting 114 provides a fluid flow passage open to an end of second fitting 114 proximate to connection nut 110. First fitting 112 and second fitting 114 can be configured to mate or abut so that the flow passages may be connected to form a continuous flow passage. Preferably, the fittings are complementary fittings that are configured to form a seal under axial force, such as a Primelock® fitting, FlareMount™ fitting or other fitting known or developed in the art. While fitting 112 is illustrated as a female fitting and fitting 114 as a male fitting, in other embodiments, fitting 112 can be a male fitting and fitting 114 a female fitting. One of the fittings can be part of an end cap of a cassette (e.g., as shown in

FIGURE 11A), a fitting on a pressure transducer, a fitting on a liquid flow controller or other device.

- [0046] Connection nut 110 comprises an opening extending from a first side 115 to a second side 116 along a primary axis of connection nut 110. The nut encircles the end portion of one of the fittings and is rotatable about the fitting coaxially with the flow passage. The opening through the nut can have areas of different diameter including an area of smaller diameter 120 and an area of greater diameter 122. According to one embodiment, the opening of the nut has a narrower diameter at a first end of the opening through connection nut 110 and a greater diameter at the second end of the opening through connection nut 110 (forming a stepped shoulder).
- [0047] According to one embodiment, one of the fittings can be shaped so that a first portion of the fitting passes through the area of narrower diameter of the connection 110 while a second portion has a larger diameter (or other shaped footprint) than the area of narrower diameter. As depicted, for example, the end portion of first fitting 112 has a first section 130 that passes through the left end of the nut and a second section 132 that is too large to pass through the narrower diameter area 120. In this embodiment, the connection nut 110 and first fitting form complementary radial shoulders 140 that are shaped and positioned to abut during use (e.g., an internal shoulder of connection nut 110 abuts an external shoulder of fitting 112). Second fitting 114 may include an end portion 142 that is received through the second end of the nut opening. The received portion of second fitting 114 may include outer threads 144.
- [0048] A set of connection nut inner threads 146 are disposed proximate to the second end of connection nut 110 and can be designed to engage the fitting external threads 144. Connection nut 110 may also include outer threads 150 disposed on at least a portion the outer side of connection nut 110 that engage housing threads 152 disposed on the inside of housing 102.
- [0049] In operation, the ends of first fitting 112 and second fitting 114 can be brought together. When the end portion of second fitting 114 is at the appropriate location, connection nut 110 can be rotated to engage the nut inner threads 146 with the fitting outer threads 144. The force on the fitting outer threads 144 and on the shoulder 140 of the fitting 112 presses first fitting 112 and second fitting 114 together to create a seal as shown in FIGURE 1B.
- [0050] Connection system 100 can be used to help maintain seals, particularly for fittings where seals are formed or promoted by axial force. According to one embodiment, nut inner

threads 146 create axial force (force that pushes second fitting 114 toward first fitting 112) 360 degrees around second fitting 114 without requiring that connection nut 110 rotate 360 degrees. That is, nut inner threads 146 can engage fitting outer threads 144 360 degrees around the fitting without requiring connection nut 110 to rotate 360 degrees to create the 360 degree engagement. To this end, nut inner threads 146 and fitting outer threads 144 can be multi-start threads, such as double start threads, triple start threads, etc. A double start, triple start or other multi-start thread can provide 360-degree axial loading around the full seal connection with roughly a half-of-a-rotation or less. Nut inner threads 146 and fitting outer threads 144 can be threads that accept high axial loads. The threads may include various standard thread profiles including, but not limited to 1-12 UNF threads, buttress threads, acme threads or other threads. Additionally, custom or proprietary threads may be used.

- [0051] In one embodiment, nut inner threads 146 and fitting outer threads 144 can be double start threads with each thread start offset by approximately 180 degrees and the threads running at least 180 degrees from each start. In this case, the connection nut 110 can be rotated to engage the double start threads. Rotating the nut 180 degrees will cause the double start threads to engage 360 degrees around the outer fitting. More particularly, using the start of a first thread as the reference, the first thread of nut inner threads 146 starting from the first start may contact the fitting outer threads 144 from 0-180 degrees and a second thread of nut inner threads 146 starting from a second start may contact the fitting outer threads 144 from 180-360 degrees such that there is an axial force on fitting 114 360 degrees around the fitting. While 180 degrees was used as an example, other embodiments may include double start threads that run for other lengths.
- [0052] Using the example of triple start threads, each start can be offset by approximately 120 degrees and the threads can run approximately 135 degrees from each start. In this case, rotating connection nut 110 about 135 degrees will create 360 degrees of engagement. In this example, a first thread of nut inner threads 146 starting at a first start can contact fitting outer threads 144 from 0-135 degrees, a second thread of nut inner threads 146 starting from a second start may contact the fitting outer threads 144 from 120 degrees to 255 degrees and a third thread starting from a third thread may contact fitting outer threads 144 from 240 degrees to 15 degrees, such that there is an axial force on fitting 114 360 degrees around the fitting. While 135 degrees was used as an example, other embodiments may include triple start threads that run for other lengths.
- [0053] Thus, multi-start thread configurations can be used to provide 360-degree axial loading around the full seal connection with less than 360 degrees, and in some cases less than 180

degrees of rotation of connection nut 110. In other embodiments, the axial loading may be applied through less than 360 degrees of threaded engagement, while remaining sufficient to create a seal. For example, small gaps may exist in the loading profile provided the seal can still hold with the gaps (e.g., where there is an angular range where there is no thread engagement). One of ordinary skill in the art would understand that the thread examples provided are provided by way of example and other configurations of multi-start threads may be used.

- [0054] Connection system 100 may include a counter rotation prevention feature to create a sufficient force so that the connection nut 110 will not counter rotate (rotate to release the seal) under axial loading. According to one embodiment, the counter rotation prevention feature may be a friction fit. The friction fit may be provided by friction between inner housing threads 152 and outer nut threads 150. Outer nut threads 150 and inner housing threads 152 can be finer threads selected to create sufficient surface area contact between the threads so that there is an effective amount of friction between connection nut 110 and connection housing 102 to prevent connection nut 110 from counter rotating under expected axial loading, including cyclical axial loading. However, the effective amount of friction may be low enough that connection nut 110 can counter rotate when sufficient external rotational force is placed on connection nut 110, thereby allowing the fittings to be disengaged. In this case, outer nut threads 150 hold the position of connection nut 110 and inner nut threads 146 bear the axial load. The counter rotation prevention threads may include any standard thread including Unified screw threads or custom thread that provides sufficient friction. Other thread designs may also be used, including, but not limited to, buttress threads. According to one embodiment, nut outer threads 150 and housing inner threads 152 are single start threads.
- [0055] A locking mechanism (e.g., such as detents and/or indents on the rotating member of fitting, snap fits or other features) may also be provided to prevent nut 150 from counter rotating unexpectedly. In some cases, the locking mechanism may be used in addition to or in lieu of the higher friction outer nut threads 150 (while still including outer nut threads or not including outer nut threads) to prevent backing out of the nut. In some embodiments, connection nut 110 does not have external threads and nut 110 is held in position axially by an alternate retaining mechanism.
- [0056] A connection system may include features to hold the nut to a required angular range (e.g., such as stops on the threads) to prevent rotation of the nut past a certain point. In particular, rotation of the nut may be limited to a range between a first angular position and a second angular position, where the first angular position corresponds to full engagement and a

second angular position corresponds to full disengagement. In the second angular position, the starts of the inner threads will be in a known position helping ensure proper alignment of the nut inner threads and fitting outer threads.

- [0057] A connection system can be adapted to different port sizes. The internal and external threads can change based on the port size, axial travel requirements, load requirements and seal performance requirements. Components can be made from a variety of materials including polymeric materials, such as but not limited to oleophilic resins, perfluorinated resin, (such as, but not limited to, PTFE, FEP), PFA, PVDF, polyimide, polyetherimide, polycarbonate, PP, PE, PEEK, metals or other materials. According to one embodiment, the connection system can be formed primarily of PFA to provide an ultra-clean PFA, quick connect seal connection for the semiconductor industry.
- [0058] The connection system may be used in a variety of applications, including with stand-alone fittings, straight union fittings, elbow fittings or other fittings and may be integrated into other devices. While the fittings illustrated above feature a FlareMount™ seal mechanism, other styles of fittings may be used. The fittings may be Purebond® welded to pipe or tubing or molded with a tubing connection at one or both ends. The fittings may also be inserted into flared ends of tubing. One of the fittings may also be welded onto or molded into a purification device housing (e.g., a Chemline or Chemlock® filter housing or other filter housing, for example). The connection system may also be used to make a tube seal style connections instead.
- [0059] FIGURE 2 is a diagrammatic representation of one embodiment of a connection system using a modified thread design. The portion of the connection system illustrated comprises a connection housing 202 having inner connection housing threads 204, a connection nut 210 having inner nut threads 212 and outer nut threads 214 and a fluid fitting 220 having an exterior thread 222. A portion of another fitting 224 is also illustrated.
- [0060] Nut inner threads 212 and fitting outer threads 222 can be modified buttress threads. An American Standard buttress thread has a load flank angle of 7 degrees to the normal axis and a relief flank angle of 45 degrees to the opposite side of the normal axis, resulting in a thread angle (the angle between a load flank and adjacent relief flank) of 52 degrees. Embodiments of nut inner threads 212 and fitting outer threads 222 may have a relief flank angle of less than 45 degrees. According to one embodiment, the relief flank angle is between 15-40 degrees, but may be less. The load flank angle may be between 0-15 degrees and may be to the same or opposite side of the normal axis as the relief flank angle. In one embodiment, for example, the relief flank angle is approximately 30 degrees and load

flank angle is approximately 3 degrees to provide a 33 degree thread angle. In one embodiment, the load flank may be angled so that the thread angle is less than the relief flank angle. In other words, the load flank and relief flank may be angled to the same side of the normal axis as the relief flank.

- [0061] Additionally, in some embodiments, the load flank angle of fitting outer threads 222 may be different than the load flank angle of nut inner threads 212 to increase interference. For example, the load flank of the fitting outer threads, as illustrated, may be approximately 0 degrees while the load flank of the connection nut inner threads is angled toward the fitting thread load flank several degrees.
- [0062] In addition, housing inner threads 204 and nut outer threads 214 may be configured to increase interference. According to one embodiment, for example, the load flank angles of inner housing threads 204 and outer nut threads 214 may be different. In some embodiments, connection nut 210 does not have outer threads and is axially retained in the housing, while another mechanism is used to prevent counter rotation of connection nut 210.
- [0063] A connection nut may have any suitable form factor and may be integrated as a portion of another component. FIGURE 3 is a diagrammatic representation of one embodiment of a connection nut 210 having connection nut outer threads 214 and connection nut inner threads 212. In some embodiments, the connection nut can feature a wing nut style design where the wings are positioned such that a user can provide the twisting load on the nut to engage or disengage from the fitting. In other embodiments, another form of rotation member may be provided that allows a user to more easily apply torque to the nut. In one embodiment, a connection nut may be coupled to a gear assembly or other drive train that rotates one more connection nuts. The drive train may be arbitrarily complex and can rotate multiple connection nuts at once to create several seals simultaneously.
- [0064] FIGURE 4A is a diagrammatic representation of one embodiment of a connection nut 400. Connection nut 400 comprises outer threads 401 and inner threads 402. Inner threads 402 may be configured so that less than 360 degrees of rotation, and in some cases less than 180 degrees of rotation, creates at least 360 degrees of threaded engagement (and in some embodiments less). Outer threads 401 may be configured to prevent connection nut 400 from backing out. In other embodiments, connection nut 400 does not include outer threads. Connection nut 401 may be axially retained in housing and another mechanism used to prevent counter rotation.

- [0065] Connection nut 400 may also comprise projections 404 projecting inward from the inner radial surface of the nut opening. Projections 404 may align with features on a fitting. With reference to FIGURE 8B, for example, projections 404 may fit through notches 816 in rib 814. Projections 404 may be spaced from the start of inner threads 402 such that inner threads 402 cannot engage the fitting external threads (e.g., threads 812 of FIGURE 8B) unless projections 404 pass through the corresponding notches. Projections 404 may be located so that inner threads 402 can only engage the external fixture threads when connection nut 400 is in a specific orientation in relation to the end cap or other fitting threads.
- [0066] Connection nut 400 may further comprise resilient fingers 406 extending from one side. Resilient fingers 406 may be captured by a gear arm or gear. Features 408 at the ends of resilient fingers 406 can provide shoulders 409 that can abut a surface of a gear or gear arm.
- [0067] FIGURE 4B is a diagrammatic representation of a view of one embodiment of connection nut 400 and fluid fitting 412. The opening through connection nut 400 may comprise an area of larger diameter and an area of small diameter to form a connection nut shoulder 415. The portion of fluid fitting 412 received in connection nut 400 may have a portion with a smaller diameter and a portion with a larger diameter to form fluid fitting shoulder 414 that abuts shoulder 415. Connection nut shoulder 415 may push against fluid fitting shoulder 414 to provide an axial force sufficient to seal fluid fitting 412 to a port of a purification cassette or other component.
- [0068] FIGURES 5A and 5B are diagrammatic representations of one embodiment of a connection system 500. Connection system 500 comprises a connection housing 502, a first connection nut 510 rotatable about a first fluid fitting 512, a second connection nut 520 rotatable about a second fluid fitting 522 and drive system. Connection housing 502 includes threaded openings passing through housing 502 from a first side of housing 502 to a second side of housing 502. The threads may be configured to engage outer nut threads of connection nuts 510 and 520. The drive system is operatively coupled to first connection nut 510 and second connection nut 520 to simultaneously rotate first connection nut 510 and second connection nut 520 within housing 502. Although illustrated with two connection nuts, embodiments can include a connection housing with one or more threaded openings and corresponding connection nuts and fluid fittings.
- [0069] A nut coupling member 534 at a first end of gear arm 530 extends to the first side of housing 502. A drive arm 532 extends from nut coupling member 534 past the second side of

housing 502 a desired distance. Connection nut coupling member 534 is coupled to first nut 510 and includes an outer surface having gear teeth 536. Gear arm 530 drives a second gear 540 coupled to second connection nut 520. Gear arm 530 acts as rotation member such that rotation of gear arm 530 causes first connection nut 510 and second connection nut 520 to rotate simultaneously to form a seal between first fluid fitting 512 and a fitting on a purification cassette (or other fitting) and second fluid fitting 522 and a second fitting on a purification cassette (or other fitting).

- [0070] When gear arm 530 is rotated, the smaller gear 540 is also rotated in the opposite direction to engage the smaller port at the same time as the larger port. This mechanism allows for sealing two ports with one single rotating action on gear arm 530. In the embodiment illustrated, the gears are have a 1.6:1 gear ratio so the smaller connection nut 520 is rotated more than larger connection nut 510 (though any suitable gear ratio can be used). If connection nut 510 is configured with a triple start inner thread so that 165 degrees of rotation results in a 360 degrees (or more) threaded engagement, then connection nut 520 can be configured with a triple start or other multi-start inner thread so that 264 degrees of rotation results in 360 degrees (or more) thread engagement. It can be noted that, when the connection nuts turn, the connection nuts may translate toward the purification cassette end cap (or other fitting). Accordingly, gear arm 530 and gear 540 may also translate. In other embodiments, the connection nuts create less than 360 degrees of threaded engagement (and less than 360 degrees of circumferential axial seal force), but still a sufficient force to seal the fittings.
- [0071] The internal and external threads of the smaller connection nut 520 may have a pitch that is scaled relative to the internal and external threads of connection nut 510 so that the purification cassette and the nuts move the same distance axially as gear arm 530 is rotated. Gear ratios and pitch heights can vary based on the choice of port sizes and the axial travel distance required. Moreover, gears can be provided to rotate additional connection nuts to provide sealing for additional ports and the connection system can be geared so that all the connection nuts rotate the same direction.
- [0072] A drive handle 550 can be provided for easy manipulation by a human or robotic user. A drive shaft 552 extends from handle 550 toward housing 502 and may be received in a drive shaft passage in gear arm 530. Drive shaft 552 and the drive shaft passage may be splined or otherwise configured to allow translation of drive shaft 552 in the passage. An alignment post 554 may extend parallel to drive shaft 552. Alignment post 554 can be received in a complementary opening in an end cap (e.g., opening 830 of FIGURE 8B) or other component. Alignment post 554 defines the drive shaft pivot axis.

- [0073] Rotation of gear arm 530 may be limited to a particular range of rotation and features may be provided to lock the angular position of gear arm 530. To this end, a portion of the drive shaft passage more proximate to the connection housing, near a first end of gear arm 530, may be open to expose the outer surface of drive shaft 552. Drive shaft 552 can be retracted so that the end of drive shaft 552 closest to connection housing 502 can pass past surface 560 as drive shaft 552 is rotated about its pivot point. That is, the drive shaft passage and housing 502 may be configured so that the end of drive shaft 552 overlaps and may be spaced away from surface 560 of housing 502 in a range of angular positions about the drive shaft pivot axis. In certain positions though the end of drive shaft 552 can be received in an opening in surface 560, a notch or groove 564 in the side of housing or other feature to lock gear arm 530 in a desired angular position. Thus, for example, the end of drive shaft 552 may pass over surface 560 from position 565 to notch 564. When drive shaft 552 is aligned with notch 564, drive shaft 552 may be translated so that a portion of drive shaft 552 is received in notch 564 (engaged position), preventing rotation of gear arm 530.
- [0074] Other mechanisms may be used to inhibit rotation of gear arm 530. As another example, surface 562 of housing 502 and facing surface of nut coupling member 534 may include bevel gear teeth or other features so that the angular position of gear arm 530 may be maintained. Other locking mechanisms such as indents and detents, locking pins, clips may also be used.
- [0075] In some embodiments, the end points of rotation may be marked by dots and arrows or other visual indicators. The dots and arrows also provide one example of a visual indicator used to confirm engagement or disengaged. In yet another embodiment, LEDs or other lights that turn on when the rotation member is in the proper position can be used, again providing an indication of proper engagement/disengagement.
- [0076] FIGURE 6 is a diagrammatic representation of one embodiment of a connection housing 502 depicting an embodiment of a first connection nut opening 602 having internal threading and a second connection nut opening 604 having internal threading. Although illustrated with two connection nut openings, embodiments can include a connection housing with one or more threaded openings and corresponding connection nuts and fluid fittings. In other embodiments, the housing may axially retain the connection nut without threads. FIGURE 6 further depicts notch 564 disposed in the sidewall of housing 502 configured to capture a portion drive shaft 552.
- [0077] Connection housing 502 may comprise a bracket having a slot 606 that can be shaped so that connection housing 502 may be mounted to a manifold plate. Fastener openings 608

allow a screw, pin or other member to be used to couple connection housing 502 to the manifold plate. A threaded hole 610 can allow an alignment feature to be coupled to connection housing 502.

- [0078] FIGURE 7A is a diagrammatic representation of one embodiment of a drive system. Gear arm 530 may include a nut coupling member 534 having an opening to receive a first connection nut and gear 540 having an opening to receive a second connection nut. Features 702 and 704 may create channels through which resilient fingers of the respective connection nuts can pass. The features at the end of the resilient fingers (features 408 of FIGURE 4A) can act to fasten the connection nut into the gear arm or gear opening. When the gear arm and gear rotate, features 702 and 704 can place radial force on the respective connection nut by pushing on the side edges of the resilient arms, causing the connection nut to rotate.
- [0079] FIGURE 7A further illustrates one embodiment of a drive handle having a drive shaft 552 and an alignment post 554. Drive shaft 552 may be inserted in a passage in gear arm 530. All or a portion of drive shaft 552 and the passage may be splined. According to one embodiment, the drive shaft passage splines may be provided by an insert 706 into the end of gear arm 530. Alignment post 554 can comprise one or more radial projections 708 that fit in channels in an end cap opening. The channels and projections 708 can cooperate to guide the movements of drive handle 550 to help ensure a proper seal as discussed below. The end of alignment post 554 may comprise a compressible ring 709 having an annular groove and lip. The lip may be captured by a portion of the end cap as discussed further below.
- [0080] FIGURE 7B is a diagrammatic representation of a cross-sectional view of the embodiment of a drive system shown in FIGURE 7A. Gear arm 530 comprises drive shaft passage 720 that receives drive shaft 552. The end portion of passage 720 is open to expose a portion drive shaft 552 (indicated at portion 710).
- [0081] Drive shaft 552 may be translatable in drive shaft passage 720, such that the drive shaft tip 722 may be pushed in and retracted. The translation in the direction to retract drive shaft 552 may be limited by insert 706. Insert 706 may include a set of resilient fingers 730 coaxial with drive shaft 552 that push inward. When drive shaft 552 is retracted out a certain distance, resilient fingers 730 push inward into annular groove 732 to inhibit further translation in that direction. Insert 706 may be rotatable in passage 720 so that drive handle 550 may rotate about the axis of drive shaft 552 until the alignment post 554 is pushed

forward into the end cap alignment opening aligning the splines with slots that permit drive handle 550 to be pushed further in to lock the two parts together rotationally.

- [0082] FIGURES 8A-8C are diagrammatic representations of another embodiment of an end cap 800 that provides port fittings for a cassette or other device. End cap 800 comprises a base 802, a first port fitting 810 and a second port fitting 820. Although two port fittings are shown, devices with one port fitting opposing ports or more than two port fittings may be used. The port fittings may be externally threaded as shown by threads 812 and 822. The port fittings may be threaded in the same or opposite directions.
- [0083] The port fittings may include alignment features that, in cooperation with corresponding alignment features of the connection nut, facilitate alignment of the port fitting with the connection nut. The alignment features may be configured so that the start of threads 812 cannot engage corresponding threads of the connection system unless the corresponding features of the fitting and connection nut align or mate.
- [0084] According to one embodiment, for example, a set of alignment features may include notches that align with inner projections of a connection nut (e.g., inner projections 404 of connection nut 400 of FIGURE 4). To this end, in the embodiment illustrated, an annular alignment rib extends radially outward from each port fitting as shown by port ribs 814 and 824. Each alignment rib may include spaced alignment notches at the periphery of the rib. For example, rib 814 includes spaced notches 816 and rib 824 includes spaced notches 826. The spaced alignment notches may be arranged so that an alignment features in a connection system may pass through the notches only when threads 812 and 822 are properly aligned with threads of the connection system. For example, the notches may be arranged to align with inner projections of a connection nut when the connection nut is a specific angular position (e.g., projections 404 of FIGURE 4A). Furthermore, in the embodiment illustrated, the connection nut cannot rotate until the projections pass through the notches. Thus, the alignment features of the fitting and connection system (on the connection nut in this example) may also prevent rotation of the connection nut until the threads are properly positioned relative to each other.
- [0085] The port rib 814 may be set back from the start of port fitting external threads 812 a selected distance such that the start of threads 812 cannot engage corresponding threads of the connection system unless the alignment features pass through alignment notches 816. Similarly, port rib 824 may be set back from the start of port fitting external threads 822 a selected distance such that the start of threads 822 cannot engage corresponding threads of the connection system unless the alignment features pass through notches 826. While the

example of corresponding projections and notches is used, any suitable alignment features may be employed.

- [0086] End cap 800 may have an alignment opening 830 to accept a drive handle alignment post 554 (FIGURE 5A). Alignment opening 830 may be axially aligned with port 810 or may be otherwise located. Alignment opening 830 may form a keyhole so that the handle may only fit in alignment opening 830 in a desired orientation.
- [0087] FIGURE 9 is a diagrammatic representation of one embodiment of an alignment opening 900 disposed in an end cap or other component to receive alignment post 554. A number of ribs or other features may be defined on the inside of alignment opening 900 to define a series of axial and radial channels. According to one embodiment, the features define entrance channels 902, a first radial channel 904, a second radial channel 906, and second axial channels 908 (one of which is shown) connecting first radial channel with second radial channel 906. In one embodiment, the channels may be defined in an insert 950 that is inserted in an end cap opening.
- [0088] With reference to FIGURES 5-9, when alignment post 554 is inserted in opening 900, projections 708 are received in entrance channels 902. This means that the drive system must be in the correct orientation before alignment post 554 can be inserted. This orientation may coincide with the orientation in which the inner threads of connection nut 510 and connection nut 520 are properly aligned with the external threads on an end cap or other fixtures. Drive handle 550 may be translated, translating drive shaft 550 in passage 720. However, the second axial channels 908 are not aligned with entrance channels 902 (e.g., rib 910 overlaps entrance channel 902 and acts as a stop) such that further translation of drive handle 550 is limited. Drive handle 550 can be rotated until projections 708 align with axial channels 908. This position can correspond to a position in which drive shaft 552 aligns with notch 564 in housing 502 and connection nut 510 and connection nut 520 are rotated to create a 360 degree seal. Drive handle 550 can then be pushed in further such that drive shaft 552 is received in notch 564. The annular lip of compression ring 709 may pass over ridge 912 such that ridge 912 is captured in the groove of compression ring 709. The compression ring 709 and ridge 912 can create a snap fit that provides haptic feedback when drive shaft 552 is fully engaged with notch 564. Furthermore, the compression ring 709 and ridge 912 provide a mechanism to prevent drive shaft 552 from being retracted accidentally.
- [0089] Thus, alignment opening 900 may provide a keyed feature configured so that when drive shaft 552 is in a first angular position, drive shaft 552 can be pushed in a limited first

distance. Drive shaft 552 can then be rotated to a second angular position by rotating drive handle 530, the second angular position corresponding to a sealed connection. Drive shaft 552 can be pushed in to a final, fully inserted position, in which drive shaft 552 acts as a retaining pin to prevent further angular rotation.

[0090] FIGURE 10A is a diagrammatic representation of one embodiment of a portion of a connection system 1000 similar to connection system 500. Connection system 1000 may include an alignment feature that engages with a complementary alignment feature on an end cap, fitting or other fixture.

[0091] In this example, the rotation member (e.g., gear arm 1030) with a slot 1032 having an entrance normal to the direction of radial travel of gear arm 1030 (that is, in the side parallel to the pivot axis). Slot 1032 may receive a radially extending rib 1034 on an end cap, fitting or other fixture (e.g., rib 130 of FIGURE 1). These mating features wrap partially around the axis of the port. According to one embodiment, slot 1032 and rib 1034 are configured so that the end of rib 1034 and entrance of slot 1032 align when the connection nut inner threads and outer threads of the end cap, fitting or other fixture are correctly positioned to allow proper engagement. Thus, the connection system alignment feature and complementary end cap, fitting or other fixture alignment feature are configured so that the threads are in the proper position and orientation before the gear arm is rotated.

[0092] In the embodiment illustrated, the rotation member (e.g., gear arm 1030) has a slot 1032 having an entrance normal to the direction of radial travel of gear arm 1030 (that is, in the side parallel to the pivot axis). Slot 1032 may receive a radially extending rib 1034 on an end cap, fitting or other fixture. These mating features wrap partially around the axis of the port. The slot 1032 and rib 1034 engage such that the rib 1034 is held in slot 1032 of gear arm 1030 due to the cross-section of rib 1034 being larger as rib 1034 extends out radially. Slot 1032 may also be wider as the slot extends out radially. This mechanism can be used to help hold the position of gear arm 1030 relative to the end cap and can also generate (e.g., through an interference fit) more axial load between the end cap and fluid fitting as gear arm 1030 is rotated about the port axis. The load on the other side of connection housing 1002 can be roughly equivalent to the load generated by the interference fit of the engagement between the walls of slot 1032 and rib 1034. This can help distribute the load on both sides of the rotating mechanism to ensure a smooth rotation and seal engagement. Rib 1034 and slot 1032 can have a pitch that is approximately equal to the pitch of the internal connection nut threads (e.g., of the larger connection nut). According to one embodiment, rib 1034 and slot 1032 may be helical.

- [0093] The drive shaft may feature a boss or other feature designed to engage a groove 1040 located on the rib 1034 of the fitting. When the drive shaft is pushed forward after the fittings are fluidically sealed, the boss is forced into groove 1040 on the rib 1034. This provides an anti-rotation feature close to the fitting. The feature will not engage if the drive shaft is not in the right orientation, alerting the user that the drive handle is not rotated to the correct orientation and the seal is not complete. FIGURE 10B illustrates one embodiment of a cross-section of rib 1034. FIGURE 10C is a diagrammatic representation of one embodiment of drive handle 1050 having a drive shaft 1052 with boss 1054.
- [0094] FIGURES 11A and 11B are diagrammatic representations of one embodiment of a purification cassette 1100 having a first end cap 1104 and a second end cap 1106 providing port fittings. (e.g., one or more of first port fitting 1108, second port fitting 1110, a third port fitting 1112 and fourth port fitting 1114). Depending on the configuration of purifier cassette 1100, any of the one or more ports may act as an inlet port, an outlet port, a vent port, drain port or other type of port. In some cases, the ports may be placed so that the purifier cassette can be reversed.
- [0095] As depicted in FIGURE 11A, the port fittings may include port fitting external threads to engage with threads of a manifold or other component. Additionally, a port fitting may include a radially projecting port rib (e.g., radial alignment rib 1130 and radial alignment rib 1132) extending from a surface of the end cap and set back from the respective port openings. Radial rib 1130 and radial rib 1132 may be used as an alignment feature and help ensure a sealed connection as discussed above. For example, the radial rib may be positioned so that it can enter a slot in a rotating arm. However, radial rib 1130 and radial rib 1132 may also have other configurations.
- [0096] The end caps may include features such as alignment holes, rails, guide channels or the like to engage with complementary features on a manifold assembly to help ensure proper placement of the purifier cassette or other device. In the embodiment of FIGURE 11A, end cap 1104 includes alignment hole 1134 and end cap 1106 includes alignment hole 1136 open to the front of cassette 1100 to receive guide pins of a manifold (e.g., such as alignment knobs in conjunction with connection housing 502). Alignment holes 1134/1136 can receive corresponding guides of a manifold to vertically position and hold cassette 1100. End cap 1104 may further include an alignment opening 1140 and end cap 1106 may include alignment opening 1142. According to one embodiment, alignment opening 1140 is axially aligned with the opening of port fitting 1108 and alignment opening 1142 is axially aligned with the opening of port fitting 1112. Alignment opening 1140 and alignment opening 1142 may receive an alignment post 554 of a drive handle 550 as discussed above.

- [0097] FIGURE 12 illustrates another embodiment of a connection system 1200 for connecting to an end cap or other fitting. Connection system 1200 can include a connection nut 1210 disposed on a connection housing 1212. The connection nut 1210 connects an elbow fitting 1214 to a fitting on an end cap 1216. A rotation member 1220 facilitates rotating of nut 1210. According to one embodiment, rotation member 1220 comprises an arm 1222 coupled to nut 1210 a radial distance from the opening through nut 1210. The arm 1222 can extend from an end face of the nut 1210. Arm 1222 can be longer than a first portion of elbow fitting 1214 that is coaxial with the end cap fitting. The rotation member 1220 can also include a platform 1224 extending perpendicular to arm 1222 so that an outer face of platform 1224 is parallel to the end face of nut 1210. Platform 1224 can include a tool interface 1226 to allow a rotary tool bit (e.g., such as a hex driver, Philips bit, flat head bit, star bit or other tool, to engage with the rotation member). Rotating rotation member 1220 rotates the nut 1210. In some embodiments, rotating rotation member 1220 less than 360 degrees, including less than 180 degrees and, in some cases, less than 135 degrees, may cause at least 360 degree engagement of the inner threads of the nut with the outer threads of the end cap 1216. In other embodiments, less than 360 degrees of threaded engagement is created, but the circumferential axial sealing force is sufficient to maintain the seal.
- [0098] The range of rotation of rotation member 1220 may be limited so that nut 1210 stops rotating in known positions. This can help ensure that the threads of nut 1210 are properly aligned in the fully disengaged position. In some embodiments, the end points of rotation may be marked by dots and arrows or other visual indicators. The dots and arrows also provide one example of a visual indicator used to confirm engagement or disengaged. In yet another embodiment, LEDs or other lights that turn on when the rotation member is in the proper position may be used, again providing an indication of proper engagement/disengagement.
- [0099] FIGURE 13 is a diagrammatic representation of a cross-section of one embodiment of connection system 1200. As depicted in FIGURE 13, connection nut 1210 may include inner nut threads 1302 that engage with outer threads 1311 on the port fitting of the end cap 1216 and outer nut threads 1304 that engage with inner threads of connection housing 1212. As describe above, threads can be configured so that nut 1210 creates a 360 seal between fitting 1214 and end cap 1216 with less than 360 degrees of rotations and will not back out under expected loads.
- [00100] A locking mechanism (e.g., such as detents and/or indents on the rotating member of fitting, snap fits between the rotating member and fitting or other component or other features) may also be provided to prevent the rotating member from rotating unexpectedly. In some cases, the locking mechanism may be used in addition to or in lieu of higher friction outer nut

threads (while still including outer nut threads or not including outer nut threads at all) to prevent backing out of the nut. In some embodiments, the connection nut does not have external threads and the connection nut is held in position axially by an alternate retaining mechanism.

- [00101] FIGURE 14 is a diagrammatic representation of one embodiment of a connection system 1400 for coupling stand-alone fittings. FIGURE 15 is a diagrammatic representation of a cross sectional view of connection system 1400 and fitting 1420. In the embodiment of FIGURE 14, the connection system comprises a first fitting 1402 and a connection nut 1404 rotatable about the first fitting in a connection housing 1406. Connection nut 1404 may include a portion that extends beyond housing 1406 to provide for easier rotation (e.g., features 1412, such as wing nut wings, features that can interface with a tool or other features). A second fitting 1420 can comprise external fitting threads 1422 that are configured to engage with connection nut inner threads 1410. Connection nut 1404 can seal second fitting 1420 to first fitting 1402 with less than 360 degrees of rotation as discussed above. Connection nut 1404 can include a set of connection nut external threads 1430 that engage with connection housing internal threads 1432 to prevent counter rotation of connection 1404.
- [00102] Housing 1406 may include features so that the nut stops in a known fully disengaged position. Housing 1406 may further include features to ensure proper alignment between the fittings. In the example of FIGURE 14, the housing includes posts 1408 extending from a face of housing 1406 that are received in openings 1426 in a collar 1424 about the second fitting. With the nut in a known disengaged position, the alignment feature of the fittings ensures that the inner nut threads and outer fitting threads will be aligned. Other corresponding alignment features may also be used including, but not limited to inner projections on connection nut 1404 and mating notches on fitting 1420 (e.g., such as projections 404 of FIGURE 4A and 4B and notches 816 of FIGURES 8A-8C).
- [00103] FIGURE 16 is a diagrammatic representation of another embodiment of a connection system 1600 and FIGURE 17 is a diagrammatic representation of a cross-sectional view of connection system 1600. Connection system 1600 includes a first fitting 1602, a connection housing 1604, and a connection nut 1606 rotatable in the connection housing about first fitting 1602. According to one embodiment, first fitting 1602 may comprise an elbow fitting. Connection nut 1606 can include a set of connection nut inner threads (threads 1704) and connection nut outer threads (threads 1706) and can seal a second fitting 1620 to first fitting 1602 with less than 360 degrees of rotation as discussed above. Connection housing 1604 can hold the nut to a required angular range so that connection nut 1606 and fitting 1620 are

not out of position prior to engagement. Furthermore, alignment features may be to ensure that fitting 1620 is properly aligned. For example, posts or other features projecting from connection housing 1604 may be received in collar 1622 to provide alignment.

[00104] A rotation member 1630 facilitates rotating of nut 1606. According to one embodiment, rotation member 1630 comprises an arm 1632 coupled to nut 1606 a radial distance from the opening through nut 1606. The arm 1632 can extend from an end face of the nut 1606. Arm 1632 can be longer than a first portion of elbow fitting 1602 that is coaxial with the connection nut. The rotation member 1630 can also include a platform 1634 extending perpendicular to arm 1632 so that an outer face of platform 1634 is parallel to the end face of nut 1606. Platform 1634 can include a tool interface 1636 to allow a rotary tool bit (e.g., such as a hex driver, Philips bit, flat head bit, star bit or other tool, to engage with the rotation member). Rotating rotation member 1630 rotates the nut 1606. In some embodiments, rotating rotation member 1630 less than 360 degrees, including less than 180 degrees and, in some cases, less than 135 degrees, may cause 360 degree engagement of the inner threads of the nut with the outer threads of fitting 1620.

[00105] Connections discussed above can be formed of any suitable material including, but not limited to PVDF, FEP, PP, PFA and PTFE, compositions comprising polymers, metals or other materials, which meet requirements for use in semiconductor manufacturing. In some cases, if high temperatures are expected, it may be desirable to use materials that exhibit lower creep. Thus, for example, it may be preferable to use PFA for the connection nut and fittings when applications exceed 100 degrees Celsius, as PTFE exhibits more creep at these temperatures. In any case, a connection systems can exceed qualifications for semiconductor manufacturing fittings and may withstand 245 psi (1.69 MPa) for 5 minutes at room temperature or higher (e.g., 535 psi (3.7 MPa) for 5 minutes at room temperature). For example, a connection system of FIGURE 43 formed of PFA and PTFE can have a leak pressure of greater than 415 psi (214 lbs. of axial sealing force) (2.87 MPa and 952 Newton sealing force), when pressure is applied at room temperature for five minutes. The leak pressure of the fitting may be greater than 500 psi (3.4 MPa) and even greater than 950 psi (6.6 MPa) at room temperature. A connection system having a nut and fittings formed of PFA, for example, can thus provide the required 150 lbs. (667 Newton) of force specified for FlareMount™ connections with a safety factor (for example, a connection system may provide over 210 lbs. (934 Newton) of axial force for a 1 inch (2.54 centimeter) fitting).

[00106] Although specific embodiments have been described, these embodiments are merely illustrative, and not restrictive of the invention. The description herein of illustrated embodiments of the invention, including the description in the Abstract and Summary, is not

intended to be exhaustive or to limit the invention to the precise forms disclosed herein (and in particular, the inclusion of any particular embodiment, feature or function within the Abstract or Summary is not intended to limit the scope of the invention to such embodiment, feature or function). Rather, the description is intended to describe illustrative embodiments, features and functions in order to provide a person of ordinary skill in the art context to understand the invention without limiting the invention to any particularly described embodiment, feature or function, including any such embodiment feature or function described in the Abstract or Summary. While specific embodiments of, and examples for, the invention are described herein for illustrative purposes only, various equivalent modifications are possible within the spirit and scope of the invention, as those skilled in the relevant art will recognize and appreciate. As indicated, these modifications may be made to the invention in light of the foregoing description of illustrated embodiments of the invention and are to be included within the spirit and scope of the invention. Thus, while the invention has been described herein with reference to particular embodiments thereof, a latitude of modification, various changes and substitutions are intended in the foregoing disclosures, and it will be appreciated that in some instances some features of embodiments of the invention will be employed without a corresponding use of other features without departing from the scope and spirit of the invention as set forth. Therefore, many modifications may be made to adapt a particular situation or material to the essential scope and spirit of the invention.

[00107] Reference throughout this specification to "one embodiment", "an embodiment", or "a specific embodiment" or similar terminology means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment and may not necessarily be present in all embodiments. Thus, respective appearances of the phrases "in one embodiment", "in an embodiment", or "in a specific embodiment" or similar terminology in various places throughout this specification are not necessarily referring to the same embodiment. Furthermore, the particular features, structures, or characteristics of any particular embodiment may be combined in any suitable manner with one or more other embodiments. It is to be understood that other variations and modifications of the embodiments described and illustrated herein are possible in light of the teachings herein and are to be considered as part of the spirit and scope of the invention.

[00108] In the description herein, numerous specific details are provided, such as examples of components and/or methods, to provide a thorough understanding of embodiments of the invention. One skilled in the relevant art will recognize, however, that an embodiment may be able to be practiced without one or more of the specific details, or with other apparatus,

systems, assemblies, methods, components, materials, parts, and/or the like. In other instances, well-known structures, components, systems, materials, or operations are not specifically shown or described in detail to avoid obscuring aspects of embodiments of the invention. While the invention may be illustrated by using a particular embodiment, this is not and does not limit the invention to any particular embodiment and a person of ordinary skill in the art will recognize that additional embodiments are readily understandable and are a part of this invention.

- [00109] It will also be appreciated that one or more of the elements depicted in the drawings/figures can also be implemented in a more separated or integrated manner, or even removed or rendered as inoperable in certain cases, as is useful in accordance with a particular application. Additionally, any signal arrows in the drawings/figures should be considered only as exemplary, and not limiting, unless otherwise specifically noted.
- [00110] Benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any component(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature or component.

WHAT IS CLAIMED IS:

1. A connection system, the connection system comprising:
 - a connection housing defining a connection housing first opening;
 - a first fitting defining a first fitting flow passage; and
 - a first connection nut disposed in the connection housing first opening and rotatable around the first fitting, the first connection nut comprising a set of first connection nut internal threads, wherein the set of first connection nut internal threads are multi-start threads configured to engage a set of second fitting external threads on a second fitting to seal the first fitting to the second fitting with less than 360 degrees of rotation of the first connection nut.
2. The connection system of Claim 1, wherein the set of first connection nut internal threads are multi-start threads configured to engage the set of second fitting external threads on the second fitting to create at least a 360 degree threaded engagement with less than 360 degrees of rotation of the first connection nut.
3. The connection system of any one of Claim 1 or Claim 2, wherein the first connection nut comprises a set of first connection nut external threads and the connection housing defines a first set of connection housing inner threads.
4. The connection system of Claim 3, wherein the set of first connection nut external threads and the first set of connection housing inner threads are configured to create a friction force that prevents counter rotation of the first connection nut under an axial sealing force.
5. The connection system of any one of Claims 1 to 4, wherein the set of first connection nut internal threads are buttress threads.
6. The connection system of any one of Claims 1 to 5, wherein the connection nut and second fitting are formed from perfluoroalkoxy polymer.
7. The connection system of any one of Claims 1 to 4 or Claim 6, wherein the set of first connection nut internal threads have a load flank angle of 0-5 degrees and a relief flank angle of 25-35 degrees.

8. The connection system of any one of Claims 1 to 7, wherein the set of second fitting external threads have a load flank angle that is different than the load flank angle of the first connection nut internal threads.

9. The connection system of any one of Claims 1 to 8, wherein the first connection nut internal threads comprise:

- a first thread running 120-180 degrees from a first start; and
- a second thread running 120-180 degrees or less from a second thread start.

10. The connection system of Claim 9, wherein the set of first connection nut internal threads further comprise a third thread running 120-180 degrees or less from a third thread start.

11. The connection system of any one of Claims 1 to 10, wherein the connection system comprises a first alignment feature configured to align with a corresponding alignment feature of the second fitting.

12. The connection system of Claim 11, wherein the first alignment feature is spaced from a start of the set of the first connection nut internal threads a distance such that the set of first connection nut internal threads cannot engage the second fitting external threads unless the first alignment features mates with the corresponding alignment feature of the second fitting.

13. The connection system of Claim 12, wherein the first alignment feature comprises a set of inner projections and the corresponding alignment feature comprises notches defined in the second fitting.

14. The connection system of Claim 11, wherein the first alignment feature comprises a slot in a rotation member and the corresponding alignment features comprises an alignment rib.

15. The connection system of any one of Claims 1 to 14, further comprising:
a third fitting defining a third fitting flow passage; and
a second connection nut rotatable about the third fitting, the second connection nut comprising a set of second connection nut internal threads, wherein the set of second connection nut internal threads are multi-start threads configured to engage a set of fourth

fitting external threads to create a seal between the third fitting to the fourth fitting with less than 360 degrees of rotation of the second connection nut.

16. The connection system of Claim 15, further comprising a gear assembly operatively coupling the first connection nut to the second connection nut such that the first connection nut and second connection nut rotate simultaneously.

17. The connection system of Claim 16, further comprising a rotation member operatively coupled to the gear assembly such that rotation of the rotation member rotates the first connection nut and the second connection nut.

18. The connection system of Claim 17, wherein the rotation member comprises a gear arm coupled to the first connection nut, the gear arm comprising gear teeth engaging a gear operatively coupled to the second connection nut.

19. The connection system of Claim 18, further comprising a drive shaft received in a drive shaft passage of the gear arm, the drive shaft translatable in the drive shaft passage from a fully retracted position to a fully inserted position.

20. The connection system of Claim 19, wherein the drive shaft is rotatable through a range of angular positions about a pivot point, wherein in a first set of selected angular positions the drive shaft cannot be translated to the fully inserted position and in a selected angular position, the drive shaft can be translated to the fully inserted position to lock rotation of the gear arm.

21. The connection system of Claim 20, wherein in the first set of angular positions a first end of the drive shaft overlaps a front surface of the connection housing and in the selected angular position, the first end of the drive shaft is aligned with a feature into which the first end of the drive shaft can be inserted.

22. The connection system of Claim 15, wherein the second connection nut is disposed in a same connection housing as the first connection nut or in another connection housing.

23. The connection system of any one of Claims 1 to 22, wherein the set of first connection nut internal threads are configured create at least 360 degrees of threaded

engagement with the set of second fitting external threads with less than 180 degrees of rotation.

24. The connection system of any one of Claims 1 to 16, further comprising a rotation member coupled to the first connection nut.