

MANIFOLD ADAPTOR PLATE FOR FILTRATION APPARATUS

Cross Reference to Related Applications

The present patent application claims the benefit of U.S. Provisional
5 Patent Application No.: 60/927, 058, filed on May 1, 2007 and claims the benefit
of U.S. Provisional Patent Application No. 60/833,891 filed on July 28, 2006 both
of which are hereby incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

10 The present invention relates to a manifold adaptor plate that functions as
a gasket utilized to separate filtrate from feed and retentate in a tangential flow
filtration apparatus. More particularly, this invention relates to such a manifold
adaptor plate of unitary construction having a plurality of layers including one or
two sealing layers and an intermediate rigid support layer.

15 Prior to the present invention, liquids, primarily aqueous liquids, have
been filtered by tangential flow modules wherein a plurality of filters are stacked
between two manifolds, one at the bottom of the stack and one at the top of the
stack. The filtration module stack comprises a collection of one or more filtration
modules and associated intermodule gaskets. The filters are separated by
20 appropriate screens and liquid-impervious layers to permit liquid flow as well as
filtrate and retentate flow into and from the stack. In addition, flow holes are
provided through the layers within the stack. The holes are sealed appropriately
with a separate sheet of gasketing material to prevent admixture of filtrate with
incoming liquid feed or retentate. The manifolds in each segment are designed so
25 that filtrate is removed from the second manifold. This manifold arrangement
necessitates fittings to both manifolds in order to supply and remove liquid to and
from manifolds in order to supply and remove liquid to and from the stack. This
can be undesirable since additional manipulative steps for removing and
connecting the fittings are required when it is desirable to replace the filtration
30 elements forming the stack.

Alternative tangential flow modules are disclosed in U.S. Patents 5,176,828 and 5,597,447 wherein a single manifold is utilized at one end of each stack of filters and a plate is positioned at the opposite end of each stack of filters. Liquid flow paths are provided to assure that filtrate is not contaminated with either retentate or feed.

In the tangential flow modules described above, a separate sheet of gasket material is positioned between the one or two manifolds and the stack of filters to assure the desired liquid flow. The gasket sheet, is used with manifold adaptor plate consists of a metal plate. The elastomeric gasket sheet, such as silicone, can be placed against each surface of the metal plate to provide desired sealing. The metal plate and elastomeric gasket sheets are provided with liquid flow paths to assure the desired liquid flow to, within and from the tangential flow module.

The use of a manifold adaptor plate having a separate elastomeric sheet layer is undesirable, since, due to its flexibility, it is difficult to properly align the liquid flow paths through the elastomeric layer with the liquid inlets and liquid outlets of the manifold. In some instances it is possible to deform the gasket sheet during application in such a manner to allow for the improper mixing of fluids. In addition, the elastomeric layer tends to stick to the manifold causing wrinkling that adversely affects uniform and complete contact with the manifold surface.

This condition can lead to external leaks as well as imperfect alignment of liquid flow paths that can cause cross contamination of flowing liquids. In addition, when the elastomeric gaskets are compressed during use of the module, they tend to move which can cause significant liquid inlet and liquid outlet distortion. The separate sheet is generally formed of silicone which has relatively high extractables that can be adding to the fluid that passes through it. These extractables need to either be removed from the fluid before use or to be tested to ensure they don't contaminate or otherwise cause an adverse reaction in the final product, particularly when it is a drug or therapeutic protein. Lastly, the gasket sheet being a relatively weak and unsupported structure formed of relatively low durometer silicone or rubber, it can tear during handling and storage rendering it useless and they can distort enough to cause an external leak as well.

Accordingly, it would be desirable to provide a manifold adaptor plate which provides satisfactory sealing without the liquid flow path alignment or handling problems of the prior art.

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SUMMARY OF THE INVENTION

The present invention provides a manifold adaptor plate comprising a rigid plate layer, a polymeric sheet layer and one or two elastomeric layers. Each layer is provided with holes which permit passage therethrough of liquid feed, filtrate and retentate without mixing of filtrate with either retentate or feed. When
10 utilizing one elastomeric layer, it is molded onto a first surface of the rigid plate layer and through all of the holes of each layer so that it is bound to a portion of the area on the polymeric sheet surrounding the holes through the polymeric sheet that is contact with the opposite or second surface of the rigid plate. By effecting binding of the polymeric sheet to the elastomeric layer, the elastomeric layer is
15 provided with a rigid support by the rigid plate layer and the elastomeric layer does not move relative to the rigid plate layer. By providing rigid support to the elastomeric layer, it can be properly and easily positioned in contact with a manifold to effect desired sealing. In an alternative embodiment of this invention, two elastomeric layers are utilized, one in contact with a first surface of
20 the rigid plate layer and the second in contact with the polymeric sheet which is in contact with the second opposite surface of the rigid plate. The elastomeric layers are bound to each other through holes formed in the rigid plate layer and the polymeric sheet. This embodiment provides two sealing layers which can be utilized to seal a manifold or a filtration module to prevent admixture of filtrate
25 with either feed or retentate. The plate can be used between two devices.

In a further alternative embodiment of this invention, the elastomeric layer is silicone-based and the polymeric layer is optionally eliminated. In one example of this embodiment, when the rigid plate is made of steel, preferably stainless steel, or a plastic to which silicone adheres such as polysulfones or
30 polyethersulfones, at least a portion of one side of the rigid plate is coated with the silicone and the silicone also extends through the holes formed in the rigid

plate to the opposite face. Alternatively, at least one entire side or both sides of the rigid plate (which can be steel or a plastic to which silicone adheres as well as any other material suggested previously for the rigid plate) are coated with silicone without the need for the polymeric layer and the silicone layers are bound to each other through holes formed in the rigid plate layer. Further, if desired one can use a polymeric sheet is desired.

In another embodiment, one or more of the holes of the plate may be filled by the elastomeric material to act as a flow diverter.

The elastomeric sheets are sufficiently flexible that they can effect sealing of a manifold or filtration module in contact with the elastomeric sheet to prevent admixture of filtrate with feed or retentate flowing within the manifold of filtration module. Preferably, they are made of thermoplastic elastomers which have low levels of extractables.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an isometric view of the manifold apparatus of this invention in use.

Fig. 2 is an exploded view of the manifold adaptor plate of this invention.

Fig. 3 is a cross sectional view of a portion of the manifold adaptor plate of Fig. 2.

Fig. 4 is an exploded view of an alternative manifold adaptor plate of this invention.

Fig. 5 is a partial cross sectional view of the manifold adaptor of Fig. 4.

Fig. 6 is an exploded view of a filtration module manifold and the manifold adaptor plate with this invention.

Fig. 7 illustrates the function of a filtration module suitable for use with this invention.

Fig. 8 is an exploded view of the manifold adaptor plate of the present invention and two filtration modules.

Fig 9 is a partial cross sectional view of an alternative embodiment of the manifold adaptor plate of the present invention.

Fig 10 and 10A is a partial cross sectional view of an alternative embodiment of the manifold adaptor plate of the present invention.

DESCRIPTION OF SPECIFIC EMBODIMENTS

5 Referring to Fig. 1, a manifold apparatus 1 within which the manifold adaptor plate of this invention can be incorporated includes a first set of manifold segments 2 and 4, connected together; a feed manifold segment 6 and a second set of manifold segments 8 and 10 connected together and mounted on manifold frame 12. The first set of manifold segments 2 and 4 is provided with a filtrate outlet 14 and a retentate vent 16. The second set of manifold segments 8 and 10 is provided with a filtrate outlet 18 and a retentate drain 20. The retentate drain 20 and retentate vent 16 are capped during filtration. The retentate vent 16 permits filling the retentate flow path with liquid and the retentate drain permits draining the apparatus of retentate upon completion of the filtration. The feed segment 6 is provided with a feed inlet 22 and a retentate outlet 25. The feed inlet can have a diameter larger than that of internal feed conduits within the manifold segments since the incoming feed is split into the first set of manifold segments 2 and 4 and the second set of segments 8 and 10. A plurality of filtration modules 24 are secured to manifold segments 2, 4, 8 and 10 by means of a plates 26 and a plurality of compression assemblies 28 such as bolts. Alternatively, threaded rods having nuts on their ends can be utilized rather than bolts. The manifold adaptor plate 11 (Fig. 6) of this invention is positioned between the filtration modules 24 and the manifold segments 2, 4, 8 and 10.

Referring to Figs. 2 and 3 manifold adaptor plate 11 of this invention consists of polymeric sheet 13, a rigid plate 19 that can be formed of a thermosetting resin, reinforced composites such as graphite or carbon composites or a metal such as stainless steel, Hastolloy metal or aluminum and an elastomeric layer 17. The rigid plate 19 has two major surfaces, 7A and 7B, respectively. The polymeric sheet is arranged to be in contact with one major surface of the rigid plate, in the instance of Figs 2 and 3 with the first major surface 7A while the elastomeric layer 17 is arranged to be in contact with the other major surface that

is opposite the first surface, in the instance of Figs 2 and 3 with the second major surface 7B. Each layer 13, 17 and 19 is provided with holes to effect desired liquid flow through the plate 11. The holes of each layer 13, 17, 19 are in line and in register with each other to ensure proper flow and sealing in the fluid pathway and to ensure proper bonding of the elastomeric layer to the polymeric layer. Each layer 13, 17 and 19 have one edge with alternating holes 50 for filtrate with hole 56 for retentate. The opposing edge is provided with holes 48 for feed which alternate with holes 50 for filtrate. As shown in Fig. 3 which is a close up of the assembled plate 11 shown through one hole, in this case hole 50, the elastomeric layer 17 extends through each hole 48, 50 and 56 to form protrusions 15 that extend over and bind to polymeric sheet 13. Preferably, the manifold adaptor plate 11 is provided with four indentations 21 which permit the plate 11 to be hung on bolts 28 (Fig. 1), however this is not required and other means can be used instead. Tabs 23 can also be provided to facilitate assembly of plate 11 onto bolts 28 and removed of the plate 11 from bolts 28.

The elastomeric layer 17 and polymeric sheet 13 are matched so that the two layers are bound to each other when the elastomeric layer 17 is molded. Optionally, the elastomeric layer can be bonded to the surface of the rigid plate against which it is applied. As optionally, the polymeric sheet instead of being a separate layer can be cast or otherwise formed on the surface of the rigid plate against which it is applied. The seal is formed of any elastomeric material. The elastomeric material does not need to be very elastic but it should have some ability to maintain the seal with the adjacent layers during flexion or compression. Preferably it has a durometer of from about 60 to about 100 Shore A.

Suitable materials include but are not limited to thermoplastics, such as polyethylene, polypropylene, EVA copolymers, alpha olefins and metallocene copolymers, PFA, MFA, polycarbonate, vinyl copolymers such as PVC, polyamides such as nylon, polyesters, acrylonitrile-butadienestyrene (ABS), polysulphone, polyethersulphone, polyarylsulphone, polyphenylsulphone, polyacrylonitrile, polyvinylidene fluoride (PVDF), and blends thereof, thermoplastic elastomers which can be formed of styrenic block copolymers,

blends of EPDM and polypropylene and the like and which are sold under brand names such as Santoprene® polymer, Kraton® thermoplastic elastomer and Dynaflex® elastomer, EPDM rubber, thermosets such as closed cell foamed urethanes, and rubbers, either natural or synthetic.

5 It is preferred that the material be a thermoplastic or thermoplastic elastomer so as to allow for its use in the preferred method of this invention, injection molding. Additional, thermoplastics and thermoplastic elastomers have lower levels of extractables making the filtered product cleaner. Exemplary preferred material include SANTOPRENE® polymer with a durometer of about
10 80 available from Advanced Elastomer Systems of Akron, Ohio or the thermoplastic elastomer Kraton® elastomer G27052 with a Shore A hardness of 56, available from Advanced Elastomer Systems located at Akron Ohio. Preferred thermoplastics include low density, linear low density, medium density and high density polyethylene, polypropylene and EVA copolymers.

15 Representative suitable polymeric sheets include polypropylene, polyethylene, polyester, polysulfone, polyamide, acetal, acrylic, polystyrene, PTFE, silicone, vinyl or the like, representative suitable rigid layers include stainless steel, steel, aluminum, phenol-formaldehyde, urea-formaldehyde, carbon/epoxy composites, graphite/epoxy composites, rigid molded plastic, glass
20 or fiber filled plastic or the like.

 Referring to Figs. 4 and 5, the alternative manifold adaptor plate 9 of this invention includes two elastomeric layers 17 and 41, polymeric sheet 13 and rigid plate 19. The polymeric sheet 13 is optional since the elastomeric layers 17 and 41 bind to each other through the holes 48, 50 and 56. The optional polymeric
25 sheet can be positioned on both surfaces 7A and 7B of rigid plate 19 as well as on only one surface 7A of plate 19 as shown in Fig. 4. Like reference numbers in Figs. 4 and 5 refer to like elements of Figs. 2 and 3. As shown in Fig. 5, elastomeric layer 41 coats polymeric sheet 13 and elastomeric layer 17 coats polymeric sheet 13. In addition, elastomeric layers 17 and 41 are bound to each
30 other within holes 50 as well as within holes 48 and 56. This embodiment of this invention provides two gasket sealing surfaces. The sealing surfaces on the

elastomeric surfaces can be flat (layer 41, Fig. 4) or can comprise protrusions (protrusions 15, Figs. 2 and 3).

Referring to Fig. 6, a filtration module useful with the manifold adaptor plate of this invention is described. A filtration element 70 is positioned between manifold segment 51 and plate 55. Manifold segment 51 is provided with liquid inlet 73, filtrate outlets 77 and 79 and retentate outlet 81. The manifold segment 51 includes a plurality of feed inlet means 33 and a plurality of retentate outlet means 26. One set of filtrate outlet means 28 is provided on one end of the manifold segment 51 while a second set of filtrate outlet means 28 is provided on the opposite end of manifold segment 51. The filtrate outlet means 28 are connected to filtrate outlets 77 and 79 by filtrate conduit paths (grooves) 46 and filtrate outlet means 29. The paths 46 are of a size which permits filtrate to flow therethrough while avoiding sagging of a filtrate screen (not shown) into the paths 46, typically about 0.06 to 0.12 inch wide. The filtration module 70 includes holes 48 which communicate with feed inlet means 33 and holes 50 which communicate with filtrate outlet means 28. The manifold adaptor plate 11 (Fig. 2) is positioned so that the elastomeric layer 17 contacts manifold segment 51 so that proper sealing is effected which prevents admixture of filtrate with either feed or retentate. As seen in Fig. 7, the filtrate side 52 of the filter layer 53 having mesh spacer 54 in contact therewith is exposed. The filtration segment 70 is also provided with holes 56 which communicate with retentate outlet means 26. The plate 55 serves as a seal for the top surface of the filtration module 70.

Referring to Fig. 7, the filtration module 70 includes a filtrate spacer 54, a filter layer 52, a retentate spacer 60 and a filter layer 62 with a second filtrate spacer 54 (not shown) and which can contact paths 46. The liquid feed represented by arrow 58 passes through holes 48 in layer 62 into spacer 60. A portion of the liquid passes through spacer 60, as represented by arrow 64 and through filter 52 as represented by arrow 66. The remaining portion of the incoming liquid passes upwardly as represented by arrow 68, through holes 48 in filtrate spacer 54 and into the next adjacent filtration module (not shown) wherein it proceeds as described above with reference to filtration module 70. The filtrate

passes into holes 50 and passes in a direction as shown by arrows 71 and 72 toward filtrate outlet means 28 (Fig. 6). The retentate passes across retentate spacer 60 as shown by arrows 64 and 65 through holes 56 and to retentate outlet means 26 (Fig. 6) in a direction as shown by arrow 78. The filtrate passes into
5 holes 28, grooves 46, outlet means 29 (Fig. 6) toward filtrate outlets 77 and 79. The retentate passes through holes 26 and to retentate outlet 81.

As shown in Fig. 8, the adaptor plate 9 (Fig. 4) is positioned between two filtration modules (Fig. 6) so that elastomeric layer 41 and elastomeric layer 17 provide the sealing function.

10 Referring to Figs 1, 6 and 7, the manifold apparatus 1 which utilizes the manifold adaptor plate 11 of this invention is utilized as follows: The liquid feed to be filtered passes into feed inlet 22 (Fig. 1), into liquid inlet 73 (Fig. 6), through feed inlet means 33, through feed inlets 48 and through filtration module 70 to separate feed into filtrate and retentate. Retentate is removed from filtration
15 modules 70, through holes 56, through holes 26 and through outlet 81. Filtrate is removed from filtration modules 70 through holes 50, along paths 46 and through outlets 77 and 79.

In a further alternative embodiment of this invention, the elastomeric layer is silicone-based and the polymeric layer is optionally eliminated. In one example
20 of this embodiment as shown at Fig 9, at least a portion of one side 102 of the rigid plate 100 is coated with the silicone layer 104 and the silicone layer 104 extends through the holes 106 formed in the rigid plate 100 to the opposite face 108 of the rigid plate 100 in order to form the seals on both sides of the plate 100. Alternatively, one may coat one side, both sides or the entire plate 100 if desired.

25 As silicone adheres to steel and some plastics such as polysulfone and polyethersulfone, the use of a polymeric sheet is not required with this embodiment, although if one wishes, one can do so. Additionally, as the silicone will in those instances adhere to the plate surface, the entire surface does not need to be fully encapsulated just those portions forming the seal or being exposed to
30 the process stream, although the entire surface may be encapsulated if so desired.

In those instances in which the silicone does not naturally adhere to the plate surface, one may simply encapsulate the entire plate in silicone and rely upon the encapsulation to hold the silicone elastomer layer to the plate, Alternatively, one can surface treat the plate surface such as with plasma or oxidation or an adhering agent to enhance the adhesion of the silicone to the plate or one may use the polymeric layer described above.

When using stainless steel, particularly 316L stainless steel or other stainless steel grades or when using the plastics described above that are acceptable for fluid contact, one does not have to coat or encapsulate all of the surfaces of the rigid plate. Thus only the areas which form the seal in the system as well as the holes and the area around the holes on the other side need to be coated with the silicone.

Alternatively, both sides of the rigid plate can be coated with silicone without the need for the polymeric layer and the silicone layers are bound to each other through the holes formed in the rigid plate layer. This may be used with steel (stainless or not), plastic or composite rigid plates as described previously. It may cover just the two major surfaces or if desired it may encapsulate the rigid plate on all surfaces.

While a polymeric layer is not needed in these embodiments, due to either the adhesion of the silicone to the selected materials of the rigid plate or the encapsulation of the plate, it may be used if desired or if the material of the rigid plate is not a steel, or one of the selected plastics described above.

Suitable silicones include but are not limited to room temperature curable silicones, platinum cured silicones, light cured silicones, moisture cured silicones or heat cured silicones. An example of a suitable silicone useful in the present invention is a platinum cured silicone available from a number of suppliers such as Dow Corning Corporation (Silastic® silicone).

In a further embodiment of any the embodiments mentioned above, one can block or close off one or more of the holes in the plate with the elastomeric material to form a flow diverter. Generally, all the holes of at least one type (feed, retentate or permeate) or all holes (feed, permeate and retentate if used) are

blocked. More preferably, the hole(s) are blocked by filling them with a volume of elastomeric or silicone material sufficient to prevent liquid flow through it.

In one embodiment of this design, as shown in Figure 10, one uses a polymeric sheet 112 on a first major surface 111 of a rigid plate 110 and the
5 elastomeric material 114 on the other major surface 113 and extending through the hole(s) 116 to overlay a portion 118 of the sheet 112 adjacent the hole(s) 116. The amount of elastomeric material used is sufficient to fill the hole(s) 116 and render it incapable of passing fluid from one major surface 111 to the other 113.

Similarly one can use the silicone embodiment without any polymeric
10 sheet and block the hole(s) in a similar manner (not shown).

In Figure 10A, is shown another embodiment in which the plate 120 is simply designed as a flow diverter and has no holes at least at those locations where the flow is to be diverted. The polymeric sheet 122 (if used) does have holes 124 and is attached to the diverter plate 120 by the use of the elastomeric
15 material 126 in and around the holes 124 in the sheet 122. A sealing layer 128 is formed on the opposite face of the plate 120 as has been described above.

Similarly one can use the silicone embodiment without any polymeric sheet and cover just the areas of the plate corresponding to the where the holes should have been or the entire plate if desired in a similar manner (not shown).

CLAIMS

What is claimed:

- 5 1. A manifold adaptor plate having a plurality of liquid pathways
 therethrough to effect passage of a liquid feed, a filtrate and a retentate
 comprising an elastomeric layer, an intermediate rigid layer and a
 polymeric sheet, said elastomeric layer being bound to said polymeric
 sheet through said liquid pathways.
- 10 2. A manifold adaptor plate having a plurality of liquid pathways
 therethrough to effect passage of a liquid feed, a filtrate and a retentate
 comprising a first elastomeric layer, an intermediate rigid layer in
 contact with at least a portion said first elastomeric layer, optionally a
15 first polymeric sheet between said first elastomeric layer and said rigid
 layer, a second elastomeric layer being bound to said first elastomeric
 layer through said liquid pathways and optionally a second polymeric
 sheet positioned between said second elastomeric layer and said rigid
 layer.
- 20 3. The manifold adaptor plate of Claim 1 wherein said elastomeric layer
 is formed from a thermoplastic elastomer.
4. The manifold adaptor plate of Claim 1 wherein said polymeric sheet is
25 formed from polypropylene.
5. The manifold adaptor plate of Claim 1 wherein said rigid layer is
 formed from stainless steel.
- 30 6. The manifold adaptor plate of Claim 4 wherein the rigid layer is
 formed from stainless steel.

- 5 7. A manifold adaptor plate having a plurality of liquid pathways
therethrough to effect passage of a liquid feed, a filtrate and a retentate
comprising an elastomeric layer, an intermediate rigid layer having a
first and a second major surface formed on opposite sides of the rigid
layer and a polymeric sheet, said elastomeric layer being in contact
with the first major surface of the rigid plate and the polymeric sheet
being in contact with the second major surface of the rigid plate and
the elastomeric layer being bound to said polymeric sheet through said
10 liquid pathways.
8. The manifold adaptor plate of Claim 2 wherein said elastomeric layer
is formed from a thermoplastic elastomer.
- 15 9. The manifold adaptor plate of Claim 2 wherein said polymeric sheet is
formed from polypropylene.
10. The manifold adaptor plate of Claim 2 wherein said rigid layer is
formed from stainless steel.
- 20 11. The manifold adapter of claim 1 wherein the elastomeric layer is
silicone.
12. The manifold adapter of claim 2 wherein the first and second
25 elastomeric layer is silicone.
13. A manifold adaptor plate having a plurality of liquid pathways
therethrough to effect passage of a liquid feed, a filtrate and a retentate
comprising a silicone layer and an intermediate rigid layer wherein the
30 silicone layer is formed on at least one side of the intermediate rigid

layer and said silicone layer is bound to said intermediate rigid layer and extends through said liquid pathways.

14. The plate of claim 13 further comprising a silicone layer formed on a second side of the intermediate rigid layer.

5 15. The plate of claim 13 further comprising a silicone layer formed on a second side of the intermediate rigid layer so as to encapsulate the rigid plate.

10 16. The plate of claim 13 wherein the rigid plate is made of a material selected from the group consisting of steel, polysulfones and polyethersulfones.

17. The plate of claim 13 wherein the rigid plate is made of stainless steel.

18. The plate of claim 13 wherein the rigid plate is made of polysulfone.

19. The plate of claim 13 wherein the rigid plate is made of polyethersulfone.

15 20. The plate of claim 13 wherein the silicone is of a volume sufficient to close off one or more of the liquid pathways.

21. The manifold adaptor of claim 1 wherein the elastomeric layer is of a volume sufficient to close off one or more of the liquid pathways.

20 22. The manifold adaptor of claim 2 wherein at least one of the first and second elastomeric layers is of a volume sufficient to close off one or more of the liquid pathways.