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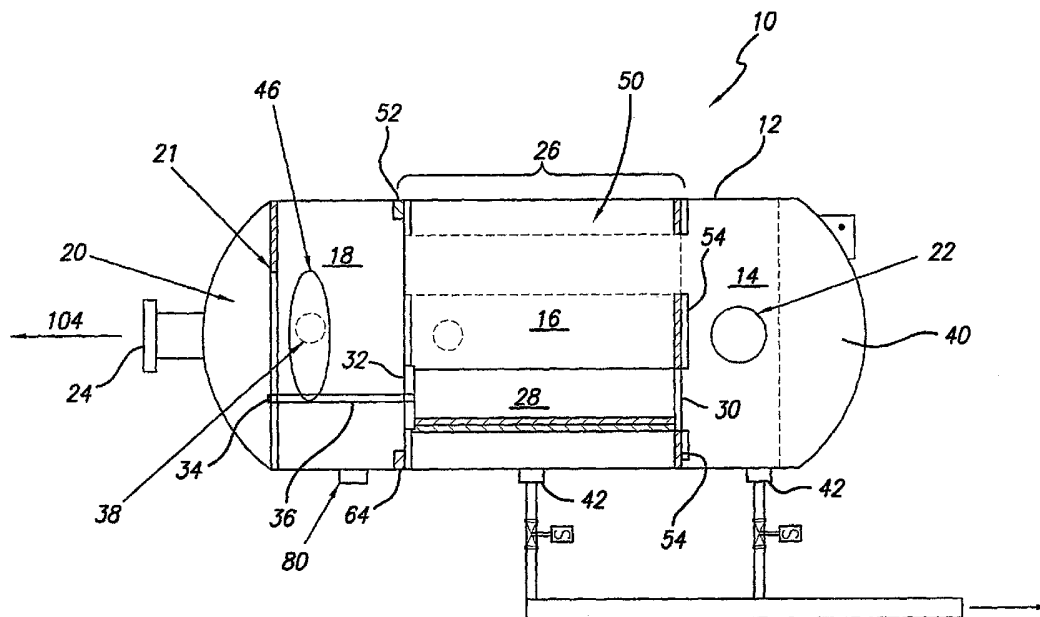
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(54) Title: BUNDLED ELEMENT FILTRATION SYSTEM AND METHOD



(57) **Abstract:** An filtration system and method provides the ability to filter a wide range of extremely fine particulate matter in solution ranging in size from micron size particles to molecular elements. The apparatus includes a pressure vessel housing a cross-flow filtration assembly including a plurality of spiral wound type membrane filtration elements in a parallel arrangement. The position of the vessel's feed inlet combined with the geometry of the membrane elements provides a continuous scouring of the face of the elements. The system significantly reduces fouling of the elements, minimized the pressure drop through the elements, and allows the elements to operate at a high efficiency for longer durations between backwash cycles.



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Bundled Element Filtration System and Method

RELATED APPLICATION DATA

[0001] This application is based on and claims the benefit of U.S. Provisional Patent Application No. 60/600,240 filed on August 10, 2004, the disclosure of which is incorporated herein in its entirety by this reference.

BACKGROUND

[0002] This invention pertains generally to filtration of a liquid for removal of suspended and/or dissolved substances from the liquid. More particularly, it relates to a system and method for removal of suspended and/or dissolved substances from a confined liquid stream flowing under pressure wherein the system and method utilize filter elements positioned in a parallel flow arrangement.

[0003] The field of devices used to filter and remove dissolved and/or suspended substances from a pressured liquid is well-developed. Indeed, many of the filtration methodologies currently employed in municipal and industrial filtration applications were developed over a century ago. Various filtration devices have employed different methods for removing particulate or impurities from a feed fluid. For example, so-called dead end filtration systems force all of the feed fluid through a filter to separate impurities from the incoming feed. Dead end filters designs may place a filter either directly across a flow path or at an oblique angle to the flow path. For example, U.S. Pat. No. 1,822,006 to Bull discloses a dead-end filter wherein the feed fluid enters a cylindrical chamber housing a cylindrical filter and follows a spiral flow path from one end of the cylindrical filter to the other. All of the feed fluid is eventually forced through the cylindrical filter as the fluid flow path terminates adjacent the far end of the filter from the input end. A sump chamber is provided below the helical fluid flow path and filter for collecting material separated by the filter component. As all of the fluid must pass through the filter and as the sump chamber is not open throughout operation, the velocity of the fluid about the filter will continuously decrease to zero unless the filter is cleared.

[0004] The majority of the currently marketed microfiltration and ultrafiltration systems utilize hollow fiber membrane technology operating in a dead-end configuration similar to that described above. As flow through a hollow fiber filter element approaches zero, the filter is backwashed with air to clear it, typically every 8-10 minutes.

The filter must then be completely backwashed with air and water every 40-60 minutes to clear the accumulated solids within the filter. This process limits the production availability of the filter to no more than 75%. Additionally, as the filters are limited in size to approximately 6 inches in diameter, a system sized to filter 1.0 million gallons per day for potable water typically will require approximately 60 rack-mounted filter modules along with the necessary piping, valving, and electrical instrumentation systems required to support the process.

[0005] Cross-flow filtration through a spiral wound membrane is an alternative method for filtering particulate from a fluid medium. Cross-flow filtration differs from dead-end filtration in that the feed fluid provided to the filter unit actually passes across the enclosed filter membrane or filter media. Cross-flow filtration describes the condition of fluid flow past a membrane while the fluid is being pressurized against the surface. Cross-flow filtration performance has been found to be governed by the pore size of the filter media, the generated fluid shear force across the surface of the filter media, and the deposited particulate layer, along with the control of the deposit layer formation. A portion of the feed fluid passes through the filter to become filtrate, or permeate, fluid. The other portion of the feed fluid continues past the filter media and exits the filter unit as concentrate, or retentate, fluid. Flow velocity is of fundamental importance to the performance of a cross-flow filter. Should the flow velocity across the surface of the filter media become zero, the cross-flow ceases and the dead-end filtration begins. Additionally, the cake which forms on the filter media at zero velocity becomes thicker as the flow velocity parallel to the media decreases. The thickness of the cake layer in a flow channel is determined by the shear force on the membrane surface, which is roughly in direct proportion to the feed viscosity and the feed flow velocity. Therefore, a higher sustained fluid velocity brings about a thinner deposit layer, a lower hydraulic resistance, and a higher filtrate flux.

[0006] As the thickness of the cake layer increases on the surface of the filtration elements, the system must be cleaned in a manner to remove the cake layer while not damaging the membrane elements. Back-flushing allows a reverse fluid flow to penetrate the filter elements in an interior-to-exterior fashion to clear any plugged pores so as to recover the decreased permeate flux (flow) rate. Periodic back-flushing is essential for challenging processes, e.g., those involving colloidal solids which are able to extrude into the pores of the filter media, so as to maintain an acceptable permeate flux rate across the filter

elements. Back-flushing provides a desirable alternative to shutting down the filter unit for filter media replacement.

[0007] In almost every filtration process a dynamic membrane will be created on the surface of the filtration element. The contaminants which constitute the dynamic membrane initially fill up the pores and then form a very thin cake layer of constant thickness on the element's surface. The transition time for pore filling may be very short. It has been observed that on first use of a filter, particulate immediately enters into the pores of the filter media, although only to a limited extent (depth). The result is that a cross-flow filtration system typically experiences a rapid flux drop at the beginning of its use for filtration. Thereafter, the flux is stabilized at a relatively satisfactory level, and remains almost constant with a very slow decline as the process continues. This is unlike dead-end filtration where the flux rate drops continuously from the time the filter is operated until complete clogging. The rate of flux drop depends on the selection of membrane pore size and the nature of the contaminants. Filter pore-size must therefore be selected with a view towards the expected contaminants in order to control the formation of the deposit layer.

[0008] While cross-flow filtration is a step improvement over dead-end filtration, an inherent weakness common to all traditional cross-flow filtration designs frustrates its operation: a pressure drop in the fluid passageway exists from the feed inlet to the concentrate outlet of a filter element. This is particularly problematic in applications utilizing an array of filter elements, i.e. multiple filter elements arranged in series within a common pressure vessel to form a fluid pathway. Such a filter array presently is used in applications requiring a high degree of filtration. The progressive fouling caused by material deposited on the inlet face of the first element in the series results in increased head loss, or a pressure drop, affecting all elements in the series. The pressure drop results in a non-uniform pressure differential through the filter membrane across the entire length of the fluid passageway of the filter array. This occurrence results in a decrease of filtration efficiency and the subsequent reduction in permeate flow from the individual elements along the length of the array.

[0009] It is an object of the present invention, therefore, to provide a liquid filtration system and that can minimize the effects of the pressure drop through the length of a filter array.

[0010] It is still another object to provide a system and method for an improved high capacity, efficient, and reliable liquid filtration.

[0011] It is yet another object and feature of the present invention to provide a high rate filtration system that is compact and that can utilize various filtration technologies, including reverse osmosis, nanofiltration, ultrafiltration, and microfiltration technologies.

[0012] It is another object of the present invention to provide a system and method suitable for high capacity filtration to replace the traditional multimedia filtration systems employed in potable water treatment.

[0013] Additional objects and advantages of the invention will be set forth in the description that follows, and in part will be apparent from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the methods and apparatus pointed out in the appended claims.

SUMMARY

[0014] To achieve the foregoing objects, and in accordance with the purposes of the invention as embodied and broadly described in this document, there is provided a method and system for filtering a fluid stream. An apparatus for filtering a liquid stream according to the invention includes a pressure vessel having an inlet chamber adapted to receive an inlet flow of a feed fluid, a concentrate collection chamber and a plurality of filter elements. Each filter element has a feed inlet for receiving feed fluid, a concentrate outlet for discharging concentrate fluid and a filtrate outlet for discharging filtrate fluid. According to one preferred embodiment, each of the filter elements comprises a cross-flow filter element, such as a spiral wound membrane filter element. The filter elements are positioned in a parallel flow arrangement within the vessel with the feed fluid inlet of each filter element in fluid communication with the inlet chamber and the concentrate outlet of each filter element in fluid communication with the concentrate collection chamber. In a preferred embodiment, the filter elements are positioned in and supported by a filter rack within the vessel. The filter rack includes an inlet plate at an upstream end and a closure plate at a downstream end. The closure plate and inlet plate define a settling chamber within which the filter elements are positioned. The closure plate isolates the concentrate collection chamber from the settling chamber. Passages through the inlet plate allow the inlet feed liquid to flow into the settling chamber and to immerse the filter elements.

[0015] According to one advantageous aspect of the invention, the feed inlet of each of the filter elements is disposed generally perpendicular to the inlet flow of feed fluid, such that the velocity and turbulence of the feed fluid inlet stream is directed across the

inlet faces of the filter elements thereby helping to clean them. The vessel also preferably includes a filtrate collection plenum in fluid communication with the filtrate outlet of each of the plurality of filter elements and a concentrate discharge port in fluid communication with the concentrate chamber for discharging concentrate fluid from the vessel. A settling trough and one or more drain outlets can be disposed in the bottom of the vessel for removing particulate matter that settles in the inlet and the settling chamber. A hinged or removable end-cap can provide access for loading the filter elements into the vessel and unloading the filter elements from the vessel. Preferably, a feed return outlet is disposed in the vessel for removing feed fluid from the settling chamber for return to the inlet flow of feed fluid.

[0016] According to another advantageous aspect of the invention, during operation of the system, the pressure drop from the feed inlet to the concentrate outlet of each of the plurality of filter elements is substantially the same. The fluid conditions at the feed fluid inlet of each of the filter elements are substantially the same for each of the filter elements and the fluid conditions at the concentrate outlet of each of the filter elements are substantially the same for each of the filter elements.

[0017] The system and method of the invention allows for sustained high flow rates through filter elements for extended periods before cleaning through backwashing is required. The system and method can be used with membrane filtration elements for reverse osmosis, nanofiltration, ultrafiltration, and microfiltration filtration applications. The system and method can be utilized in water treatment systems and a wide variety of industrial process applications requiring the removal of suspended particles and substances from a flow stream.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate the presently preferred embodiments and methods of the invention and, together with the general description given above and the detailed description of the preferred methods and embodiments given below, serve to explain the principles of the invention.

[0019] FIG. 1 is a side elevation cross-sectional view of one embodiment of a bundled element filtration system according to the present invention, showing the pressure vessel with the filter rack installed and holding a filter element.

[0020] FIG. 2 is a left side elevation view of the pressure vessel of FIG. 1 showing the feed inlet and the access port.

[0021] FIG. 3 is a right side view of the pressure vessel FIG. 1 showing the concentrate discharge outlet and the feed return outlets.

[0022] FIG. 4 is a top plan view of the pressure vessel of FIG. 1.

[0023] FIG. 5 is a perspective view of the vessel of FIG. 1 showing the hinged end cap opened for loading the filter rack into the vessel.

[0024] FIG. 6 is an end view of the inlet plate.

[0025] FIG. 7 is an end view of the closure plate.

[0026] FIG. 8 is a perspective end view of the interior of the vessel without the filter rack, showing the filtrate outlet, the isolation plate, the thrust ring and the settling trough.

[0027] FIG. 9 is a perspective end view of the interior of the vessel with the filter rack installed, showing the closure plate and the inlet and showing one filter element loaded into the filter rack.

[0028] FIG. 10 is a perspective side view of the concentrate collection chamber as seen through the open access port, showing the closure plate bolted to the thrust ring and showing one filter element installed.

[0029] FIG. 11 is a side view showing a filter element installed in the filter rack with the discharge end of the element seated into a closure plate hole.

DESCRIPTION

[0030] The presently preferred embodiments and methods of the invention will be described in more detail with reference to the accompanying drawings, in which like reference characters designate like or corresponding parts throughout the drawings. In the following description, embodiments and methods of the invention have been shown and described simply by way of illustration of the best mode contemplated by the inventor of carrying out the invention. As will be realized, the invention is capable of modification in various respects, all without departing from the invention. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not restrictive.

[0031] Referring to FIGs. 1-5, an illustrative embodiment of a bundled element filtration system 10 according to the present invention is shown. The system 10

includes a generally cylindrically-shaped pressure vessel 12 having an inlet chamber 14, a concentrate collection chamber 18 and a filtrate collection plenum 20. The filtrate collection plenum 20 is separated from the concentrate collection chamber 18 by an isolation plate 21 fixed to the interior wall of the pressure vessel, such as by welding. A feed inlet 22 is disposed in the vessel 12 in communication with the inlet chamber 14 for receiving an input flow of feed liquid 100 into the inlet chamber 14 and a filtrate outlet 24 is positioned in the vessel 12 in communication with the filtrate collection chamber 20 for the discharge of filtrate liquid. The feed inlet 22 includes a nozzle adapted to connect to incoming process piping (not shown) for providing the feed liquid flow into the vessel 12.

[0032] As shown in FIG. 1, a removable filter assembly 26 is positioned within the vessel 12 between the feed inlet 22 and the filtrate outlet 24. The filter assembly 26 includes a filter rack 50 that supports one or more cross-flow filter elements 28 for filtering the feed flow stream entering the vessel 12. In a preferred embodiment, each filter element 28 is cylindrical in shape and includes a feed inlet 30 for receiving feed fluid into the filter element 28, a concentrate outlet 32 for discharging concentrate fluid from the filter element 28 and a filtrate tube outlet 34 for discharging filtrate fluid from the filter element 28. Preferably, the filter elements 28 are spiral wound cross-flow filter elements. Such elements commercially available and typically comprise membranes that are spiral wound on a filtrate tube enclosed within a cylindrical shell having an antitelescoping device (ATD) in the form of a plastic collar attached on each end (see FIG. 9). A brine seal is typically positioned on the outside of the filter element shell near the discharge end. Referring again to FIG. 1, a filtrate tube extension 36 is connected between the filtrate outlet 34 of each filter element 28 and the filtrate collection plenum 20. As used in this disclosure, the term "filtrate" is intended to include fluid passed through a filtration device, including a permeate fluid. It will be understood by those of ordinary skill in the art that, depending on the application, the filter elements 28 can be membrane filtration elements of various suitable types, including those used for reverse osmosis, nanofiltration, ultrafiltration and microfiltration filtration applications.

[0033] The filter rack 50 includes a closure plate 52 located at a discharge end of the filter rack 50 and an inlet plate 54 located at an inlet end of the filter rack 50. The closure plate 52 and the inlet plate 54 are mounted on threaded rods 56, which extend through the closure plate 52 and the inlet plate 54. With the filter rack 50 assembled and installed, the plates 52, 54 are held in place on the rods 56 by nuts 58 positioned on the rods 56 on both

sides of each of the plates 52, 54. In this configuration, the closure plate 52 defines an upstream boundary of the concentrate collection chamber 18 and the inlet plate 54 defines a downstream boundary of the inlet chamber 14. Also, the closure plate 52 and the inlet plate 54 define a downstream boundary and an upstream boundary, respectively, of a settling chamber 16, within which the filter elements 28 are disposed when they are loaded into the filter rack 50. The inlet plate 54 has filter holes 60, each of which is sized to receive a filter element 28 loaded through it. The closure plate 52 has holes 62 corresponding to each of the inlet plate filter holes 60 and sized to receive the discharge end of a loaded filter element 28. The closure plate hole 62 has a peripheral lip 63 against which the filter element 28 seats when it is loaded. The inlet plate filter holes 60 and the closure plate hole 62 are positioned such that they align when the inlet plate 54 and the closure plate 52 are mounted on the threaded rods 56. A thrust ring 64 is fixed to the interior wall of the vessel 12, such as by welding, at a position upstream of the isolation plate 21. The thrust ring 64 forms a flange around the periphery of the vessel interior wall. A thrust ring gasket 66 is positioned on the upstream side of the thrust ring 64. With the filter rack 50 installed in the vessel 12, the closure plate 52 seats against the thrust ring gasket 64 and the thrust ring 64 secures the filter rack 50 in position while providing a liquid-tight seal around the closure plate 52 between the settling chamber 16 and the concentrate collection chamber 18. Also in this installed position, the end of each of the threaded rods 56 is received and held in place by a correspondingly aligned threaded nipple 70 fixed to the isolation plate 21. The isolation plate 21 also includes through holes 72 that allow filtrate fluid to pass from the filtrate tube extensions 36 into the filtrate collection plenum 20. On the upstream side of the isolation plate 21, a nipple 74 is provided for each through-hole 72 for receiving the downstream end of the filtrate tube extension 36. The downstream end of the filtrate tube extension 36 can be provided with o-ring seals, as are well known in the art, to provide a sealed engagement with the isolation plate through-hole nipple 74. In this configuration, the element filtrate tube outlets 34 are placed in fluid communication with the filtrate collection plenum 20 and in fluid isolation from the concentrate collection chamber 18. The filtrate tube extension 36 can be a section of pipe that fits into the inner diameter of the element filtrate tube outlet, such as standard PVC pipe filtrate tube extensions as are known in the art. Preferably, the filtrate tube extension will be manufactured as an integral extension of the element filtrate tube. Alternatively, the filtrate tube extension can be a flexible hose or pipe.

[0034] With the filter rack assembled and installed into the vessel 11, a filter element 28 can be loaded into to filter rack 50 by sliding the filter element through an inlet plate filter hole 60 until the discharge end of the filter element 28 seats against the lip 63 of the corresponding closure plate hole 62 so that the brine seal of the filter element 28 forms a sealed engagement with the closure plate hole lip 63. The inlet plate filter hole 60 has a groove formed within the periphery of the hole for receiving a tension snap ring. With the filter element 28 loaded into the filter rack 50 the tension snap ring can be inserted into the groove of the inlet plate filter hole 60 to retain the filter element 28 in the rack 50 and so that it the discharge end of the filter element 28 is pressed firmly against the closure plate hole lip 63. In a preferred embodiment, the filter rack 50 also includes support members 76 for supporting the filter elements 28 when they are being loaded into the filter rack 50. As shown in FIGs. 1 and 11, the support member 76 is in the form of a tray having a cross-section in the shape of a circular segment (see FIG. 11). The support member 76 is positioned between the closure plate 52 and the inlet plate 54 for supporting the weight of filter element 28 as it is slid through the inlet plate filter hole 60 to be loaded into the filter rack 50. Each of the ends of the support member 76 rests in a lip 78 formed along a portion of the edge of the inlet plate filter hole 60 and a similar lip 79 formed along a portion of the edge of the corresponding closure plate recess 62.

[0035] A removable end cap 40 is located at the inlet end of the vessel 12 to provide access for the loading and unloading of the filter elements 28. In a preferred embodiment, the end cap 40 is in the form of a hinged door with a gasket seal and T-bolt closures 41 such that the end cap 40 can be opened to provide access to the interior of the vessel 12 and that can be closed and bolted to seal the vessel 12 for operation under pressure.

[0036] As shown in FIGs. 6 and 7, in one preferred embodiment the inlet plate and the closure plate provide for the mounting of the filter elements in a concentric geometry. The inlet plate 54 includes passages 56 that allow feed fluid to move between the inlet chamber 14 and the settling chamber 16. In operation, the inlet plate passages allow feed fluid entering the inlet chamber 14 to fill the settling chamber 16. In a preferred embodiment, the inlet plate passages 56 are in the form of scallops located around the periphery of the inlet plate 54, as shown in FIG. 6. Upon reading this disclosure, however, it will be understood that inlet passages may be provided in other forms, such as by providing perforations or holes in the inlet plate 54. Also in a presently preferred embodiment, the inlet plate 54 is not fixed to the interior wall of the vessel 12, thereby allowing the position of the inlet plate 54 on the

threaded rods 56 to be adjusted along the length of the rods 56 and within the vessel 12 by adjusting the position of the nuts 58 that hold the inlet plate 54 in position on the rods 56. By allowing for the adjustment of the position of inlet plate 54 in this manner, the filter rack 50 can be adjusted to hold filter elements 28 of various lengths. For example, a standard spiral wound cross-flow filter element is 40 inches long, but such elements are commercially available in lengths from 14 inches to 60 inches. By providing the filter rack 50 in the adjustable configuration described above, the system of the present invention can accommodate the use of any of these lengths of filter elements. As previously mentioned above, during operation of the system the feed fluid in the settling chamber 16 fills with feed fluid. This provides several benefits. First, it equalizes the pressure in the settling chamber 16 (i.e. the pressure on the downstream side of the inlet plate 54) with the pressure in the inlet chamber 14 (i.e., the pressure on the upstream side of the inlet plate 54). In addition, it tends to equalize the pressure on the outside of the filter element 28 with the pressure inside the filter element. Thus, the filter element shell is not used as a structural member and the filter element 28 can operate at higher pressures than it would if the filter element shell were required to provide a structural function.

[0037] A concentrate discharge outlet 38 is disposed in the vessel 12 in communication with the concentrate collection chamber 18 for discharging a concentrate fluid flow 102 from the concentrate collection chamber 18. The concentrate fluid discharge flow 102 and can be channeled through pipes for waste disposal or recycling recovery. As shown in FIGs. 3 and 4, the concentrate discharge outlet 38 is shown in the side of the vessel 12. Upon reading this disclosure, however, it will be understood by those of ordinary skill in the art that the concentrate discharge outlet 38 could also be placed in other suitable locations in communication with the concentrate collection chamber 38, including a location in the bottom of the vessel 12. A concentrate drain 80 is disposed in the bottom of the concentrate collection chamber for cleaning and maintenance of the chamber.

[0038] One or more precipitate drains 42 are disposed on the bottom of the vessel 12 in communication with the inlet chamber 14 and the settling chamber 16 for removal of precipitated particles that settle out of the feed liquid in the inlet chamber 14 and settling chamber 16, respectively. In a preferred embodiment, the precipitate drain 42 is in fluid communication with a settling trough 44 formed in the vessel wall 12 and located along a portion of the length of the inlet chamber 14 and the settling chamber 16. The settling trough 44 collects precipitate that settles out of the feed liquid in the inlet chamber 14 and the

settling chamber 16. The precipitate drain 42 can be coupled to pipes for removing the precipitate from the settling trough 44 for waste disposal or recycling recovery. This precipitate removal can be performed automatically and continuously during operation of the system, such as by using actuated drain valves. Using this configuration, the precipitate drain 42 can be used to draw settled solids away from the filter element feed inlets 30 and to remove the solids from the vessel 12.

[0039] An access port 46 in the vessel 12 provides access to the concentrate collection chamber 18. The access port 46 is covered by an access port cover plate 47 which seals the access port 46 closed and which can be removed to provide physical access to the concentrate collection chamber 18. This allows for installation and maintenance of the filter elements 28 and for inspection of the filter elements 28 and the filtrate tube extensions 36 without removing them from the vessel 12. In a preferred embodiment, the access port 46 is positioned opposite the concentrate discharge outlet 38, as shown in FIGs. 2-4.

[0040] One or more feed return outlets 48 are disposed in the vessel 12 in fluid communication with the settling chamber 16 near the discharge end of the filter rack 50. The return outlets 48 allow feed fluid in the settling chamber to be returned to the inlet feed fluid stream 100 via return pipes (not shown). A vent 49 is provided in the top of the vessel 12 as a pressure relieve valve to meet applicable safety codes.

[0041] In operation, the inlet feed liquid flow 100 is directed through the feed inlet 22 into the inlet chamber 14. Because the inlet chamber 14 is an expanded volume in comparison to the feed inlet 22, the inlet feed liquid flow 100 enters the inlet chamber 14 as a turbulent flow stream. Because of this and because the feed inlet 22 is oriented generally perpendicular to the inlet plate 54 and the filter element feed inlet faces 30, the inlet feed liquid flow 100 scours the filter element faces, thereby helping to clean the filter element faces by removing solids deposited on the faces of the filter elements 28 during operation of the system. A portion of the inlet feed liquid flow 100 enters the filter element feed inlets 30. Also, a portion of the inlet feed liquid flow 100 passes through the inlet plate passages 57 and into the settling chamber 16. Because the inlet chamber 14 has an expanded volume the feed fluid flow velocity slows after entering the inlet chamber and suspended solids in the feed fluid flow settle out of the feed fluid to the bottom of the inlet chamber 14, where they are collected in the settling chamber and into the settling trough 44. Also, the feed fluid flow in the settling chamber 16 has a very low velocity and low turbulence. Therefore, suspended solids and the feed fluid in the settling chamber 16 also settle out of the feed fluid to the

bottom of the settling chamber and into the settling trough 44. As discussed above, the solids that settle into the settling trough are removed from the vessel 12 via the precipitate drains 42.

[0042] A portion of the feed fluid in the settling chamber 16 flows out of the return outlets 48 to be returned to the inlet feed fluid stream 100 as described above. Because some suspended particles have been removed from the feed fluid in the settling chamber 16, the feed fluid returned through the return outlets 48 is cleaner than that feed fluid was when it originally entered the vessel 12 through the feed inlet 22. This process of returning feed fluid from the settling chamber 16 to the inlet fluid stream 100 dilutes the combined inlet feed fluid flow entering the vessel, thereby lessening the solids loading entering the vessel.

[0043] The feed fluid entering filter element feed inlets 30 passes through each of the respective filter elements 28. The filtered feed fluid flow is discharged from the filters 28 through the filter element filtrate outlets 24 and flows through the filtrate tube extensions 36 into the filtrate collection plenum 20. The filtrate outlet 24 serves as a single outlet for discharge of the filtrate fluid from the vessel 12. The rejected portion of the feed fluid flow entering the filter elements 28 passes out of the filter element concentrate outlets 32 and into the concentrate collection chamber 18 as concentrate fluid. The concentrate fluid is discharged from the concentrate collection chamber through the concentrate discharge outlet 38 as a waste stream for disposal or recycling.

[0044] Suitable piping, electrical, and instrumentation components can be provided to automate the process flow in and through the pressure vessel 12.

[0045] The apparatus and method according to our invention can be used for filtration of municipal potable water. A typical microfiltration system for the filtration of 1.0 million gallons per day of municipal potable water offered by a major supplier will require approximately 500 square feet of floor space and is about 11 feet high. In contrast, a system according to the present invention for filtering the same capacity of potable water occupies about 40 square feet of floor space and is less than five feet high. In addition to the space savings, operational availability of the filtration system according to our invention is expected to be about 20% higher than the majority of previous systems for filtering municipal potable water.

[0046] We have constructed a system according to our invention for filtering municipal potable water. The body of the pressure vessel 12 is made of carbon steel. The vessel is approximately nine feet long and three feet high. The closure plate 52 and the inlet

plate 54 are fabricated from machined high-density plastic. Upon reading this disclosure, however, it will be understood by those of skill in the system can be fabricated in various sizes and of various materials, depending on the application.

[0047] The above described system and method of the present invention provides a number of advantages. The invention can be applied to reverse osmosis, nanofiltration, microfiltration and ultrafiltration systems in municipal water treatment and industrial processes, as well as general filtration needs. According to one aspect of the system and method of the invention, a novel filter element configuration of multiple single array elements is positioned in a concentric geometry within a pressure vessel, in contrast to the multiple elements positioned in series typically used in spiral wound element filtration systems. This bundled single element array configuration allows for maximum filtrate production from each element because system head loss is limited to the head loss of a single filter element. The element configuration also allows the individual elements to receive the inlet flow at the same feed volume and pressure so as to operate as a parallel system instead of in series. The filtrate produced by the filter elements is collected in a common filtrate collection plenum with a single filtrate discharge outlet. This configuration minimizes the backpressure on the element filtrate tubes and improves the operating hydraulics of the filter elements. Because the filter is allowed to operate for longer periods at higher imposed pressures through the filter elements, filtrate flow is increased and the volume of backwash waste streams is reduced. Concentrate flow through the elements is collected in a common concentrate collection chamber where it is discharged as a common flow stream.

[0048] According to another aspect of the invention, the problem of fouling at the filter inlet is minimized by positioning the incoming flow stream tangentially to the inlet face of the geometrically positioned, bundled, single element array. The velocity of the inlet feed flow scours and assists in clearing away the particulate fouling at the inlet face of the filter element. Because inlet flow is not directed into the face of the element, suspended particulates are allowed to settle in an expanded inlet chamber from which they can be continually removed. Thus, the majority of the particles in suspension do not contact the inlet face of the elements, delaying formation of a cake layer on the face of the elements. This feature allows for longer filter operation until backwashing is required and increased filtrate flow resulting from the higher sustained velocities through the filter elements.

[0049] The system of the present invention provides a filter assembly wherein the filter elements can be interchanged in a common pressure vessel for operation in reverse

osmosis, nanofiltration, ultrafiltration, and microfiltration applications. This provides a high degree of operational flexibility in refining the filtration system for a particular process application while utilizing the same pressure vessel, component layout, and basic system controls.

[0050] While the particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the teachings of the present invention. The matter set forth in the foregoing description and accompanying drawings is offered by way of illustration only and not as a limitation. The actual scope of the invention is intended to be defined in the claims when viewed in their proper perspective based on the prior art.

What is claimed is:

1. A filtration apparatus for filtering a feed liquid, the apparatus comprising:
a vessel having an inlet chamber adapted to receive an inlet flow of the feed fluid and a concentrate collection chamber; and
a plurality of filter elements wherein each filter element has a feed inlet for receiving feed fluid, a concentrate outlet for discharging concentrate fluid and a filtrate outlet for discharging filtrate fluid;
wherein the filter elements are positioned in a parallel flow arrangement within the vessel with the feed fluid inlet of each filter element in fluid communication with the inlet chamber and the concentrate outlet of each filter element in fluid communication with the concentrate collection chamber.
2. The filtration apparatus of claim 1 wherein each of the plurality of filter elements comprises a cross-flow filter element.
3. The filtration apparatus of claim 2 wherein the cross-filter element comprises a spiral wound membrane.
4. The filtration apparatus of claim 1 wherein the vessel further comprises a filtrate collection plenum in fluid communication with the filtrate outlet of each of the plurality of filter elements.
5. The filtration apparatus of claim 1 wherein the feed inlet of each of the plurality of filter elements is disposed generally perpendicular to the inlet flow of feed fluid.
6. The filtration apparatus of claim 1 wherein during operation of the apparatus, the pressure drop from the feed inlet to the concentrate outlet of each of the plurality of filter elements is substantially the same.
7. The filtration apparatus of claim 1 wherein the fluid conditions at the feed fluid inlet of each of the filter elements are substantially the same for each of the filter elements and the fluid conditions at the concentrate outlet of each of the filter elements are substantially the same for each of the filter elements.
8. The filtration apparatus of claim 1 further comprising a concentrate discharge port in fluid communication with the concentrate chamber for discharging concentrate fluid from the vessel.

9. The filtration apparatus of claim 1 further comprising a drain outlet disposed in the inlet chamber for removing particulate matter that settles in the inlet chamber.

10. The filtration apparatus of claim 1 further comprising a drain outlet disposed in the settling chamber for removing particulate matter that settles in the settling chamber.

11. The filtration apparatus of claim 1 further comprising a hinged [removable?] end-cap to provide access for loading the filter elements into the vessel and unloading the filter elements from the vessel.

12. The filtration apparatus of claim 1 further comprising a feed return outlet disposed in vessel for removing feed fluid from the vessel for return to the inlet flow of the feed fluid.

13. A filtration method for filtering a flow stream of feed liquid, the method comprising:

positioning a plurality of filter elements within the feed fluid flow stream wherein each filter element has a feed inlet for receiving a portion of the feed fluid flow stream, a concentrate outlet for discharging concentrate fluid and a filtrate outlet for discharging filtrate fluid and wherein the each of the plurality of filter elements filters the portion of the flow stream in parallel.

14. The filtration method of claim 13 wherein each of the plurality of filter elements comprises a cross-flow filter element.

15. The filtration method of claim 14 wherein the cross-filter element comprises a spiral wound membrane.

16. The filtration method of claim 13 further comprising discharging the filtrate fluid from each of the plurality of filter elements into a single filtrate collection plenum.

17. The filtration method of claim 13 further comprising directing an inlet feed flow stream generally perpendicular to filter feed inlet of at least one of the filter elements.

18. The filtration method of claim 13 wherein the pressure drop from the feed inlet to the concentrate outlet of each of the plurality of filter elements is substantially the same.

19. The filtration method of claim 13 comprising providing the feed flow stream such that the fluid conditions at the feed fluid inlet of each of the filter elements are substantially the same for each of the filter elements and the fluid conditions at the

concentrate outlet of each of the filter elements are substantially the same for each of the filter elements.

20. The filtration method of claim 13 further comprising discharging the concentrate fluid from each of the plurality of filter elements into a single concentrate chamber.

21. A filtration apparatus for filtering a feed fluid inlet stream, the apparatus comprising:

a plurality of filter elements each having a feed inlet for receiving feed fluid, a concentrate outlet for discharging concentrate fluid and a filtrate outlet for discharging filtrate fluid;

wherein each filter element feed inlet is adapted to receive feed fluid from an inlet chamber;

wherein each filter element concentrate outlet is adapted to discharge concentrate fluid into a concentrate collection chamber; and

wherein each filter element filtrate outlet is adapted to discharge filtrate fluid to a filtrate collection plenum that is isolated from the concentrate collection plenum.

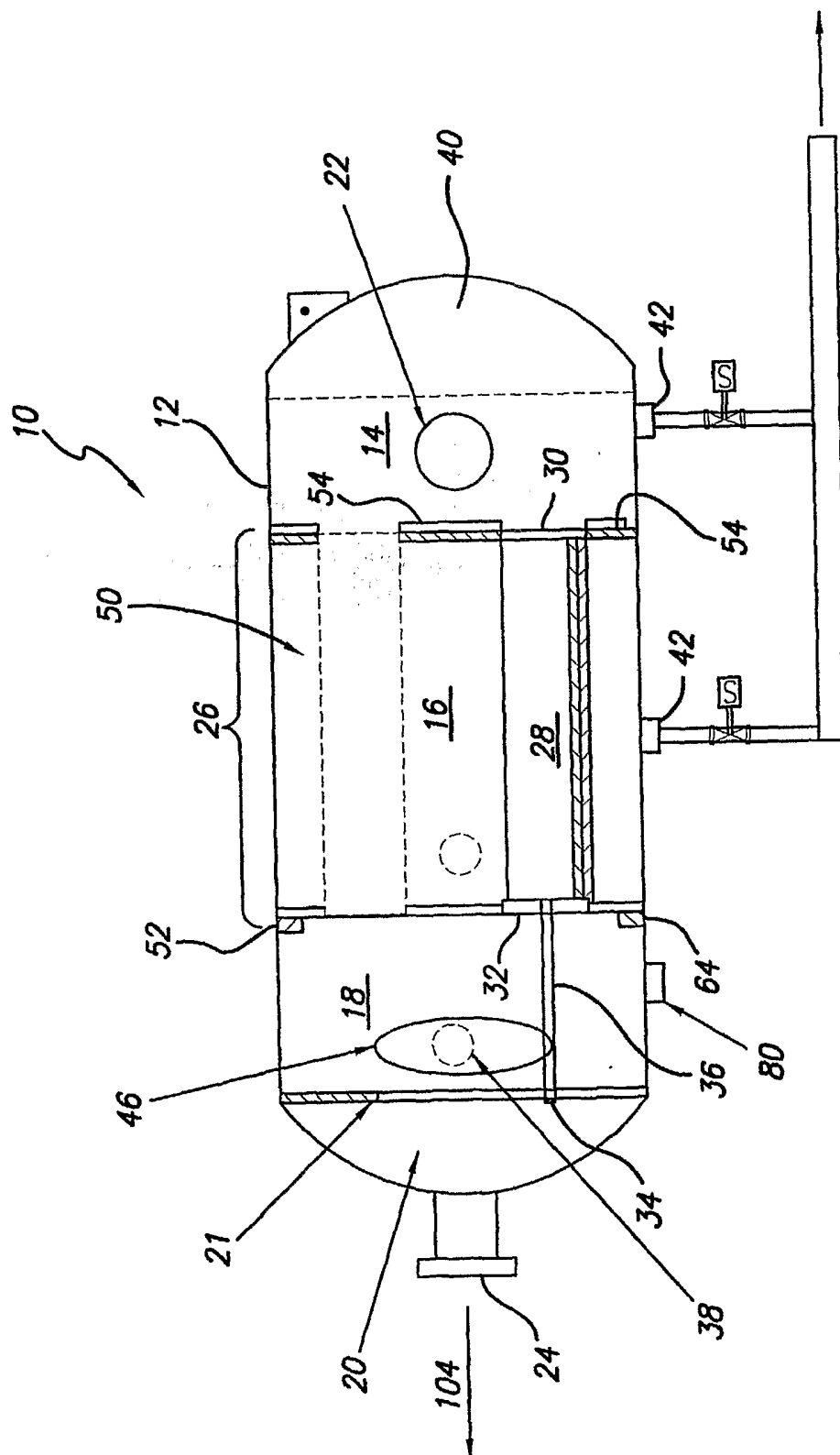


FIG. 1

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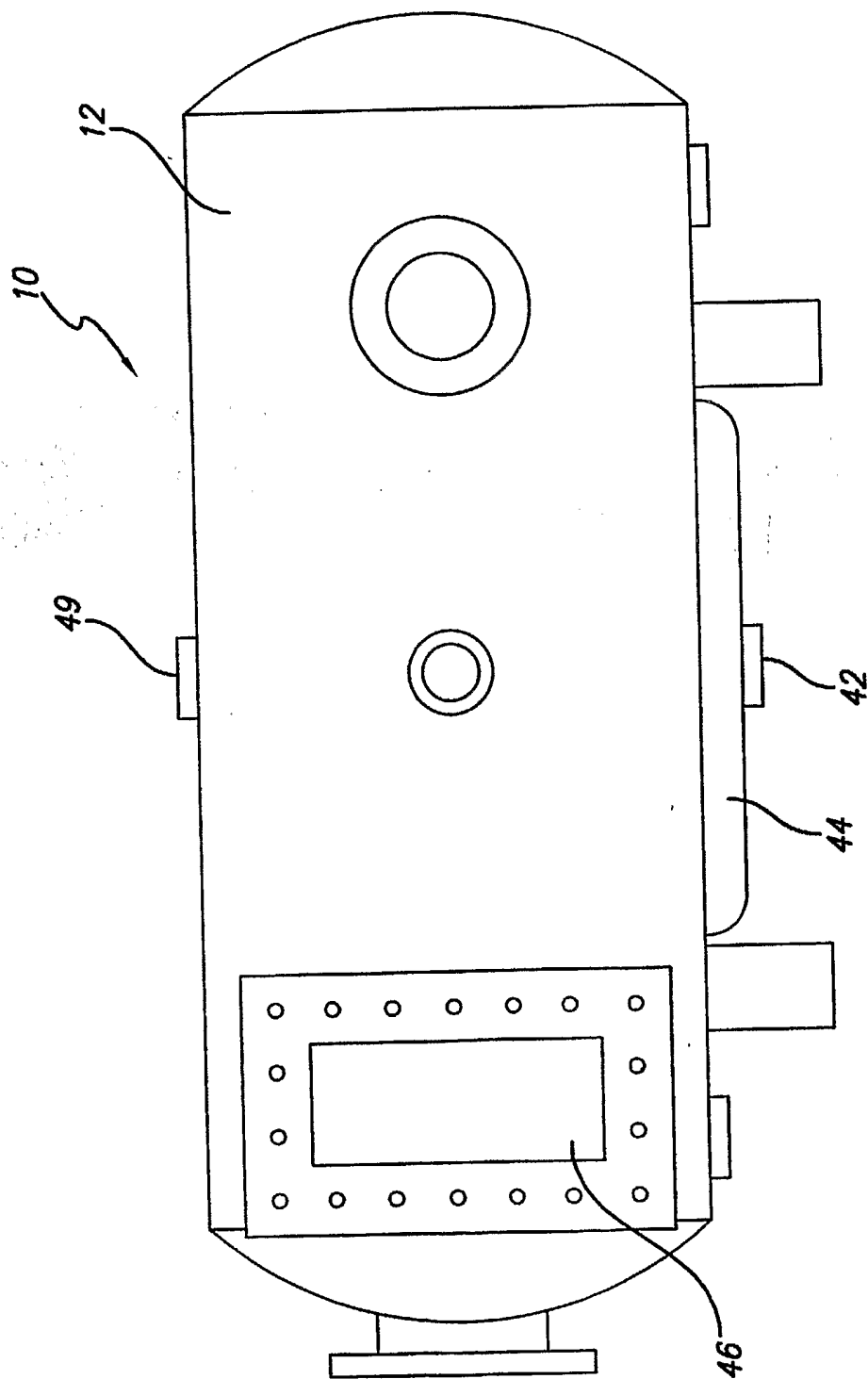


FIG. 2

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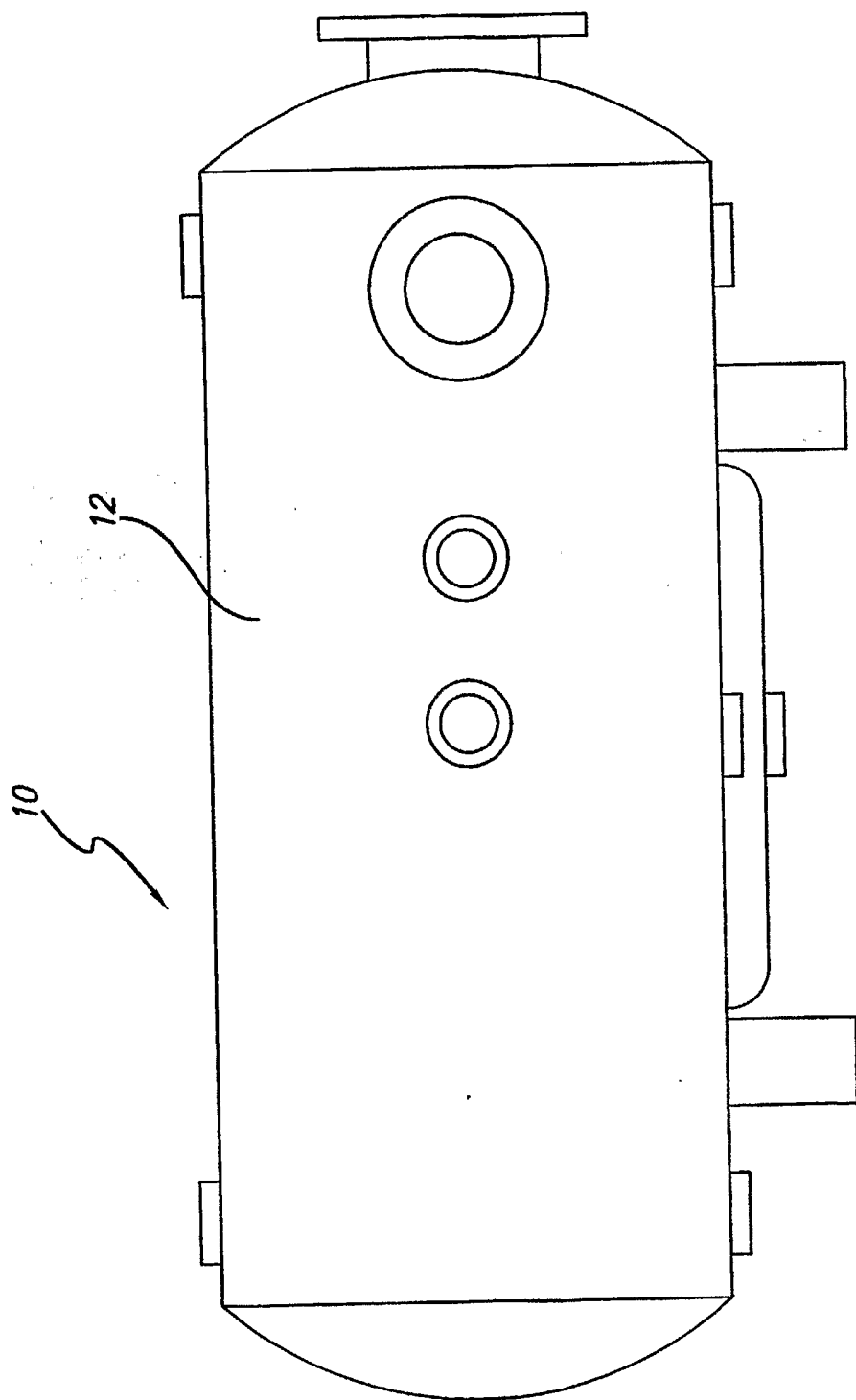


FIG. 3

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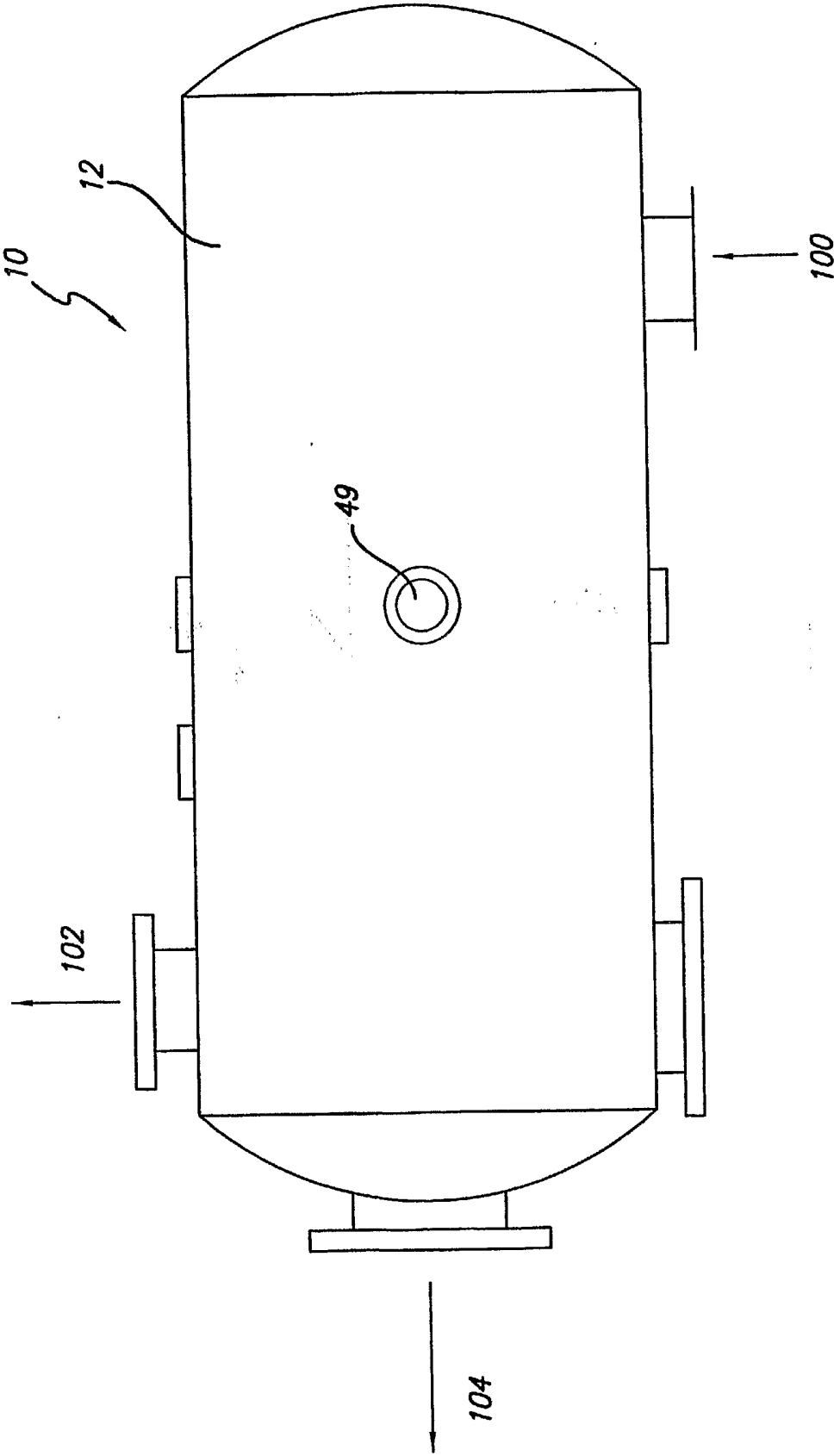


FIG. 4

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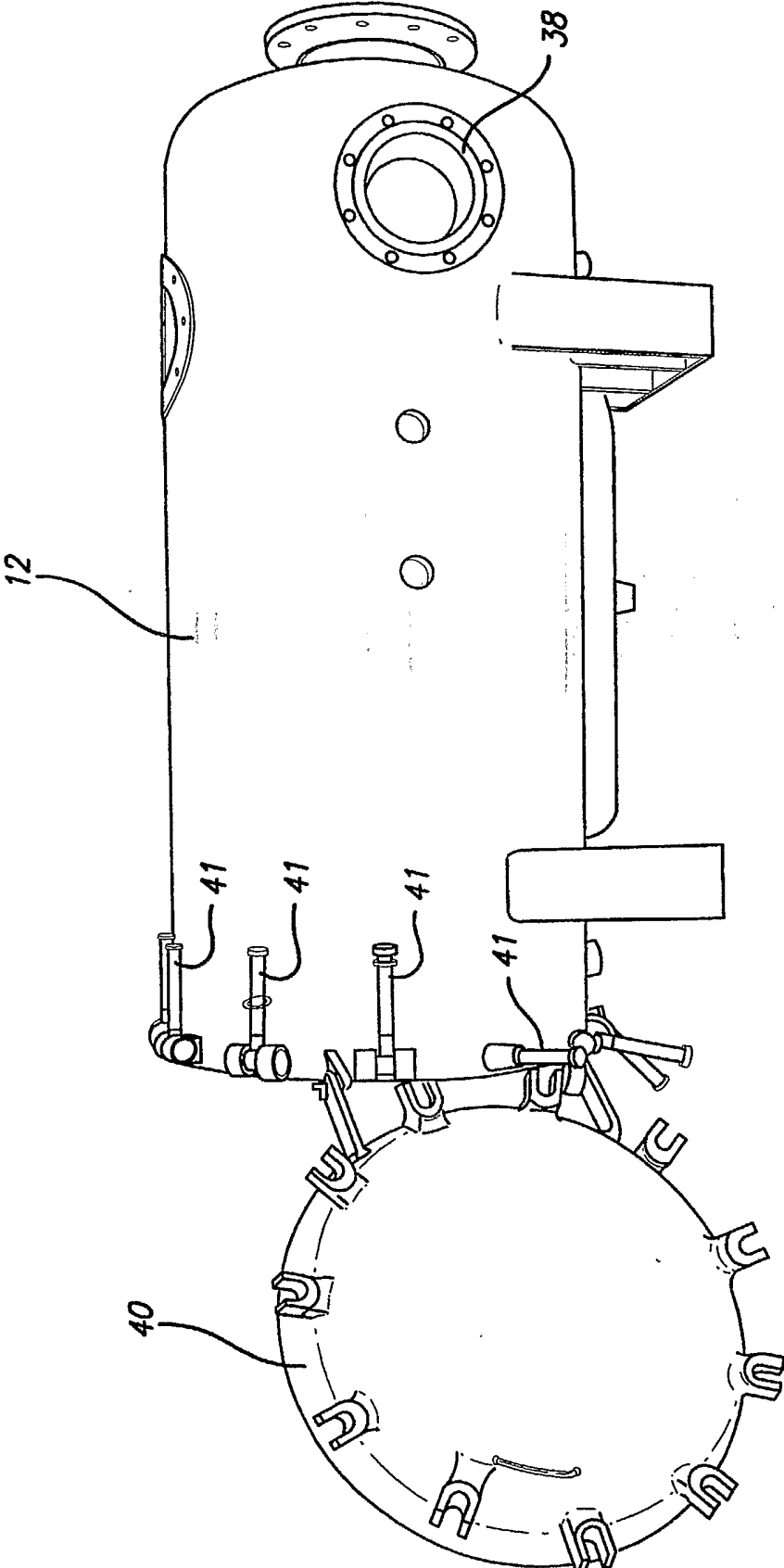


FIG. 5

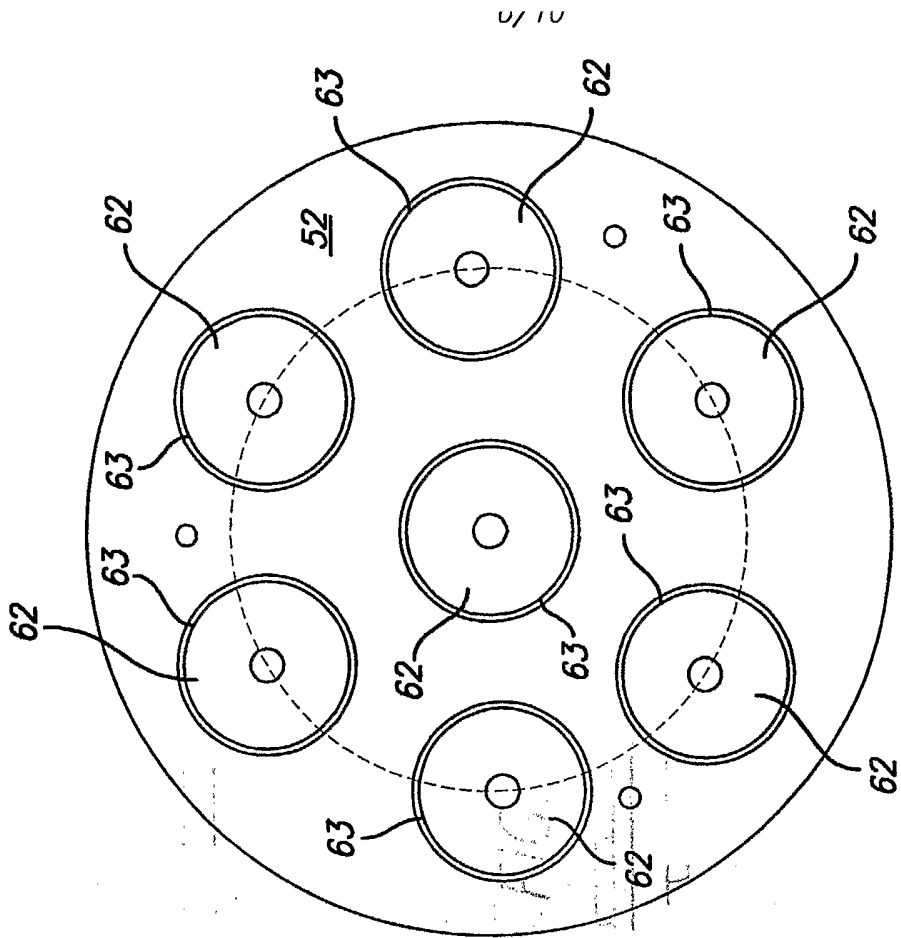


FIG. 7

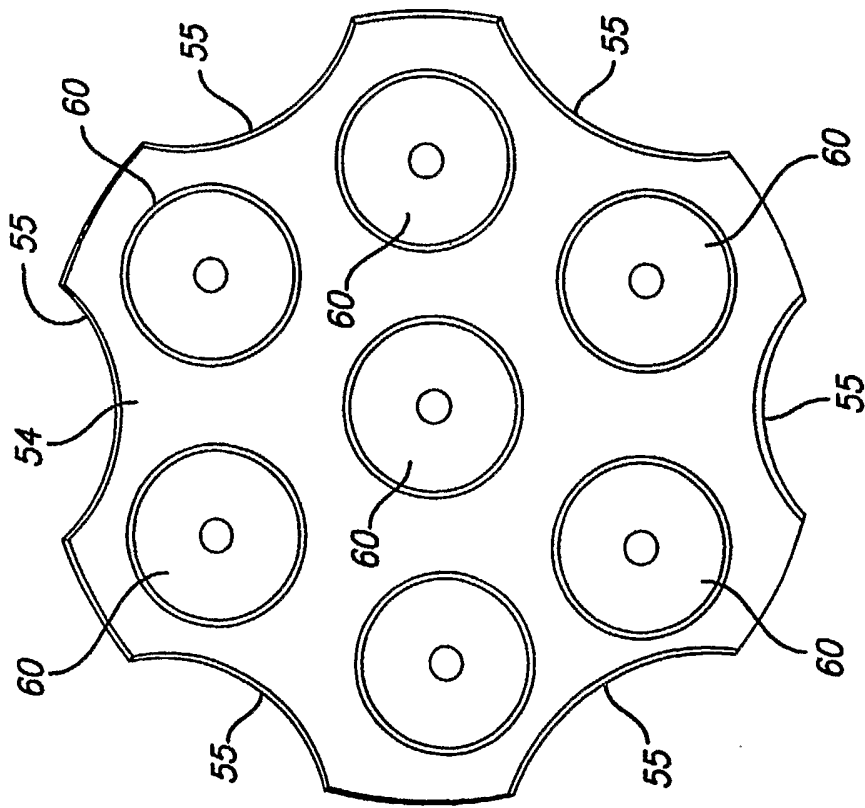


FIG. 6

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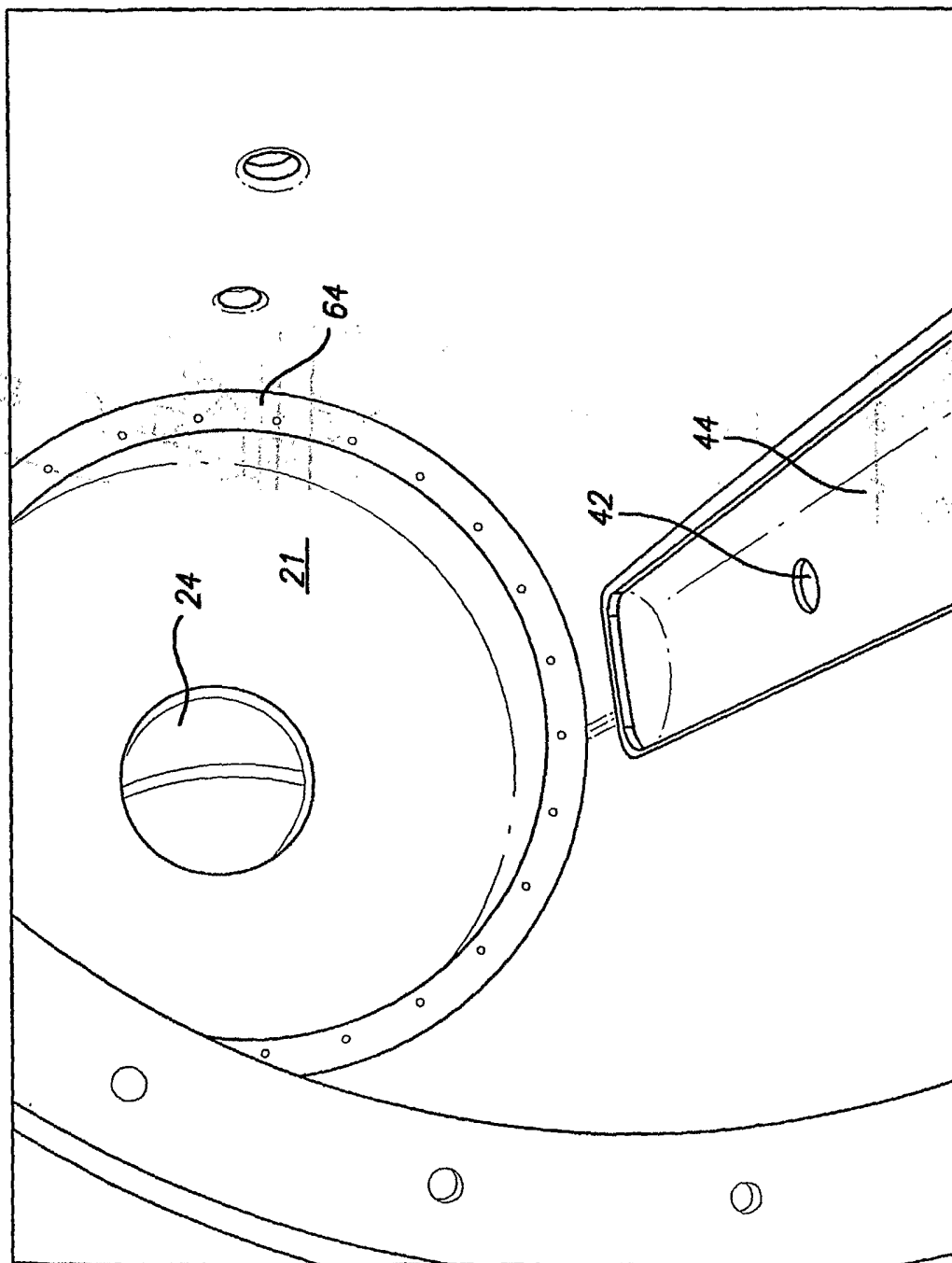


FIG. 8

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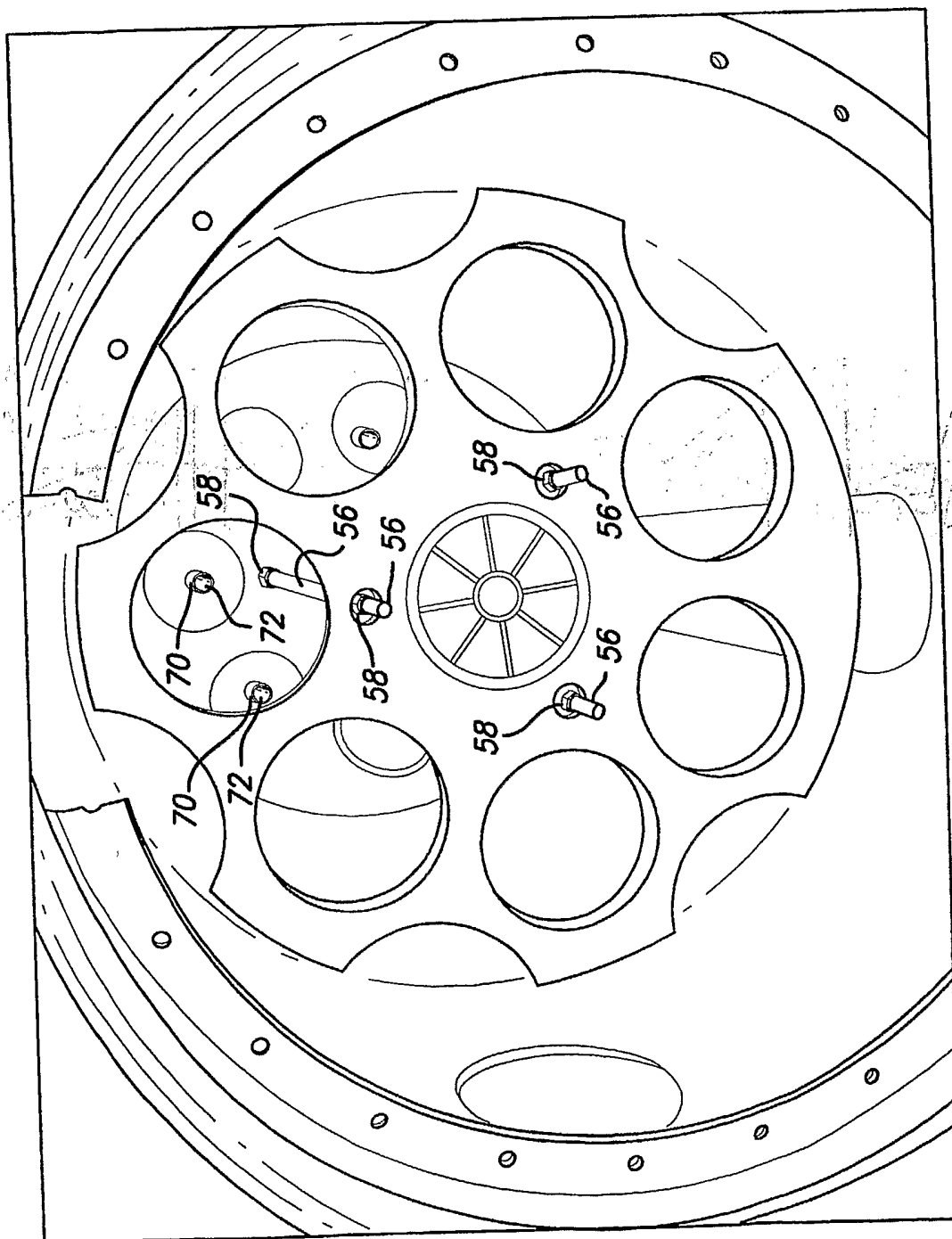


FIG. 9

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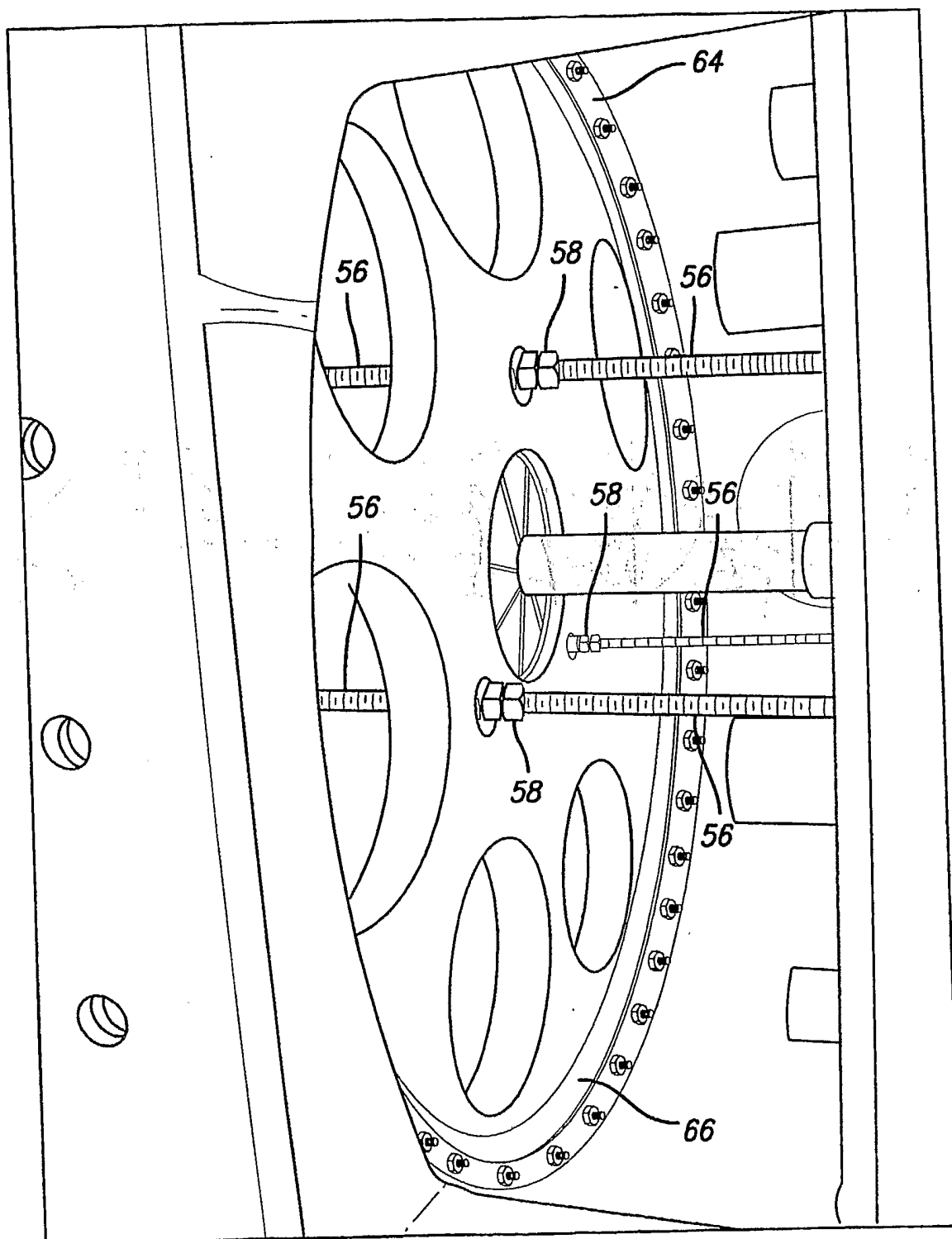


FIG. 10

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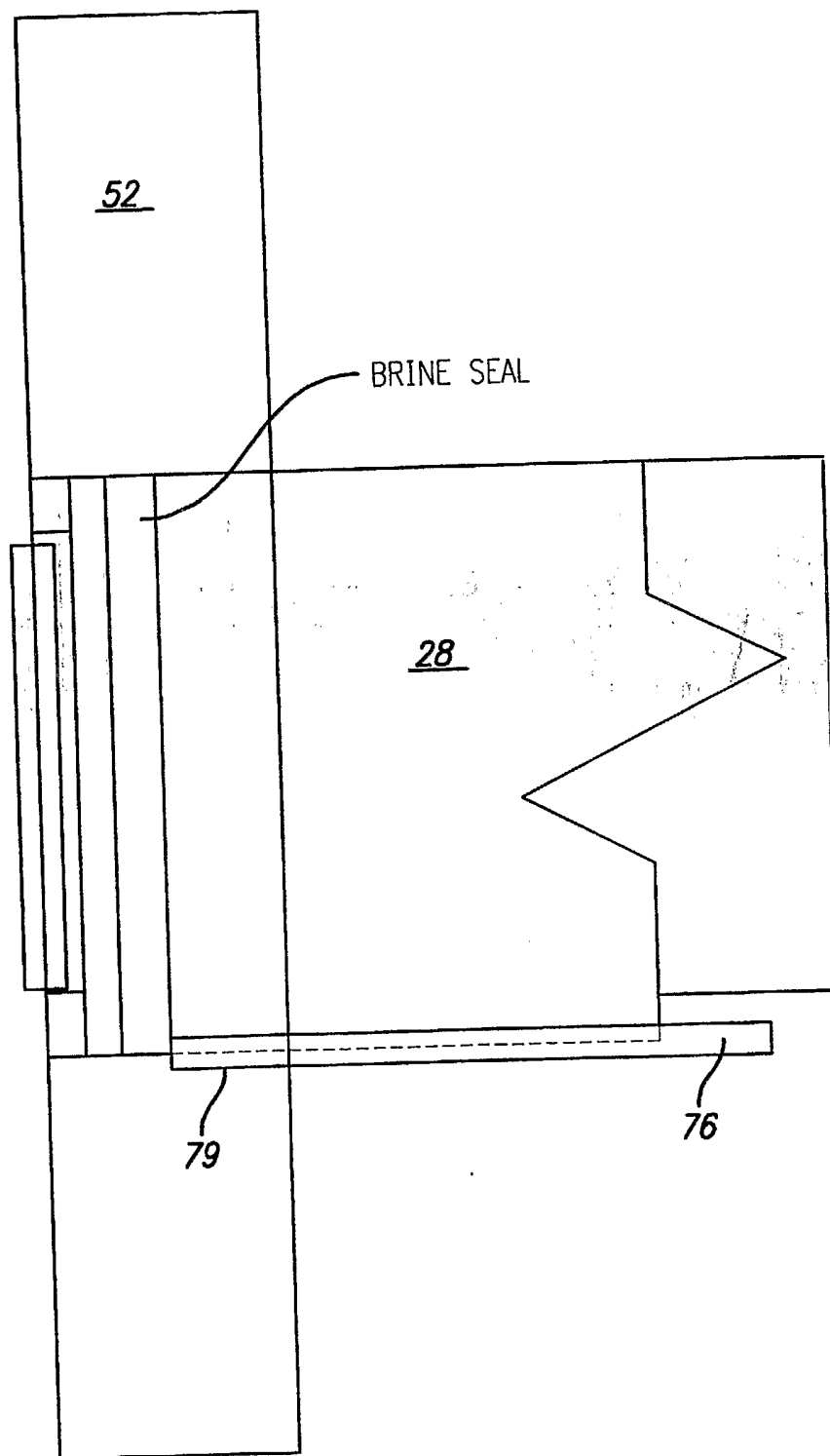


FIG. 11

SUBSTITUTE SHEET (RULE 26)