expensive, difficult to transport and assemble into the vessels, and susceptible to deforming under pressure or weight.

Another problem with using a perforated plate as a lower support is that solid materials such as sludge or particles entrained in the feed fluid tend to settle onto the plate over time. These solids are difficult to remove from conventionally-designed vessels because they have to be partially disassembled (such as by removing elements) to be cleaned. It is possible to introduce additional perforations into the lower support plate to allow the solids to sink to the bottom of the vessel, from which they can be more easily drained. However, adding more perforations further weakens the plate, making it more prone to sagging or even breaking.

Summary of the Invention

In accordance with one aspect of the present invention, there is provided a multi-element filtration apparatus, the apparatus comprising

a) a pressure vessel;

b) multiple filtration elements, each containing at least one filtration membrane in an interior portion thereof, the multiple filtration elements being disposed substantially vertically within the pressure vessel, the multiple filtration elements each having a bottom end having one or more through-holes that admit a fluid into the interior portion of the filtration element,

c) one or more aerators within the pressure vessel for supplying an aeration gas to the bottom ends of the multiple filtration elements; and

d) a first set of multiple spaced beams mounted on an interior surface of the pressure vessel, the first set of multiple spaced beams being engaged with the bottom ends of the multiple filtration elements such that i) each of the bottom ends is supported by two adjacent spaced beams and extends downwardly between said two adjacent spaced beams, each bottom end by itself or together with the two adjacent spaced beams defining a cavity that provides a feed fluid path for a feed fluid and a gas supplied by the aerator(s) to travel upwardly through the cavity to the through-holes in the bottom end, and ii) fluid passages, separate from the feed fluid paths, extend from above to below each pair of adjacent spaced beams and between the bottom end caps of adjacent filtration elements mounted on each pair of adjacent spaced beams.

The lower support design of this invention offers several important advantages. Manufacturing is simplified in many cases because the beams often have a simple geometry. They use less material than the pressure plate, reducing raw material, manufacturing and transportation costs. Transportation is easier because the beams can be shipped separately and assembled into place at the location where the multi-element filtration vessel is to be assembled and used.

The lower support design of the invention also offers operational advantages. Adjacent pairs of beams can act as baffles to direct fluids, and in particular an aeration gas, up to the filtration elements. In addition, gaps between the beams form fluid passages through which sludge and other solids can easily settle down through the lower support to the bottom of the pressure vessel, from which they are easily removed.

In accordance with a second aspect of the present invention, there is provided a filtration element comprising

a) an elongated body portion comprising a shell defining an interior portion that contains at least one filtration membrane;

b) a top end affixed to and in fluid communication with the elongated body portion, the top end comprising separate openings for the removal of concentrate and permeate from the filtration element; and

c) a bottom end affixed to the elongated body portion, the bottom end being adapted to rest upon an adjacent pair of beams and to extend downwardly between the adjacent pair of beams and, by itself or together with the adjacent pair of beams form a cavity, the cavity being in fluid communication with the interior portion of the elongated body portion.

In accordance with a third aspect of the present invention, there is provided a filtration apparatus comprising

a) a pressure vessel;

b) multiple filtration elements, each containing at least one filtration membrane in an interior portion thereof, the multiple filtration elements being disposed substantially vertically within the pressure vessel, the multiple filtration elements each having a bottom end having one or more through-holes that admit a fluid into the interior portion of the filtration element, and

c) one or more removable aerators extending the pressure vessel for supplying an aeration gas to the bottom ends of the multiple filtration elements, wherein the one or more removable aerators are each removably and sealingly mounted onto a protrusion provided on an

exterior surface of the pressure vessel and through an opening through the protrusion and the exterior surface of the pressure vessel and into the pressure vessel.

Brief Description of the Drawings

FIGURE 1 is a front view, in section, of an embodiment of a filtration apparatus of the invention.

FIGURE 1A is a side view, in section, of the embodiment of the filtration apparatus shown in FIGURE 1, being rotated 90° about a central vertical axis.

FIGURE 2 is a top sectional view, taken along lines 2-2A of Figure 1, of an embodiment of a filtration apparatus of the invention.

FIGURE 3A is an isometric view of an embodiment of spaced beams mounted on a peripheral support, for use in this invention.

FIGURE 3B is an isometric view of a second embodiment of spaced beams mounted on a peripheral support, for use in this invention.

FIGURE 3C is an isometric view of a third embodiment of spaced beams mounted on a peripheral support, for use in this invention.

FIGURE 4 is a side view of an embodiment of a beam for use in the invention.

FIGURE 5A is front view of a portion of an embodiment of a filtration element for use in the invention.

FIGURE 5B is a front view of a portion of a second embodiment of a filtration element for use in the invention.

FIGURE 6 is a side view, in section, of an embodiment of a filtration element for use in the invention.

FIGURE 7A is an isometric view of an embodiment of a beam with integrated aerator for use in the invention.

FIGURE 7B is a sectional view of the beam with integrated aerator shown in Figure 7A.

FIGURE 8 is a side view, partially in section, showing the operation of a beam with integrated aerator.

FIGURE 9 is a side view, partially in section, showing the operation of an embodiment of an aeration system for use in the invention.

FIGURE 10 is a side sectional view of a filtration apparatus of the third aspect of the invention.

Claims

What is claimed is:

1. A multi-element filtration apparatus, the apparatus comprising

a) a pressure vessel;

b) multiple filtration elements, each containing at least one filtration membrane in an interior portion thereof, the multiple filtration elements being disposed substantially vertically within the pressure vessel, the multiple filtration elements each having a bottom end having one or more through-holes that admit a fluid into the interior portion of the filtration element;

c) one or more aerators within the pressure vessel for supplying an aeration gas to the bottom ends of the multiple filtration elements;

d) a first set of multiple spaced beams mounted on an interior surface of the pressure vessel, the first set of multiple spaced beams being engaged with the bottom ends of the multiple filtration elements such that i) each of the bottom ends is supported by two adjacent spaced beams and extends downwardly between said two adjacent spaced beams, each bottom end by itself or together with the two adjacent spaced beams defining a cavity that provides a feed fluid path for a feed fluid and a gas supplied by the aerator(s) to travel upwardly through the cavity to the through-holes in the bottom end, and ii) fluid passages, separate from the feed fluid paths, extend from above to below each pair of adjacent spaced beams and between the bottom end caps of adjacent filtration elements mounted on each pair of adjacent spaced beams.

2. The multi-element filtration apparatus of claim 1, wherein each bottom end comprises an upper portion that resides above the adjacent spaced beams and a lower portion that extends downwardly between the two adjacent spaced beams on which the bottom end is supported, wherein the upper portion defines an upper portion of the cavity that extends above the two adjacent spaced beams.

3. The multi-element filtration device of claim 1 or 2 further comprising at least one upper support for aligning the multiple filtration elements.

4. The multi-element filtration device of any preceding claim wherein the filtration membrane is a hollow fiber membrane.

5. The multi-element filtration device of any preceding claim further comprising a feed inlet port for introducing a feed fluid into the pressure vessel; a permeate discharge port for discharging from the pressure vessel a permeate produced by the multiple filtration elements, and a concentrate discharge port for discharging from the pressure vessel a concentrate produced by the multiple filtration elements.

6. The multi-element filtration device of any preceding claim wherein the first set of multiple spaced beams is mounted onto an alignment structure that aligns beams and forms a unitary structure.

7. The multi-element filtration device of any preceding claim further comprising positioning elements for engaging with and positioning the multiple filtration elements in a fixed position on the first set of multiple spaced beams.

8 The multi-element filtration device of any preceding claim wherein the one or more aerators are integrated with the first set of multiple spaced beams such that an aeration gas is supplied to the cavities through gas outlets in the first set of multiple spaced beams.

9. The multi-element filtration device of any preceding claim wherein the one or more aerators are removable aerators.

10. A filtration element comprising

a) an elongated body portion comprising a shell defining an interior portion that contains at least one filtration membrane;

b) a top end affixed to and in fluid communication with the elongated body portion, the top end comprising separate openings for the removal of concentrate and permeate from the filtration element; and

c) a bottom end affixed to the elongated body portion, the bottom end being adapted to rest upon an adjacent pair of beams and to extend downwardly between

the adjacent pair of beams and, by itself or together with the adjacent pair of beams form a cavity, the cavity being in fluid communication with the interior portion of the elongated body portion.

11. The filtration element of claim 10 wherein the bottom end has an upper section and a lower section, the upper section being wider than the lower section and defining shoulders at the conjunction of the upper section and lower section for resting on an adjacent pair of beams, and the lower section being adapted to extend downwardly between such adjacent pair of beams.

12. The filtration element of claim 11 wherein the upper section defines an upper cavity that resides above the level of the adjacent pair of beams and the lower section by itself or together with the adjacent pair of beams defines a lower cavity that extends between the adjacent beams.

13. A filtration apparatus comprising

a) a pressure vessel;

b) multiple filtration elements, each containing at least one filtration membrane in an interior portion thereof, the multiple filtration elements being disposed substantially vertically within the pressure vessel, the multiple filtration elements each having a bottom end having one or more through-holes that admit a fluid into the interior portion of the filtration element, and

c) one or more removable aerators extending into the pressure vessel for supplying an aeration gas to the bottom ends of the multiple filtration elements,

wherein the one or more removable aerators are each removably and sealingly mounted onto a protrusion provided on an exterior surface of the pressure vessel and through an opening through the protrusion and the exterior surface of the pressure vessel and into the pressure vessel.

14. The filtration apparatus of claim 13 wherein each removable aerator includes (i) an interior section positioned within said pressure vessel, the section comprising an elongated conduit closed at a distal and having multiple holes down a longitudinal axis for supplying an aeration gas to the bottom ends of the multiple

filtration elements, and further wherein the interior section is adapted to fit through the opening and (2) an opening to the exterior of the pressure vessel adapted to connect the removable aerator to a source of an aeration gas;

the filtration apparatus further comprising d) sealing means to seal the aerator to the protrusion, and an attachment means located at least partially on the protrusion to fix the aerator position within the pressure vessel.

15. The filtration apparatus of claim 14 wherein the multiple filtration elements are arranged in a plurality of parallel rows within the pressure vessel, and the inner section of each aerator extends in a direction parallel to said rows.