

CLAIMS

We claim:

1. A viral inactivation device comprising:
at least one continuous viral inactivation reactor including an inlet, an outlet, and a tubular flow path comprising a set of alternating turns that form a serpentine pattern between the inlet and the outlet.
2. The device of claim 1, wherein the at least one continuous viral inactivation reactor is an in-line tubular continuous viral inactivation reactor.
3. The device of claim 1, wherein the set of alternating turns comprises at least two alternating turns having an angle of from about 270° to about 280°.
4. The device of claim 1, wherein the set of alternating turns comprises from about 2 to about 325 or more alternating turns having an angle of from about 270° to about 280°.
5. The device of claim 1, wherein the tubular flow path includes a diameter of from about 0.6 cm to about 0.7 cm.
6. The device of claim 1, wherein the set of alternating turns are segmented vertically into at least two stacked layers.
7. The device of claim 6, wherein each of the at least two stacked layers comprises

12.5 alternating turns in a single plane, wherein each of the alternating turns includes an angle of from about 270° to about 280°.

8. The device of claim 6, wherein each of the at least two stacked layers include a thickness of from about 0.7 cm to about 1.2 cm.

9. The device of claim 6, wherein each of the at least two stacked layers is connected to one another via a 180° turn of the tubular flow path.

10. The device of claim 9, wherein the at least two stacked layers are 26 layers connected to one another via 25 180° turns of the tubular flow path.

11. The device of claim 1, wherein the at least one continuous viral inactivation reactor comprises from about 2 to about 6 viral inactivation reactors connected in series.

12. The device of claim 1, wherein the set of alternating turns is arranged to generate a vortex to induce mixing a product stream having a laminar flow with a Reynolds Number of from about 187.7 to about 375.5.

13. The device of claim 1, wherein the tubular flow path includes dimensions such that a product stream is in the continuous viral inactivation reactor for at least 30 minutes.

14. A viral inactivation device comprising:

a low pH continuous viral inactivation reactor having an inlet in fluid communication with a first static mixer and an outlet in fluid communication with a second static mixer;

wherein the low pH continuous viral inactivation reactor includes a tube formed of a set of alternating turns.

15. The device of claim 14, wherein the tube includes dimensions such that a product stream is in the low pH continuous viral inactivation reactor for at least 30 minutes.

16. The device of claim 14, wherein each turn in the set of alternating turns comprises an angle of from about 270° to about 280°.

17. The device of claim 14, wherein the set of alternating turns includes a radius of curvature of from about 0.85 cm to about 2 cm.

18. The device of claim 14, wherein the tube includes 325 alternating turns.

19. The device of claim 14, wherein the tube is segmented into 26 vertical layers connected to one another by 25 tubular flow paths, each having a 180° turn.

20. The device of claim 14, wherein the tube comprises at least 12.5 alternating turns in a single plane.

21. The device of claim 14, wherein the low pH continuous viral inactivation reactor

comprises from about 2 to about 6 viral inactivation reactor connected in series.

22. A process for a continuous low pH viral inactivation of a product stream comprising:

introducing the product stream to a first static mixer to lower its pH to a predetermined viral inactivation pH;

introducing the product stream to be inactivated exiting the first static mixer into an inlet of a tube having a set of turns in a single plane;

flowing the product stream through the tube under virus-inactivating conditions; and

exiting the product stream from the tube through an outlet of the tube;

wherein to lower the pH of the product stream, a low pH buffer is introduced to a first static mixer.

23. The process of claim 22, wherein the turns in a single plane form a serpentine pattern.

24. The process of claim 22, wherein the product stream is introduced to a first static mixer from a protein A capture.