

TITLE: Continuously Variable Aeration

## TECHNICAL FIELD

The present invention relates to membrane filtration systems and more particularly, to the use of aeration to control fouling of the membranes in such systems.

## BACKGROUND OF THE INVENTION

In submerged or immersed membrane filtration systems aeration using gas, typically air, is often employed on a continuous basis to control fouling. This is particularly the case for wastewater bioreactors. Other prior art systems utilise cycles of high gas flows followed by a lower gas flow or no gas flow. Mixtures of liquid/gas have also been used to scour the membranes and provide a reduction in gas consumption.

There are several problems with the cycling approach:

1. The cycle frequencies are typically very high, as it is not good to have the gas off in the process for too long as fouling increases rapidly during this phase. High cycle frequencies increase wear on valves that are required to cycle between multiple cells or membrane tanks, so as to keep the overall gas flow more or less constant from the blower. There are also practical limits to how fast the valves can be cycled between on and off caused by limitations of valve design and the time it takes to accelerate the gas flow.
2. When the gas is off for one cell it provides an opportunity for sludge to flow back into the aerators which can cause clogging of the aerators over time.

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3. The longer the time between cycles the more likely it is for fouling to increase and the sludge to go anoxic.

#### DISCLOSURE OF THE INVENTION

According to one aspect, the present invention provides a method of  
5 controlling fouling in a membrane filtration system of the type where gas is used to clean or scour the membranes wherein the method includes supplying the gas to the system with a continuously variable flow rate.

For preference the system includes a number of modules and the supply of gas to each module has a continuously variable flow rate. Alternatively, the  
10 system may include a number of sets of modules and the supply of gas to each set of modules has a continuously variable flow rate. Optionally, the system may include a number of membrane tanks with each tank containing modules in sets. The supply of gas to each membrane tank and the sets of modules therein has a continuously variable flow rate.

15 Preferably the continuously variable gas flow rate, ranges from a high flow to a low flow (or to zero). For preference, the flow rate pattern of the gas flow follows any continuously variable curve that achieves this result such as a sinusoidal or triangular wave. The varying gas flow not only provides the normal cleaning effect but the unstable nature of the gas flow has been found to provide  
20 an additional cleaning effect resulting from the inherent surges in flow.

According to another aspect, the present invention provides a membrane filtration system including one or more membranes, a source of gas for providing a gas flow to form bubbles which scour the surfaces of the membrane, wherein said source of gas provides said gas flow at a continuously variable flow rate.

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In one form, the gas source is coupled to the filtration system via a flow control device and the flow control device varies the flow rate continuously. In another form, the gas supply itself is varied, for example by varying the drive speed in a gas blower. Various combinations of known valve arrangements may  
5 also be used to provide the continuously varying flow rate.

The invention may be applied to a variety of membrane filtration system and is particularly applicable to submerged or immersed membranes and may be used in pressurised and non-pressurised systems.

According to another aspect, the present invention provides a flow control  
10 device for use in the control of the flow of aerating gas in a membrane filtration system, said flow control device including a housing having an inlet port and one or more outlet ports, a movable valve member for providing a continuously variable flow from said inlet port to said one or more outlet ports.

The housing may also be provided with a plurality of inlet ports.

15 Where a number of membrane modules or cells are used within the membrane filtration system, a flow control device may be used having separate outlets connected to associated modules such that as the flow rate is being increased to one module or modules it is being reduced to another module or modules.

20 Preferably, the flow control device is a rotating or reciprocating valve.

The flow control device may also provide a variable distribution of gas to one location. Distribution of the gas to each outlet port can be of continuously varying flow or an on/off flow. A feature of the flow control device is that it operates in a continuously rotating manner, not an open/close static manner. In

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the present application, the flow control device is used to provide a continuously variable flow rate of gas to one or more locations.

In a preferred form, the rotating valve is made up of three main components, the valve housing, the rotating distributor and the drive motor. The valve housing is mounted to the motor and contains the inlet and outlet ports of  
5 the valve. The distributor is located within the valve housing and is driven by the motor. As the distributor rotates within the valve housing, it closes and opens the housing outlets and thereby directs gas out one outlet or out another.

The number of outlet ports within the housing can vary, thus providing  
10 control of the airflow to any desired number of locations.

The shape of the distributor can be varied to suit the number of outlet ports and to control the rate of airflow distributed through each outlet port.

Hence the valve may be used to control gas flow to a number of membrane modules or cells and optimise the total volume of gas used.

15 The valve is able to complete the function that would normally be achieved by a combination of standard valves.

The valve has negligible operating friction and therefore has a long operating life expectancy.

The valve operates in a continuous rotating manner and can therefore  
20 cycle at a wide range of frequencies; typically 60 to 0.05Hz.

#### BRIEF DESCRIPTION OF DRAWINGS

Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows a schematic drawing of one embodiment of a filtration  
25 system according to the invention;

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Figure 2 shows a graph of air flow-rate over time for continuous variation versus cyclic variation of airflow;

Figure 3 shows a perspective cutaway view of the rotating valve which may be employed in the invention;

5        Figure 4 shows a graph of air flow rate over time for the rotating valve of the time illustrated in Figure 3 against the ideal continuous flow pattern;

Figure 5 shows a schematic sectional elevation view of a further type of valve which may be used to produce continuous variation in air flow rate;

10       Figure 6 shows a graph of air flow rate over time for a valve of the type illustrated in Figure 5; and

Figure 7 shows a graph of transmembrane pressure (TMP) over time for a filtration module first having scouring by continuous variation in air flow rate and secondly having a cyclic flow rate.

#### DESCRIPTION OF PREFERRED EMBODIMENTS

15       Referring to Figure 1, a pair of typical membrane filtration modules 5 is shown. Each module 5 includes a plurality of hollow fibre membranes 6 extending between upper and lower headers 7 and 8. Filtrate is withdrawn from the upper header 7 through the open ends 9 of fibre membranes 6 which open into collection chamber 10 connected to outlet 11. The lower header 8 has a  
20       plurality of openings 12 connected to a chamber 13 which in turn is connected to an inlet pipe 14. Each pipe 14 is connected to a respective outlet port 15 and 16 of a rotating valve 17. The valve 17 has an inlet port 18 connected to a source of pressurised gas, typically an air blower or pump (not shown).

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The ideal gas flow pattern for continuous variation of the gas flow rate of gas used in scouring the membranes against a cyclic gas flow pattern is shown in Figure 2.

Figure 3 shows the rotating valve 17 in more detail. The valve 17  
5 comprises a valve housing 19 with a rotating distributor 20 rotatably mounted therein and driven by a motor 21. The housing 19, in this embodiment has a centrally located inlet port 18 and two outlet ports 15 and 16, though it will be appreciated that the number of ports can be varied to suit different applications.

In operation, gas is supplied to inlet port 18 of the rotating valve 17.  
10 The distributor 20 continuously rotates within the housing 19 slowly opening one outlet port to the inlet pipe 14 of one module 5, increasing to full flow, then slowly restricting the flow and eventually closing it at the same time as the flow path reaches fully open on the next module 5. It will be appreciated that any number of modules can be used and the appropriate number of outlet ports can  
15 be provided in the valve housing 19. The cycling period of the gas flow can be readily adjusted by altering the speed of rotation of the distributor 20.

The gas supplied to the inlet pipe 14 is fed through openings 12 to scour the membranes in the normal manner.

Figure 4 shows a graph of the gas flow rate produced by the rotating valve  
20 of Figure 3. The small plateaus in the pattern were produced by minor leakage of the cylinder and the pattern will approximate the ideal flow rate if this leakage is minimised.

Figure 5 shows an alternate embodiment of a continuous flow rate valve.  
In this embodiment a piston 25 is slidably mounted in a tubular valve body 26  
25 having outlet ports 27 and 28 at either end and an inlet port or opening 29 in the

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wall of the valve body 26. Typically the valve body 26 would be cylindrical in shape though other cross-sectional shapes could be used.

In use, the piston 25 reciprocates within the valve body 26 so as alternately fully open the input port 29 to output ports 27 and 28, respectively. The range of piston movement is arranged such that when port 29 is fully open to port 27 it is fully closed to port 28 and vice versa. As the piston 25 moves between its limits the gas flow to one outlet port is gradually increased while the gas flow to the other outlet port is correspondingly reduced.

Figure 6 illustrates the pattern of continuously variable gas flow rate produced by the valve arrangement of Figure 5.

Figure 7 shows the effect of continuous variable gas flow rate on the scouring process. The first part of the graph shows change in transmembrane pressure (TMP) with a continuously varying gas flow rate (pulsatile flow) to the membranes while the second portion of the graph illustrates change in TMP with a cyclic gas flow rate. As more efficient scouring produces a more stable TMP over time, it is clear from this graph that the continuously variable gas flow rate produces a more efficient scouring effect and a more stable TMP over time than the cyclic flow rate scouring.

The advantages which may be typically provided by the method and system according the embodiments of the invention are:

1. The gas flow is only at the low or zero point for a very short period of time. This minimises the opportunity for backflow of sludge within the filtration system.
2. The essentially continuous flow of gas also means that the period of the cleaning/scouring cycles may be extended over the conventional "alternating" approach. This is achievable because the gas flow is not in the low or no flow

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condition for very long so there is less likelihood of sludge settling and for anoxic conditions to develop.

3. The process may be employed by using a variable speed drive on a blower and programming the flow cycle profile, in which case there would be no valve  
5 issues, as they are not required to cycle. Or alternatively, if conventional valves are used to control the cycles, then the longer period that the process enables means less wear of the valves.

4. The process may also be employed by using a rotary valve described in the preferred embodiment. In this embodiment the blower runs at essentially  
10 constant speed, and the valve rotates continuously. There is no sudden open close action on the valve and only the one valve is required.

5. Using the rotary valve above also enables much shorter cycle periods to be obtainable by increasing the speed of the valve rotation.

6. There is a potential saving in gas requirements of up to 50%.

15 It will be appreciated that further embodiments and exemplifications of the invention are possible without departing from the spirit or scope of the invention described.

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## CLAIMS:

1. A method of controlling fouling in a membrane filtration system of the type where gas is used to clean or scour the membranes wherein the method includes supplying the gas to the system with a continuously variable flow rate.
- 5 2. A method according to claim 1 wherein the system includes a number of modules and the supply of gas to each module has a continuously variable flow rate.
3. A method according to claim 1 wherein the continuously variable gas flow rate ranges from a high flow to a low flow.
- 10 4. A method according to claim 3 wherein the low flow is zero.
5. A method according to claim 1 wherein the flow rate pattern of the gas flow follows a continuously variable curve in the form of a sinusoid.
6. A method according to claim 1 wherein the flow rate pattern of the gas flow follows a continuously variable curve in the form a triangular wave.
- 15 7. A membrane filtration system including one or more membranes, a source of gas for providing a gas flow to form bubbles which scour the surfaces of the membrane, wherein said source of gas provides said gas flow at a continuously variable flow rate.
8. A membrane filtration system according to claim 7 wherein the rate of flow  
20 of gas from said gas source is continuously variable.
9. A membrane filtration system according to claim 8 wherein said gas source is a variable speed blower.

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10. A membrane filtration system according to claim 7 wherein said gas source is coupled to the filtration system via a flow control device and the flow control device varies the flow rate continuously.

11. A membrane filtration system according to claim 10 wherein said  
5 membrane filtration system includes a plurality of membrane modules and said flow control device has separate outlet ports connected to associated modules such that as the flow rate is being increased to one module or modules it is being reduced to another module or modules.

12. A membrane filtration system according to claim 10 wherein said  
10 membrane filtration system includes a number of sets of modules and the gas flow to each set of modules has a continuously variable flow rate.

13. A membrane filtration system according to claim 12 wherein the membrane filtration system includes a number of feed containing vessels with each feed containing vessel having a respective set of modules located therein.

14. A membrane filtration system according to claim 10 wherein said flow  
15 control device includes a housing having an inlet port and one or more outlet ports, and a movable valve member for providing a continuously variable flow from said inlet port to said one or more outlet ports.

15. A membrane filtration system according to claim 14 wherein said movable  
20 valve member is a rotating distributor positioned within said housing to control flow from said inlet port to said one or more outlet ports.

16. A membrane filtration system according to claim 15 wherein said outlets ports are located relative to the rotating distributor such that one of said outlet ports is fully open when another is fully closed.

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17. A membrane filtration system according to claim 14 wherein said movable valve member is a reciprocating distributor positioned within said housing to control flow from said inlet port to said one or more outlet ports.

18. A membrane filtration system according to claim 17 wherein said outlets  
5 ports are located relative to the reciprocating distributor such that one of said outlet ports is fully open when another of said outlet ports is fully closed.

19. A membrane filtration system according to claim 17 or claim 18 wherein said reciprocating distributor includes a piston slidably mounted in said housing, said housing being tubular and said outlet ports being located at either end  
10 thereof and said inlet port being located in a wall of said housing intermediate of the ends thereof.

20. A membrane filtration system according to claim 19 wherein said piston is arranged such that, as the piston moves between its limits, flow from the inlet port to one of said outlet ports is increased and the flow to another of said outlet  
15 ports is reduced.

21. A membrane filtration system according claim 14 wherein the movable valve member is continuously driven by a motor.

22. A membrane filtration system according claim 14 wherein said housing has a plurality of inlet ports.

20 23. A flow control device for use in the control of the flow of aerating gas in a membrane filtration system, said flow control device including a housing having an inlet port and one or more outlet ports, a movable valve member for providing a continuously variable flow from said inlet port to said one or more outlet ports.

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24. A flow control device according to claim 23 wherein said movable valve member is a rotating distributor positioned within said housing to control flow from said inlet port to said one or more outlet ports.

25. A flow control device according to claim 24 wherein said outlets ports are  
5 located relative to the rotating distributor such that one of said outlet ports is fully open when another is fully closed.

26. A flow control device according to claim 23 wherein said movable valve member is a reciprocating distributor positioned within said housing to control flow from said inlet port to said one or more outlet ports.

10 27. A flow control device according to claim 26 wherein said outlets ports are located relative to the reciprocating distributor such that one of said outlet ports is fully open when another of said outlet ports is fully closed.

28. A flow control device according to claim 26 or 27 wherein said reciprocating distributor includes a piston slidably mounted in said housing, said  
15 housing being tubular and said outlet ports being located at either end thereof and said inlet port being located in a wall of said housing intermediate of the ends thereof.

29. A flow control device according to claim 28 wherein said piston is arranged such that, as the piston moves between its limits, flow from the inlet port to one  
20 of said outlet ports is increased and the flow to another of said outlet ports is reduced.

30. A flow control device according to claim 23 wherein the movable valve member is continuously driven by a motor.

31. A flow control device according to claim 23 wherein said housing has a  
25 plurality of inlet ports.