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# FLOW CONTROL AND FILTRATATION METHOD AND APPARATUS

This application claims benefit and incorporates by reference the entire disclosure of U.S. Provisional Application No. 60/153,647, filed September 13, 2000.

## FIELD OF THE INVENTION

The present invention relates to flow control and filtration methods and apparatuses applicable to medical devices, drug delivery devices, food dispensing devices, aerosol generation devices and the like.

## BACKGROUND OF THE INVENTION

Fluid dispensing devices are used for a variety of applications, including, for example, the delivery of medicaments, the dispensing of food stuffs, the

dispensing of cleansers or hair sprays and the like. Such devices may typically include an aerosol generation surface and a channel for conveying fluid, with the channel having an inlet in fluid communication with a reservoir and an outlet positioned above the aerosol generation surface. The fluid to be delivered is contained in the reservoir.

Conventional fluid dispensing apparatuses, however, lack cost effective and adequate methods and devices for controlling the flow of fluid. Moreover, conventional fluid dispensing devices, especially drug delivery devices, suffer from lack of effective mechanisms for controlling evaporation and contamination of the fluid reservoir. Mechanical devices are not considered a viable option due to their high cost and unreliability (high rate of failure).

Thus, there exists a need to develop a cost effective and reliable shut-off valve for controlling fluid flow and preventing evaporation and contamination of the fluid reservoir.

SUMMARY AND DESCRIPTION OF THE INVENTION

The present invention presents new and unique methods and apparatuses for closing off and controlling the fluid flow in a fluid dispensing system used in medical devices, drug delivery systems, food dispensing, aerosol generation and the like.

A porous material is used in the present invention for

both a flow control regulator and/or a pressure dependent shut-off valve for fluid dispensing. The porous material may also be used to prevent seepage of fluid from a pressurized fluid source, minimizes evaporation of fluid contained therein, and/or to prevent contamination.

The present invention presents a closure and/or a flow control valve for fluid dispensing systems and the like. The fluid metering and dispensing system according to the present invention delivers a fluid from a source reservoir to a dispensing location by application of a pressure drop.

To protect the source reservoir and minimize evaporation, a shut-off valve in the fluid conveyance path is established. Mechanical shut off valves such as check valves, poppet valves, flapper valves, duckbill valves and others are too costly and too unreliable.

Thus, the present invention provides novel methods and apparatuses wherein a porous media inserted in the fluid conveyance path of fluid dispensing systems acts as a shut-off valve, fluid flow control mechanism, and contamination preventative device.

The porous media requires a predetermined activation pressure drop or threshold pressure to establish a flow of fluid. At any pressure below the activation pressure, fluid will not flow. Thus, the pressure drop

of the porous media acts as a shut-off valve when the pressure drops below a certain level. Such a pressure drop occurs in an inhalable drug delivery device upon the inspiratory effort of a user.

The size of pores, overall pore volume, and to a certain extent the hydrophillic/hydrophobic balance of the porous material, determines the amount of pressure necessary to initiate flow (i.e., the threshold pressure). These variables also determine the rate of flow in the material. For example, some porous media promote free-flow after the threshold pressure has been reached. The flow promoted in other porous media, once the threshold pressure has been met, increases as the pressure increases, reaching a maximum predetermined value.

Pore size also limits the size of the particles entering and leaving the porous media. Thus, the size of the particles leaving the fluid dispensing apparatus are limited to a particular size, as well as substantially eliminating fluid loss due to vapor pressure (evaporation of the fluid) in the fluid reservoir. Accordingly, the porous valve may be considered a filtration device as well, filtering the fluid to dispense only fluid particles of a certain size.

The particle size limitation also results in substantially eliminating contamination of the fluid in the fluid reservoir. Biological contamination is

effectively prevented from traversing the porous material since the biological contaminants will not fit through the pores of the porous valve. The pore size can be manufactured to a particular pore size to prevent a particular type of biological cell from contaminating the fluid reservoir.

For example, pores can be sized to prevent the following biological bodies from entering the fluid path or reservoir:

- viruses: from 0.05 to 0.1 microns;
- bacteria: from 0.5 to 1.5 microns;
- red blood cells: 5 microns; and
- lymphocytes: from 5 to 8 microns.

Additionally, sizing of the particles leaving the fluid reservoir is important in many fluid dispensing systems. For example, in drug delivery systems, especially inhaler devices, the medication dose for dispensing into a patient is more readily absorbable at a particular particle size.

The hydrophillic/hydrophobic balance of the porous material and porosity can be adjusted to minimize evaporation of fluid from the source reservoir through the porous media valve. Porous valves according to the present invention have reduced evaporative losses by 60% over mechanical valves.

Thus, by changing the parameters such as the thickness of the porous material, the size of the pores, the pore

volume, and the hydrophillic/hydrophobic balance of the material, an infinite number of activation/closure pressures and/or flow rates can be achieved.

Accordingly, in one aspect of the present invention, a pressure valve for an outlet of a fluid reservoir of a fluid dispensing device includes a porous media.

In another aspect of the present invention, a pressure valve for a fluid dispensing device includes a fluid conveyance channel having an internal diameter, an outlet and an inlet in fluid communication with a fluid reservoir. The valve also includes a porous media positioned adjacent to the outlet.

In yet another aspect of the present invention, a dispensing tube for a fluid dispensing device includes a fluid conveyance channel having an internal diameter where the channel includes an outlet positioned above an aerosol generation surface and an inlet in fluid communication with a fluid reservoir. The dispensing tube also includes a pressure valve adjacent to the outlet where the valve includes a porous media.

In yet another aspect of the present invention, a pressure regulator for an outlet of a fluid reservoir of a fluid dispensing device includes a porous media.

In yet another aspect of the present invention, a regulator for a fluid dispensing device includes a fluid conveyance channel having an internal diameter

with an outlet positioned above an aerosol generation surface and an inlet in fluid communication with a fluid reservoir. The regulator also includes a porous media positioned adjacent the outlet.

In yet another aspect of the present invention, a porous media for a fluid dispensing device includes a porous plastic having a pore size between approximately about 0.02 microns to 0.80 microns.

In yet another aspect of the present invention, a pressure valve system for a fluid dispensing device includes means for conveying a fluid from a fluid reservoir to an aerosol generation surface and porous means in fluid communication with the conveying means. The porous means allows fluid to flow onto the aerosol generation surface upon the application of a pressure drop.

In yet another aspect of the present invention, a method of dispensing a fluid in a fluid dispensing device is presented wherein the fluid dispensing device includes a fluid reservoir having an outlet positioned adjacent an aerosol generation surface, an airflow flowing over the surface, and a valve comprising a porous media positioned adjacent the outlet. The porous media includes a predetermined activation pressure. The method includes the steps of applying the predetermined activation pressure across the porous media, dispensing the medicament onto the aerosol generation surface and entraining aerosolized

particles generated by the surface into the airflow.

In yet another aspect of the present invention, a system for dispensing a fluid in a fluid dispensing device is presented. The fluid dispensing device includes a fluid reservoir having an outlet positioned adjacent an aerosol generation surface, an airflow flowing over the surface, and a valve comprising a porous media positioned adjacent the outlet. The porous media includes a predetermined activation pressure. The system comprises means for applying the predetermined activation pressure across the porous media, means for dispensing said medicament onto the aerosol generation surface, and means for entraining aerosolized particles generated by the surface into the airflow.

In yet another aspect of the present invention, a method of dispensing a medicament in a drug delivery device is presented. The drug delivery device includes a medicament reservoir having an outlet positioned adjacent an aerosol generation surface, an airflow flowing over the surface, and a valve comprising a porous media positioned adjacent the outlet. The porous media includes a predetermined activation pressure. The method includes the steps of applying the predetermined activation pressure across the porous media, dispensing the medicament onto the aerosol generation surface, and entraining aerosolized particles generated by the surface into the airflow.

The above aspects of the present invention will become more clear with reference to the following figures and written description.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A-1F illustrate views of an assembled three-section fluid dispensing system.

Figs. 2A-2F illustrate views the end section of the fluid dispensing system shown in Figs. 1A-1F.

Figs. 3A-3G illustrate views of the center section of the fluid dispensing system illustrated in Figs. 1A-1F.

Figs. 4A-4F illustrate views of the rear section of the fluid dispensing system illustrated in Figs. 1A-1F.

Fig. 5 is a side-sectional view of a dispensing tube having a porous material valve according to the present invention.

Fig. 6 illustrates a view of the porous valve according to the present invention.

Fig. 7 shows a chart illustrating efficiency of a fluid dispensing system using a porous valve according to the present invention.

Fig. 8 shows a chart illustrating the performance of a porous valve according to the present invention.

Fig. 9 shows a chart illustrating the performance summary of a drug delivery device using the porous valve according to the present invention.

Fig. 10 shows a chart illustrating water flowrate versus tube dimension.

Fig. 11 shows a chart illustrating the tube pressure drop for the inner tube diameters listed in Fig. 10.

Fig. 12 illustrates the pressure calculation for an inhaler device.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figs. 1A-1F illustrate various views of an assembled three-section fluid dispensing system 2 having a porous valve according to the present invention. The system includes rear section 4, center section 6, and spout section 8, containing spout 10 and spout tip 12.

Figs. 2A-2F illustrate various views the end section of the fluid dispensing system shown in Figs. 1A-1F containing a spout which includes the porous material valve according to the present invention.

Figs. 3A-3G illustrate various views of the center section of the fluid dispensing system illustrated in Figs. 1A-1F.

Figs. 4A-4F illustrate various views of the rear section of the fluid dispensing system illustrated in

Figs. 1A-1F.

Fig. 5 is a side-sectional view of a dispensing tube 14 for a fluid dispensing system having a porous material valve 18 at the end 16 of the dispensing tube 14 which is in fluid communication with a fluid reservoir.

Fig. 6 illustrates various views of the porous valve according to the present invention.

Fig. 7 shows a chart illustrating the efficiency of a fluid dispensing system using a porous valve according to the present invention versus particle size. The x-axis represents the size of particles allowed to pass through the porous filter and the y-axis represents the device efficiency in percentage. The graph illustrates that as the particle size increases, so does the efficiency of the device. In regard to the present invention, efficiency increases with the porous valve according to the present invention over simply using a long tube average. Average efficiency increase is over 7%.

Fig. 8 shows a chart illustrating the performance of a porous valve according to the present invention when used with an open mouthpiece, inhaler-type drug delivery device versus using the same device with no valve at all. The graph illustrates respirable fraction in percentage, respirable dose in ug and device efficiency in percentage. When the porous valve is use, each category shows improvement.

Fig. 9 shows a chart illustrating the performance summary of a drug delivery device using the porous valve according to the present invention. The chart lists a particular specification, the target value, the original value which was obtained by using a long metal tube with a fluid dispensing system, the measured value when using the porous filter according to the present invention, and a benchmark which was obtained from a best in class - nearest commercial product.

It is clear from the chart of Fig. 9, that placement of the porous valve in the fluid conveyance path yields the following:

- increased efficiency of a fluid dispensing system;
- delivers the fluid more consistent and uniform to aerosolizer mechanism of an inhaler device (piezoelectric horn);
- lowers evaporative losses by approximately 60%;
- enhances metering accuracy by approximately 4%; and
- is relatively low in cost.

Fig. 10 shows a chart illustrating water flowrate versus the dimension of the tube dispensing the fluid from the fluid reservoir. The chart includes columns for tube inner diameter (in inches and cm), tube flowrate (in $cm^3/s$ and $\mu L/s$), droplet diameter (in cm), the mass of the droplet (in grams), and finally, the force (in grams) required to pass the droplet through

the porous material.

Fig. 11 shows a chart illustrating the tube pressure drop for the inner tube diameters listed in Fig. 10. For a given inner tube diameter, the pressure drop, or pressure required to drive the fluid through the porous material is listed (in millibar and psi).

Fig. 12 illustrates the maximum pressure calculation for flow through the porous media. As shown, the maximum force generated is 20N, and the maximum pressure generated at the tip of the cannula is 2,571 $lb._f/in^2$.

Examples of porous materials include polysulfone, polyether sulfone, cellulose acetate, nylon, polyvinylidene fluoride, polytetraflouoroethylene and polyolefin. Specific examples of porous material that may be used are Sartorious 0.2 or 0.45 micron cellulose acetate CA 12587, Millipore 0.20 micron GVPH 2935, Millipore 0.22 micron GSW P096 or Pall 0.22 micron nylon media.

Pore sizes may be between approximately about 0.05 to 1.0 microns, and more preferably between approximately about 0.15 to 0.90 microns, and most preferably between approximately about 0.20 - 0.80 microns.

A preferred porous valve configuration for a drug delivery device according to the present invention includes a fluid conveyance channel having an internal

diameter of 0.5 mm, a 0.5 mm gap, with 2.0 mm above a piezoelectric aerosolizer device (device for producing aerosolized particles from a fluid).

Medicament is dispensed in a drug delivery device according to the present invention by applying a pressure drop across the porous media of the medicament dispensing tube. Such a pressure drop may be applied as a result of the inspiratory effort of a user of the drug delivery device, which also causes an airflow within the device. Concurrently, or shortly thereafter the application of the pressure drop, medicament is dispensed onto an aerosol generation surface of the drug delivery device. The medicament is aerosolized and then entrained in the airflow which was created by the inspiratory effort.

The following example is illustrative of the present invention:

A commercial, porous filtration material was inserted into a small diameter cannula in a drug delivery device. The material included hydrodynamic pores having diameters of 0.45 microns (preferably no less than 0.2 microns), and a total thickness less than 0.010". This material included an appropriate surface area and pressure drop characteristics to enable the drug delivery apparatus to dispense 300 micro liters per second fluid flow at a 10 psi pressure drop. The porous material allows particles and fluid with mean diameters less than 200 nanometers to pass.

WHAT IS CLAIMED IS:

1. A pressure actuated valve for an outlet of a fluid reservoir of a fluid dispensing device comprising a porous media.

2. The valve according to claim 1, wherein said valve provides fluid to an aerosol generation surface.

3. The valve according to claim 1, wherein said porous media comprises a porous plastic.

4. The valve according to claim 3, wherein said porous plastic comprises a polysulfone or polyether sulfone material.

5. The valve according to claim 3, wherein said porous plastic comprises a cellulose acetate material.

6. The valve according to claim 3, wherein said porous plastic comprises a nylon material.

7. The valve according to claim 3, wherein said porous plastic comprises a polytetrafluoroethylene material.

8. The valve according to claim 3, wherein said porous plastic comprises a polyolefin material.

9. The valve according to claim 3, wherein said porous plastic comprises a nylon media.



10. The valve according to claim 3, wherein a pore size of said porous plastic is between approximately about 0.15 microns to 0.80 microns.

11. The valve according to claim 1, wherein a pressure drop applied to said outlet causes fluid to flow from said reservoir and through said porous media.

12. The valve according to claim 11, wherein said pressure drop is a predetermined value.

13. The valve according to claim 1, wherein said porous media acts as a filtration element.

14. The valve according to claim 11, wherein an amount of said pressure drop allowing fluid to flow is determined by a pore size of said porous media.

15. The valve according to claim 11, wherein an amount of said pressure drop allowing fluid to flow is determined by a pore volume of said porous media.

16. The valve according to claim 11, wherein an amount of said pressure drop allowing fluid to flow is determined by a hydrophillic/hydrophobic balance of said porous media.

17. The valve according to claim 1, wherein said porous media inhibits seepage of fluid from said reservoir.



18. The valve according to claim 1, wherein said porous media minimizes evaporation of fluid from said reservoir.

19. The valve according to claim 1, wherein said porous media prevents contamination of said fluid reservoir.

20. The valve according to claim 1, wherein said fluid is a medicament, and wherein said fluid dispensing device is an inhalable drug delivery device.

21. A pressure valve for a fluid dispensing device comprising:

a fluid conveyance channel having an internal diameter, said channel having an outlet positioned above an aerosol generation surface and an inlet in fluid communication with a fluid reservoir; and

a porous media positioned adjacent said outlet.

22. A dispensing tube for a fluid dispensing device comprising:

a fluid conveyance channel having an internal diameter, said channel having an outlet positioned above an aerosol generation surface and an inlet in fluid communication with a fluid reservoir; and

a pressure valve adjacent to said outlet comprising a porous media.

23. A pressure regulator for an outlet of a fluid reservoir of a fluid dispensing device comprising a porous media.

24. A regulator for a fluid dispensing device comprising:

a fluid conveyance channel having an internal diameter, said channel having an outlet positioned above an aerosol generation surface and an inlet in fluid communication with a fluid reservoir; and

a porous media positioned adjacent said outlet.

25. A porous media for a fluid dispensing device, said porous media comprising a porous plastic having a pore size between approximately about 0.15 microns to 0.80 microns.

26. A pressure valve system for a fluid dispensing device comprising:

means for conveying a fluid from a fluid reservoir to an aerosol generation surface; and

porous means in fluid communication with said means for conveying, wherein said porous means allows fluid to flow onto said aerosol generation surface upon the application of a pressure drop.

27. A method of dispensing a fluid in a fluid



dispensing device, said fluid dispensing device including a fluid reservoir having an outlet positioned adjacent an aerosol generation surface, an airflow flowing over said surface, and a valve comprising a porous media positioned adjacent said outlet, wherein said porous media includes a predetermined activation pressure, said method comprising the steps of:

applying said predetermined activation pressure across said porous media;

dispensing said medicament onto said aerosol generation surface; and

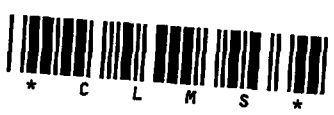
entraining aerosolized particles generated by said surface into said airflow.

28. A system for dispensing a fluid in a fluid dispensing device, said fluid dispensing device including a fluid reservoir having an outlet positioned adjacent an aerosol generation surface, an airflow flowing over said surface, and a valve comprising a porous media positioned adjacent said outlet, wherein said porous media includes a predetermined activation pressure, said system comprising:

means for applying said predetermined activation pressure across said porous media;

means for dispensing said medicament onto said aerosol generation surface; and

means for entraining aerosolized particles generated by said surface into said airflow.



29. A method of dispensing a medicament in a drug delivery device, said drug delivery device including a medicament reservoir having an outlet positioned adjacent an aerosol generation surface, an airflow flowing over said surface, and a valve comprising a porous media positioned adjacent said outlet, wherein said porous media includes a predetermined activation pressure, said method comprising the steps of:

applying said predetermined activation pressure across said porous media; and

dispensing said medicament onto said aerosol generation surface; and

entraining aerosolized particles generated by said surface into said airflow.

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