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Lucero et al.

[11] **3,904,849**

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[54] **TEMPERATURE CONTROLLED ELECTRIC FLUID HEATING APPARATUS**

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[52] **U.S. Cl.** **219/299;** 165/155; 219/301; 219/308; 219/331; 219/368; 261/142

[51] **Int. Cl.** **H05b 1/02;** F24h 3/04

[58] **Field of Search** 219/296–309, 219/368, 367, 373, 379–382, 331; 165/155; 261/141, 142

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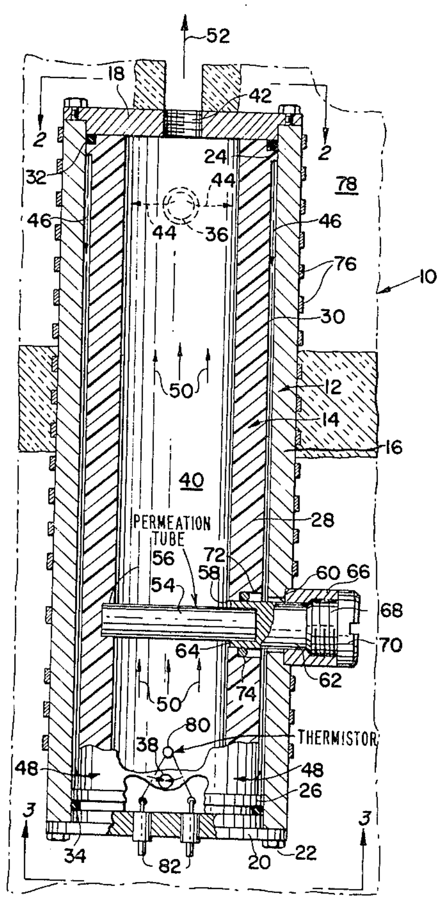
[57] **ABSTRACT**

An apparatus for providing precise control of the temperature of a fluid includes a cylindrical housing having its side wall spaced from the side wall of a hollow cylindrical core contained therein to provide a thin flow passage therebetween for the fluid. An electric heater coil is wound around the exterior of the housing to supply heat to the fluid in the passage. The fluid is admitted to the passage at one end thereof, flows the length of the passage to the other end thereof, passes through a port which communicates the other end of the passage with the interior of the core, flows the length of the core and exits through an outlet from the core adjacent to said one end of the passage. The heater power output is controlled in response to a temperature sensor positioned in the housing to sense the temperature of the fluid which has passed along the passage so that the temperature is precisely controlled. The exterior of the housing is thermally insulated from the ambient to maintain stable tmperature conditions.

8 Claims, 7 Drawing Figures



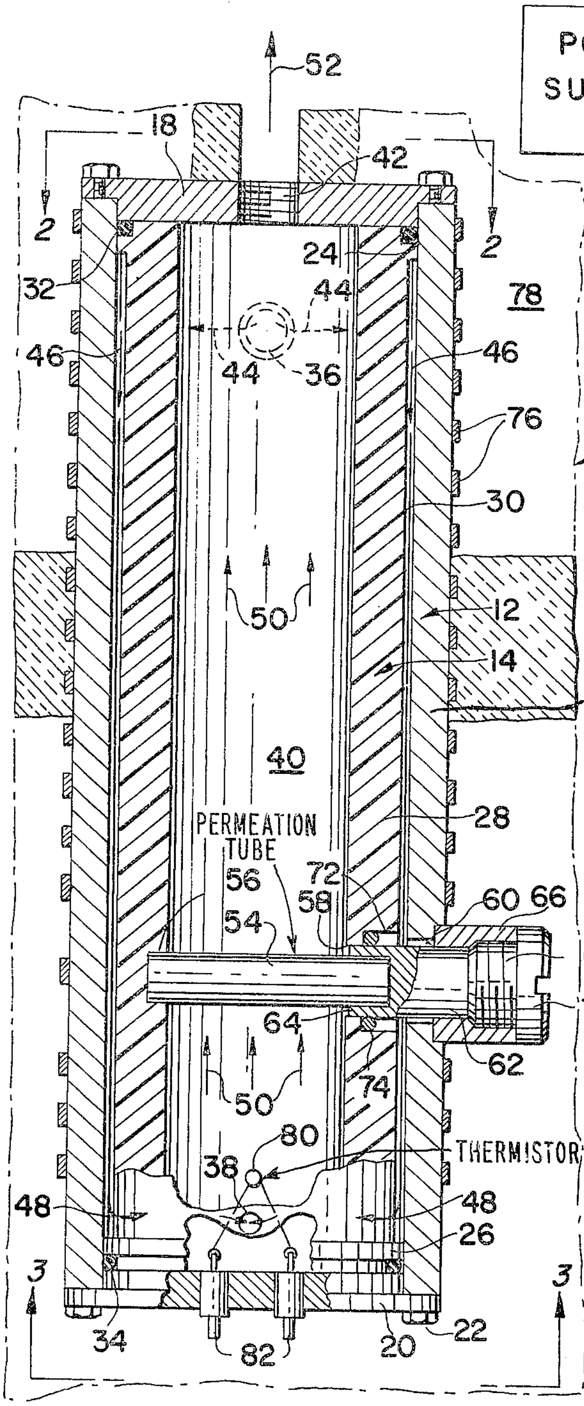


FIG. 1

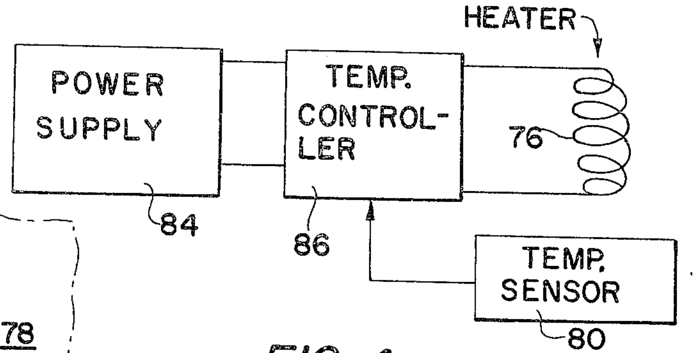


FIG. 4

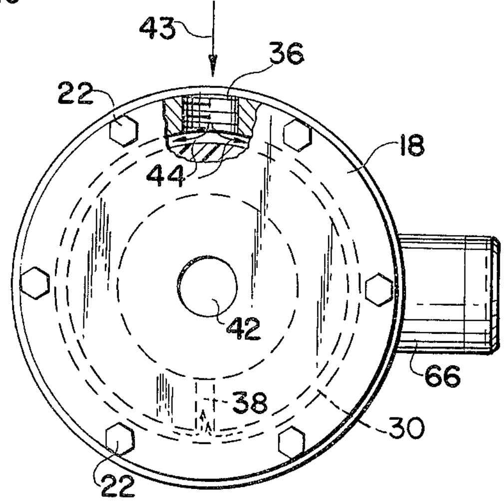


FIG. 2

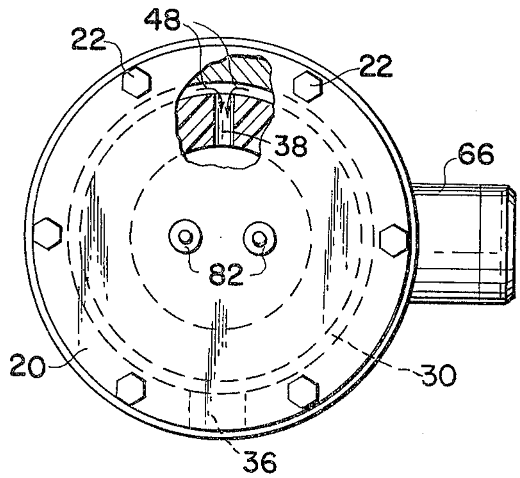


FIG. 3

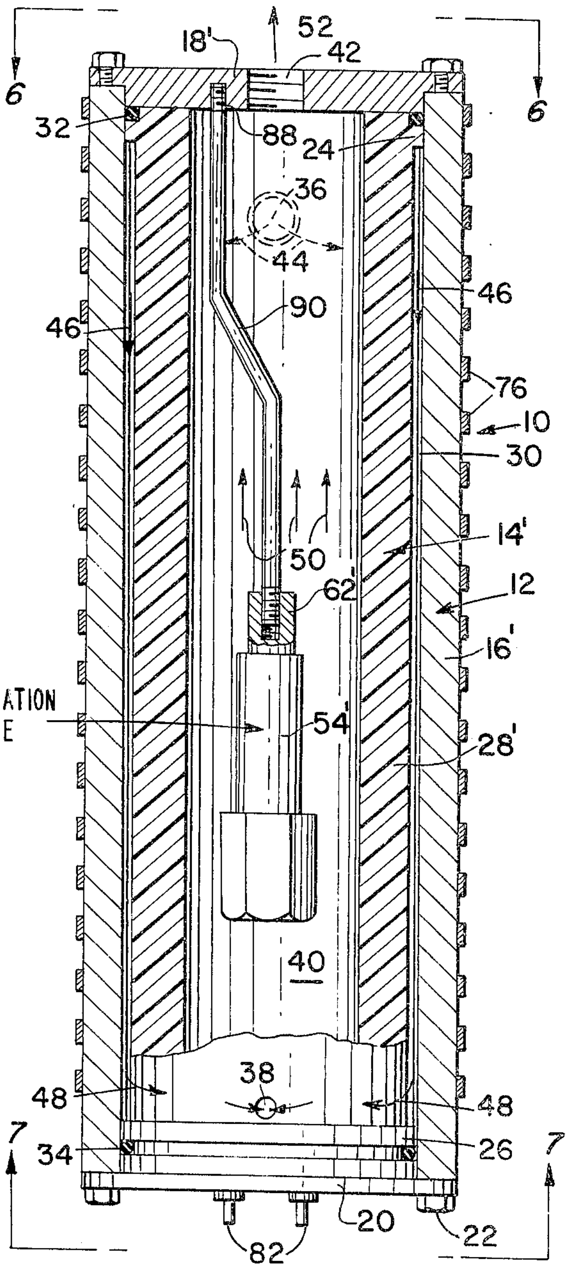


FIG. 5

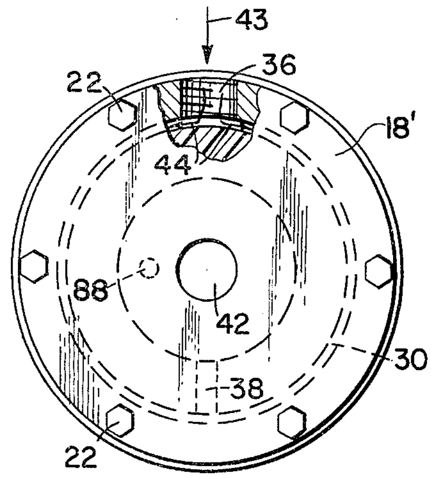


FIG. 6

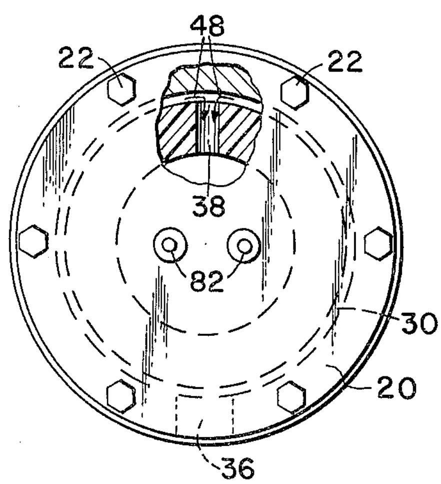


FIG. 7

TEMPERATURE CONTROLLED ELECTRIC FLUID HEATING APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to temperature-controlled apparatus and more particularly to temperature-controlled apparatus for precise control of the permeation of a fluid into a carrier fluid.

It has previously been proposed to provide controlled mixing of one fluid with another by the utilization of diverse types of dilution or proportioning techniques, such as permeation or diffusion. See, for example, U.S. Pat. Nos. 3,521,865; 3,533,272; 3,618,911; 3,209,579; 3,669,637; 2,843,138; 3,516,278; British Pat. No. 811,401; and *Review of Scientific Instruments*, March, 1955, Vol. 26, No. 3, pp. 305–306. For example, by one method used in calibrating a sulphur dioxide analyzer, a permeation tube containing liquified sulphur dioxide is placed in a heater chamber or conduit through which air, serving as a carrier or dilution gas, is passed. The sulphur dioxide sample diffuses through the permeation tube wall into the air stream at a known rate, dependent upon temperature. The sulphur dioxide concentration of the gas mixture is thus precisely controlled. It is used to calibrate the analyzer accordingly.

Prior attempts to provide precisely controlled mixing of fluids or dilution of one fluid by another through permeation or diffusion techniques have left much to be desired, however, because of the complexity and expense of the apparatus required, the difficulty in obtaining reproducible results, the limited range of dilution control, and/or the inability to accommodate variations in fluid temperature and flow rate. It has been known that the amount of permeation or diffusion of a fluid through a permeable wall is a function of temperature, but prior attempts to provide precise temperature control of the permeation process have left much to be desired, despite an extensive body of prior art in the heater, heat exchanger, and temperature controller field, including, for example, U.S. Pat. Nos. 2,706,620; 2,446,367; 1,480,922; 3,368,546; 1,906,450; 1,389,166; 2,730,083; 1,519,395; 1,772,557; and 1,624,843.

BRIEF SUMMARY OF THE INVENTION

It is accordingly a principal object of the present invention to provide improved temperature controlled apparatus, and particularly improved temperature controlled apparatus for controlling the permeation or diffusion of one fluid into another, which overcomes the deficiencies of the prior art.

A further object of the invention is to provide apparatus of the foregoing type which is simple, inexpensive, easy to manufacture, easy to use, and which is compact.

Another object of the invention is to provide apparatus of the foregoing type in which the temperature of a carrier gas and a permeation tube immersed therein are precisely controlled, and hence in which the rate of diffusion of a sample into the carrier gas is precisely controlled.

Yet another object of the invention is to provide apparatus of the foregoing type which readily accommodates variations of the inlet temperature of the carrier gas, which is relatively independent of ambient conditions, and which is less sensitive to the rate of flow of the carrier gas.

Briefly stated, in accordance with a preferred embodiment of the invention a temperature-regulated enclosure is provided, essentially an isothermal enclosure, in which a permeation tube or the like is located, the permeation tube containing a supply of a fluid which is to be diffused into a carrier fluid. The enclosure provides a thin large-surface-area passage through which the carrier fluid passes and by which the carrier fluid is heated to a precisely controlled temperature. More specifically, the enclosure is constituted by a cylindrical housing having a cylindrical core therein, with the side wall of the core spaced from the side wall of the housing to provide a cylindrical passage of thin annular cross-section. The carrier fluid, such as air, is admitted to one end of this passage, and at the other end of the passage a port through the hollow core is provided for admission of the carrier fluid to the hollow interior of the core, in which the permeation tube is located. The carrier fluid passes along the length of the hollow core interior and then through an exit port from the housing. The outer surface of the housing is provided with a heater winding, the power output of which is controlled in response to a temperature sensor in the core to provide heating power for precise temperature regulation of the carrier fluid as it passes into the hollow interior of the core. The entire housing is insulated from the ambient condition by external insulation. The permeation tube may extend transversely of the core or longitudinally of the core, and access to the tube may be provided at one side of the housing or at an end thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further described in conjunction with the accompanying drawings, which illustrate preferred and exemplary embodiments, and wherein:

FIG. 1 is a longitudinal sectional view, partially broken away, of a first embodiment of the invention;

FIG. 2 is an end view, partially broken away, as seen in the direction of arrows 2—2 of FIG. 1;

FIG. 3 is an end view, partially broken away, as seen in the direction of the arrows 3—3 of FIG. 1;

FIG. 4 is a block diagram of a circuit for regulating the temperature;

FIG. 5 is a longitudinal sectional view, partially broken away, of a modification of the invention;

FIG. 6 is an end view, partially broken away, as seen in the direction of arrows 6—6 of FIG. 5; and

FIG. 7 is an end view, partially broken away, as seen in the direction of arrows 7—7 of FIG. 5.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the drawings, and initially to FIG. 1 thereof, the present invention comprises a temperature-regulated enclosure **10** including a tubular housing **12** and a tubular core **14** contained within the housing. The housing is preferably a circular cylinder, which may be formed of aluminum, for example, having a side wall **16** and end closures **18** and **20**, which may be secured to the housing as by screws **22** (see FIGS. **2** and **3**). The core **14** is also preferably a circular cylinder with a hollow interior. The core may be formed completely of Teflon, for example. The inner surfaces of the housing, which as seen hereinafter are contacted by gas flowing in the enclosure, are preferably Teflon coated.

The length of the core is approximately the same as the interior length of the housing, and the core is provided with circumferential flanges **24** and **26** adjacent to the opposite ends thereof for spacing the outer surface of the side wall **28** of the core from the inner surface of the side wall **16** of the housing to provide a cylindrical passage **30** therebetween having thin annular cross-section. O-rings **32** and **34** surround the core beyond the flanges **24** and **26**, respectively, to provide a seal between the side wall of the core and the side wall of the housing at opposite ends of the passage **30**.

A port **36** extends through the side wall **16** of the housing adjacent to one end thereof (see FIGS. **1** and **2**) to provide access to the passage **30** for the admission of fluid to one end thereof. The port may be internally threaded as shown to permit the coupling of a tube (not shown) thereto. The side wall **28** of the core is provided with a port **38** therethrough adjacent to the end of the housing opposite the end at which port **36** is provided, in order to provide communication between one end of the passage **30** and the hollow interior **40** of the core. A port **42** is provided through the end wall **18** of the housing (adjacent to port **36**) by which fluid may leave the hollow interior **40.** Port **42** may be internally threaded as shown in order to permit connection with a tube (not shown).

Port **42** may be connected to a vacuum pump (not shown) for moving a carrier fluid, such as clean air, through the temperature-regulated enclosure (or port **36** may be connected to a source of positive pressure). The carrier fluid enters port **36** and one end of passage **30,** as indicated by arrow **43.** The fluid moves circumferentially around the core **14** and longitudinally along the passage **30,** as indicated by arrows **44** and **46.** At the opposite end of the passage the carrier fluid moves circumferentially about the core, as indicated by arrows **48,** and enters the port **38.** Then the fluid moves longitudinally through a further flow passage provided by the hollow interior **40** of the core, as indicated by arrows **50,** and leaves the enclosure by the port **42,** as indicated by arrow **52.**

Within the enclosure is a permeable wall, one side of which is exposed to the carrier fluid in the hollow interior **40** of the core, and the other side of which is exposed to a supply of a fluid to be diffused into the carrier fluid. In the form shown the wall is constituted by the side wall of a permeation tube **54** of a type well known in the art. The permeation tube may be a Teflon tube, for example, containing a supply of liquified sulphur dioxide which diffuses through the permeation tube wall into the stream of carrier gas in the hollow core. A recess **56** is provided internally of the side wall **28** of the core, and aligned openings **58** and **60** are provided in the side wall **28** of the core and the side wall **16** of the housing, through which the permeation tube **54** may be inserted into the core. A holder **62** has a cup **64** into which one end of the permeation tube is received, the other end being received in the recess **56.** A boss **66** extends outwardly from the side wall **16** of the housing and is internally threaded to mate with external threads **68** on the holder **62,** the outer end of which may be provided with a screw head **70.** The opening **58** in the side wall **28** of the core may be undercut at **72** to receive an O-ring **74** to prevent fluid communication between passage **30** and the hollow interior **40** of the core through opening **58.**

The rate at which the fluid in the permeation tube diffuses into the carrier gas is a function of the permeation tube temperature and indirectly a function of the temperature within the enclosure **10.** In order that the mixture of the fluids may be precisely controlled, it is necessary that the temperature of the carrier gas and permeation tube be regulated. For this purpose a heater coil **76,** such as insulated electrical heater tape, is wound helically about the exterior surface of the side wall **16** of the housing, and the entire housing is enclosed in thermal insulation **78,** which may be in the form of foam rings stacked upon the housing, for example. The temperature within the hollow core may be sensed by a thermistor **80** connected to terminals **82** on end wall **20** of the housing.

As shown in FIG. **4,** the heater **76** is energized from a power supply **84** through a temperature controller **86,** which is responsive to the temperature sensor **80.** The temperature controller may be a conventional solid state or other type of device which precisely regulates the electric power supplied to the heater **76** in response to the temperature sensor **80** and which may be adjusted to select a desired temperature. Such temperature controllers are well known in the art.

It will be noted that the carrier fluid moves along the passage **30** as a thin sheet of large surface area in intimate contact with the side wall **16** of the housing upon which the heater winding **76** or heat exchanger is mounted. A long large-surface-area flow path is provided for the carrier fluid in order to ensure that the carrier is heated and precisely controlled to a predetermined temperature. The enclosure **10** is isolated from ambient conditions by the insulation **78** to further ensure temperature control and conserve power. In accordance with the invention it is possible to ensure temperature regulation of the carrier fluid to within plus or minus 0.01°C, for example, over a large range of carrier fluid input temperatures and flow rates. Equilibrium conditions are quickly reached and temperature variations in the admitted carrier fluid are quickly compensated by the large thermal mass, the walls of the enclosure being very thick compared to the thickness of passage **30.** Compactness and efficiency are promoted by the reverse carrier gas flow through the enclosure, the permeable wall being beyond the cylindrical passage **30** of thin annular cross-section but within the confines of the passage. No preheater is required and the provision of the heater **76** only on the exterior of housing **12** (not on the core or the inside of the housing) greatly simplifies the construction.

A modification of the invention is illustrated in FIGS. **5–7.** This embodiment of the invention is essentially the same as that previously illustrated (the external insulation not being shown in the drawing) except that a permeation tube **54'** is supported longitudinally within the hollow interior of the core **14'** instead of transversely. The side wall **16'** of the housing and the side wall **28'** of the core are devoid of the holes and recess provided in FIG. **1** for insertion and support of the permeation tube. Instead, the end wall **18'** of the housing has a threaded recess **88** into which a bent rod **90** is threaded, the opposite end of the rod being threaded into a permeation tube holder **62'.**

In one practical configuration of the invention the housing **12** is 7.19 inches long with an outer diameter of 2.50 inches and an inner diameter of 2.00 inches. The core **14** is 6.87 inches long with an outer diameter (neglecting the flanges) of 1.98 inches and an inner diameter of 1.25 inches, the flanges having an outer diameter matched to the inner diameter of the housing.

While preferred embodiments of the invention have been shown and described, it will be apparent to those skilled in the art that changes can be made in these embodiments without departing from the principles and spirit of the invention, the scope of which is defined in the appended claims. For example, other types of permeable walls may be employed for the diffusion of fluids diffusable through such walls.

The invention claimed is:

1. Apparatus for providing precise control of the temperature of a fluid, which comprises a cylindrical housing, a hollow cylindrical core in said housing with a side wall thereof spaced from a side wall of the housing to provide a thin flow passage therebetween along the length of the core and the housing, means for closing said passage at one end thereof, means for admitting fluid to said passage adjacent to said one end thereof, closure means for the housing adjacent to the opposite end of the passage, means for providing communication between the opposite end of the passage and the interior of the core, means for providing a fluid outlet from the core adjacent to said one end of the passage, heater means secured to the outer surface of the side wall of the housing, means for insulating the housing from the ambient, means in said housing for sensing the temperature of fluid which has passed along said passage, and means responsive to said temperature sensing means for controlling said heater means.

2. Apparatus in accordance with claim **1**, wherein said housing has further closure means adjacent to said one end of said passage with a port through said further

closure means to provide said outlet.

3. Apparatus in accordance with claim **2**, wherein said closure means are removably connected to the side wall of said housing.

4. Apparatus in accordance with claim **1**, wherein said core has circumferential flanges at opposite ends thereof spacing the side wall of the core from the side wall of the housing.

5. Apparatus in accordance with claim **4**, further comprising means for providing fluid seals between the side wall of the housing and the side wall of the core at opposite ends thereof.

6. Apparatus in accordance with claim **1**, wherein said admitting means comprises a first port through the side wall of said housing at one side only of said core adjacent to said one end of said passage, wherein said means for providing communication between said passage and said hollow interior of said core comprises a second port through the side wall of said core adjacent to the opposite end of said passage and only at the side of said core opposite to the side at which fluid is admitted to said passage, whereby said fluid is constrained to flow around said core in order to pass from said first port to said second port.

7. Apparatus in accordance with claim **1**, wherein the adjacent surfaces of the side walls of said housing and said core are uniformly separated cylindrical surfaces throughout the length of said thin flow passage.

8. Apparatus in accordance with claim **1**, wherein the thickness of the side wall of said housing is many times the thickness of said flow passage and the housing side wall is formed of metal.

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