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3,264,720

POROUS METAL ARTICLES OF DIFFERENTIAL PERMEABILITY

Filed Sept. 11, 1964

3 Sheets-Sheet 1

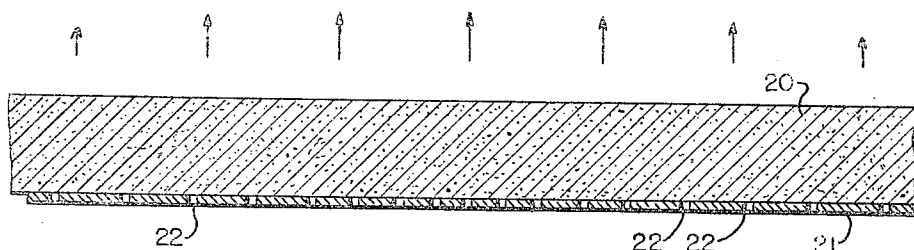


FIG. 1

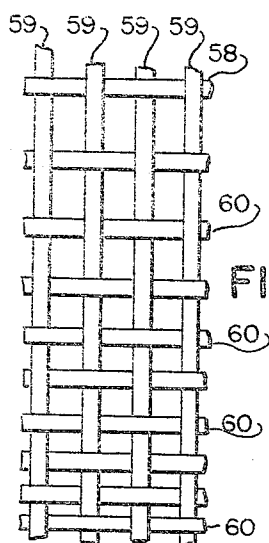


FIG. 7

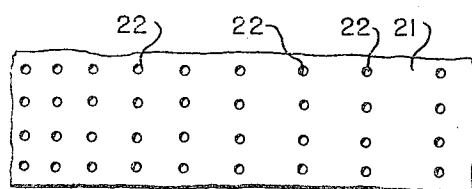


FIG. 2

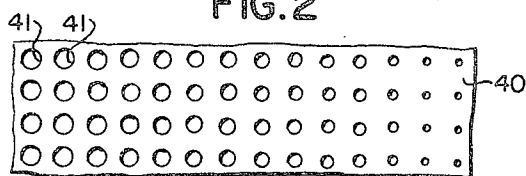


FIG. 3

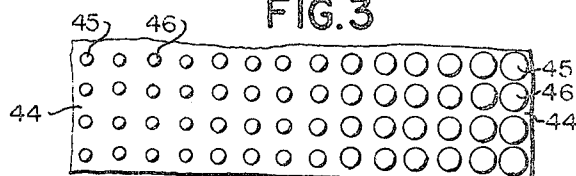


FIG. 4

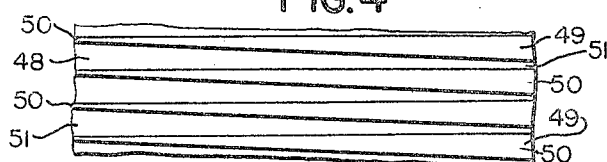


FIG. 5

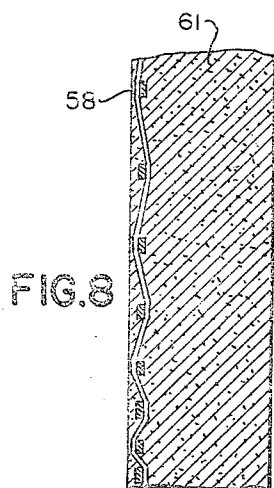


FIG. 8

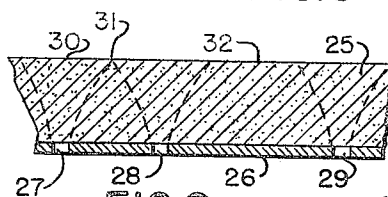


FIG. 9

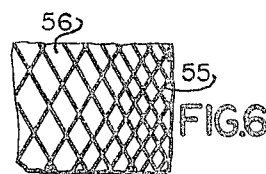


FIG. 6

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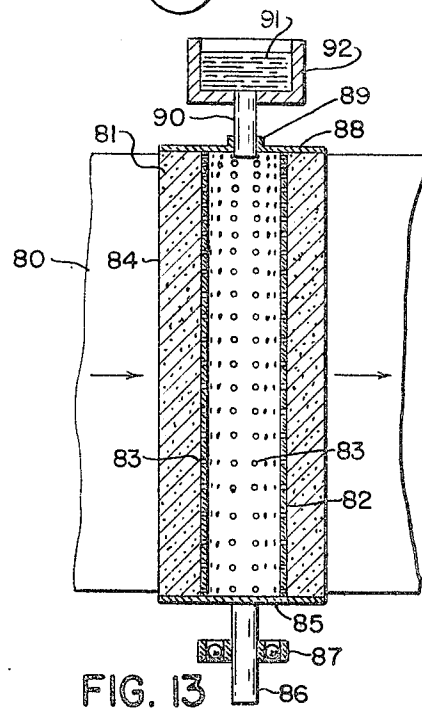
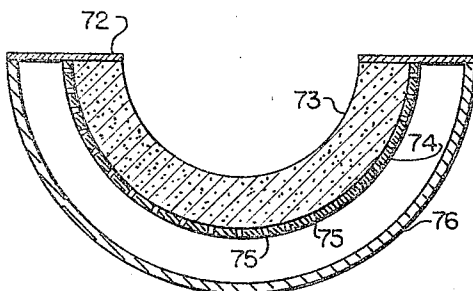
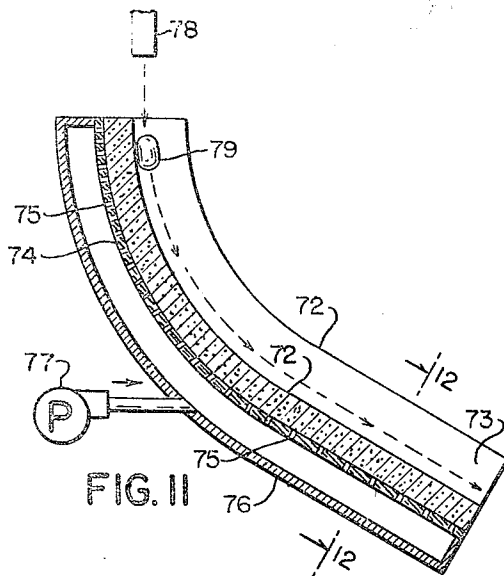
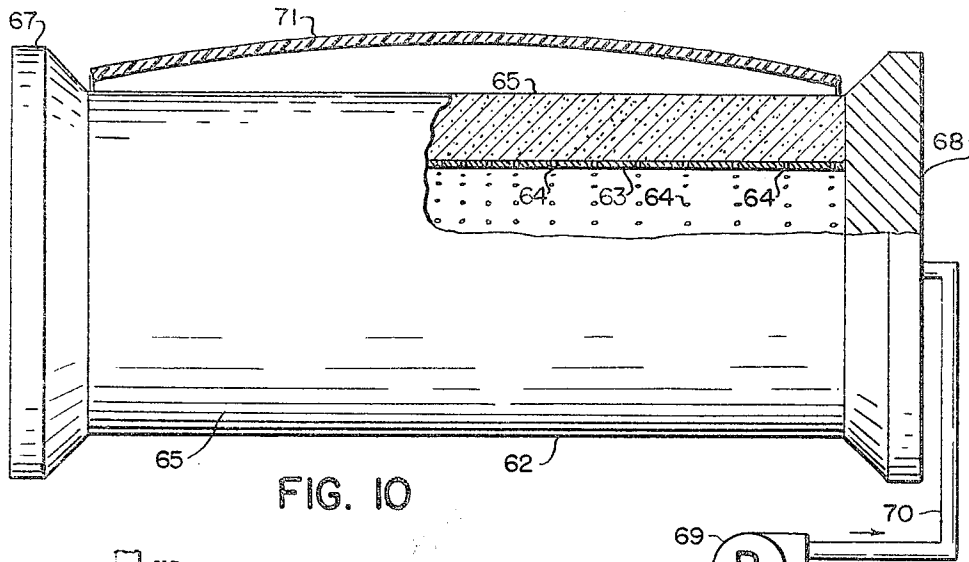
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POROUS METAL ARTICLES OF DIFFERENTIAL PERMEABILITY

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3 Sheets-Sheet 2



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POROUS METAL ARTICLES OF DIFFERENTIAL PERMEABILITY

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3 Sheets-Sheet 3

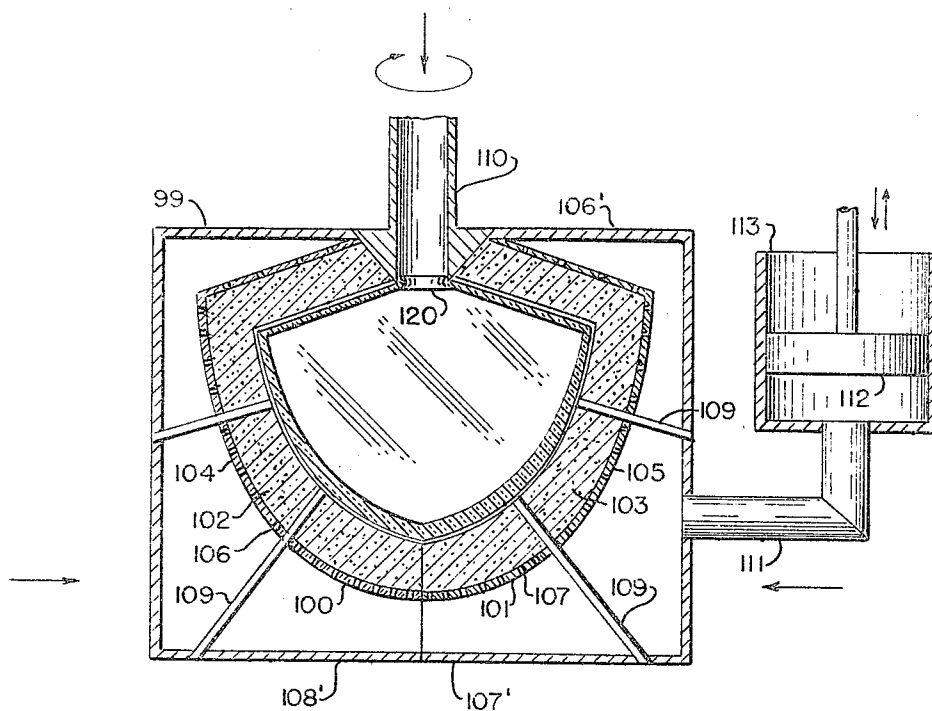


FIG. 14

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3,264,720 POROUS METAL ARTICLES OF DIFFERENTIAL PERMEABILITY

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Filed Sept. 11, 1964, Ser. No. 395,823
14 Claims. (Cl. 29—183.5)

This is a continuation-in-part of application Serial No. 862,522, filed December 29, 1959, now abandoned.

This invention relates to porous materials in general, and, more particularly, to porous metal objects which can be made so that they vary in their permeability from one area to another to control the flow of a liquid or a gas therethrough.

In recent years porous metals of many kinds have been made, such as porous stainless steel, porous nickel, porous bronze, etc. A well known example of the formation of a porous metal would be the following. A fine metal powder, such as 347 stainless steel, is mixed with an even finer stearate powder so that the grains of metal become coated with the stearate. The coated grains of the stainless steel powder may then be pressed lightly together to hold their shape and they are then sintered in a furnace in a controlled atmosphere at a temperature of about 2200° F. This bonds by solid state diffusion the individual grains together at their points of contact. The resulting porous metal product may be further rolled or coined to final precise dimensions, density, and pore size. It will have a tensile strength of from 7,000 to 20,000 pounds per square inch and its porosity will vary according to the grain size of the metal being used, the degree to which the powder was compressed, and many other factors.

Sheets of porous metal formed in this manner may be welded or otherwise conventionally fabricated into shapes. In addition, molds may be used to directly form articles in a wide variety of shapes from metal powders. These forms may then be removed from the mold and sintered in the manner that has been described. Using these methods and a wide variety of metals, many porous products are now being made and have achieved a wide use as filter elements, but many more valuable applications may be found for porous metals if the permeability to a gas or a liquid of a given porous metal object can be accurately controlled and varied from one area to another.

It is, therefore, an object of this invention to provide a porous metal object having a wall of varying and controlled permeability from one area to another.

Another object of this invention is to provide a porous metal object which is differentially permeable and which may be produced with less expense.

A further object of this invention is to provide a porous metal wall for flow therethrough whose permeability may be more accurately controlled.

Additional objects, advantages and features of invention reside in the construction, arrangement, and combination of parts involved in the embodiments of the invention and its practice otherwise as will be understood from the following description and accompanying drawing wherein:

FIGURE 1 is a section taken through a fragment of a porous metal wall of varying or differential permeability according to this invention;

FIGURES 2, 3, 4, 5 and 6 are bottom views of a fragment of a wall similar to that shown in FIGURE 1, these figures showing several of many possible patterns which may be formed by the impermeable layer of metal of this invention;

FIGURE 7 shows the configuration of a fragment of a wire screen with a varying mesh;

FIGURE 8 shows the wire screen of FIGURE 7 em-

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bedded in a wall of porous material to vary and control the permeability of the wall from one area to another;

FIGURE 9 is a cross section through a wall of porous metal and an impermeable layer of metal bonded thereto with apertures formed in the impermeable layer and spaced apart to indicate a limitation of this invention;

FIGURE 10 is a side view of an air roller according to this invention with a fragment of one side of the roller broken away in section to show interior construction and with a piece of plastic tape, shown in section, passing about the air roller;

FIGURE 11 is a longitudinal vertical section through a molten glass delivery chute fabricated according to this invention;

FIGURE 12 is a section taken on line 12—12 of FIGURE 11;

FIGURE 13 is a longitudinal, vertical section through an upstanding liquid applying coating roller with an attached liquid feed tank according to this invention with a fragment of a vertical strip shown being coated and passing behind the roller; and

FIGURE 14 is a transverse vertical section through a glass mold formed according to this invention.

Referring to the drawing in detail, FIGURES 1 and 2 show a first embodiment of this invention. As one example, a thin sheet of stainless steel 21 may have a large number of equal sized apertures 22 formed in it. In the manner which has been described, coated grains of fine stainless steel powder are compressed on top of the sheet 21 to form an even layer thereon. Sheet 21 and the overlying layer of pressed stainless steel powder are then sintered to bond the individual grains of powder together and to sheet 21 to form the porous and uniformly permeable layer 20 as shown in FIGURE 1. When a gas or a liquid is passed through the wall shown in FIGURE 1 from bottom to top, the apertures 22 in the center of sheet 21 meter or pass more liquid or gas than do the apertures 22 at the edges of sheet 21 because the apertures 22 are disposed more closely together in the center of sheet 21. At the edges of sheet 21 where the apertures 22 are spaced further apart, they permit less flow through them in a given area. Thus flow through the porous layer 20 of FIGURE 1 is controlled and varied from its center to its edges.

FIGURE 9 shows a layer of permeable material or porous metal 25 to which there is bonded a perforated layer of impermeable material 26. Layer 26 is shown containing the apertures 27, 28 and 29. The dotted lines above these apertures in porous layer 25 indicate zones within layer 25 within which gas or liquid flow therethrough will vary less than 25 percent. Since the apertures 27 and 28 are spaced closer together than the thickness of the layer 25 above them, the flow or seepage of gas or liquid from the downstream side or top of layer 25 at points 30 and 31 will not vary more than 25 percent. Since the apertures 28 and 29 are spaced further apart than the thickness of layer 25 above them, almost no gas or liquid will seep or flow from the upper surface of layer 25 at point 32. Thus when apertures in the impermeable layer 26 are further apart than the thickness of the porous layer above them, "dead" spots of little or no flow result on the downstream side of layer 25. These "dead" spots or the uneven seepage from the downstream side of the porous layer render this invention unsuitable for the applications which will be described hereafter. Thus despite the fact that conditions may vary greatly with different circumstances of temperature, pressure, porosity, the viscosity of the diffusing gas, etc., the maximum distance between open areas of the impermeable layer of this invention must not be greater than the thickness of the porous metal layer on the downstream side of the impermeable layer. When this limitation is observed, an almost

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constant seepage emerges from the entire downstream surface of the porous layer although the flow rate from a given area is controlled by the openings in the impermeable metal layer.

Further, the cost advantage of this invention becomes particularly effective when the pore size of the porous metal layer must be less than .005". With larger pore sizes, finely drilled plates may be substituted for the porous wall of this invention. However, it is very difficult to drill or form small holes and space them to control flow therethrough and such fine drilling is prohibitively expensive. When a particular application requires a very small pore size from .005" down to .0001" or even smaller, drilled plates cannot be fabricated at any cost to be substituted for the construction of this invention.

Referring further to FIGURES 1 and 2, the object of this invention could be made by first forming a layer or wall 20 of porous metal and then silk screening or otherwise depositing on the upstream side of layer 20 a pattern of wax, grease, or other non-conducting material. If dots were screened on the upstream side of layer 20 in a pattern shown by the apertures 22 of FIGURE 2, a metal layer 21 could then be plated on layer 20 to create the impermeable metal layer 21. The non-conducting material would then be dissolved, melted or washed away leaving the apertures 22. Naturally, if the entire layer 20 of conducting porous metal were immersed in a plating solution, the downstream side of layer 20 would have to be solidly coated with a non-conducting layer which would later be removed.

Still another way in which the layer 21 may be formed is to take a layer 20 of porous metal andpeen, machine or otherwise compact its upstream surface. This peening or machining exerts a localized force to compress the particles of the porous metal to render them into a solid layer which is impermeable. This impermeable layer may then be covered with wax in a pattern leaving openings where it is desired to have the openings 22. Acid may then be applied to the wax where it will etch through the impermeable peened layer 21 to form the apertures 22. The wax coating may then be removed.

Many other porous metals besides stainless steel may be used in the practice of this invention. For example, pure nickel powder may be compacted and sintered at a temperature of 2300° F. to form a porous layer 20. This nickel layer 20 may be sintered on a nickel foil layer 21 containing suitable perforations or openings 22. Inconel powder may be compacted and sintered at a temperature of 2300° F., Monel metal powder may be compacted and sintered at a temperature of 2200° F., bronze powder may be compacted and sintered at a temperature of 1750° F. If the porous layer 20 is compacted on and sintered on a perforated metal sheet 21, this sheet should have a higher or the same melting point as the metal powder.

Many other patterns of openings in the impermeable metal layer may be provided. FIGURE 2 shows an impervious layer 21 containing a large number of apertures of the same size which are spaced closer together or further apart in the impermeable layer to differentially meter flow through the porous layer extending downstream from them.

FIGURE 3 shows a modification of this invention in which an impermeable layer 40 has a number of apertures 41 formed in it with the centers of the apertures 41 spaced the same distance apart from each other. Increased flow may take place through the apertures 41 on the left hand side of FIGURE 3 because these apertures 41 are formed with a larger diameter. Flow decreases to the right side of FIGURE 3 as the apertures are made smaller to control and reduce flow through them.

FIGURE 4 shows a further modification of this invention in which a porous metal layer 44 has associated with it on its upstream side a discontinuous impermeable metal layer 45 consisting of the round dots 46 of metal which may be plated or otherwise fixed to layer 44. Flow

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through layer 44 is differentially metered or controlled according to the size of the dots 46. Thus, as shown in FIGURE 4, the smaller dots 46 on the left permit more flow past them than do the larger dots on the right side.

FIGURE 5 shows a layer of porous metal 48 which has an impermeable layer 49 fixed to its upstream side in the form of the tapering strips 50. As the spaces 51 between the strips 50 become narrower towards the right of FIGURE 5, they progressively reduce and meter flow therethrough.

FIGURE 6 shows another of many possible patterns 55 which could be plated on a porous metal layer 56 to differentially control flow therethrough.

In a like manner, as shown in FIGURES 7 and 8, a screen 58 may be woven from longitudinal metal strips or wires 59 across which there are woven the transverse strips or wires 60. The transverse strips 60 may be spaced closer together, as at the bottom of FIGURES 7 and 8, to more greatly restrict and meter fluid flow past them. The screen 58 is bonded and sintered within a layer of porous metal 61 to render it differentially permeable and control flow therethrough.

FIGURE 10 shows an air roller which illustrates one use to which the differentially permeable wall of this invention may be put. The air roller 62 is made in the following manner. A length of metal tubing 63 has the closely spaced metering apertures 64 drilled or otherwise formed in it. The length of tubing 63 then has a cylindrical layer of porous metal 65 compacted and then sintered about it. End members 67 and 68 close the ends of the air roller 62 and may be welded or otherwise fixed in place. A pump 69 forces air through pipe 70 into the air roller 62.

If a length of plastic tape 71, which could be magnetic recording tape during the coating stage of its fabrication or which could be motion picture film being coated with emulsion or developer, or the like, is to pass about and be guided by air roller 62, it is desirable to have a greater amount of air escape at the center of air roller 62 to provide an effect similar to the crown on a conventional flat belt pulley. Thus the apertures 64 in the metal tube 63 are spaced more closely together in the center of air spool 62. This closer spacing passes more air through the porous metal layer 65 to provide a crown effect which positions strip 71 laterally as it passes over air roller 62.

For ordinary applications, an air roller may merely consist of a piece of tubular material through which small apertures are drilled and spaced to provide more air where needed. However, as shown in FIGURE 10, the inner or bottom surface of tape 71 may have to have been freshly coated with a liquid such as an emulsion or developer during processing. The passing of tape 71 over pressurized air holes, even extremely fine holes, will cause a rippling of a still liquid coating on the roller side of tape 71. However, the layer 65 of porous metal having a small pore size and being thicker than the maximum distance between the apertures 64 ensures that air emerges or seeps from the surface of roller 62 so smoothly that it will not ripple liquid on the underside of tape 71.

FIGURES 11 and 12 show a glass delivery chute which illustrates another use to which the differentially permeable wall of this invention may be put. A glass delivery chute 72 has a trough formed from a layer of porous metal 73 which is bonded within and lines an outer impermeable layer 74. Layer 74 contains apertures 75. An outer casing 76 extends about the impermeable layer 74 so that the outer casing may be pressurized by means of an air pump or blower 77. When a delivery apparatus 78 drops a globule of molten glass to charge a glass molding machine or the like in the chute 72, air escaping from the porous inner surface of layer 73 supports the globule 79 of molten glass.

As shown in FIGURE 11, globule 79 requires greater air support where it strikes the upper portion of chute 72. It also requires greater support where it is con-

ducted in a curved path than it does in the lower straight portion of chute 72. Thus the upper portion of the impermeable layer 74 contains more closely spaced or larger apertures 75 to meter a larger quantity of air therethrough. The lower portion of chute 72 conducting the globule of molten glass 79 in a straight path requires less air to support it, thus the lower portion of the impermeable layer 74 contains more widely spaced or smaller apertures. The even flow and escape of air through the layer of porous metal 73 of this invention prevents undesirable rippling or distortion of the glass globule 79.

Referring now to FIGURE 13, a further use for the differentially permeable porous metal wall of this invention is shown. It is often desirable to distribute glue or another liquid evenly on a strip or sheet 80 which is in a vertical position. Sheet 80 could be plastic before being laminated, it could be film being coated with developer, and the like. Strip 80, in a vertical position, passes the upstanding coating roller 81. Roller 81 consists of a tubular impermeable layer 82 containing the metering apertures 83. Sintered to the metal tube 82 is a porous cylindrical layer 84. A lower end cap 85 closes roller 81 and has a shaft 86 projecting down from it which is rotatably fixed in a bearing 87. A top plate 88 having a suitable seal 89 is entered by the tube 90 which conducts a coating fluid 91 from a tank 92 into the coating roller 81.

If the vertical coating roller 81 was made from a uniformly porous metal, the greater hydraulic pressure of the coating fluid 91 at the bottom of the roller 81 would deposit a thicker layer of liquid on the sheet 80. However, the apertures 83 are spaced further apart or made smaller at the bottom of coating roller 81 to counteract the increased hydraulic pressure and thus insure that sheet 80, although in a vertical position is uniformly coated with fluid 91.

One additional application for the differentially permeable wall of this invention will be described. Some glass articles are formed in what are known as paste molds. These molds come in two or more parts and have their interior mold surfaces coated with graphite, burnt cork, burnt wood chips, or the like. These coatings are very closely guarded secrets held by glass molders. When the paste mold is opened, a few drops of water are introduced into the mold cavity to be sucked up by the interior coating. A bubble of rotating molten glass is then blown into the cavity from a rotating nozzle. Heat from the molten glass flashes moisture in the graphite or other coating into steam which forms a pillow or air bearing for the rotating glass which then cools. This is a particularly critical operation as temperature is very important. If the glass is too hot or if insufficient steam is generated, the glass will stick within the mold. If there is too much steam, it will check or craze the glass surface. The paste molding of glass is costly as the mold cavity coating wears and must be constantly replaced.

FIGURE 14 shows a glass mold according to this invention. This glass mold 99 consists of two halves 100 and 101 each having a mold cavity formed in porous metal 102 and 103. Bonded to or associated with the outer sides of the two porous metal mold cavities 102 and 103 are the impermeable layers 104 and 105 containing the metering apertures 106 and 107. Both halves 100 and 101 of the mold cavity are surrounded by a suitable outer casing 106' which is formed in two parts 107' and 108'. In some mold situations vent pipes 109 should be provided every half inch to one inch within the mold cavity to lead to the atmosphere beyond the casing 106'. A conventional spinning glass blowing nozzle 110 is provided to enter the top of the mold cavity. A duct 111 leads from a piston 112 and a cylinder 113 into the outer casing 106'.

The glass mold 99 of this invention is used as follows. The mold halves 100 and 101 are closed and the rotating glass blowing nozzle or pipe 110 is introduced spinning

into the mold cavity. As a charge of molten glass 120 is blown spinning into the mold cavity, piston 112 is forced downward within cylinder 113 to drive steam into the outer casing 106'. This steam is thus forced through the apertures 106 and 107 and the porous metal layers 102 and 103 to cushion the spinning molten glass 120 with slight clearance from the sides of the mold cavity. Excess steam may flow from between the spinning molten glass and the mold cavity through the vent pipes 109 as it does in the conventional paste mold. When the blown glass 120 solidifies, mold 99 is opened and the finished article removed as in the conventional paste mold. Any suitable means (not shown) may be provided to generate steam to be introduced into casing 106'.

In some applications, superior results may be obtained by introducing superheated air by means of piston 112 into the outer casing 106'. This superheated air may prevent the overly rapid solidification of thinner walled sections of the blown glass article as well as supporting it within the mold cavity. Since different quantities of steam or hot air must be introduced through different parts of the porous metal mold cavity, the flow through the mold cavity is controlled by forming larger and smaller apertures 106 and 107 in the impermeable layers 104 and 105 or by spacing apertures 106 and 107 closer or further apart. Thus this invention allows mold conditions within a glass molding cavity to be even more closely controlled than it is possible in a conventional paste mold.

Drilled apertures could not be used leading into a mold cavity of this invention as the flow of a gas, whether steam or superheated air, through apertures would mark the surface of the spinning and cooling glass article. Further, "dead" spots or uneven seepage of air or steam from the inner surface of the porous mold cavity will also mark the surface of the glass object being molded and may tend to cause it to stick to the surface of the mold cavity. Thus the porous wall of this use of my invention requires that the thickness of the porous layer 102 or 103 over a given pair of apertures 106 or 107 must be greater than the distance apart of the apertures 106 or 107.

While this invention has been disclosed in the best forms known to me, it is nevertheless to be understood that these are purely exemplary and that modifications may be made without departing from the spirit of the invention except as it may be more limited in the appended claims wherein I claim:

1. A porous wall for differential flow therethrough, said wall comprising a porous metal layer having an upstream and a downstream side, and an impermeable layer associated with the upstream side of said porous metal layer, said impermeable layer containing openings metering different amounts of flow therethrough in different portions of said impermeable layer, said porous metal layer being thicker on the downstream side of openings in said impermeable layer than the distance between openings.

2. The combination according to claim 1 wherein the pore size of said porous metal layer is less than .005".

3. A porous wall for differential flow therethrough, said wall comprising a porous metal layer having an upstream and a downstream side, and a thin metal plate or sheet associated with the upstream side of said porous metal layer, said metal sheet containing apertures metering different amounts of flow therethrough in different portions of said metal sheet, said porous metal layer being thicker on the downstream side of any given pair of apertures in said sheet than the distance between the apertures.

4. A porous wall for differential flow therethrough, said wall comprising a porous metal layer having an upstream and a downstream side, and a metal sheet associated with the upstream side of said porous metal layer, said metal sheet containing apertures of the same size spaced different distances apart to meter different amounts

of flow therethrough in different portions of said metal sheet, said porous metal layer being thicker on the downstream side of any given pair of apertures in said metal sheet than the distance between the apertures.

5. A porous wall for differential flow therethrough, said wall comprising a porous metal layer having an upstream and a downstream side and a metal sheet associated with the upstream side of said porous layer, said metal sheet containing apertures of different sizes metering different amounts of flow therethrough in different portions of said impermeable layer, said porous metal layer being thicker on the downstream side of any given pair of apertures than the distance between the apertures.

6. A porous wall for differential flow therethrough, said wall comprising a porous metal layer having an upstream and a downstream side, and an impermeable metal layer plated on the upstream side of said porous metal layer, said impermeable layer containing openings metering different amounts of flow therethrough in different portions of said impermeable layer, said porous metal layer being thicker on the downstream side of openings in said impermeable layer than the distance between openings.

7. A porous wall for differential flow therethrough, said wall comprising a porous metal layer having an upstream and a downstream side, and an impermeable peened surface on the upstream side of said porous metal layer, said impermeable peened surface containing openings metering different amounts of flow therethrough in different portions of said impermeable peened surface, said porous metal layer being thicker on the downstream side of openings in said impermeable peened surface than the distance between openings.

8. An air roller comprising, in combination, metal tubing containing closely spaced metering apertures metering a greater amount of flow in the center portion of the metal tubing, a cylindrical layer of porous metal compacted and sintered about the metal tubing with a thickness greater than the maximum distance between the metering apertures in said metal tubing, the cylindrical layer of porous metal having a pore size less than .005", closures for the ends of the metal tubing and the cylindrical layer of porous metal, and means introducing pressurized air within the metal tubing.

9. A glass delivery chute comprising, in combination, a trough formed from a layer of porous metal, an impermeable layer extending about said trough of porous metal, said impermeable layer containing openings metering different amounts of flow therethrough to different portions of said trough of porous metal, said trough of porous metal being thicker above openings in said impermeable layer than the distance between openings, an outer casing extending about said impermeable layer, and means introducing pressurized air into said outer casing.

10. A liquid coating roller comprising, in combination, a cylindrical layer of porous metal having an inner and an outer surface, an impermeable layer extending about the inner surface of said cylindrical layer of porous metal,

said impermeable layer containing openings metering different amounts of flow therethrough in different portions of said impermeable layer, said cylindrical layer of porous metal being thicker outside openings in said impermeable layer than the distance between openings, means closing the ends of said cylindrical layer of porous metal, means rotatably mounting said cylindrical layer of porous metal, and means introducing a coating fluid within said cylindrical layer of porous metal to be metered through the openings of said impermeable layer and emerge from the outer surface of the cylindrical layer of porous metal.

11. The combination according to claim 10 in which said coating roller is upstanding and in which openings in the lower end of said impermeable layer more greatly restrict flow therethrough to compensate for increased hydraulic pressure of the coating fluid within the coating roller so that the coating fluid emerges evenly from the outer surface of the coating roller.

12. A glass mold comprising, in combination, a multipart porous metal mold having a central cavity, outer impermeable metal layers extending about the multipart porous metal mold, said outer layers containing openings metering different amounts of flow therethrough in different portions of said outer layers, said multipart porous metal mold being thicker to the inside of the opening than the distance between openings, an outer casing extending about the porous metal mold, a glass blowing pipe entering said central cavity of said porous metal mold, and means introducing a gas into said outer casing to flow through the openings in said impermeable layers and the porous metal mold to enter the central cavity and provide temperature control and a gas cushion within the central cavity during the molding cycle.

13. A porous wall for differential flow therethrough, said wall comprising a woven screen of varying mesh size from one portion of said screen to another, and a layer of porous material bonded to said screen.

14. A porous wall for differential flow therethrough, said wall having an upstream and a downstream side and comprising a woven metal screen having parallel evenly spaced longitudinal members and transverse members woven across said longitudinal members, some of said transverse members being woven across said longitudinal members closer to each other to restrict flow therebetween, and a layer of porous metal bonded to the downstream side of said screen.

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