

APPARATUS AND METHOD FOR
TESTING AN IMPERVIOUS SURFACE /

Field of Invention

This invention relates to testing apparatus adapted for testing whether surfaces, that are intended to be impervious, are in fact impervious to the required degree. The invention has particular but not exclusive application to apparatus for testing surfaces of buildings and other architectural structures and their ability to withstand wind and rain. The invention also relates to a method of testing such surfaces using such an apparatus.

Background

External surfaces of architectural structures are expected to act as an impervious barrier to keep out atmospheric elements, such as wind and rain. Unfortunately, it is not uncommon for the structures to fail to fully provide this protective function. The failure may be due to poor construction or workmanship, or may also be the result of inadequate design. The common entry points for wind, moisture and rain are at the joints of windows, doors, cracks and crevices in walls, skylights and other openings or entrances. The range of possible entry points for the wind and rain is of course extensive. The cost of repair is usually substantial.

One established method of testing surfaces the weatherproofing of surfaces is specified in the standard A.A.M.A. 501.2 (American Aluminum Manufacturing Association). The test essentially requires a person to spray water onto a building surface using a hand-held garden hose. Although the standard A.A.M.A. 501.2 stipulates the specifications and water pressure required for the hose, the user is merely required to spray the surface with water back and forth for five minutes. Therefore, the amount of water splashing on the surface will not be consistent from test to test, because it depends on how the user handles the hose. Furthermore, this test does not adequately simulate the effect of real rain, nor does it attempt to simulate the effect of wind. Consequently, this test also cannot simulate the synergistic effect of wind and rain acting together, as it occurs in nature.

A more detailed apparatus and test method is specified in A.S.T.M. E 1105 (American Society for Testing and Materials). In an attempt to simulate the external pressure exerted by wind, the A.S.T.M. test requires the construction of a chamber that is positioned up against the exterior or interior of the surface. The interface between the chamber and surface is sealed hermetically so that the interior of the chamber can be pressurised. When the chamber is constructed on the outside surface, the pressure in the chamber is increased usually by supplying air to the chamber. This causes a positive pressure that acts against the outside surface which simulates the pressure exerted by wind. Alternatively, the chamber can be constructed on the inside surface, the pressure in the chamber is decreased by exhausting air from the chamber to create a suction force on the surface. This suction force is also intended to simulate the effect of wind on the surface, except that the force acting on the surface is simulated by suction on the inside surface, rather than by applying pressure to the outside surface. In either case, the air pressure or suction force, as the case may be, can be varied cyclically to simulate the intermittent effect of wind. However, even the cyclic pressure cannot closely parallel the dynamic and turbulent effect of wind blowing on a surface. Furthermore, since the chamber must be sealed, it is difficult to direct water onto the same side of the surface that is being affected by the air in the chamber, since this requires the liquid spraying mechanism to be positioned inside the sealed chamber. It is also time-consuming and costly to construct the sealed chamber especially for uneven surfaces, and once constructed it is not convenient to transfer the chamber to another test location. In particular, it would be inconvenient to construct a number of chambers for testing the massive planar "curtain walls" (as the glass-windowed surfaces of skyscrapers are usually known in the building industry).

An object of the present invention is to overcome or substantially ameliorate at least some of the disadvantages of the prior art.

Summary of Invention

According to the present invention, there is provided an apparatus adapted for testing a surface intended to be impervious, the apparatus comprising:

a liquid outlet connectable to a liquid source, said liquid outlet arranged and adapted to direct liquid from said liquid source towards the surface;

a current generator arranged and adapted to generate an air current towards the surface;

wherein the liquid outlet and current generator are capable of simultaneously directing liquid and an air current towards the same side of the surface in order to ascertain the actual degree of imperviousness of said surface.

Preferably, said apparatus is provided with counteracting means adapted to counteract the reaction to the force which, in use, is generated by said air current acting on the surface.

The counteracting means may be in the form of a secondary current generator which generates a secondary air current that is able to counteract said reaction.

In one aspect of the invention, in use when the apparatus is positioned adjacent the surface, it is an option for the reaction to the force of said air current from said current generator which acts on the surface to be able to be substantially balanced by a suction force created by air entering the secondary current generator.

Preferably, said counteracting means is in the form of the current generator being provided with an air inlet through which air enters the apparatus and an air outlet from which the air current is directed from the apparatus towards the surface.

Preferably, in use when the apparatus is positioned adjacent the surface, the reaction to the force of said air current which acts on the surface is able to be substantially balanced by a suction force created by air entering the apparatus through the air inlet.

Preferably, in use when the apparatus is positioned adjacent the surface, the amount of air entering the inlet and the amount of air current expelled through the outlet establishes a state of mass balance in the apparatus such that the apparatus is able to maintain a general equilibrium position with respect to the surface while the liquid and air current are directed towards the surface.

Preferably, the air inlet and air outlet are arranged and adapted such that, in use when the apparatus is positioned adjacent the surface, a substantial portion of the air current being

expelled from the air outlet towards the surface is able to re-enter the apparatus through the air inlet.

The inlet may be adapted and arranged for air to enter the apparatus in a direction that is substantially opposite to the direction to which air current is expelled through the air outlet.

Preferably, the air inlet and the air outlet may be located on the same side of the apparatus.

Preferably, the air travelling through the air inlet reverses direction in order to be expelled through the air outlet.

Preferably, the air inlet surrounds the air outlet, and preferably the air outlet is concentrically located within the air inlet.

The position of said air outlet may be adjustable, with respect to said air inlet, to allow said air outlet to be either closer or further away from said surface in use.

Alternatively, the air outlet may surround the air inlet, and the air inlet may be concentrically located within the air outlet.

The air inlet and air outlet may have circular cross-sections.

The air inlet may comprise one or more ducts.

The current generator may include a rotatable rotor.

Preferably, the air current generator is mounted within the air outlet. Alternatively, the air current generator may be mounted within the air inlet.

Preferably, the liquid outlet is positioned in or in the path of the air outlet such that the liquid is able to be directed towards the surface by the air current emanating from the air outlet.

An inclined surface may be provided at the juncture of the air inlet and the air outlet to guide the flow of air from the inlet to the outlet.

The apparatus may be provided with means for increasing static pressure within the apparatus. Preferably, said means for increasing static pressure is provided in the form of apertures in the surface of said apparatus, said apertures enabling the air in said air inlet and/or said air outlet to communicate with the air in the atmosphere outside the apparatus; and said apertures being adjustable in size.

The apparatus may be provided with a blocking device positioned generally at the interface of the air entering the air inlet and leaving the air outlet, wherein said blocking device redirects a portion of air at said interface out of the apparatus in order to provide a buffer zone at said interface.

Preferably, the apparatus is portable and/or suspendable.

Alternatively, the apparatus may, if desired, be supported on a stand.

The apparatus may be provided with a control device such as an adjustable valve mechanism for controlling the amount of liquid ejected through the liquid outlet.

The liquid outlet may include one or more spray nozzles.

Alternatively, the liquid outlet may be in form of at least one narrow elongated slit.

According to another aspect of the invention, there is provided a method of testing a surface intended to be impervious, comprising the steps of :

positioning a testing apparatus adjacent the surface; and

using the apparatus to simultaneously direct liquid and an air current towards the same side of the surface in order to ascertain the actual degree of imperviousness of said surface.

Preferably in the method, the apparatus is positioned sufficiently close to the surface to enable a substantial portion of the air current being expelled from the apparatus towards the surface to re-enter the apparatus through an air inlet, such that the amount of air entering

the apparatus and the amount of air expelled from the apparatus establishes a state of mass balance in the apparatus that enables the apparatus to maintain a general equilibrium position with respect to the surface while the liquid and air current are directed towards the surface.

The use of the word "surface" herein does not imply that the surface has to be flat. For instance, the invention is useful for testing crevices and joints in buildings which may not be planar.

The mention that the surfaces are intended to be impervious does not mean that the surface must be totally waterproof and/or airtight; as the case may be. The invention is not restricted to a particular degree of imperviousness. The required standard of imperviousness would be set by the particular design, for instance by the designer of the building. The invention is able to test whether the surface has met the required standard.

Drawings

In order that the invention might be more fully understood, embodiments of the invention will be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a cut-away perspective view of an embodiment of a testing apparatus adapted for testing a surface intended to be impervious;

Figure 2 is a side cross-sectional view of the embodiment of Figure 1;

Figure 3 is a front cross-sectional view of the embodiment of Figures 1 and 2;

Figure 4 is a schematic representation of the embodiment of Figures 1, 2 and 3, which illustrates how an air current and liquid are directed towards a surface;

Figure 5 is a variation of the embodiment of Figure 2 and which incorporates a blocking ring which partially blocks the entrance to the air inlet;

Figure 6 is a further embodiment of a testing apparatus which uses a current generator and a secondary current generator;

Figure 7 illustrates another further embodiment of the invention; and

Figure 8 shows the other further embodiment of Figure 7 being supported on a stand.

The drawings are not necessarily drawn to scale, particularly Figures 6, 7 and 8, and are provided to illustrate embodiments of the invention. The drawings do not define particular dimensions required for the invention to work.

In the drawings of the embodiments, similar components are numbered with the same numerals for the sake of simplifying the description, but this should not be taken to imply that the embodiments need necessarily be of identical design.

Description of Embodiments

Referring to the drawings, Figure 1 is a perspective view of an exemplary embodiment of a testing apparatus adapted for testing a surface that is intended to be impervious, while Figure 2 show a side cross-sectional view and Figure 3 shows a front view of the same embodiment.

The testing apparatus, generally indicated as 10, is adapted to test a surface that is intended to be impervious. For example, joints of windows and doors in buildings should have an adequate degree of sealing against the elements such as wind and rain. It is the purpose of the testing apparatus 10, therefore, to test whether, in fact, the surface has been constructed properly to achieve the required level of sealing.

Figure 4 illustrates the testing apparatus 10 during use wherein the apparatus is positioned adjacent a test surface 15.

In order to test the ability of the surface 15 to withstand rain and wind, the testing apparatus 10 is able to simulate these two elements of rain and wind as follows:

Wind Simulation

Wind is able to be simulated because the apparatus 10 is also provided with a current generator arranged and adapted to generate an air current towards the surface 15. In the embodiment, the current generator comprises a number of parts and features that combine to provide a means of directing a current of air towards the surface 15.

The current generator is provided with an air inlet through which air enters the apparatus, and is also provided with an air outlet from which the air current is directed from the apparatus towards the surface 15. The air inlet and outlet, in the embodiment, are formed and defined by the structure of the housing of the apparatus 10.

The apparatus of the present embodiment consists of one passage contained within another passage. Referring to either Figure 2 or 4, the inlet passage 60 that functions as the air inlet is located between the inner surface of the outer housing 65, and the outer surface of the inner housing 75. The inner surface of the inner housing 75 surrounds an air outlet passage 70 that functions as the air outlet. Thus, it is preferred that the air inlet surrounds the air outlet, and in the embodiment the air outlet is concentrically located within the air inlet. It is conceivable, although not preferred, that the opposite configuration may be used where the air outlet surrounds the air inlet, and the air inlet would in such cases be preferably concentrically located within the air outlet.

In the embodiment of Figures 1 to 4, the air inlet and air outlet are illustrated as having circular cross-sections. However, the invention is not limited to having a circular design, since the actual cross-sectional shape does not limit the function of the apparatus. The cross sections of the air inlet and outlet may alternatively be square, rectangular or of any suitable shape.

In the embodiment, the air inlet passage 60 comprises a single cylindrical duct. However, it is conceivable that the air inlet may comprise one or more separate ducts acting together to form an air inlet through which air is able to enter the apparatus.

The current generator includes a means of generating the current which, in the embodiment, is a diesel motor 40 which drives a rotatable rotor 50. Other forms of motors

and engines may be used. The motor may also be electrically powered. As best seen in Figure 2, the air current generator, in the form of the motor 40, is mounted within the air outlet passage 70. The air current generator provide the impetus for movement of air through the apparatus. In alternative embodiments, the air current generator may be mounted within the air inlet to provide the same function of moving the air through the apparatus. In further embodiments, current generators may be provided for which the speed of the rotor is able to be varied. A/C motors are ideally adapted for variable speed applications. Variation in the speed of the rotor is useful for simulating variation in wind speed. In the embodiment illustrated in Figures 1 and 6, a twin bladed propeller has been used, and a multi-blade propeller may be substituted to produce a stronger current that may be required for certain applications.

Rain Simulation

Rain is able to be simulated because the apparatus 10 is provided with a liquid outlet that is connectable to a liquid source (not shown). In the embodiment, the liquid outlet is in the form of spray nozzles 20. These spray nozzles are located in a narrow duct 30 that is positioned across an opening of the testing apparatus 10. (The narrow, elongated duct 30 is best seen in the perspective view of Figure 1.) The duct 30 is connectable to the liquid source, which may be a hose connected to a nearby tap. The duct may either be connected directly to the liquid source, or indirectly through intermediate parts. The water source may be an external source or may be a separate tank of water specially adapted to provide the necessary source of liquid. The liquid outlet is arranged and adapted to direct liquid from the liquid source towards the surface in order to simulate the splashing effect of rain on the surface.

The liquid spray originating from the spray nozzles 20 is illustrated in Figure 4 as dotted lines that emanate from the duct 30 through the nozzles 20.

The spray nozzles 20 are positioned in or in the path of the air outlet passage 70 in order that the liquid is able to be directed towards the surface by the air current emanating from the air outlet.

The rate of liquid output through the liquid outlet is able to be varied, either manually perhaps by controlling the liquid source by a tap, or through the use of an electro-mechanical control device (not shown). For instance, an adjustable valve mechanism may be provided for controlling the amount of liquid ejected through the liquid outlet. The valve mechanism may be used in conjunction with a pressure gauge for controlling the amount and/or force of water ejected through the spray nozzles 20. The valve mechanism may be of any type or configuration which will provide the function mentioned above.

This ability to vary or modulate the liquid output enables the apparatus to simulate the variations in rain, since rain does not fall at a constant rate. A timing device or an electronic control circuit may be used to control the variation of the rate of the liquid and air current generated by the apparatus.

Simultaneous Rain and Wind Simulation

The apparatus 10 is capable of simultaneously directing towards the surface both liquid from the liquid outlet and an air current generated by the current generator. Thus, the apparatus is capable of simulating the synergistic effect of wind and rain impacting a surface simultaneously as it happens in nature.

Of course, the apparatus may be capable of directing, one at a time, either the liquid or the air current towards the surface. But it is important that the apparatus has the ability to direct the air and water simultaneously so that it can simulate the synergistic effect of wind and rain impacting a surface at the same time.

Movement Of Air Through the Apparatus

Referring to Figure 4, the movement of air through the air inlet passage 60 and air outlet passage 70 is shown in dotted lines. In the embodiment, the air inlet allows air to enter the apparatus in a direction which is substantially opposite to the direction in which air current is expelled through the air outlet. The air inlet and the air outlet are located on the same side of the apparatus.

Using the orientation of Figure 4 as a reference, air moves rightwardly through inlet passage 60, and then makes a “U-turn” and is re-directed back in a leftward direction through outlet passage 70. Thus, air travelling through the air inlet reverses direction in order to be expelled through the air outlet. As seen in Figures 2 and 4, an inclined surface 80 is provided at approximately the juncture of the air inlet and the air outlet in order to guide the flow of air from the inlet to the outlet. The purpose of the inclined surface is to minimise turbulence of air, which arrives from the various parts of the inlet passage 60, and which comes together at the rear of the apparatus 10.

In the embodiment of Figures 1 to 4, the air flowing through the current generator follows essentially a straightforward path through the air inlet and out through the air outlet. There are no convolutions in either the inlet passage 60 or outlet passage 70. However, further embodiments may incorporate convolutions, either in the air inlet and/or outlet, perhaps with a view to controlling the flow of air as required by the particular design.

Adjustability of the Air Outlet With Respect To the Air Inlet

The position of the air outlet is adjustable with respect to the air inlet. Referring to Figure 2, the inner housing 75 is adjustably fastened within the outer housing 65, by struts 67 which are held in place using bolts and nuts. The inner housing 75 is thus able to be positioned selectively along the longitudinal axis of the outer housing 65. This adjustability effectively enables the air outlet 70 to be adjusted with respect to the air inlet, either closer or further from the surface 15 in use. For instance, when the inner housing 75 is positioned closer to the opening of the outer housing 65 (i.e. closer towards the right hand side in the diagram), this would mean that, in use, the air outlet 70 is able to be positioned closer to the surface 15, which would consequently enable a greater force to be exerted on the surface by the air current. Similarly, the air outlet may be retracted further into the outer housing 65 (i.e. closer to the left hand side of the diagram), which, in use, would have the effect of lessening the force of the air current on the surface. This adjustability of the position of the air outlet with respect to the air inlet enables the user to vary the force of the air current that is directed towards the surface.

In further embodiments, more refined means for adjusting the position of the air outlet with respect to the air inlet may be used. For instance, the inner housing 75 may be

moveable within the outer housing using a rack and pinion gear system that would allow the parts to move incrementally, rather than in stepped amounts, and without having to disassemble the whole apparatus.

Positional Stability of the Apparatus In Use

The present embodiment of the invention will have a particular advantage when it is constructed in a sufficiently compact housing, and with sufficiently light-weight components, to enable the apparatus to be portable or readily transportable. Embodiments of the apparatus may be supported on a stand of some sort. However, those embodiments of the invention which are portable, or at least easily suspendable or transportable, would be particularly advantageous, because the surfaces of buildings to be tested may, in many instances, consist of large surface areas. For example, the massive planar "curtain walls" of glass-windowed surfaces of skyscrapers would have to be tested for weather-proofing.

In certain embodiments, particularly those that are lightweight, portable and/or suspendable, the act of directing an air current towards a surface creates a problem, because the air current has a tendency of forcing the apparatus away from the surface. This happens because the reaction to the force which is generated by the air current acting on the surface, has the tendency to urge the apparatus away from the surface. This problem would arise particularly in those apparatus which direct very strong air currents towards the surface, and/or are sufficiently lightweight so as to be significantly affected by the reaction to the force of the air current. Therefore, in such embodiments of the invention, the apparatus is provided with counteracting means adapted to counteract the reaction to the force which is generated by the air current acting on the surface.

In the embodiment of Figures 1 to 4, the counteracting means is in the form of the current generator being provided with the air inlet passage 60 through which air enters the apparatus and the air outlet passage 70 from which the air current is directed from the apparatus towards the surface 15. The counteracting effect of this configuration is described as follows: When the apparatus is positioned adjacent the surface, the force of the air current emanating from the air outlet passage 70, which acts on the surface, is able to be substantially balanced by a suction force created by air entering the apparatus through the air inlet passage 60. The suction force is achieved because in the embodiment, the amount of air entering the

inlet and the amount of air current expelled through the outlet establishes a state of dynamic mass or flow balance in the apparatus, such that the apparatus is able to maintain a general equilibrium position with respect to the surface while the liquid and air current are directed towards the surface.

The term “general equilibrium” is used because the system is a dynamic one, and from a practical viewpoint, there is no expectation that the apparatus in the equilibrium state must be absolutely motionless. The intention of the counteracting effect is merely to avoid the possibility of the apparatus being urged away from the surface. When the apparatus is suspended, it would be unacceptable for the apparatus to be urged away from the surface. After being urged away, gravitational force would cause the apparatus to swing back towards and impact the surface, which would result in damage to both the apparatus and/or the surface.

Two situations are acceptable. A first preferred situation is that a dynamic force balance, resulting from the mass balance, is achieved so that the suspended apparatus maintains a general equilibrium position in front of the surface. In some circumstances, a second situation, which may be acceptable in some circumstances, is that the suction force of the apparatus is greater than the reaction force of the air current acting on the surface. The apparatus would be drawn towards the surface and would rest adjacent and on the surface while the air current and/or liquid is directed towards the surface. However, contact between the apparatus and surface may not be advisable if such contact might damage the surface, for instance in the case of delicate glass window surfaces.

The dynamic flow balance may be understood using the following basic equations:

$$A_o V_o = A_i V_i$$

where A_o is the cross-sectional area of the air outlet (m^2),

A_i is the cross-sectional area of the air inlet (m^2),

V_o is the velocity of the air current leaving the air outlet ($m.s^{-2}$), and

V_i is the velocity of the air entering the air inlet ($m.s^{-2}$).

The subscript “i” refers to the inlet conditions, while the subscript “o” refers to the outlet conditions.

The mass balance, corresponding to the above flow balance, is defined as follows:

$$\rho A_o V_o = \rho A_i V_i$$

where ρ is the density of the air. In use, the apparatus is able to maintain a general positional equilibrium adjacent the surface when the above mass balance is achieved substantially. The ultimate goal is to ensure that the reaction to the force that is generated by the air current acting on the surface does not cause the apparatus to be urged away from the surface..

Pressure (P) varies with velocity (V) according to the following equation:

$$P = \frac{1}{2} \rho V^2$$

Now, the general equation for force (F) is:

$$F = A P$$

Therefore, the force acting outwardly at the outlet (F_o) is calculated as:

$$F_o = A_o P_o$$

and the force acting inwardly at the inlet is calculated as:

$$F_i = A_i P_i$$

A force difference, ΔF , is calculated as:

$$\Delta F = F_o - F_i = A_o P_o - A_i P_i$$

ΔF is the overall resultant force, taking into account all the forces that are acting on the apparatus itself. The values of P_i , P_o and ΔF may be adjusted by varying the speed of the rotor, and/or varying the size of the opening of the control holes, which will be described below.

In practice, when a general equilibrium mass balance is achieved, such that the apparatus is not urged away from the surface, ΔF , as defined above, is not usually a zero value, because the total force balance must take into account other effects, such as the effect due to the gravitational force on the apparatus itself. However, there would be a general overall force balance for the total resultant forces acting within the system when a general equilibrium state is achieved.

It is not necessary for the force acting inwardly, F_i , to be generally equal to the force acting outwardly, F_o . As mentioned above, it may be acceptable, in some instances, for the suction force of the apparatus to be greater than the reaction force of the air current acting on the surface. In such cases, the apparatus would rest on or against the surface while the air current and/or liquid is directed towards the surface.

The factor of pressure (P) would be influenced by the power of the motor 40, since pressure is proportional to the velocity of the air. The cross-sectional area (A) is determined by the dimensions of the apparatus. In the actual design of a particular embodiment of the invention, the shape of the components plays a part in influencing the flow of air through the passageways of the current generator, so the above mathematical equations merely provide a guide as to how the overall dimensions of the apparatus may be calculated in order to enable the apparatus to attain the general state of equilibrium. Some experimentation may be necessary to determine the dimensions and power of the motor, depending on the particular application in which the apparatus is to be used.

Overall, when the conditions of air flow are such that the mass balance is achieved substantially, the apparatus is able to maintain the abovementioned general equilibrium position adjacent to the surface while the liquid and air current are directed towards the surface.

As best seen in Figure 4, a substantial amount of air leaving the air outlet passage 70 is re-directed back into the apparatus 10 through the air inlet channel 60. This re-cycling motion of air in the apparatus is illustrated in Figure 4 with dotted lines. However, since the apparatus 10 is not sealed from the atmosphere, part of the air entering the air inlet channel 60 will also come from the surrounding atmosphere.

Liquid emanating from the nozzles 20 would not usually be sucked back into the apparatus through the air inlet passage in substantial amounts. However, should a particular embodiment be designed with such parameters that liquid is indeed sucked back into apparatus after it has reached the surface 15, it would be advisable for the motor or engine 40 to be of a waterproof construction.

In use, the apparatus 10 is positioned adjacent the surface 15, and the apparatus is used to simultaneously direct liquid and an air current towards the same side of the surface. A person will then check the surface to ascertain whether the required degree of weather-proofing has been achieved, presumably by looking for water and wind leakage at the other side of the surface. In use of the embodiment, care is taken to position the apparatus sufficiently close to the surface to enable a substantial portion of the air current being expelled from the apparatus towards the surface to re-enter the apparatus through an air inlet, such that the amount of air entering the apparatus and the amount of air expelled from the apparatus establishes a state of mass balance in the apparatus that enables the apparatus to maintain a general equilibrium position with respect to the surface while the liquid and air current are directed towards the surface. The actual distance of the apparatus from the surface will depend on the power of the motor 40, and the degree of effectiveness of the suction effect achieved by the particular design of the embodiment. Some experimentation will be necessary to find the desirable distance for separating the apparatus 10 and the surface 15. Alternatively, as mentioned above, the suction force may be sufficient for the apparatus to be sucked onto the surface, so that it rests adjacent and on the surface while the air and liquid are directed onto the surface.

Increase of Internal Static Pressure

The equation for the force difference, ΔF , has been stated above as:

$$\Delta F = F_o - F_i = A_o P_o - A_i P_i$$

This equation takes into account the dynamic pressure of the moving air. However, this equation may be further refined to take into account the static pressure, P_{static} , within the apparatus and the atmospheric pressure, P_{atmos} , outside the apparatus:

$$\Delta F = A_o (P_o + P_{static}) - A_i (P_i - P_{static}) - (A_o + A_i) P_{atmos}$$

Static pressure, P_{static} , in a closed system, such as in the present embodiment, is a negative value, i.e. it is lower than atmospheric pressure, P_{atmos} . Thus, the effect of having the static pressure being less than the atmospheric pressure causes ΔF to decrease, thus causing the suction force to pull the apparatus towards the surface. This is how changes in the internal static pressure influence the suction force. While ΔF , which is the overall resultant force of all the forces acting on the apparatus, is dependent on the difference between static pressure P_{static} and atmospheric pressure P_{atmos} , the force F_o exerted on the surface by the air current depends only on the static pressure P_{static} .

The static pressure, P_{static} , can also influence the force of the air current acting on the surface, F_o , as follows:

$$F_o = A_o (P_o + P_{static})$$

When it is desirable to maximise F_o , in other words, to maximise the force of the air current acting on the surface 15, one method of increasing this force is to increase the static pressure, P_{static} , within the apparatus. To begin with, the static pressure in a closed system, such as in the present embodiment, would be a negative value, i.e. it is lower than atmospheric pressure. Therefore, as the holes are opened or increased in size, the internal static pressure, P_{static} , rises as it approaches the level of atmospheric pressure outside the apparatus. Thus, opening the holes causes the internal static pressure, P_{static} to increase. This increase in P_{static} causes the force acting on the surface, F_o , to also increase.

Using this principle just described, the apparatus of the present embodiment is provided with means for increasing static pressure within the apparatus. The means for increasing static pressure is provided in the form of apertures in the surface of the apparatus. The apertures allow the air in the air inlet and/or the air outlet to communicate with the atmospheric air outside the apparatus. In Figure 2, the apertures, holes or openings 100 in the apparatus surface, which are openable to the atmosphere, have the ability to increase the static pressure, P_{static} , within the apparatus when the apertures are opened. Thus, the force exerted on the surface is able to be increased by opening up or enlarging the holes, since this causes the internal static pressure, P_{static} , to increase.

The apertures 100 are provided with mechanisms for adjusting the size of the holes, so that the amount of static pressure, and hence the force of the air current, is able to be varied. The ability to adjust the size of the holes allows the user to adjust the amount of force, F_o , acting on the surface.

Since the internal static pressure, P_{static} , can only be increased up to the level of the atmospheric pressure, P_{atmos} , the adjustment of the force applied to the surface would not affect the overall positional equilibrium or state of the apparatus with respect to the surface.

The feature of relying on changes in the internal static pressure are not as applicable to those embodiments of the invention which do not incorporate a closed system.

Further Embodiments

A further embodiment is illustrated in Figure 5, which is a variation of the embodiment of Figure 1 to 4. The further embodiment incorporates a blocking device in the form of circumferential blocking ring 90. In Figure 5, the ring 90 is illustrated in a cross-sectional view. The blocking ring 90 consists of two concentric ring members 95A, 95B. The blocking ring is positioned generally around the region where the air current from the air outlet passage 70 would be expected to flow past the air entering the air inlet passage 60. The blocking ring receives incoming air and expels this portion of air out of the apparatus through small passageways 97.

By re-directing a portion of air from a narrow region, generally at the interface of the incoming and outgoing air, it is intended that the blocking ring would create a buffer zone at the interface of the incoming and outgoing air.

The blocking ring is open to the atmosphere, due to passageway 97. Therefore, another effect of causing a portion inside to apparatus to approach atmospheric is that the internal static pressure, P_{static} , is increased, thus increasing the force of the air current acting on the surface, F_o . This effect has been discussed above.

In another embodiment in Figure 6, the counteracting means is in the form of a secondary current generator which generates a secondary air current that is able to counteract

the reaction to the force of the main motor 40. The secondary current generator is provided as secondary motors 40A. When the apparatus of Figure 6 is positioned adjacent the surface, the reaction to the force of the air current from the motor 40 which acts on the surface is able to be substantially balanced by a suction force created by an air current generated by the secondary motors 40A. Liquid from duct 30 is able to be directed towards the surface simultaneously with the air current. In this type of embodiment, where there is no closed system, a force balance is used to establish the positional equilibrium of the apparatus adjacent to the surface, but there would be no mass balance present.

Apparatus of the present invention finds a particular, but not exclusive application, in the testing the weatherproofing characteristics of surfaces of architectural structures or buildings. When the apparatus is to be used for a standardised test, the parameters of the velocity of the air current and rate of liquid discharge may be standardised.

It should be appreciated that the user of the apparatus may not always require the apparatus to maintain a general equilibrium position automatically. For certain tasks, it may suffice merely for an apparatus of the invention to be hand-held by the user or mounted rigidly on a stand, and for the apparatus to merely spray liquid and direct air current towards a surface as required by the user.

Embodiments of the invention have been described with respect to impervious surfaces that would be expected to have a high degree of imperviousness against wind and rain, although the level of imperviousness, for buildings and houses for instance, are not always required to be vacuum tight. The acceptable level of imperviousness is determined by the builder, architect or other designer. It is also possible for embodiments of the invention to be used for testing structures that can block out wind and/or rain, for instance, louvers. Louvers are intended to block out rain substantially, although their ability to block wind would be less than, say, a sealed window. The degree of "imperviousness" for louvers would be the degree of wind and rain resistance set by the manufacturer. In this sense, it is considered that embodiments of the present invention may be useful for testing the rain and wind resistance of such structures also.

Other Further Embodiments

Another further embodiment is illustrated in Figures 7 and 8. This embodiment incorporates the two features that allow the apparatus to simulate wind and rain, simultaneously if necessary. The apparatus is provided with a current generator in the form of blower 200. The blower 200 is connected to an air outlet in the form of duct 210. The opening of the duct 210 is of substantial length but has a narrow height. The substantial length of the duct opening ensures that as liquid is expelled from the duct, the spray covers a wide area. However, the narrowness of the width of the duct ensures that liquid spray emanating from the duct maintains some degree of pressure and/or velocity. The duct 210 overall has the shape and configuration of a narrow elongated slit. The embodiment is provided with one slit, although it is conceivable that more than one slit may be provided. The two portions are connected by a flexible hose 220 that directs the air current from the blower out of the duct 210. The end of the duct 210 is provided with liquid outlets in the form of spray apertures 230. The spray apertures 230 are connectable to a liquid source such as a tap or perhaps a pressurised water source (not shown). In the embodiment, the spray apertures 230 and blower 200 are capable of simultaneously, or individually, directing liquid and an air current towards the same side of a surface to test the surface for its water-proof and/or wind-proof characteristics. An advantage of this other further embodiment is that it is relatively cheap to manufacture and can be transported easily.

The embodiment is able to be supported on a stand 240, as shown in Figure 8, although the apparatus of this embodiment may also be suspended. It should be noted that other embodiments may also be used on a stand when appropriate. Preferably, the stand includes an attachment system that enables the stand to be mounted on an external support, for instance, to an external scaffold, gondola or some other platform or support. For instance, the attachment system may include a bracket, struts or clamps for example. The shape and configuration of such an attachment system is dependent on the nature of the external support. Hence, this aspect of the embodiment is not limited to any one shape or configuration of a particular form of attachment. This other further embodiment is especially useful when the apparatus, itself, is not moved, but rather the apparatus is attached to an external support such as a moveable platform that is transported to the required location.

The embodiments have been advanced by way of example only, and modifications are possible within the spirit and scope of the invention as defined by the appended claims.

**CLAIMS:**

1. An apparatus adapted for testing a surface intended to be impervious, the apparatus comprising:
 - a liquid outlet connectable to a liquid source, said liquid outlet arranged and adapted to direct liquid from said liquid source towards the surface;
 - a current generator arranged and adapted to generate an air current towards the surface;
 - wherein the liquid outlet and current generator are capable of simultaneously directing liquid and an air current towards the same side of the surface in order to ascertain the actual degree of imperviousness of said surface.
2. An apparatus according to claim 1 wherein said apparatus is provided with counteracting means adapted to counteract the reaction to the force which, in use, is generated by said air current acting on the surface.
3. An apparatus according to claim 2 wherein said counteracting means is in the form of a secondary current generator which generates a secondary air current that is able to counteract said reaction.
4. An apparatus according to claim 3 wherein, in use when the apparatus is positioned adjacent the surface, the reaction to the force of said air current from said current generator which acts on the surface is able to be substantially balanced by a suction force created by air entering the secondary current generator.
5. An apparatus according to claim 2 wherein said counteracting means is in the form of the current generator being provided with an air inlet through which air enters the apparatus and an air outlet from which the air current is directed from the apparatus towards the surface.
6. An apparatus according to claim 5 wherein, in use when the apparatus is positioned adjacent the surface, the reaction to the force of said air current which acts on the surface is able to be substantially balanced by a suction force created by air entering the apparatus through the air inlet.



7. An apparatus according to either claim 5 or 6 wherein, in use when the apparatus is positioned adjacent the surface, the amount of air entering the inlet and the amount of air current expelled through the outlet establishes a state of mass balance in the apparatus such that the apparatus is able to maintain a general equilibrium position with respect to the surface while the liquid and air current are directed towards the surface.
8. An apparatus according to any one of claims 5 to 7 wherein the air inlet and air outlet are arranged and adapted such that, in use when the apparatus is positioned adjacent the surface, a substantial portion of the air current being expelled from the air outlet towards the surface is able to re-enter the apparatus through the air inlet.
9. An apparatus according to any one of claims 5 to 8 wherein the inlet is adapted and arranged for air to enter the apparatus in a direction that is substantially opposite to the direction to which air current is expelled through the air outlet.
10. An apparatus according to claim 9 wherein the air inlet and the air outlet are located on the same side of the apparatus.
11. An apparatus according to any one of claims 5 to 10 wherein air travelling through the air inlet reverses direction in order to be expelled through the air outlet.
12. An apparatus according to any one of claims 5 to 11 wherein the air inlet surrounds the air outlet.
13. An apparatus according to 12 wherein the air outlet is concentrically located within the air inlet.
14. An apparatus according to any one of claims 5 to 13 wherein the position of said air outlet is adjustable, with respect to said air inlet, to allow said air outlet to be either closer or further away from said surface in use.
15. An apparatus according to any one of claims 5 to 11 wherein the air outlet surrounds the air inlet.



16. An apparatus according to claim 15 wherein the air inlet is concentrically located within the air outlet.
17. An apparatus according to any one claims 5 to 16 wherein said air inlet and air outlet have circular cross-sections.
18. An apparatus according to any one of claims 5 to 17 wherein said air inlet comprises one or more ducts.
19. An apparatus according to any one of claims 5 to 18 wherein said current generator includes a rotatable rotor.
20. An apparatus according to any one of claims 5 to 19 wherein said air current generator is mounted within the air outlet.
21. An apparatus according to any one of claims 5 to 19 wherein said air current generator is mounted within the air inlet.
22. An apparatus according to any one of claims 5 to 21 wherein the liquid outlet is positioned in or in the path of the air outlet such that the liquid is able to be directed towards the surface by the air current emanating from the air outlet.
23. An apparatus according to any one of claims 5 to 22 wherein an inclined surface is provided at the juncture of the air inlet and the air outlet to guide the flow of air from the inlet to the outlet.
24. An apparatus according to either claims 1 or 2, or any one of claims 5 to 23 wherein said apparatus is provided with means for increasing static pressure within the apparatus.
25. An apparatus according to claim 24 wherein said means for increasing static pressure is provided in the form of apertures in the surface of said apparatus, said apertures enabling the air in said air inlet and/or said air outlet to communicate with the air in the atmosphere outside the apparatus, and said apertures being adjustable in size.



26. An apparatus according to any one of claims 5 to 25 wherein said apparatus is provided with a blocking device positioned generally at the interface of the air entering the air inlet and leaving the air outlet, wherein said blocking device redirects a portion of air at said interface out of the apparatus in order to provide a buffer zone at said interface.
27. An apparatus according to any one of the preceding claims wherein said apparatus is portable and/or suspendable.
28. An apparatus according to any one of claims 1 to 26 wherein said apparatus is able to be supported on a stand.
29. An apparatus according to claim 28 wherein the stand includes an attachment system that enables the stand to be mounted to an external support.
30. An apparatus according to any one of the preceding claims wherein said apparatus is provided with a control device such as an adjustable valve mechanism for controlling the amount of liquid ejected through the liquid outlet.
31. An apparatus according to any one of the preceding claims wherein said liquid outlet includes one or more spray nozzles.
32. An apparatus according to any one of claims 1 to 30 wherein said liquid outlet is in form of at least one narrow elongated slit.
33. A method of testing a surface intended to be impervious, comprising the steps of :
positioning a testing apparatus adjacent the surface; and
using the apparatus to simultaneously direct liquid and an air current towards the same side of the surface in order to ascertain the actual degree of imperviousness of said surface.
34. A method according to claim 33 wherein the apparatus is positioned sufficiently close to the surface to enable a substantial portion of the air current being expelled from the apparatus towards the surface to re-enter the apparatus through an air inlet, such that the amount of air entering the apparatus and the amount of air expelled from the apparatus establishes a state of mass balance in the apparatus that enables the apparatus to maintain a



general equilibrium position with respect to the surface while the liquid and air current are directed towards the surface.

35. A method according to claim 33 wherein said apparatus is constructed according to any one of claims 1 to 32.

36. A method according to either claim 34 wherein said apparatus is constructed according to either claims 1 or 2 or any one of claims 5 to 32.

37. Use of an apparatus constructed according to any one of claims 1 to 32 for testing the weatherproofing characteristics of a surface of an architectural structure or building.

38. Use of a method according to any one of claims 33 to 36 for testing the weatherproofing characteristics of a surface of an architectural structure or building.