

SYSTEM AND METHOD FOR PREVENTION OF BACKFLOW IN VERTICAL RAINWATER DRAINAGE PIPE WITH MULTIPLE SIDE BRANCHES

Field of the Invention

The invention relates to rainwater drainage for wind driven rain spaces. In particular, the invention relates to down pipes and associated branches, such as those used for multi-storey buildings.

Background

Rainwater pipes with multi-level side branch connections have the risk of backflow of water through the side branches. This risk is very difficult to predict with current gravity rainwater downpipe design principles.

The key factors that cause backflow in the side branches are:

- Release of air that is trapped within the pipework;
- The unpredictability of 2-phase flow characteristics when flow rate rises beyond a safe limit where a clear separation between air and water can be maintained.

To prevent the above uncertainty, the flow rates for vertical stacks have to be limited to very low flow capacity. The rainwater drainage codes for a lot of countries have adopted the principle of not allowing the connection of side branches to vertical roof drainage pipes to prevent backflow problem.

At very low flow rate where the flow of water does not affect the air flow, there is no risk of backflow. However, as flow increases the fill rate of water in the pipe increases. This increased flow of water has an effect on the air that is inside the vertical pipework. The increased flow of

water downwards can draw in additional air either from the top of the vertical pipe (where it is located on the roof) or from the side branches located on the higher portion of the stack.

When air that is brought in together with the flow of water can freely travel downwards and freely discharge at the downstream end, such as a pipe that discharges vertically into open space, there is no risk of backflow.

However, in situations where air cannot discharge freely at the downstream end of the pipe such as:

- long horizontal run of pipe downstream,
- presence of elbows downstream,
- merging of flow from other stacks or
- pipe discharge that is being submerged due to flooding of external drain, Air will escape through the multi-level side branches connections, especially at the lower portion of the stacks.

The air escaping through the side branches creates 3 problems:

- Prevents effective flow of water into the floor outlets (which forms the inlet into the side branches);
- Prevents effective flow of water through the side branch pipeworks;
- Pushes water that are flowing in the vertical stack out through the side branches and thus creating backflow.

Summary of Invention

In a first aspect the invention provides a branch pipe arrangement for branching from a vertical pipe, the branch pipe arrangement comprising: a branch junction mounted to said vertical pipe having a restricted cross section on a vertical portion forming a nozzle, said nozzle arranged to increase a velocity head of water passing through said nozzle, an expansion chamber directly below the nozzle, said expansion chamber having a cross sectional area greater than a cross

sectional area of the vertical pipe; a branch portion projecting from the expansion chamber; a floor outlet and; a branch pipe connecting the branch portion to the floor outlet.

In a second aspect the invention provides a floor outlet for receiving a water inflow, said floor outlet comprising: a spigot for connecting to a pipe; an inlet having two apertures, a first aperture for receiving the inflow of water and a second for venting air, said apertures in fluid communication with said spigot.

In a third aspect the invention provides an elbow for providing an angular connection between two pipes, the elbow comprising: an inside radius and an outside radius; wherein the inside radius is large relative to the pipe diameter.

In a fourth aspect the invention provides an air release device for mounting to a pipe, the device comprising: a housing defining a vertically oriented internal chamber; an opening in a base of the chamber for receiving air from the pipe; a vent at a top of the chamber for venting received air; wherein a height of the chamber being equal to or greater than a width of the chamber.

Brief Description of Drawings

It will be convenient to further describe the present invention with respect to the accompanying drawings that illustrate possible arrangements of the invention. Other arrangements of the invention are possible and consequently, the particularity of the accompanying drawings is not to be understood as superseding the generality of the preceding description of the invention.

Figure 1 is an elevation view of a vertical pipe having a branch under Stage 2 flow conditions;

Figure 2 is an elevation view of a vertical pipe having a branch under Stage 3 & 4 flow conditions;

Figure 3 is a schematic elevation view of a vertical pipe and side branch;

Figure 4A is an elevation view of a junction according to one embodiment of the present invention;

Figure 4B is an isometric view of an elbow according to one embodiment of the present invention;

Figure 4C is an isometric view of a flow outlet according to one embodiment of the present invention;

Figure 4D is an air release device according to one embodiment of the present invention;

Figure 5 is a schematic elevation view of a vertical pipe having a junction according to one embodiment of the present invention;

Figure 6 is a schematic elevation view of a junction according to one embodiment of the present invention;

Figures 7A to 7C are schematic elevation views of an elbow according to prior art undergoing backflow conditions;

Figure 8 is a schematic elevation view of an elbow according to one embodiment of the present invention;

Figures 9A and 9B are schematic elevation views of a flow outlet according to one embodiment of the present invention;

Figures 10A and 10B are schematic elevation views of an air release device according to two embodiments of the present invention;

Figures 11A to 11D are isometric views of various arrangements of a vertical pipe and side branch according to several embodiments of the present invention.

Detailed Description

Flow along a vertical pipe goes through the following phases (with increase of flow)

- Stage 1: very low flow rate where there is clear separation between air and water. Water typically flows along the inner surface of the pipe wall, and can be described as annular flow
- Stage 2: low flow rate where the flow of water affects the flow of air in the pipework. This stage of flow causes additional air being brought into the pipeworks and causes building up of air at the lower portion of the pipe.

- Stage 3: two phase flow stage: flow rate where pressure fluctuations occurs within the pipework and air and water are mixed together in the flow. The flow condition can very unstable and unpredictable.
- Stage 4: flow rate reach a stable pressure flow condition where pressure is relatively stable. This is characterized by presence of small air bubbles that are mixed with the water flow.
- Stage 5: highest possible flow rate where flow reaches full bore flow condition in the vertical stack.

Risk of backflow occurs at Stages 2, 3, 4 and 5. Conventional gravity design principles limit gravity system capacity to flowrate of Stage 1 in order to prevent any backflow.

Figure 1 shows a downpipe arrangement 5 with a vertical pipe 10 having a side branch 15. At stage 2, air 30 is brought down due to water flow. The problem occurs where building up of air pressure 20 forces air 35 to push out sideways through the side branch. The escaping air intersects with the water that is flowing downwards along the inner surface of the pipe wall and thus pushes water 25 into the side branches.

This causes water to build up in the side branches and eventually prevents free escape of air through the branch pipe. When this happens, air will push water along the branch pipe upstream and cause back flow.

Figure 2 shows the same arrangement 5 as Figure 1, but with increased water flow so as to progress through stages 3 and 4 to stage 5. At this stage, water flow has the characteristics of pressure flow, with the downward water flow including entrained air, so as to represent 2 phase flow. As a flow through the branch connection has higher pressure than atmospheric pressure, the water pressure will cause water 45 to be pushed out through the branch connection causing back flow.

Air flow conditions in side branches differ based on the different flow conditions in the vertical stack. There are different stages of air flow in relation to increase of flow through vertical stack:

- Stage 1: minimum air flowing outwards against direction of water flow
- Stage 2: maximum air flowing outwards against direction of water flow
- Stage 3: minimum air flowing outwards against direction of water flow (similar to Stage 1)
- Stage 4: neutral condition with minimum air movement
- Stage 5: air movement inwards following the direction of water flow

Critical conditions occur at Stage 2 flow of the branch pipe, which happens at Stage 2 and Stage 3 flow in the vertical pipe. The solutions to backflow need to cater to the situation where there is maximum air flowing outwards against the direction of water flow in the branch pipes.

Figure 3 shows those locations at risk of backflow in a vertical rainwater drainage pipe 50 with multi-level side branch connection, being:

- Along the vertical stack 55 due to:
 - The escaping air pushing water from the stack outwards through the side branches;
 - The fluctuation of pressure within the vertical section of the pipe.
- At the connection point 60 between the vertical stack and side branch;

- Along the side branch pipe 65 where flow changes direction from horizontal to vertical, and;
- At the ingress point 70 of water into the side branches (such as balcony floor outlets).

The present invention is directed to several aspects, each of which may be incorporated to solve the issue at the locations identified in Figure 3. It will be appreciated that these various aspects may be used individually as required, but may also be used in combination with any or all of the other aspects, to form a system wide solution, should the particular application require this.

Embodiments of the different aspects, which are arranged to solve situations at the different locations, are shown in Figures 4A to 4D:

- Figure 4A: A backflow prevention junction 75 at the connection point of every side branch into the vertical pipe
- Figure 4B: An adapted elbow 80 at every turning of angle between vertical and horizontal in the branch pipe
- Figure 4C: A adapted floor outlet 85 where water enters the branch pipes
- Figure 4D: An adapted air release device 90 that can be incorporated to the backflow prevention junction as well as other locations in the branch pipe.

Figure 5 shows a vertical pipe having branches extending therefrom. Each branch includes a backflow prevention junction 75.

The backflow prevention junction 75, as shown in Figure 6, includes a restricted cross-section 120 forming a nozzle level 124 with the opening 132 of the branch 134. The restriction creates a build-up of water 100, 105 above the junction 75 forming a pressure head. This forces the flow

pattern to switch from gravity non-pressure flow to pressure flow, with the nozzle converting the pressure head to a high velocity head in the form of a high velocity jet 130 of water passed the branch, and so creating an air-water separation zone 125 through which trapped air can escape 135 through the branch 134 both vertically or horizontally. At high flow rate in the vertical pipe, the pressure jet achieves very high velocity which creates a suction effect at the connection point with the side branch. This increases the flow capacity of the side branch.

The wider separation zone 125, which is also open to atmospheric pressure through the branch 134, then allows expansion of the water jet and so returning to gravity directed flow.

At every connection point, the nozzle causes a break in pressure below the nozzle while inducing pressure flow condition above the nozzle. This happens at every branch point regardless of location of the junction in the vertical pipework and height of the pipework. Therefore, the flow condition in the vertical stack is broken into small controlled pressure flow segments. Fluctuation of pressure in the vertical stack is eliminated.

This enables the system to work under a controlled pressure flow condition and achieves much higher flow rate as compared to conventional solutions which is only safe at Stage 1 (very low flow rate conditions).

In order for air to be able to escape through side branch pipe without interfering with water flow, a controlled water level in the side branch is crucial. Water flow needs to be designed to maintain open channel condition at the horizontal segment of the branch pipe.

While conventional gravity drain pipe design for horizontal pipes allows water depth of up to 70% of the total depth of pipe cross section, this fill rate does not allow sufficient space for air to escape freely.

The maximum water depth where air can be allowed to discharge freely through the branch pipe is at 50% of total depth of pipe cross section.

Beyond water depth of 50% depth, special air release device 90 may be incorporated into the backflow prevention junction, as will be discussed with reference to Figures 11A to 11D

Figures 7A to 7C show a further point within a branch pipe arrangement that suffers as a result of backflow. Where water flow changes direction from a horizontal segment of the branch pipe downwards to the vertical segment of the pipe, the configuration of the elbow/bend 140 at the change in direction is crucial in preventing backflow.

Risk of backflow occurs when air flow 145 from the vertical segment of the pipe intersects with the water flow 150 which can be projected across the path of airflow due to the profile of the turn between horizontal upstream segment and the vertical downstream segment. In effect, this acts as a discontinuity for the water flow 150, leading to separation from the pipe at this point 152. The upwards air flow 145 will push 147, 160 the water backwards 155 and create a buildup of water upstream of the turn and eventually forming a water plug 166 that can be pushed long distance upstream causing backflow.

A turn with a sharp inner edge 152 (typical of sharp 90-degree plastic fittings) tends to cause the water to overshoot away from the inner side of the pipe wall, causing a projection of flow across the center of the vertical segment of the pipe.

Figure 8 shows a solution to this problem, with the adapted elbow 170. Having a curved surface, having an inner radius 172 on the elbow helps to keep water flow 190 along the lower portion of the horizontal pipe, by providing a continuous surface and so preventing separation between the water flow and the pipe. The water 195 follows the turn along the pipe wall at the inner side of the bend. This prevents intersection between water flow and air flow 175, 180, 185 and allows separation of air flow from water flow along the change in flow direction.

An elbow 170, according to the present invention, with a minimum inner diameter, corresponding to twice the inner turning radius of $0.3 \times \text{diameter of pipe}$ is used to ensure that water flow of max 50% depth does not intersect with air flow.

An enlargement 178 at the outer radius of the elbow provides additional air space to avoid interference of air flow with water flow. To this end, the cross sectional area of the elbow, defined by a line 171 connecting the centres 173, 174 of the inner and outer radii is greater than that of the cross sectional area of the upstream and downstream portion of the elbow, including the spigots to which the elbow connects to the pipe.

In a further embodiment, the radius on an inner portion 172 of the elbow may be greater than the outer radius 176 of the elbow. Typically, prior art elbows have radii which are equal, or perhaps the inner radius being smaller than the outer. In further embodiment of the present invention, the inner radius may be made larger to prevent separation as the water flows about the curve, with the outer radius being smaller, and so creating an additional space for air to flow and remain separate from the water flow. The outer radius may therefore approach zero as the shape emulates a rectangular corner.

In a further aspect, Figures 9A to 9C show a floor outlet 200, used as the entry point of water into the side branch. It is also the exit point of air escaping from the side branch.

The conflict between the outgoing air and the incoming water can prevent effective drainage, where water can be prevented to enter into the outlet and subsequently into the branch pipe.

In this embodiment, the floor outlet 200 has a horizontal spigot 208 that ensures that air travels at the upper portion of the pipework and into a chamber 240 having a cross sectional area greater than the spigot and so enlarged relative to the spigot, said chamber having an upper section and a lower section. Please note, whilst the figures show a horizontal spigot, the spigot may alternatively be vertical. In a further alternative, an elbow according to Figure 8, either attached or integral with said spigot. At the other end of the outlet 200, and in fluid communication with the spigot, is an inlet having two apertures 214, 215. The first aperture 215 is arranged to receive an inflow of water and the second aperture 214 is arranged to vent air from the pipe and. Air at an upper portion of the pipe cross-section is channeled towards the center of the floor outlet, where it is allowed to escape 230 through the second aperture 214 without interfering with the water 220 that is flowing in through the first aperture 215. The entry to the second aperture is

defined by the internal edge 213 which is in turn connected to a canopy 210. The first aperture is defined by a perimeter edge 205 and the internal edge 213. When positioning the floor outlet, the peripheral and internal edges are arranged to be flush with the surface of the floor, notwithstanding conventional slope to direct water to the inlet. Thus, the water flow 220 received by the outlet 200 is directed through the first aperture 215 and directed into a lower section 235 of the chamber 240, which then is permitted to flow 225 into the horizontal pipe 208.

The floor outlet 200 has 2 main features:

- Vertical enlargement air chamber 240 at the joint between the branch pipe 208 and the floor outlet 205. This enlargement 240 allows additional upward air space in the upper section to direct air flow towards the air vent opening at the center.
- An extended half round canopy 210 extending from the wall of the floor outlet towards the center, which directs air flow to release at the center of the outlet. This allows separation of air flow which is releasing outward from the floor outlet from the flow of water which is flowing inward into the floor outlet.

Figure 10A shows an air release component 245. The air release component 245 is arranged to be used near a branch, so as to facilitate the release of trapped air, and so assist in overcoming backflow issues at the branch. It will therefore be in fluid communication with the branch and vertically above said branch, though not necessarily directly above. Whilst it may be installed in isolation from other aspects of the invention, when used in association with a backflow prevention junction, for instance, the air release component allows direct air release immediately at the connection point of the junction thus reducing/removing the need for the release of air through the branch pipe. This can allow the branch pipe to drain at full bore condition i.e. 100% water, which significantly increases its drainage capacity. The chamber within the housing may have a height equal to or greater than a width of the chamber. It may also have a cross-sectional area larger than a cross-sectional area of the branch or branch pipe.

The air release device 245 includes a housing 250, with a top 255. In the base of the device is an opening 265 that fits to a spigot or other attachment on, or near, the junction. The opening 265 allows air to escape from the branch pipe. The air enters a chamber 285 and passes through a centralized tray 270 which, in this case, is an inverted conical plate. The tray 270 includes a central vent 273 and peripheral vents 271, 275 about the circumference of the tray 270. The tray's conical shape allows for a ball 277 to sit within the device 245 when inactive. As air enters the chamber 285 and through 280 the tray 270, the air eventually exits through the vent 260 in the device top 255, and so exiting the device.

A float ball 277 is incorporated in the device to ensure that the device will self-seal against the vent 260 in the event of water being brought into the device, with the ball rising and falling 279 based upon the water level within the device.

Figure 10B shows an alternative arrangement, whereby one or more flaps 274 are attached to the device top 255 and arranged to move 276 from an open position to a closed position, sealing the top vent 260 on an inflow of water from the base and seal the top vent

It will be appreciated that the ball acts in a similar manner to a one way valve, and so it will be appreciated that the ball could be replaced by a free moving disc that floats on top of a rising water level to seal the vent;

As mentioned, the invention includes four distinct aspects, as listed in Figures 4A to 4D. Whilst available for use in isolation, these components may be used together to form a branch pipe arrangement.

For example, Figures 11A to 11D show various combinations that may be used for such a branch pipe arrangement, which are directed to providing a continuous air path and a continuous inflow path, both separated from each other so as to prevent air being caught in the branch pipe.

Figure 11A: High fill rate where vertical drop is incorporated into branch pipe:

- A branch arrangement 295 having a branch junction 305 with an air release device 310, two elbows 315 and a floor outlet 320;

Figure 11B: Low fill rate where vertical drop is incorporated into branch pipe

- A branch arrangement 325 having a branch junction 305, two elbows 315 and a floor outlet 320;

Figure 11C: High fill rate where branch pipe connects directly into backflow prevention junction

- A branch arrangement 330 having a branch junction 305 with an air release device 310 and a floor outlet;

Figure 11D: Low fill rate where branch pipe connects directly into backflow prevention junction

- A branch arrangement 335 having a branch junction 305 and a floor outlet 320;

Each of the branch pipe arrangements involve various components to achieve high flow rate making use of the principles of pressure flow while effectively preventing backflow at the side branches.