Technical paper

Air Pressure transients in drainage systems
Longer relief times in higher buildings

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Abstract

Air pressure transient propagation is a wholly natural consequence of any change in operating conditions for a fluid carrying system. Rapid changes in flow conditions generate surge conditions that may result in system failure. Air Pressure transients are often discussed when talking about drainage systems and in particular drainage ventilation. When air pressures transients reach a level in excess of +-500Pa or more the water traps seals can be pulled (negative transients) or pushed(positive transients), with the loss of the protection that they provide. In high-rise and complex building designs, these transients have a greater importance due to the loadings and the pipe periods associated with these types of buildings. Understanding these transients allows designers to select suitable systems to limit their effect.

Context of this paper

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Introduction

What are pressure transients?

Any discussion on the challenge of draining a building would be incomplete without reference to air pressure transients, but what are they? Air pressure transients are very simply the physical communication of a condition at one point in a system to another point. This means that if there is an event at point A (the water trap) then this information is communicated to point B (vent at the top of the stack) some distance away by means of a pressure wave.

The wave moves much faster than the air in which it travels and can move in any direction, not necessarily in the flow direction.

In a pipe the speed at which an air pressure transient travels is the acoustic velocity of 320 m/sec. A negative transient communicates a need for more air and represents a suction force while a positive transient communicates the need to reduce the air flowing and represents a pushing force.

A negative transient can be caused by air leaving the system (hence the need for more air) and a positive transient can be caused by the air reaching a closed end (stop the air there's no escape route).

An analogy may help to visualize how this works in practice. Imagine driving along a highway at rush hour when cars are traveling at a modest 40 MPH nose to tail. The road is long and winding with a slight incline, it is dark so the stream of taillights can easily be seen for several miles ahead. At some point in the journey, a car, now out of sight, is forced to stop. The driver is forced to apply the brakes. At this time you are still traveling at 40 MPH. Up ahead in the distance you can see the brake lights illuminating as drivers respond to the event out of sight. The 'wave' of brake lights works its way back through the traffic until you are forced to apply your brakes and stop. The illuminating lights are analogist to a pressure transient communicating to you that there has been an event up ahead (which you can't see) and that you must stop. This "positive" type pressure wave travels much faster than the 40MPH that you were traveling at before braking (although in this case the speed of the wave is determined by the response of drivers to seeing brake lights up ahead). When the road is cleared up ahead the reverse happens as brake lights go out and drivers find themselves with a space to drive into as the car in front moves away. Again the information to move is communicated by the "negative" type pressure wave.

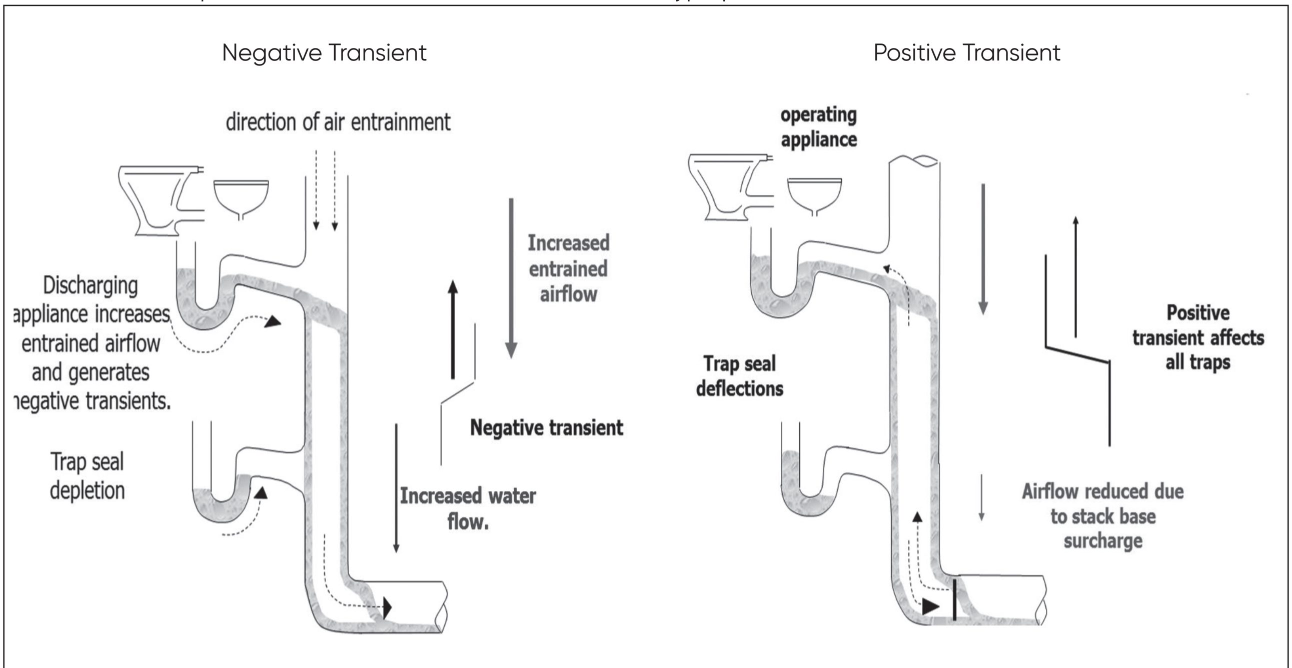

Figure 1.
Negative and positive transients

It is interesting to consider the consequences if the car speed is increased. If the cars were traveling at 70 MPH and the first car stopped abruptly then there is a good chance of a pile up, the driving equivalent of a Jowkowsky type pressure surge. [Jowkowsky determined that the magnitude of a pressure surge is dependent on the product of the velocity of the fluid, its density and its wave speed].

What do these pressure transients do in a building drainage system?

A negative transient will attempt to suck water out of a water trap seal. The pressure may not be sufficient to completely evacuate the water in one go, but the effect can be cumulative. A sewer negative transient greater than -500Pa, generated by a sudden increase in applied water flow-for example following and appliance discharge, may deplete a trap seal due to induced siphonage, caused by the discharge of water from another sanitary fixture connected to the same discharge pipe. As the water falls down the pipe and passes the branch pipe connected to it, it draws air from it, thus creating a partial vacuum and subsequently siphonage of the trap can take place. Bubble through may occur even if the trap is not completely lost.

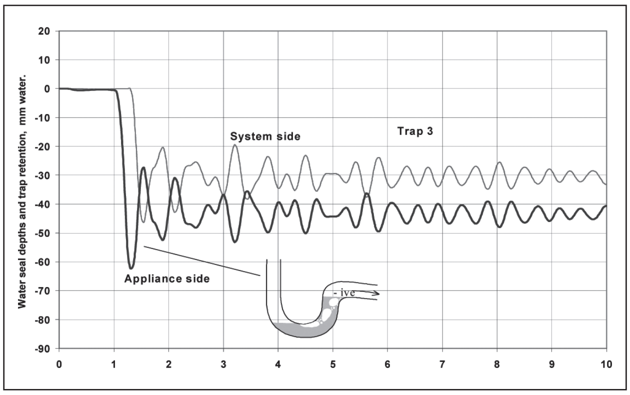

Figure 2.
Negative Transient

Positive air pressure transients cause air to be forced through the water seal from the sewer side to the habitable space inside. The positive transient generated by a sudden decrease in entrained airflow, for example the closure of the air path at the base of the stack due to a surcharge, may deplete a trap by forcing the contents up the appliance. Bubbling through may occur even if the trap is not completely lost, and the water barrier is breached and possible smells and pathogens may enter the living space.

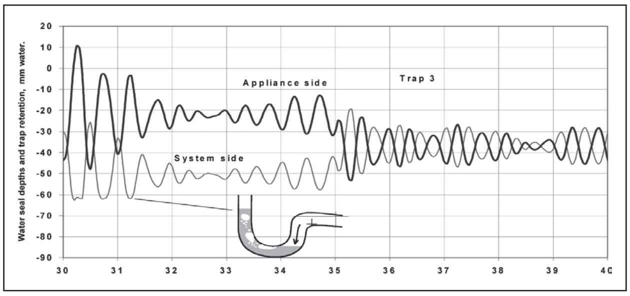

Figure 3.
Positive Transient

Conclusion

The need to communicate an increase or decrease in the air flow and the finite time that this takes is central to the requirements of providing a safely engineered drainage system. The absolute key to maintaining a state of equilibrium in a drainage system is to provide pressure relief as close to the source of an event as possible, in high-rise and more complex buildings the source of relief is a greater distance so the longer the time it takes for the system to respond. To limit the effect of these transients in taller buildings active drainage ventilation solution will reduce the response times or alternatively solution is to control the flow so that the air paths and the pressures generated in the system do not reach levels that the water trap seals are lost, stack-aerators control the flow and prevent the closure of the air paths in the system.

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