

Reducing the risk of cross-contamination from the building drainage system using the reflected wave technique



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Project Scope

The appliance trap seal is the primary defence against cross-contamination from the foul air present within the building drainage system. Failure of the trap seal, either as a result of poor system design or lack of maintenance, provides a potential route for the ingress of infection and disease. This research introduces a novel approach to system maintenance which, by employing the well-known mechanisms governing pressure transient propagation applicable to any fluid carrying system, offers a systematic method of remotely monitoring trap seal status as a preventative tool against the risk of cross-contamination.

Rationale

Trap seal retention remains one of the greatest concerns for engineers and system designers. Only by compliance with good design practice, to ensure the pressure response of the system does not exceed recommended limits, can trap integrity be safeguarded. However, the inherently unsteady flow regime that exists within the building drainage system as a result of the normal, yet random, appliance discharge ensures that trap seal depletion remains a major issue. The consequence of trap seal depletion was finally confirmed following the outbreak of severe acute respiratory syndrome (SARS) in Hong Kong in 2003 when 42 fatalities were attributed to the airborne transmission of the virus via an undetected depleted trap seal. Figure 1

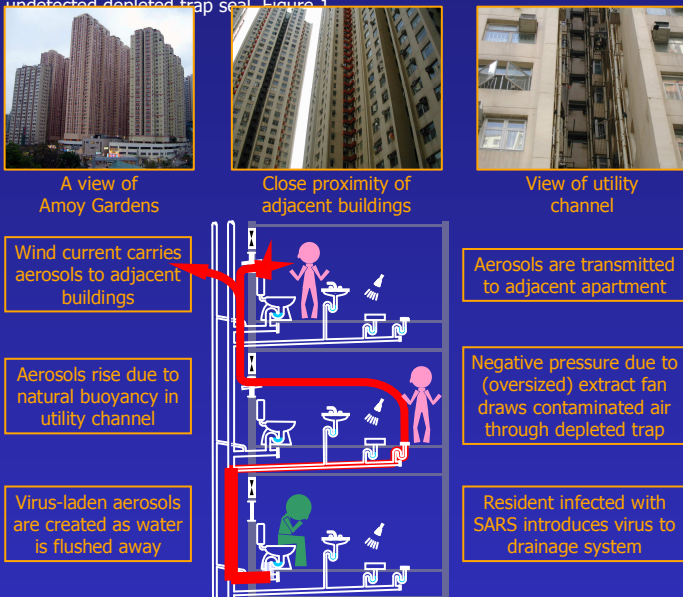


Figure 1: Amoy Gardens complex in Hong Kong and demonstration of the transmission route of the SARS virus

The reflected wave technique

Although normally considered a problem due to their ability to cause trap seal depletion, as a pressure transient propagates through the building drainage system, every boundary condition (whether it be a junction, an air admittance valve or a trap seal) will induce a characteristic reflection which alters the normal shape of the transient. Recognition of these reflections in the monitored system response and the identification of their return time, T_R , allows their location, L , to be determined provided the wave propagation speed, c , is known using:

$$T_R = \frac{2 \times L}{c}$$

The reflection induced by a trap seal is dependant upon the status of the trap. Responding to an applied positive transient a fully primed trap seal will generate a +1 reflection and a depleted trap seal will generate a -1 reflection, Figure 2. The presence of a depleted trap can therefore be identified by the change in reflection coefficient when compared with the response of the system under defect free conditions.

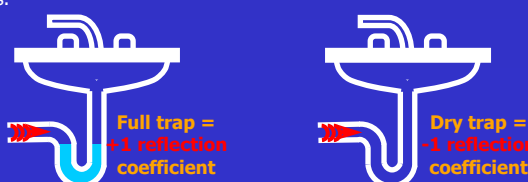


Figure 2: Demonstration of the characteristic reflection coefficient experienced at the trap seal boundary

Test methodology

Careful considerations are required when introducing a pressure transient into the building drainage system, Figure 3:

- To ensure the test is non-destructive, a sinusoidal transient wave is used which is generated by driving an electromagnetic piston at a frequency of 10 Hz. At this frequency the impact of the applied transient upon the trap seal is negligible.
- Directional control of the applied transient is provided by a 3-port valve installed within the upper dry stack. Under normal conditions the valve would remain in the "stack open" position, switching to the "stack closed" position during testing.

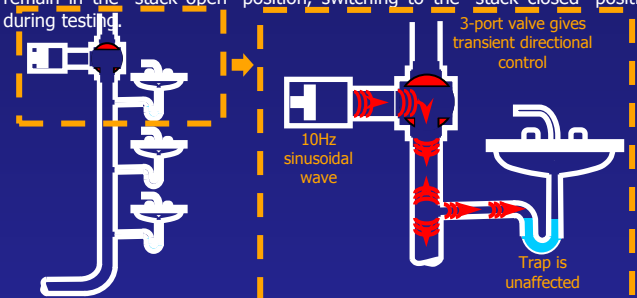


Figure 3: Demonstration of the characteristic reflection coefficient experienced at the trap seal boundary

To ensure effective protection against potential cross-contamination the entire system must be systematically monitored by an automated system test. Automatic data analysis is achieved by calculating the absolute difference, D_t , between the measured test system response, P_j^{DF} , and a previously obtained defect free baseline, P_j^M :

$$D_t = |P_j^{DF} - P_j^M|$$

Field trials

An extensive series of field trials have been undertaken to evaluate the performance, and to support the development, of the proposed system monitoring technique. Differing in complexity, the systems are summarised in Figure 4:



Figure 4: Three buildings used to validate the reflected wave technique during extensive field trials

During the field trials, all depleted traps were successfully detected and located with good accuracy. Figure 5 demonstrates the automatic data analysis used to identify a depleted trap during the Glasgow field trials.

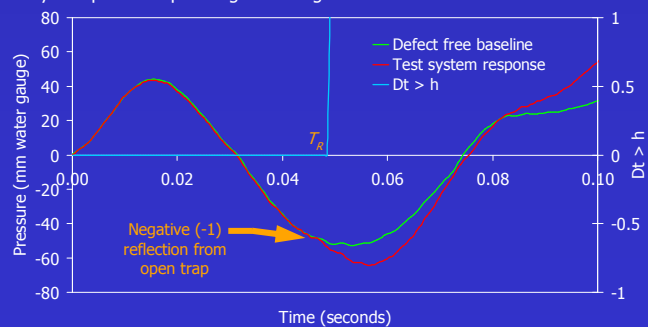


Figure 5: Automatic detection and location of a depleted trap seal during the Glasgow field trials

Future work

Further funding has been secured from Studor Ltd to develop this proposed monitoring test into a working prototype with the aim of establishing it as a marketable product to improve building drainage system maintenance.