Institution: Edinburgh Research Partnership in Engineering - ERPE (Heriot-Watt/Edinburgh)

Unit of Assessment: B15: General Engineering

Title of case study: Improving Public Health: Protecting Water-based Trap Seals for Complex and Multi-Storey Buildings

1. Summary of the impact (indicative maximum 100 words)

Research undertaken at ERPE on the unsteady flow and air pressure regime in building drainage networks led to the development of the Positive Air Pressure Attenuator - PAPA™ (http://www.studor.net/papa-system) and Dyteqta™ (http://www.dyteqta.com/introduction.html) devices which reduce the risk to health presented by the potential for cross-transmission of aerosolised pathogenic micro-organisms e.g. SARS. Since 2008, the PAPA™ has been installed in 300 plus buildings in 15 countries, reducing the risk of infection and improving air-quality for an estimated 20,000 people. Studor, who employ 9 people to market these devices, have increased turnover [removed for publication].

2. Underpinning research (indicative maximum 500 words)

The ERPE Drainage Research team of Professor Jack, Dr Campbell, Dr Gormley (joined 2000), Dr Kelly (joined 2006) and Professor Swaffield (deceased 2011) have been in post throughout the period unless otherwise stated. The team has enabled and enhanced the development of unsteady flow simulations to model the wastewater and air pressure regimes within building drainage networks.

Since 1993, our research has concentrated on the development of methods and technologies to support system integrity in building drainage networks. Should system integrity become compromised, the resulting linkage made between the miasma present within the drainage network and the habitable space occupied by the building user can, depending on circumstances, adversely affect public health due to the possibility of cross-contamination – a causative factor in the 2003 Amoy Gardens SARS outbreak in Hong Kong.

Following an extensive programme of EPSRC-funded research [G1,G2,G3], carried out during the mid-to-late 1990s, it became evident that although the focus of the design engineer had, to date, been on the prevention of excessively high negative pressures introduced as a result of appliance downflows, the positive pressures generated within a system were of a magnitude that could present significant risk to system integrity [1]. Around this time, Swaffield, Campbell and Jack were alerted to a number of trap-seal loss problems experienced in high-rise high-density residential accommodation in Hong Kong. Identification of this problem confirmed the relevance of application of the group's numerical simulation model, AIRNET, to problems of this type. Industry funding followed (2000-2001), enabling the employment of a full-time researcher (Gormley)

The three key research outputs were:

- The development of the PAPA™; a variable volume containment device that suppresses positive air pressure transients by providing an alternative route for, and deceleration of change of, airflow [2,3]. Related research established material and installation preferences; as well as confirming the validity of 'series mounting' and distributed positioning [4]. Additionally, this work led to patent GB2379459 (Pressure relief device in drainage systems).

- Extending this approach to suppression of both positive and negative air pressure transients, using the PAPA™ device and the already-in-use Air Admittance Valve (AAV) led to the proposal of the 'sealed building' methodology for complex buildings, where roof penetration may be avoided due to the positioning of localised intervention and the interconnection of vertical stacks [5].

- The development of the Dyteqta™ device, invented in 2004 and commercially launched in 2009 (http://www.dyteqta.com/press-releases.html), with patent registrations GB2441788, US

2010/0000298A1 in 2007 ("Method and equipment for detecting sealing deficiencies in drainage and vent systems for buildings"). It enabled the ability to identify defective trap seals in complex buildings and made direct use of the AIRNET simulation model developed by the Drainage Research Group. By coupling this with a pressure surge generator, the Dyteqta^{TM} can be installed in a building to detect system failure, irrespective of its location or the cause of the trap seal loss.

The last of the above key outputs arose from making a link between the ability to prevent trap-seal loss and the detection of points within the network that have already been inadvertently comprised. EPSRC and industry-funded research [G4] undertaken between 2006 and 2008 enabled the employment of an additional researcher (Kelly) and led to the development of the first non-invasive, non-destructive, remote access monitoring system to detect depleted trap seals in complex buildings. The group recognised that depleted trap seals contributed to the 2003 SARS outbreak in Hong Kong and that knowledge of the trap-seal condition would have prevented some of the infection spread. Based on pressure transient theory, research suggested that the altered reflection coefficients for full or empty trap seals could be used to detect and locate a depleted trap as the system response to a low amplitude short duration sinusoidal pressure transient introduced into the network would show a change relative to a defect-free baseline [6].

3. References to the research (indicative maximum of six references)

The references identified with * are the ones which best indicate the quality of the underpinning research.

[1] Swaffield, J.A., Jack, L.B., 'Drainage Vent Systems: Investigation And Analysis Of Air Pressure Regime' Building Service Engineering Research and Technology, 1998; vol. 19: pp. 141-148. DOI:10.1177/014362449801900305 10 Google Scholar (GS) citations.
This publication presents evidence from site tests that confirm the presence of positive pressures of sufficient magnitude to present a risk to trap seal retention. It also establishes a numerical relationship between these pressures and design, and imposed flow, characteristics.

[2] Swaffield, JA, Jack, LB, Campbell, DP, Gormley, M, 'Positive Air Pressure Transient Propagation In Building Drainage And Vent Systems', Building Services Engineering Research and Technology, Vol. 25, No. 2, pp. 77-88, 2004. DOI:10.1191/0143624404bt080oa
This publication identifies sources of positive transients (from, for example, surcharged or offset pipework), and presents developments in understanding and modelling of transient propagation.

[3] * Swaffield, JA, Jack, LB and Campbell DP., 'Control And Suppression Of Air Pressure Transients In Building Drainage And Vent Systems'. Building and Environment, Vol. 39, No. 7, pp. 783–794, 2004. DOI:10.1016/j.buildenv.2003.12.003 19 GS citations.
This publication presents the first illustration of the transient control and suppression methodology used in development of the PAPA^{TM}, highlighting the basic principle of providing an alternative airflow path while deceleration at a reduced rate is enabled.

[4] * Swaffield J.A., Campbell D.P. and Gormley M., 'Pressure Transient Control: Part II—Simulation And Design Of A Positive Surge Protection Device For Building Drainage Networks', Building Services Engineering Research and Technology, 2005; vol. 26(3): pp. 195 - 212. DOI:10.1191/0143624405bt120oa
This publication focuses on the proof-of-concept, supporting simulation and design of the PAPA^{TM}. It also presents recommendations for bag material and positioning of devices (including the validity of series mounting and distributed installation).

[5] Swaffield J.A. (2006) 'Sealed Building Drainage And Vent Systems – An Application of Active Air Pressure Transient Control And Suppression.' Building and Environment, 41, 2006, pp1435-1446. DOI:10.1016/j.buildenv.2005.08.011
This publication confirms the validity of the 'sealed' building methodology as an option for complex buildings. The work focuses on modelling the impact of localised intervention of pressure transients to protect trap seals.

[6] * Kelly, D.A., Swaffield J.A., Jack L.B., Campbell D.P. and Gormley M., 'Pressure Transient Identification of Depleted Trap Seals: A Sinusoidal Wave Technique', Building Services Engineering Research and Technology, Vol. 29, No. 3, pp. 219-232, 2008. DOI:10.1177/0143624408091321
This publication confirms the suitability of the introduction of a sinusoidal pressure wave to identify depleted trap seals. It shows that use of a sinusoidal wave ensures that the imposed wave does not, in itself, present a risk to trap seal integrity.

Grants

[G1] EPSRC GR/H91367/01 £96k Swaffield (PI) "Building Drainage Vent Systems Design Based On Transient Air Pressure Analysis" 1993 – 1997

[G2] EPSRC GR/K81997/01 £108k Campbell, Swaffield (PI) "Determination Of The Effect Of Common Detergents On Building Drainage Ventilation System Performance" 1996 – 1998

[G3] EPSRC GR/L49949/01 £78k Swaffield (PI), Campbell Simulation Of Building Drainage Vent System Operation 1997 –2000

[G4] EPSRC EP/D027969/1 £163k Swaffield (PI), Campbell "Transient identification of the location of defective water seal traps within building drainage and vent systems." 2006 – 2008

4. Details of the impact (indicative maximum 750 words)

The impacts of ERPE research in Drainage systems are the PAPA™ device to limit positive transients and the trap seal detection device (Dyteqta™) to enhance public health for all building users. Studor – an international company working in the area of drainage design and surge suppression, market the PAPA™ and Dyteqta™ devices and promote, where applicable, use of the sealed building methodology (referred to by Studor as the 'Studor Single Pipe System, SPSS').

Impacts include:

- Enhanced protection of the internal space within buildings that now integrate the PAPA™. The PAPA™ has been widely used in remedial action to limit the adverse effects of positive transients in apartment blocks and housing complexes both in the UK and internationally. Examples include their use in the Greenwich Creekside building in London which, prior to this retrofit, had experienced unpleasant smells that made their way to the 15th Floor penthouse apartment, and the retrofit of 63 PAPA™s in the 1025 apartment Pak Tin Housing Estate in Hong Kong where continual trap seal loss and water ejection into the habitable space have now been prevented.

- Installation of both the PAPA™ and the 'already-in-use' Air Admittance Valve (AAV) to limit both positive and negative transients. The initial thrust of this development was aimed at security sensitive buildings but its first application was the refurbished O2 Dome venue in East London. The AIRNET simulation allowed the feasibility of a sealed system, relying on PAPA™ and AAV technology to limit both positive and negative transients, to be understood. During conversion of the O2 Dome (http://www.studor.net/reference/title/theo2/id/435) from a temporary structure to a permanent entertainment and conference space, a local council directive deemed the in-situ ventilation stacks inadmissible as a future design solution; meaning that, at that time, the only options were either to penetrate the tented roof structure or to run long lengths of pipework externally. However, the subsequent specification and use of PAPAs and AAVs meant that the Dome's iconic roof design was able to be preserved and the installation of costly external pipework avoided. This impact has provided an exemplar for similar installations worldwide. An example is the Ferrari World Theme Park in Abu Dhabi that utilises 110 PAPA™s (http://www.studor.net/blog/2013/06/sleek-roof-for-ferrari/) which enabled construction of the eye-catching car-like roof structure and in doing so, reduced associated material, time and labour costs. In addition, for the Hamilton Harbour housing development in Brisbane, Australia, the use of the SSPS system has been shown to have reduced the cost of drainage provision by $52,365 Aus. - more than 17% compared to a traditionally vented solution.

- The ability to identify defective trap seals in complex buildings through use of the Dyteqta™ device, launched as a commercial entity in 2009. This device makes direct use of the AIRNET simulation model developed by the Drainage Research Group and by coupling this with a pressure surge generator, can be installed in a building to detect system failure; irrespective of its location or the cause of the trap seal loss. This removes the need for visual inspection of trap seals; an activity that is both impractical and difficult to sustain. The target market for the Dyteqta™ is that of Healthcare (Dyteqta.com), where the prevention of cross-transmission of pathogens is particularly crucial. The Dyteqta™ device is now marketed internationally and underwent an initial in-situ 8-day Proof of Concept trial in Gothenburg, Sweden in November 2012.

The PAPA™ continues to mature and gain acceptability globally. The device complies with the Australian Technical Standard ATS 5200.463-2005, and has been approved for installation in USA based on the ANSI approved standard ASSE 1030:2013 '*Performance Requirements for Pressure Reduction devices for Sanitary Drainage Systems*' (which has performance requirements written by Gormley). This document includes the international test standard for the evaluation of all pressure reduction devices used in sanitary drainage systems for buildings. An exact replica of the test apparatus has been constructed by the National Science Foundation (NSF International) in the U.S. for accreditation of all pressure reduction devices. Additionally, the PAPA™ is currently being evaluated by the British Board of Agrément (BBA) for further certification for applications in the UK.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[S1] Business Development Manager, Studor Ltd will confirm that since 2008, the PAPA™ has been installed in 300 plus buildings in 15 countries, reducing the risk of infection and improving air-quality for an estimated 20,000 people. He will additionally confirm the employment of 9 people to market these devices, and Studor's increased turnover [removed for publication].

[S2] Chairman of the 2013 Product Standards Committee, ASSE will confirm the centrality of Gormley's work to the standard ASSE 1030:2013 'Performance Requirements for Pressure Reduction devices for Sanitary Drainage Systems'

[S3] Member of the British Board of Agrément will advise how the BBA intend to certify PAPA™