

G5) Development of Smart Floor Trap for Enhanced Seal Protection

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Abstract

SARS outbreak in 2003 has imposed a threat on a communicable infection which human body has little or no immunity. However, it has triggered an intensive research on how it spreads within the building space. The report by an investigation delegate from World Health Organization on the plague occurred in Amoy Garden concluded that the SARS virus transmitted via the re-entrants and drainage stacks of the residential buildings. Since then, it has become a common sense for citizens that traps and floor drains in drainage systems should be kept filled up by water all the time.

Floor traps in the bathrooms and kitchens are short falls in keeping them filled up because people now only mop floors for cleaning rather than wet it. More often, floor traps are left dry when the occupants take a week long vacation. It reduces the risk of contaminated air flow from drainage stacks into indoor spaces if the floor drains can hold water for a longer drying period without increasing the currently adopted size of the drain in practice. This paper describes a new design of floor traps which increases the drying period. This paper also describes the design of a test rig which facilitates the test of floor traps for its drying up performance.

Keywords

Floor traps; evaporation; test rig

1. Introduction

Outbreak of the SARS in 2003 was absolutely a tragedy. The main cause of the Amoy Garden tragedy was due to the spread of the virus via the drainage pipe as the U-shape water trap is dry out. The U-shape water seal is not quite reliable. People are unaware of it as it is located outside the building. Some even blamed that the resident should be responsible for the tragedy as they have not regularly kept the U-trap filled with water.

Excess drainage stack air pressures can decrease water seal of floor trap; however, even there is no effect of air pressures, evaporation must be considered as another main factor which dry out water seal of the trap.

2. Evaporation

Hong Kong has a sub-tropical climate, with cool dry winters and hot wet summers. In summer, the highest temperatures often exceed 32° C. Many tall buildings are constructed closely to each other, so that natural ventilation by wind is not sufficient to decrease heat load on surface of building. Buildings absorb heat and convert to floor slab and wall. When air-conditioning adjusts cooler temperature inside the flat, it causes high temperature difference inside and outside the building. Floor traps being heated outside have a higher evaporation rate and are easy to get dry.



Figure 1 - High and Density Residential Buildings



Figure 2 - Floor trap installed outside a building

3. Type of floor traps

3.1 Traditional floor traps are P trap, S trap and bottle trap



Figure 3 - P, S and bottle traps

These designs (U trap outside the wall, easily blocked but difficult to clean) are widely used in Hong Kong.

Many people aware about the height of water seal which is decreased by excess air pressure inside the drainage stack. The deep water seal is recognized as 70 mm and the minimum is 50mm. However, many people ignore floor trap which can be dried because of evaporation.

3.2 Innovative design-water loss prevention in the water seal –smart trap

Smart trap is a bell type floor trap. The most significant difference with the above-mentioned one is that it has larger buffer space to recover the loss of evaporation.

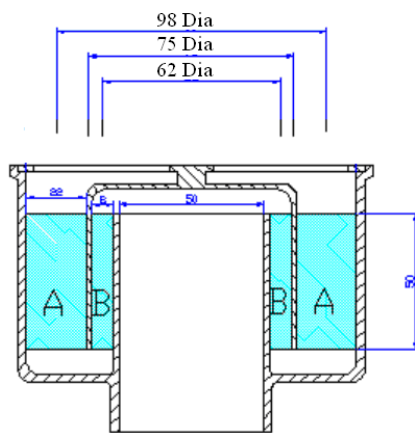


Figure 4 - Bell type floor trap

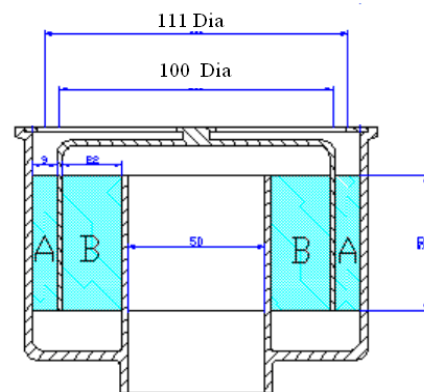


Figure 5a - Smart Bell type floor trap



Figure 5b - Elevation of Smart trap



Figure 5c - Top of Smart trap

Smart trap introduce a new concept: Safety of floor trap not only depends on the height of water seal. It considers the contact surface of water to atmosphere. An innovated design of minor consumed trap is illustrated above. The appearance of floor traps in Fig4 and Fig 5a are the same, but they vary in their ability of water retention. From 5a,

Smart trap possess front (A zone) and back (B zone) water seals. They have different volume of water seal and have different retention duration of water seal.

3.2.1 Making a calculation in figure 4: (Bell type $D = 75\text{mm}$)

Area of water seal	$F_A = 22 \times 98 \times 3.14 = 6769.84\text{mm}^2$ $F_B = 8 \times 62 \times 3.14 = 1557.44\text{mm}^2$
Total area of water seal	$F_T = 6769.84 + 1557.44 = 8327\text{mm}^2$
Total consumption of water seal	$\omega_T = F_T \times 50 = 416364\text{mm}^3$
Total suction of water seal	$\omega_S = F_A \times 50 = 6769.84 \times 50 = 338492\text{mm}^3$
Daily evaporation of water seal	$\omega_E = F_A \times 2 = 6769.84 \times 2 = 13539.7\text{mm}^3$
Residue of water seal after suction	$\omega_R = \omega_T - \omega_S = 77872\text{mm}^3$
Safety period of water seal	$\text{Day} = \omega_R / \omega_E = 77872 / 13539.7 = 5.8$

3.2.2 Making a calculation in figure 5a: (Smart Bell type $D = 100\text{mm}$)

Area of water seal	$F_A = 8 \times 111 \times 3.14 = 2788.3\text{mm}^2$
Total area of water seal	$F_T = 6769.84 + 1557.44 = 8327\text{mm}^2$
Total consumption of water seal	$\omega_T = F_T \times 50 = 416364\text{mm}^3$
Total suction of water seal	$\omega_S = F_A \times 50 = 2788.3 \times 50 = 139415\text{mm}^3$
Daily evaporation of water seal	$\omega_E = F_A \times 2 = 2788.3 \times 2 = 5576.64\text{mm}^3$
Residue of water seal after suction	$\omega_R = \omega_T - \omega_S = 276949\text{mm}^3$
Safety retention period of water seal	$\text{Day} = \omega_R / \omega_E = 276949 / 5576.64 = 49.7$

All of them have 50mm discharge pipes. From calculation, higher water seal loss is found in traditional bell trap and efficiency of recovery is low. The smart bell trap is improved by means of cascaded arrangement. It owns 2 tiers water seals, the front tier (F_A) is smaller contact surface for evaporation and the back tier (F_B) possess larger water seal. F_B is to backup and compensate loss of water seal in F_A . Neglect environmental conditions, such as wind speed at ground surface, temperatures difference between inside and outside of traps. Smart trap owns longer retention period (50 days) of water seal.

The retention of water seal for floor trap is also a concern. It is required to consider not only the height of water seal, but also its retention period. Surface area of water seal plays an important role here.

4. Evaporation rate of smart trap and U Trap

A direct evaluation of the theoretical mass transfer equation (Aerodynamic Equation) used to calculate evaporation from water surface.

4.1 Evaporation model

$$E = (\rho r / P)(e_0 - e_z) f(u_z)$$

Where E = evaporation rate (in $\text{g}/\text{cm}^2 \cdot \text{sec}$)
 ρ = density of air
 r = ratio of the molecular weight of water to the molecular weight of air
 P = ambient pressure
 e_0 = vapor pressure of water at the water surface
 e_z = vapor pressure of water at elevation of z
 u_z = wind speed at elevation z

A simple form of the wind friction is

$$f(u_z) = C_z u_z \quad \text{where } C_z = \text{drag coefficient}$$

The equation transforms into experience formula and is for the calculation of evaporation is:

$$E = -\rho * L * k * f(u_z) * (q_0 - q_z) / \ln(z/z_0)$$

where E is evaporation, ρ is air density, L is the latent heat of vaporization, k is von Karman's constant, $f(u_z)$ is the friction velocity, $(q_0 - q_z)$ is the specific humidity difference between the air and near the water surface, $\ln$ is the natural log, z is the height of the dew point temperature measurement, and z_0 is a height near the water surface.

ρ can be approximated as $0.0012 \text{ g}/\text{cm}^3$, L is approximated by $598 \text{ cal}/\text{g}$, k is 0.38 and convert wind speed to cm/s ($100 \text{ cm}/\text{s}$ will be used). Assume $f(u_z)$ is to be one tenth of the wind speed ($10 \text{ cm}/\text{s}$). Air pressure is converted to mBar and point of temperature measurement height to cm .

By experience formula, the vapor pressure in mb (e_z) for the air dew point temperature (at z) and the vapor pressure in mb (e_0) for the water temperature (at z_0 , which will be close to the dew point near the water surface because the air there is almost saturated) using the following equation for both:

$$e = C_0 T^0 + C_1 T^1 + C_2 T^2 + C_3 T^3 + C_4 T^4 + C_5 T^5 + C_6 T^6$$

Where
 $C_0 = 6.11$
 $C_1 = 0.4437$
 $C_2 = 0.014289$
 $C_3 = 0.000265065$
 $C_4 = 0.00000303124$
 $C_5 = 0.000000020340809$
 $C_6 = 0.00000000006136821$

and where the temperature T is in degrees C; also note that each coefficient is multiplied by as many T s as the number in the coefficient.

The specific humidities (unitless), q_z (at z) and q_0 (at z_0) can be calculated from the following equation:

$$q = (0.622 \cdot e) / (P - 0.378e)$$

Where P is atmosphere air pressure ($P = 1000$ mBar). Using the above information, evaporation rate can be estimated.

4.2 Setup of test rig

In Hong Kong, U trap is usually used as floor trap and bell trap is not common. A test rig had been set up to verify the evaporation rate of Smart trap and P trap. An air chamber is employed for this issue. There are 2 approaches: The first one uses model 4.1 above to evaluate the evaporation rate of Smart Trap and U Trap. It requires to measure different z_0 , z , T_0 and T_z . The second one is to measure evaporation rate of traps (survey over 100 hours) in an air chamber which will describe later.

The air chamber possesses steel case with insulated function (inner volume: $720 \times 510 \times 550$ height mm^3). Inner temperature and air flow can be controlled. All floor traps are installed outside the chamber, and water seal of the trap can be checked visually. Temperature inside the traps can be controlled by an external heater and can be measured.

2 traps are placed out of air chamber but their inlets are installed inside the chamber (Figure 6a to 6c).



Figure 6a



Figure 6b



Figure 6c

Fig 6a to 6c are test rig for evaporation, U trap and smart trap are installed for testing. 6a and 6b show appearance of air chamber. Traps are placed outside and control hot temperature by a heater. 6c is wind velocity controlled by 2 fans. An anemometer (includes thermal meter) is placed in air chamber and located above the traps to measure wind velocity and temperature. The level of pan is z and z_0 which is above water level of trap water seals.

Firstly, related traps are heated to a temperature that is similar to summer in Hong Kong (say 30°C) and temperature inside the air chamber will be cooler (say 28°C). It simulates a model that floor trap is placed outside (Figure 2) the building. In the air

chamber, temperature is simulated as an indoor condition. It simulates an inner condition of a toilet with a wind speed below 1m /s.

A thermal meter is to measure the temperatures at surface of water seal of traps.

4.2.1 Estimation of evaporation rate of floor traps

4.2.1.1 P trap, with size 50mm dia drain pipe



Figure 7 - P trap is used to measure its evaporation rate

Measured data:

$Z = 38.1 \text{ cm}$
 $Z_0 = 21.1 \text{ cm}$ (near water surface)
 $T_z = 28^\circ\text{C}$
 $T_0 = 30.7^\circ\text{C}$
 $V_{\text{Wind}} = 100 \text{ cm/s}$

Evaporation Rate is calculated by model
 $E = 0.01886 \text{ cal/cm}^2/\text{s}$
 $= 789.27 \text{ W/m}^2$

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Figure 8 - Smart trap is used to measure its evaporation rate

Measured data:

$Z = 19.7 \text{ cm}$
 $Z_0 = 1.9 \text{ cm}$ (near water surface)
 $T_z = 28^\circ\text{C}$
 $T_1 = 31.9^\circ\text{C}$
 $V_{\text{Wind}} = 100 \text{ cm/s}$

Evaporation Rate is calculated by model
 $E = 0.00711 \text{ cal/cm}^2/\text{s}$
 $= 297.4 \text{ W/m}^2$

The estimation result for evaporation rate is that Smart trap is less 2.6 times than P trap.

4.2.2 Measurement of evaporation rate of floor traps

In the second approach, when the floor traps are placed outdoor, they suffer higher wind speed at surface of inlet. Temperature at the inlet is higher than the surface of water seal.

A test was held to measure seal loss under these conditions (Figure 9a~b). The Smart and U traps were placed inside the air chamber. Temperature at surface of inlet surface is to maintain at 33°C and surface of water seal is at 29°C . Wind velocity at the top surface of traps is adjusted to 2.5m/s. From test record, the initial reading of water seal:

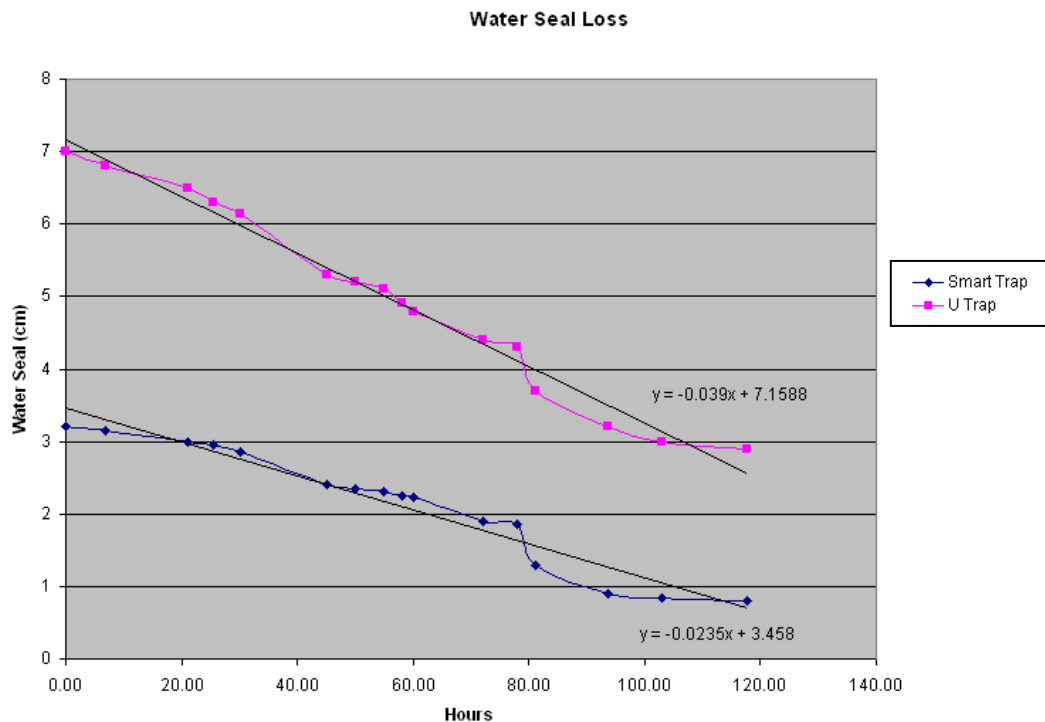
Smart and U traps started from 3.2 cm and 7cm respectively, then the test runs continuously over 100 hours under these parameters.



Figure 9a - Air Chamber



Figure 9b - Evaporation Test for U and Smart



Under captioned wind speed and temperatures, for 100 hours, test result (figure 10) shows that evaporation rate (based on height of water seal) for U trap is 0.032 cm per hour (0.3 mm/hour) and 0.011 cm per hour (0.1 mm /hour). 2 regression formulas are found from the test results and used for calculation as below:

If the evaporated rate is based on loss of water volume, U trap and Smart trap shows:

$$\text{Water evaporated from U trap} = \pi \times (5/2)^2 \times (0.032) = 0.62 \text{ cc / hour}$$

$$\text{Water evaporated from Smart trap} = \pi \times (0.8 \times 6.2) \times (0.011) = 0.17 \text{ cc /hour}$$

Evaporated rate of Smart trap is less than U trap for 3.6 times.

5. Conclusion

Good design of floor traps benefits the health of our living environment. Smart trap provides a new concept of 2 tier water seals. Two water seals are not standalone and have different sizes. Front water seal contact the outside atmosphere and suffer from various conditions (e.g. wind speed, temperature difference). The back water seal is larger than the front so that it can backup the loss in the front water seal. A new concern for water trap is water retention period apart from the height of water seal.

The new design has been proved to be applicable and it functions better in water retention.

6. Reference

1. Hong Kong weather: <http://www.chinahighlights.com/hongkong/weather.htm>
2. Chan Iat Keong (June 2008). The functions and installation of PVC drainage traps with an anti-siphon valve, Hong Kong: Journal of Hong Kong Engineer in p19.
3. Frank E. Jones (1992). Evaporation of Water with Emphasis on Applications and Measurements, Michigan: Lewis Publishers, Inc.
4. David R. Cook. , Ask a Scientist, <http://www.newton.dep.anl.gov.htm> Atmospheric Research Section, Environmental Research Division, Argonne National Laboratory.

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7. Presentation of Authors



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