Study of the Pressure Resistance of Odour Traps

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The paper deals with the study of the pressure resistance of odour traps, which are the only ones that protect the interior from the spread of unpleasant smells and viruses from the building's drainage system. The study was carried out on two reference types of odour traps based on earlier research and our simulation in Ansys.

Keywords: pressure fluctuations, drainage system, sanitary appliances, odour traps, viruses, smells

Odour traps are the only protection against the spread of unpleasant odors and viruses from the building's drainage system. The issue of pressure fluctuations in the foul water stacks and its effect on the water level in the odour traps is not new, but the pandemic situation associated with SARS-CoV-2 has brought it up to date once again. There has been a lot of research in recent years that confirms the presence of this virus in the building's sewer system. When the function of the odour traps is lost, this virus can get out and endanger the health of the building occupants [1, 2]. Overpressure occurs most often over stack direction changes as a result of hydraulic jump, **Figure 1b**. At lower overpressure values, water bubbles in the traps, and at higher values, water is ejected or knocked out from sanitary appliances. Negative pressure occurs in the stack at the connection points of the branch pipes with the flow or below the change of direction of the stack where the air core of the stack closes, **Figure 1a, c**. When the negative pressure limits are exceeded, water is sucked out of the odour trap [3].

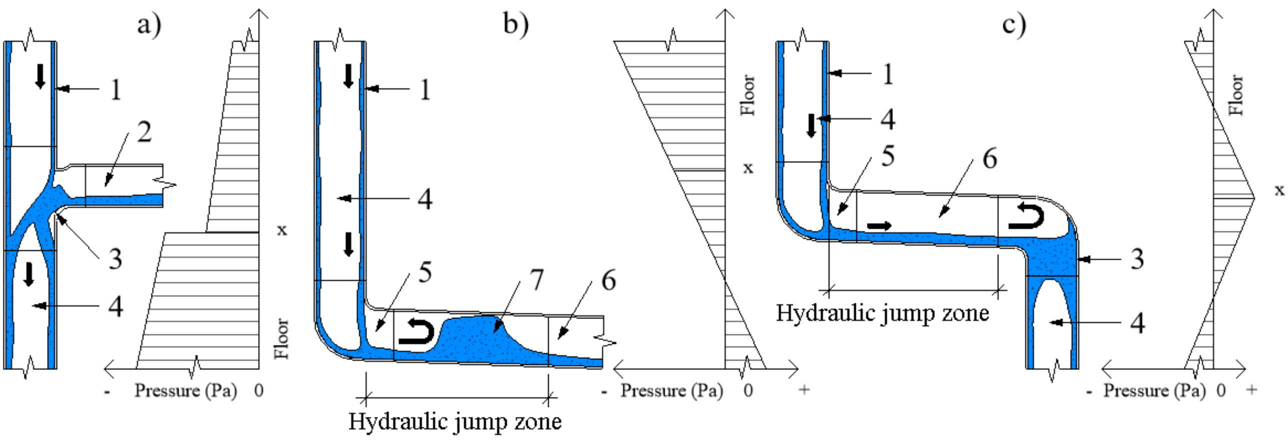

Figure 1. Water flow and pressure fluctuations in the waste pipe. a) at the point of connection of the branch pipe to the stack, b) at the point of transition of the stack to the drain, c) at the point of stack offset, 1 – annular flow, 2 – water flow from the branch pipe, 3 – piston effect, 4 – air core, 5 - water impact on the wall of the arc, 6 – steady state flow regime, 7 – hydraulic jump.

Pressure resistance of odour traps

According to EN 12056 [6] and Slovak national standard STN 73 6760 [7], the minimum water level in the trap at the connection to a foul water pipe is h_{tot} = 50 mm, and at the connection to the rainwater pipe, it is h_{tot} = 80 mm. The pressure resistance of odour traps at different water level heights is shown graphically in **Figure 2**. The pressure resistances were calculated based on formulas that were developed in the 1980s and are still in use today [4]. However, these formulas have one major drawback in that they do not take into account the shape of the odour traps, which has a major impact on its pressure resistance. Currently, there are a large number of 50 mm odour traps on the market that have a pressure resistance of around 400 Pa or quite a bit higher, which does not correspond to these calculations. This information is also not found in the manufacturers' datasheets, which would greatly reduce the error rate of the designs.

Mathematical simulation of the pressure resistance of an odour trap

Our simulation observed the effect of pressure fluctuations in a stack on the water level in the trap. Two reference traps, which are most commonly used for sinks or basins and toilets, were used, **Figure 3a, b**. Pressure ranging from – 550 Pa to + 1500 Pa was

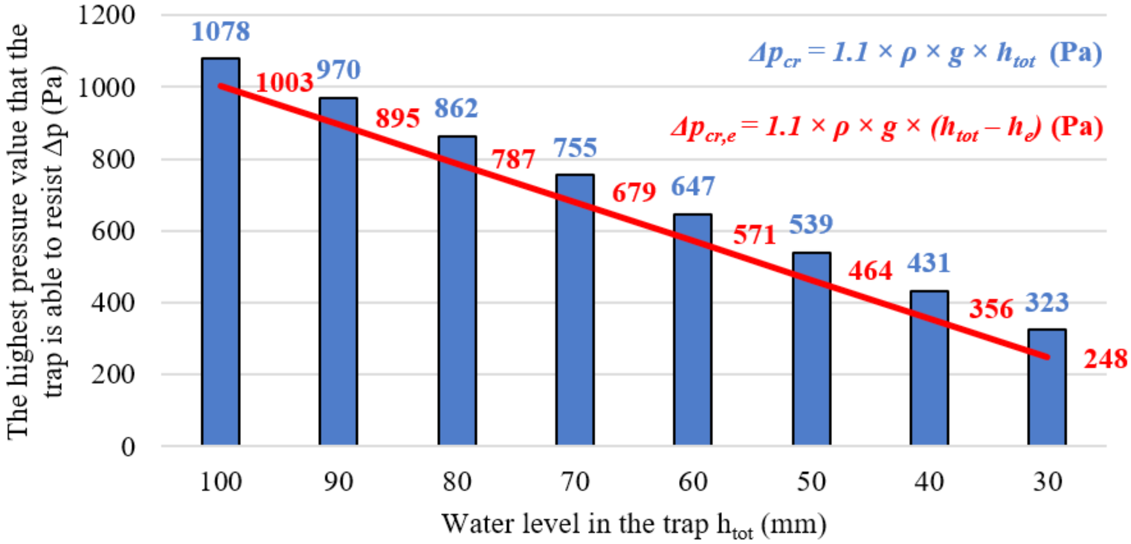

Figure 2. Resistance of the trap to pressure according to the water level. ■ without taking into account evaporation according to Formula (1), ■ taking into account the evaporation after 14 days of not using the sanitary appliance (evaporation 0,5 mm/day), Δp_{cr} – the maximum pressure that the trap can resist (Pa), ρ – water density (kg/m^3), g – gravitational acceleration (m/s^2), h_{tot} – the height of water in the trap (m), h_e – decrease of water in the trap due to evaporation (m).

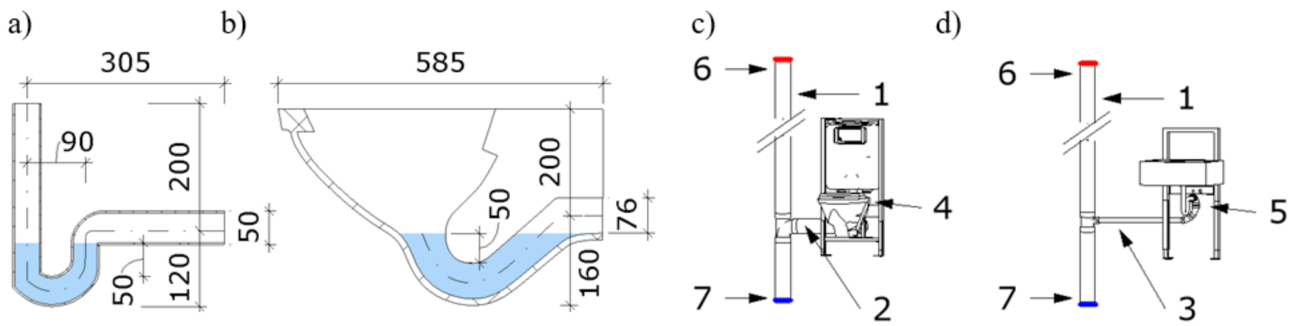

Figure 3. Traps used for simulation. a) trap for sink or basin with 50 mm height of the water, b) trap for WC with 50 mm height of the water, c) WC connection to the stack, d) connection of the sink or basin to the stack, 1 – DN 100 stack, 2 – DN 100 branch pipes with a length of 1 m, 3 – DN 50 branch pipes with a length of 1 m, 4 – the trap for WC with a water seal height of 50 mm, 5 – the trap for the sink or basin with a water seal height of 50 mm, 6 – pressure outlet (atmosphere), 7 – pressure inlet (– 550 to + 1500 Pa).

simulated in the stack. The range of values was chosen based on various experimental measurements outside of Slovakia, where similar ranges of pressures were measured [4, 5]. The boundary conditions of the simulation are shown in **Figure 3c, d**. The following inputs and settings were used for the simulation:

- the trap contained water with a density of 999.1 kg/m³,
- air with a density of 1.225 kg/m³ was present in the stack and branch pipe,
- pressure values ranging from – 550 Pa to + 1500 Pa were generated in the stack [4, 5],
- calculations were performed with 1000 time steps, a time step length of 0.005 s, and a number of iterations per time step of 40.

The following water level conditions were monitored in the trap:

- water level fluctuations due to overpressure or negative pressure (without compromising the functioning),
- the suction of part of the water due to negative pressure (without compromising the function/ with compromising the functioning),
- complete suctioning of the water due to negative pressure (loss of function),
- water bubbling due to overpressure (loss of function),
- ejection of water due to overpressure (loss of function).

Effect of negative pressure on the water level in the trap

The traps from **Figures 3a, c**, were tested for negative pressures ranging from 0 to 550 Pa. The above-mentioned water level conditions were observed in the trap. The toilet trap, which could withstand a negative pressure of p_n = 525 Pa without any loss of function, achieved the best results in this test. The trap for the basin or sink withstood a negative pressure of p_n = 475 Pa. The detailed simulation results are shown in **Table 1** and **Table 2**.

From the point of view of safety, the lowest risk of sucking water out of the water seal is the negative pressure $p_n \leq 300$ Pa. At these values, the water drop in the trap is minimal, **Figure 4a**. The safest design method is to assess the stacks for a negative pressure $p_n \leq 300$ Pa. There was more water suction from the trap and a negative pressure from 300 to 450 Pa, but the functioning of the trap was not compromised. The maximum recorded water drop in the trap was 25 mm, **Figure 4b**. Considering issues of safety and

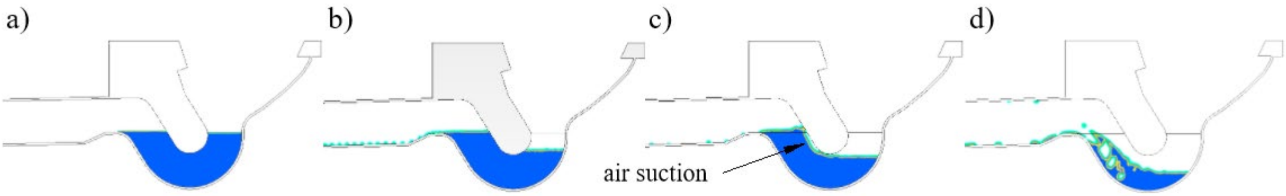

Figure 4. Effect of negative pressure on the water level in the trap. a) no impact on the water level, b) water level losses (without compromising its functioning) c) water level losses with air intake from the interior (compromising its function) d) complete suction of water from the odour trap (loss of functioning).

Table 1. *Effect of negative pressure on the water level in the sink trap.*

Negative pressure p_n (Pa)	Effect on the water level
≤ 300	without compromising its functioning, drop in water minimal
300 to 450	without compromising its functioning, drop in water up to 25 mm
450 to 475	compromising its function, drop in water up to 30 mm, suctioning of air from the interior
> 475	loss of functioning, complete suction of water from the trap

Table 2. *Effect of negative pressure on the water level in the WC trap.*

Negative pressure p_n (Pa)	Effect on the water level
≤ 300	without compromising its functioning, drop in water minimal
300 to 450	without compromising its functioning, drop in water up to 25 mm
450 to 525	compromising its function, drop in water up to 35 mm, suctioning of air from the interior
> 525	loss of functioning, complete suction of water from the trap

costs, assessing stacks to a negative pressure $p_n \leq 450$ Pa is an economical solution and is still relatively safe.

Effect of overpressure on the water level in the trap

The traps from **Figures 3a, c**, were tested for overpressures ranging from 0 to 1500 Pa. The high overpressure range was chosen based on experimental measurements from outside of Slovakia when the overpressure of 1500 Pa was measured. The overpressure was measured at the incorrectly chosen technical solution of the stack offset in a 9 – story building [5]. The above-mentioned water level conditions were observed in the trap. The best results in this test were achieved by the toilet trap that could withstand an overpressure p_o = 875 Pa without any loss of functioning. The trap for the basin and sink withstood an overpressure p_o = 725 Pa. The detailed simulation results are shown in **Table 3** and **Table 4**.

From a safety point of view, an overpressure of $p_o \leq 725$ Pa (sink, basin) and $p_o \leq 875$ Pa (WC) runs the lowest risk of the water bubbling or the ejection of water from the sanitary appliance. At these values, the water level in the trap only fluctuates, without any undesirable processes occurring, **Figure 5b**.

The problems with the high overpressure values cannot be solved by the correct design of the stack's dimensions. An incorrectly resolved change in the direction of the stack can cause overpressure above 1000 Pa even in low buildings (10 floors). Nowadays, there are various accessories for stacks, including positive pressure attenuators, which can sufficiently eliminate such high values.

Summary of results

Based on the simulation of the effect of pressure on the water in a trap, it can be stated:

- the safest solution is to assess the stacks for a negative pressure of $p_n \leq 300$ Pa, which has a minimal effect on the water level in the trap,
- after taking into account the costs and safety, it is acceptable to design stacks for
- a negative pressure of $p_n \leq 450$ Pa when there is a drop in the water in the trap, which does not endanger its functioning,
- at a negative pressure of $p_n > 450$ Pa, the functioning of traps is compromised due to the suctioning of air from the interior; and when $p_n > 475$ Pa, the functioning of the trap ceases due to the suctioning of the water seal,

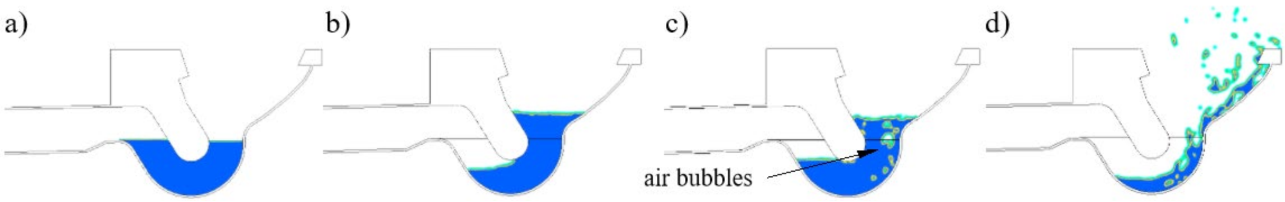

Figure 5. Effect of overpressure on the water level in the trap. a) no impact on the water level, b) water level fluctuations (without compromising its functioning), c) water bubbling (loss of function), d) complete ejection of water (loss of function).

Table 3. *Effect of overpressure on the water level in the sink or basin trap.*

Overpressure p_o (Pa)	Effect on the water level
≤ 725	without compromising functioning, water level fluctuations
725 to 1025	loss of function, water bubbling
> 1025	loss of function, complete ejection of water

Table 4. *Effect of overpressure on the water level in the WC trap.*

Overpressure p_o (Pa)	Effect on the water level
≤ 875	without compromising functioning, water level fluctuations
875 to 1025	loss of function, water bubbling
> 1025	loss of function, complete ejection of water

- when the overpressure of p_o > 725 Pa, water bubbles in traps, which leads to the spread of annoying smells in the building,
- when the overpressure of p_o > 1025 Pa, the water is ejected from sanitary appliances,
- the shape of a trap affects its pressure resistance.

All results will be verified by experimental measurement in the future.

Conclusion

The proper design of foul water stacks is crucial, particularly in high-rise buildings. To avoid undesirable effects that may arise when water is sucked or ejected from the traps, it is necessary to assess them for the correct limit values. The most important part of assessing stacks is assessing the maximum negative pressure because the overpressure can only be influenced by the correct design of the stack offset. Consideration must be given to direct vent stacks, which may exceed the maximum negative pressure if adequately designed according to the standards. The assessment of the stacks at a negative pressure of $p_n \leq 450$ Pa represents a safe and cost-effective route based on the simulation and the assumption of a 50 mm high water seal. However, this value should be very well considered in spite of these results, and any odour traps that are planned to be used on the stack should be analysed. It would be a great help if manufacturers would just add this information to their datasheets, as this information must be available to them before they can be placed on the market. ■

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