Heat loss via internal drainage vent pipes

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1 Introduction

This paper examines the theory and practice of heat loss from ventilated internal drainage pipes. Pipes for drainage of waste water (foul drainage) are often vented to outside at their top. We call the main vertical pipe a stack – various sanitary appliances drain to the stack via branch pipes.

There are two reasons for ventilating the stack: first, when the drain runs full with falling waste water there is a negative pressure behind the water and this could break the water seal at traps on sinks and baths etc, potentially allowing smelly air into the building. Allowing free flow of air into the top of the stack overcomes this problem (subject to maximum branch pipe lengths and other details). The second reason for ventilating the stack is to avoid build up of excess pressure in the drainage system as a whole.

The negative pressure issue can be dealt with using air admittance valves (AAVs) at the top of a stack. These are located inside the building envelope and allow air into the stack under negative pressure but do not allow smelly air to leak out. The requirements for installing AAVs are clearly defined according to the configuration of the drainage system. The need for the second type of ventilation is not well defined, and is usually taken to require an open vent at the head of a below-ground drainage run, so one vent is required per detached house, or one per group of attached houses.

The air flowing through a ventilated stack comes from outside so will be below room temperature and there is a heat loss from the building to the air in the stack. PHPP 7&8 recognise this and provides a procedure for calculating an approximation to the thermal bridge and hence the heat loss. This is based on 50% of the Ψ-value for a water-filled pipe and external air temperature. For an uninsulated stack 6m tall the heat loss calculated this way is 7 W/K, an increase in annual heat demand typically 2-4kWh/(m^2.a) depending on house size for the UK climate.

There are two ways to reduce this heat loss where a vented stack is required. One is to install a separate vented stack outside the thermal envelope with the internal stack topped with an AAV. The other is to insulate the stack – however the stack is at least as long as the house is high so this is not very effective. Some Passivhaus dwellings were designed before this detail was included in PHPP and so have uninsulated stacks. We wanted to see if the heat loss was as severe as predicted, and what retrofit measures would be worthwhile.

2 Model

A spreadsheet model was used to make a more accurate estimate of the heat loss via the stack. Overall we can see the heat loss in two ways – one is the conduction through the pipe wall, the other is the increase in heat in the air travelling through the stack. The consistent driving force for air movement is the buoyancy effect or stack effect, though wind will also have an effect. The buoyancy driven flow is dependent on the difference between air temperature in the stack and outside, as well as the resistance to airflow in the system. The air temperature at the base of the stack is determined by the ground temperature under the house, with possibly some additional heating from waste water and some possible cooling from air leaking into the drains through covers. The temperature at the top of the stack is determined by how much heat is transferred across the pipe from the house. However both the stack pressure and the heat transfer rate are in turn dependent on this temperature so there isn't a straightforward solution of the equations.

Our approach was to use an iterative model of a simple stack. The assumed starting conditions generate an initial estimate of pipe wall heat transfer, stack pressure, and in turn an air flowrate, which then produces a revised temperature at the top of the stack by equating the pipe wall heat transfer with the heat transfer of the air movement.

The duct heat transfer coefficients were calculated using the PHPP formulae for ventilation duct heat transfer. This is on the basis that the vent pipe is normally dry (and when water flows down the lower half it is generally at or above room temperature). This gives heat transfer rates less than half of those for water carrying pipes. Pressure loss for the below ground section of the drainage was estimated, and understood to be an unknown variable which will vary between houses.

Initial results of the modelling indicated that airflow velocities of 0.5-1.0 m/s were likely, the air temperature would rise by a few degrees as it rose up the stack, and the temperature difference between the air in the stack and the room was less than we had expected. The impact of the unknown external pressure loss in the drainage system did have an impact, but not a major one.

3 Measurements

Detailed measurements of soil vent pipe (SVP) temperature and airflow were made at a Passivhaus in Ledbury, UK. The stack is vented above the roof and was installed uninsulated within removable plywood boxing and so can be accessed along the whole length of the pipe.

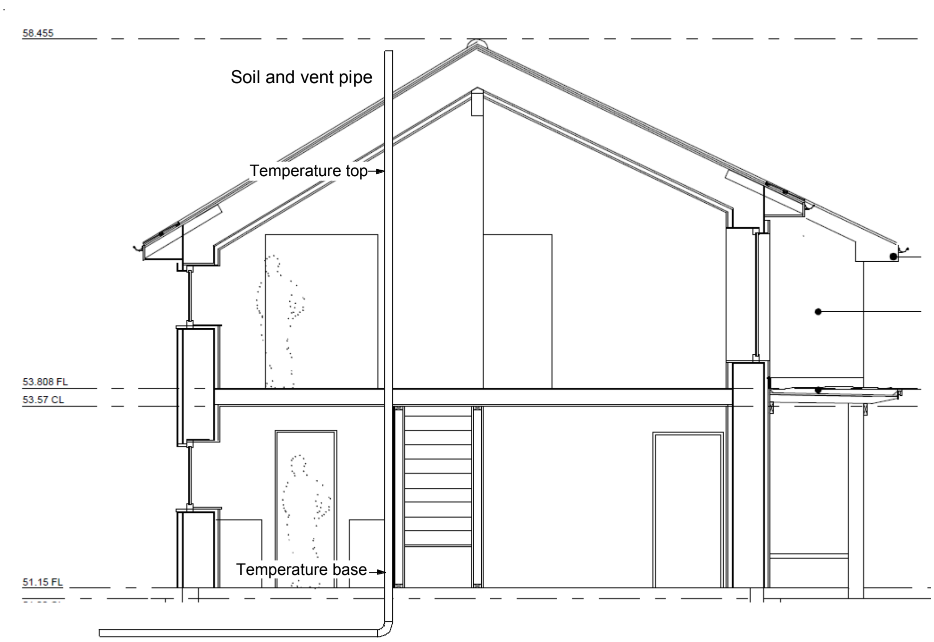

Figure 1: section drawing of the house showing soil vent pipe location

We installed thermocouples and data loggers at the base and top of the stack, and took spot measurement of air velocity at the top, checking with smoke that the airflow was upwards. We also measured external temperature and looked at the drain temperature in an access chamber outside. This was not conclusive but did indicate that temperatures in the drain could be higher than ground or external air temperatures:

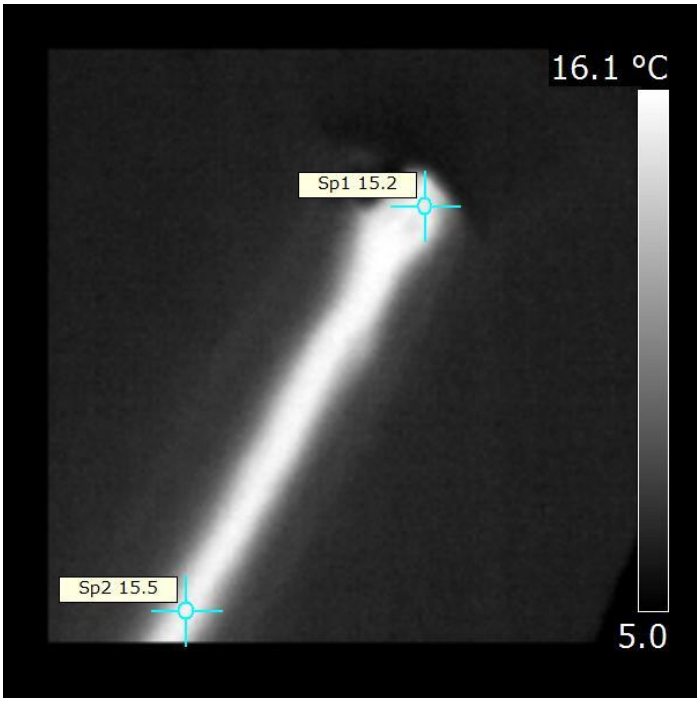

Figure 2: thermographic image of drain in access chamber

Measurement	Value	Units
Outside air temperature	7	°C
Wind speed at roof top (estimated)	4-8	m/s
Room temperature	19.5	°C
Temperature in stack enclosure at ground floor	17	°C
Air in base of stack	11.8	°C
Air at top of stack	14.1	°C
Air velocity in stack	0.6	m/s

Table 1: example measurements

Using the measured temperatures and airflow rate the model predicted a temperature at the top of the stack of 15.1°C which is higher than measured. We had noticed that the surface temperatures of the boxing within the stack enclosure were lower than the room temperature, which isn't surprising as the pipe surface temperature was as low as 13°C. Allowing for the thermal resistance of a 200mm x 200mm enclosure reduced the heat loss from the pipe by around 25% and reduced the predicted top temperature to 14.6°C.

The measured airflow rate (around 22m^3/h) and temperatures gave a heat loss via the air leaving the stack of 20W (1.7 W/K referenced to external air temperature) and the model estimated this at 22W (1.9 W/K). This compares with 82W (6.8 W/K) for the PHPP 8 approximation.

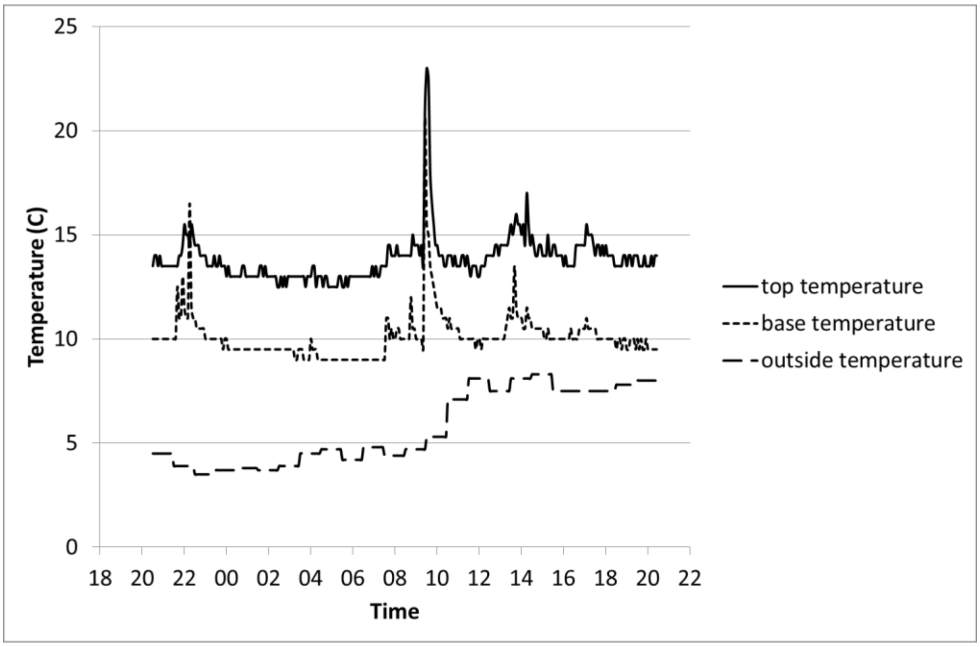

Figure 3: measured temperatures over 24 hours

Over a longer period of observation the temperature in the stack increases from time to time due to discharge of warm water into the drain but the temperature difference between top and bottom remains steady. Changes in outside air temperature do not have a strong immediate impact on temperatures in the SVP.

4 Analysis

Using the PHPP climate data and PHPP predicted ground temperatures for the site we looked at the monthly heat loss from the stack with standard internal conditions of 20°C.

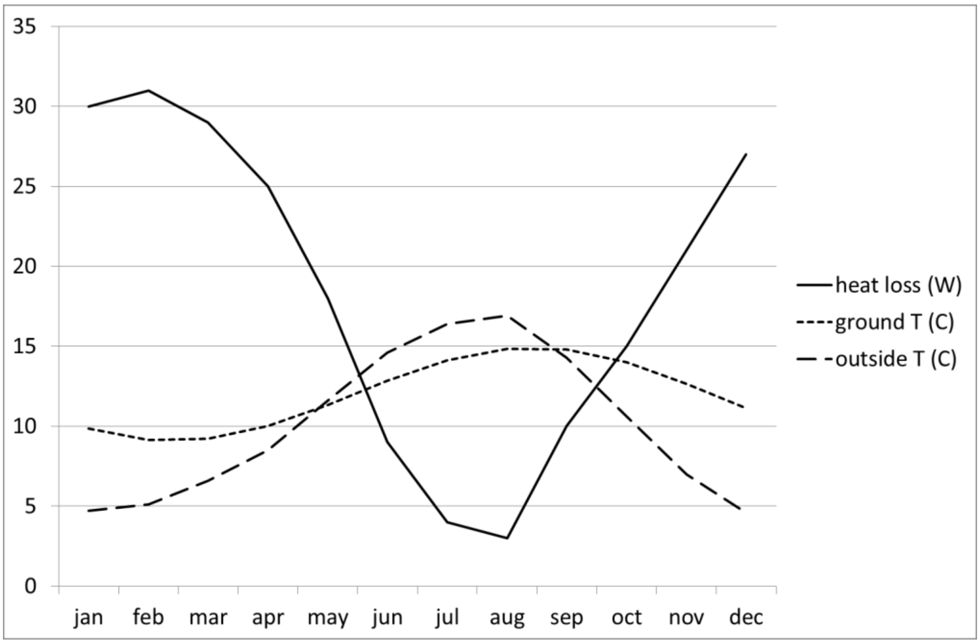

Figure 4: modelled annual heat loss

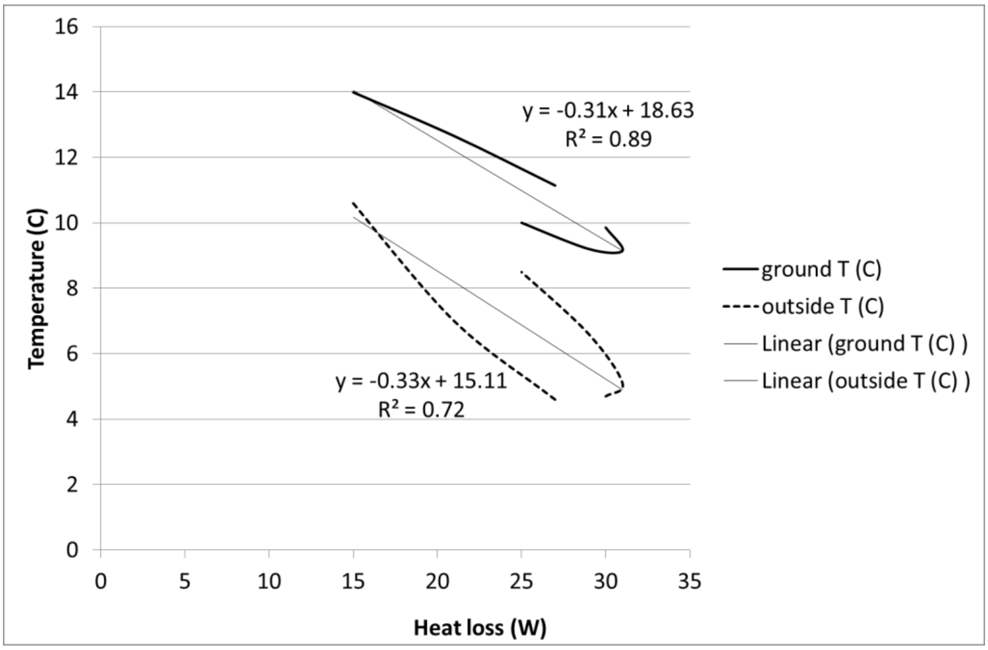

Figure 5: external and ground temperatures from fig 4 plotted against heat loss

Looking at the relationship between ground and air temperature and calculated heat loss (for Oct-Apr) shows a closer correlation with ground temperature.

We then modelled the insulation options for this house: 25mm of mineral fibre reduced heat loss to 0.9 W/K, 0.4 kWh/(m^2.a) and 50mm reduced heat loss to 0.7 W/K, 0.3 kWh/(m^2.a). This suggests that 25mm insulation is worth using but thicker insulation may not be justified.

We also explored throttling the airflow through the stack – a 50% reduction in air flow rate reduced the heat loss from 2 to 1.4 W/K. This was modelled by increasing the assumed length of sewer pipe to increase the total effective length. The reason seen for the non-linear response is that air entering the SVP remains cold and simply warms up more whilst travelling more slowly. If this approach were applied at a level which significantly reduced heat loss then restrictions to airflow out would also restrict airflow in and risk causing problems of pressure fluctuations in water seals which is the primary purpose of the vent.

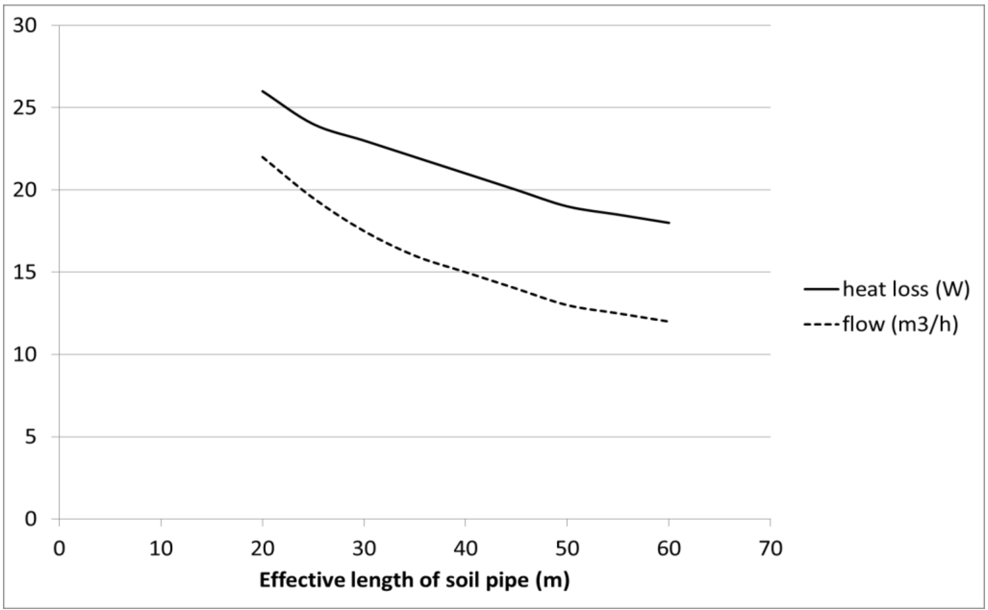

Figure 6: vent flowrate and heat loss against effective resistance in terms of pipe length

5 Conclusions

PHPP is the only domestic energy model we know which accounts for heat loss via the SVP, however the approximations in the PHPP model overestimate the heat loss by a large margin. Where the SVP is uninsulated or poorly insulated this has a significant impact on the predicted overall heating demand. For recent projects we have specified external vent pipes to avoid this penalty in the PHPP but this has a cost and visual impact that may not always be justified by the actual heat loss in the UK and similar climates.

The principle reason for the difference is the assumption in PHPP of a Ψ–value for a water filled pipe when the actual heat transfer is to air. A standard Ψ–value for a duct carrying air at winter ground temperature and 1 m/s would give a reasonable, yet conservative approximation. In our uninsulated SVP the average temperature increases by up to 2K, but when insulated the air temperature will be <1K above ground temperature, so we suggest treating this as a thermal bridge to ground rather than air.