Effect of Ageing on Service Life of Vacuum Insulation Panels

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Introduction

Vacuum insulation panels (VIPs) represent in their pristine condition a high-tech state-of-the-art thermal insulation solution with thermal conductivities 5 to 10 times lower than traditional thermal insulation. VIPs consist of a solid porous core sealed with an airtight and watertight foil maintaining vacuum in the core.

This work presents an overview of the graphical plots relevant for predicting service life of VIPs with respect to increase in thermal conductivity. The governing equations are given in the full version of the article. Furthermore, the background for and how accelerated ageing of VIPs may be carried out is discussed. Finally, some preliminary accelerated ageing experiments are presented.

VIP Build-up

VIPs are composed of a porous core, usually pressed fumed silica (SiO_2), with an air and water vapour tight foil material enveloping the core in order to maintain vacuum inside. In Fig.1 various VIP foil configurations are depicted.

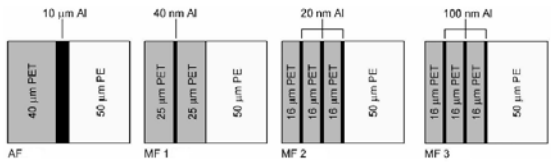

Fig.1. Cross-section of some typical VIP foil configurations. Note that different foil types with the same name are used in literature (Willems et al. 2005).

Water Content and Air Pressure inside VIPs

Based on work by Scwab et al. (2005), Tenpierik et al. (2007), Baetens et al. (2010) and others, various models and equations are presented for calculation of water content and air pressure increase inside VIPs during time.

The calculated results are shown in Fig.2 and Fig.3 for a time period up to 100 years (Wegger et al. 2010).

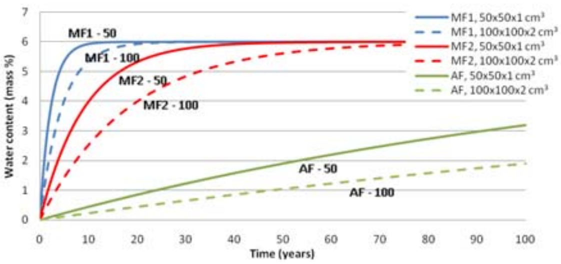

Fig.2. Water content inside VIPs vs. time for various foil types and panel sizes.

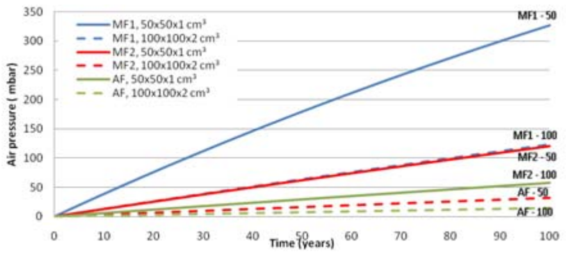

Fig.3. Air pressure inside VIPs vs. time for various foil types and panel sizes.

Thermal Conductivity of VIPs

Applying the water content (Fig.2) and air pressure (Fig.3) increase inside VIPs, the centre-of-panel thermal conductivity of VIPs during time periods up to 100 years is calculated and shown in Fig.4, where thermal bridges thus are not included (Wegger et al. 2010).

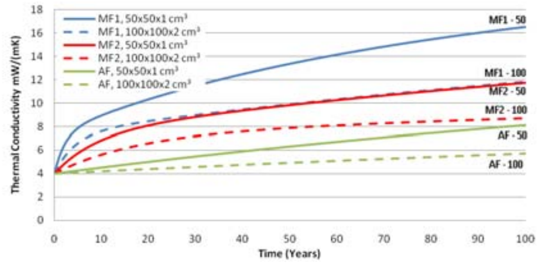

Fig.4. Centre-of-panel thermal conductivity for VIPs vs. time for various foil types and panel sizes.

Accelerated Ageing of VIPs - Calculations

Accelerated ageing of VIPs during testing and development is desirable in order to determine their service lives within a limited time frame.

Utilizing the various known ageing mechanisms, accelerated ageing experiments may be performed by varying the external environment of the panels, including air temperature, humidity and pressure.

Figure 5 depicts the total thermal conductivity for VIPs vs. time for different temperatures, and shows a larger increase in thermal conductivity during time with a larger temperature (Wegger et al. 2010).

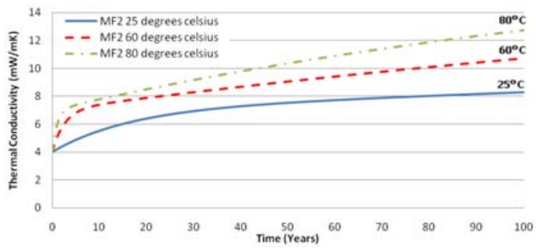

Fig.5. Centre-of-panel thermal conductivity for VIPs vs. time for different temperatures (MF2 foil).

The air pressure and water content increase for VIPs vs. time for different external pressures are demonstrated in Fig.6 and Fig.7, respectively.

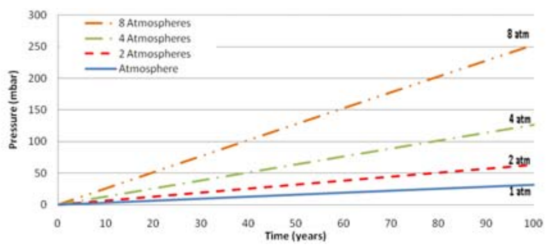

Fig.6. Air pressure inside VIPs vs. time for different external pressures (MF2 foil).

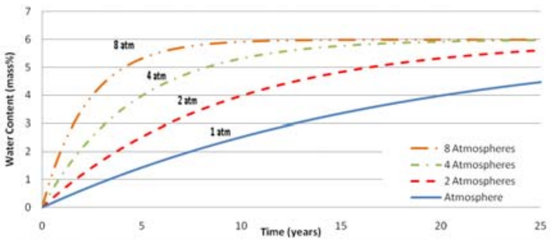

Fig.7. Water content inside VIPs vs. time for different external pressures (MF2 foil).

Based on Fig.6 and Fig.7 the total thermal conductivity for VIPs vs. time for different external pressures is given in Fig.8 (Wegger et al. 2010).

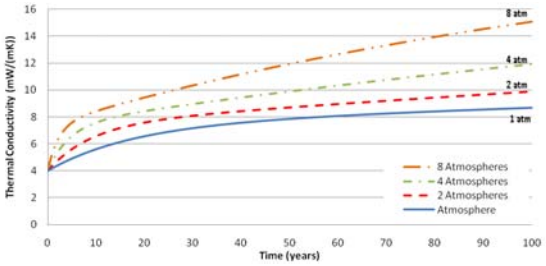

Fig.8. Centre-of-panel thermal conductivity for VIPs vs. time for different external pressures (MF2 foil).

Panel dimensions of 100 cm x 100 cm x 2 cm and MF2 foils are assumed for the VIPs in Figs.5-8. Further details are given in Wegger et al. (2010).

Accelerated Ageing of VIPs - Experiments

The VIPs employed in the experiments presented here are of the type va-Q-vipB from the producer va-Q-tec (2009). Va-Q-vipB consists of a core of amorphous silicon dioxide and an inorganic opacifier, where the enveloping foil is covered with a black fire protection fleece.

The following two accelerated ageing procedures were carried out:

- **Temperature Ageing – CUAP 12.01/30**
  - Cycling for 8 cycles, where each 24 h cycle consists of 80°C for 8 h and -15°C for 16 h.
  - 80°C for 180 days (180 x 24 h).
  - Thermal conductivity measurements at certain ageing intervals.
- **Climate Ageing – NT Build 495**
  - UV radiation (UVA = 33 W/m^2, UVB = 2.4 W/m^2) and IR radiation giving a black panel temperature of 63°C.
  - Water spray (15 $dm^3/(m^2h)$).
  - Freezing at -20°C.
  - Thawing at laboratory climate.
  - Each 4 h cycle consists of 1 h of each of the above 4 exposures, i.e. 6 cycles per day (24 h). Total ageing duration to be determined.
  - Thermal conductivity measurements at certain ageing intervals.

The thermal conductivity of the VIPs was measured by applying a heat flow meter apparatus.

Two VIPs were employed for the accelerated climate ageing according to NT Build 495. One panel was directly exposed to the various climate strains, whereas the other panel was built into a timber frame wall and thus not directly exposed to the climate strains.

Figure 9 shows the delamination of the VIP fire protection fleece during temperature ageing at 80°C. A similar delamination, in addition to a panel curving, was observed during the ageing according to NT Build 495 for the directly exposed VIP.

The measured total thermal conductivity for three VIPs vs. ageing time for different ageing procedures and exposure conditions are depicted in Fig.10. With a measurement uncertainty of ± 0.1 mW/(mK) it is seen that for the temperature aged VIP (CUAP 12.01/30) and the built-in climate aged VIP (NT Build 495), the variation in thermal conductivity is within the uncertainty, thus no significant difference is observed for either of these two panels. The directly exposed climate aged VIP (NT Build 495) experienced an increase in thermal conductivity of 0.2 mW/(mK) during about 1 month.

The presented accelerated ageing tests are still ongoing, and firmer conclusions may be drawn after a more prolonged ageing period. It should also be noted that in an actual building application the VIPs are not supposed to be directly exposed to outdoor weather conditions. For further details it is referred to Wegger et al. (2010).

Fig.9. Visible delamination of the VIP fire protection fleece after temperature ageing at 80°C for about 1 month.

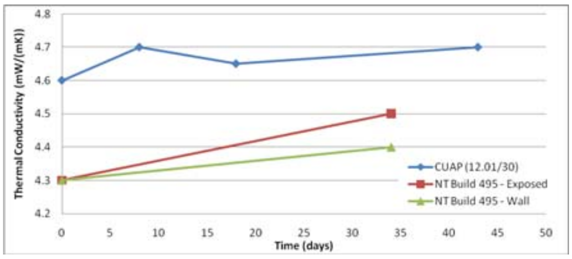

Fig.10. Centre-of-panel thermal conductivity for three VIPs vs. ageing time for different ageing procedures and exposure conditions measured by a heat flow meter apparatus.

Conclusions

A summary of ageing relationships for VIPs have been presented. Changes in air pressure, water content and thermal conductivity have been plotted for a time span of hundred years for various foil types and panel sizes. Based on these theoretical relationships accelerated ageing of VIPs with respect to air temperature, humidity and pressure has been investigated and some preliminary experiments have been carried out.

Acknowledgements

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