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Experimental Verification of the Theoretical Aging of Vacuum Insulated Panels

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1 Introduction

Many international research efforts have focused on the thermal properties of VIPs over time. Several works have proposed methods to predict the service life of VIPs with Fumed Silica (FS) core and on the development of models to determine their moisture content. Theoretical approaches to predict their long-term performances by means of interpreting accelerated aging tests done in laboratories have also been proposed. The increase in pressure and humidity inside a VIP panel over time is often pointed as the main aging mechanism for VIPs. The objective of this paper is to evaluate experimentally the thermal conductivity of some VIP after several aging exposures and to assess the accuracy of existing thermal conductivity aging models through verification of collected results for different core materials of VIPs.

2 Results

The thermal conductivity of various VIPs with different core panels including fiberglass, fumed silica, compressed microporous silica, and compressed microporous silica with celluloses fiber, were tested in this study. Different types of multilayer films which are common in the market were selected. The employed films include metal foils (AF), metalized films (MF) and polymer films (PF). The most common types can be described as follows:

- AF: In these ones, the thickness of the aluminum in the center is up to 5-10 μm and this layer is laminated by a polyethylene terephthalate (PET) as a protective layer in outer and polyethylene in the inner side of the layer.

- MFs: In these ones, there are three barrier layers of aluminum metalized PET and polyethylene (PE) sheets on the inner side with an aluminum coat of 20-100 nm thickness. This is a standard solution to make VIPs applicable in buildings because multiple aluminum layers provide a better impermeable layer in comparison to one-layer aluminum. However, MF type has a low thickness which is an issue as a low thickness results in higher gas and moisture permeance compared to the AF laminates. Table 1 reports the main characteristics of the selected VIPs. The induced changes in thermal conductivity of VIP samples with the exposure at high temperature, simulating their accelerated aging, are presented in Fig. 1.

Table 1. Experimentally characteristics of VIPs provided by manufacturers.

Sample type	Envelope type	Thermal conductivity (W/mK)	Company density (kg/m^3)	Core material	Pressure (mbar)	Size (cm x cm)
1	*NA*	0.0028	250	Fibreglass	≤ 5	30 x 30
2	MF3	0.0048	190	Fumed Silica	≤ 5	24 x 13.7
3	MF2	0.0037	208	Compressed microporous silica	≤ 5	30 x 30
4	MF2	0.0070	200	Compressed microporous silica + celluloses fibre	≤ 2	30 x 30
5	MF2	0.0070	250	Compressed microporous silica	≤ 5	30 x 30

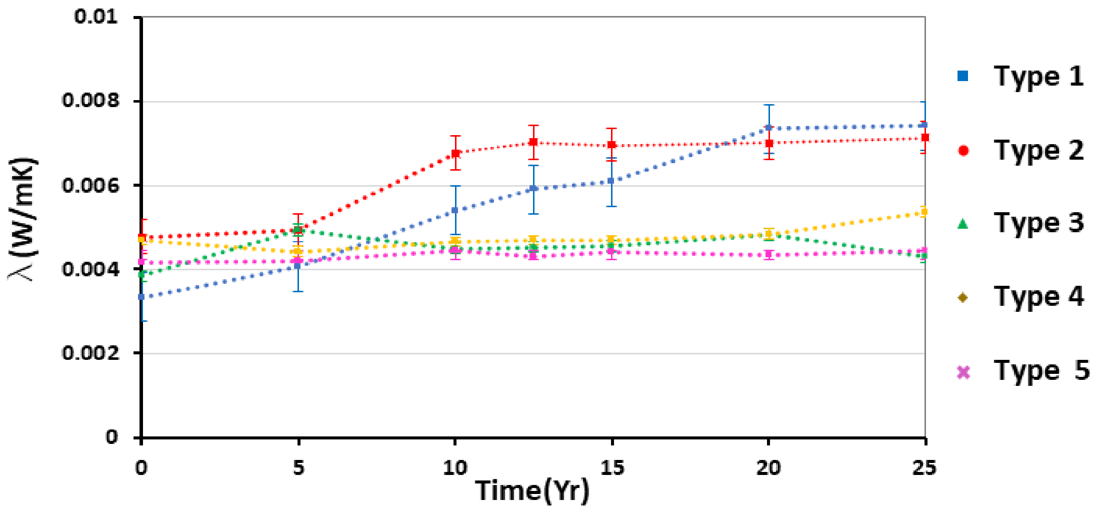

Figure 1. Dynamic variation with the accelerated aging of the thermal conductivity of the VIPs at 18 ºC.

Service life is one of the main characteristics of VIP assessment. The threshold value for the first definition of service life (ASTM C1484) is assumed to be 0.008 W/mK and 0.011 W/mK based on different references. The threshold limitation and the service life of each specimen are reported in Table 1. The primary variables which define the quality of VIPs are the density of the core, the transmission rates of gas, and water vapor through the film barrier. Here, the test results collected from thermal conductivity measurements show that the thermal performance of the samples is mainly affected by temperature and, the amount of effect by moisture is minimal as they were exposed to different levels of humidity without any appreciable results.

Table 2. Service life of VIPs samples under test.

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Service life for 0.008 W/mK	25 years	30 years	> 100 years	70 years	> 100 years
Service life for 0.011 W/mK	40 years	65 years	> 100 years	> 100 years	> 100 years

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