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Design details and long-term performance of VIPs in Canada's North

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Abstract

Vacuum Insulation Panels (VIPs) have been used in a variety of insulation applications in the built-environment in Yukon, Canada, which is located North of 60° latitude. As a result of this experience in a cold climate, more information is now available about the long-term thermal performance of VIPs and the best ways to install them. This paper compiles updated design, field and monitoring information from our experience for researchers, designers, building owners and contractors to help accelerate the use of high-performance VIPs with the goal of achieving Near Net Zero energy-use in buildings in the most cost-effective way.

Peer-review under responsibility of KES International.

Keywords: Vacuum Insulation Panels (VIPs); long-term performance; construction challenges; construction details; thermal performance; thermal insulation; wall systems; Near Net Zero; Northern Canada

1. Introduction

In Canada, the country's cold climate has encouraged innovation to reduce annual building heating cost. In Yukon, for example, the minimum recorded winter temperature is -52.2 °C in Whitehorse, -55.8 °C in Dawson City, and lower in more isolated northern areas [1]. In addition, new regulations, such as the requirements of Canada's

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latest revision in 2015 of the National Energy Code for Buildings (NECB), are helping to accelerate this process. In fact, a goal of this latest code revision is to update the performance requirements for energy use in buildings as the market moves closer toward Net Zero Energy buildings [2].

Nomenclature

RSI thermal resistance (˚K-m^2/W)

There is increased interest in new and better ways to use VIPs to reduce building heat loss. VIPs have a high thermal resistance per unit of thickness, and so take up much less space than conventional insulation alternatives to provide the same amount of thermal insulation. Although the benefits of VIPs, including the potential for a greater economic return, are becoming better known, the mass application of VIPs in the construction industry is still hindered by the lack of understanding of their long-term performance and a shortage of published proven construction details.

In response to these problems, a number of pilot projects have been completed. Two small pilots, both at the same location in Yukon, will be described here. In addition, the latest results of long-term monitoring at a second location are outlined.

2. Wall construction pilots

Two approaches to wall insulation retrofits using VIPs were piloted at 35 Tutshi Road in Whitehorse, Yukon, Canada. The first design was the simpler of the two. The framing consisted of two layers of nominal 50 mm x 100 mm preserved wood installed with the widest face against an existing wall to give an overall frame thickness of 75 mm as shown in Fig. 1 (a) below. (Two layers of 2 x 4 wood are only 75 mm thick as the actual dimensions of the wood are approximately 38 mm x 86 mm).

Mineral wool batt insulation was split, and a layer about 32 mm thick was installed first. Sheathing tape (Canadian Technical Tape Ltd, 205-02 60 mm) was used to hold the insulation in place. The VIPs, with the wax paper backing left in place, were placed over the batt insulation and also held in place with sheathing tape. Then the top layer of mineral wool insulation was installed and held in place with tape as shown in Fig. 1 (a). The insulation, covered with preserved wood plywood, is shown in Fig. 1 (b).

The two layers of mineral wool protect the VIPs from rubbing due to movement caused by temperature changes, and from any damage from wood splinters or a rough wall surface, and also increase the insulation level.

a

b

Fig. 1. (a) Installation of a layer of mineral wool insulation followed by a layer of VIPs and a layer of mineral wool; (b) insulated area after it was covered with preserved wood plywood and before sealing to prevent entry of insects.

The addition of VIP insulation, with a centre of panel thermal resistance of approximately RSI 3.7 and the two mineral wool layers (RSI 1.8) bring the added wall thermal resistance up to RSI 5.5. (RSI is the measure of thermal resistance. The units are ˚K-m^2/W.)

With the addition of this insulation, the wall thickness was increased 89 mm. To achieve the same nominal RSI value using fiberglass insulation the wall thickness would have to be increased by 230 mm.

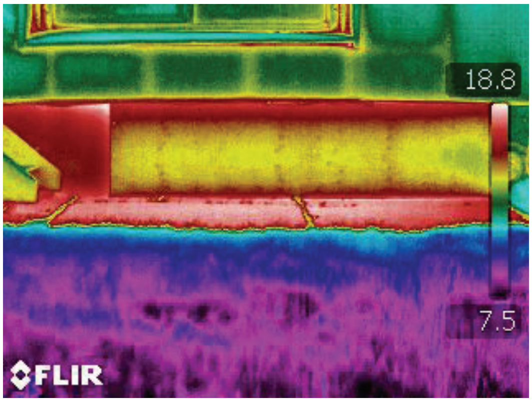
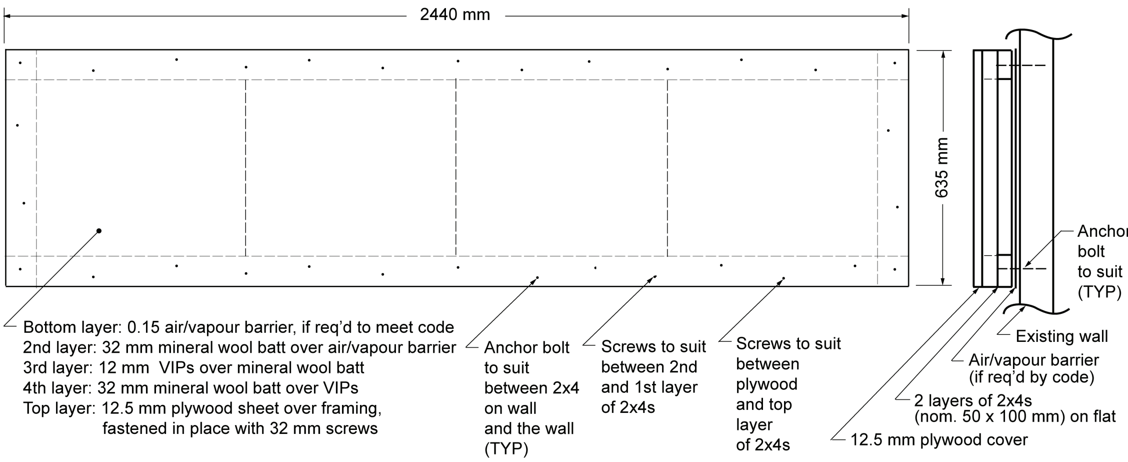


Fig. 2. Infrared image of first wall.

An infrared image shown in Fig. 2 confirms the improved insulation level in the retrofitted area. The retrofitted area shows as yellow (cooler) on the image, which compares well with the bare wall to the left which shows as red (hotter) on the image, indicating a lower heat loss in the retrofitted area.

The construction details are shown in Fig. 3 below to assist designers considering using this approach to retrofitting, or for new construction.



NOTES
1. Not to scale.
2. Insulation layers held in place using sheathing tape, if needed during construction.
3. Preserved wood in applications near ground level required to comply with local code requirements.

NOTES (continued)
4. Approved stainless steel or coated wood screws required required to meet manufacturer's specifications if cement board siding will be used on top of the plywood.
5. Finish layer and/or painting details not shown.
6. All details subject to engineering review and approval and local code requirements.

Fig. 3. Detail of Vacuum Insulation Panel (VIP) insulation to add RSI 5.5 nominal to an existing wall.

From a construction standpoint, this method of insulation retrofit was found to be simple and straight-forward. However, the compromise is that it has a relatively low nominal thermal resistance, compared to that achieved with the second design.

The second wall insulation design is more ambitious in comparison to the one just described. The second insulation retrofit design, on the south wall of the same house, consists of one layer of 12 mm VIPs covered by two layers of 140 mm thick mineral wool.

For this design, two layers of 0.15 mm polyethylene vapour barrier film and framing were installed on the existing wall (Fig. 4 (a)). The second layer was installed to ensure that the VIPs would not be damaged by the existing stucco surface. The polyethylene was held in place with sheathing tape. Placing sheathing tape over precut holes in the second layer of polyethylene film was found to be effective for attaching the second layer of polyethylene. This happened because the framing supported the first row of VIPs that then supported the second row of VIPs directly above (Fig. 4 (b)). Also, the VIPs are very light so there was very little mechanical stress on the polyethylene film.

The VIPs were then covered with two layers of RSI 3.8 mineral wool batts (Figures 4 (c) and 4 (d)). The first layer was fitted horizontally behind the vertical studs. The second layer was fitted vertically between the studs. The exterior sheathing was then installed (Fig. 4 (e)).

As with the first design, the VIPs were installed quickly. The use of top and bottom baseplates to support the framing also sped up construction. Once the baseplates were solidly fastened to the existing structure, brackets could be installed quickly, without concerns about the substrate at any particular location on the structure. This design resulted in a much higher additional insulation level of RSI 11.5, but required more framing than the first design to hold the two layers of mineral wool batts. Which design is most effective will depend on the design objectives.

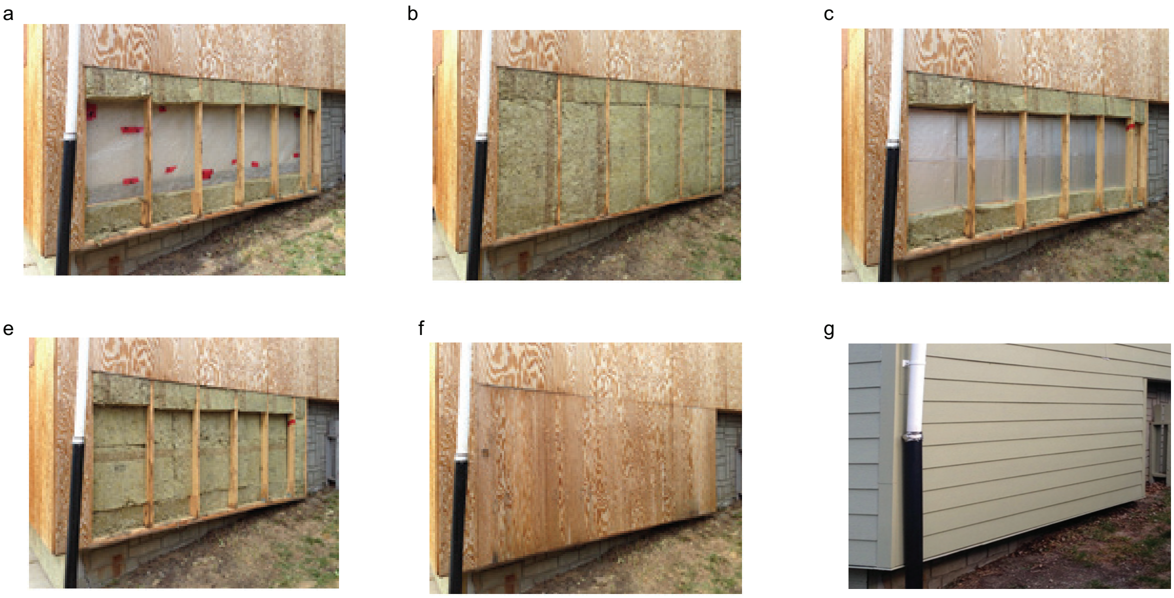


Fig. 4. (a) The first stage of installation of VIPs -- two layers of polyethylene vapour barrier; (b) the layer of VIPs installed; (c) the first layer of mineral wool insulation installed; (d) the second layer of mineral wool insulation installed; (e) the sheathing installed over the insulation; (g) the siding installed.

Construction details are shown in Fig. 5 to assist designers considering using this approach to retrofitting, or for new construction.

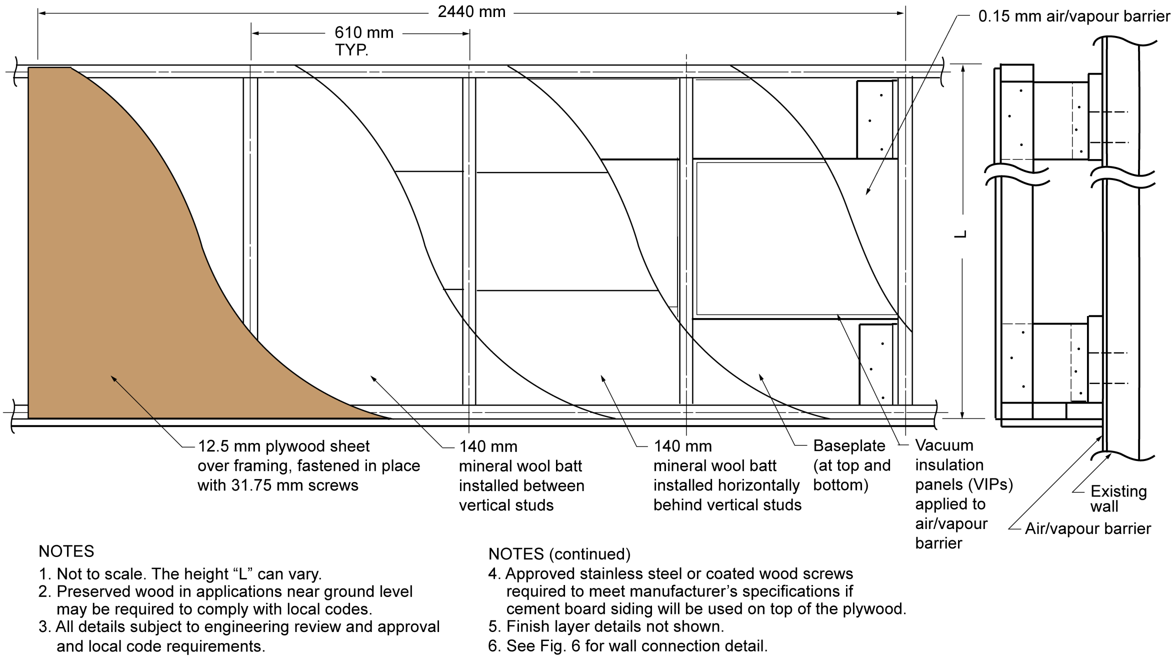


Fig. 5. Detail of Vacuum Insulation Panel (VIP) installation to add RSI 11.5 nominal to an existing wall.

Perhaps of note is the simplicity of the bracket that was used – a 215 mm x 215 mm square piece of plywood with a 215 mm long piece of 2x4 as a base as shown in Fig. 6. (Sizing will vary depending on the load.)

The use of wood instead of steel reduced thermal bridging. The work of other authors has demonstrated that the use of joint materials with high thermal resistance can dramatically reduce thermal bridging [3-5].

The fact that these brackets can be made from readily available materials, and can be made quite quickly on site or in a shop prior to beginning construction, are further advantages.

The installation of VIPs with this design went quickly because the studs are offset from the wall and so do not interfere with the installation of the VIPs. This made it possible to cover a higher proportion of the wall with VIPs, without the need to purchase and use VIPs in custom sizes.

There are circumstances when the owner may wish to use custom-sized VIPs, in order to cover more of the wall surface with VIPs. However, our experience has been that placement and sizing of doors and windows can be done to minimize the area that is not covered with VIPs, avoiding the need for non-standard sizes of VIPs. When doing a retrofit, the VIPs can be placed to minimize the area that is not covered. This topic has been addressed further in a paper by Zimmerman and Brunner [6].

3. Monitoring results

Temperature monitoring using thermistors and data-loggers is being done at a second location, 410 Jarvis in Whitehorse, Yukon.

The insulation retrofit construction method there is different, and has been reported on previously [7,8]. To summarize, a 0.15 mm polyethylene air-vapour-moisture barrier was installed first on an existing concrete block wall. 25 mm polystyrene board (XPS) was glued to the polyethylene to provide a smooth surface on which to mount

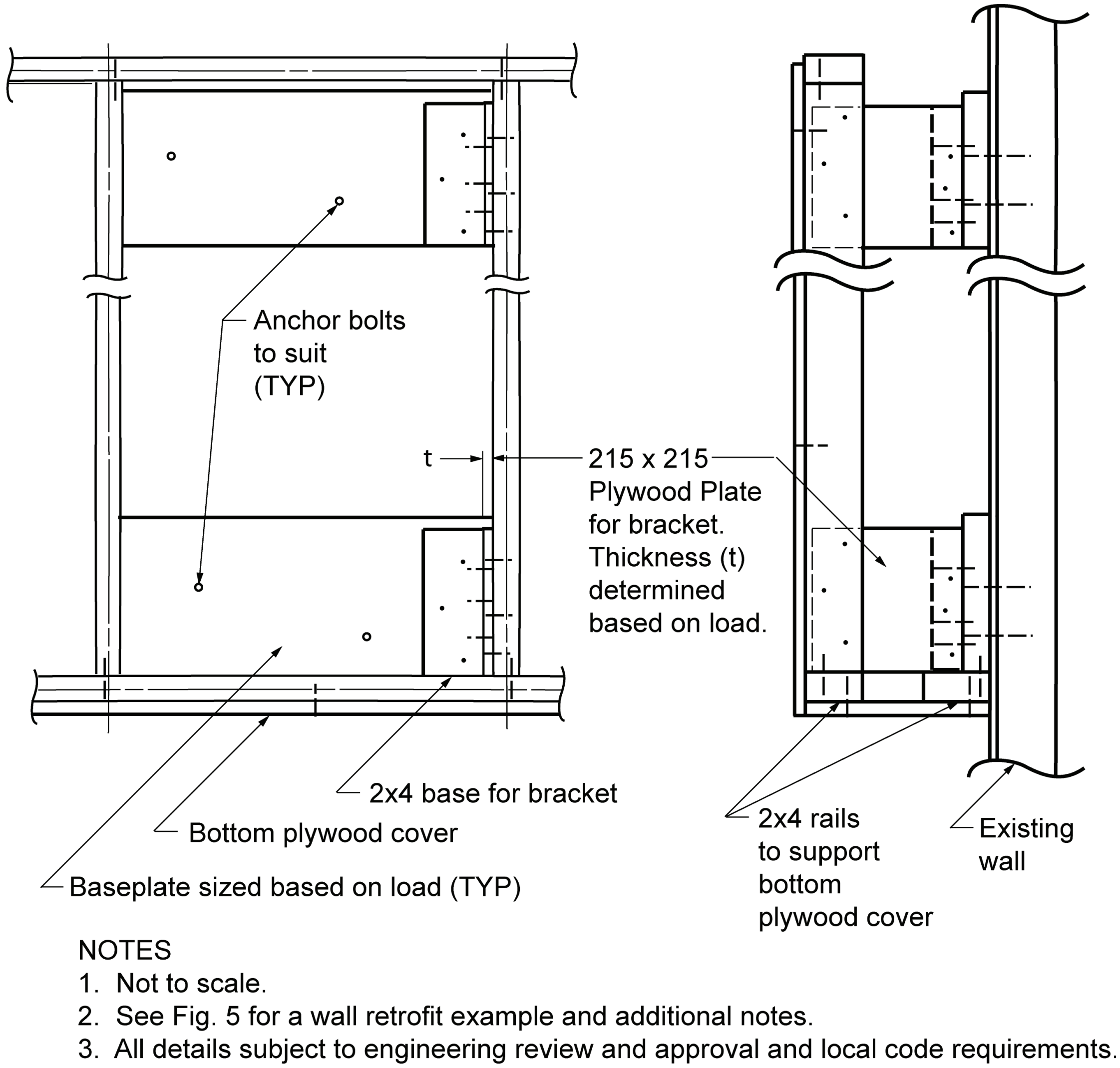
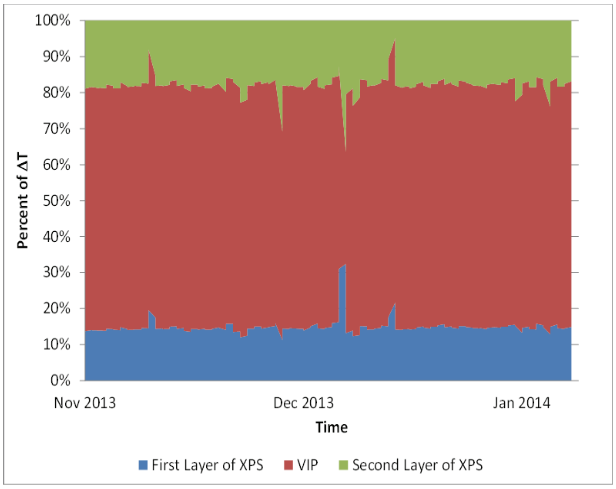


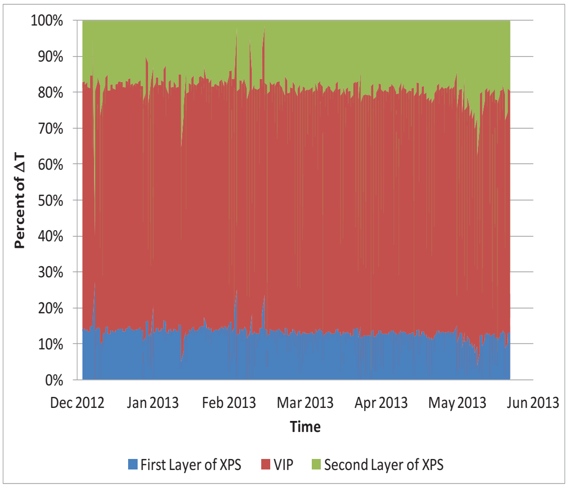
Fig. 6. Typical bracket detail.

the VIPs. 50 mm x 75 mm horizontal studs were mounted on the polystyrene board and attached to the concrete wall with anchors. The VIPs were then mounted between the 50 mm x 75 mm studs. The VIPs were covered with 6 mm Domfoam 1095 foam material held in place with sheathing tape. 25 mm polystyrene board was placed on the outside of the foam layer to prevent condensation on the VIPs, and to protect them from mechanical damage during and after construction. Sensors (thermistors) were placed to measure the temperature on the existing wall surface, on the exterior of the first polystyrene layer, on the exterior surface of the VIPs, and on the exterior surface of the second polystyrene layer.

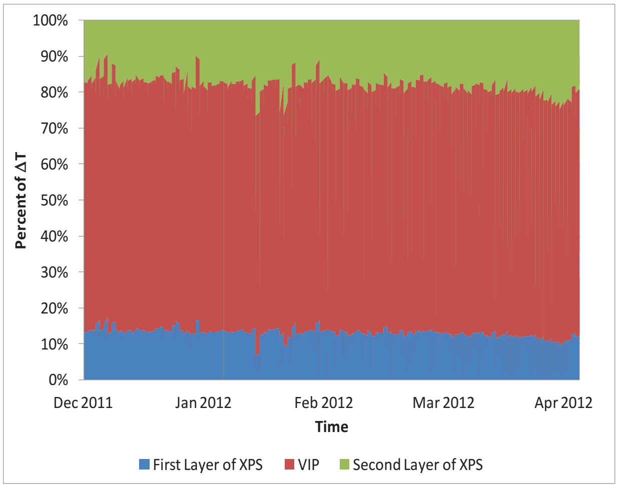
An analysis of the hourly temperature data was done to calculate the temperature difference across each of the three exterior insulation layers over time. The temperature difference across each layer was then expressed as a percentage of the total temperature difference. Results over a period of five years show that there were no significant changes over time in the relative in-situ performance of the VIPs compared to the polystyrene (XPS) insulation, confirming the good performance of the VIPs.



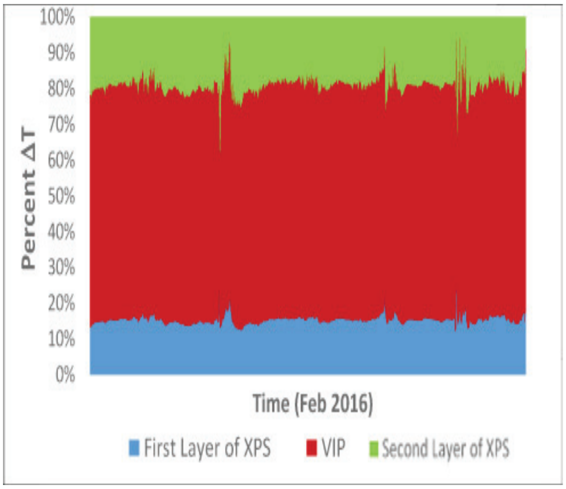
(a) insulation performance Winter 2011-12;



(b) insulation performance Winter 2012-13;



(c) insulation performance Winter 2013-14;



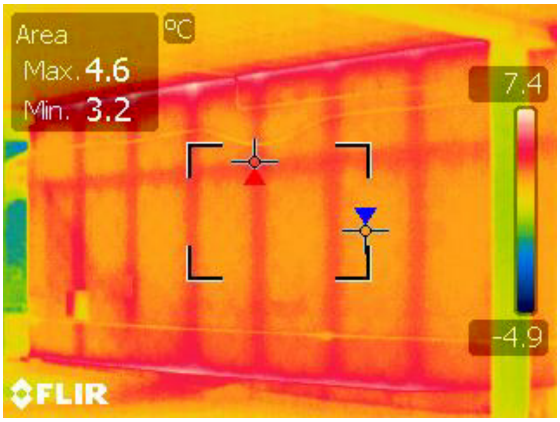
(d) insulation performance February 2016.

Fig. 7. Performance of VIPs over a period of five years (Whitehorse, Yukon).

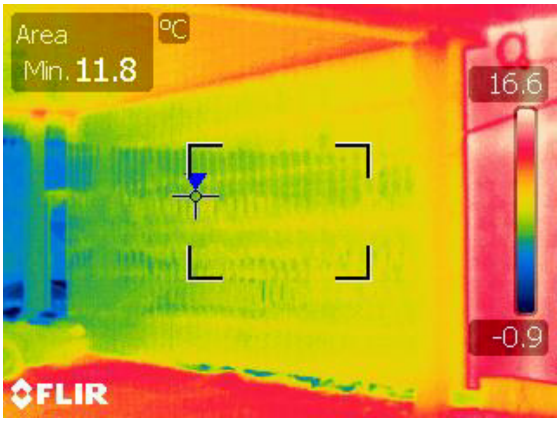
The graphs in Fig. 7 show the percentage of the temperature difference across each of the three insulation layers using hourly averages over five years. This data for the entire time period verifies the performance of the VIPs relative to polystyrene insulation.

This favourable result may be expected in other regions where the relative humidity is also generally low, and the climate is cold. Low humidity and low temperature are known to help lengthen the life of VIP panels.

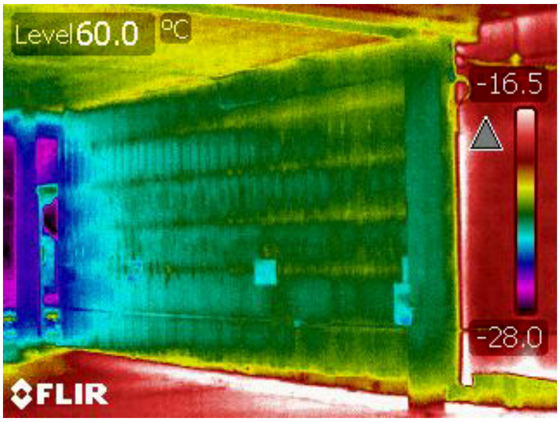
There has also been no failure of any VIPs over time (verified using infra-red testing – see Fig. 8) and no indication of any significant aging of the insulation that could otherwise reduce the insulation value. Finally, as with other types of insulation, proper sealing of the air barrier is key in order to achieve the full insulating value of VIPs. Air leakage can significantly reduce the overall wall RSI-value [9,10].



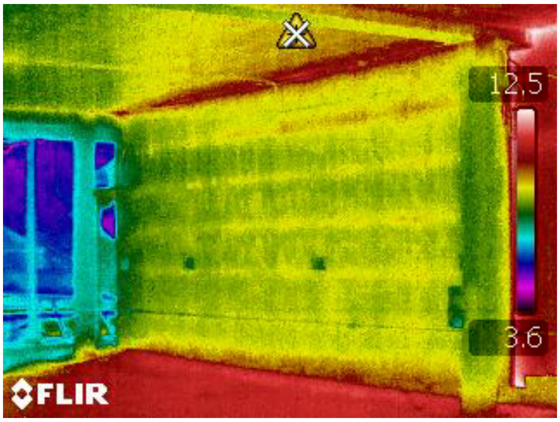
(a) 2011 pre-retrofit;



(b) 2011 post-retrofit;



(c) 2014 pre-retrofit;



(d) 2016 post-retrofit.

Fig. 8. Infrared images of VIP insulated wall (Whitehorse Yukon).

3. Conclusions

Experience using VIPs in these applications in Yukon has been informative. The work done has identified two effective ways of installing and incorporating VIPs in building enclosures to increase building wall thermal insulation (RSI-value) while reducing wall thickness.

There is also potential to reduce construction time and cost due to the reduced volume of insulation that needs to be shipped, handled and installed when using VIPs. Cost is also expected to drop as use of VIPs for building insulation increases, permitting greater production economies of scale.

The monitoring results were positive, confirming the good performance of the VIPs over five years, relative to the other types of insulation, from an insulation effectiveness point of view. This result may be expected in other regions where the relative humidity is also generally low, and the climate is cold.

It is hoped that the information from this successful experience will provide encouragement to researchers, building owners, designers and contractors to consider the use of VIPs for insulating new buildings or retrofitting existing ones.

Acknowledgements

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