REDUCING THE ENVIRONMENTAL IMPACT OF REFRIGERATED TRANSPORT VEHICLES USING VACUUM INSULATION PANELS (VIPs)

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Executive Summary

Effect of using VIPs on reducing the thermal load of a refrigerated vehicle was investigated for two different temperatures +2°C and -18°C for different operating conditions. The transmission load of the refrigerated vehicle considered in this report is responsible for more than 70% of the thermal load; the enhancement of the insulation with VIPs would reduce the total thermal load of the refrigerated vehicle by around third. Consequently, we can conclude that the running time of the refrigeration unit and thus its fuel consumption and its emissions would be reduced by one third with VIPs under the same working conditions.

According to the case study considered in this report, the VIPs are promising solution to reduce the cooling requirements of a refrigerated vehicle. Therefore, they can be either used to reduce the fuel consumption and emissions of a diesel refrigeration unit.

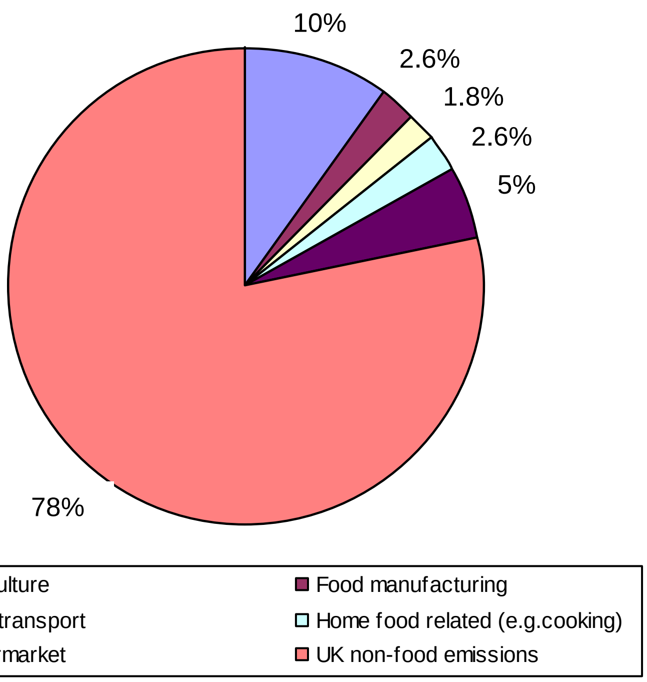
Recommendations

It is important to consider further this technology and its potential to application in food transport refrigeration. It would be interesting to prepare a detailed financial analysis to calculate precisely the payback time of vacuum insulation in refrigerated transport. Several issues such as the weight added by VIPs to the trailer and their service life under severe working conditions must still be fully addressed but their potential is attractive.

Table of Contents

1. Introduction

The commercial food sector is responsible for 22% of the UK's total greenhouse gas emissions (this includes agriculture, food manufacturing, transport and retailing in supermarkets). Retail and distribution of food contribute approximately one third of this, mainly through the burning of non-renewable fossil fuel to provide heat and power. [1].

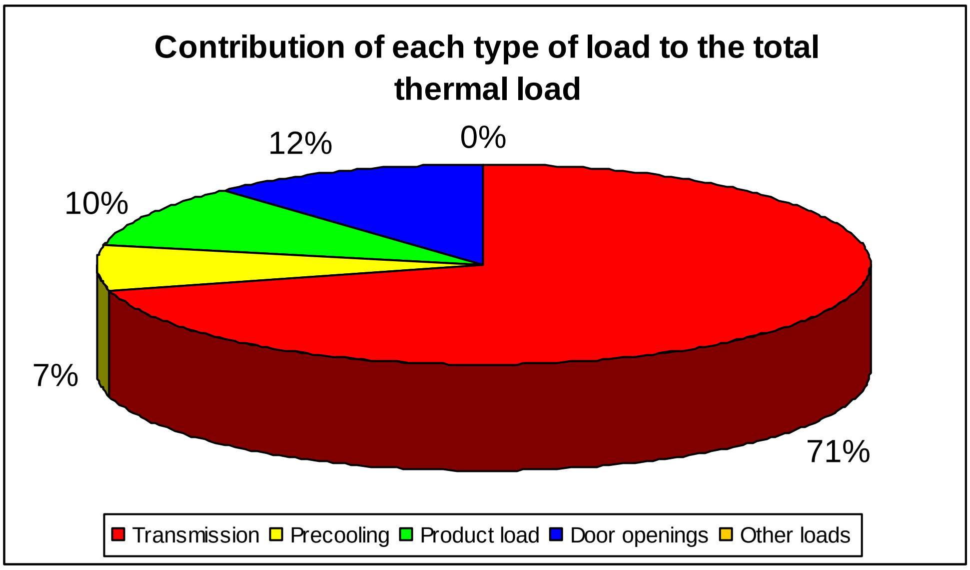


Contribution of food to UK's green house gas emission

The contribution of food transport to the UK's greenhouse gas emissions is estimated to be 1.8% (motive power and refrigeration whenever necessary have presumably been taken into account in this calculation).

Between 1978 and 1999, the distance food moved in the UK increased by 50% and food transport remains one of the fastest growing categories of road freight. Airfreight uses six times more energy than lorries and about eighty times more than sea vessels per kilometre during long haul. Local food is often described as coming from within a 30-mile radius of the use point [1].

One of the approaches to reduce the environmental impact of refrigerated transport is to look at the energy efficiency of the insulated body i.e. to address the thermal load. The calculations of the thermal load components of the refrigerated trailer shows that the transmission load is more than 70% of the total load (T_{amb} 20°C, T_{inside} 2°C, total opening door time 360 sec).



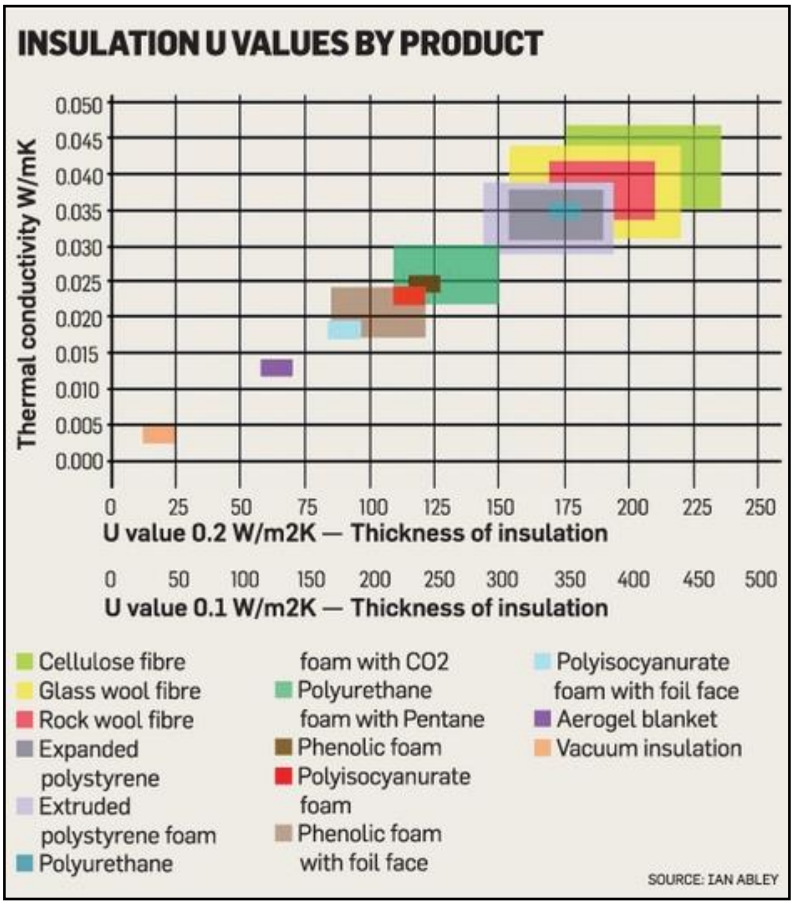
Indeed, the main part of the thermal load of a refrigerated vehicle is attributable to the thermal conduction through its insulation.

It is particularly true for long-haul operations but other loads such as door openings also play an important role in the case of delivery vehicles. Finding a way to reduce this part of the total thermal load could nevertheless be a particularly interesting way to decrease the total energy consumption of a refrigerated trailer.

2. Principles of Vacuum Insulating Panels

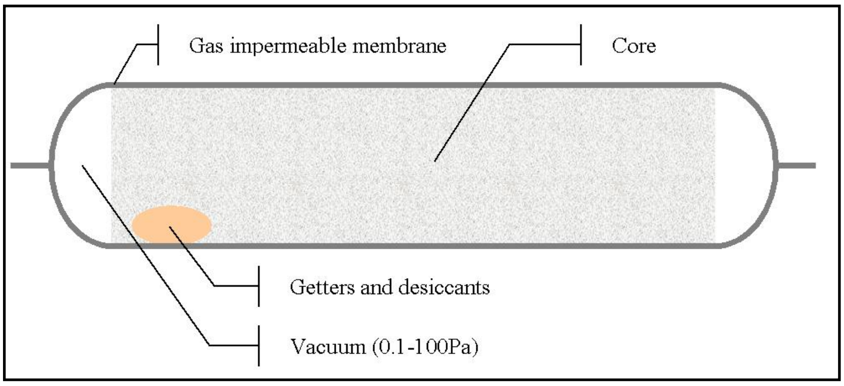
In conventional insulation materials (mineral wool, glass wool or organic foams), the total heat transfer is dominated by the contribution of the non-convective gas within the hollow spaces or pores. When the gas pressure is reduced so that the mean free path of gas particles (i.e. the average distance a particle can cover between two collisions with another particle) reaches values of the order of the size of the largest pores of the material, the thermal conductivity decreases strongly [5].

In a VIP, the gaseous heat transfer is almost negligible so heat transfer is limited to solid conduction (2-3mW/ (mK) for fumed silica) and thermal radiation (1mW/ (mK) for fumed silica with an opacifier).



http://www.bdonline.co.uk/story.asp?storycode=3140081

The typical components of a VIP are a core material, a gas impermeable membrane and getters and/or desiccants [6].

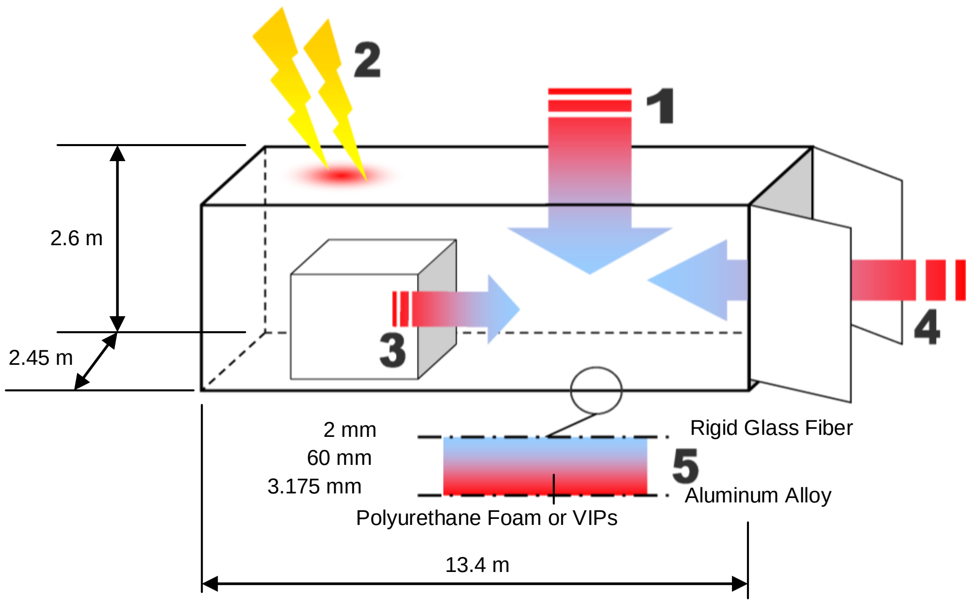


The core material must have a very small pore diameter, an open cell structure, a good resistance to compression (because of atmospheric pressure and be as impermeable to infrared radiation as possible [5]. The most popular core material seems to be fumed silica because it does not need such a high vacuum as other materials.

3. Load calculations for a refrigerated vehicle

We may use an example to illustrate the potential benefits or drawbacks of using VIPs to reinforce the insulation values of refrigerated vehicles. We consider a refrigerated vehicle with the following specifications: the walls, ceiling and doors comprise 2mm of aluminium alloy (external surface), 60mm of polyurethane foam insulation and 3.175mm of glass fiberboard; the floor is composed of 3mm of mild steel (external surface), 60mm of polyurethane foam and 3mm of aluminium. The insulated body is 13.4m long, 2.45m wide and 2.6m high (internal dimensions).

ASHRAE [2] and Hui et al. [3] provide thermal load calculation procedures and data. This information has been used to develop the spreadsheet model. The schematic diagram below illustrates the main sources of heat entering a refrigerated body.



Main sources of heat in refrigerated transport
1: Transmission load, 2: Solar radiation load, 3: Product load, 4: Infiltration during door openings and 5: Precooling load.

The total refrigeration load of a refrigerated vehicle includes [2]:

- Transmission load, which is heat transferred into the refrigerated space through its surface. In the following sections it is referred to as transmission load and solar radiation load (which is just an adjustment to allow for the sun effects).
- Product load, which is heat produced by the products brought and kept in the refrigerated space.
- Infiltration air load, which is heat gain associated with air entering the refrigerated space (during door openings).
- Precooling load (insulated body), which is heat removed from the vehicle to bring its interior surfaces to the planned thermostat settings.
- Other loads: internal load, which is heat produced by internal sources, and equipment-related load.

These five categories of load have been taken into account in the development of the spreadsheet model.

3.1. Transmission load

The heat transfer due to conduction and convection can be calculated by:

$$Q_1 = \sum UA(T_o - T_i)$$

The heat transfer for a wall with n flat parallel surfaces of materials is given by:

$$U = \frac{1}{\sum_{i=1}^{n} \frac{x_i}{k_i}}$$

It should be noted that the air infiltration through the vehicle body and closed doors is usually included in the UA value given by manufacturers.

In the spreadsheet model this was included as a part of the transmission load and was calculated as:

$$Q_1^{'} = q\rho_a C_{pa}(T_o - T_i)$$

3.2. Solar radiation adjustment

Solar radiation increases significantly the refrigeration load of a semi-trailer. The cooling requirements of stationary vehicles have been found to increase by 20% when exposed to sunlight for several hours [3]. That is why aluminium plates and reflective paints are usually used on the exterior of refrigerated vehicles to reduce the heat gain through radiation

According to ASHRAE, the temperature difference T_o-T_i can be adjusted to compensate for the solar effect on heat load. The values reported by ASHRAE have been used directly in the spreadsheet model as a “solar radiation temperature adjustment”.

3.3. Product load

The refrigeration load from products brought into and kept in a refrigerated space comprises: heat that must be removed to bring the products to storage temperature and heat generated by products in storage [2]. The first load should be reduced as much as possible by precooling properly the products. Improperly precooled products bring a considerable extra heat to be removed from the refrigerated space, which may be impossible for small mobile refrigeration units to cover. Moreover, any time spent away from the optimum storage temperature makes loss of product quality inevitable [2]. The commodity temperature pulldown load can be calculated as follows:

$$Q_3 = mC_p \Delta T$$

Fruits and vegetables continue to respire after harvest, producing CO_2, moisture and heat. Highly perishable products tend to generate more respiratory heat and the respiration rate increases with an increase in produce temperature. The amount of respiratory heat load is calculated by:

$$Q_3^{'} = \frac{h_r m}{1000}$$

3.4. Infiltration by air exchange (door openings)

The heat gain from air infiltration during door openings is considerable in the case of delivery vehicles. It is, therefore, necessary to take it into account in this modeling work. A simplification of the equation developed by Gosney and Olama is given in ASHRAE [2] (applicable for fully established flows):

$$q = 0.577WH^{1.5}\frac{Q_S}{A}\frac{1}{R_S}$$

In the spreadsheet model, the average load related to door openings is calculated hour by hour. For example, if we consider a T-second opening, the resulting thermal load for the hour during which the opening occurs (Q_4, in kW or, since this is the average power over an hour, in kWh) will be calculated by:

$$Q_4 = \frac{T}{3600}q$$

3.5. Precooling load

The precooling load of the insulated body is the heat that must be removed from the vehicle to bring its interior surfaces to the planned thermostat setting before loading it with the produce to be carried. The temperature pulldown of the warm air inside the trailer when the refrigeration unit is started must also be taken into account. Therefore, the precooling load can be calculated as follows:

$$Q_5 = \frac{(C_{pt} + V\rho_a C_{pa})(T_{ini} - T_s)}{1000}$$

3.6. Other loads

To calculate the thermal load of large cold stores, it is often necessary to take into account the internal load related to the electrical equipment (motors, lights), forklifts and processing equipments in use in the refrigerated space. The people working in the cold room also add to the heat load. The equipment related load (fan motors if forced-air circulation is used, heat from defrosting) may also de considered [2]. All these loads are not specifically specified in the model, but are referred to as “other loads”, and can be taken into account if necessary.

3.7. Safety factors

It is possible to enter a safety factor for each type of load (transmission, precooling, product load, door openings and other loads) to allow for possible discrepancies between theoretical approach and actual operation. Usually, the calculated loads are increased by 10% [2].

4. Two different types of cargo.

Two cases have been considered in the following case studies: transport of frozen food and transport of chilled food. Frozen food is transported at temperatures in the range -18°C whereas chilled food requires temperatures between 2°C and generates a respiration load. There is no heat from respiration for frozen products. For chilled products, it can vary widely depending on the temperature and on the nature of the commodity that is carried.

Quantity: 15000kg for the articulated vehicle		
Type of cargo	Frozen food	Chilled food
Designation	Generic frozen	Cranberries
Temperature conditions (°C)	-18	2
Freezing point (°C)	0	-0.9
Specific heat below freezing (kJ/(kgK))	3	1.93
Specific heat above freezing (kJ/(kgK))	4	3.91
Latent heat of fusion (kJ/kg)	275	289
Heat of respiration (mW/kg)	0	12

5. Four different ways to operate the vehicle.

Four scenarios corresponding to different ways to make use of the refrigerated vehicle have been developed. Although they are fairly different (see Appendix A).

5.1. Long haulage operations (Case A)

The vehicle is used continuously and spends most of the time on the road, covering long distances with just a few deliveries. Therefore, both the precooling load and the infiltration during door openings are neglected.

General information	
Daily use of the vehicle	24h
Thermal load calculation	
Transmission load	Taken into account
Precooling load	Ignored
Product load	Taken into account
Door openings	Ignored
Other (thermal) loads	Ignored

Activity of the vehicle on each hour of the day			
Hour	**Status**	**Hour**	**Status**
0-1h	On the road, cargo 100%	**12-13h**	On the road, cargo 100%
1-2h	On the road, cargo 100%	**13-14h**	On the road, cargo 100%
2-3h	On the road, cargo 100%	**14-15h**	On the road, cargo 100%
3-4h	On the road, cargo 100%	**15-16h**	On the road, cargo 100%
4-5h	On the road, cargo 100%	**16-17h**	On the road, cargo 100%
5-6h	On the road, cargo 100%	**17-18h**	On the road, cargo 100%
6-7h	On the road, cargo 100%	**18-19h**	On the road, cargo 100%
7-8h	On the road, cargo 100%	**19-20h**	On the road, cargo 100%
8-9h	On the road, cargo 100%	**20-21h**	On the road, cargo 100%
9-10h	On the road, cargo 100%	**21-22h**	On the road, cargo 100%
10-11h	On the road, cargo 100%	**22-23h**	On the road, cargo 100%
11-12h	On the road, cargo 100%	**23h-0h**	On the road, cargo 100%

5.2. Long hours and deliveries (Case B)

The vehicle is intensively used for long delivery rounds, covering a long distance between each delivery point. Infiltration during door openings cannot be neglected, and since the refrigeration unit is switched off a few hours a day, a daily precooling load must be taken into account.

General information	
Daily use of the vehicle	17h
Thermal load calculation	
Transmission load	Taken into account
Precooling load	Taken into account
Product load	Taken into account
Door openings	Taken into account
Other (thermal) loads	Ignored

Activity of the vehicle on each hour of the day			
Hour	**Status**	**Hour**	**Status**
0-1h	Unused	**12-13h**	On the road, cargo 62%
1-2h	Unused	**13-14h**	Delivery (180s), cargo 50%
2-3h	Unused	**14-15h**	On the road, cargo 50%
3-4h	Unused	**15-16h**	Delivery (180s), cargo 37%
4-5h	Precooling, no cargo	**16-17h**	On the road, cargo 37%
5-6h	Loading (300s), cargo 100%	**17-18h**	Delivery (180s), cargo 25%
6-7h	On the road, cargo 100%	**18-19h**	On the road, cargo 25%
7-8h	Delivery (180s), cargo 87%	**19-20h**	Delivery (180s), cargo 12%
8-9h	On the road, cargo 87%	**20-21h**	On the road, cargo 12%
9-10h	Delivery (180s), cargo 75%	**21-22h**	Unused
10-11h	On the road, cargo 75%	**22-23h**	Unused
11-12h	Delivery (180s), cargo 62%	**23h-0h**	Unused

5.3. Delivery rounds (Case C)

The vehicle is used for relatively short delivery rounds. Infiltration during door openings cannot be neglected, and since the refrigeration unit is switched off a few hours a day, a daily precooling load must be taken into account.

General information	
Daily use of the vehicle	10h
Thermal load calculation	
Transmission load	Taken into account
Precooling load	Taken into account
Product load	Taken into account
Door openings	Taken into account
Other (thermal) loads	Ignored

Activity of the vehicle on each hour of the day			
Hour	**Status**	**Hour**	**Status**
0-1h	Unused	**12-13h**	Delivery (180s), cargo 25%
1-2h	Unused	**13-14h**	Delivery (180s), cargo 12%
2-3h	Unused	**14-15h**	Unused
3-4h	Unused	**15-16h**	Unused
4-5h	Precooling, no cargo	**16-17h**	Unused
5-6h	Loading (300s), cargo 100%	**17-18h**	Unused
6-7h	Delivery (180s), cargo 100%	**18-19h**	Unused
7-8h	Delivery (180s), cargo 87%	**19-20h**	Unused
8-9h	Delivery (180s), cargo 75%	**20-21h**	Unused
9-10h	Delivery (180s), cargo 62%	**21-22h**	Unused
10-11h	Delivery (180s), cargo 50%	**22-23h**	Unused
11-12h	Delivery (180s), cargo 37%	**23h-0h**	Unused

5.4. Short deliveries (Case D)

The vehicle is only used for short delivery rounds. Infiltration during loading and the daily precooling load are both taken into account since they account for an important part of the overall thermal load.

General information	
Daily use of the vehicle	5h
Thermal load calculation	
Transmission load	Taken into account
Precooling load	Taken into account
Product load	Taken into account
Door openings	Taken into account
Other (thermal) loads	Ignored

Activity of the vehicle on each hour of the day			
Hour	**Status**	**Hour**	**Status**
0-1h	Unused	**12-13h**	Unused
1-2h	Unused	**13-14h**	Unused
2-3h	Unused	**14-15h**	Unused
3-4h	Unused	**15-16h**	Unused
4-5h	Precooling, no cargo	**16-17h**	Unused
5-6h	Loading (300s), cargo 100%	**17-18h**	Unused
6-7h	On the road, cargo 100%	**18-19h**	Unused
7-8h	On the road, cargo 100%	**19-20h**	Unused
8-9h	On the road, cargo 100%	**20-21h**	Unused
9-10h	Unused	**21-22h**	Unused
10-11h	Unused	**22-23h**	Unused
11-12h	Unused	**23h-0h**	Unused

6. Calculations and results

CASE A

VIPs (mm)	Polyurethane Foam (mm)	UA (W/K)	Kcoef (W/m².K)	Total hourly load per day(kWh)	Load saving (%)	Additional weight in respect to 0 (mm)VIPs(kg)	Installation cost (£)	Fuel cost per day(£)	Pay back (day)
0	60	57.65	0.38	38.32	0%	0	0	**72**	-
20	40	28.01	0.18	21.01	45%	537	9398	39	137
40	20	18.78	0.12	15.62	59%	1073	18778	29	239
60	0	14.27	0.09	12.99	66%	1610	28175	24	337

CASE B

VIPs (mm)	Polyurethane Foam (mm)	UA (W/K)	Kcoef (W/m².K)	Total hourly load per day(kWh)	Load saving (%)	Additional weight in respect to 0 (mm)VIPs(kg)	Installation cost (£)	Fuel cost per day(£)	Pay back (day)
0	60	57.65	0.38	48.06	0%	0	0	**51**	-
20	40	28.01	0.18	34.7	28%	537	9398	37	234
40	20	18.78	0.12	30.54	36%	1073	18778	32	421
60	0	14.27	0.09	28.51	41%	1610	28175	30	603

CASE C

VIPs (mm)	Polyurethane Foam (mm)	UA (W/K)	Kcoef (W/m².K)	Total hourly load per day(kWh)	Load saving (%)	Additional weight in respect to 0 (mm)VIPs(kg)	Installation cost (£)	Fuel cost per day(£)	Pay back (day)
0	60	57.65	0.38	40.36	0%	0	0	**30**	-
20	40	28.01	0.18	32.99	18%	537	9398	25	459
40	20	18.78	0.12	30.69	24%	1073	18778	23	846
60	0	14.27	0.09	29.57	27%	1610	28175	22	1,224

CASE D

VIPs (mm)	Polyurethane Foam (mm)	UA (W/K)	Kcoef (W/m².K)	Total hourly load per day(kWh)	Load saving (%)	Additional weight in respect to 0 (mm)VIPs(kg)	Installation cost (£)	Fuel cost per day(£)	Pay back (day)
0	60	57.65	0.38	14.52	0%	0	0	**15**	-
20	40	28.01	0.18	11.68	20%	537	9398	12	859
40	20	18.78	0.12	10.79	26%	1073	18778	11	1,584
60	0	14.27	0.09	10.36	29%	1610	28175	11	2,291

Fuel consumption of a typical semi trailer diesel engine of a refrigeration unit is about 3L/h [4]

diesel price £1/l

operating hours	**case A**	**24h a day**
operating hours	**case B**	**17h a day**
operating hours	**Case C**	**10h a day**
operating hours	**case D**	**5h a day**

Tset =+2°C

CASE A

VIPs (mm)	Polyurethane Foam (mm)	UA (W/K)	Kcoef (W/m².K)	Total hourly load per day(kWh)	Load saving (%)	Additional weight in respect to 0 (mm)VIPs(kg)	Installation cost (£)	Fuel cost per day(£)	Pay back (day)
0	60	57.65	0.38	64	0%	0	0	**96**	-
20	40	28.01	0.18	31.05	51%	537	9398	47	190
40	20	18.78	0.12	20.78	68%	1073	18778	31	290
60	0	14.27	0.09	15.78	75%	1610	28175	24	390

CASE B

VIPs (mm)	Polyurethane Foam (mm)	UA (W/K)	Kcoef (W/m².K)	Total hourly load per day(kWh)	Load saving (%)	Additional weight in respect to 0 (mm)VIPs(kg)	Installation cost (£)	Fuel cost per day(£)	Pay back (day)
0	60	57.65	0.38	128.25	0%	0	0	**68**	-
20	40	28.01	0.18	103.81	19%	537	9398	55	725
40	20	18.78	0.12	96.2	25%	1073	18778	51	1,105
60	0	14.27	0.09	92.48	28%	1610	28175	49	1,486

CASE C

VIPs (mm)	Polyurethane Foam (mm)	UA (W/K)	Kcoef (W/m².K)	Total hourly load per day(kWh)	Load saving (%)	Additional weight in respect to 0 (mm)VIPs(kg)	Installation cost (£)	Fuel cost per day(£)	Pay back (day)
0	60	57.65	0.38	116.43	0%	0	0	**40**	-
20	40	28.01	0.18	102.54	12%	537	9398	35	1,969
40	20	18.78	0.12	98.21	16%	1073	18778	34	3,000
60	0	14.27	0.09	96.1	17%	1610	28175	33	4,034

CASE D

VIPs (mm)	Polyurethane Foam (mm)	UA (W/K)	Kcoef (W/m².K)	Total hourly load per day(kWh)	Load saving (%)	Additional weight in respect to 0 (mm)VIPs(kg)	Installation cost (£)	Fuel cost per day(£)	Pay back (day)
0	60	57.65	0.38	32.04	0%	0	0	**20**	-
20	40	28.01	0.18	25.94	19%	537	9398	16	2,468
40	20	18.78	0.12	24.03	25%	1073	18778	15	3,756
60	0	14.27	0.09	23.11	28%	1610	28175	14	5,054

Fuel consumption of a typical semi trailer diesel engine of a refrigeration unit is about 4L/h [4]

operating hours	**case A**	**24h a day**
operating hours	**case B**	**17h a day**
operating hours	**caseC**	**10h a day**
operating hours	**case D**	**5h a day**

Typical day with a 20°C ambient temperature

Tset= -18°C

diesel price £1/l **Density for VIPs used 200 kg/m³**

6.1. Effect of ambient temperature

Case B was considered to investigate the effect of ambient temperature

Case B

Chilled Temperature +2°C

Ambient Temp. (°C)	VIPs (mm)	Polyurethane Foam (mm)	UA (W/K)	Kcoef (W/m².K)	Total hourly load per day(kWh)	Load reduction (%)	Fuel cost per day(£)
20	20	40	28.01	0.18	34.7	0%	51
15	20	40	28.01	0.18	30.1	13%	44
10	20	40	28.01	0.18	16.59	52%	24

Freezing Temperature -18°C

Ambient Temp. (°C)	VIPs (mm)	Polyurethane Foam (mm)	UA (W/K)	Kcoef (W/m².K)	Total hourly load per day(kWh)	Load reduction (%)	Fuel cost per day(£)
20	20	40	28.01	0.18	103.81	0%	68
15	20	40	28.01	0.18	92.87	11%	61
10	20	40	28.01	0.18	63.92	38%	42

7. Conclusions

- Significant reduction in the thermal load, up to 60% and consequently in the energy consumption of refrigeration units can be achieved with vacuum insulating panels, depending on the operating conditions of the refrigerated trailer and the thickness of the VIPs.
- The case study of an insulated body enhanced with VIPs has shown that a 20mm-thick vacuum insulation can reduce the fuel consumption and emissions of the refrigeration unit by about one third, even when considering rather unfavourable assumptions for example about the thermal conductivity of VIPs.
- More saving of thermal load achieved by using 20 mm thickness of VIPs compared to 40 or 60 mm thickness of VIPs
- Payback period was ranging from 190 to 5054 day depending on the operating conditions of the refrigerated trailer including the daily operating hours.
- At ambient temperature of 20°C, more saving was achieved by using the VIPs at freezing operating conditions with longer payback period compared to chilling operating conditions.
- At ambient temperature lower than 20°C and constant thickness (20 mm) of VIPs more saving achieved for chilling operating conditions compared to freezing operating conditions.

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[6] B Malone, K Weir. *State of the Art for VIP Usage in Refrigeration Applications*, 2001 (available online, http://www.dupontteijinfilms.com/datasheets/markets/Reprint-IAM-2001-VIP-usage-in-refig.pdf#search=%22B%20Malone%2C%20K%20Weir.%20State%20of%20the%20Art%20for%20VIP%20Usage%20in%20Refrigeration%20Applications%2C%202001%22).

NOMENCLATURE

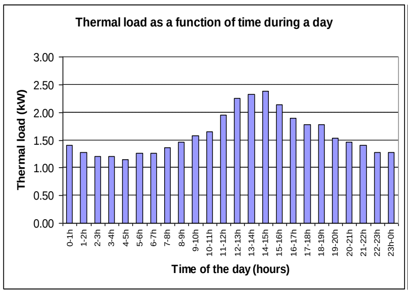
Q_1	Total amount of heat transferred through conduction and convection
U	Overall heat transfer coefficient
A	Surface of this section
T_o-T_i	Temperature difference between the outside and the inside of the vehicle
x_i	Thickness of the material in m and k_i is the thermal conductivity
$\frac{x_i}{k_i}$	Can be referred to as R_i and is the thermal resistance
Q_1’	Heeat transfer through infiltration
q I	Infiltration rate
ρ_a	Air density
C_{pa}	Specific heat of air
Q_3	Amount of field heat to be removed
m	Mass of produce
Cp	Specific heat of the produce
ΔT	Difference between the initial and the required temperature for produce
Q_3’	Respiratory heat load
h_r	Heat of respiration
q	Sensible and latent refrigeration load
Q_S/A	Sensible heat load of infiltration per square meter of doorway opening
R_S	Sensible heat ratio of the infiltration air
W	Doorway width in m and H the doorway height
Q_5	Precooling load
C_{pt}	Specific heat of the insulated body
V	Payload volume of the vehicle
ρ_a	the air density
C_{pa}	Specific heat of air
T_{ini}	Initial temperature inside the body
T_s	Thermostat setting temperature

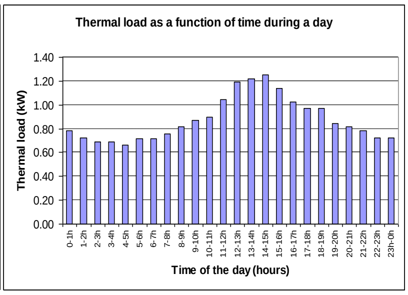
Appendix A

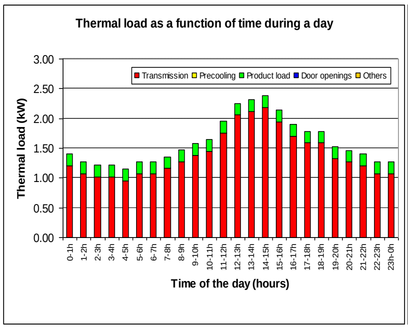
0 mm VIPs *20 mm VIPs*

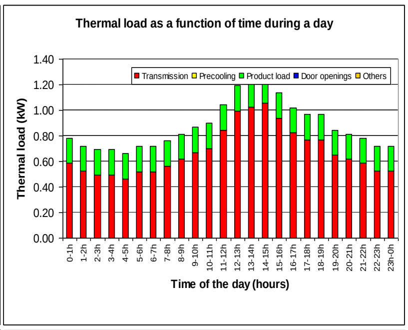
CASE A

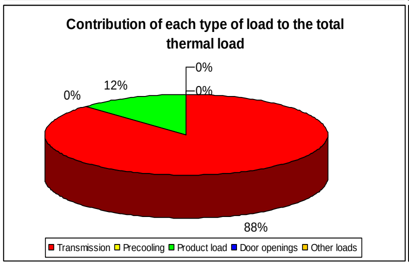
Chilled

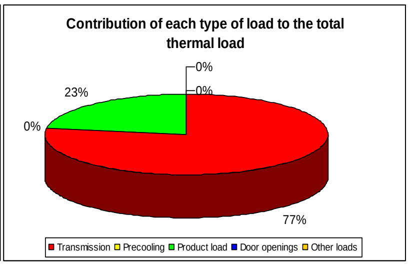






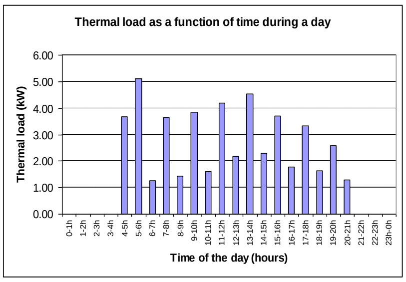


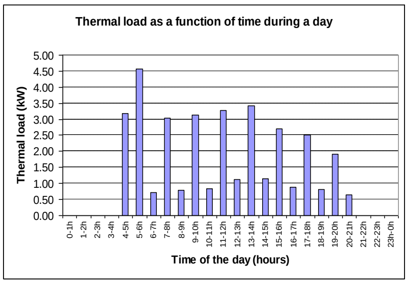


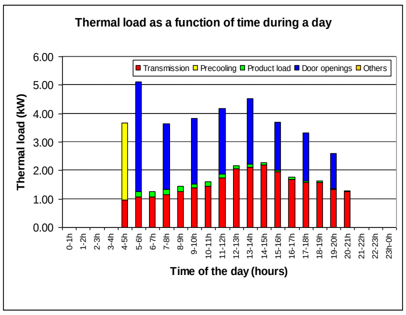


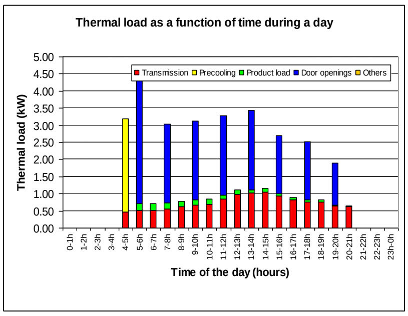
CASE B

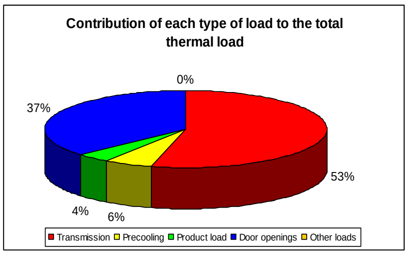
Chilled

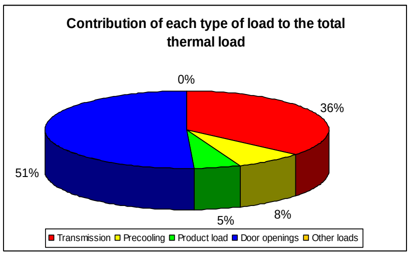








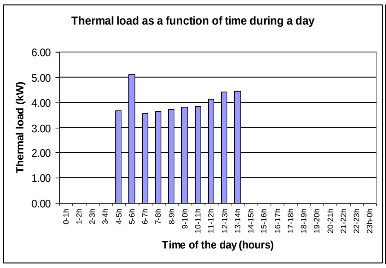


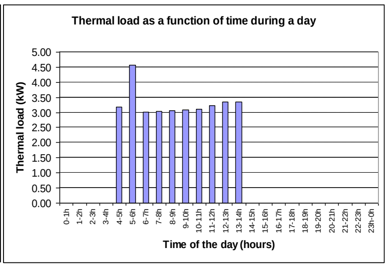


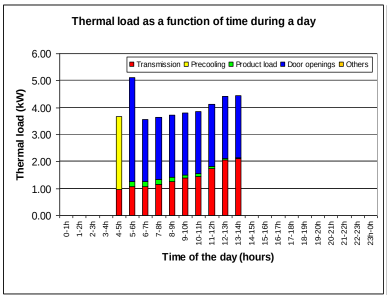
0 mm VIPs *20 mm VIPs*

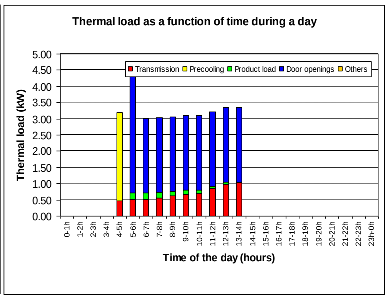
CASE C

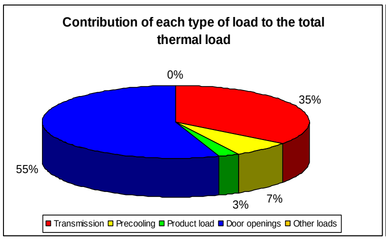
Chilled

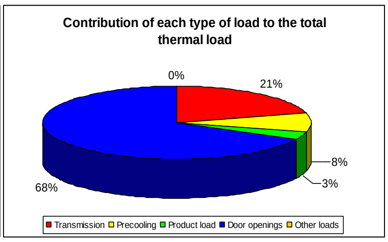






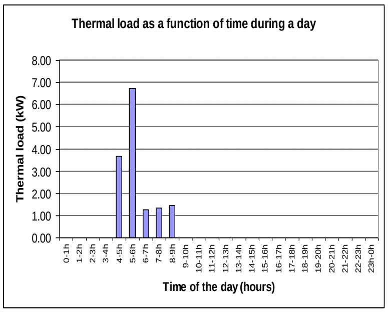


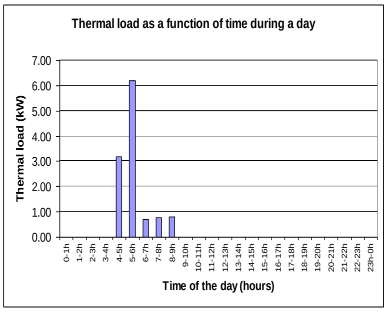


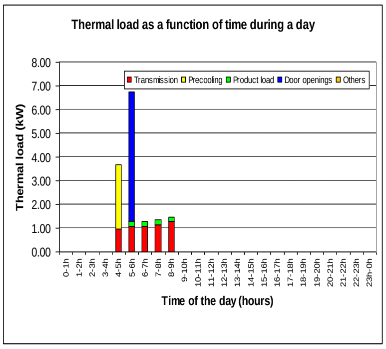


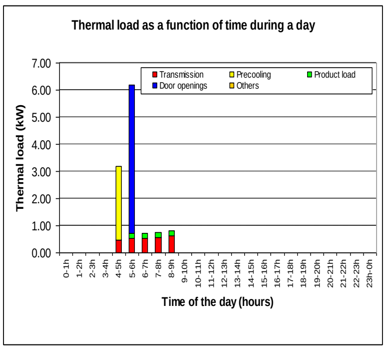
CASE D

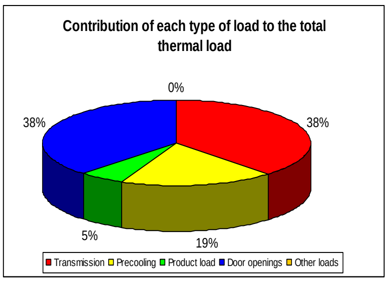
Chilled

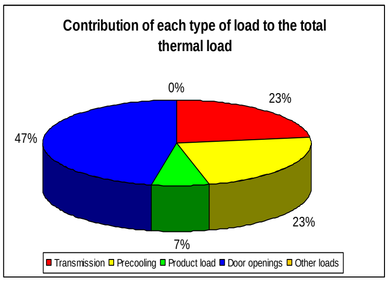








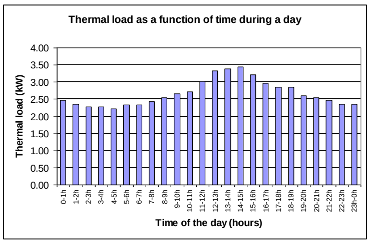


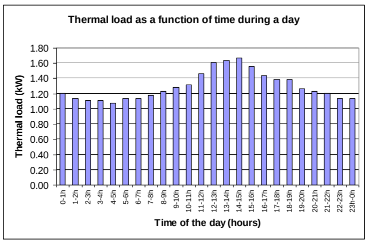


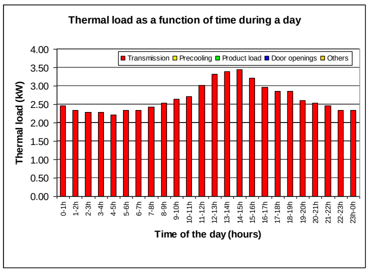
0 mm VIPs *20 mm VIPs*

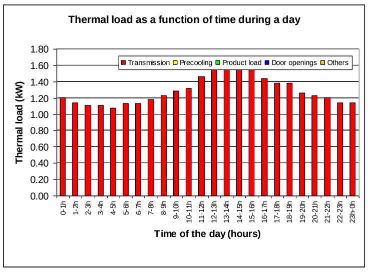
CASE A

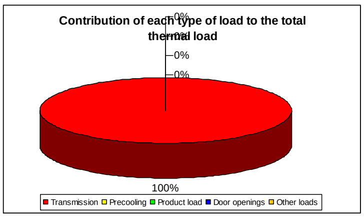
Frozen

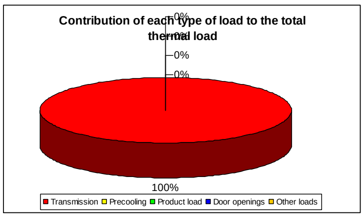






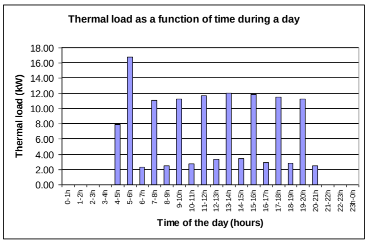


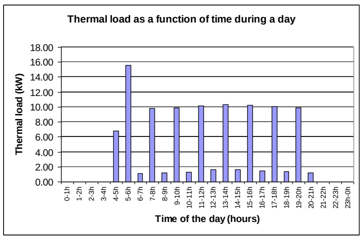


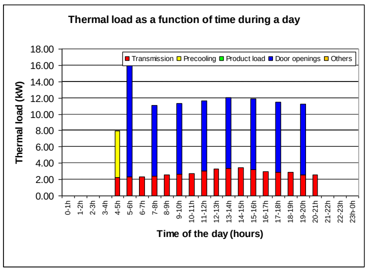


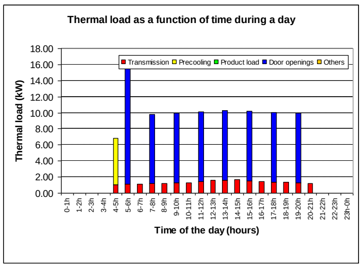
CASE B

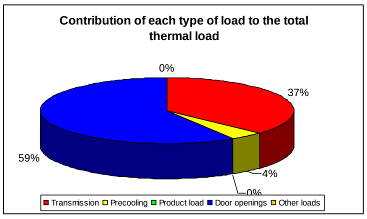
Frozen

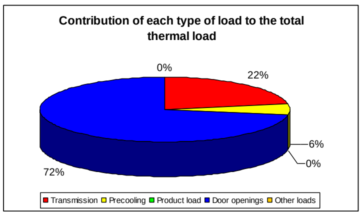








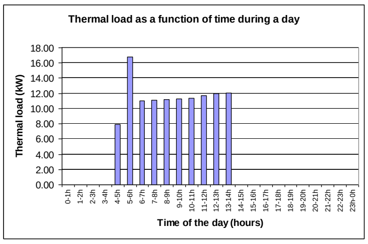


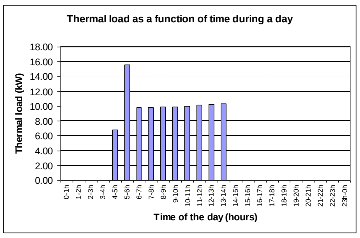


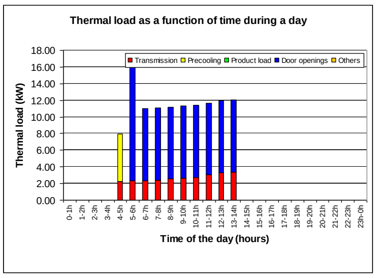
0 mm VIPs *20 mm VIPs*

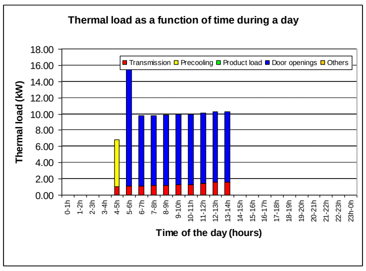
CASE C

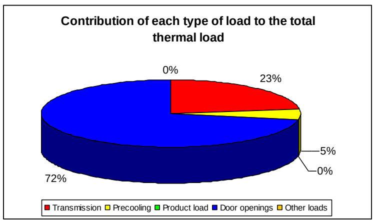
Frozen

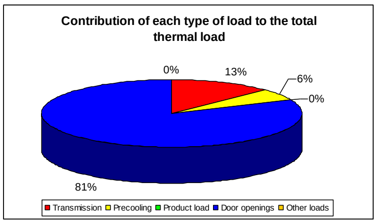












CASE D

Frozen