

## Field test of the performance of a double skinned ORV8 Tent Envelope

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### Abstract:

More and more people globally are living in temporary structures as a result of catastrophic or systemic displacement of populations, as a result of climate change, wars and economic pressures. The need for more research on the cost and performance efficiency of tent materials and structures is clear but hindered the lack of precedents in the field. Little systematic research has been put into optimising tent designs for different climates and many new materials that may potentially be very effective in tents are not tested in relation to their performance as building materials. This paper describes first steps taken towards the development of an experiment evaluation of an innovative fabric, ORV8, in relation to its potential use in constructing a yurt like tent to be erected in the extremely cold and windy climate of Antarctica. The manufacturers of the specialised fabric (ORV8) encouraged testing in advance to check it would perform adequately thermally and structurally on site. This would also help justify larger scale manufacture of the material. To explore and test its performance, an experimental proto-tent was fabricated and then tested in a meat storage facility in Hull that is run continuously at around -20°C. This paper reports on how the tent performed thermally during these exploratory tests and concludes with the lessons learned during the process.

### Keywords:

## 1. Introduction

When looking at a range of innovative materials for use in an experimental tents to be erected in Antarctica in January 2019 it was thought that perhaps a space-blanket like material may work really well, with its very good thermal performance and lightness. With advice from contacts in Dupont and Camvac a 'wish list' of the properties for the tent materials were developed and material identified that might provide for them: Light. Strong, thermally excellent and fire-resistant. Based on the advice the manufacturer of suitable materials Orvec, based at Hull were approached (<http://www.orvec.com> ). With them, the pre-selection of a fabric for experimental testing was undertaken and Orvec+insul8 (ORV8) was chosen. However, the manufacturers were unwilling to supply the large quantities of the material needed for an experimental tent without further testing being done to provide confidence in its suitability for the project.

ORV8 is a four layered material and there were no experimental results available and the understanding of its performance was based largely on empirical evidence and field trial experiences of the manufacturers and two groups of users. No thermal modelling was undertaken, or calculations of the balance of heat produced and lost during its hypothetical use of the tent were made. Stainton Reid, director of Sheerspeed Shelters Ltd. (<https://www.sheerspeed.com>) and a master tent maker, had already used ORV8 on ice

fishing tents supported on a collapsible structure with an Orvec+insul8 (ORV8) external envelope and had found it to stand up very well on an exposed outdoor site over twelve months. ORV8 is also used successfully in Finland as the container material for emergency evacuation, hypothermic, carriers by the Finnish army at temperatures down to -25°C. It was thus decided to test the ice fishing tent with the additional inner suspended lining to provide the confidence needed in its thermal performance to construct the full tent to be pitched in Antarctica in February 2019 for the Extreme Lodge project ([www.extremelodge.org](http://www.extremelodge.org)).

The aim of the field test undertaken in August 2018 was to practically evaluate the thermal performance of a Sheerspeed Ice fishing tent with a ORV8 external envelope and an additional inner envelope of Orve-wrap (<http://www.orvecare.com/orvewrap/>) with fleece on one side and Mylar on the other side of the material sandwich. This was tested in a very low temperature facility (-20°C) in the meat and fish storage warehouse of AJK Ltd. cold storage in Hull. This was done in two stages:

1. The thermal performance was evaluated first with the outer envelope only then with the inner suspended lining, looking at heat transfer through the tent cloth(s) and structure.
2. Look at the details of the thermal performance of the construction of the fabric envelopes to assess where flaws in the design exist or could be improved upon.

## **2. People involved in the field tests**

The test rig for the experimental envelope was been developed by two main players. The Material supplied by Tony Codd / Orvec ([www.orvec.com/](http://www.orvec.com/)) and the production manager David Arksey for the ORV8, a four layer material including a waterproof external material with a reflective low emissivity Mylar core and fleece internal layer. The tent envelope was detailed and manufactured Stainton Reid of Sheerspeed ([www.sheerspeed.com](http://www.sheerspeed.com)). The final tent will have an external rain-proof and super-strong Dyneema fabric envelope reused from racing yacht sails made by Northsails (<https://www.northsails.com/>) but during the field trials the external 'raincoat' was not tested. The fixings of the envelopes to the structure are largely of Velcro. The testing was done inside the facilities of AJK Ltd., cold storage specialists in Hull since 1881 (<http://www.ajkltd.co.uk>).

The testing team includes Professor Adrian Pitts of the School of Architecture at the University of Huddersfield, Tony Codd of Orvec and Susan Roaf of Heriot Watt University.

## **3. Testing Programme**

In field and climate chamber testing of fabrics for clothing, sleeping bags and tents the most relevant measurement parameters are considered to be the insulation and vapour resistance properties of a material, followed by its wind and waterproofness and moisture absorption properties (Havenith, 2009). For this experiment vapour permeability and wind and waterproofness are not being investigated. In experiments relating to tent materials here the key measurements are considered to be for:

- heat resistance (convection/radiation)
- air permeability (affecting heat resistance in wind)
- wicking
- perforations in the construction

The five-stage approach advocated for such testing by Goldman and Umbach (1974) and used widely in the clothing research community and is shown in the schema presented in Table 1 to which we have added stage zero.

Level 7	Test tested over a year in Antarctica
Level 6	Final tent fabricated
Level 5	Test design modified
Level 4	Analysis
Level 3	Prototype tested in Cold Store
Level 2	Prototype test tent assembled
Level 1	Materials selected
Level 0	Tasks developed

Table 1. Experimental Levels of the Project (after Goldman and Umbach (1974))

The structure being experimented with consists of a pop out tent structure 1.5 x 1.5 m x 2m high with two envelopes of ORV8, one stretched over the structure and attached internally by Velcro to it and a second suspended from it by Velcro, internal to the structure.



Figure 1 a) Four ORV8 layers include an external silicon coated polyester layer that offers wind and water-proofing with a metalised PET (Polyethylene terephthalate) or MPET and a PET bonded using a glue to ensure that it is non-conductive. A needle punched a polyester fleece is added, needled and carded to a level that cost efficiently optimises its thermal properties and provides a wipeable inner surface, b) Tent erected in warehouse.

In order to establish the rates of heat gain and loss under different heat charging conditions the tent performance was interrogated within the cold store in the following testing order:

- Tent erected with the outer skin of ORV8
- Left for 1 hour with door open to allow the structure to reach equilibrium in the facility.
- Heat source (small gas camping stove on low) placed in the tent and the door shut to see the thermos-dynamic impact of the internal heat source. Left for 30 minutes only as the camping stove went out. Surface measurements and thermal images taken.
- Structure opened, heater removed, inner lining fitted and door left open to get temperatures back down to equilibrium – close up leave for an hour.
- Introduce heat source for five minutes.
- Person occupies tent for 15 minutes

#### 4. Testing Equipment

- 3 Central HOBO loggers (type UX 100-023) thermometers suspended by string centrally from clips attached to each of the internal surfaces of the tent linings at c. 30cm (sleeping height), 100cm (sitting height) and 1.40 (standing height) above the ground and externally at c. 750 above the ground.
- An external air temperature logger was placed externally c. 1 foot from tent corner.
- 2 internal HOBO loggers (type U12-012) were suspended in the centre of the right and left hand sides of the tent some 10 cms below the roof / wall junction.
- A CEM DT-615 digital thermometer for general readings in support of the tests and to which a thermocouple surface temperature probe was also attached and used only for spot checks. This showed the external surface temperature to be consistent with the cold room environment. In the absence of significant radiative variations it is doubtful that these would be important for the cold room. It was not possible to measure other surfaces without interfering with the experiment.
- Seek thermal RevealXR thermal imaging camera.



Figure 2. a) ORV8 outer skin



b) ORV8 with hung data loggers



c) Tent with inner

#### 5. The testing schedule:

09.00 – Health and Safety induction with Stuart from AJK Ltd.

09.30 - Half hour to assemble and put tent in cold store.

10.00 - Test 1 begins – leave equipment to get to equilibrium

10.00 - Test 1 ends, thermal images and surface temperatures taken and tent extracted and reassembled

10.30 - Test 2 begins – close tent down and leave for an hour.

11.30 - Test 2 ends, thermal images and surface temperatures taken.

12.30 - Test 3 begins – put cooker in and leave for c. half an hour.

13.00 - Test 3 ends, thermal images and surface temperatures taken and inner lining tent attached and left to reach equilibrium.

14.00 - Test 4 begins – cooker put in tent for c. 15 mins. and SR stays in tent for 15 mins.

14.30 - Test 4 ends, thermal images and surface temperatures taken

15.00 – Test rigs and equipment removed and data taken home for analysis

## 6. Cold store facility test results

Of the measurements it may be deduced that anything before 11.00am readings is transport and set up/stabilization time so is not irrelevant to the questions posed in the experiment, although helpful for calibration. Anything after about 14.00 is also not relevant to the main experiment but shows how all sensors returned to relatively stable and close values showing the internal and external climates are virtually similar.



Figure 3. Data logger and fixings



Figure 4. tent open showing central loggers

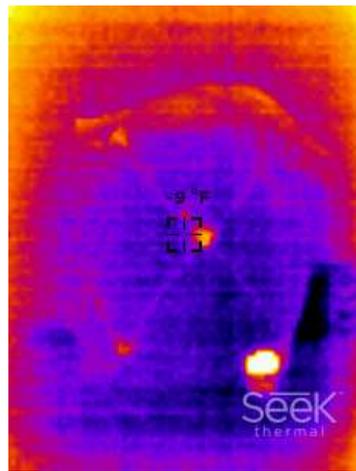
Of the reading results, the top right position and top left position are those sensors were put up close to the tent fabric and are likely to have different readings because of the proximity and impact of the tent surface itself but they are indicative that there are some variations. Their data can be used to infer very little about the actual surface temperature, likewise readings from the sensors in the small black balls gave one or two strange values which is why they were discounted as it seems likely the cold/damp affected the connecting cable. Three very valuable lessons were learnt from the thermal images:

- The single envelope did not perform that well as it did in this tent construction result in very clear cold bridging. Any heat source internally was captured and visibly transported through the Orve-Insulate skin, as shown in the figures below.
- The single skin tent did not provide a very high level of insulation as evidenced by the clear thermal stratification visible through the tent envelope with the light gas stove.
- The tent was extremely well sewn together as there were no cracks or splits where the internal heat was visible through the external envelope along the seams or zips.

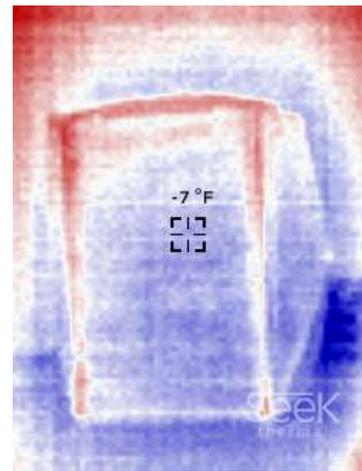
Figures 2b) and 4) show top, middle and bottom HOBOS suspended in the centre of the tent and the outside temperature. The fact that the outside temperature is slightly warmer at times may be because the logger was in the corner close to the floor.



Figure 5. a) Cold bridging visible With ORV8 only



b) Thermal stratification clearly visible with single skin



c) Structural cold was clear with 1 skin

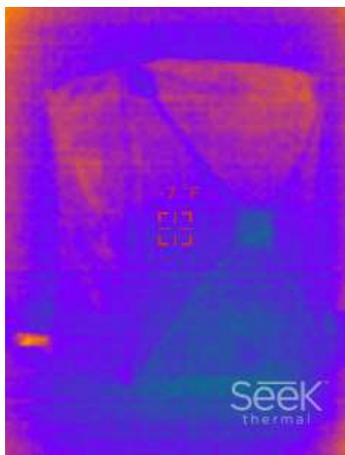
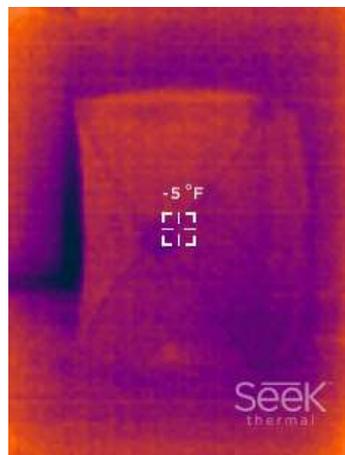
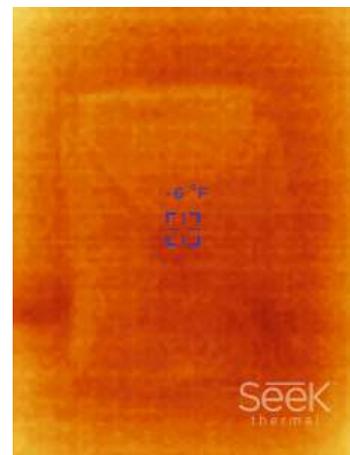


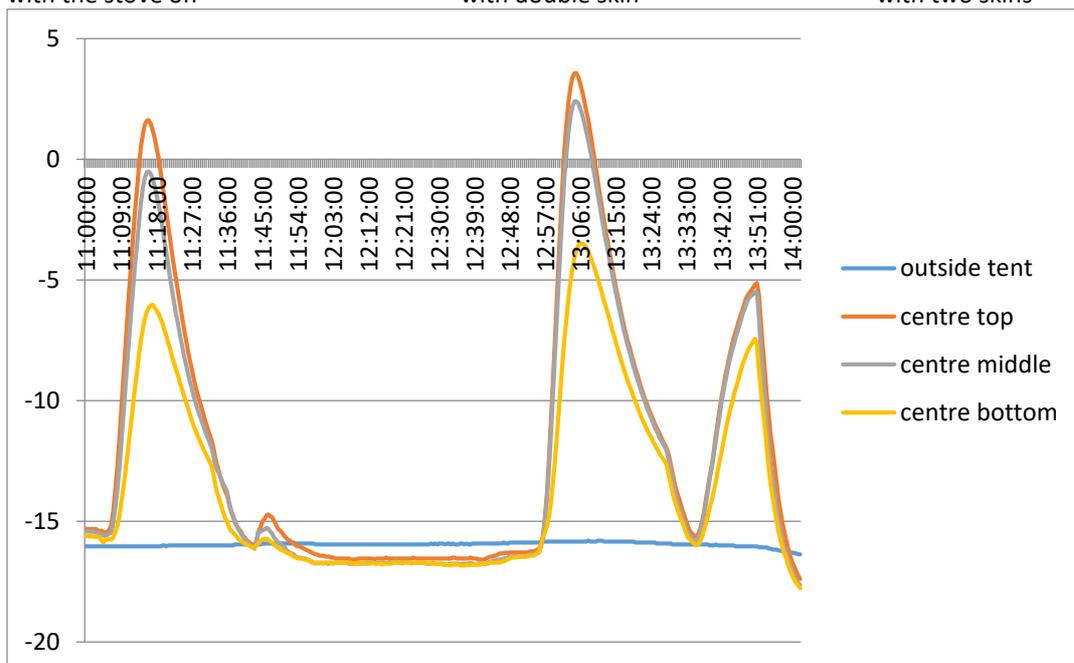
Figure 6 a) Some Stratification with the stove on



b) Cold bridging nearly gone with double skin



c) Very good thermal performance with two skins



Graph 1. Readings from the three HOBOS hung vertically in the centre of the tent.

The thermal measurements and the thermal images show a number of clear lessons:

- The thermal stratification within the closed tent during different test phases of the experiment shows that the upper reaches of the space are warmest, followed by the central area then the lower level closer to the uninsulated floor. The temperature increase in the basic tent with the heater on was significant before it was stopped. The temperature at head height rose over approximately 10 minutes from -15.4C to +1.6C with a maximum rate of increase of about 2.2C/minute
- It also clearly shows that over the very short period that that the gas stove was alight during the two test phases (first and second peaks) each test phase that the internal tent temperature rose higher in the tent with the internal lining fitted (second peak) than in the tent with only the external tent enveloped in place and sealed up (first peak). The temperature increase in the tent with the additional layer of fabric with the heater on was also significant before it was stopped. The temperature at head height rose over approximately 10 minutes from -16.2C to +3.6C with a maximum rate of increase of about 3.4C/minute - ie a better performance.
- It was also clear that when Susan Roaf occupied the tent with no other heat source (peak three) that she caused the internal temperature within the tent to rise fairly steeply, then plateauing off slightly until the temperature fell when the tent flap was opened. The temperature at head height rose over approximately 15 minutes from -15.6C to -5.1C with a maximum rate of increase of about 1.1C/minute - ie some benefit even if only occupied by one person as a heat source.
- The comparative calibration between all the sensors shows only modest variations with a maximum average variation of between 0.1 and 0.2 C, a not significant finding in the circumstances but with more time some small adjustments to accuracy of those readings might be made.

The CEM DT-615 digital thermometer was used for general readings in support of the tests and to which a thermocouple surface temperature probe was attached for spot checks. These showed the external surface temperature to be consistent with the cold room environment. In the absence of significant radiative variations, it is doubtful that this would be important for the cold room. We could not measure other surfaces without interfering with other tests.

## **7. Second Polar Lodge Envelope Testing Experiments 8<sup>th</sup> August 2018**

A second experiment was undertaken in Hull in August 2018 looking at the impact of using the highly reflective side of an Orve+wrap lining with one side reflective and one side on the inside or the outside of the inner lining envelope of the tent. The experiment was carried out by Tony Codd and the team at ORVEC International Ltd and proved useful in interrogating that question. The shelter was tested in an outside area with initially dry sunny conditions. As the test progressed it clouded over so direct sunlight was intermittent.



Fig 7a). Car park erection



b) ORV8 external skin on



c) ORV8 + Orve+wrap inner lining

Three temperature probes were positioned as follows:

- 1- 40cm from the top of the shelter
- 2- 100cm from the top of the shelter
- 3- Outside and in the shade of the shelter

**Test 1:** Standard ORV8 envelope, closed shelter for a one hour duration

**Test 2:** Orve+wrap lining in place with fleece innermost, shelter closed for one hour

**Test 3:** Person stood in closed shelter for 15 minutes - Shelter left open for around one hour

**Test 4:** Orve+wrap reversed, green reflective side innermost, shelter closed for one hour

**Test 5:** Person in closed shelter for 15 minutes

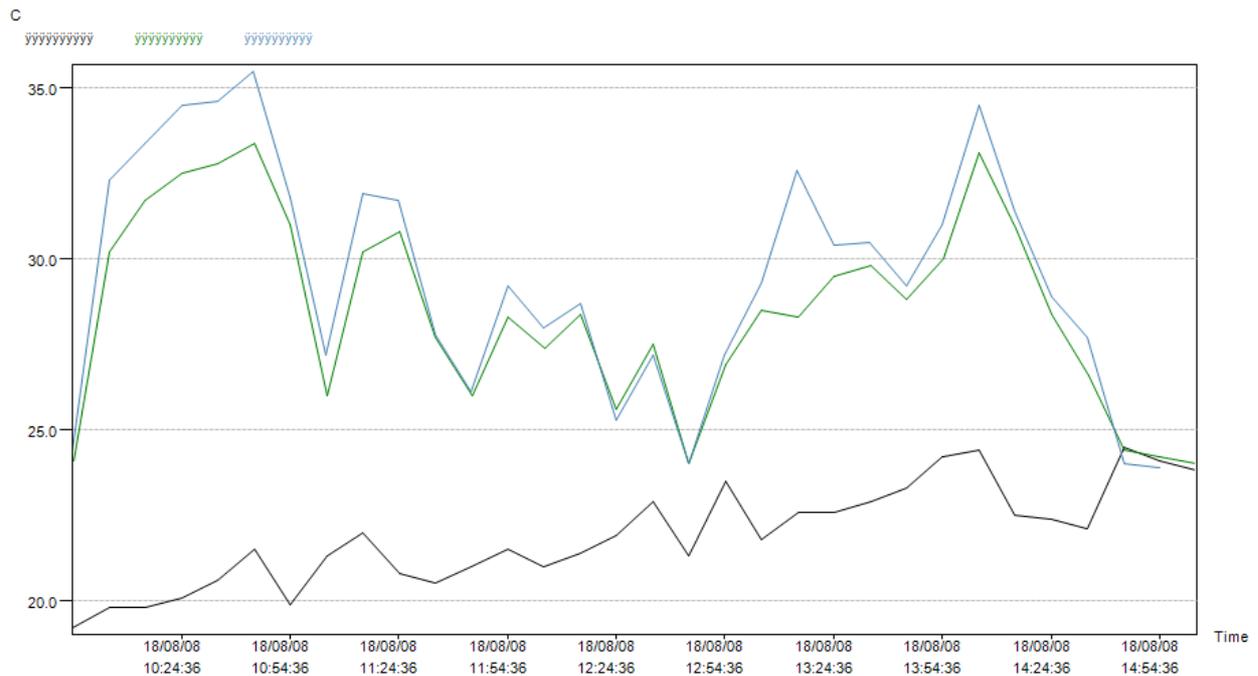
## 8. Second Polar Lodge test results (see Graph 2)

- Readings confirm the significance of the stratification of temperatures within the tent.
- Test 1 shows the external envelope performs worse than with a double envelope when the conditions outside were warm.
- Shows that when the fleece is on the inside of the material the internal temperatures are lower internally than when the shiny reflective lining is to the inside.

When the green reflective lining, with its very high emissivity, is facing inwards the internal temperature peaks are demonstrably higher than with the fleece lining. This is because more of the heat is being let through from the outside. With the fleece internally and the high emissivity to the outside of the inner lining the heat is not penetrating from the outside because that reflective surface is not allowing heat flow through it. It is clear here that the addition of a second Orve+wrap inner lining to the outer ORV8 skin significantly reduces the heat ingress through the envelop. This is less so when the low emissivity fleece lining is located internally than when the high emissivity reflective green surface is placed inside.

## 9 Conclusions

The lessons from fairly rudimentary field tests such as those outlined above can be influential in persuading investors to fund the use of innovative materials for experimental projects. The learning from such tests can also be useful in helping shape the design decisions of those developing new ideas and forms that in turn may yield good results in more advanced tests. Empirical learning that results from such tests can be important in shaping new design ideas.



Graph 2. Graph of temperature readings from 2<sup>nd</sup> Hull tent experiment. Key: Blue- 40cm from top of shelter; Green- 100cm from top of shelter; Black- outside and in the shade of the shelter

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