Tent Research and Development project
For a new light self-standing tent
2015 winter test in Luxembourg

Overview

In 2011 the three largest entities operating in humanitarian sheltering, IFRC, ICRC and UNHCR launched a R&D project to continue the efforts of defining a lightweight, self-supporting family-shelter solution for emergency operations. The aim was to develop a solution even lighter than the standard family tent, at a lower cost and with fewer constraints regarding production, transport and storage. In addition to these technical and logistic criteria, further criteria for usability, user-satisfaction and climatic response were introduced.
The process has been coordinated and managed by Senior Shelter Specialists from IFRC-Shelter and Settlements Department (IFRC-SSD) and UNHCR.

After different tests and a selection process, two proposed models were selected to be tested on winter conditions. The Project industrial partners of these models were requested to produce two prototypes of each model for comparative testing, one sample of each model with winter cover and another without.

The winter test was originally planned to take place in Pakistan. However, following an analysis of the security situation, the IFRC-SRU together with the Project Committee (IFRC, ICRC and UNHCR), decided to organize the field test in two blocks. The first part would be a theoretical winter test in Luxembourg and the second part would be a remote monitoring in real winter conditions in Peshawar, Pakistan. The present report focuses on the theoretical test in Luxembourg.

In November 2015, the prototypes of the different tent models were ready for winter testing.
The IFRC-SRU conducted the winter test in Luxembourg.

The following matrix shows a basic description of the tested models:

Tent 1 – STD Family Tent + WK

Short description:
Rectangular-based double fly tent with two covered polygonal entrance-spaces. The outer tent must be supported by 3 poles+ 1 ridge pipe. Inner, the side walls must be supported by 6 metallic poles. Inner tent hanging from the inside. Winter kit made of one poli-cotton piece for hanging to the inner tent + NFI. The tent structure is non-self-standing (tensioners+ guide ropes+ pegs needed)

Covered inner Surface 23,02 m^2	*Packaging volume 0,21 m^3*	*Packaging weight 106 kg*

Tent 2 – STD Family Tent

Short description:
Rectangular-based double fly tent with two covered polygonal entrance-spaces.
The outer tent must be supported by 3 poles+ 1 ridge pipe Inner, the side walls must be supported by 6 metallic poles. Inner tent hanging from the inside. The tent structure is non-self-standing (tensioners+ guide ropes+ pegs needed)

Covered inner Surface23,02 m^2	*Packaging volume 0,21 m^3*	*Packaging weight 58 kg*

***Tent 3 – Dome Tent + WC** (winter cover)*

Short description:
Square-based double fly tent with a Self-standing structure system. Frame made of 3 flexible poles in sections, sliding in sleeves on the outer face of the canvas. Two long poles for the diagonal lines and one short pole for the central line. Exterior winter kit in poli-cotton placed over the tent. Four additional poles+ guide ropes and pegs are needed.

Covered inner Surface 27m^2	*Packaging volume 0,45 m^3*	*Packaging weight 109kg*

***Tent 4 – Semi-geodesic tent +WC** (winter cover)*

Short description:
Square-based double fly tent with a Self-standing structure system. Frame made of 5 flexible poles in sections, sliding in sleeves on the outer face of the canvas. All poles with same dimensions for the central and brazing lines. Exterior winter cover placed over the tent. 7 additional poles + guide ropes and pegs are needed.

Covered inner Surface27m^2	*Packaging volume 0,45 m^3*	*Packaging weight 115kg*

Tent 5 – Dome Tent

Short description:
Square-based double fly tent with a Self-standing structure system. Frame made of 6 flexible poles in sections, sliding in sleeves on the outer face of the canvas. Two long arches for the diagonal lines + 2 short arches for the central lines and 2 arches for the front and rear faces.

Covered inner Surface 17,4m²	*Packaging volume 0,36 m³*	*Packaging weight 60kg*

Tent 6 – Geodesic tent

Short description:
Polygonal-based double fly tent with a Self-standing structure system. Frame made of 5 flexible arches in sections, sliding in sleeves on the outer face of the canvas. All arches on the same side for the central and brazing lines.

Covered inner Surface 17,5m²	*Packaging volume 0,21 m³*	*Packaging weight 52kg*

Tent 7 – Geodesic tent + WC (winter cover)

Short description:
Polygonal-based double fly tent with a Self-standing structure system. Frame made of 5 flexible arches in sections, sliding in sleeves on the outer face of the canvas. All poles on the same dimension for the central and brazing lines. Exterior winter cover placed over the tent with an independent structure. 7 additional poles + bridge pipes + guide ropes and pegs are needed.

Covered inner Surface N/A	*Packaging volume 0,41 m³*	*Packaging weight 107kg*

Test procedures

The main objective of the winter test was to assess the performance of the shelters in winter conditions in terms of temperature, humidity and air quality as basic parameters of human comfort.

The same procedure was followed with all the shelters in order to collect consistent quantitative data. The same model of electric oil radiator was placed inside the shelters as a heating system and the energetic consumption was registered. Automatic thermometers, humidity sensors, CO and CO2 loggers were placed inside the shelters to record quantitative information. More than 7000 values of data were collected by keeping periodic records and measuring the inside temperature, relative humidity and gas concentration on the air in each of the different tent types. By using a weather station installed on site, 15000 values of weather information including wind speed, rainfall, humidity and temperature were recorded. A continuous monitoring to record qualitative data was conducted by the SRU Research officer during the entire testing period.

The following matrix shows the analysed topics organised by test:

Test	Objective	Measured criteria
Test 1	Comparison of different operational and logistic parameters during the setup time.	Evaluate practical and logistic aspects (setup, packaging, weight, etc.)
Test 2	Comparison of thermal performances between New tents with winter cover and STD Family tent with winter kit.	Interior air temperature with heating system and weather conditions.
Test 3	Thermal performance of the tent and influence of the winter cover unoccupied. Different measuring points and comparison with the weather station data.	Interior air temperature with heating system and weather conditions.
Test 4	Influence of winter cover openings on the thermal performance unoccupied. Different measuring points inside the tent and weather station data.	Interior air temperature with heating system and weather conditions.
Test 5	Humidity in the air of the tent, when closed and unoccupied.	Interior humidity in the air without occupancy.
Test 6	Air quality unoccupied inside the tent CO and CO2 concentration when tent is closed (a heating system with open combustion chamber is needed for this test).	Interior CO and CO2 concentration in the air

Site location

10, Cite Henri Dunant - Bertrange, Luxembourg.

Site preparation

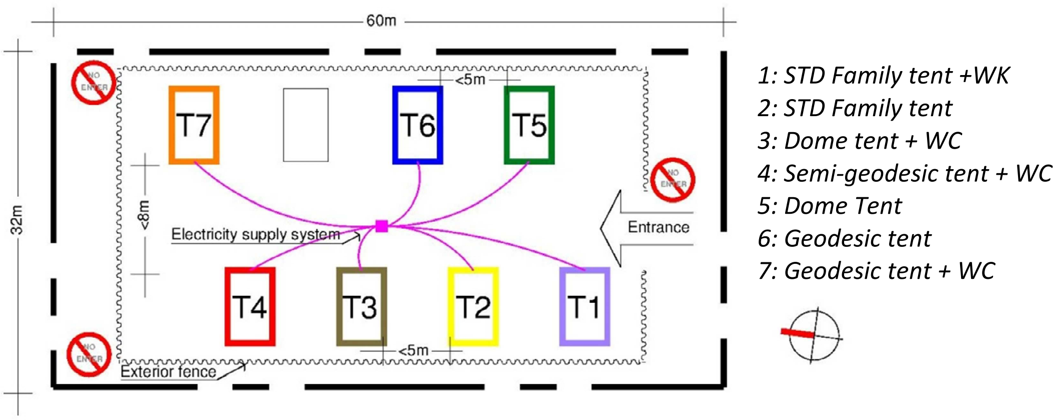
The site was set up to ensure that each of the tent prototypes experienced consistent test conditions.

This includes but is not limited to:

- Preparation of ground/ homogenous ground conditions/ level ground
- Availability of continuous and stable electricity connection for the heating system 24h/day.
- Security signs and perimeter fence avoiding accidents and/or the presence of non-authorized people inside the plot.

Arrangement and orientation of tents:
This has a significant effect on testing and in particular on the exposure to seasonal prevailing wind conditions.

The diagrams below show optimal tent configurations:



The entrances of the tents are aligned perpendicular to the prevailing winter wind for an optimal testing configuration.

NOTE:

We tried to avoid shading/ overshadowing or close building interferences over the tents.

External weather conditions monitoring.

An independent/autonomous weather station placed on the testing plot recorded :

- Air temperatures (Celsius)
- Relative humidity (%)
- Precipitation (mm)
- Wind speed and direction (km/h)

Weather station general characteristics:

RainWise INC. www.rainwise.com

Model: MK III series LR-TRI

General Specifications

- Operating Environment :
  Temperature: -55 to 85C; Accuracy +- 0.2C
- Relative Humidity:
  0-100%; Accuracy -+2%<10%RH<90
- Wind Speed:
  0 to 241km/h; Accuracy +-1,62km/h

Logger general characteristics:

RainWise INC. www.rainwise.com

Model: Hardware CC-3000;

Software: Weatherview32 V8.0

Memory:

Type Flash

Capacity: 2GB (490834 data records)

Retention >20years

Write cycles: 10 M:chip erase cuycles

Resume of weather station data

Max. temp 16.9C	**Max wind peak** 55km/h	**Max rainfall** 13mm
Min. temp. -4.8C	**Av.max wind speed** 20km/h	

Measurement used instruments

1) Relative humidity sensor with automatic data logger

Model:	LogTag HAXO-8
Measurement Range	Temperature: -40°C to +85°C / Humidity: 0 to 100% RH
Resolution	Temperature: <0.1°C / Humidity: <0.1% RH
Accuracy	Temperature: < ±0.5°C @ 25°C / Humidity: < ±3%RH @ 25°C
Data Storage	8,000 Humidity & Temperature Readings
Sampling Interval	Adjustable, 30 seconds to several hours
Power Source	3V Lithium Battery - Non-Replaceable
Weight	35g
Case Material	Polycarbonate
Dimensions	86mm x 54.5mm x 8.6mm

2) Thermometer - air temperature automatic data loggers.

Model:	LogTag TRIX-8
Measurement Range:	*-40°C to 85°C*
Resolution:	*0.1°C (-40°C to 40°C); 0.2°C (40°C to 85°C)*
Accuracy:	±0.5°C: -20°C to +40°C
Data Storage Capacity:	8000 Readings (16000 bytes Memory)
Sampling Frequency:	30 Seconds to 18 Hours
Power Source:	3 Volt Lithium Battery - Non-Replaceable
Case Material:	Polycarbonate
Weight:	35g
Dimensions :	86mm x 54.5mm x 8.6mm

3) Carbon dioxide sensors with automatic data logger, alarm and air mixture including relative Humidity temperature in the air

Measurement range: *0 -10,000ppm (1%) or 300,000ppm*
Sensing Method*:* *Non-dispersive infrared (NDIR)*
Sampling Method: *Diffusion*
Response Time: *< 25 seconds gas diffusion time*
1% CO2 Sensor Repeatability*:* *± 20 ppm ± 1 % of measured value*
1% CO2 Sensor Accuracy: *± 30 ppm ± 3 % of measured value*
30% CO2 Sensor Repeatability: *± 0.1% vol. CO2 ± 2 % of measured value*
30% CO2 Sensor Accuracy: *± 0.2% vol. CO2 ± 3 % of measured value*
Temperature Measurement Range: *-40 to +60C*
Temperature Accuracy: *± 0.4C at 25C*
Relative Humidity Measurement Range*:* *0 – 100% RH non-condensing*
Relative Humidity Accuracy*:* *± 3% RH*

4) Carbon monoxide sensor with automatic data logger, alarm and air mixture including relative Humidity temperature in the air.

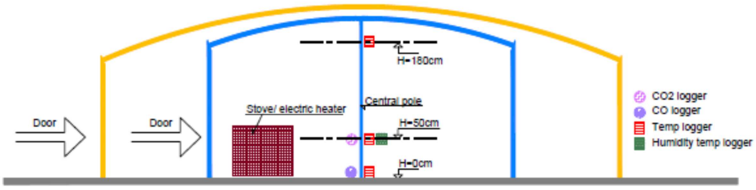
Model: *EL-USB-CO*

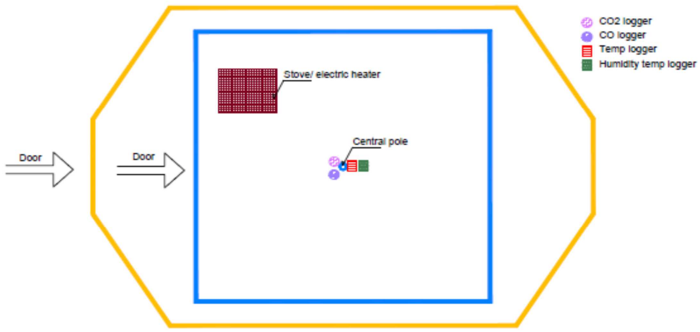
Measurement range: *0 to 1000 ppm CO*
Internal resolution: *0.5 ppm CO*
Accuracy: *+-6 % of reading (overall error)*
Logging rate: *10s to 300s*
Operating temperature range: *-20 to +40*

5) Electric power meter

Model: *PM 231*
Type of protection: *IP20*
Nominal voltage: *230 V ~ 50 Hz*
Max. load: *3600 W (230 V ~ 16 A)*
Measuring range voltage: *190 - 276 V AC*
Measuring accuracy voltage: *+/-1%*
Measured range current*:* *0.01 - 16 A*
Measuring accuracy current: *+/-1% or +/-0.01 A*
Measuring range power: *0.2 - 3600 W*
Measuring accuracy power: *+/-1% or +/-0.2 W*
Power consumption range*:* *0 - 9999.9 kWh*

Plan and elevations views showing the location of proposed sensors





Testing considerations

Occupancy: all the tents remained empty during the entire testing period.

Electric heating: Model: AEG RA 5589NE with automatic temperature programing. Power level 2000W

Fuel/Energy: The fuel source for the identical liquid fuel stoves was as consistent in composition and weight as possible, and purchased from the same batch from a reputable supplier. This is to ensure that the liquid fuel has the same calorific value per unit weight.

Stove: During Test 6, the stove must operate continuously in order to produce consistent data
Model: Tosai 241
Heating output: 2200W
Fuel: kerosene
Fuel consumption: 0.23l/h
Dimensions: 395x345x340mm (HxWxD)

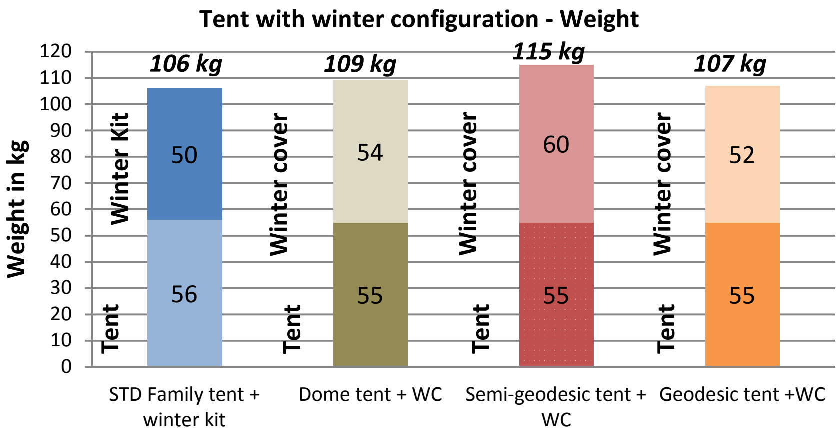
Logging: During the entire testing period the remarkable observations have been recorded.

Basic analysis of the technical obtained data organized by test.

Test 1 — *Comparison of practical and logistic parameters.*

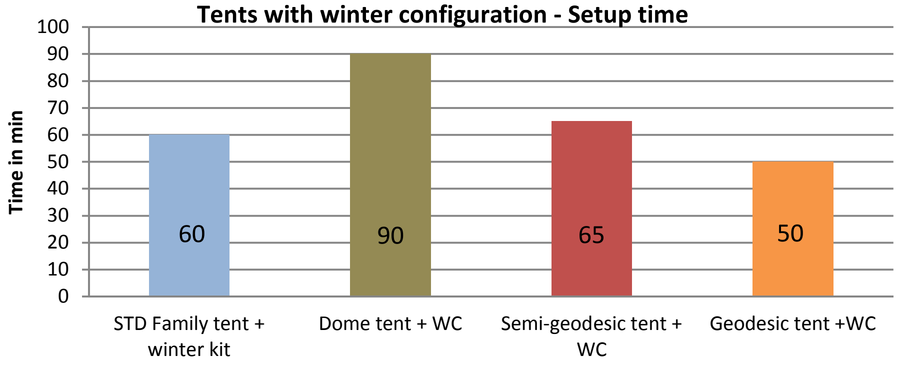
- *Description and general conditions*
  Evaluate practical and logistic aspects (setup, packaging, weight, etc.)
  The research officer had to document, compare and evaluate the predefined practical and logistic aspects, based in the observation, the experience of the research officer and obtained quantitative data.
- *Approach*
  In the testing spot and before to start the setup process, the research officer had to take the measures and weight of packaging, pictures and other relevant appreciations and to record all the data in a pre-established format. During the setup process, it was required to count the needed time, to take pictures and to document other relevant comments. All the related data had to be recorded in pre-established formats that include pictures and other complementary graphic information of the setup process and testing plot. GPS coordinates and north directions have also been registered.
- *Density of measures:*
  An individual matrix per each shelter to document all the predefined data and pictures.
- *Values to collect:*
  Packaging dimensions (m)
  Packaging Volume(m^3)
  Packaging weight (kg)
  Setup time (min)

Analysis of collected data:



Test 1- comments:
-The heaviest tent is the Semi-geodesic tent +WC.
-The Geodesic Tent + WC have almost the same weight than the Standard Family one
-The WK represents 53% of the total weight of the STD Family Tent + WK; and the WC represents 48% of the total weight of the Geodesic tent + WC.

Analysis of collected data:

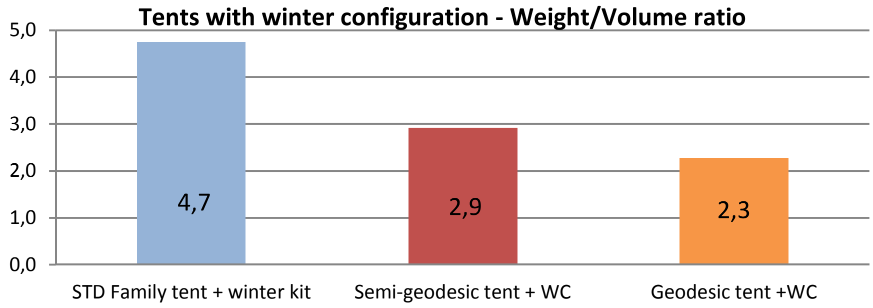


Test 1- comments:

- Based in a team of 4 volunteers the Dome Tent + WC needs more time be erected.
- The shortest setup time was recorded on the Geodesic tent +WC, i.e. 50min in total (the sleeves make a big difference).
- The setup time of the Geodesic tent is 10min shorter than the time to setup the Standard Family Tent + WK.

Note: it was not possible to dig drainage or bury the tent flaps due to particular conditions of the testing plot.

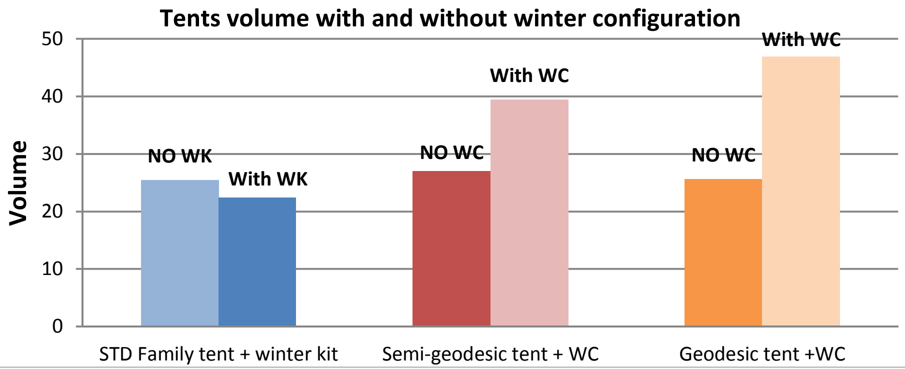
Analysis of collected data:



Test 1- Weight/volume graph comments:

-On the Graph Weight/ volume ratio the Geodesic tent provided the best relation with a 2,3 relation, i.e. 50% less than the Standard Family Tent with 4,7 (Small ratio ∴ better relation)

Analysis of collected data:



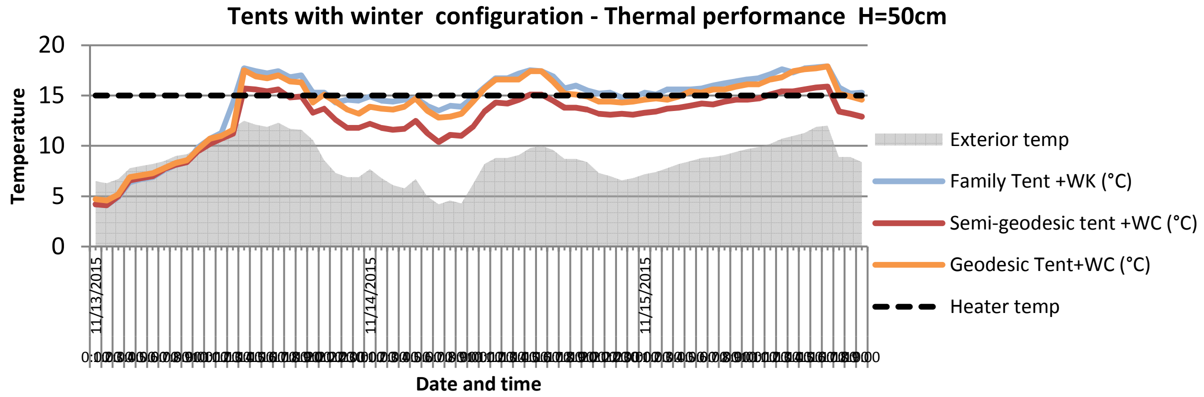
Test 1- Tent volume with and without winter configuration graph comments:

-The winter cover increases the covered volume on the Semi-geodesic tent and the Geodesic tent.
-The winter kit decreases the covered volume on the STD Family tent.
-The max. covered volume without winter configuration is on the Semi-geodesic tent
-The max. covered volume with winter configuration is on the Geodesic tent.

Note: volume values provided by the Industrial Project Partners.

TEST 2	***Comparison of interior temperature between New tents with winter cover and STD Family Tent with winter kit.***
o	*Objective or measured criteria:* Obtaining data by measuring the interior air temperature in different relevant points inside the shelter, comparison between the shelters with winter cover and Standard Family Tent with winter kit .Comparing the interior data with the external recorded temperatures.
o	*Approach:* In a vertical line at the center of the shelter, 3 logtags have been placed to record the temperature each 15 min. The first logtag was attached to the bottom of the shelter (over the ground), the second at the height of 50cm and the last one at the height of 180cm or next to the shelter ceiling. The same type of heating (electric oil radiator) was placed inside the shelter.
o	*Density of measures:* Interior temperature recorded each 15min Exterior temperature recorded each 15min
o	*Values to collect:* Interior air temperature in different points (Celsius) Exterior air temperature (Celsius)

Analysis of collected data:



Test 2 Comments

-The recorded temperatures inside the Family tent with WK and the Geodesic tent with WC are very similar with no significant differences on the temperature curves.

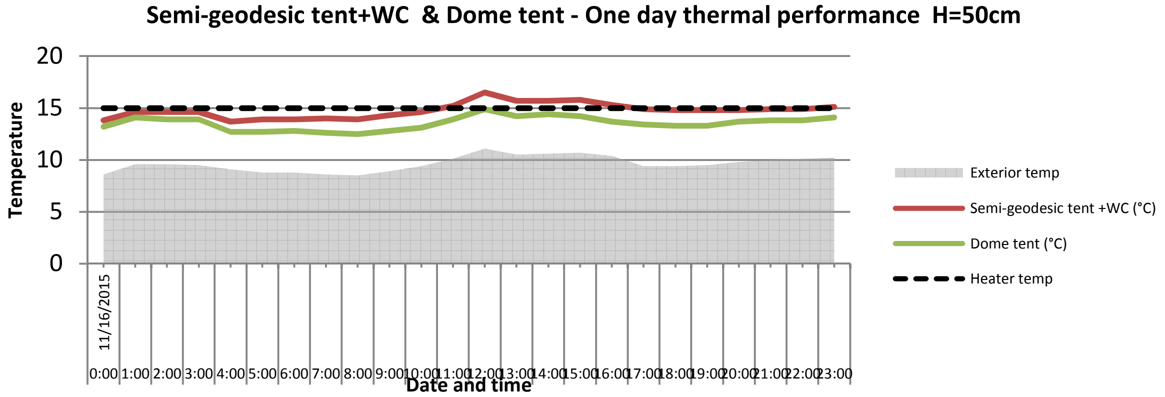
-The recorded temperatures at H=50cm on the Semi-geodesic tent with WC is lower than the other tents(ΔT -2C).

-The average temperature difference (ΔT) inside/outside is between **5 to 7,8C**.

-With the electric heating ON; the tents need between **105 to 123 min** to reach the max temperature difference inside/outside.

TEST 3	***Thermal performance of the tent and influence of the winter cover unoccupied.***
o	*Description and general conditions* Obtaining data by measuring the interior air temperature in different relevant points inside the shelter, comparison between shelters with and without winter configuration. Comparing the interior temperatures with the external recorded temperatures and registering the energetic consumption during the testing process.
o	*Approach:* In a vertical line at the center of the shelter, 3 logtags have been placed to record the temperature each 15 min. The first logtag was attached to the bottom of the shelter (over the ground), the second at the height of 50cm and the last one at the height of 180cm or next to the shelter ceiling. The same type of heating (electric oil radiator) was placed inside the shelter. The electric consumption of the heating has been recorded individually.
o	*Density of measures:* Interior air temperature recorded each 15min Exterior air temperature recorded each 15min Electric consumption after the test period

Analysis of collected data:

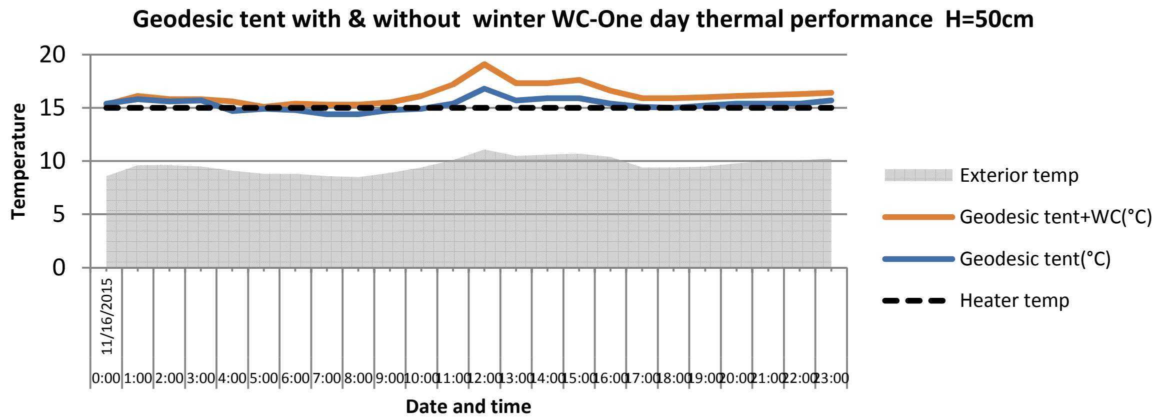


Test 3 – Semi-geodesic tent comments:

-The graph shows that the WC on the Semi-geodesic tent had a positive effect on the recorded temperatures. The average of recorded temperatures between the tent with winter cover and the one without is **1,6C**.

- Exterior/interior Δt at 50cm over the ground in the Semi-geodesic tent with WC is **5,14C**.
- Exterior/interior Δt at 50cm over the ground in the Dome tent without WC is **3,9C.**

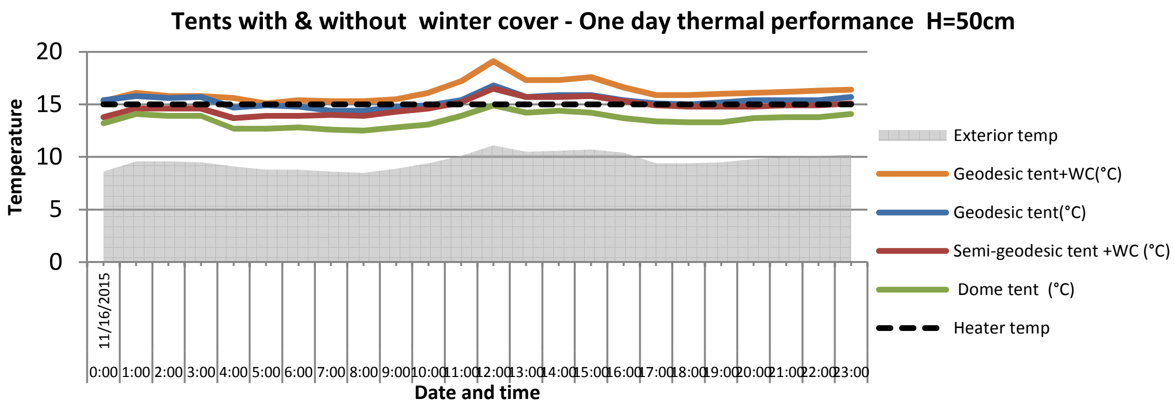
Analysis of collected data:



Test 3 – Geodesic tent comments:

- The recorded data shows that by using the WC on the Geodesic tent a positive increase of the interior temperatures of **1C** was recorded at H=50cm over the ground level.
- Exterior/interior Δt at 50cm over the ground in the Geodesic tent with WC is **6,6C**
- Exterior/interior Δt at 50cm over the ground in the Geodesic tent without WC is **5,7C**

Analysis of collected data:



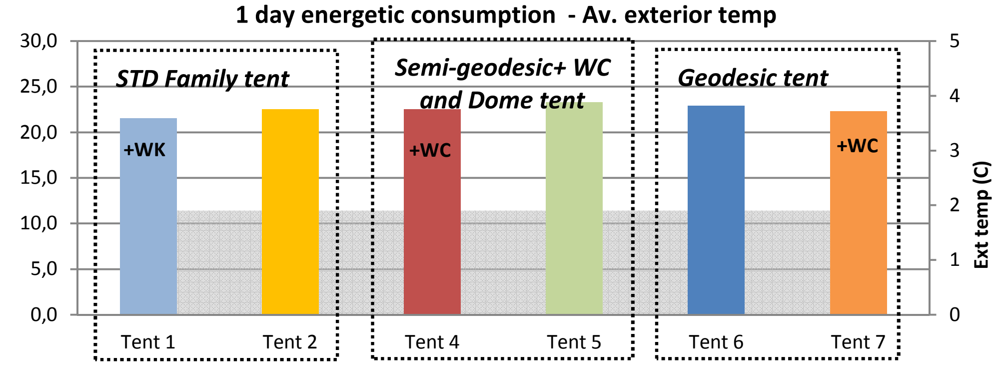
Test 3 – All tent comments:

-The influence of the solar-load provides the highest variation on the temperatures recorded in the interior.

-The last graph shows that the recorded temperatures inside the tents are very similar. But inside the Semi-

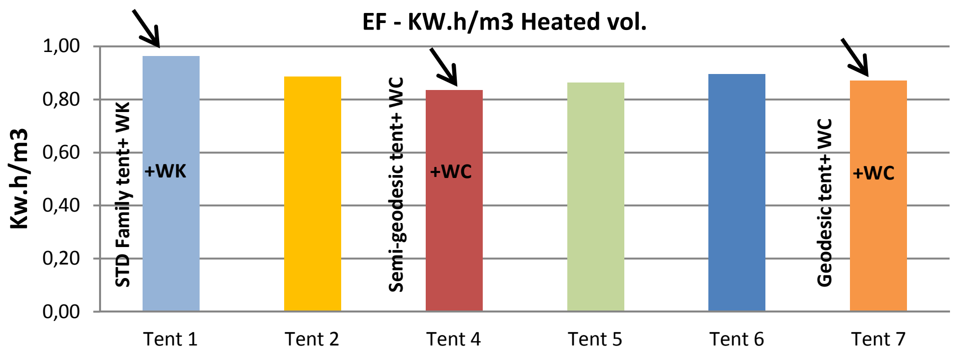
geodesic tents are lower than the ones inside the Geodesic tents.
- The recorded temperatures on the Semi-geodesic tent with WC are very similar to the temperatures inside the Geodesic tent without WC.

Analysis of collected data:



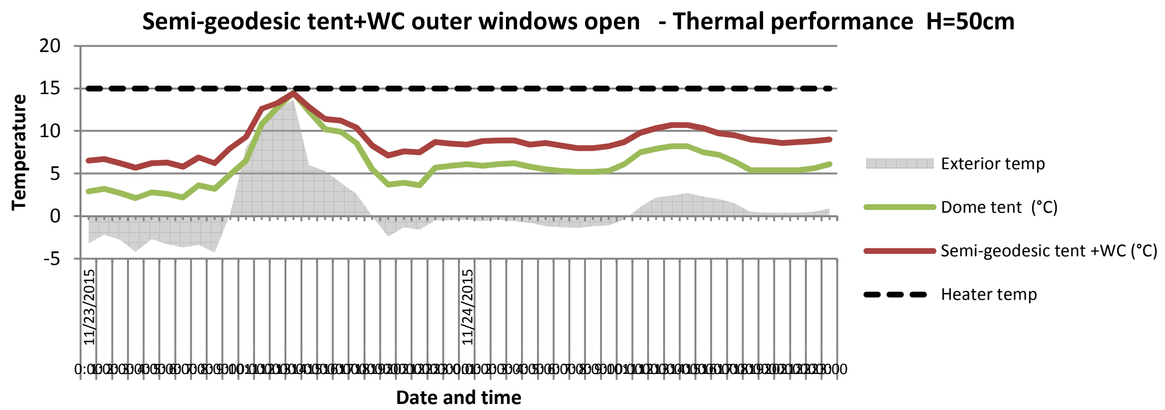
Test 3 – Energetic consumption comments:
-The recorded energetic consumption is lower in the tents with winter kit or winter cover**.**
-The difference is: 5% lower energetic consumption on the Std. Family tent; 2.7% lower energetic consumption recorded on the Semi-geodesic and 3% lower energetic consumption on the Geodesic tent.
-The maximum energetic consumption was in the Dome tent without WC and the minimum in the Std. Family tent with WK.

Analysis of collected data:



Test 3 – Energetic consumption on all tents, comments:
-The Geodesic tent + WC and the Semi-geodesic tent+ WC perform better than the Std. Family tent + WK in terms of Energetic Efficiency. The recorded energetic consumption per m3 in the Semi-geodesic tent + WC was 0.84kwh/m3; in the Geodesic tent + WC was 0.87 kwh/m3 and in the Std. Family tent + WK 0.96 kwh/m3.

TEST 4	***Influence of openings on the thermal performance unoccupied.***
o	*Description and general conditions* Obtain data by measure the interior air temperature in different relevant points inside the shelter, compare the temperature between the shelters with WK/WC and windows open or close. Compare the interior temperatures with the two different configurations with the external recorded temperatures.
o	*Approach:* In a vertical line at the center of the shelter, 3 logtag have to be placed to record the temperature each 15 min. The first logtag have to be attached in the bottom of the shelter (on the ground), the second 50cm high and the last at 180cm high or next to the shelter ceiling. The same type of heating (electric oil radiator) has to be placed inside the shelter. The test will be conducted with the winter kit windows open (exterior windows only) and record data for at least 24h.
o	*Density of measures:* Interior air temperature recorded each 15min Exterior air temperature recorded each 15min
Analysis of collected data:	

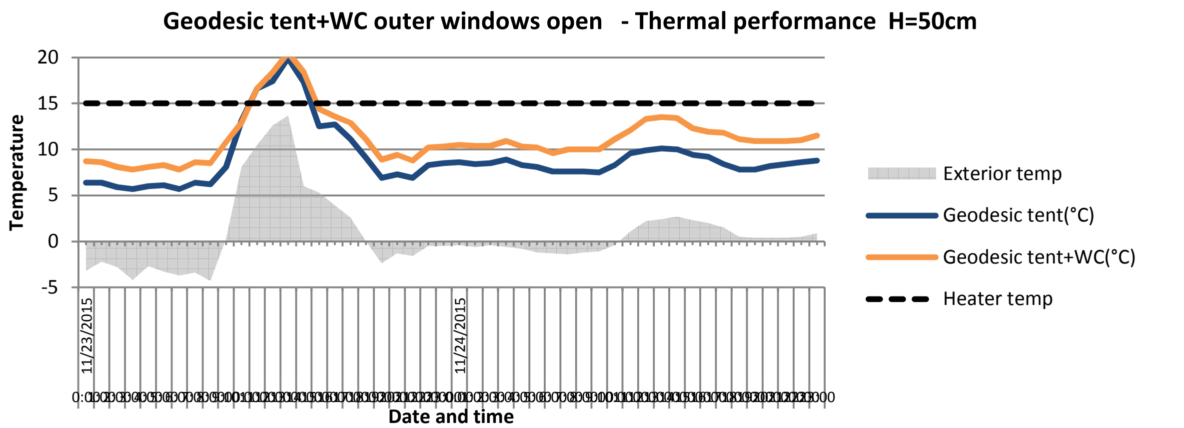


Test 4 Semi-geodesic tent with winter cover windows open comments:

-The recorded temperatures are higher inside the Semi-geodesic tent + WC and windows open in comparison with the Dome tent without WC.

- By using winter cover with windows open we have recorded higher temperatures than inside the tent without WC.

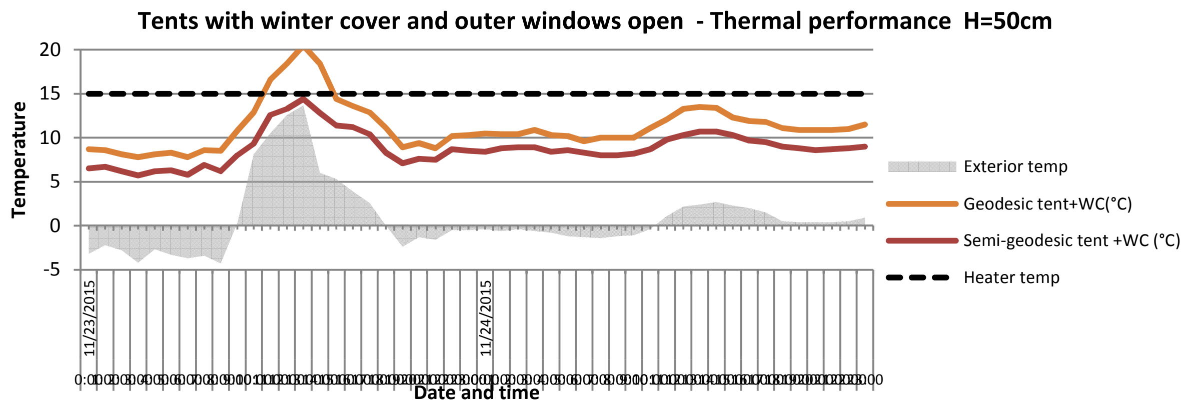
Analysis of collected data:



Test 4 Geodesic tent with winter cover windows open comments:

-The recorded temperatures are higher inside the Geodesic tent + WC and windows open in comparison with the same tent without WC.

Analysis of collected data:



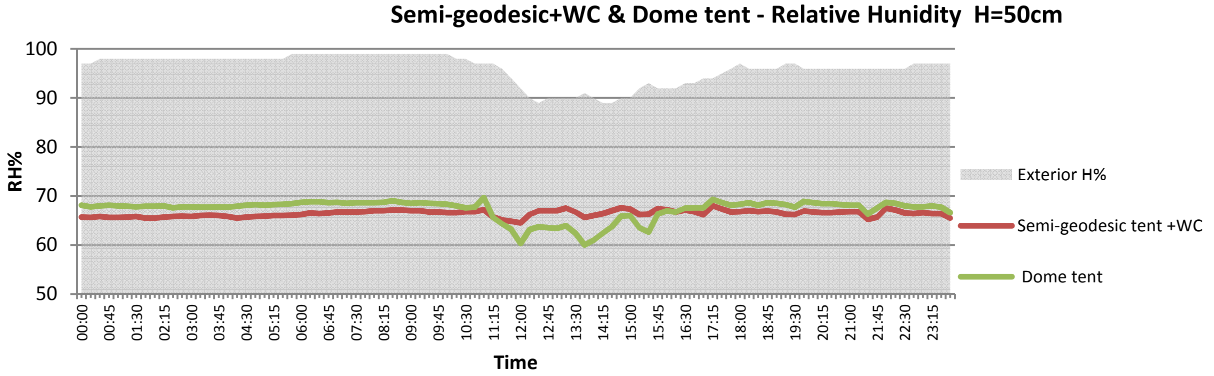
Test 4 Tents with winter cover and windows open comments:

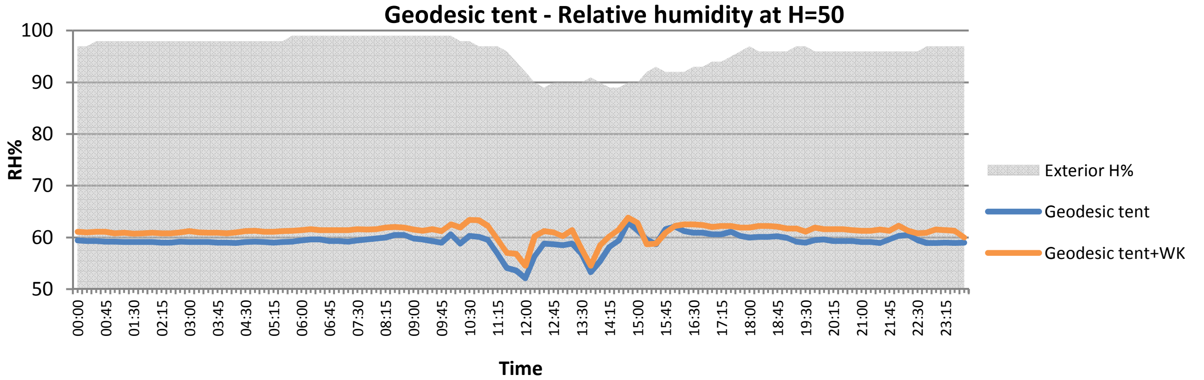
-By using WC with the windows open we have recorded higher temperatures on the Geodesic tent. The temp difference between the Geodesic tent + WC and Semi-geodesic tent + WC is Δt=2 to 5 C.

TEST 5 | ***Relative humidity on air unoccupied and tent close.***

- *Description and general conditions*
  Obtain data on the interior Relative Humidity in air inside the unoccupied shelter in order to compare the obtained values between shelters.
  Monitoring the humidity and interior temperature in the shelter as a basic comfort parameter.
- *Approach:*
  In a vertical line at the center of the shelter, 1 logtag has been placed to record relative humidity and temperature each 15 min. The logtag was attached 50cm over the Shelter ground level.
  The same type of heating (electric oil radiator) has been placed inside the shelter.
- *Number of measures:*
  Interior relative humidity and air temperature recorded each 15min
  Exterior relative humidity and air temperature recorded each 15min
- *Values to collect:*
  Interior/exterior Relative Humidity in air (%)
  Interior/exterior air temperature (Celsius)

Analysis of collected data:

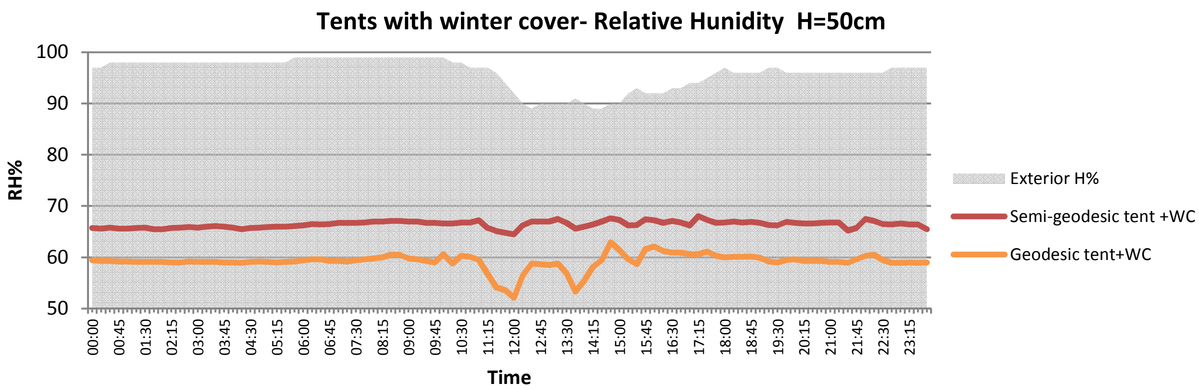




Test 5 Relative Humidity in the air unoccupied comments:

-The recorded relative humidity inside the tents H=50 is generally higher in the tents without WC than in the tents with WC.
-In the Semi-geodesic tent the recorded values of Relative Humidity in air are more stables in the tent with WC.
-The exterior Relative Humidity is from 30 to 40% higher than the recorded values inside the tents.

Analysis of collected data:



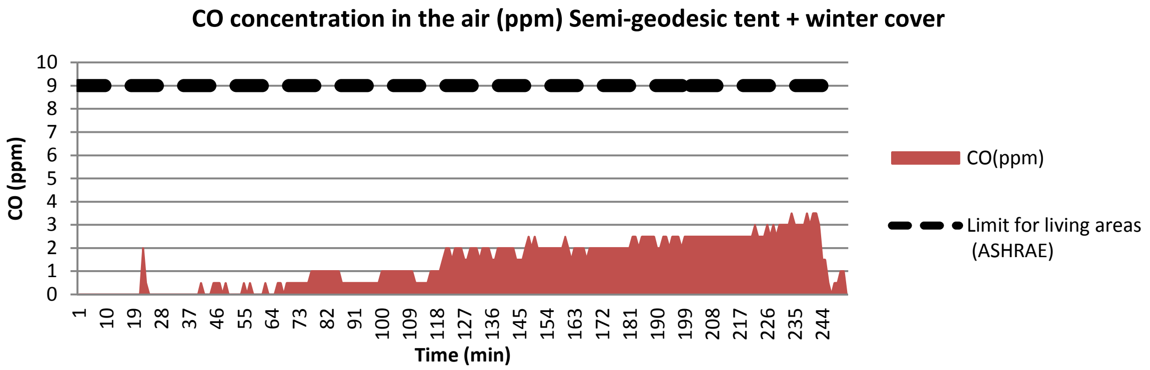
Test 5 Relative Humidity in the air unoccupied comments:

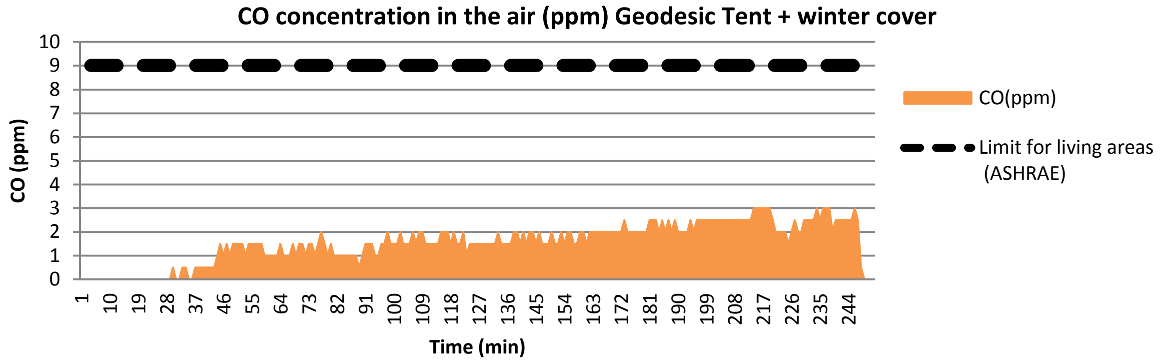
-The recorded % of Relative Humidity inside the tent is around 10% higher inside the Semi-geodesic tent with WC in comparison with the recorded values inside the Geodesic tent.

TEST 6	***Air quality unoccupied inside the tent.***

- *Description and general conditions*
  Obtaining data on CO and CO2 concentration from the interior air in the unoccupied shelter by using independent automatic data-loggers. One radiator with open combustion chamber has been placed inside the shelter. CO and CO2 concentration, humidity in the air and the interior air temperature in a predefined point have been measured and compared with minimum health requirements (the ASHRAE recommendations have been used as a reference).
- *Approach:*
  In a vertical line at the center of the shelter, one logtag has been placed to record CO2 concentration, humidity and temperature each 10 min. A second log tag has been placed in the same vertical line at the ground level to record the CO concentration.
  Before the beginning of this test, the shelter has remained fully open for at least 15min, to ensure the correct and complete inside aeration.
  For this test a kerosene stove with open combustion chamber has been used. The shelter has remained close during the entire monitoring period.
  All the stoves have used the same quantity and type of fuel, that has been recorded and documented.
- *Density of measures:*
  Interior temperature recorded each 10min
  Interior Humidity recorded each 10min
  Interior concentration of CO2 each 10min
  Interior concentration of CO each 10min
- *Values to collect:*
  Interior air temperature (Celsius)
  Interior Relative humidity in the air (%)
  Interior concentration of CO2 (ppm)
  Interior concentration of CO (ppm)

Analysis of collected data :



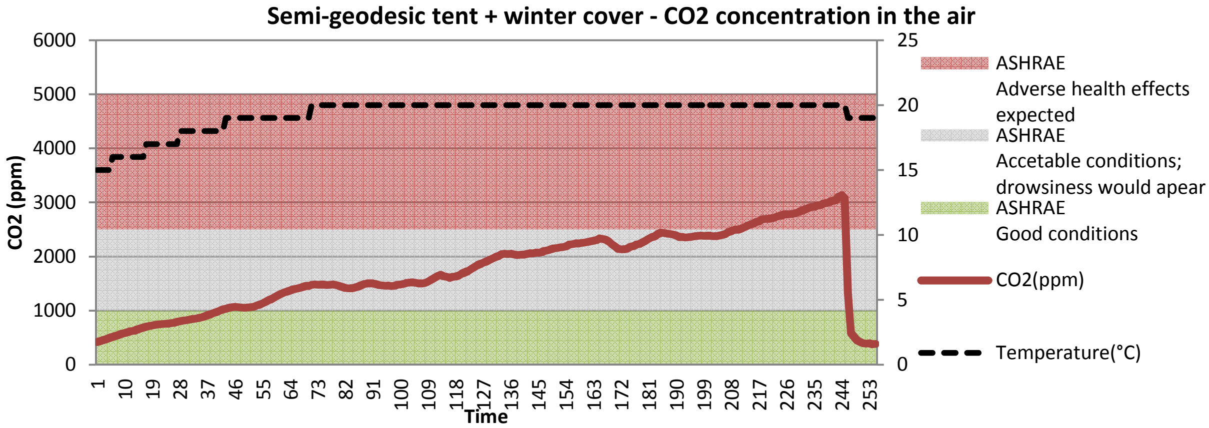


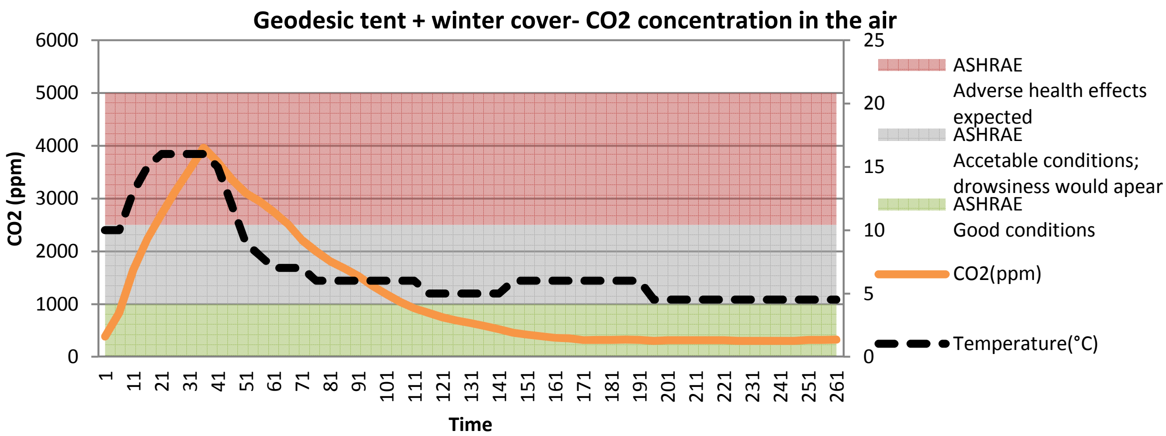
Test 6 CO comments:

-Using a Kerosene Stove (with an open combustion chamber), the recorded CO levels inside the tents H=0 after 4hours (250min) are from 3 to 3.5 ppm (under the safe ASHRAE recommended values, i.e. 9ppm).

Heating output	*2200kw*
Fuel consumption	*0.23L/h*
Max heating time	*Approx. 16h*
Dimensions (HxWXD)	*395x345x340mm*
Weight	*7kg*
Origin	*China*

Analysis of collected data of Air quality unoccupied inside the tent:





Test 6 CO2 comments:

-Using the same kerosene stove inside all tents, recorded CO2 levels inside the tents H=50 are between 3000 and 4000 ppm (OVER the safe ASHRAE recommended values, and thus likely to produce "adverse health effects")

-On the Geodesic tent + WC the highest CO2 value (3998ppm) has been recorded while the alarm was ringing. The tent doors have then been opened and the stove has been switched off.

-On the Semi-geodesic tent +WC the max value was 3133ppm. All the tent doors and windows have been opened after four hours and the stove has been switched off.

Highlighted observations during the testing period

1.- Observations during testing period

Visit observations*: Setup days*

Semi-geodesic tent during setup:

- The bag was easy to transport in four but the handles could be short (volunteers' comment)
- The instructions need to be simplified (volunteers' comment).
- The color code was much appreciated.
- The plastic connector and elastics inside the structure pipes need to be improved (the pieces slide and are difficult to assemble.
- The triangle mark on the arch foot was much appreciated
- The winter cover does not fit over the tent structure; it was difficult or impossible to attach it to the structural arches (cutting and/or patterning could be improved to solve this).

Geodesic tent:

- The bag was easy to transport in four but the handles could be short (volunteers' comment)
- Sleeve and Velcro very good valorized
- The inner hanging system on the top center of the tent was displaced from the position and difficult to rehang (stairs needed)
- The structure of the winter cover was difficult to setup, in particular the bridge over the tent.
- The screw system needs very strong hands to be effective.

Pictures Semi-geodesic tent

Pictures Geodesic tent:

2.- Observations during testing period

Visit observations*:* 12 days of testing – Semi-geodesic tent + Geodesic tent

- After 12 days of testing, the condensation under the winter cover of the two tent models was dropping over the exterior membrane of the tents.
- Similarly, with temperatures below 0C, a fine layer of ice appeared between the exterior layer of the tent and the winter cover tent during days*.*

Pictures Semi-geodesic tent



Pictures Geodesic tent:



3.- Observations during testing phase

Visit observations*:* Entire testing time – Semi-geodesic tents + Geodesic tent

- The closing systems on the bottom part of the doors do not close completely.
- There is cold air infiltration
- There is lack of an effective vector control on this point.
- The Ground inside the Geodesic tent shows irregularities and is difficult to setup straight.
- In general the ground on the Geodesic tent produces an "uncomfortable sensation".

Pictures Semi-geodesic tent


Pictures Geodesic tent:




4.- Observations during testing phase

Visit observations*:* We have recorded wind of 55km/h during a wind storm

Semi-geodesic tent

- The poles next to the door of the winter cover were bended and the winter cover was partially damaged
- The pole and the tent were easily repaired

Std. Family tent

- The tensioners and one anchor were displaced and the tent was partially damaged
- The side poles of the tent collapsed
- The anchors, tensioners, poles and the tent in general were easy to re-setup.

Geodesic : nothing to highlight

Pictures Semi-geodesic tent

Pictures Family tent

5.- Observations during testing phase

Visit observations: Durability of the tents – Semi-geodesic tents + Geodesic tent - 30 days of test

Semi-geodesic tent

- Metallic hooks rusted on the front arch

Geodesic tent

- Fungus on the Velcro between winter cover and external membrane.

Pictures Semi-geodesic tent

Pictures Geodesic tent

6.- Observations during testing phase

Visit observations: Vector control – Dome tent

Dome tent

- After 20 days of test the flap-pockets of the New Dome tent were full of water with mold and different animals inside (Mosquitos, warms, etc.)

Pictures Dome tent

General conclusions

The new tent models are very similar between them in terms of design, packaging, weight, surface and overall conception. Both models possess adequately designed solutions that bring added value in terms of performances. The correct combination in one last model of results and designed solutions will definitely provide a better response for a lightweight emergency shelter for cold conditions.

Logistics:

All the tents with winter configuration are heavier than 100kg, with the heaviest being the Semi-geodesic tent with WC. The weight difference between the new tent models is 8kg (Semi-geodesic tent + WC : 115kg and Geodesic Tent + WC: 107kg) that in one operation of 500 units will represent 4000kg. The economic repercussion of this additional weight could be a big part of the operational budget. Therefore, it would be advisable to reduce weight as much as possible.

The two new tents (Semi-geodesic Tent and Geodesic tent) are easy to build in comparison with the Dome tent that presents important difficulties with the “sleeves” and the structural arches. The Geodesic tent was faster to setup than the Semi-geodesic tent. The difference of 15min between one and other could represent 7500min or 5 days less in an operation of 500 tents. Furthermore in harsh winter conditions the setup time is a key factor in order to bring the adequate shelter response.

By changing the sleeve materials and dimensions, simplifying the tensioners and guide ropes, reducing the quantity and complexity of the structural pieces and having inner and outer tent in one piece, the setup time will be reduced.

Interior temperatures

In general the use of a winter configuration provides a positive difference on the interior temperatures. The two new tents with WC do not present significant positive differences with the temperatures inside the Std. Family tent with WK but the interior volume is bigger in the new models. On these conditions the thermic efficiency of the new tents is better than that of the Std. Family tent (bigger volume same temperature = better efficiency = better response quality for beneficiaries)

In general, the temperatures inside the Semi-geodesic tent + WC are lower than the recorded temperatures inside the Geodesic tent + WC. Since the testing conditions were the same for the two tents, the difference on the recorded interior temperature has been ascribed to small design differences.

The thermal performance could be improved by “tuning” the design of the windows in terms of surface, closing system and position. Also the doors closing system could be improved, in particular with regard to the bottom part of the doors that do not close completely.

To better understand the entire model it could be necessary to have a complementary study in terms of thermic transmission and air permeability of the used fabrics in combination.

Interior Air quality

CO poisoning is the most common type of fatal air poisoning in many countries. Carbon monoxide is colorless, odorless, and tasteless, but highly toxic. The ASHRAE recommendations (<9ppm) have been used as a reference. There are no records of danger levels of CO inside the new tents during the testing period using a kerosene stove without chimney or extraction system.

CO2 high levels (between 3000 and 4000ppm) have been recorded during the testing period. The ASHRAE recommendations for CO2 indoor concentrations fix the limit to 1000ppm, with the first symptoms of drowsiness appearing between 1000 and 2000ppm and headaches, sleepiness and others between 2000 and 5000ppm; after this other sever consequences could happen for humans.

The air quality inside the shelter is a basic comfort parameter. If the minimum recommended limits are exceeded the human health/life will be at risk. By studying the openings system (windows and doors) and the breathability of the used membranes on the shelter, we can approach to a safer ventilation system.

By using heating/stove with smoke extraction systems the risk of dangerous gases inside the shelter will be reduced.

Structure

During the testing period we have recorded wind over 55km/h. All the tested shelters have withstood except the STD Family Tent. This tent has been partially damaged but easily repaired after the storm.
The structure (arches) of the Dome Tent has been damaged during the setting up process. This proves that the structure of this model was not an adequate solution.
The structure of the Semi-geodesic tent resisted well the wind pressure but the exterior vertical poles were often laterally displaced and/or bended. The belts to anchors on the tent without winter cover needed frequent control and re-tension. The exterior poles of the winter cover structure have been damaged and easily repaired during the same storm that hit the STD Family tent.
The structure of the Geodesic tent with winter cover is stable and has resisted the wind pressure. The winter cover structure of this tent model was difficult to setup and the curved shape of the pipes demand bigger packaging volume.

The structure of the winter cover solutions has to be improved in terms of standardization of the pipes, better pipe joints, easy setup and final resistance.
The inclusion of alternative anchor systems could be necessary in operations with extremely soft ground (sand) or extremely hard ground (concrete slaps or rocks).

Accessibility

The problem of wheelchair access to the shelter was well solved in the two models. This solution could generate additional drawbacks, which would demand an extra redesign. In the Geodesic tent the interior door is not accessible for wheelchair because the metallic pole of the winter cover is placed in front of the door.

The wheelchair flap on the bottom of the doors needs to be redefined to ensure a proper closing system on the door. The compatibility of the doors with the winter cover structure needs to be redesigned in order to ensure the wheelchair access.

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