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PumpItUp, gite mobile for the European cultural capital Esch-sur-Alzette

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Key words: membrane, polyester-ropes, pneumatic structure, temporary structure.

Summary. This paper presents the project PumpItUp, from the design to the fabrication and installation. It is a pneumatic shell on a trailer with two foldable wings. The shelter is set up and dismantled several times, at different locations. The pneumatic envelope forms a spherical shape from two layers of membrane, coupled at many nodes with synthetic fibre ropes.

1 INTRODUCTION

Esch-sur-Alzette in Luxembourg was Capital of Culture 2022, together with Novi Sad in Serbia and Kaunas in Lithuania. Under the motto "Remix Culture", the city wants to present the cultural mix of the region and combine the old industrial culture with the new. One of the projects for Esch 2022 is the Minette Trail, an approximately 90 km long hiking trail through a former industrial region in the south of Luxembourg. As overnight accommodation, 11 "Kabaisercher" have been planned by various teams of architects. One of these hostels is PumpItUp, a pneumatic mobile shelter.

2 DESIGN

Based on the architects' competition design, a pneumatic shape was developed. The internal pressure and the prestress in the membranes balance the system. The prestress creates bending stiffness in the two-layer envelope to resist against external loads.

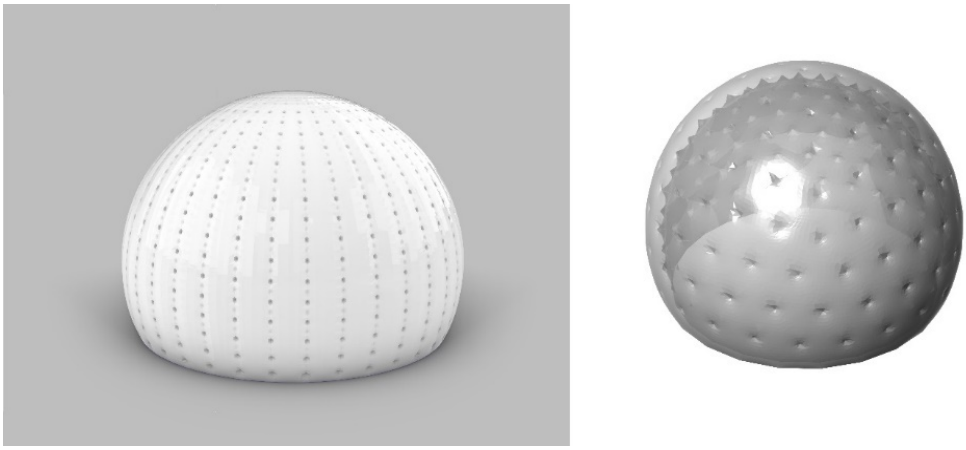

Figure 1: Radial connections and Geodesic dome

In order to achieve the required stiffness, a significantly thicker wall was created compared to the competition design. The wall thickness of 0.3 m was increased to approximately 1 m. Due to the steep walls inside, this does not restrict the use.

Two approaches were examined to determine the connection points. In the first approach, the two parts of the envelope are coupled in radial sections, with the disadvantage that the density of the ropes increases towards the zenith. Therefore, the principle of the geodesic dome was applied as a second variant. The dome is divided into bigger triangular panels, each then subdivided into 36 smaller triangles. The rope connections are attached to the corners of the small triangles. This creates a harmonious shape with an even distribution of the connection points.

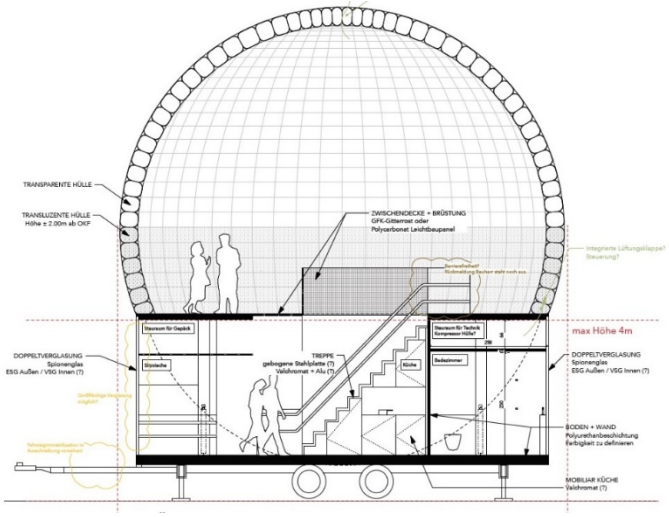

Figure 2: Section through the competition design (source: 2001)

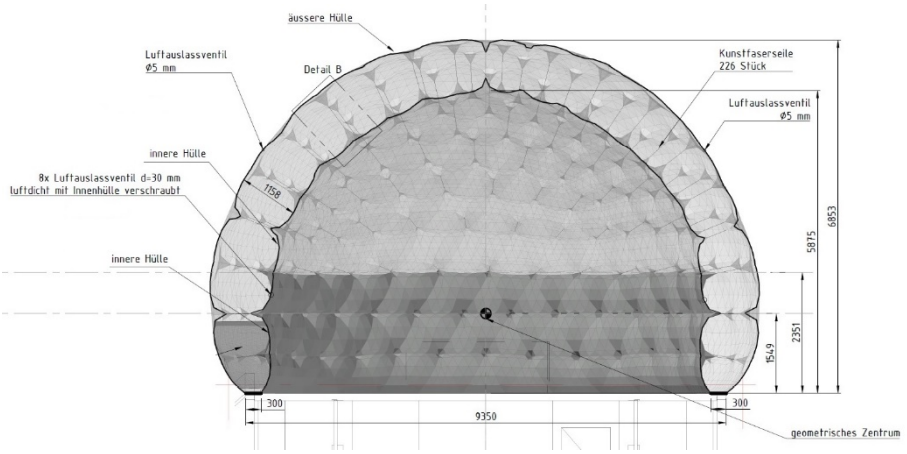

Figure 3: Section through the formfinding shape

3 PROJECT DESCRIPTION

The pneumatic envelope forms a sphere made from two layers of membrane. Both layers are made of high translucent PVC coated polyester membrane. Ten transparent bulls' eyes allow the view to the sky.

The outer and inner membranes are coupled at the nodes with synthetic ropes. The connection to the platform is made with zips and aluminium clamping strips along the perimeter.

In order to allow natural ventilation, two ventilations tunnels connect inner and outer membrane, closed with an open mesh on the outside, and a removable cover on the inside.

4 ANALYSIS

Professor Mike Barnes' software was used for the analysis. TLform for formfinding and TLload for the load analysis. The software uses the method of dynamic relaxation and considers the behaviour of membrane, foil and rope structures. These are, to name some examples, formfinding, orthotropic material behaviour (longitudinal and transversal direction) and large deformations.

The numerical model is discretised by cable elements, as well as triangular membrane elements. It is analysed with geometric non-linearity, considering the change in length of the elements as well as the deformation of the entire structure. The equilibrium is determined in the deformed states.

Figure 4: Isometric view numerical model

The mobile hut (gite mobile) is a temporary structure according to EN 13782. According to the Luxembourg national application document for Eurocode 1 part 1-4, the reference wind speed is 24 m/s, thus the wind load table from EN 13782 can be applied. Snow load was not considered as the use in winter is not foreseen.

The wind load is distributed according to EN 1994-1-4 for a hemisphere.

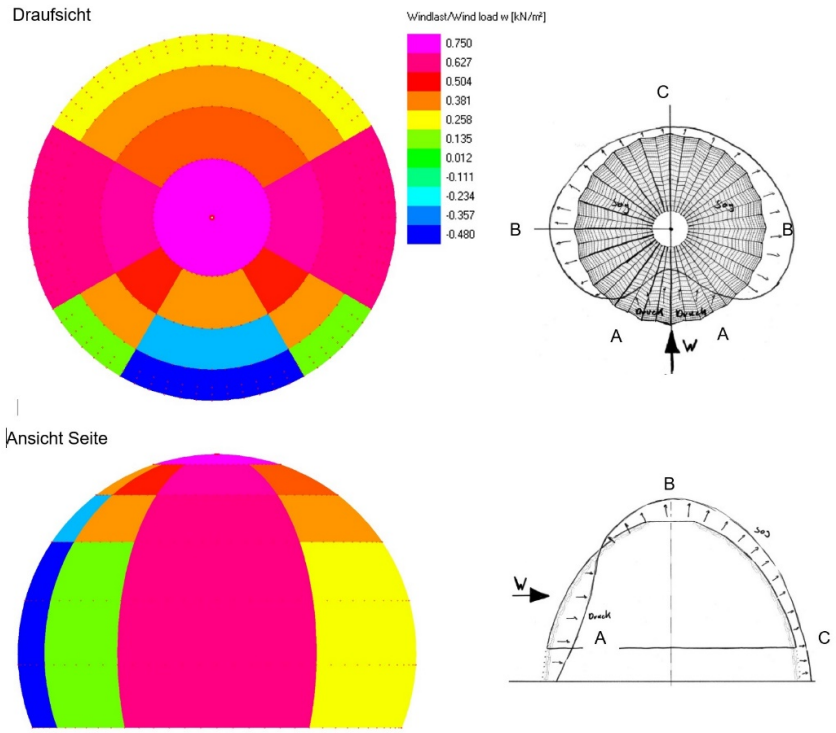

Figure 5: Applied wind load distribution

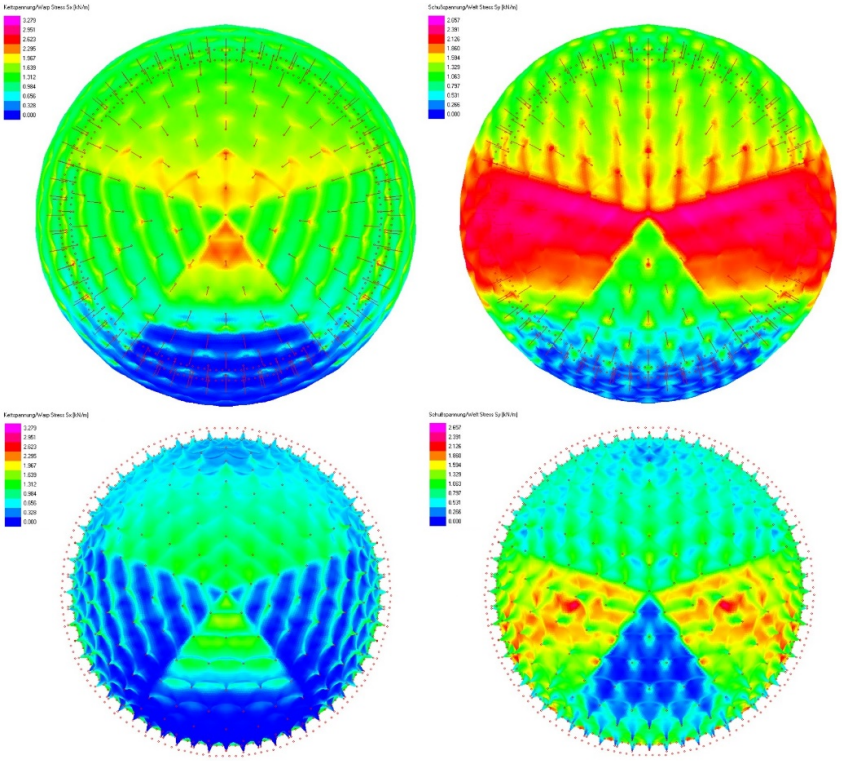

Figure 6: Stress in the outer and inner envelope under full wind load

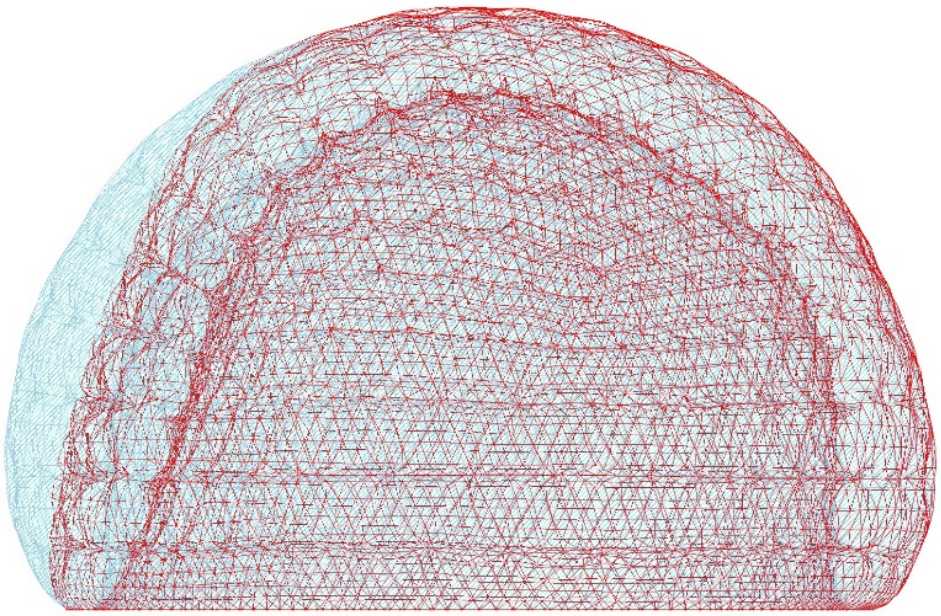

Figure 7: Deformation under maximum wind

Since the bending stiffness of the envelope is not very high, it reacts to wind pressure with a significant inward deformation. However, the stability under design wind conditions is not limited.

5 AIR SUPPLY

A support air unit provides an internal pressure of 1000 Pa in order to provide the pneumatic prestress. The unit is fabricated as a special design. The blower and the dryer are housed in two separate cases, installed in the chassis of the trailer.

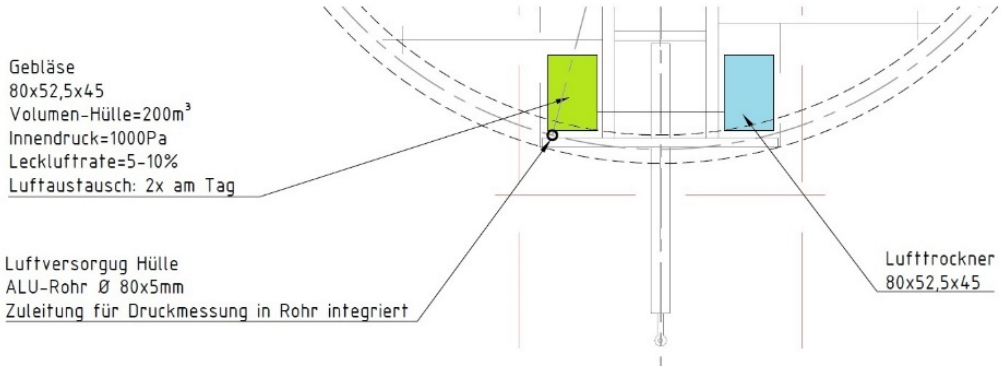

Figure 8: Integration of the blower unit in the chassis

In order to minimise the permanent stress, the inner pressure was reduced from initially 1500 Pa to 1000 Pa, as the analysis showed sufficient stability even at lower pressure.

6 DETAILING

The two layers of membrane are connected by polyester ropes. Polycarbonate discs with carriage bolts and eye nuts are welded into the membrane. The ropes are connected with small carabiners.

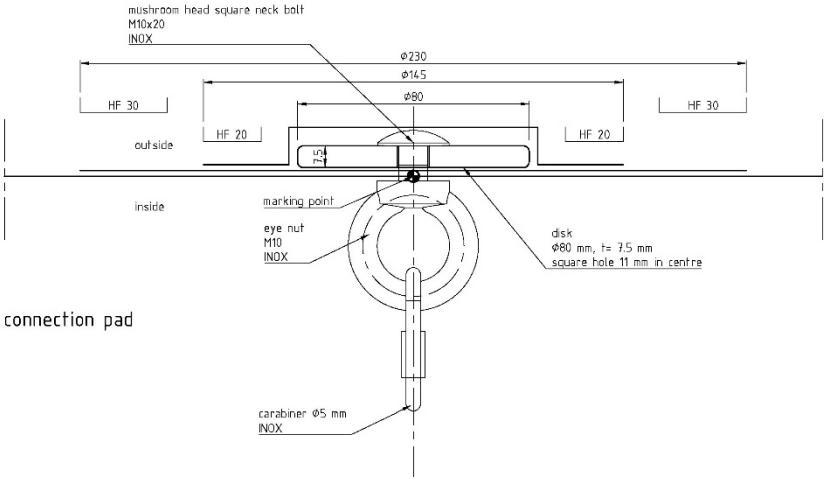

Figure 9: Connection for the ropes

This node detail was checked in a load test for the initially foreseen PVC foil. At 1.5 kN load, which corresponds to the maximum load in the project, a shape was achieved that fits well to the shape analysed. Up to a force of 8 kN the detail resisted against failure, but with significant plasticisation.

Figure 10: Nodal test in the load steps 1.5 kN and 4.5 kN

The connection to the platform is made with clamping plates along the perimeter of the platform. Keder strips with zips allow quick assembly and disassembly. The pneumatic structure is welded airtight, and the zips are applied on the outside to the pneumatic system, so that no airtightness is required for this detail.

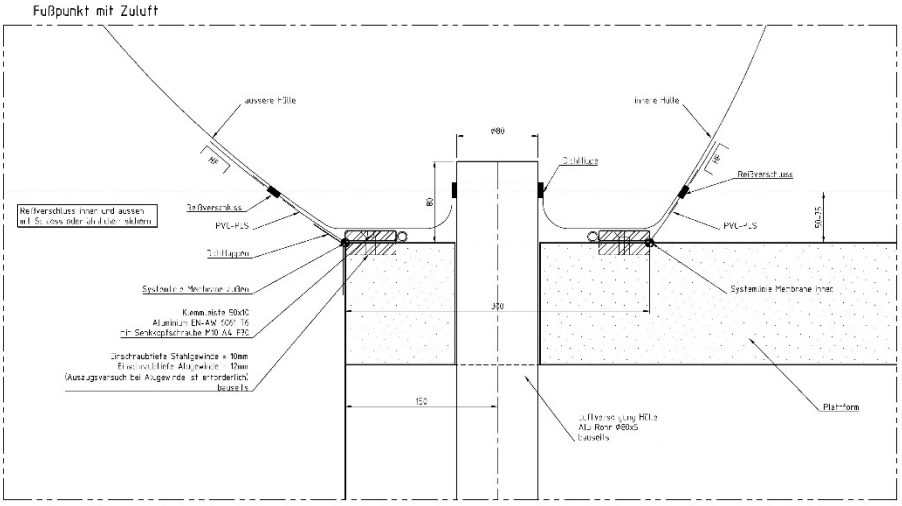

Figure 11: Connection to the platform

In one corner of the trailer, the 80 mm air supply pipe ends between the two clamping lines above platform level. The membrane has a an opening, where this pipe enters into the chamber.

7 CUTTING PATTERN AND FABRICATION

The shape of the structure is locally heavy curved, which would require a very high effort for the fabrication. For an optimal manufacturing process, the patterning model was generated as an averaged rotational surface, with an almost identical overall surface.

A comparing analysis with this model under inner pressure led back to the original membrane geometry, which confirmed the feasibility of this cutting method.

This cutting model was separated at the main lines of the geodesic dome and then cut horizontally. The cutting patterns also contain the location of the connection points for the cables, the bull's eyes and the ventilation tunnels.

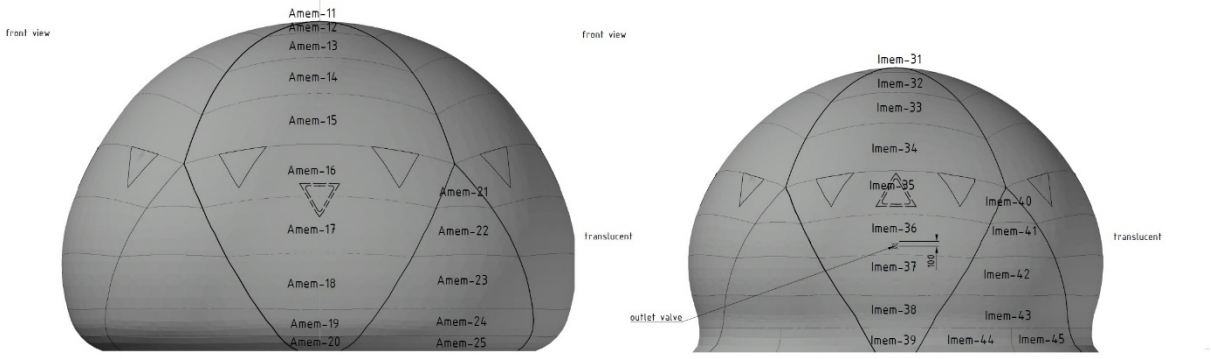

Figure 12: Smooth patterning model Outside and Inside

The compensation was determined on the basis of biaxial tests. The biaxial tests and their evaluation were carried out in accordance with EN 17117-2, based on the project-specific stress level.

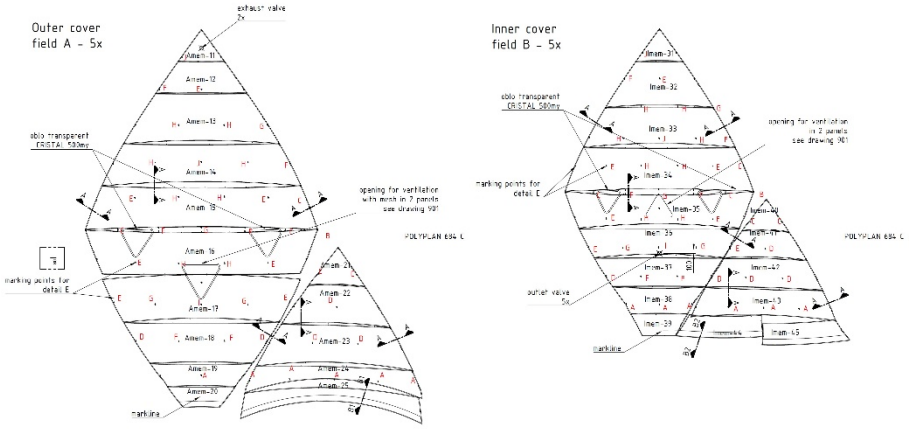

Figure 13: Membrane and Foil pattern

The single pattern are joined with HF weld seams. In a first step, the sub-panels are manufactured and later the sub-panels are assembled. Special round electrodes were fabricated for the nodal supports.

8 INSTALLATION

At the end of December 2021, directly after completion of the envelope, a test assembly was carried out to test the inflation and folding of the membrane.

With the increase of the internal pressure, the envelope is lifted up. The outer membrane pulls the inner membrane via the connecting ropes.

Shortly before the pressure of 1000 Pa was reached, the zenith was also completely up and the planned shape was achieved. If you lean against the wall from the inside, the construction only reacts slightly.

Figure 14: Test inflation of the finalised translucent envelope (source: Canobbio)

The assembly of the PumpItUp project on the trailer took place in an old industrial hall in Schifflange. The chassis comes from Belgium, the body from France and the membrane envelope from Italy.

The circumferential keder strips with the corresponding zip half were attached along the perimeter of the platform with clamping plates.

Then the pneumatic cover was placed in the centre of the platform with a crane. The cover was spread out and the zips were connected all around. After all the connecting lines were connected, the blowers could pressurise the envelope. As already seen in the test set-up in Italy, the hull slowly lifted.

As the internal pressure increases, the theoretical shape sets in and the gite mobile becomes walkable and tangible.

Figure 15: Final installation

Figure 16: Inner view

Figure 17: Bulls eye

Figure 18: Evening hours (source: Ludmilla Cerveny)

Figure 19: Final project at night (source: 2001)

9 CONCLUSION

The mobile hut was created in an interdisciplinary collaboration. It is both a vehicle and a full accommodation. The transparent envelope covers the sleeping place for hikers. During the day the translucent envelope provides a clear and bright space inside, and at night, it appears like a glowing bulb, and through the bulls eyes the guests can see the sky. The overnight stay becomes a special and unforgettable experience.

10 PROJECTDATA

Surface area outer membrane: 251 m²
Surface area inner membrane: 168 m²
Covered area: 93 m²
Membrane material: Sattler Polyplan 684 C
Foil material bull's eyes: Cristal Plus 500 µm

11 ACKNOWLEDGEMENTS

Client: Ville d'Esch-sur-Alzette
Architecture: 2001 territories, buildings, spaces & ideas, Esch-sur-Alzette, Luxemburg
Interior design: NJOY_architecture inside, Luxemburg
Structural design pneumatic envelop: formTL ingenieure für tragwerk und leichtbau gmbh, Radolfzell, Germany
Execution pneumatic envelop: Canobbio Textile Engineering srl, Castelnuovo-Scrivia, Italy
Air supply: Elnic, Rosenheim, Germany

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