

Textile Roofs 2024



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Content

1. New Ideas in Architecture – Freedom & Experiments
2. New materials - ETFE
3. From the
4. The EDEN breakthrough
5. Technical Developments



Old New Objectivity & Industrial Design



Bauhaus – University Dessau (1925) -
Walter Gropius

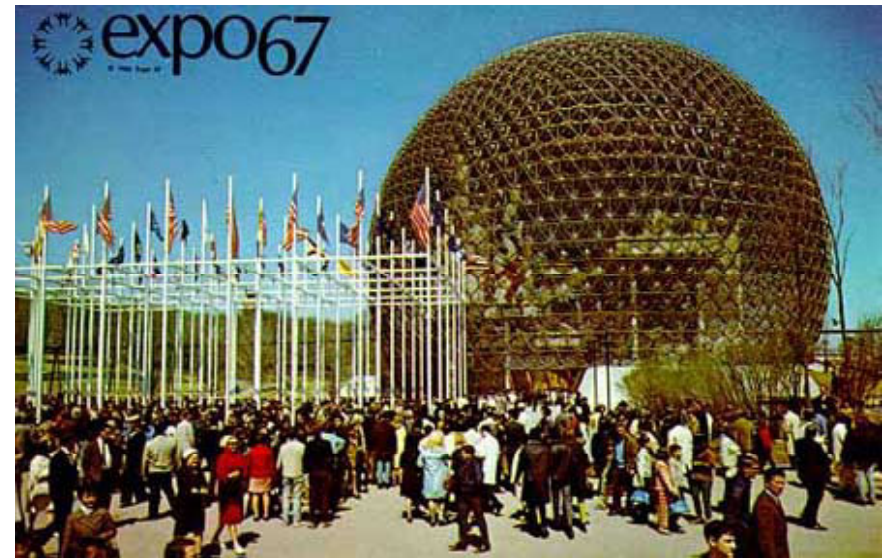


1928 – Hamburg – Deutschlandhaus
Fritz Block & Ernst Hochfeld

1960s - New Lightweight Architecture I



Buckminster Fuller (1960)
Dome over Manhattan



1967 – EXPO Montreal Biosphere –
US Pavillon

Steel structure covered with acrylic honeycomb

1960s - New Lightweight Architecture II



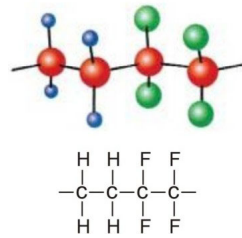
1965 – Test tent for EXPO
Stuttgart - Institut für Leichtbau



1967 – EXPO Montreal
German Pavillon

ETFE – Main Characteristics

- high transparent
- UV stable
- extremely flexibel
- low weight
- Long lifetime
- Self cleaning
- Outstanding fire performance
- 100% recycling
- High chemical resistance
- Acoustic comfort



History of ETFE – synthesis & properties

- 1st PTFE synthesis - Developed in the 1938 by Dupont following PTFE (Teflon)
- 60ies Development of Tefzel
- Development in Germany by Hoechst (ET 6235) – Dr. Herbert Fritz in Gendorf
Now 3M Dyneon

- Use as a foil
 - blow extrusion film by Hoechst
 - sheet extrusion

1983 - **NORDWOLLE FOL**
NORDWOLLE FOLien - Roots from Bremen/Delmenhorst



1st projects – Non-permanent structures



1980 –
Solarforum

Bomin Solar
Research &
KOIT

Single layer
ETFE
blow extrusion
films



K. Moritz – ETFE-Folie als Tragelement, München 2007

1982 – 1st permanent ETFE Project (the eldest)

1982: Burger's Zoo in Arnhem, NL
the first ETFE Installation in the world

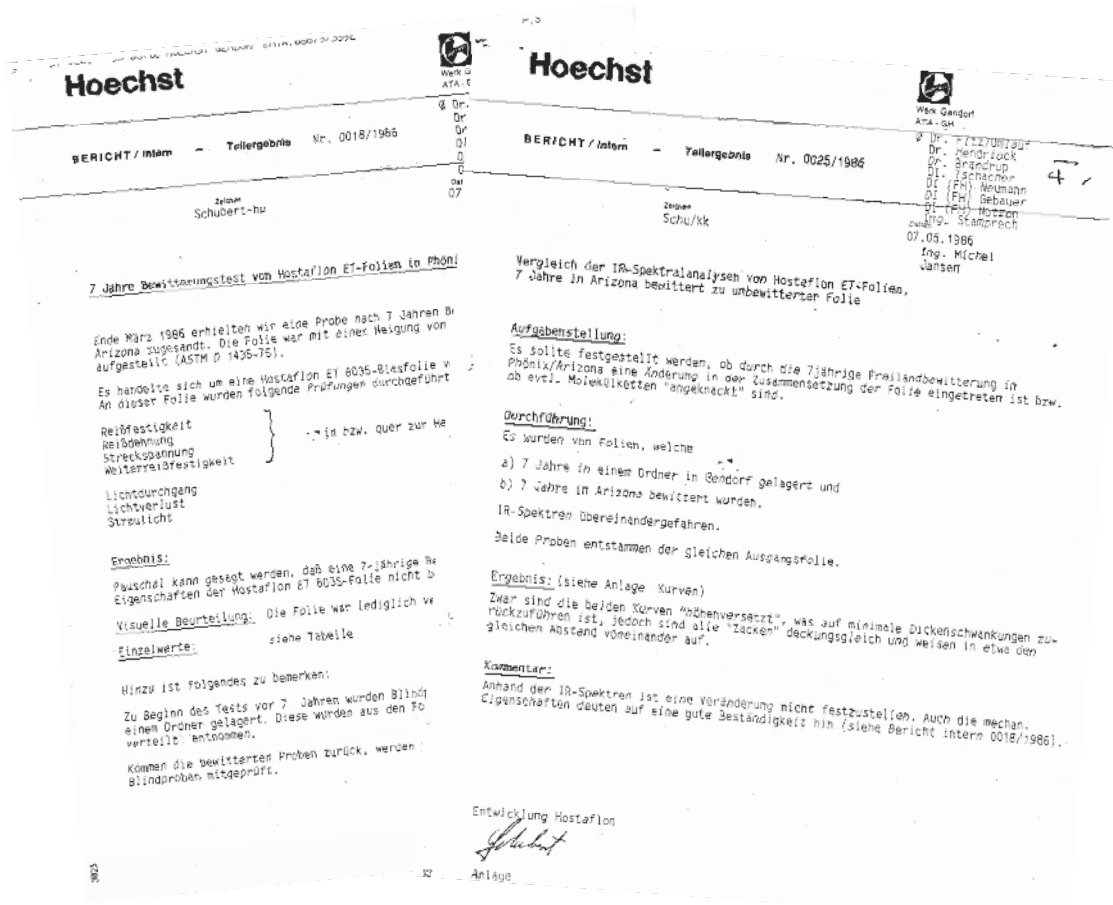
Pre-manufactured foil cushion with frame &
on-off air supply with pressure of 250 Pa



2017: Burger's Zoo in Arnhem, NL
35 years later – the same building and
the new Mangrove Hall in the background



1986 -Life time of ETFE – Hoechst



Weathering Tests (10 years) in Arizona
blow extrusion films 100 µm thickness
Warranty extension to 20 years.



Life time of ETFE -Weathering Test Results in Arizona June 1986

Prüfung	Einheit	Blindwerte						nach Bewitterung					
		Anfang	1. Jahr	2. Jahr	3. Jahr	5. Jahr	7. Jahr	1. Jahr	2. Jahr	3. Jahr	5. Jahr	7. Jahr	10. Jahr
Zugfestigkeit lgs	N/mm ²	46,7	48,3	47,4	43,7	54,5	50,9						
Zugfestigkeit qu	N/mm ²	42,3	44,5	47,3	41,8	52,4	48,9	43,8	45,5	42,6	44,8	42,4	44,6
Streckspannung lgs	N/mm ²	22,6	23,1	24,8	21,7	23,7	22,1	22,5	25,0	22,3	23,2	22,8	22,5
Streckspannung qu	N/mm ²	18,8	20,7	22,6	21,9	25,3	21,3	21,4	22,0	22,2	22,3	21,0	21,5
Bruchdehnung lgs	%	330	360	340	370	335	345	340	310	345	315	325	340
Bruchdehnung qu	%	390	435	400	370	410	425	405	390	390	410	390	405
Weiterreiß- festigkeit lgs	N/mm	420	415	430	435	400	497	430	415	445	440	523	-
Weiterreiß- festigkeit qu	N/mm	435	445	460	500	410	521	425	420	480	430	531	-
Gesamter Lichtdurchgang	%	95	96	95	96	-	-						
Streulicht	%	8	8	10	10	-	-	8	11	9	11	11	8
geradlinig durchgehende Lichtmenge	%	87	88	85	86	-	-	88	83	86	85	85	88

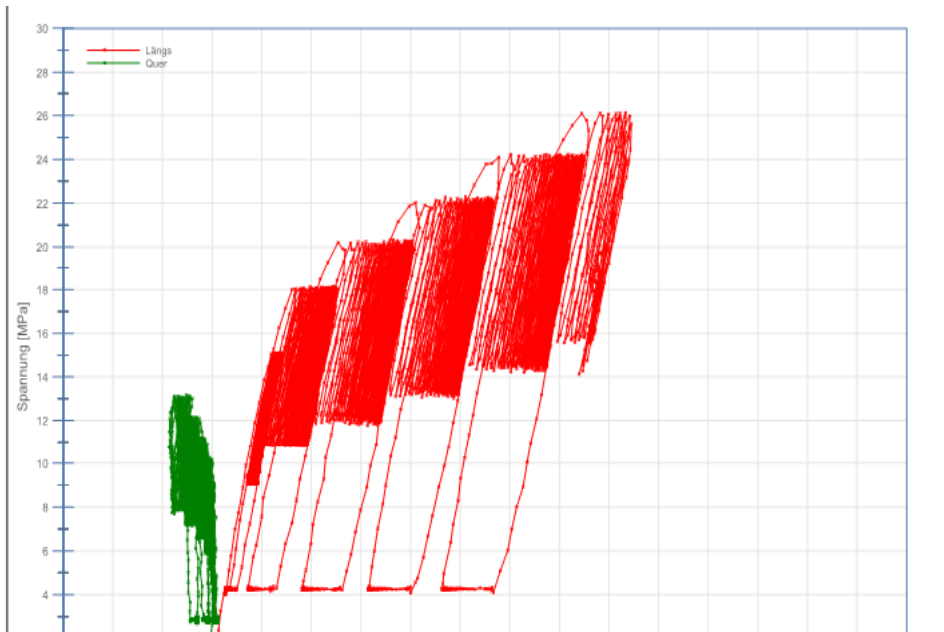
193 08:08 HOECHST GENDORF ENTW. 08679/3992



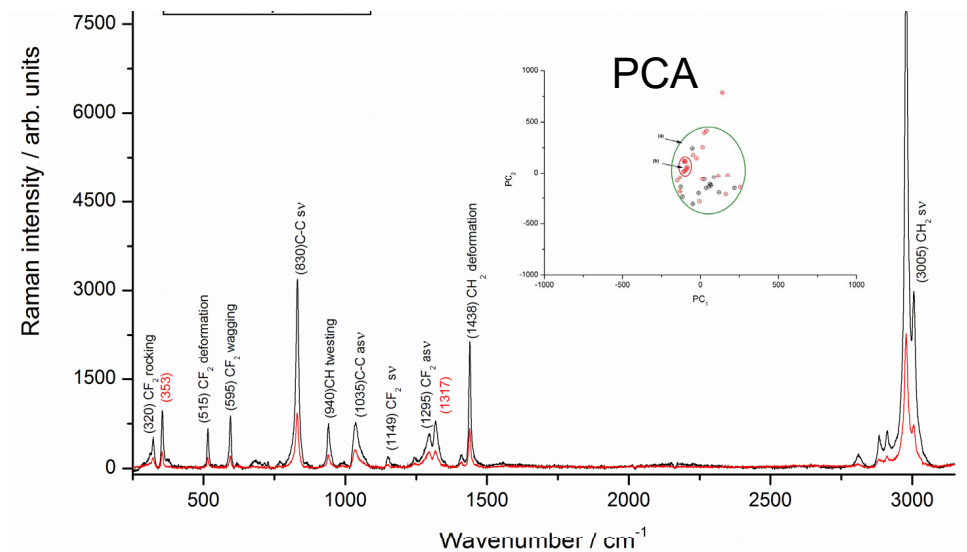
ETFE – Lifetime – No Ageing

1. Tensile Testing Uniaxial & Biaxial Testing

Uniaxial results: Arnhem 42.9±2.6 N/mm²
Retain sample Nowofol 44.9±6.6 N/mm²



2. Raman spectroscopy Principal Component Analysis (PCA) extraordinary stability only new additives



1992 – Development of Printing for Solar Control

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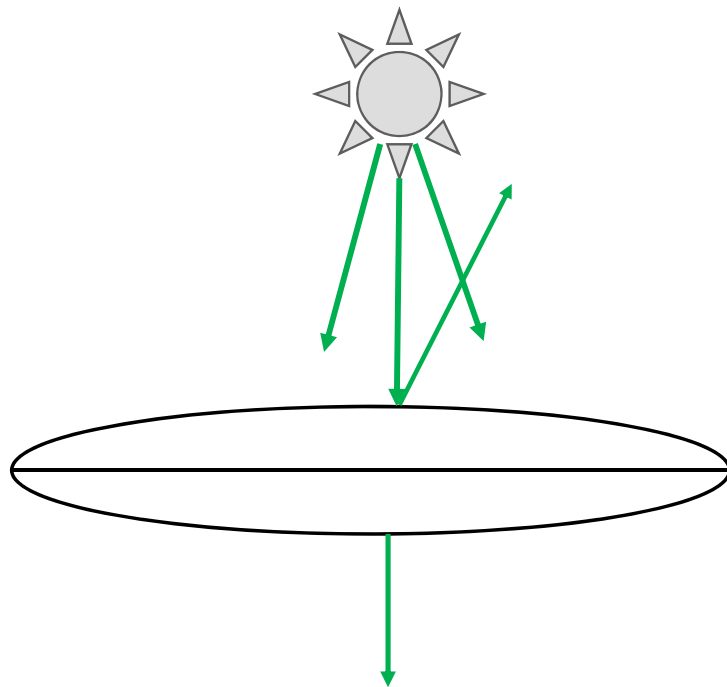
Cambridge,
Schlumberger Research
Institute in Cambridge
(UK)

DM 4:65 light



Solar Control – Mode of Operation

Reduction of transmitted light & solar radiation (ET 6235Z)



Solar values	Trans- mission	Reflection	Absorp- tion
Clear	74.4%	20.1%	5.5%
DM 4:65 light (S0421)	49.1%	33.3%	17.0%
DM4:65 light (56045)	39.5%	34.4%	26.1%

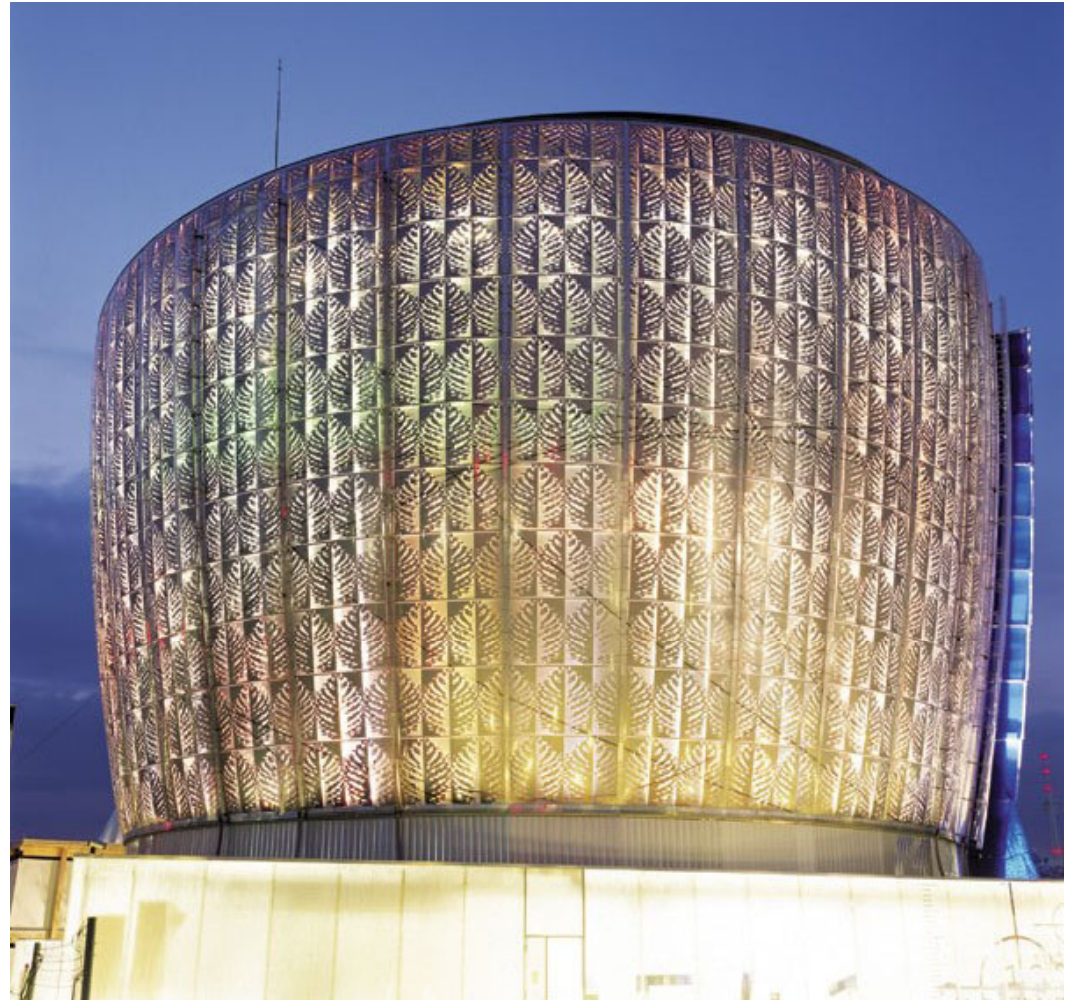
Summer day: 1000 W/m²

Variable Shading

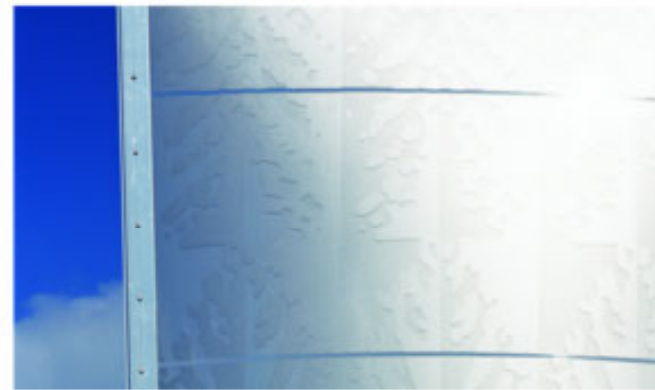
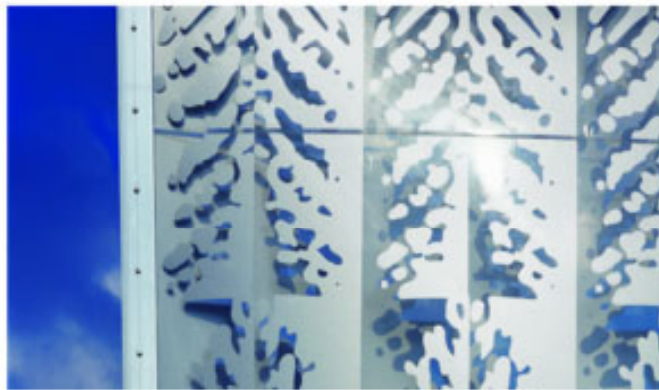
2000 – Expo Hannover – Cycle Bowl
1500 m²

Architects: Atelier Brückner
Foiltec/Plantec GmbH

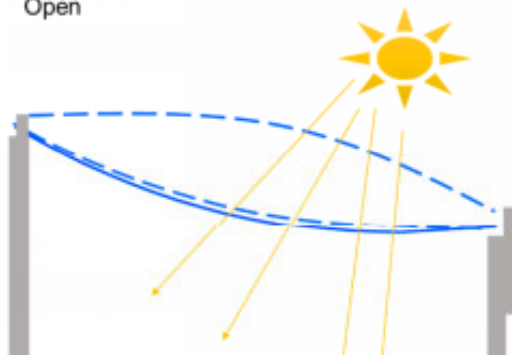
Variable Shading system controlled
by pressure difference



Variable Shading – Working principle



Open



Closed



Further Development steps of Single Layer Foil System

1999 Prienavera – 3 layer roof

With single layer canopy

Zeller & Romstätter
Koch Membrane Structures



Testing of relaxation behaviour of single layer

2001 E.On Powerstation @ Lake Kochel -
With single layer canopy

Architects: Schulitz & Partners
Engineering: Moritz & Linke GbR
Execution: Covertex



First permanent single ETFE Layer structure



2001: Back to the Buckminster Fuller Approach – The EDEN project

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GB – Cornwall - Eden Project (2001) – 30.000 m²

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Architects: Sir Nicholas
Grimshaw & Partners

Engineering Steel: Anthony Hunt
Associates Ltd. and Ove Arup &
Partners, London

ETFE & Frames: Vector Foiltec

Breakthrough of ETFE solutions
worldwide

Sophisticated Node design

New frame solution for size
independent cushions design.

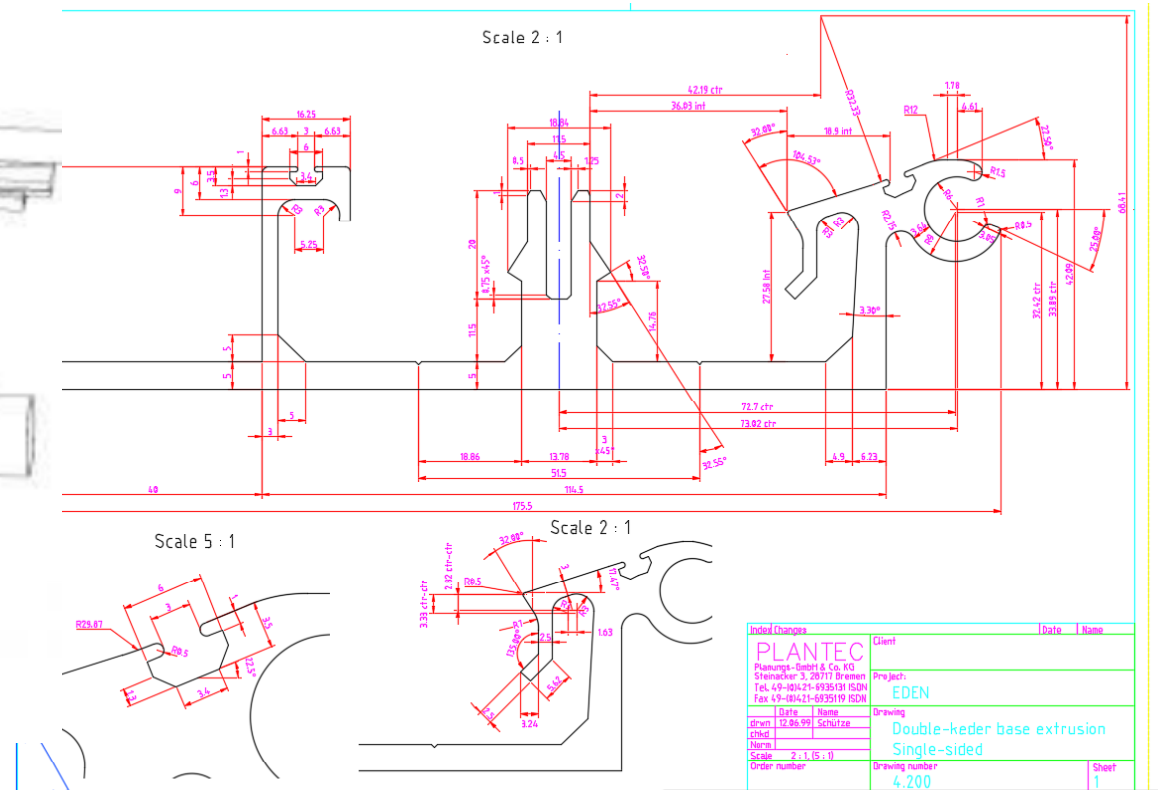
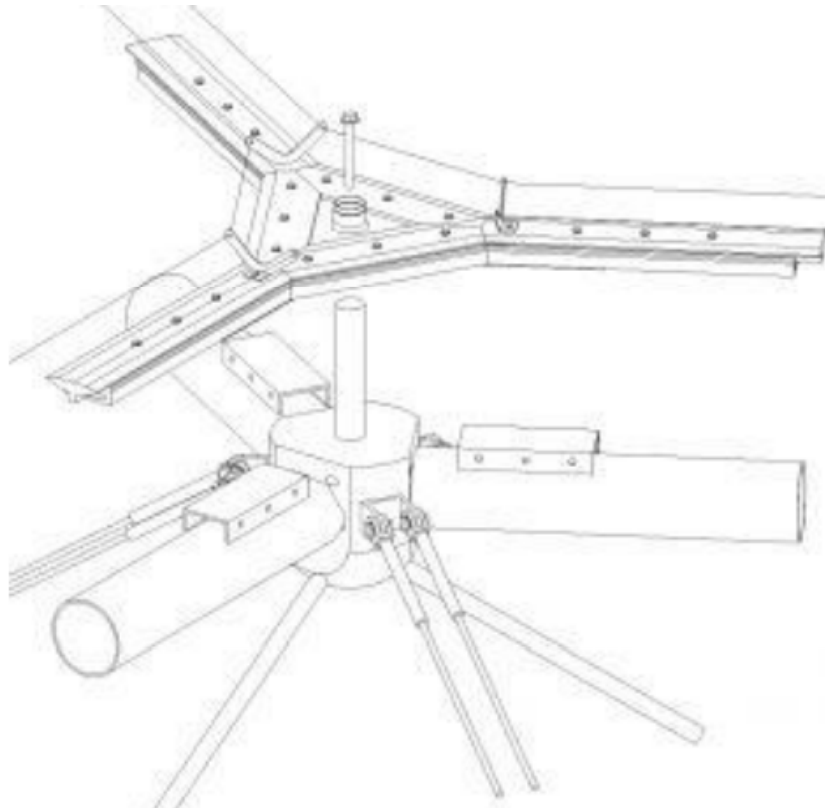


2001: GB – Cornwall - Eden Project – 30.000 m²

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Profile design - EDEN



2003 – UK – London – Classroom of the future - Photovoltaics

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Royal Borough of Kensington and Chelsea

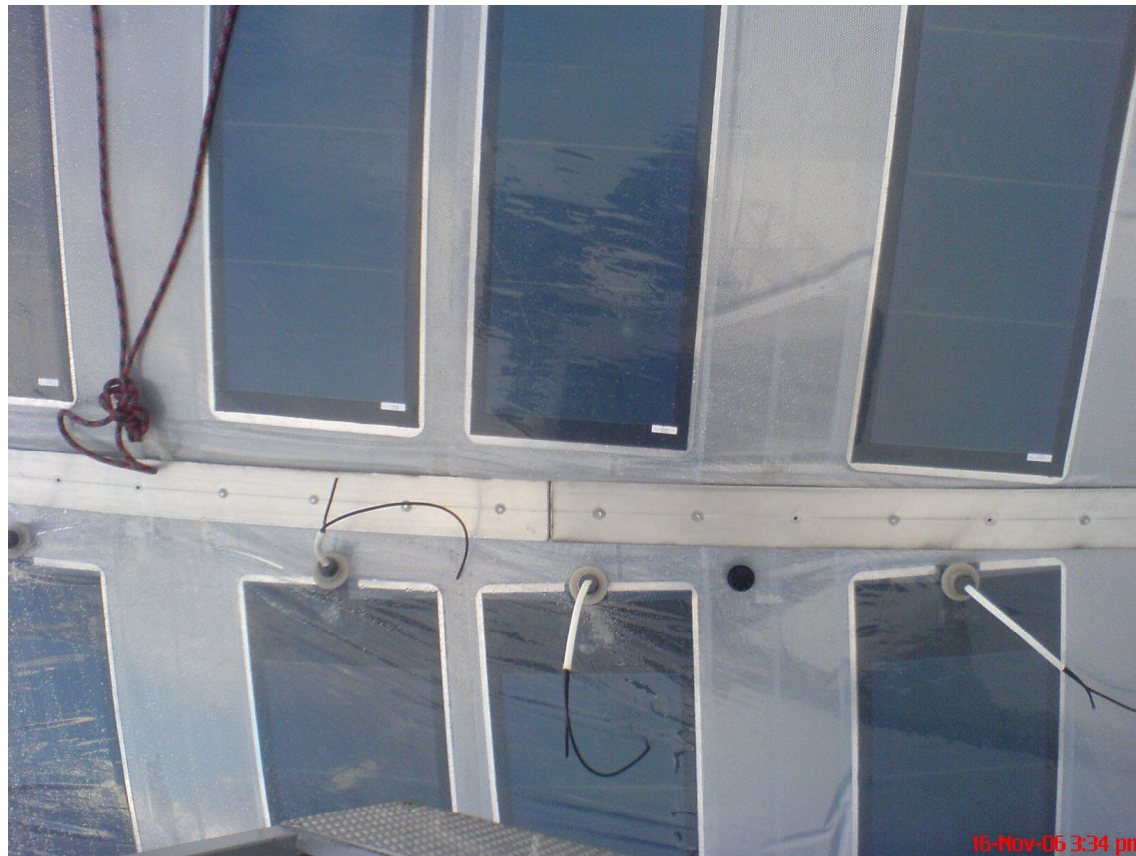
Studio E Architects

Vector Foiltec ETFE



2003 – UK – London – Classroom of the future - Photovoltaics

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Solar Cells from Uni-Solar

Incorporation into ETFE-
Pockets into TopLayer

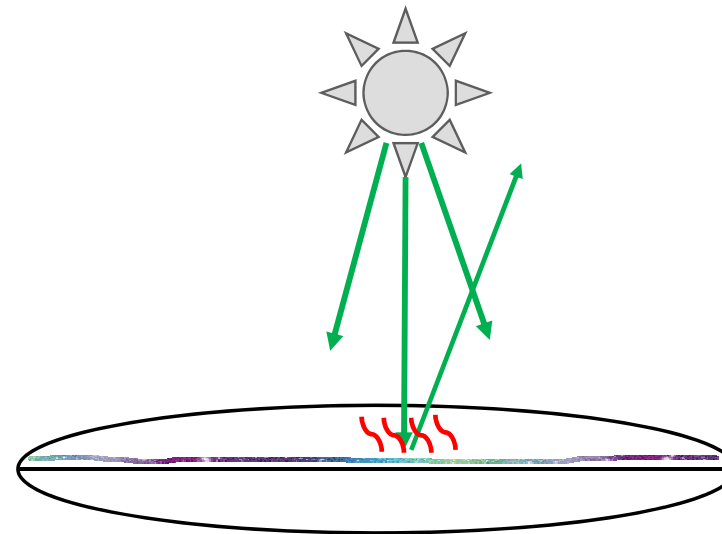
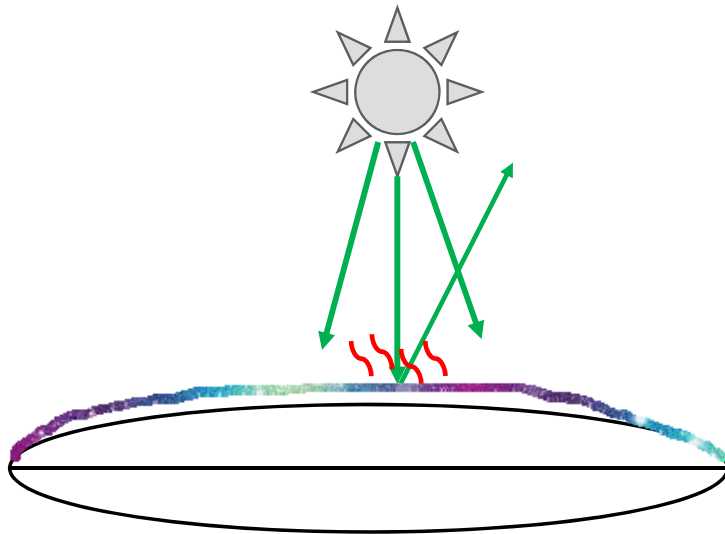
Condensation & Overheating
Cooling with air not sufficient

Temperature rise of above
100°C possible @ day
lower than surrounding in
night



Solar Control – Mode of Operation

Reduction of transmitted light & solar radiation (ET 6235Z)



Summer day: 1000 W/m²

Solar cell –
Absorption ~86 %

Reflection ~14%

Transmission 0%



2008 – GB – Stoke – Chatterley Valley

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Solar cells outside the cushions
only

AWM Munich – taken part in tender

Our suggestion:

Solar cells outside -

but bad performance for steel

We were not awarded with the
project.



2009 – Unilever HQ Building, Hamburg - Germany



Architects: Behnisch Architects

Engineering: Form TL, Weber Poll (Primary Structure)

ETFE: Vector Foiltec

Area: 6454 m²

1st permanent cable supported curtain wall structure

Vector Foiltec 1st tests for tensioning devices to keep the stress in the foil



2011 – Delemenhorst - Grafftherme

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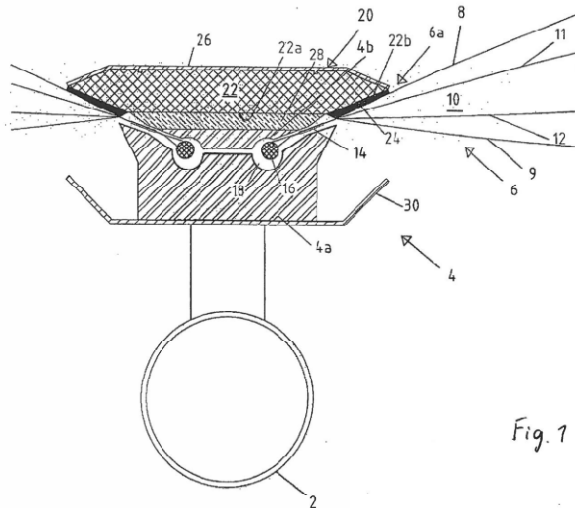
Architects & Engineering:
de Witt Janßen Partner
Steel

ETFE: Vector Foiltec

Thermocap



2011 – Delemenhorst – Grafftherme - Thermocap



(11) EP 2 643 534 B1

(12) EUROPÄISCHE PATENTSCHRIFT

(45) Veröffentlichungstag und Bekanntmachung des Hinweises auf die Patenterteilung: 07.01.2015 Patentblatt 2015/02
 (51) Int. Cl.: E04H 15/64 (2006.01) E04H 15/20 (2006.01) E04D 5/14 (2006.01) E04D 5/10 (2006.01)
 (21) Anmeldenummer: 11787882.7
 (86) Internationale Anmeldenummer: PCT/EP2011/070946
 (22) Anmeldetag: 24.11.2011
 (87) Internationale Veröffentlichungsnummer: WO 2012/069589 (31.05.2012 Gazette 2012/22)

(54) GEBÄUDEUMHÜLLUNGSELEMENT MIT THERMISCHEM ISOLIERELEMENT
 BUILDING ENVELOPE ELEMENT COMPRISING A THERMAL INSULATING ELEMENT
 ENVELOPPE DE BÂTIMENT COMPORTANT UN ÉLÉMENT D'ISOLATION THERMIQUE

(84) Benannte Vertragsstaaten:
 AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

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28790 Schwanewede (DE)
- GERHOLD, Sebastian
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28717 Bremen (DE)

(30) Priorität: 24.11.2010 DE 202010015743 U

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(74) Vertreter: Eisenführ Speiser
 Patentanwälte Rechtsanwälte PartGmbH
 Johannes-Brahms-Platz 1
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 28717 Bremen (DE)

(56) Entgegenhaltungen:
 EP-A1- 0 342 147 EP-A2- 1 350 906
 EP-B1- 1 348 823 DE-A1-102006 005 707

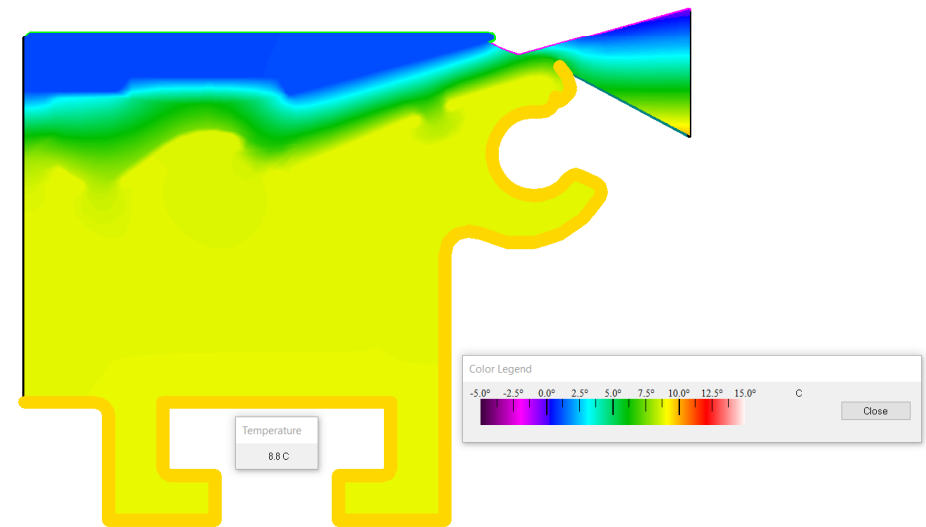
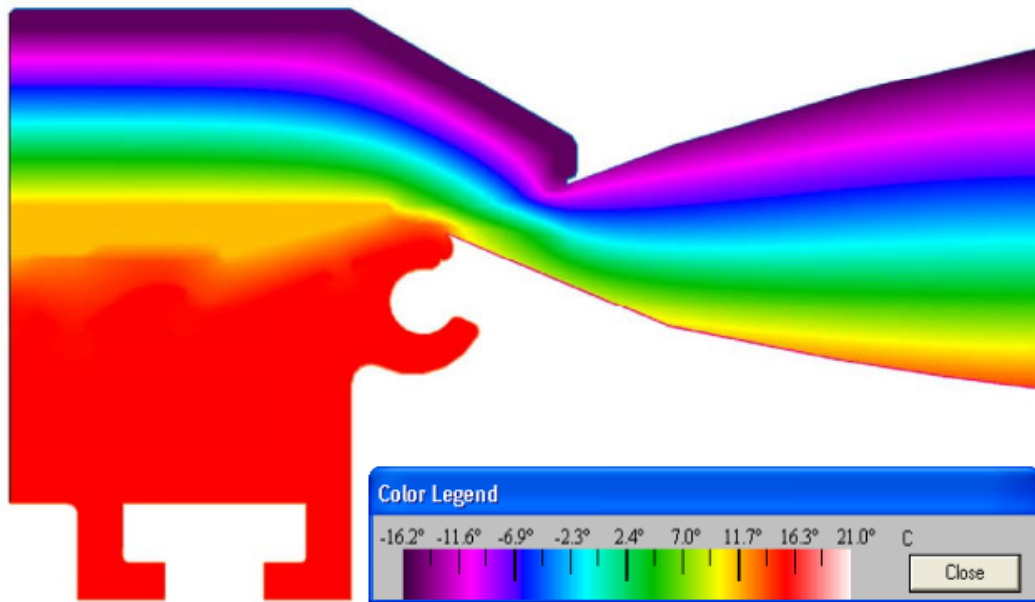
(72) Erfinder:
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 28357 Bremen (DE)



Thermal calculations (ISO 15099) of Standard & Thermo Cap

Thermo Cap

Standard Cap



2011 - Environmental product declaration – ISO 14025

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1st with Dyneon & Nowofol

Today:

Vector Foiltec – AGC/Nowofol+Dyneon

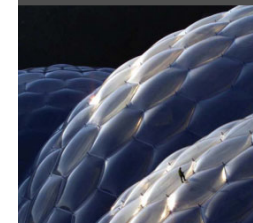
Tayo Europe - AGC

Novum + Nowofol + Elnic

Pfeifer



Umwelt-Produktdeklaration
nach ISO 14025



TEXLON®-System

Vector Foiltec
Nowofol
Dyneon

Deklarationsnummer
EPD-VND-2011111-D

Institut Bauen und Umwelt e.V.
www.bau-umwelt.com



Institut Bauen
und Umwelt e.V.



2013 - ETFE - Design

Collection of design rules
from all ETFE companies
but not Vector Foiltec

We know, how to design ...
because of our experience ...

It's our trade secret ...

...

& other reasons.



2018 – HK – Hongkong – Ocean Park

1. Chinese officers ask for verification of criteria according to JRC-report.

2. Foils become more and more thicker.

⇒ Issue

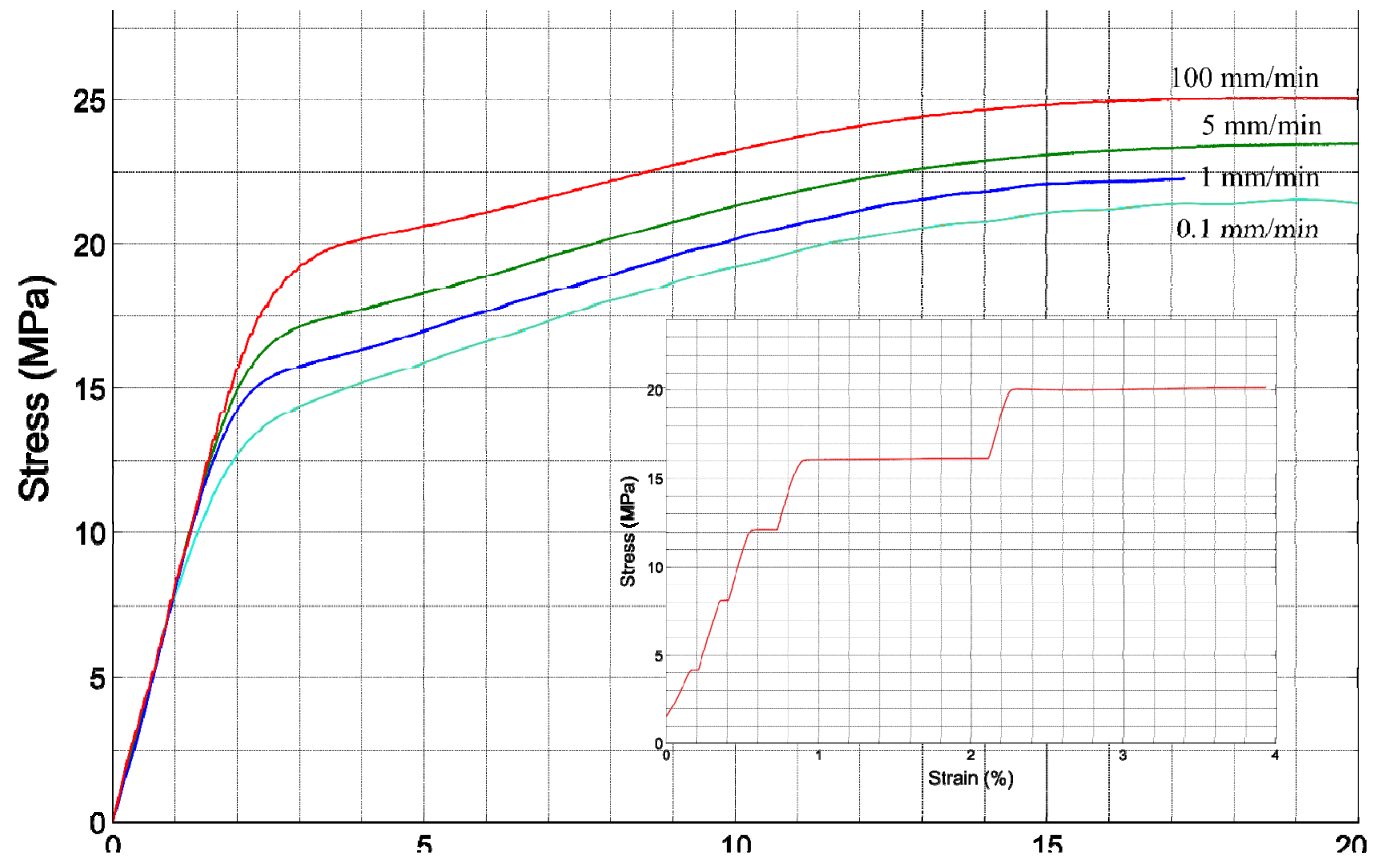
Vector Foiltec never used the concept of a yield point & always allowed limited plastic deformations



HOW TO INTRODUCE our old concept into the design !

ETFE – partially thermoplastic polymer

- ⇒ Real elastic range only ~0.2%
- ⇒ no change in volume of sample
- ⇒ Yield point concept is not valid for ETFE
- ⇒ Always mixture of elastic, viscoelastic & - plastic behaviour
- ⇒ No ISO 527-1/3 for design
- ⇒ Biaxial Testing



Beside the SLS concept of allowed plastic deformation

PD CEN/TS 19102:2023

ULS

Using quality control data of welding seams.



Based on EN 1990 with statistic concept of failed welding seams

Design of tensioned membrane structures

RC2	1/13,822
RC3	1/117,097

5 measurement samples of tensile strength of welds

bsi.



2020 – Las Vegas, NV – Raiders Stadium - 32.515 m²

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Architects: Manica
Architects and HNTB
Architects

32.515 m²

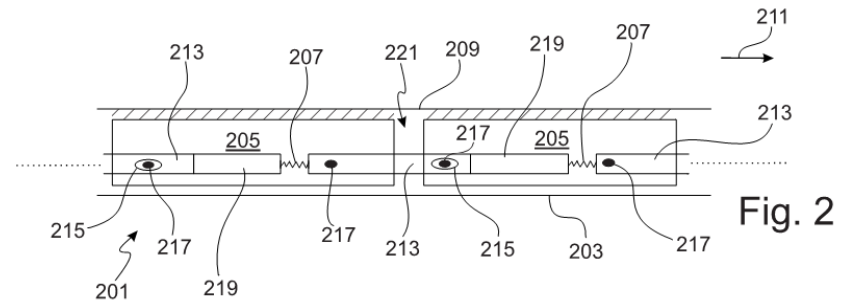
ETFE

Hold by a cable-net
structure

1st movement joint



2020 – Las Vegas, NV – Raiders Stadium



PCT/DE2020/200097

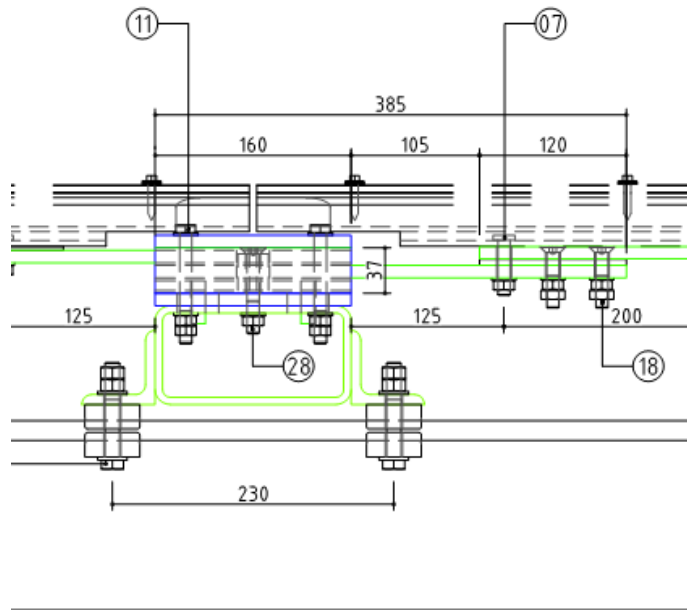
Distribution of Cable – movement between the ETFE cushions by coupled movement joints



2023 CA – Winnipeg – Assiniboine Park – The Leaf

Botanical Garden
KPMB Architects
6000 m²





ETFE-Cushions resides on sliding bearings 2-D on upstand

Measurements of Friction Coefficients (1st work)

Choose of appropriate material for sliding

Variation over time

2023 CA – Winnipeg – Assiniboine Park – The Leaf

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- Distribution of movements due to wind loads



How to design the tents nowadays – Interview with Frei Otto

Interview from Detail – 2000/6 p.964

Detail: What material would you suggest today as the covering to the roof of the Olympic stadium in Munich?

Otto: Instead of the material I suggested at the time, I would span a prestressed layer of synthetic sheeting over the cable net. It would be just as transparent and durable as perspex, but all the complicated details and junctions would be obviated. At the time of construction, that would have involved risks I was not prepared to take. This question does not arise

Detail: How do you view the environmental sustainability of the materials commonly used for membrane construction?

Otto: If one wishes to build tents with a long life, one inevitably has to use materials that are more difficult to recycle. With the introduction of glass fibre, PVC and Teflon, it became possible to create membranes of great durability. It will be one of the tasks of the future to develop durable materials that can be easily recycled.

Create New Worlds!

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**Tradition is not the worship of ashes, ...
but to keep the fire alive.**

Very free version acc. to Jean Jaures

Thank you very much for your attention

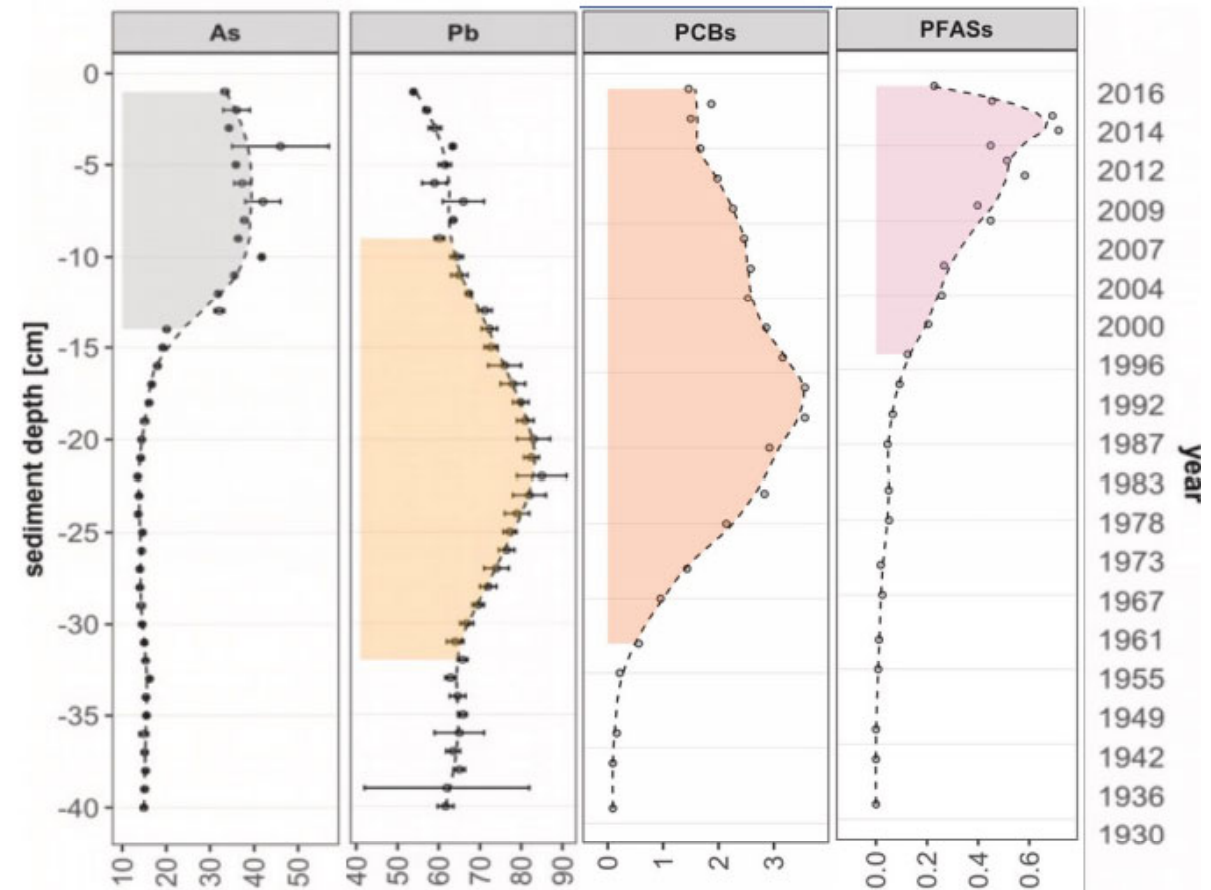


Messieurs, oui, nous avons, nous aussi, le culte du passé. Ce n'est pas en vain que tous les foyers des générations humaines ont flambé, ont rayonné ; mais c'est nous, parce que nous marchons, parce que nous luttons pour un idéal nouveau, c'est nous qui sommes les vrais héritiers du foyer des aïeux ; nous en avons pris la flamme, vous n'en avez gardé que la cendre.



BUT, the **truth** is ...

... concentration of PFAS is going down in the environment (Skagerrak)



Profile of metals and organic contaminants in the sediment core from the Skagerrak (Logemann et al. 2022)

<https://doi.org/10.1016/j.envpol.2022.119040>