Trelleborg Offshore

The Evolution of Syntactic Foam Technology to Meet Increasingly Diverse Subsea Applications and Demands

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Agenda

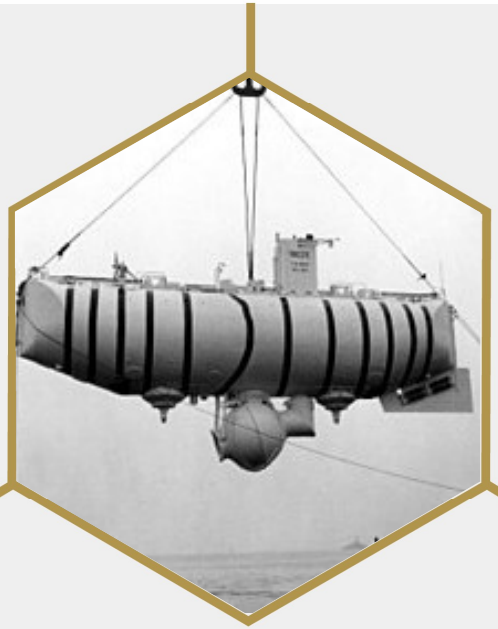
1. History of Subsea exploration
2. Our Background in Syntactic Foam
3. What is Syntactic Foam?
4. Syntactic Foam Applications
5. Where Next?

History

Going Subsea for Underwater Exploration

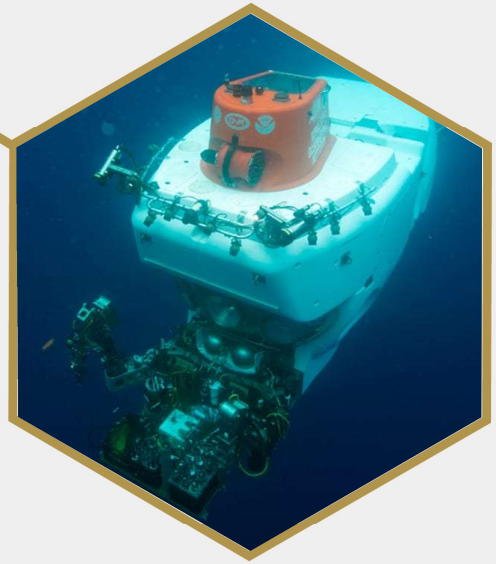
1934

- Beebe & Barton
- New York Zoological Dept.
- 914 MSW (3,000 FSW)
- Sphere suspended on a cable



1960

- TRIESTE Bathyscaphe by Jacques Piccard
- 10,912 MSW (35,800 FSW)
- Kerosene based buoyancy
- 150 te weight in air



1964

- *'Alvin'* - Human Occupied Vehicle (HOV)
- 3 occupants
- 4,500 MSW (14,764 FSW)
- Syntactic Foam & titanium sphere.
- Discover the Titanic wreck in 1986

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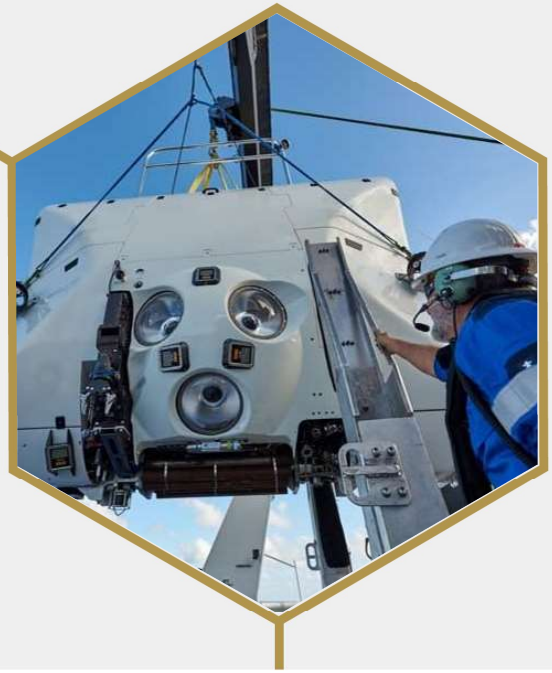
History

Going Subsea for Underwater Exploration

1984

- *'Nautile'* by Ifremer CNEXO
- HOV – 3 occupants
- 6,000 MSW (19,680 FSW)
- Syntactic Foam blocks bonded together by DCN
- Included smaller ROV – *'Robin'*



2019

- *'Triton LF'* by Victor Vescovo et al
- Mariana trench
- HOV – 2 occupants
- Record breaking 10,928 msw (36,089 FSW)
- Trelleborg Syntactic Foam TG11500
- Pressure tested to 14,000 msw

THE 5 DEEPS
IN PROFUNDO: COGNITIO

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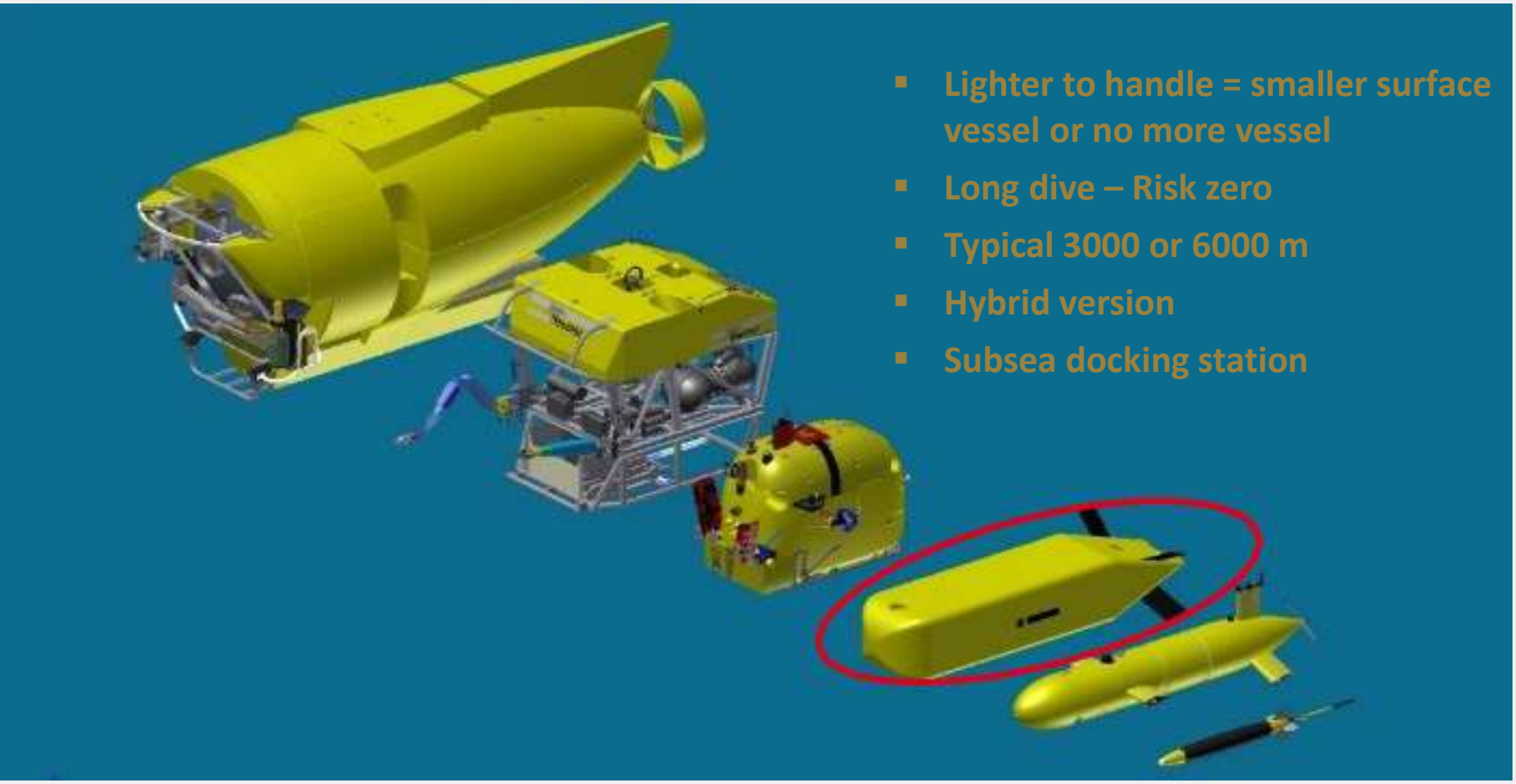
HOV, ROV, H-ROV, AUV

For Subsea Exploration



- Lighter to handle = smaller surface vessel or no more vessel
- Long dive – Risk zero
- Typical 3000 or 6000 m
- Hybrid version
- Subsea docking station

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Our Background in Syntactic Foam

- 1948 Emerson & Cuming created (near Boston, US)
- 1960s 1st patent for Microballons™
- 1974 CRP Marine created (near Manchester, UK)
- 1980 CRP begin manufacturing syntactic foam
- 2000 Emerson & Cuming – ECCM join CRP
- 2003 Balmoral International Inc. facility (Houston) join CRP
- 2006 CRP Group became Trelleborg Offshore
- 2013 Ambler Technology Ltd. join Trelleborg Offshore

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Syntactic foam manufacturing

For Subsea Exploration

- TOUK Skelmersdale (UK)
- TAT Rochdale (UK)
- TAT Boston (YSA)

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What is Syntactic Foam?

- The word syntactic comes from a Greek word for syntax – '*syntaxis*'.
- Syntactic means the 'science of combination and order'
- Syntactic Foam is a mix of air bubbles and a matrix to create a composite containing voids.
- The term *'foam'* relates to the cellular nature of the material.
- With the arrival of epoxies, Syntactic Foam became a structural material.

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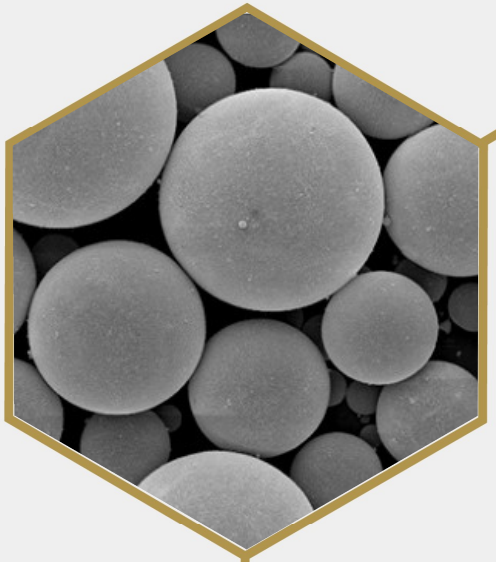
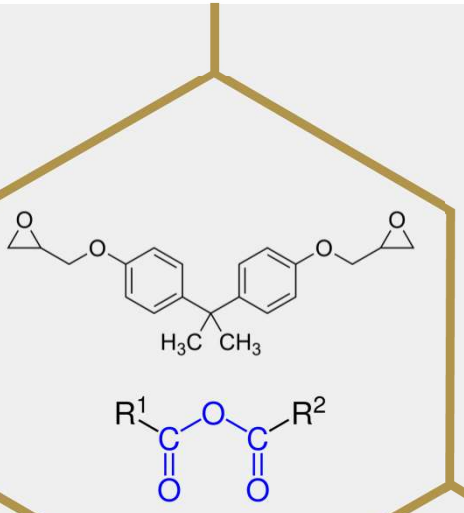
What is Syntactic Foam?

HGMS





Polymer Binder

Macrosphere

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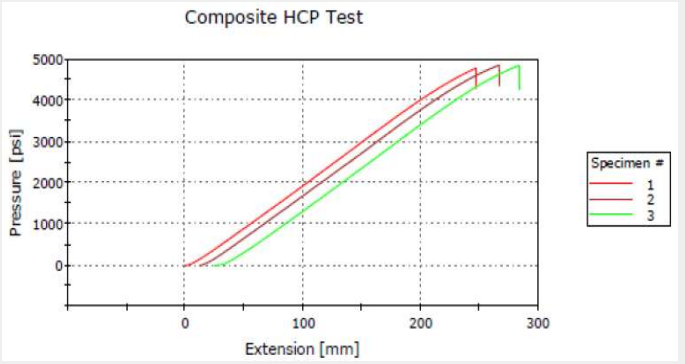
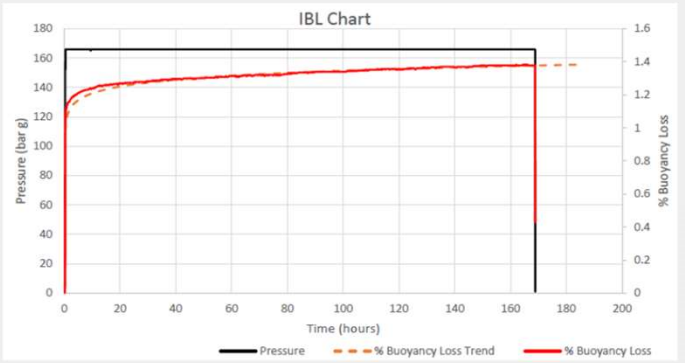
What is Syntactic Foam?
Key Material Properties

Subsea Applications	Non-subsea Applications
Low density	Low density
High crush strength	Low thermal conductivity
Low water ingress	High temperature resistance
High stiffness	Fire resistant properties
Low creep	Low coefficient of thermal expansion (CTE)





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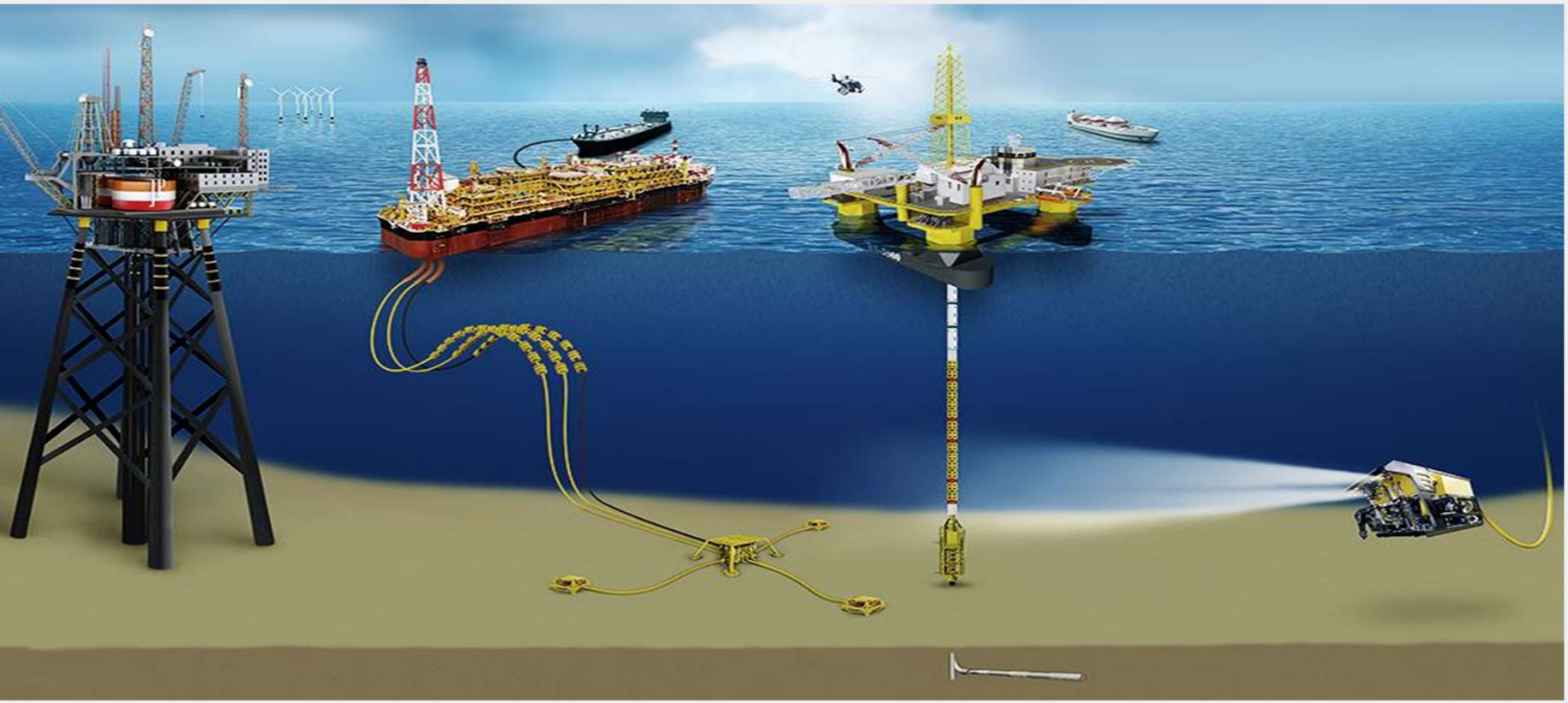
Syntactic Foam

For Oil & Gas



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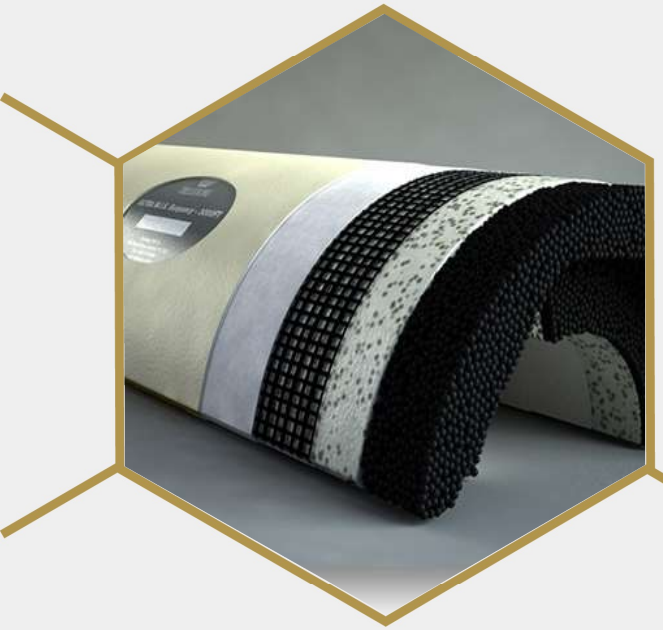
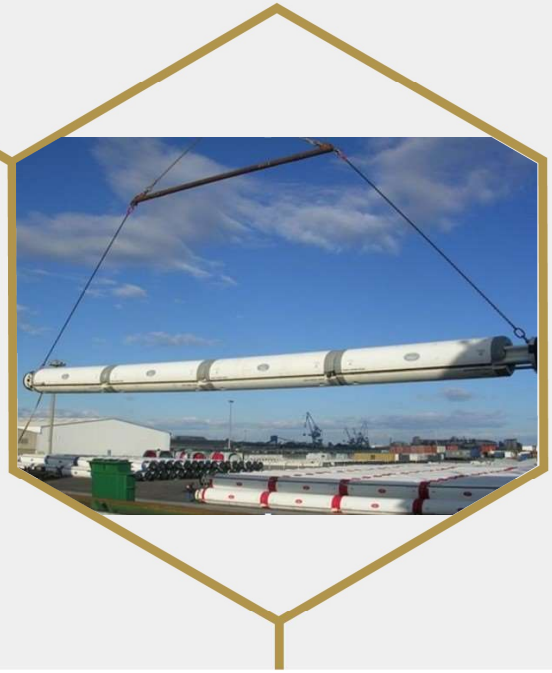
Syntactic Foam

For Deep Offshore Drilling





Drill Riser Buoyancy Modules (DRBM)

- Non permanent buoyancy
- GRE outer skin
- Core made up of Syntactic Foam with FRE spheres
- Max drilling buoyancy 3,445 MSW in Guyana
- Target 4,000 MSW

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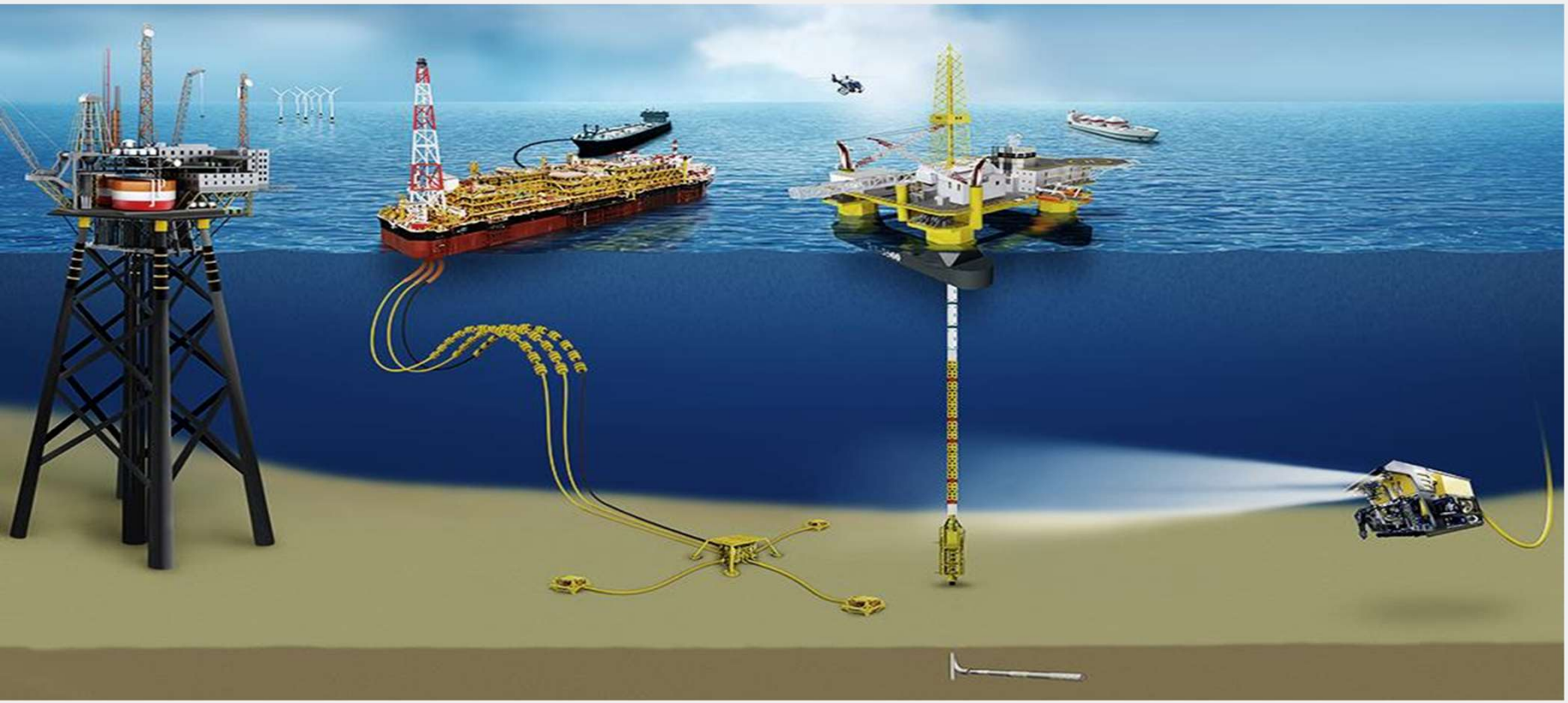
Syntactic Foam

For Oil & Gas



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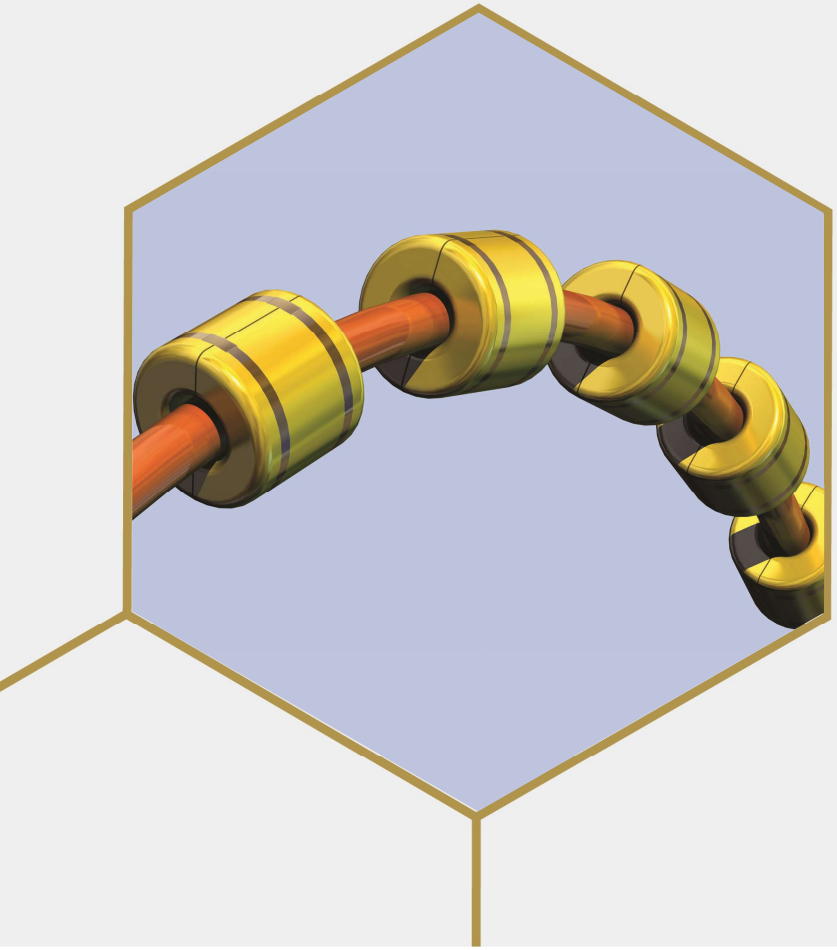
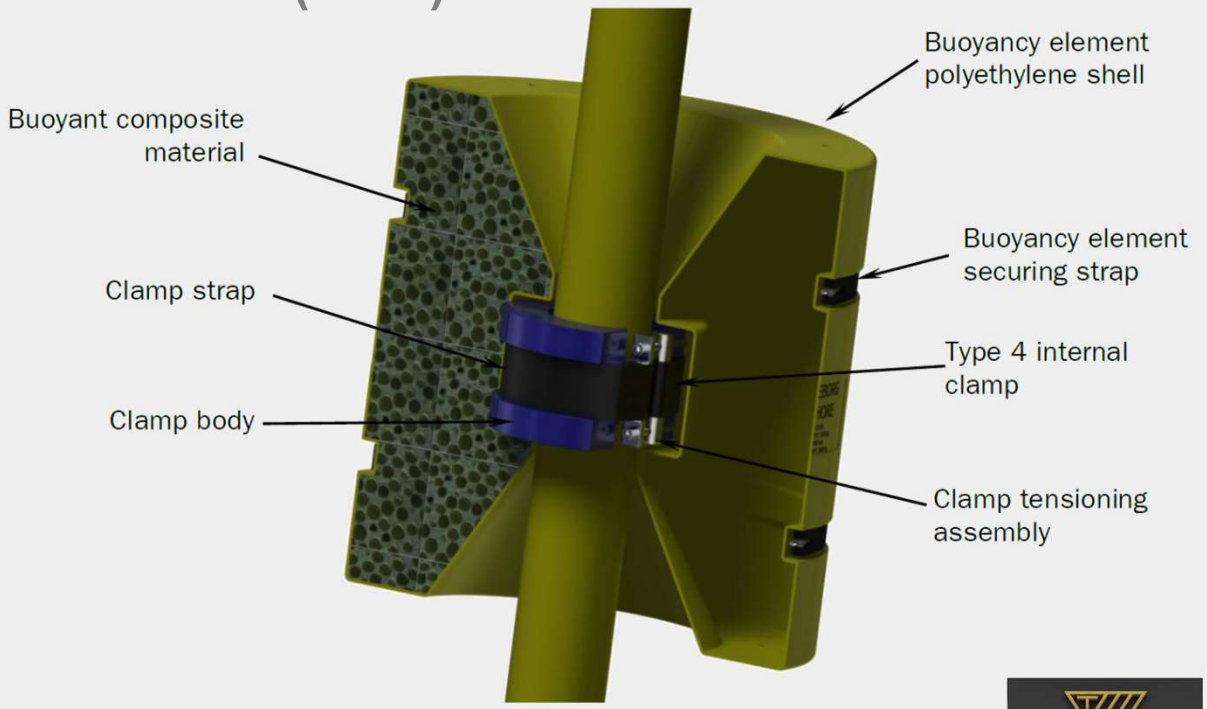
Syntactic Foam

For Permanent Risers



Distributed Buoyancy Modules (DBM)



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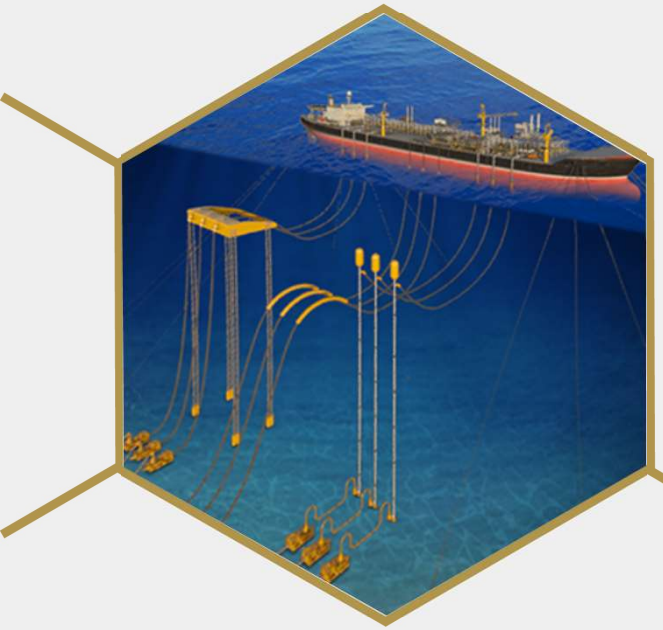
Syntactic Foam
For Riser Towers



Riser Towers

- Bundle of pipelines standing upright
- Bundle towed to site & up-ended
- Biggest man made object
- GIRRASOL (Total 1999)
- ROSA (Total)
- GREATER PLUTONIO (BP)
- CLOV (Total)

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Syntactic Foam

For Riser Towers

Rosa (Total)

Greater Plutonio (BP)

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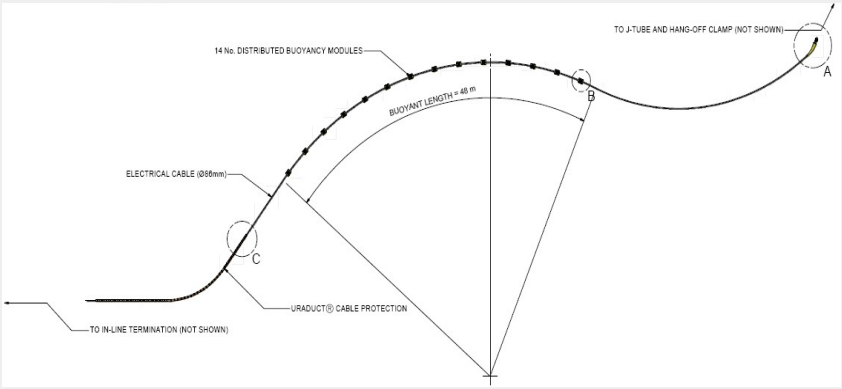
Syntactic Foam

Outside of Oil & Gas

- Floating wind platform
- Shallow water lazy wave
- Small DBM (typically 150 kg)
- Ultra low coast foam
- Speed-up installation time



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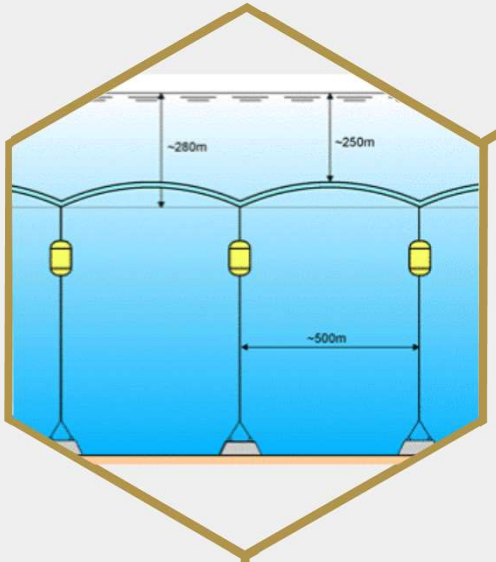
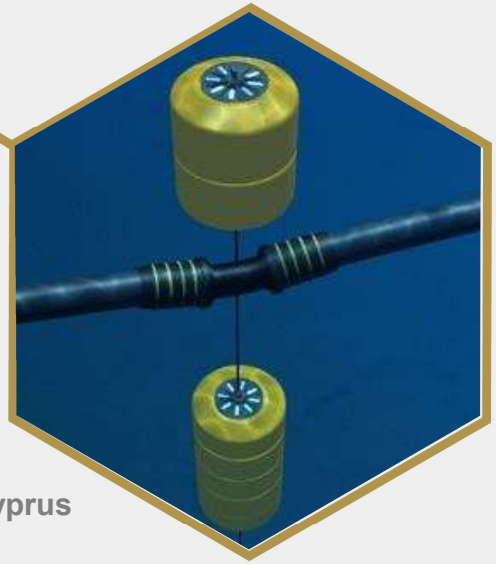
Syntactic Foam

Outside of Oil and Gas





Cyprus Water Line

- 80km mid water pipe line
- 320 buoys, 30 & 20 Te
- Rated 250 MSW
- Providing water from Turkey to Cyprus
- Trelleborg's largest contract ever

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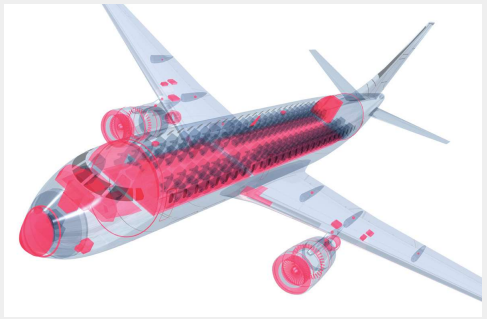
Syntactic Foam
Outside of Oil & Gas

- Other applications:
- **Electronic** **(electrical potting compounds)**
- **Aerospace** **(Ablative heat shield, void fillers, abradable seals, Mars rover)**
- **Defence** **(radar absorbing material, conductive coatings, impact material)**
- **Tooling blocks** **(mould pattern, light weight composites; thermoforming tooling)**

Aerospace

Red parts are current uses of Syntactic foams in commercial aircraft



Defence

Syntactic Foam missile supports

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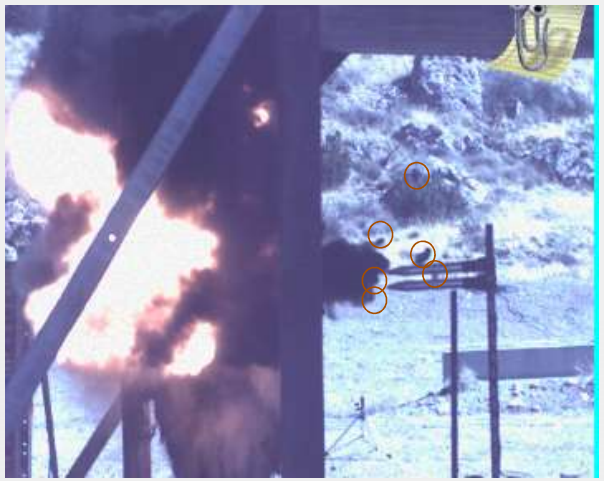
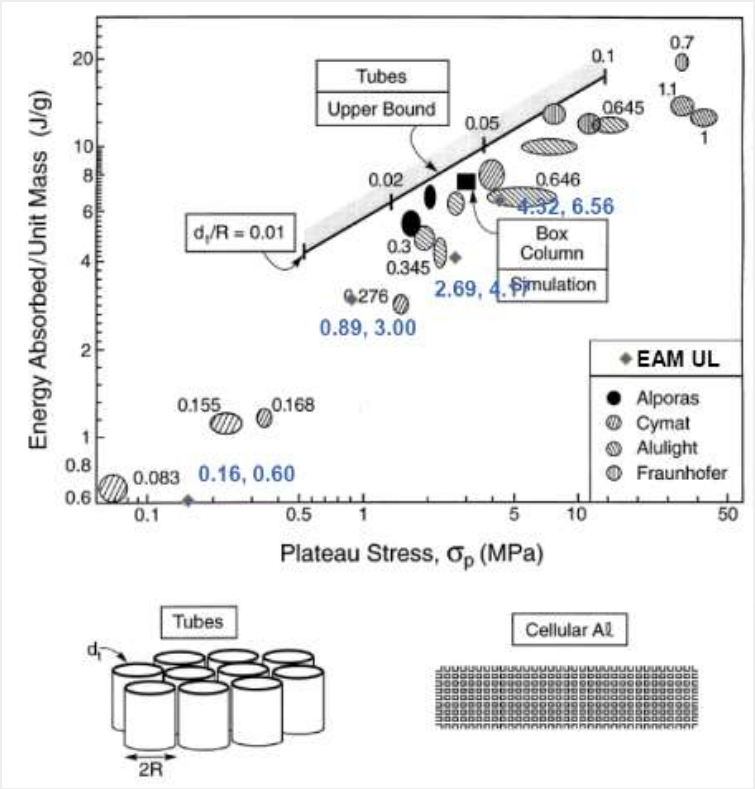
Syntactic Foam

Where Next – Other Applications?

Energy Absorbing Material (EAM)

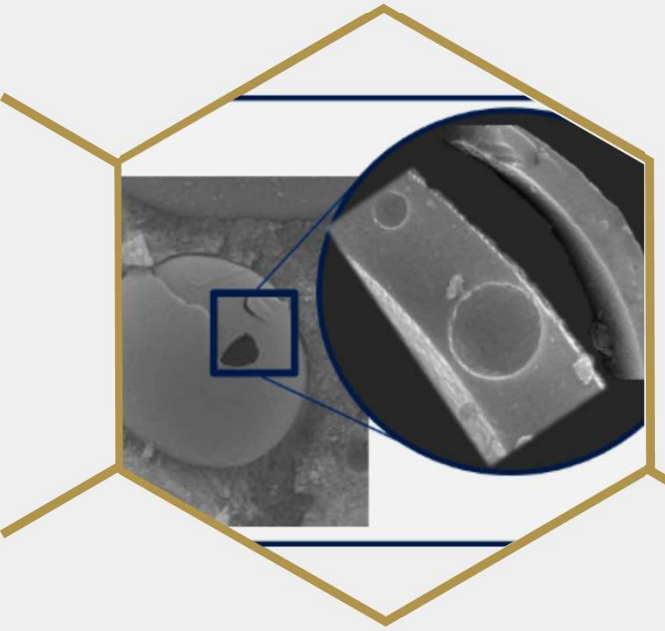
- Energy Absorbing Material (EAM) syntactic foam
- Shockwave mitigating material
- Developed to protect people and high value infrastructure





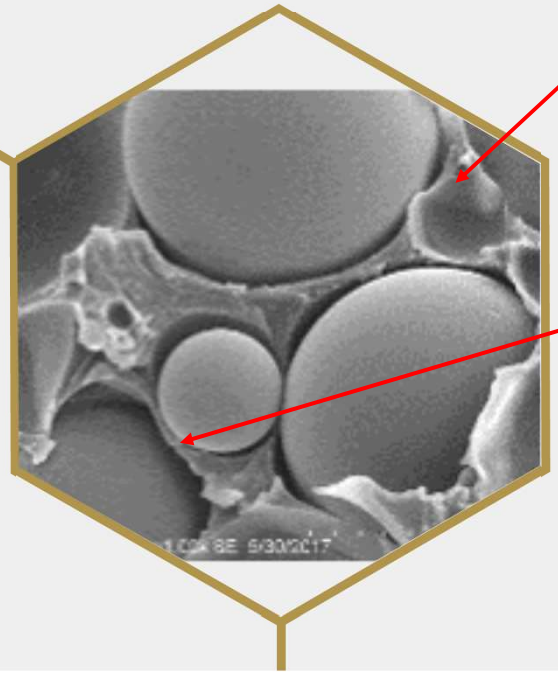
Syntactic Foam

Where Next?



Hollow Glass Microsphere (HGMS)

- Ultra low density HGMS
- High strength/weight ratio
- Particle size modification



Polymer Matrix (Resin)

- Low viscosity alternative resins
- Polyester, vinyl-ester, DCPD as alternates to epoxy
- Additives to reduce water ingress and improve processing

Polymer Matrix/HGMS Interaction

- Coupling agents to chemically fuse materials together
- Improve water absorption properties

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Syntactic Foam

Where Next – Challenges?

- Understand the long term ageing of Syntactic Foams
  - Aging mechanisms
  - Rate of ageing
- Lower cost Syntactic Foams to compete with alternate materials
  - Improve composite strength/weight ratio
- Deeper rated Syntactic Foams
  - Cost competitive deep water foams – > 4,000 MSW
- Testing capabilities
  - Testing full scale parts at pressure

- 2018-2019 investment in TOUK as Trelleborg global CoE for buoyancy ~ €15M
- Production capacity increasing 3x for deep-water buoyancy
- World leading test centre under construction, including 700bar test vessels capable of full scale DBM testing

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