Syntactic Foam Buoyancy Materials for Subsea Service: Composition, Design, Applications, Testing and Challenges

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EUROPEAN MECHANICS SOCIETY

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Introduction – Balmoral Offshore Engineering

- Privately owned company
- Headquarters on 45-acre manufacture site in Aberdeen
- Supplying world-wide

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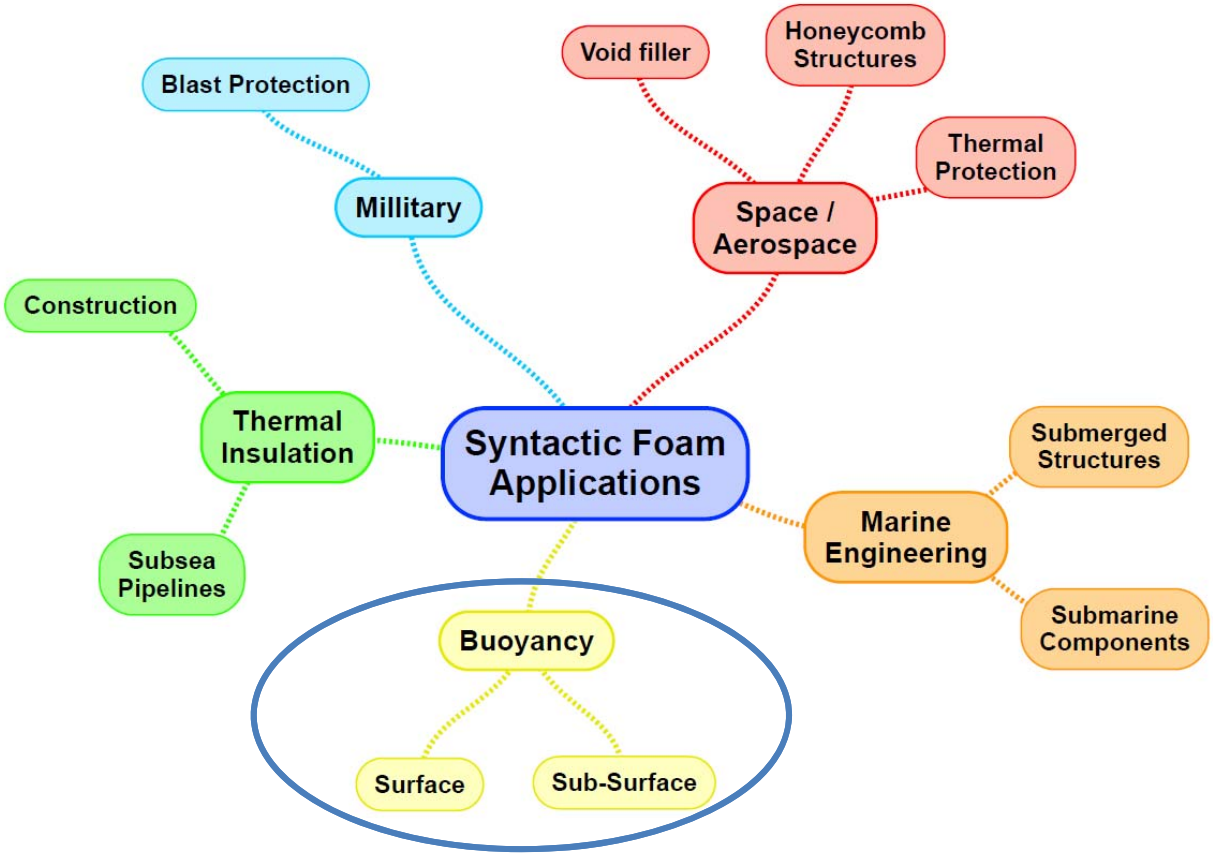
Syntactic Foam Applications



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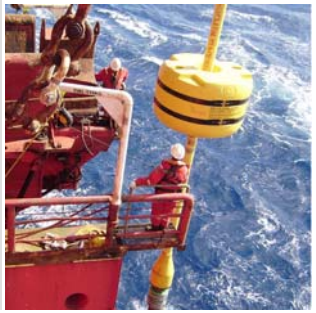
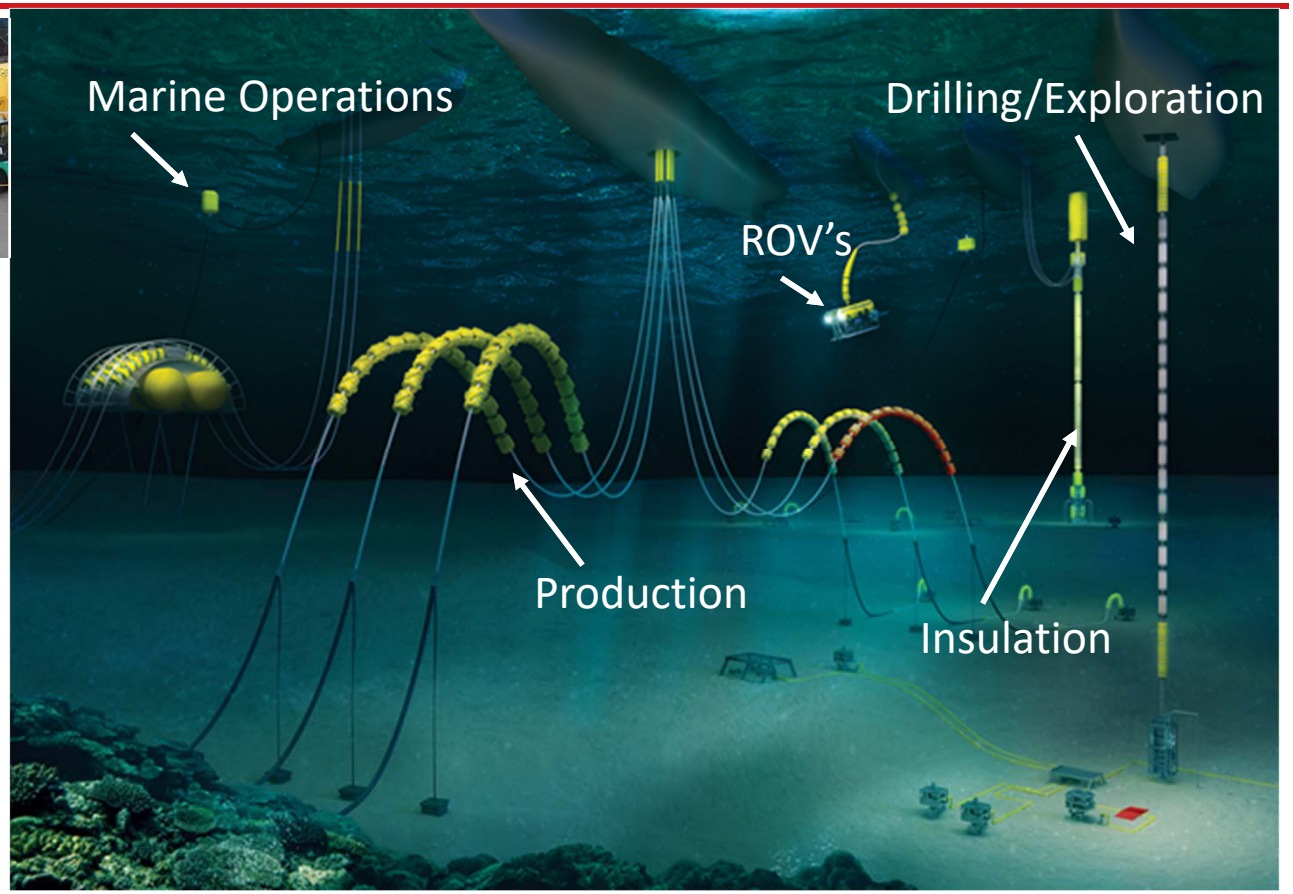
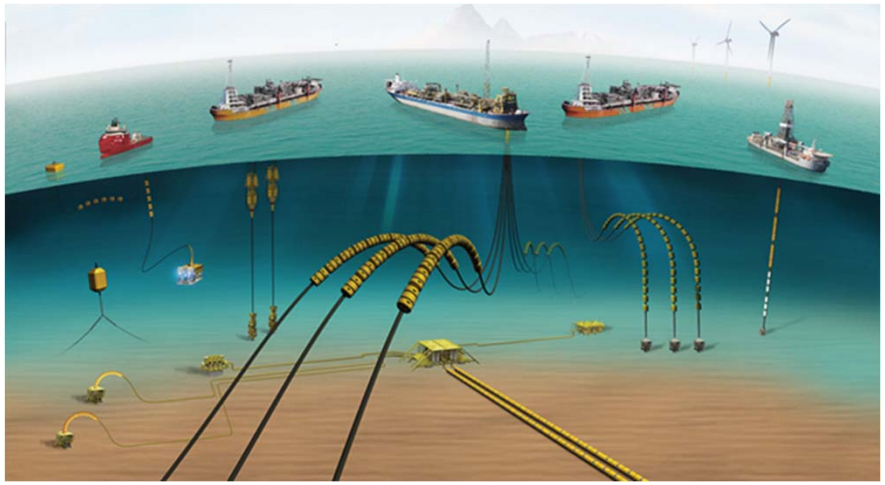
Subsea Syntactic Foam Applications





Syntactic Foam Design

- Considerations
  - National/International or client-specific specifications
  - Manufacturability
  - Required minimum service life
  - Operational depth/pressure
  - Seawater temperature during operation
  - Minimum safety factors
  - Minimum net buoyancy at EOL
    - EC
    - WA
    - Creep
    - Marine fouling
  - Mechanical Loads
  - **COST vs Performance… £ $ €**



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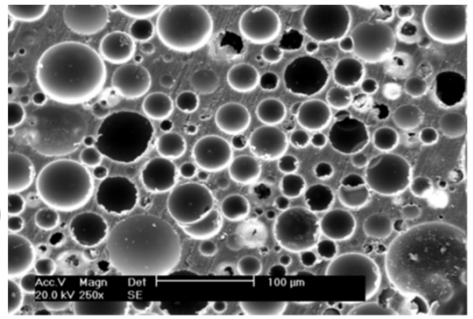
Syntactic Foam (Pure Syntactic) Composition

Syntactic Foam = Resin matrix + hollow microspheres (glass/polymer/ceramic & metallic)

Hollow Glass MicroSpheres (HGMS)

- Borosilicate glass spheres <150 µm diameter
- HGMS collapse pressures of 13.7 bar (200 psi) to 2275 bar (33,000 psi)
- Densities of 125 kg/m^3 to > 600 kg/m^3
- HGMS collapse resistance is increased in the resin matrix



Polymer resin system: The 'Matrix'

- Enhances collapse pressure of the HGMS. (Matrix amplification)
- MA of 1x to >20x are common.
- Thermosets and thermoplastic polymer systems are used.

Combination of resin system + HGMS results in unique Tg, HCP & water absorption characteristics.

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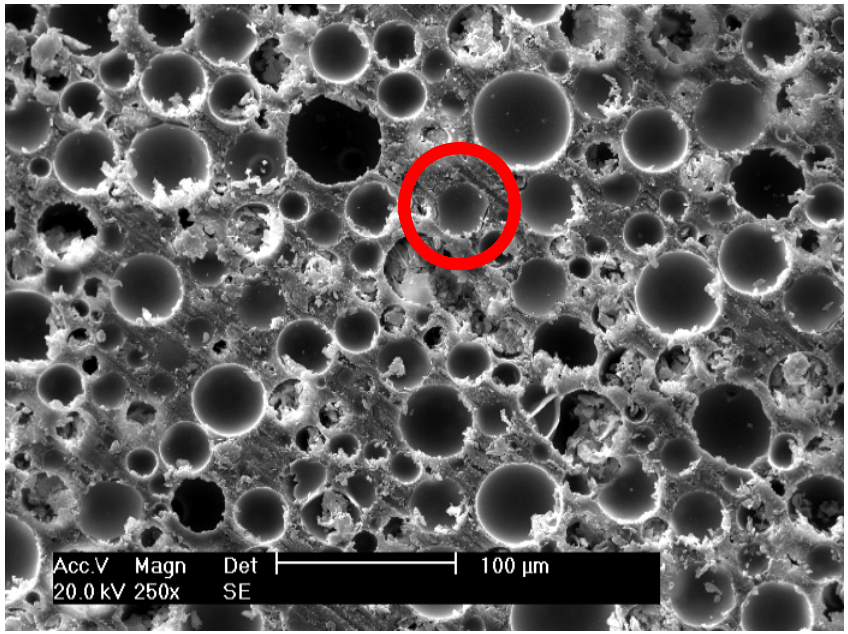
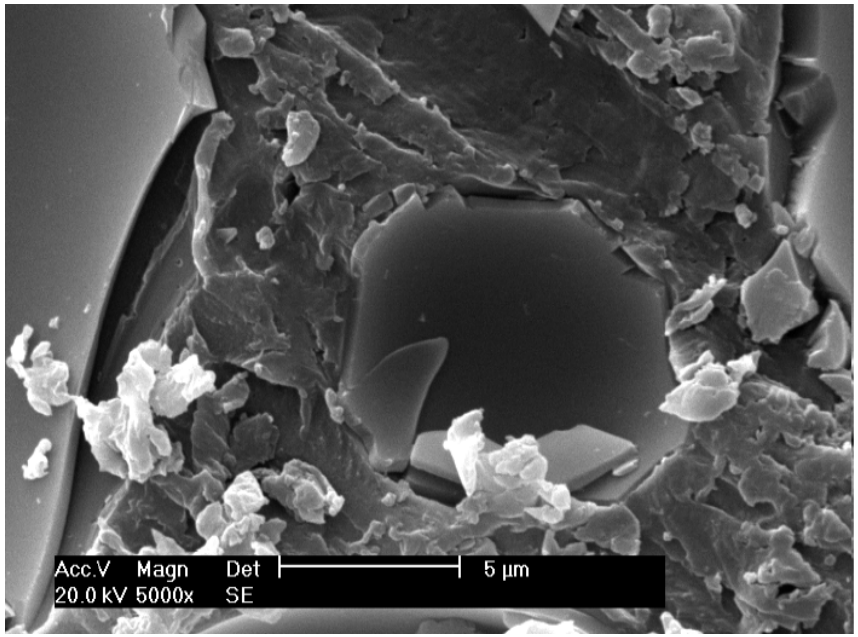
Syntactic Foam Composition





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Composite Syntactic Foam Composition

Composite Syntactic Foam = Syntactic foam (Pure Syntactic) + Macrospheres

Macrospheres

- Used to decrease overall density of foam
- Diameters 10 mm to 60 mm
- Injection moulded or pan coated
- Thermoplastic or Thermosetting
- Unique density and collapse (burst) pressure

Combination of pure syntactic + macrospheres results in unique HCP, BL and mechanical performance.

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Properties of Syntactic Foam (Pure Syntactic)

Property	Low-Density HGMS	Medium-density HGMS	High-density HGMS
Finished Foam Density (kg/m^3)	~560	~600	~700
Uniaxial Compressive Strength at Maximum Compressive Load (MPa)	>28	>40	>60
Tensile Strength at Maximum Tensile Load (MPa)	>15	>20	>30
Hydrostatic Collapse Pressure (bar)	>330	>550	>700
Punch Shear Strength (MPa)	>15	>20	>25

Properties of Syn. Foam vs Composite Foam

Property	Syntactic Foam (Pure Syntactic) Medium-density HGMS	Composite Syntactic Foam (with macrospheres)
Finished Foam Density (kg/m^3)	~600	~530
Uniaxial Compressive Strength at Maximum Compressive Load (MPa)	>40	>15
Tensile Strength at Maximum Tensile Load (MPa)	>20	<10
Punch Shear Strength (MPa)	>20	>30

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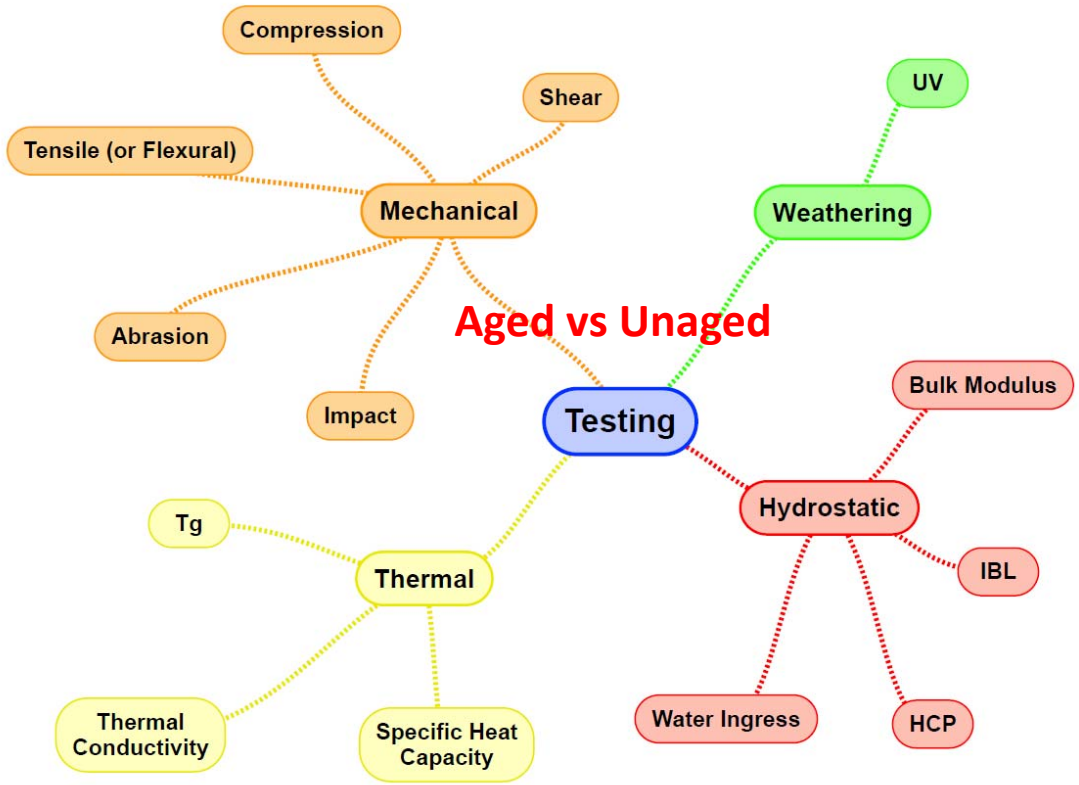
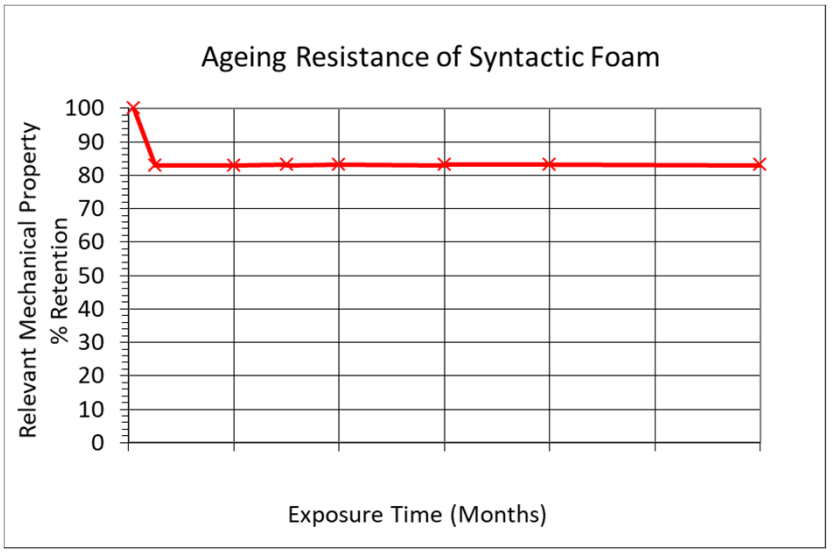
Syntactic / Composite Syntactic Foam Testing



Syntactic Foam Testing

- **Mechanical**
  - Different methods for foam vs composite
  - National/International standards only suitable for syntactic foam so large-scale in-house equipment required for composite syntactic foam
  - **AGED VS UNAGED**
- **Weathering Resistance**
  - ‘UV resistance’



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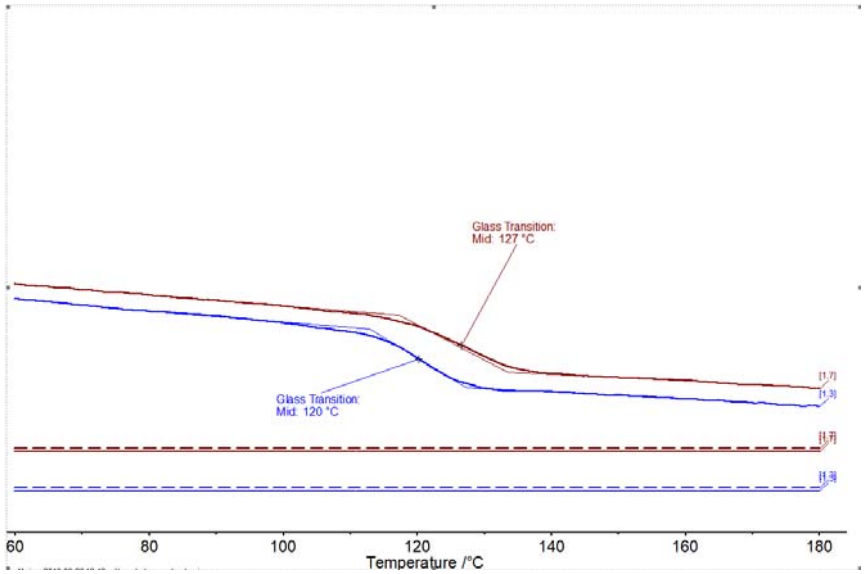
Syntactic Foam Testing

- **Thermal**
  - DSC,
  - DMA,
  - Thermal conductivity



- **Hydrostatic**
  - Water Ingress
  - Hydrostatic Collapse Pressure (HCP)
  - Instrumented Buoyancy Loss (IBL)

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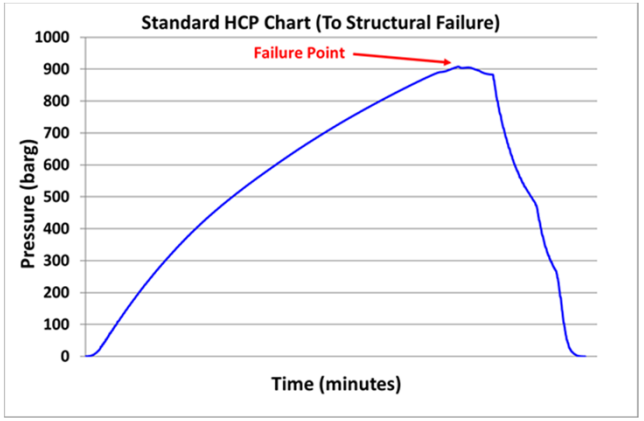
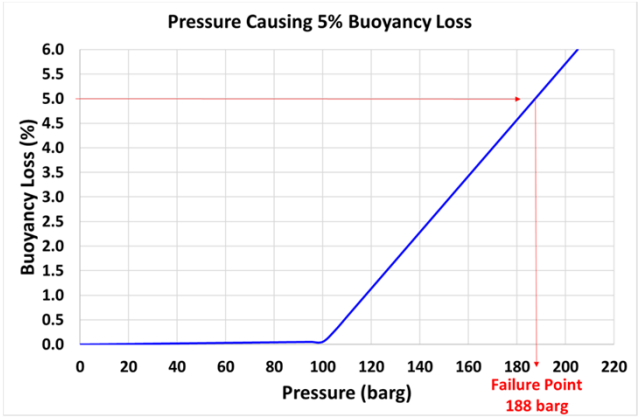
Hydrostatic Collapse Pressure (HCP) Testing

Hydrostatic Collapse Pressure – Gives the 'short term' safety factor over operating pressure.

Syntactic Foam (Pure Syntactic) "Hydrostatic Pressure relating to a non-recoverable change in the Pressure vs Time chart (or on the Load vs Deflection chart) which is measurement dependant"

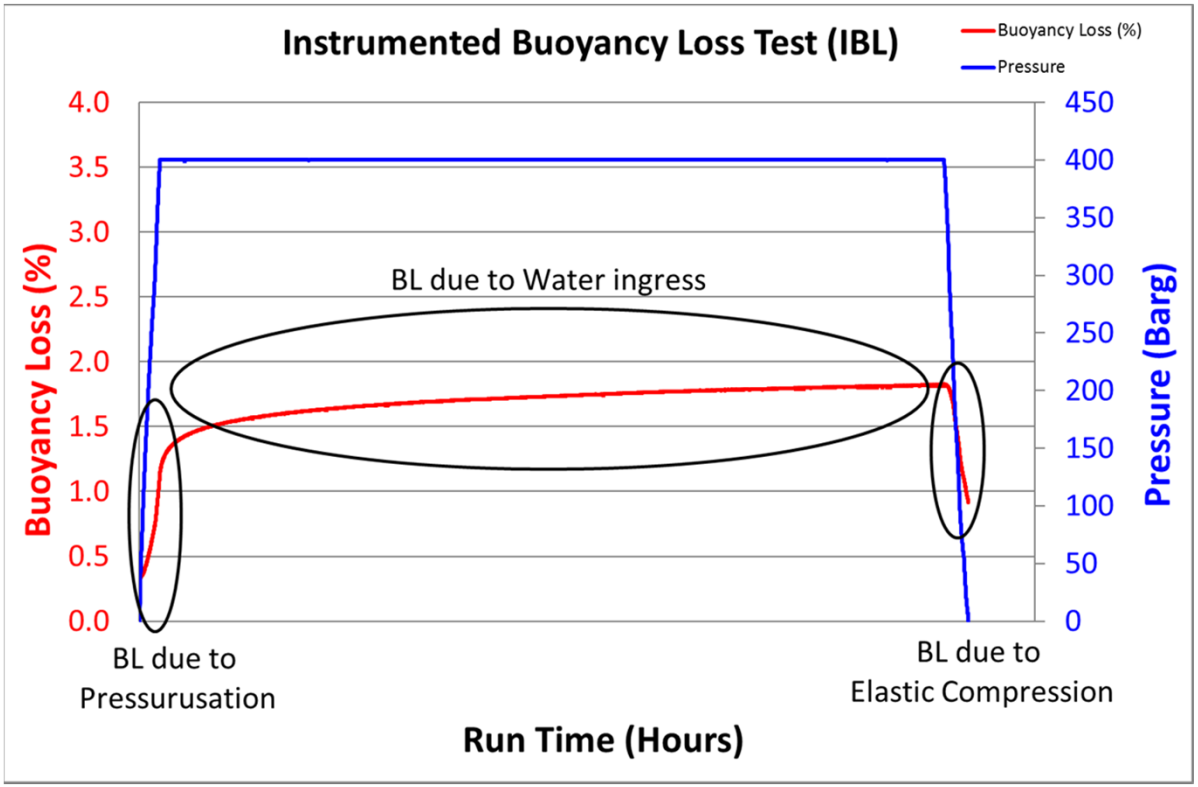
Composite Syntactic Foam (with spheres) – "Hydrostatic pressure which results in an immediate 5% Buoyancy Loss"





Instrumented Buoyancy Loss (IBL) Testing

Allows an ‘end of life’ buoyancy loss prediction



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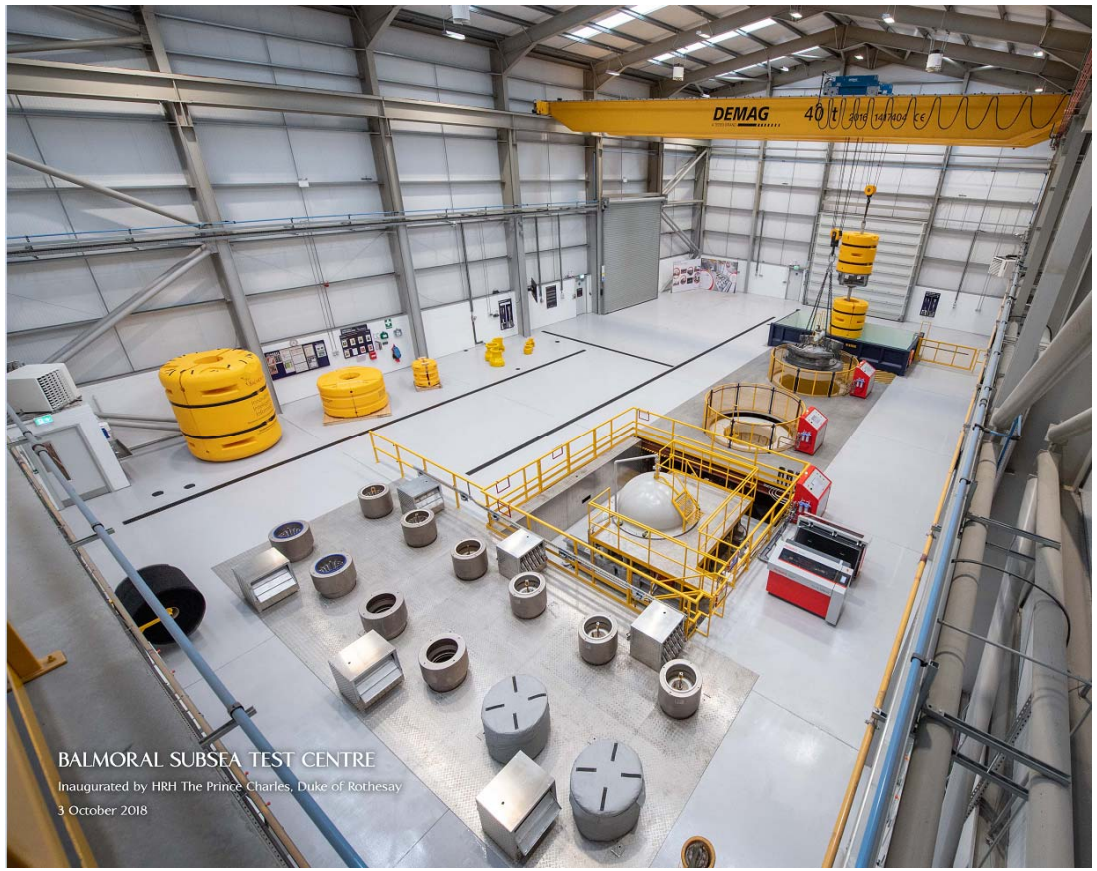
Syntactic Foam Hydrostatic Testing



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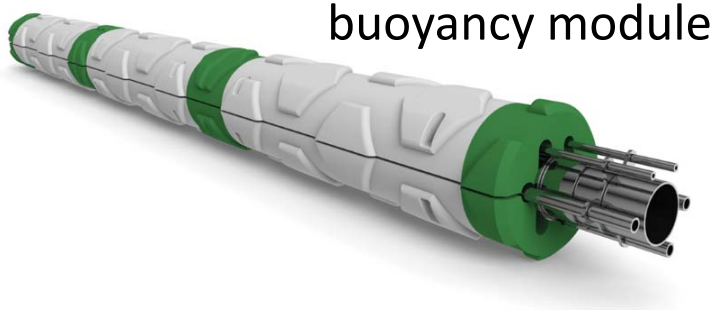
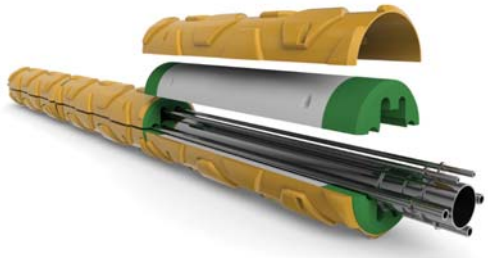
Future of Buoyancy Foam

Producing in deeper water & over longer service lives ≥ 30 years!

- **Deeper waters = Longer, heavier pipelines**
  - More buoyancy required
  - Buoyancy to withstand higher hydrostatic & mechanical loads
  - Increased drag from modules in sea currents can increase risk of fatigue in the line through Vortex Induced Vibration (VIV)
    - Lower density, higher performance buoyancy required to keep buoyancy module volume down and reduce drag





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Future of Buoyancy Foam

Producing in deeper water & over longer service lives ≥ 30 years!

- **Longer Service Durations**
  - Continually seeking more advanced material/product solutions to ensure longevity
  - Ensure robust, reliable, long-term extrapolations methods of full-scale products
  - Balance: **COST vs Performance… £ $ €**

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Thank-You

Questions?