Assessing the Risk of Overpressure from Liquid Thermal Expansion

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Wood Process Solutions

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- **Modelling**
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- **Applications & Mitigation Measures**
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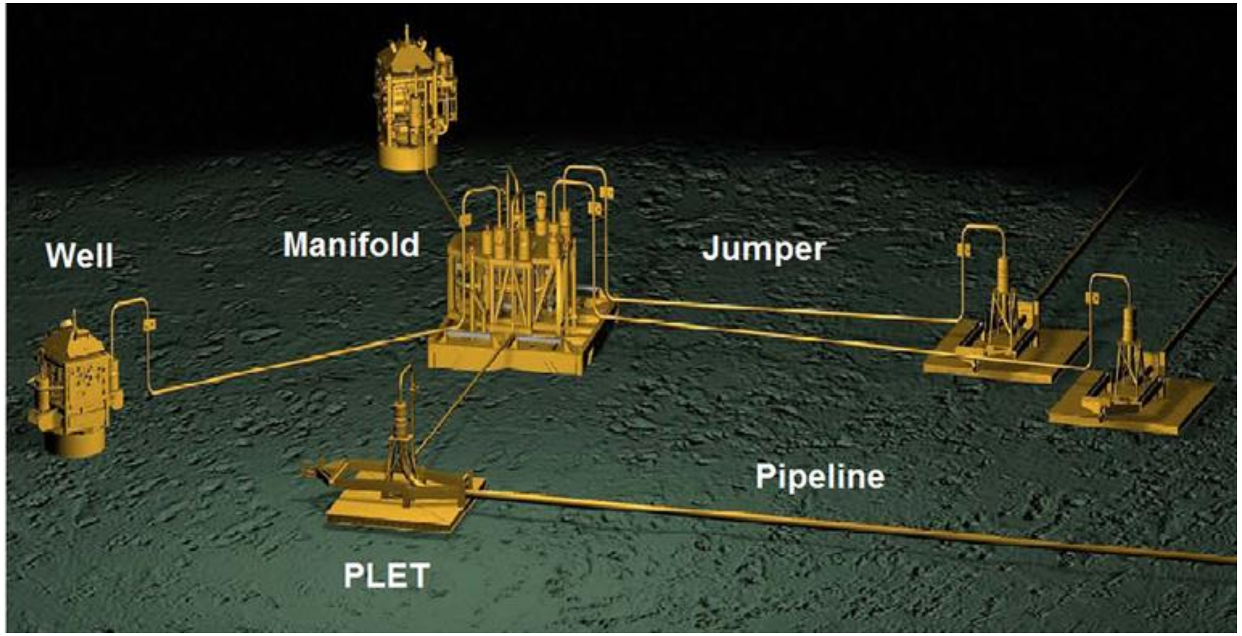
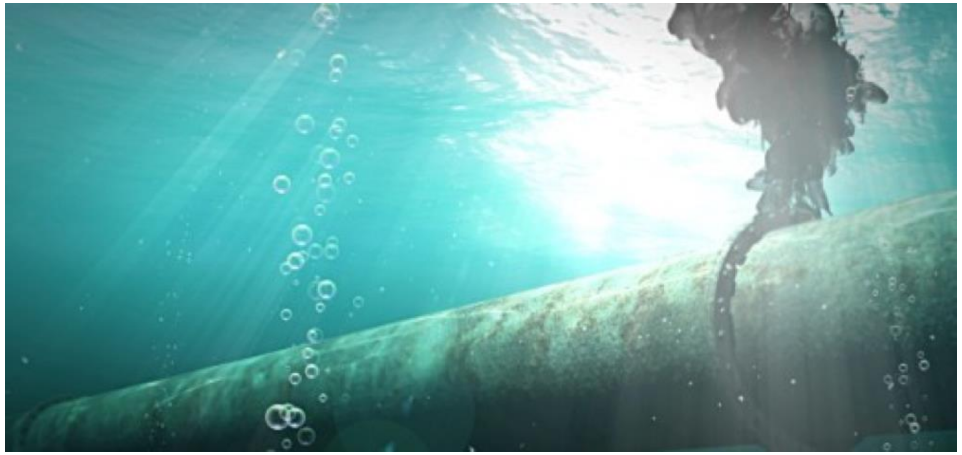
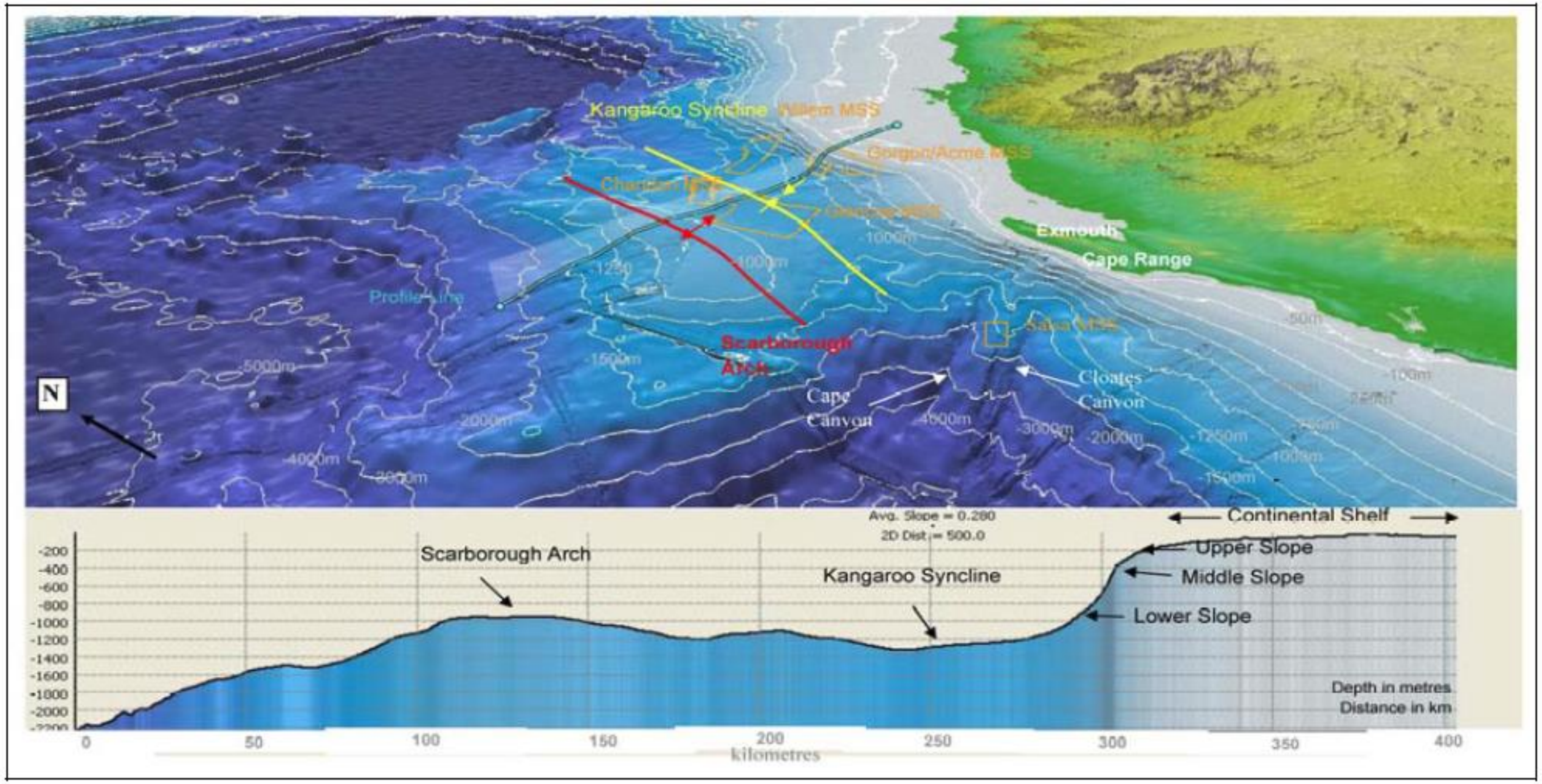
  - Application 2: Offshore Hydrotesting Activities
  - Application 3: Trapped Fluids during Operation

Introduction

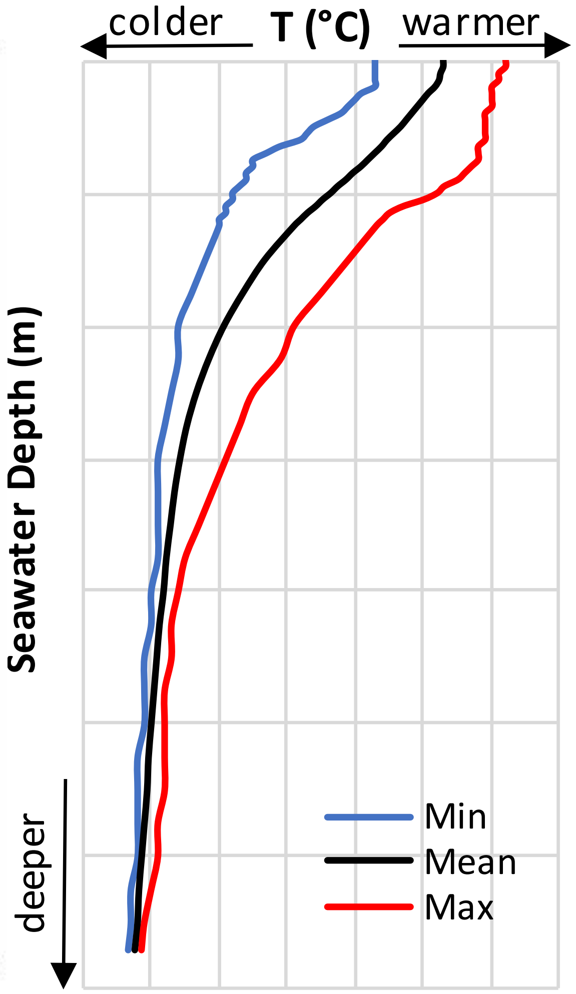




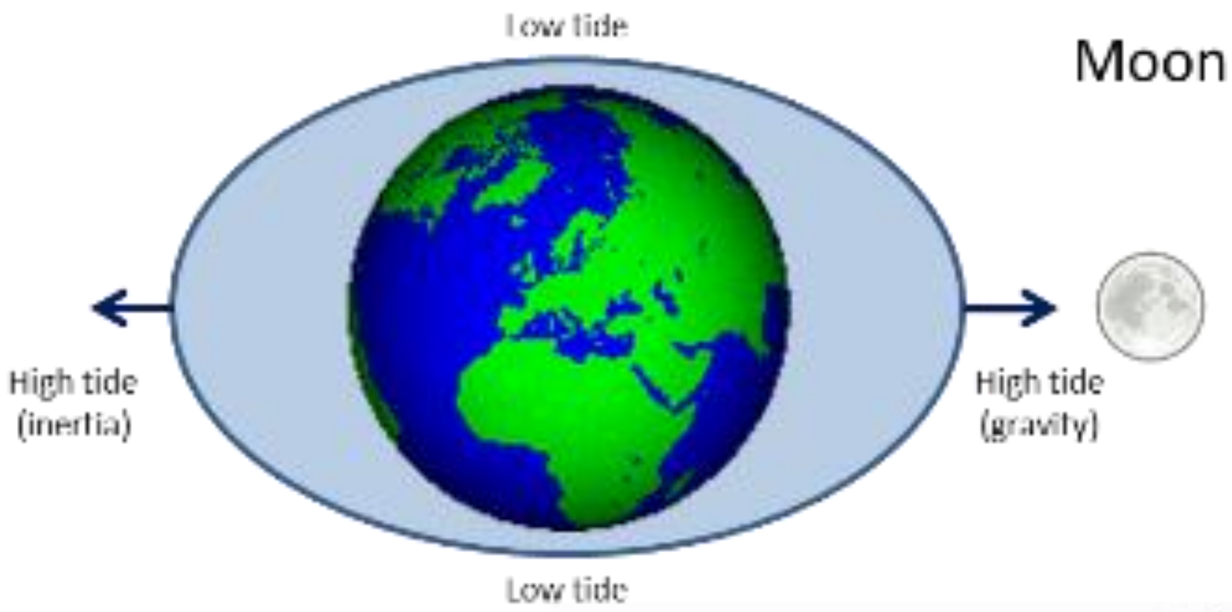
Metocean – Location of Various Fields in WA

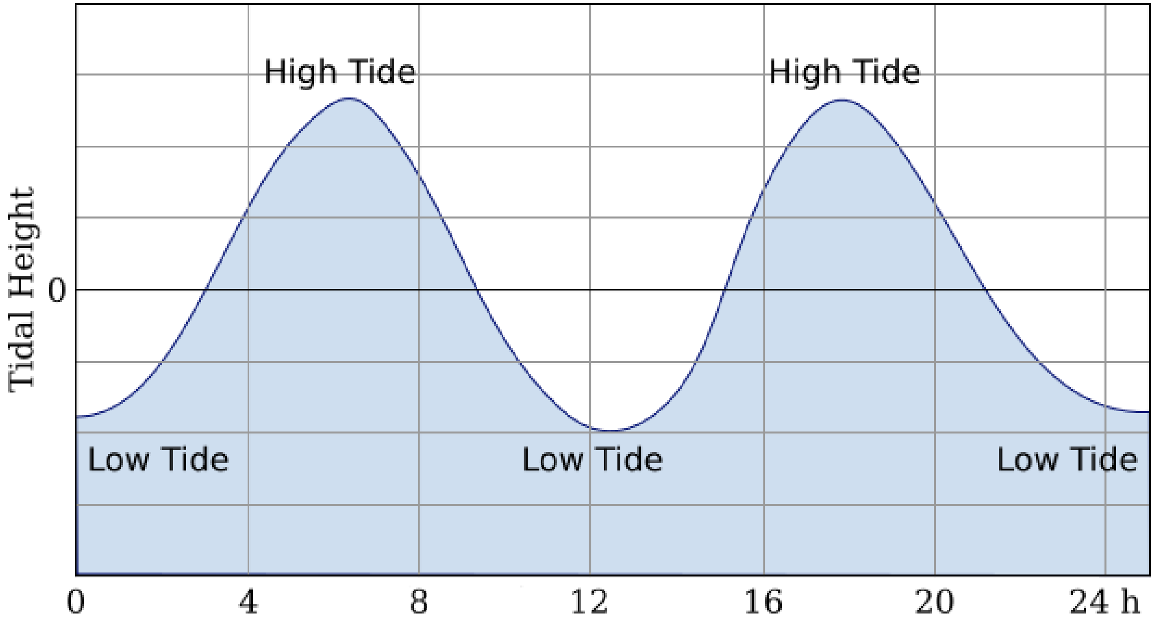


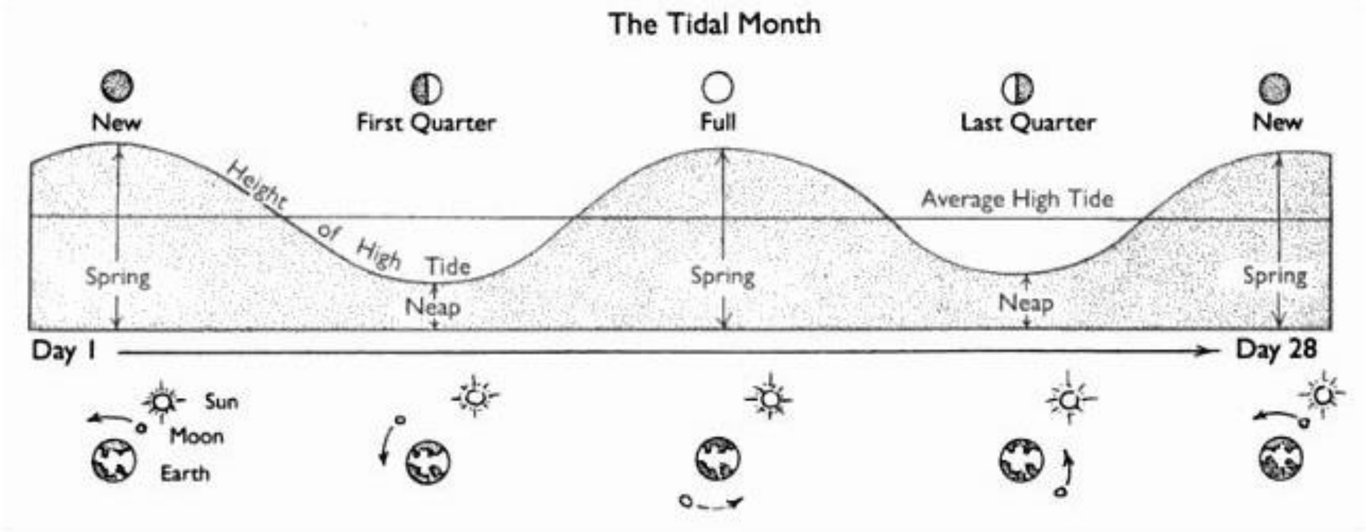
(Ref. Hengesh, J.V., Dirstein, J.K. and Stanley, A.J., "Landslide Geomorphology Along the Exmouth Plateau Continental Margin, North West Shelf, Australia",. Published in the Australian Geomechanics Journal, Special Offshore Edition, December 2013, p.71-92.)



Metocean – Diurnal Tides

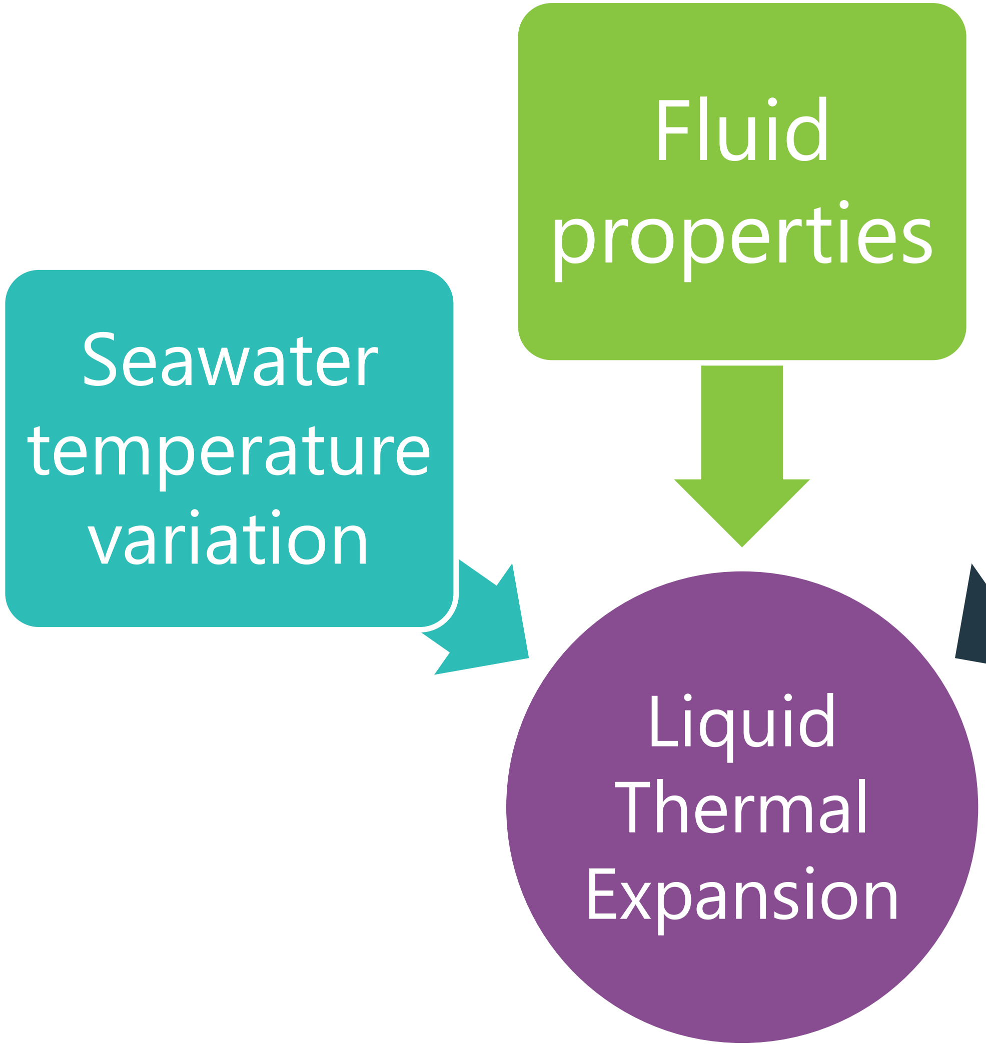






Modelling

Contributing Factors to Liquid Thermal Expansion



Fluid Properties

Liquids	Uses
MEG	• Commonly used as inhibitor to prevent/reduce hydrate formation • Used for hydrotesting / leak testing • Flooding medium after subsea installation
Water	• Used for hydrotesting / leak testing • Flooding medium after subsea installation

Required fluid properties:

α_V is the cubic expansion coefficient of the liquid, expressed in 1/°C (1/°F);

χ is the isothermal compressibility coefficient of the liquid, expressed in 1/kPa (1/psi);

Pipe Properties

Wall Material	Uses
Steel	• Pipeline • Main production system piping • Umbilicals carrying inhibitors and chemicals for subsea injection

Required pipe properties:

α_l is the linear expansion coefficient of metal wall, expressed in 1/°C (1/°F);

d is the internal pipe diameter, expressed in metres (inches);

δ_W is the metal wall thickness, expressed in metres (inches);

E is the modulus of elasticity for the metal wall at T_2, expressed in kPa (psi);

μ is Poisson's ratio, usually 0,3;

Equation for Liquid Thermal Expansion

API 521 methodology used to give the pressure increase in a closed vessel due to thermal expansion

$$p_2 = p_1 + \frac{(T_2 - T_1)(\alpha_v - 3\alpha_l) - \left(\frac{q_{ll} \cdot t}{V}\right)}{\chi + \left(\frac{d}{2E \cdot \delta_w}\right)(2,5 - 2\mu)}$$

where

p_2 is the final gauge pressure of blocked-in, liquid-full equipment, expressed in kPa (psi);

p_1 is the initial gauge pressure of blocked-in, liquid-full equipment, expressed in kPa (psi);

T_2 is the final temperature of blocked-in, liquid full equipment, expressed in °C (°F);

T_1 is the initial temperature of blocked-in, liquid full equipment, expressed in °C (°F);

α_v is the cubic expansion coefficient of the liquid, expressed in 1/°C (1/°F);

α_l is the linear expansion coefficient of metal wall, expressed in 1/°C (1/°F);

χ is the isothermal compressibility coefficient of the liquid, expressed in 1/kPa (1/psi);

d is the internal pipe diameter, expressed in metres (inches);

E is the modulus of elasticity for the metal wall at T_2, expressed in kPa (psi);

δ_w is the metal wall thickness, expressed in metres (inches);

μ is Poisson's ratio, usually 0,3;

q_{ll} is the liquid leakage rate across the block valve seat (usually taken as 0), expressed in m^3/s (in^3/s);

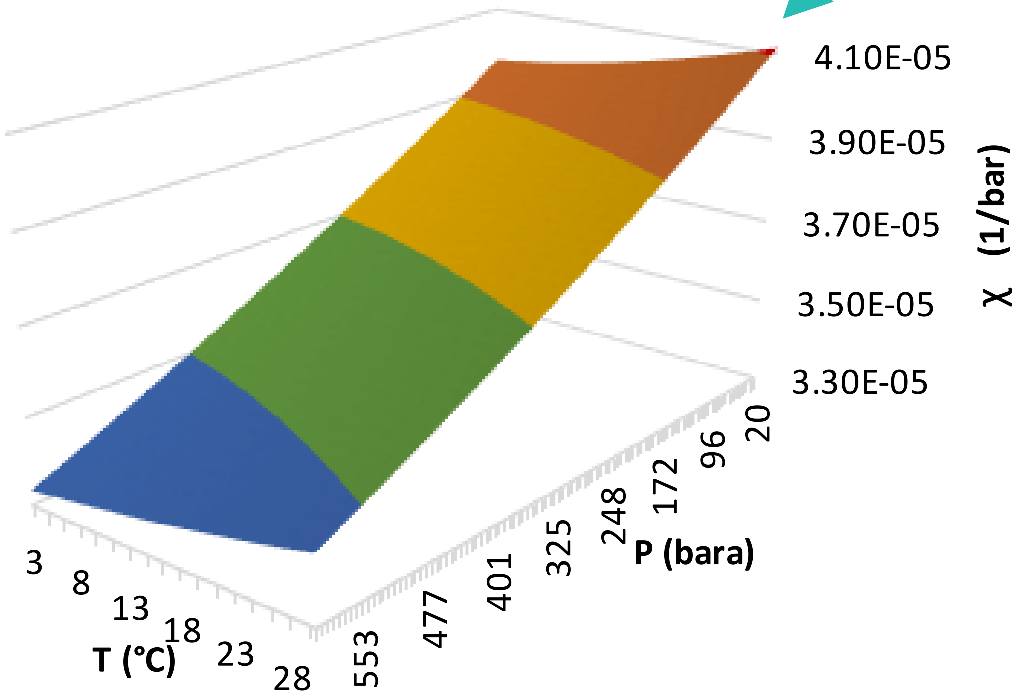
t is the elapsed time for leakage, expressed in seconds;

V is the pipe volume, expressed in cubic metres (cubic inches).

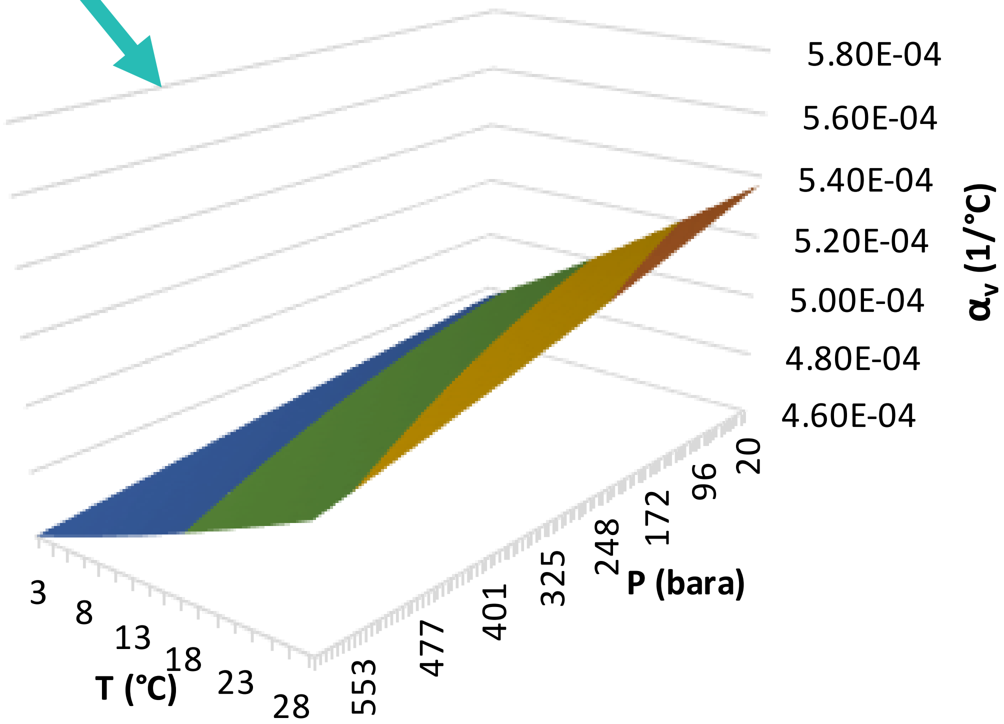
Equation for Liquid Thermal Expansion

$$p_2 = p_1 + \frac{(T_2 - T_1)(\alpha_v - 3\alpha_l) - \left(\frac{q_l t}{V}\right)}{\chi + \left(\frac{d}{2E \cdot \delta_w}\right)(2{,}5 - 2\mu)}$$

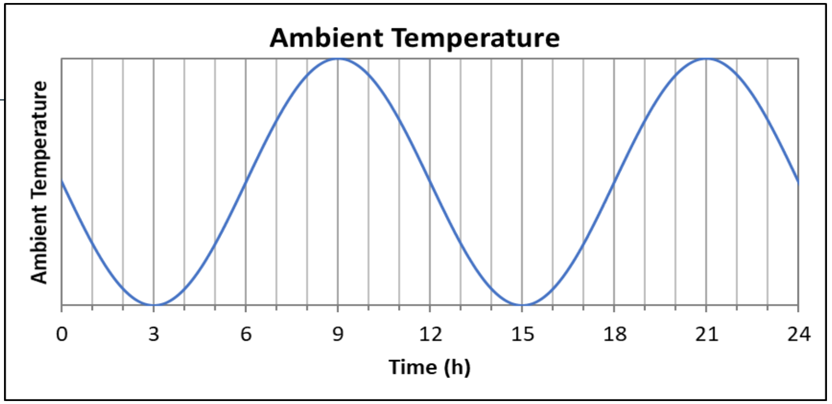
Fluid Compressibility:

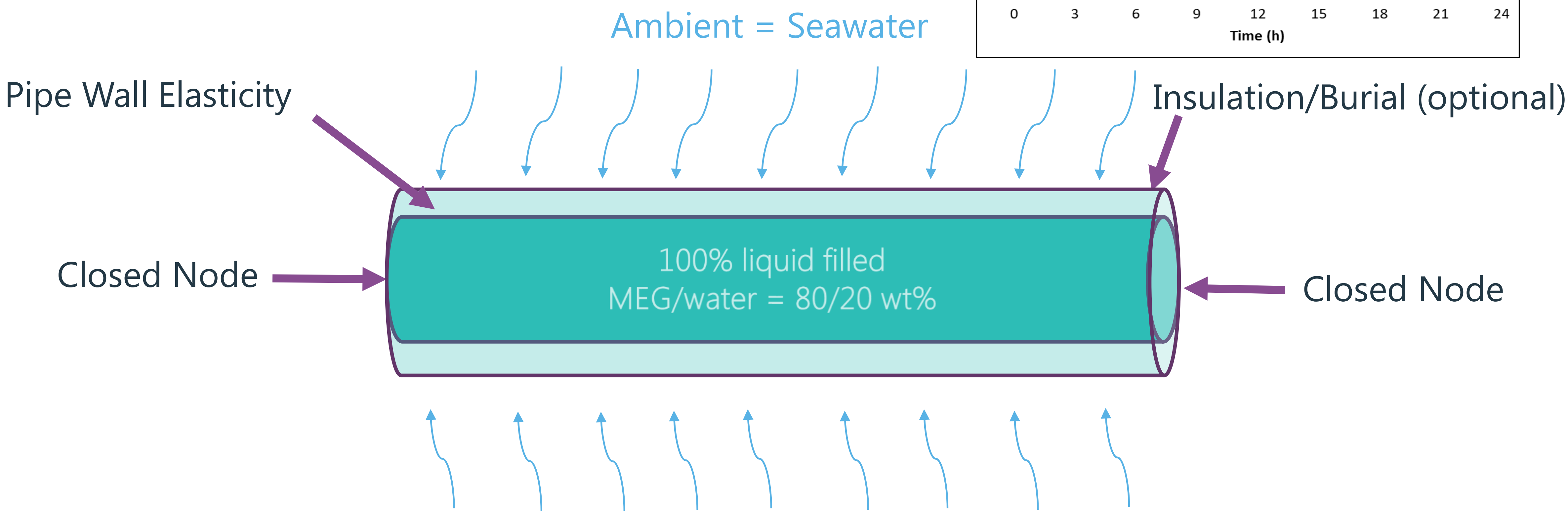


Fluid Thermal Expansivity:



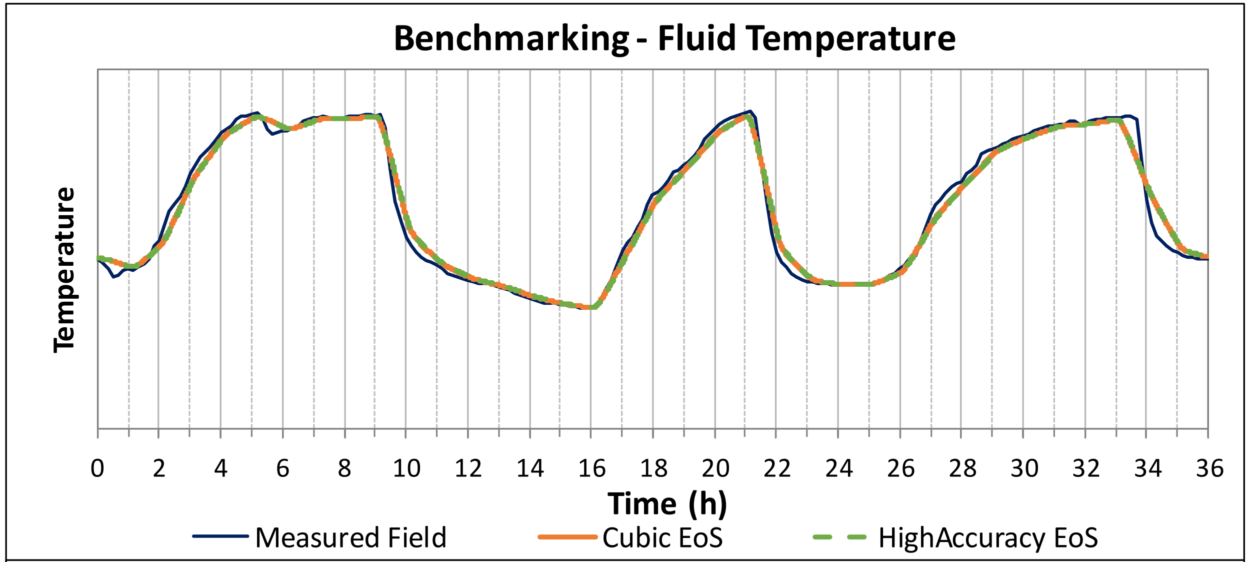
Model Schematic

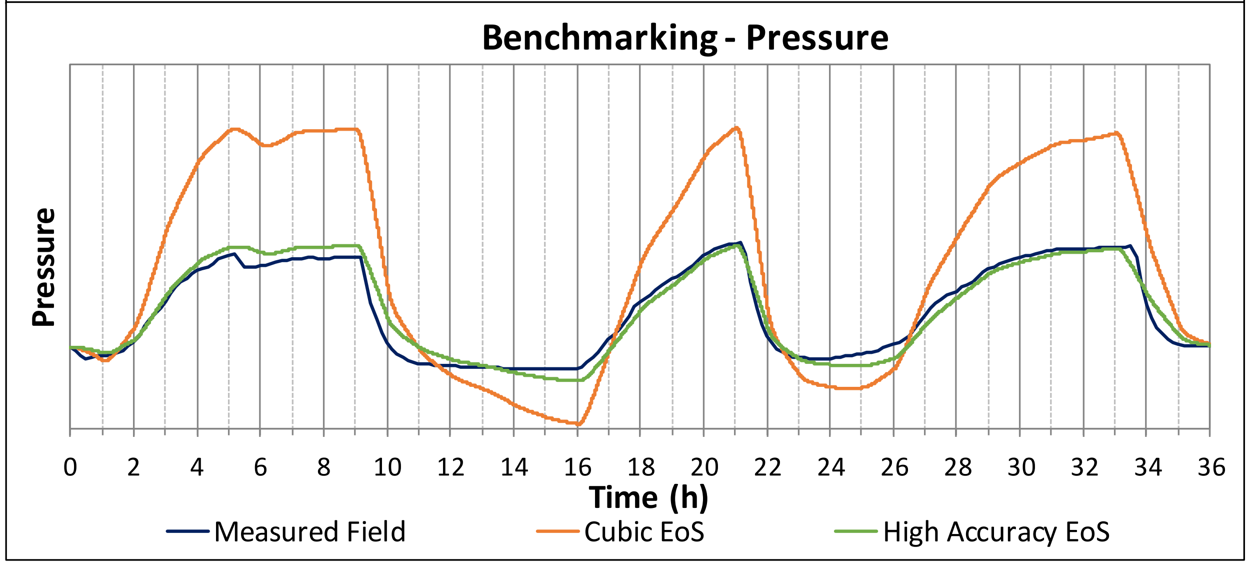




Benchmarking (Field Data vs Cubic EoS vs High Accuracy EoS)

	ΔP / ΔT (bar/°C)
Measured Field Data	9.7 – 11.1
Out of Box Standard Tools (e.g. Cubic EoS)	~22 (CPA) ~21 (PR78) ~16 (RKSA)
High Accuracy EoS	10.6 (CSMA)





Parameters

Sensitive

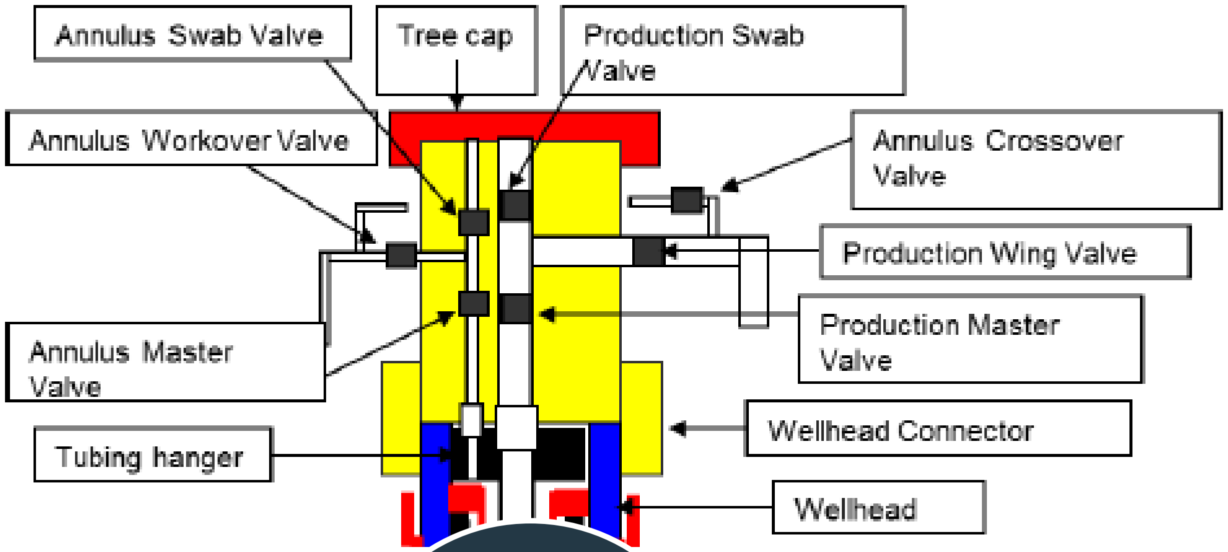
- Change in Fluid Temperature (ΔT)
- Fluid Thermal Expansivity (α_V)
- Fluid Compressibility (γ)
- Insulation Thickness

Not Sensitive

- Wall Elasticity (E)
- Diameter to Wall Thickness Ratio (D/t)
- Wall Coefficient of Expansion (α_l)

Applications and Mitigation Measures

Application 1 – Subsea Tree Cavity



Challenge:

– Large ΔT experienced from hot production fluids heating up the tree cavity

Approach:

CFD (complex geometries) + Accurate fluid properties = Pressure increase due to thermal expansion

Mitigation:

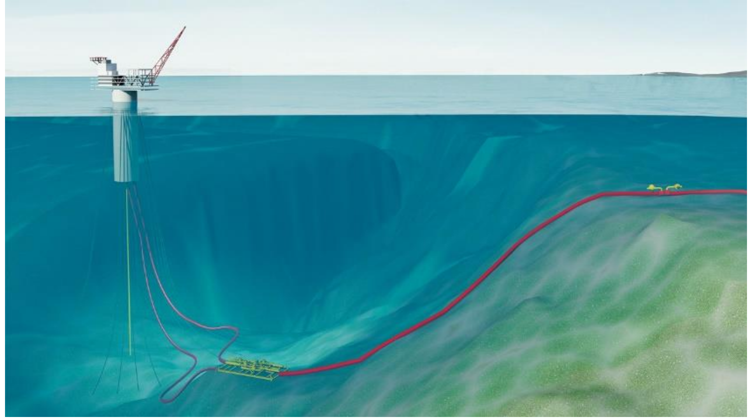
– **In design:** Account for liquid thermal expansion in design of subsea tree cavity. Remove actuated valves where not required.

– **In operation:** Avoid trapped liquid situations such as dual isolation.

Application 2 – Offshore Hydrotesting Activities

Requirement:

- Hydrotesting requires testing the system at high pressures for extended periods (e.g. 24 h at a holding pressure above design).



Challenge:

- Stabilizing pressure with varying seawater temperatures.
- Pressures above design, approaching burst limit.

Approach:

Seawater temperature variations + Accurate fluid properties = Pressure increase due to thermal expansion

Mitigation:

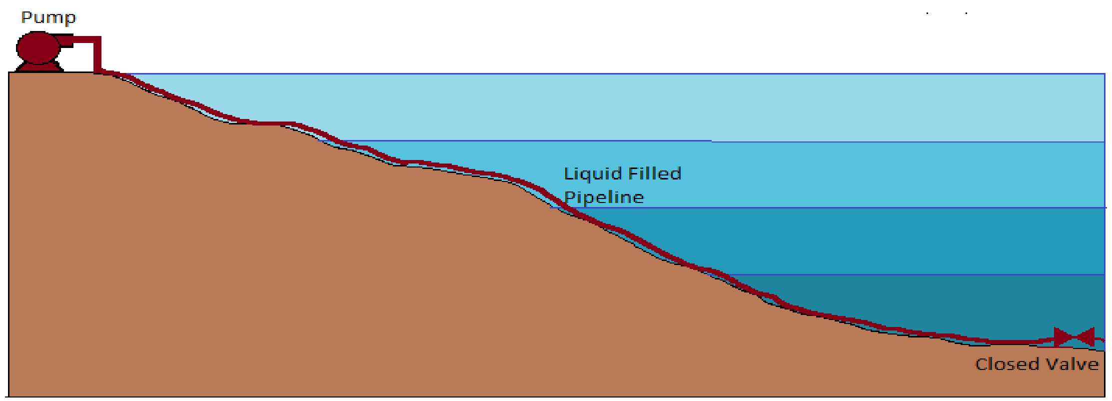
- **In design:** Account for liquid thermal expansion in design of subsea systems (e.g. pipelines, structures, valves).
- **In operation:** Address through bespoke procedures.

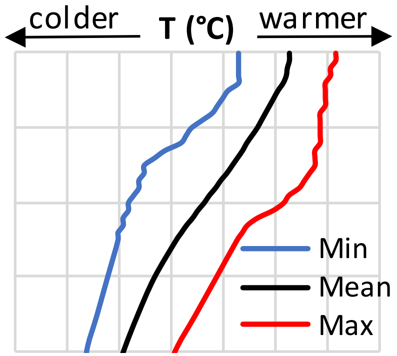
Application 3 – Trapped Liquids during Operation

Challenge:

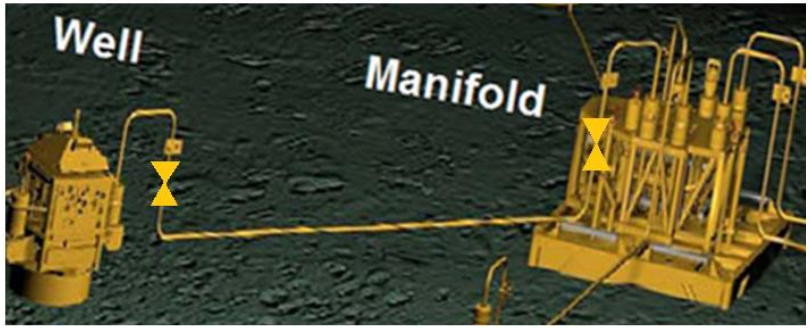
– Unplanned shutdown of pumps / valves
– Seawater temperature swings → pressure increases → possibly exceed design pressure

(a)





(b)



Approach:

– As per Application 2.

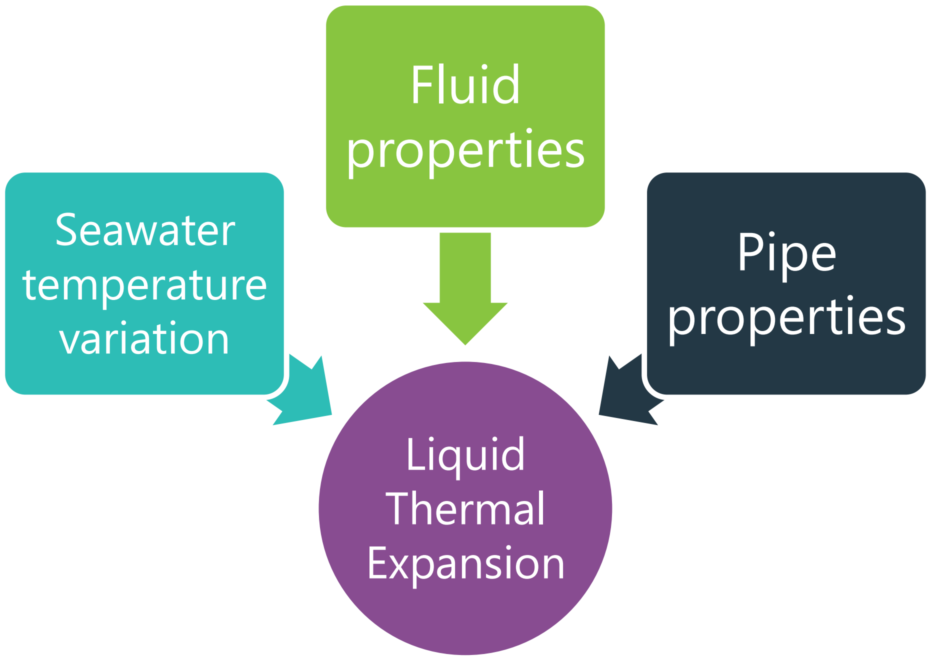
Mitigation:

– **In operation:** Selecting an appropriate pump discharge PSV set point. Pressure / temperature monitoring and high alarms.

Key Take-Aways

- Liquid thermal expansion can lead to increase in pressures possible above design.

- An approach was developed to assess extent of liquid thermal expansion & possible mitigations.



- Challenge in varying seawater temperature / nearby hot production fluids resolved by:
  – Appropriate modelling techniques & accurate input data
  – Introducing mitigations

wood.

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