Hydrate Control – Still a Major Flow Assurance Challenge

By Xiaoyun Li, Specialist at Statoil R&T FA

Flow Assurance Lecture at NTNU, 25^{th} January 2016

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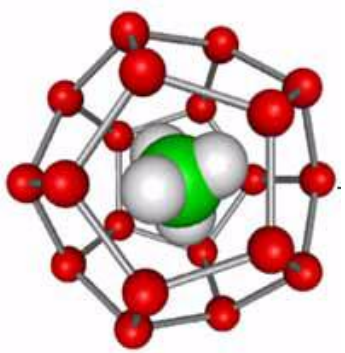
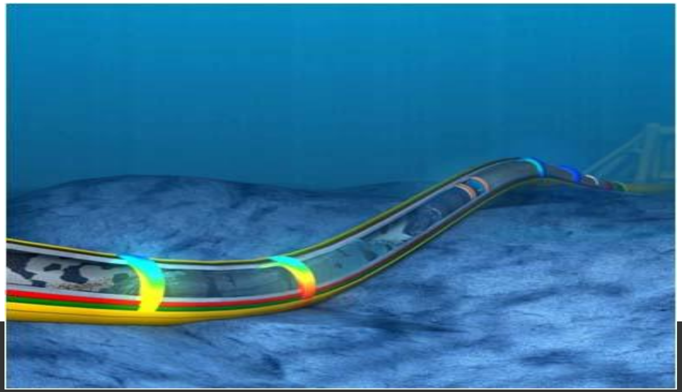


- Introduction on gas hydrates
- Hydrates as a flow assurance challenge
- Traditional hydrate control methods
- Safe operations in hydrate domain
- Hydrate plug detection and remediation
- Hydrate control in Statoil



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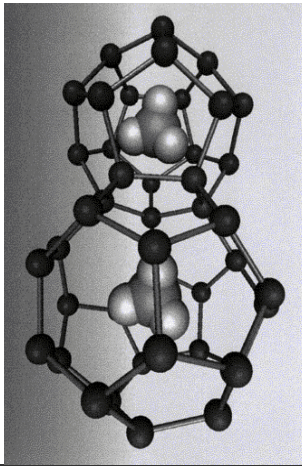
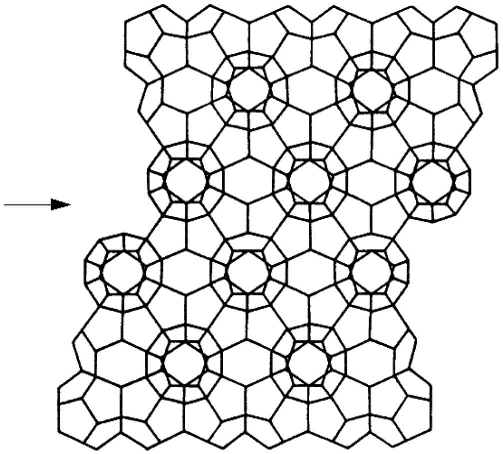
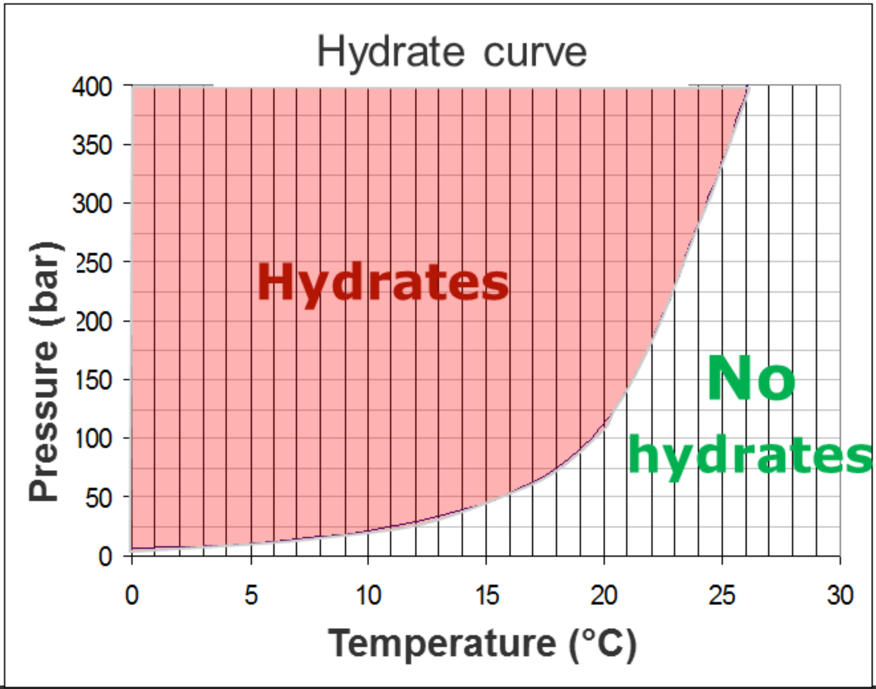
What are gas hydrates

- ✓ ***Free water***
- ✓ ***Small gas molecules***
  - ➢ ***$C1, C2, C3, I\text{-}C4, CO_2, H_2S, N_2$***
- ✓ ***High pressure***
- ✓ ***Low temperature***







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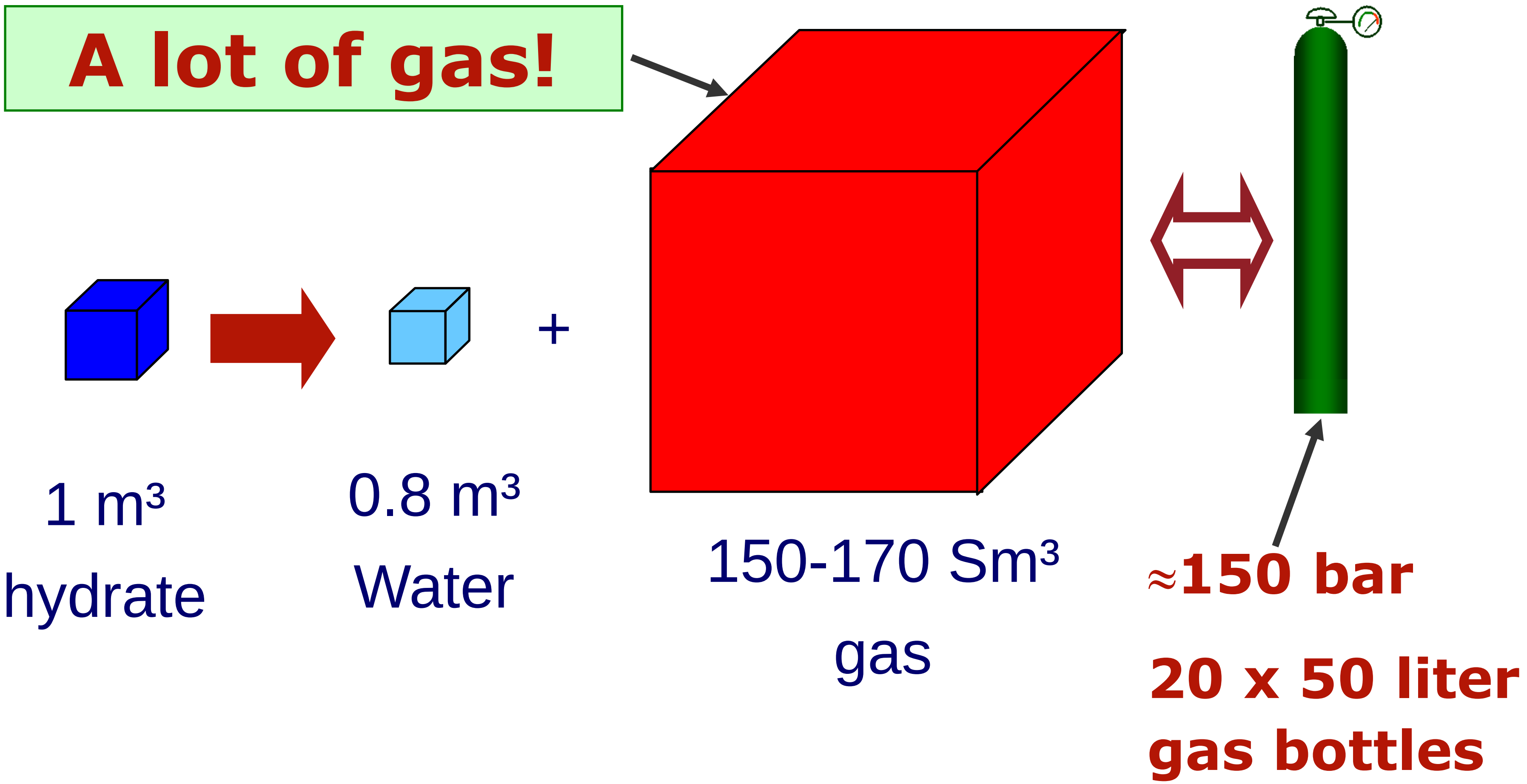
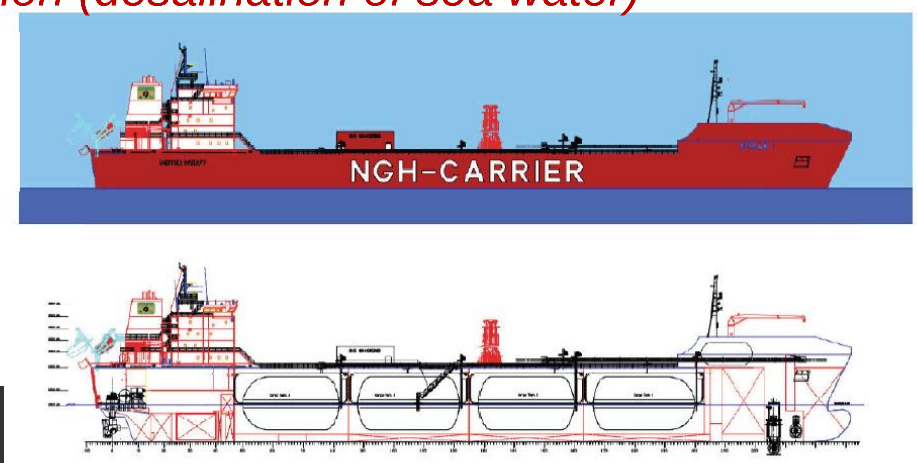
Gas content in gas hydrates

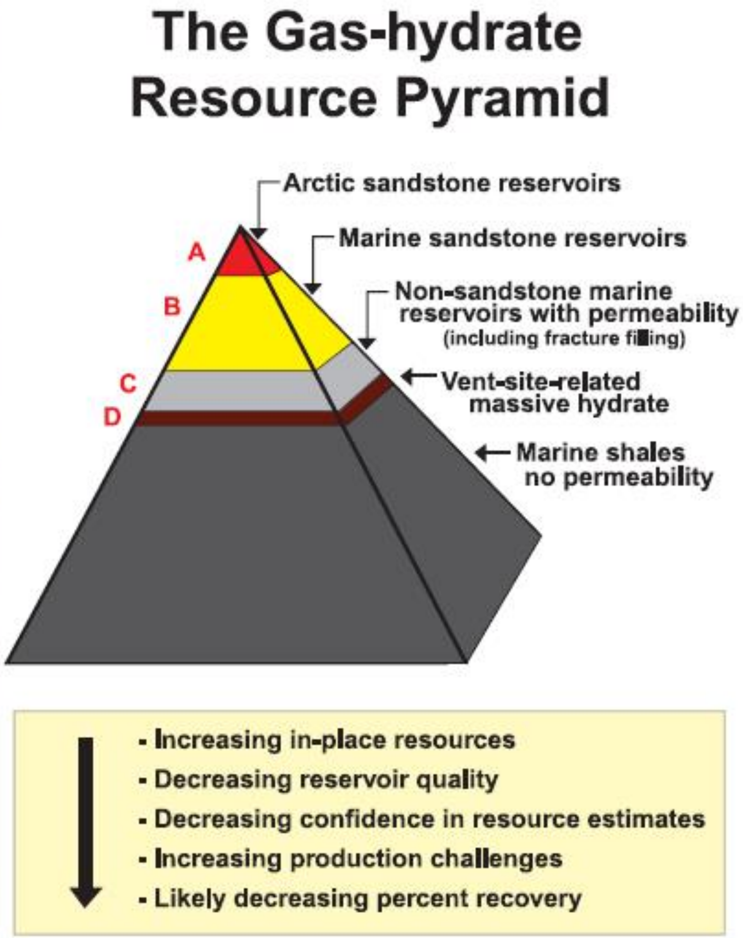


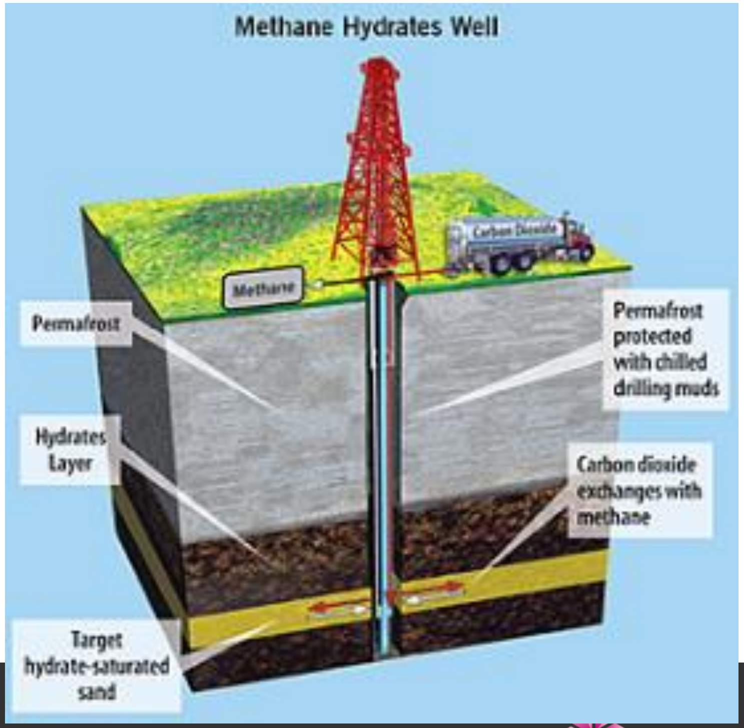
Gas hydrates – both a problem & an opportunity

- ***A major FA challenge/issue for gas/oil industry***
  - *High field development and operational costs*
- ***Gas hydrate in nature/sediments***
  - *A new energy resource with huge potential - several field tests*
  - *Potential geo-hazard due to thermal instability in hydrate bearing sediments*
- ***As a carrier medium for natural gas transport/storage***
- ***Many new applications of gas hydrates, e.g.:***
  - Flue/exhaust gas *separation (CO_2 capture) and CO_2 storage*
  - *Water purification (desalination of sea water)*



Natural occurring gas hydrates

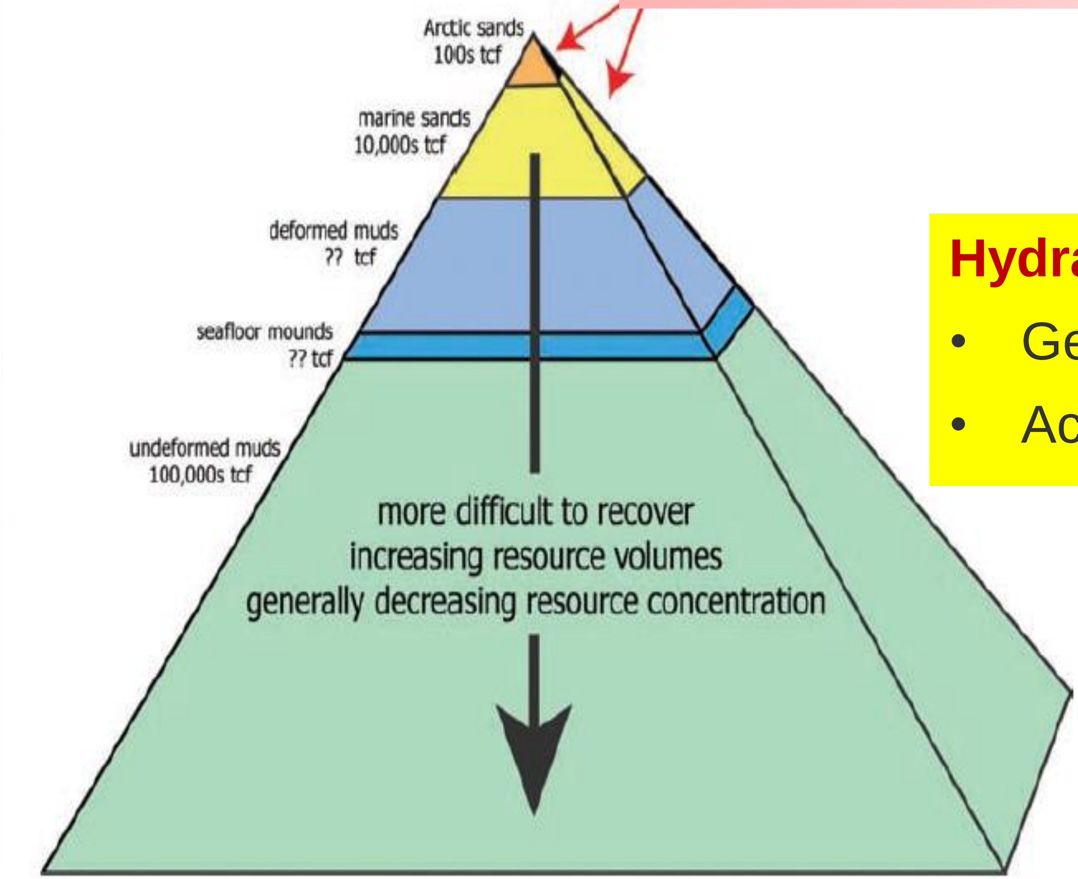




Source : Johnson 2011, Collett 2009

Natural occurring gas hydrates

As energy resources - commercially recoverable?

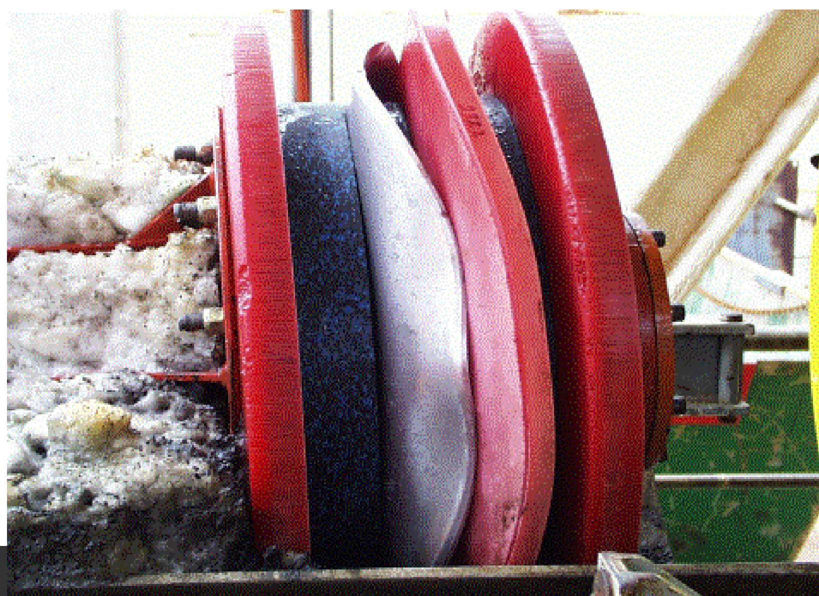


Hydrate melting gives concerns:

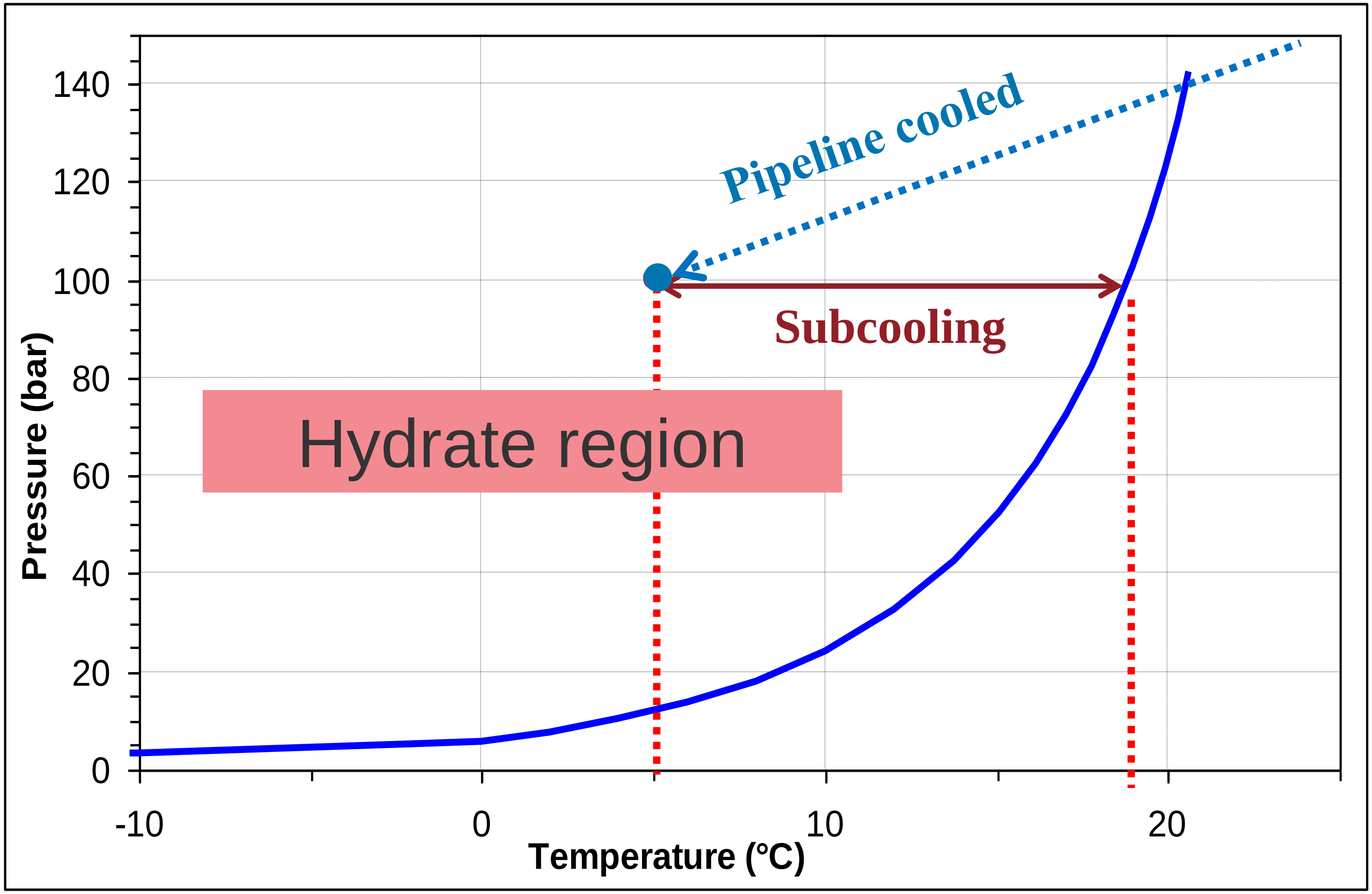
- Geo-hazard like land-slide
- Accelerating global warming

Source : Johnson 2011, Collett 2009

Gas hydrates as a flow assurance challenge



Hydrate curve and subcooling



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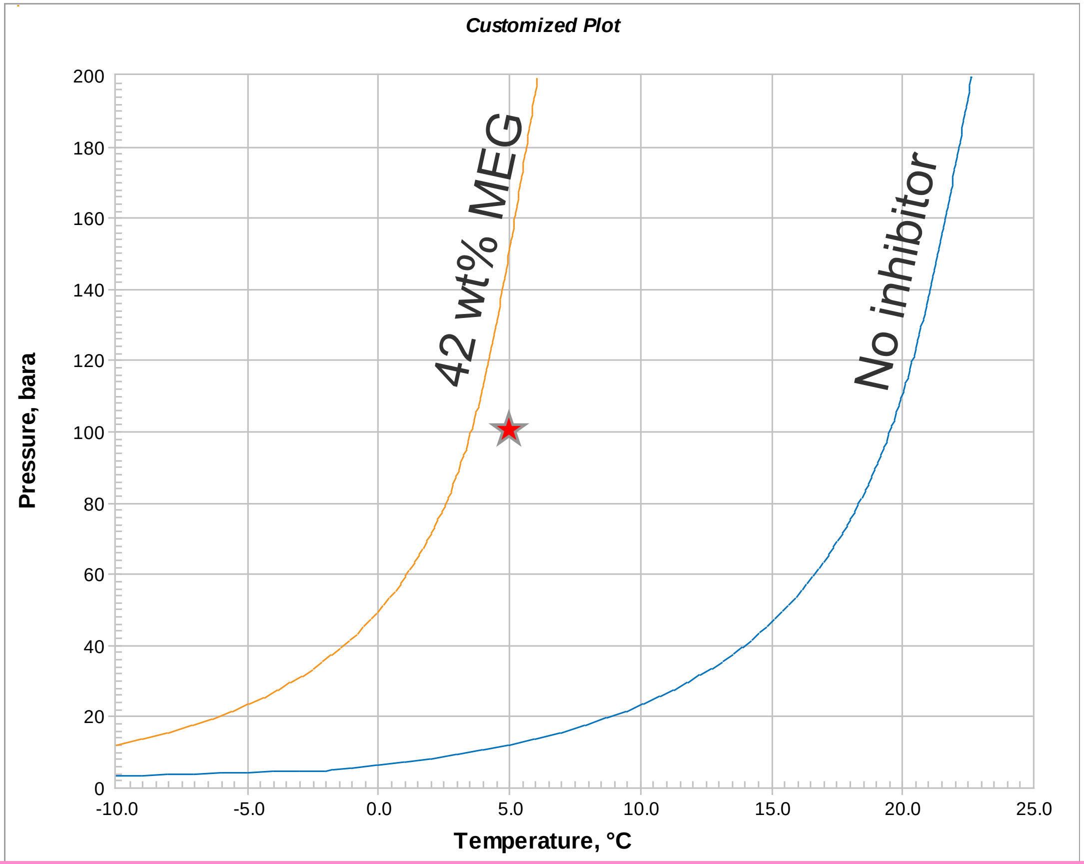
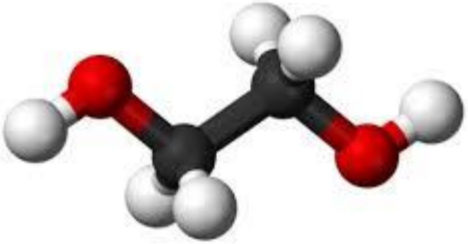
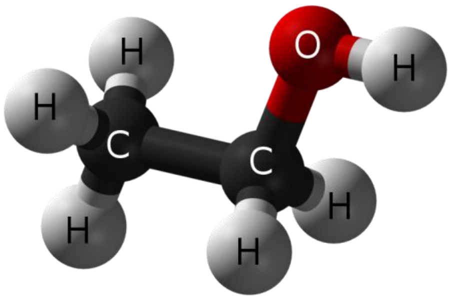
Hydrate avoidance: thermodynamic inhibitors



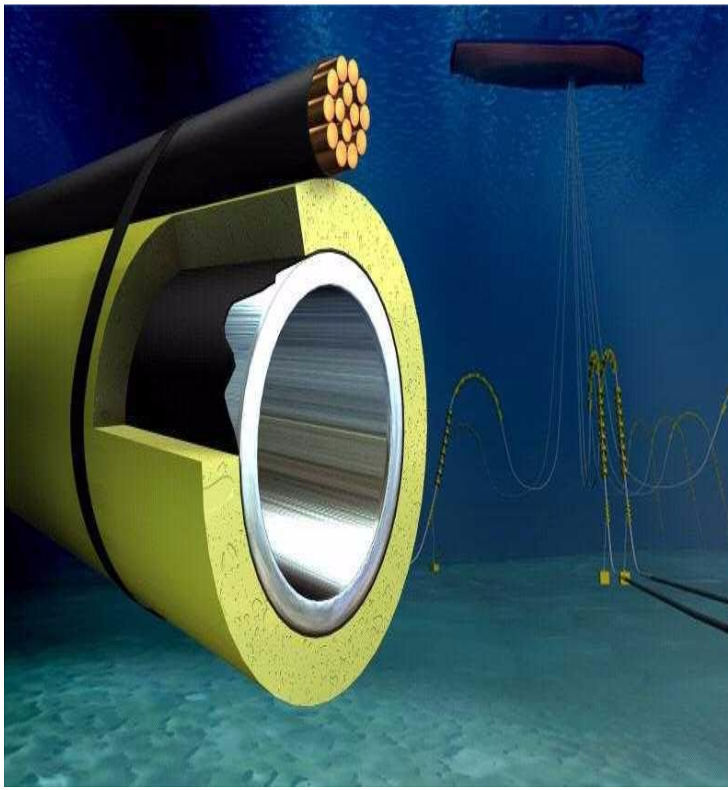




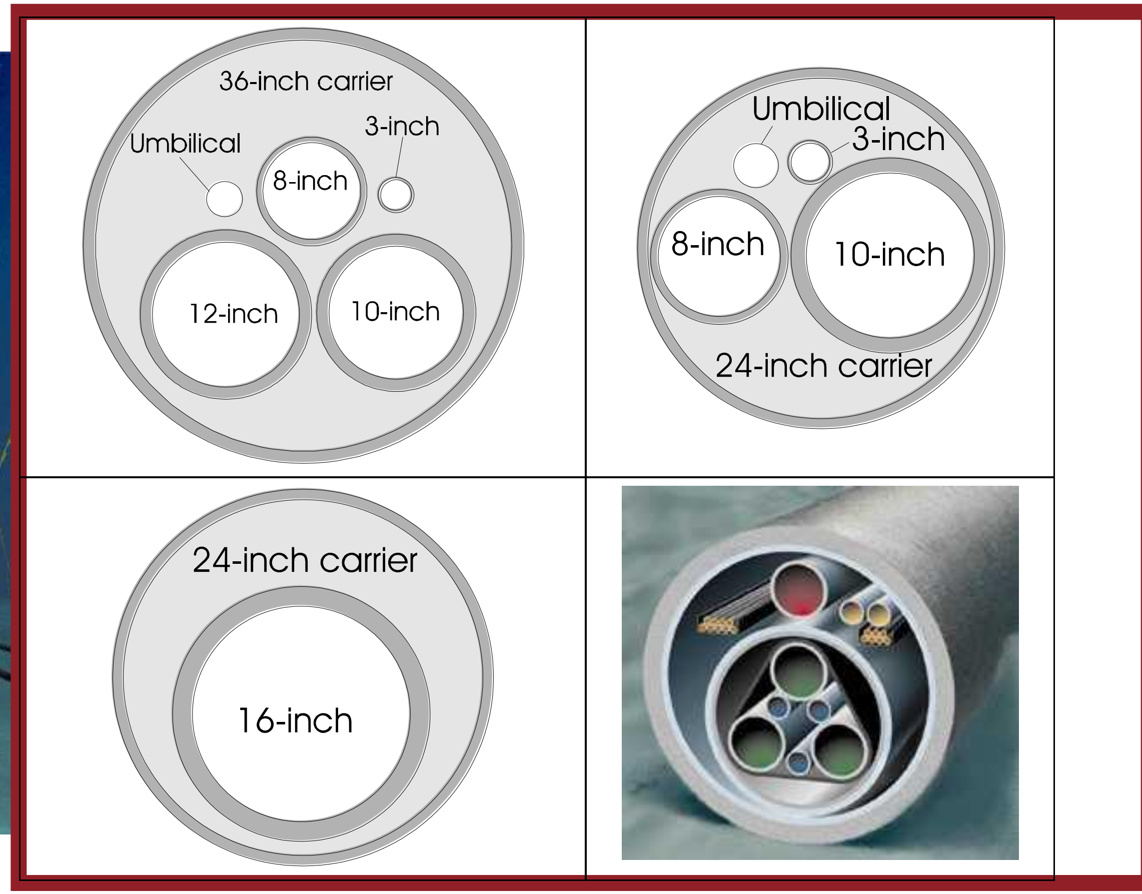
- THI shifts hydrate curve to the left – i.e. lower hydrate equilibrium temperature
- Typical thermodynamic inhibitors: mono-ethylene glycol/MEG, salts, ethanol, methanol
- Typical THI concentrations applied: ~30-60 wt% in water

Heating based hydrate prevention methods

Direct electrical heating (DEH)

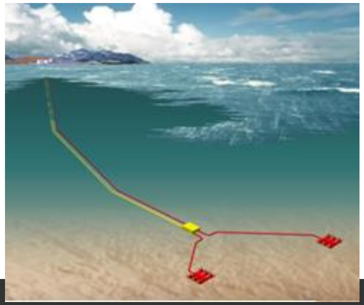


Bundles and Pipe-in-pipe



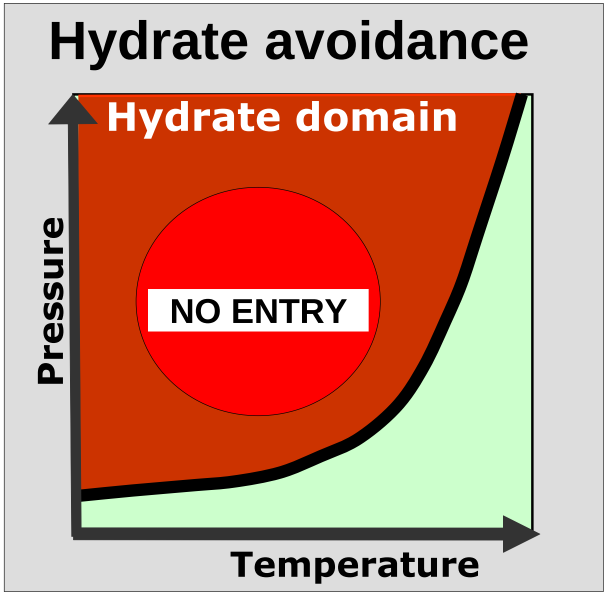
Needs for less conservative hydrate control strategy

- Conventional hydrate control strategy is expensive
  - Based on: inside hydrate domain = hydrate plugging/problem
  - Complete hydrate avoidance
- Constant needs to improve hydrate control strategy:
  - Reduce CAPEX of field development (enabler for certain cases)
  - Reduce chemical consumption and OPEX
  - Simplify procedures
  - Accelerate production

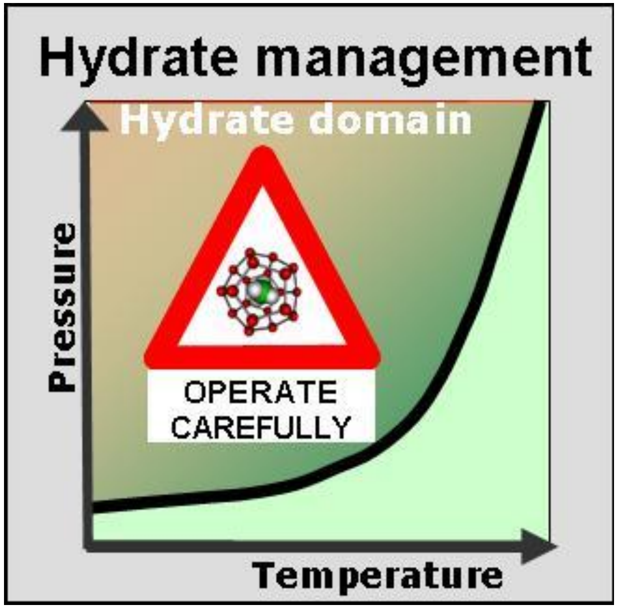


Step change of hydrate control strategy

The old time



The new era of **hydrate management**



Traditional strategy (outside hydrate domain):

- Inhibition by MEG, methanol etc.
- Super insulation or heated pipes
- Depressurization (to below hydrate curve)
- Dead oil circulation, duo pipelines

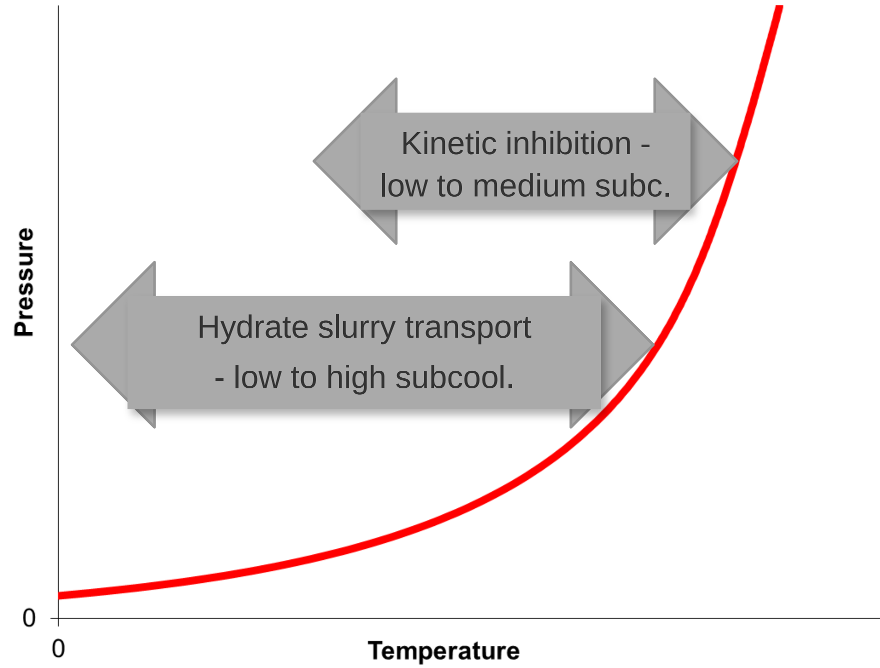
=> Safe but very costly

New strategy (<u>primarily for oil-dominated systems</u>):

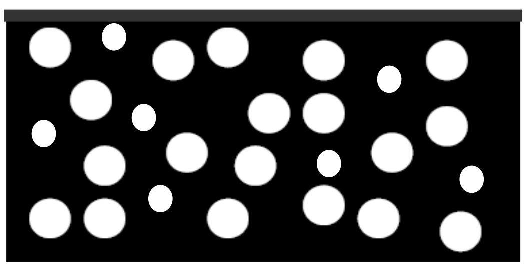
- Allow operation inside hydrate domain based on
  - Hydrate formation kinetics
  - Hydrate transportability (plugging potential)
  - Hydrodynamics, local water content, etc.
- Risk based & tailor made for each application
- Combining the traditional and new technologies

Safe operations in hydrate domain – Main methods

- **Hydrate kinetics – delayed formation**
  - Injection of KHI (kinetic hydrate inhibitor)
  - KHI effect of natural surfactants in crude
  - **No visible hydrates**
  - Have time-limited operation window
  - Function from low to medium subcooling
- **Hydrate slurry transport**
  - Injection of AA (anti-agglomerant)
  - AA effect of natural surfactants in crude
  - Under-inhibition of THI (e.g. MEG, ethanol)
  - **Hydrates as fine slurry particles**
  - More water-cut dependent
  - Function from low to high subcooling
  - Not time-limited



- **Both green KHI & AA have been developed now!**

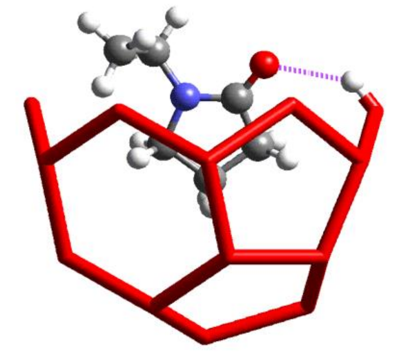


Transportable hydrate slurry

LDHI - Kinetic hydrate inhibitors (KHI)

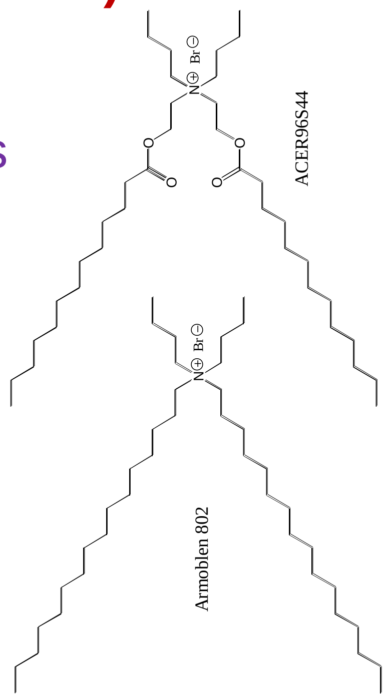
- Normally water soluble polymers
- **Prevent/delay hydrate nucleation and growth for certain time**
  - Water residence time important
  - Normally for short flowlines and shut-ins (one to several days)
  - Best KHIs prevent hydrates at 10-12 °C subcoolings for 1-2 days
  - Can prevent hydrate formation for many days at lower subcoolings
  - Can be combined with MEG to handle higher subcoolings

- Typical dosing range: 0.25 - 5 vol% wrt water
- Generally no visible hydrates in the system
- Work on gas/water and gas/oil/water systems
- No water cut limit



LDHI - Anti-agglomerants (AA)

- Contain head-groups adsorbing on hydrate crystal surfaces
- Contain oil-soluble tails dragging hydrate particles into oil phase
- **Form hydrate-in-oil dispersions (transportable slurry particles)**
  - Best AAs can work at 15-17°C subcoolings
  - Can be combined with MEG to handle higher subcoolings
  - Normally need an oil phase to work properly
  - Work normally up to 40% water-cut



- Typical dosing range: 0.3 - 3 vol% wrt water
- Performance independent of water residence time
  - Can be used for long shut-ins and long flowlines

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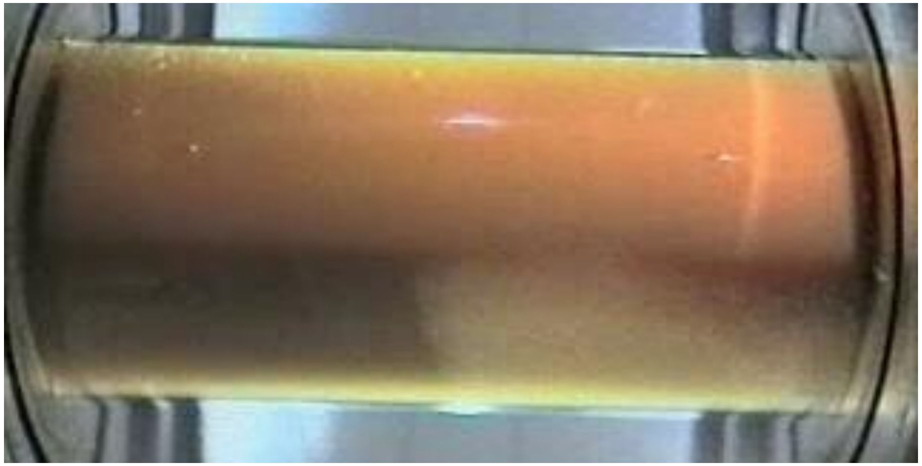
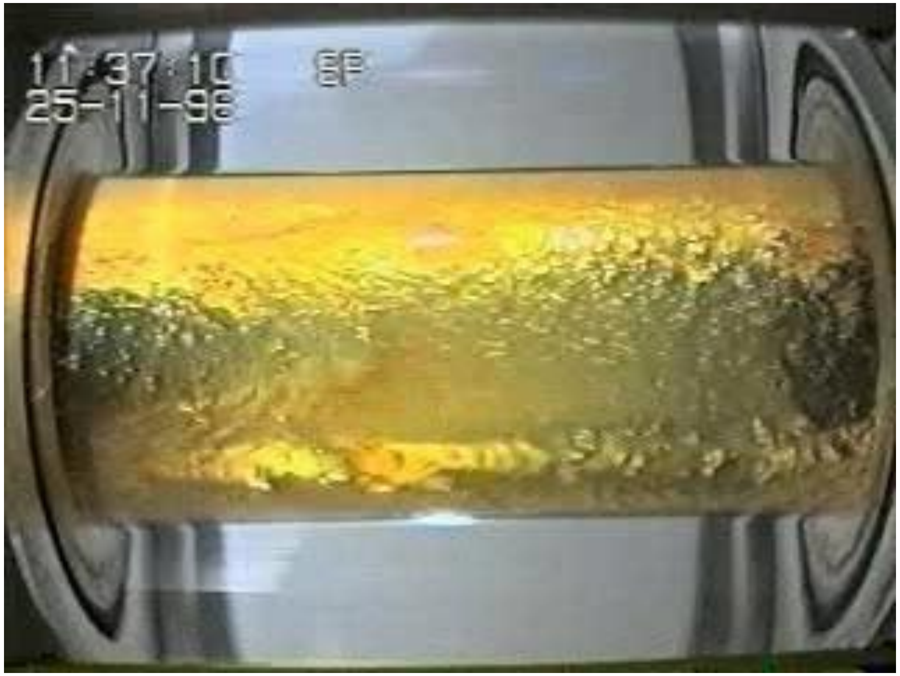
Plugging vs non-plugging hydrates



Plugging hydrates



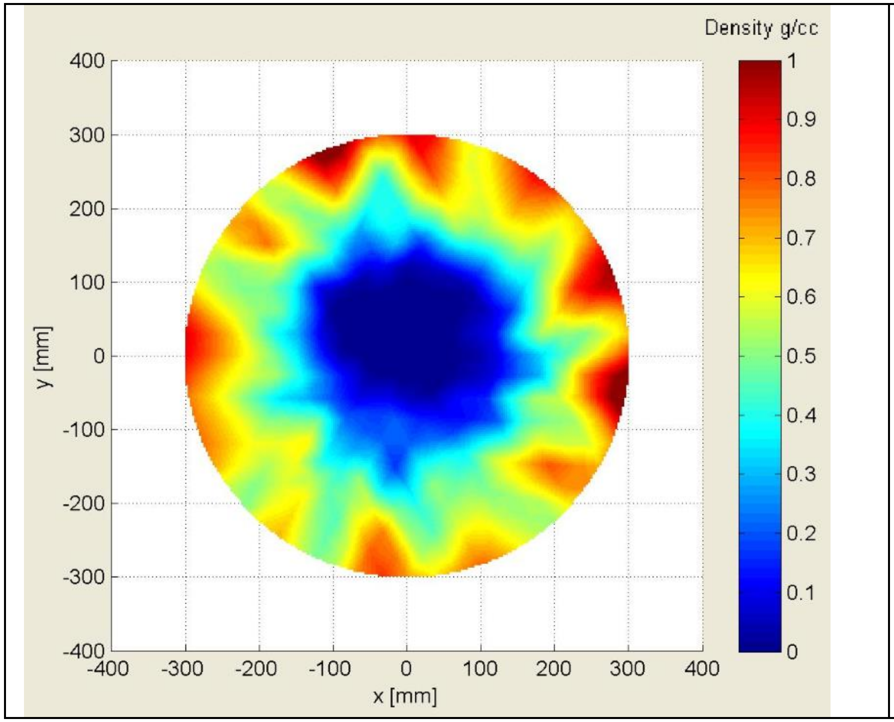
Hydrate plug detection & remediation

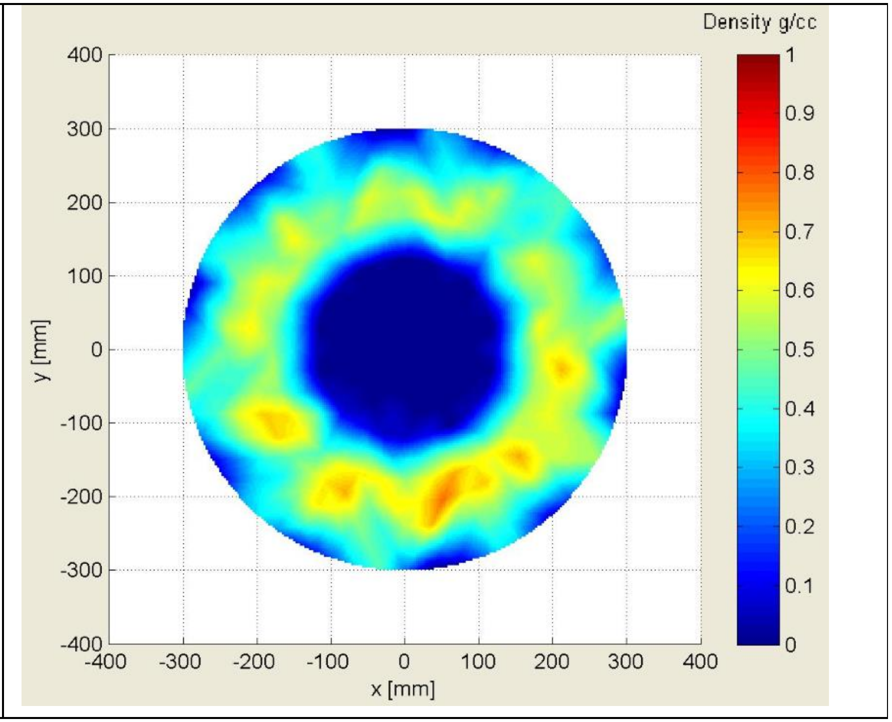
Important issues:

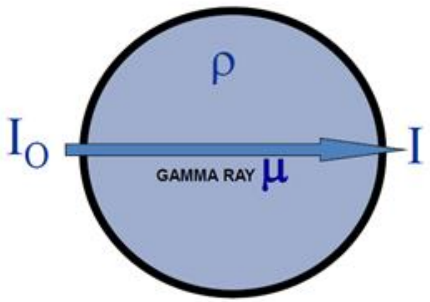
- Reliable plug detection/localization methods
- Plug remediation efficiency
- Safety aspect

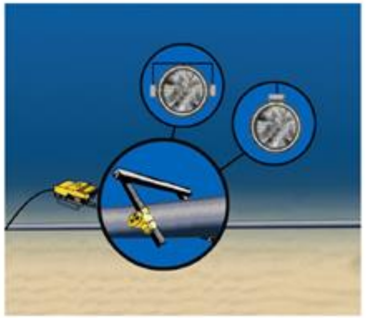
Applicability and efficiency of remediation methods depend on plug location!

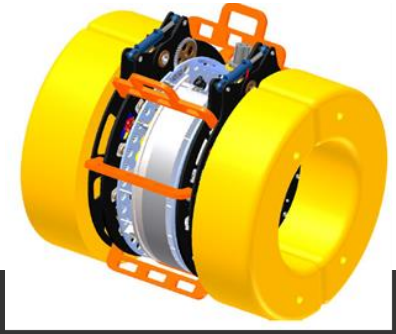
3D γ-ray measurements showing even hydrate depositions at the pipe wall











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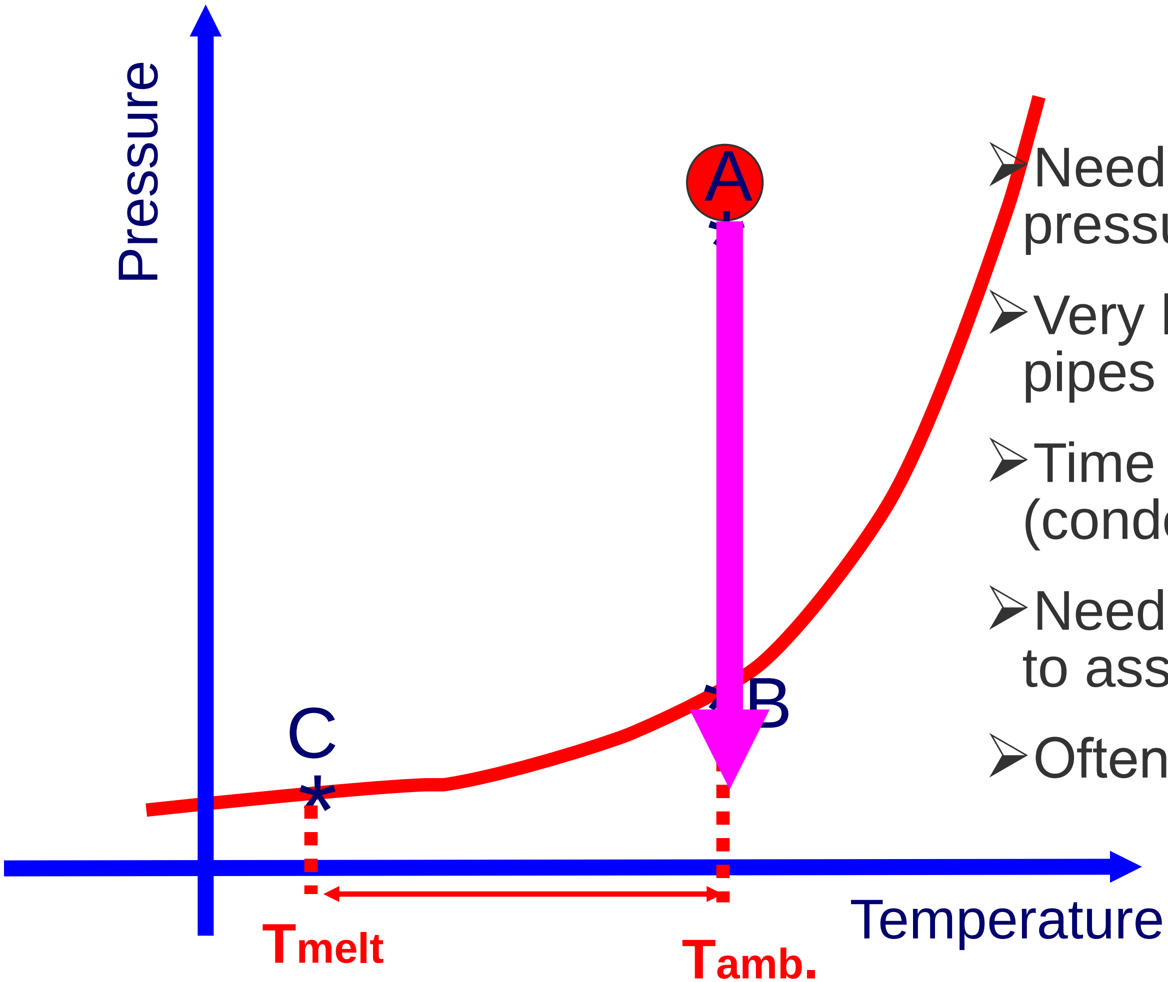
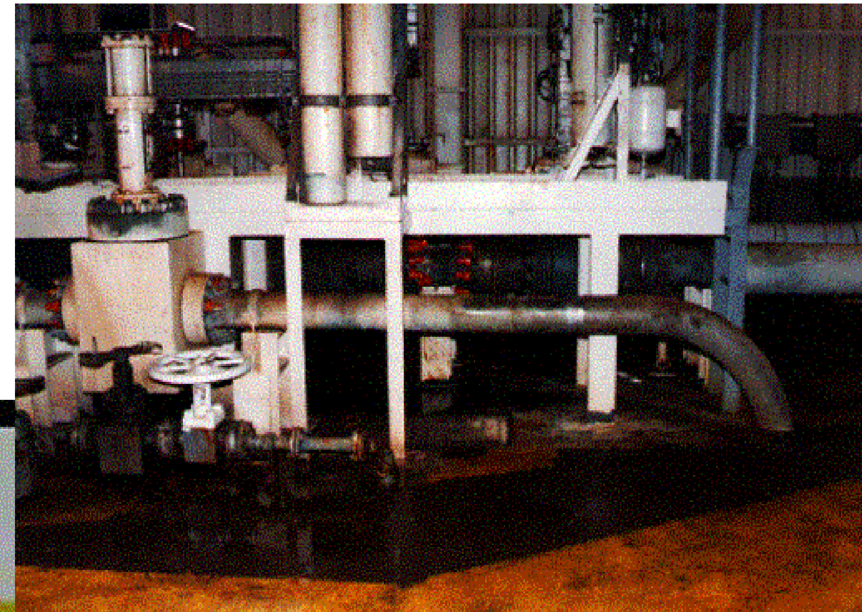
Plug melting by depressurization

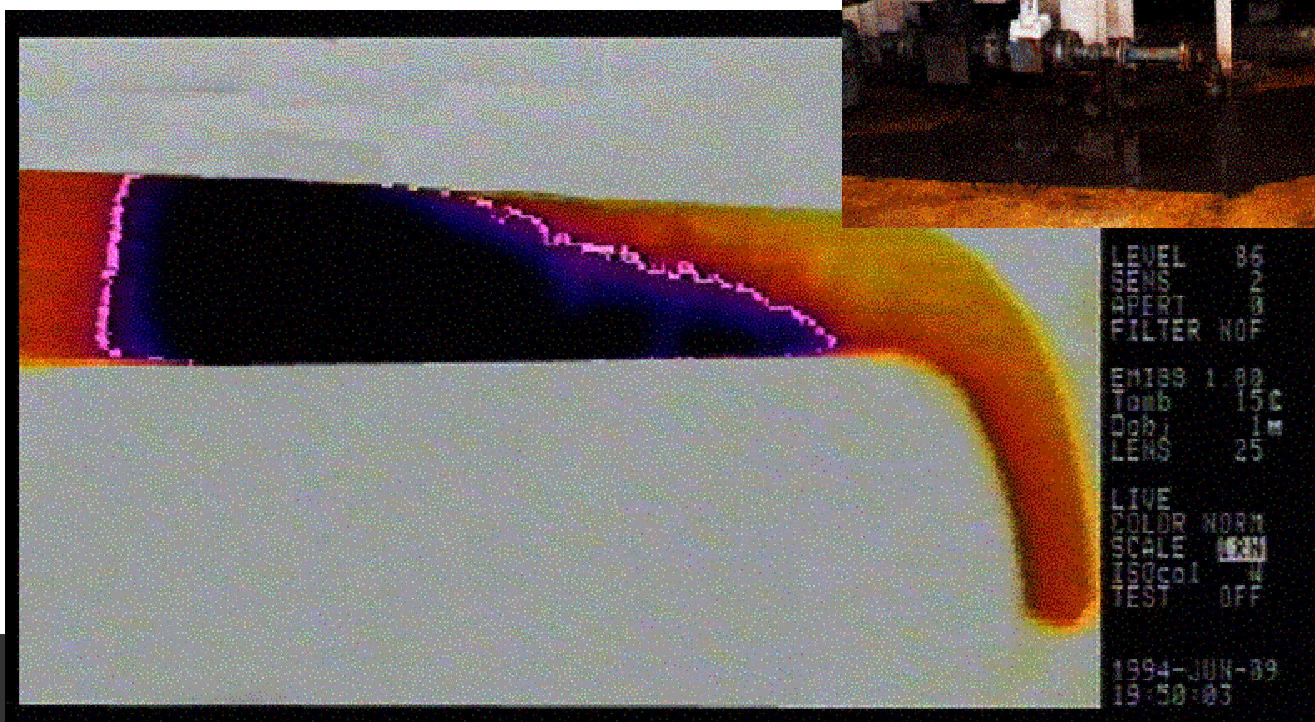


- Need to remove hydrostatic pressure at deep water
- Very low efficiency for insulated pipes
- Time consuming for gas (condensate) lines
- Need to maintain low pressure to assure melting
- Often “only” applicable method

Plug seen through a thermo-camera

– during depressurization





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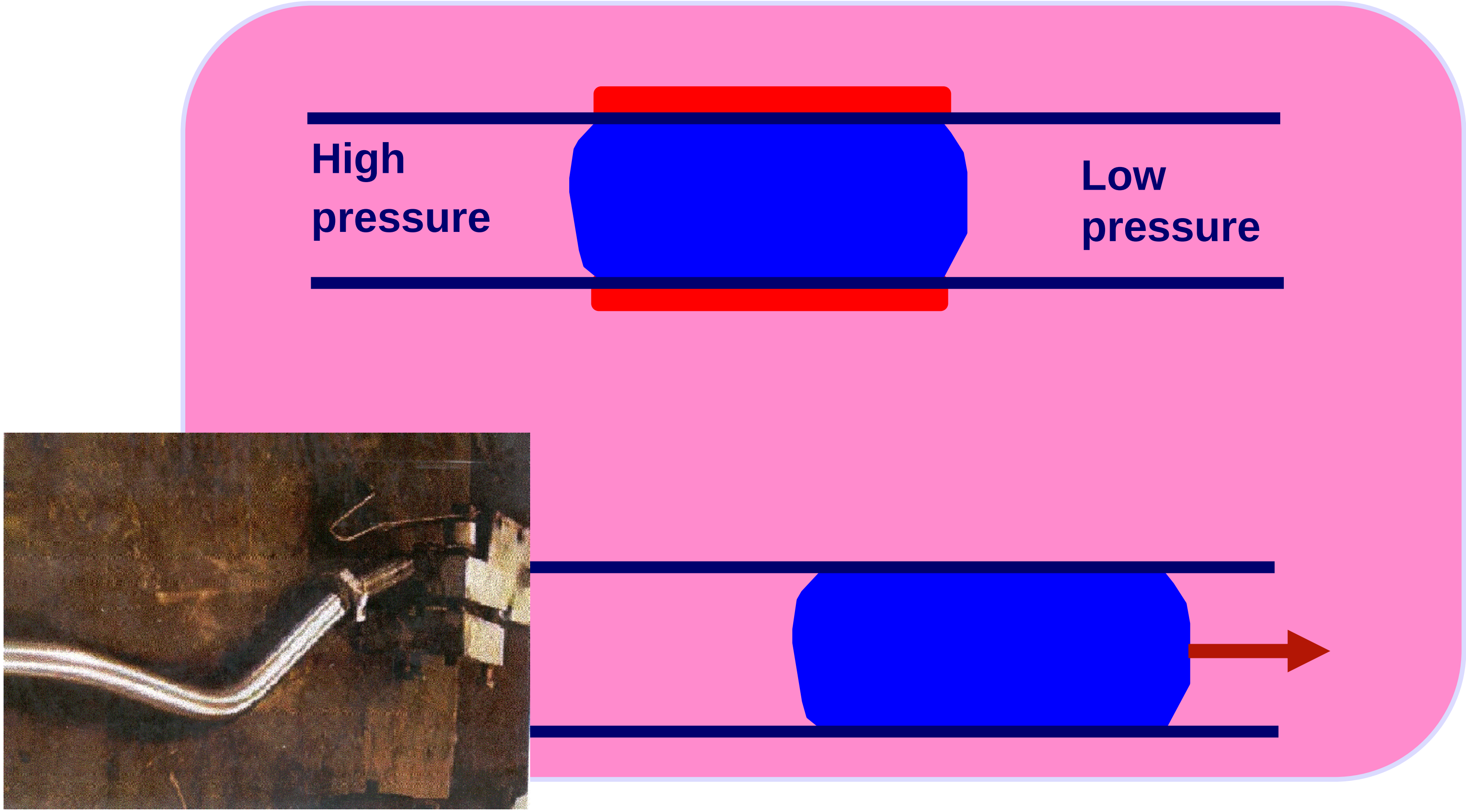
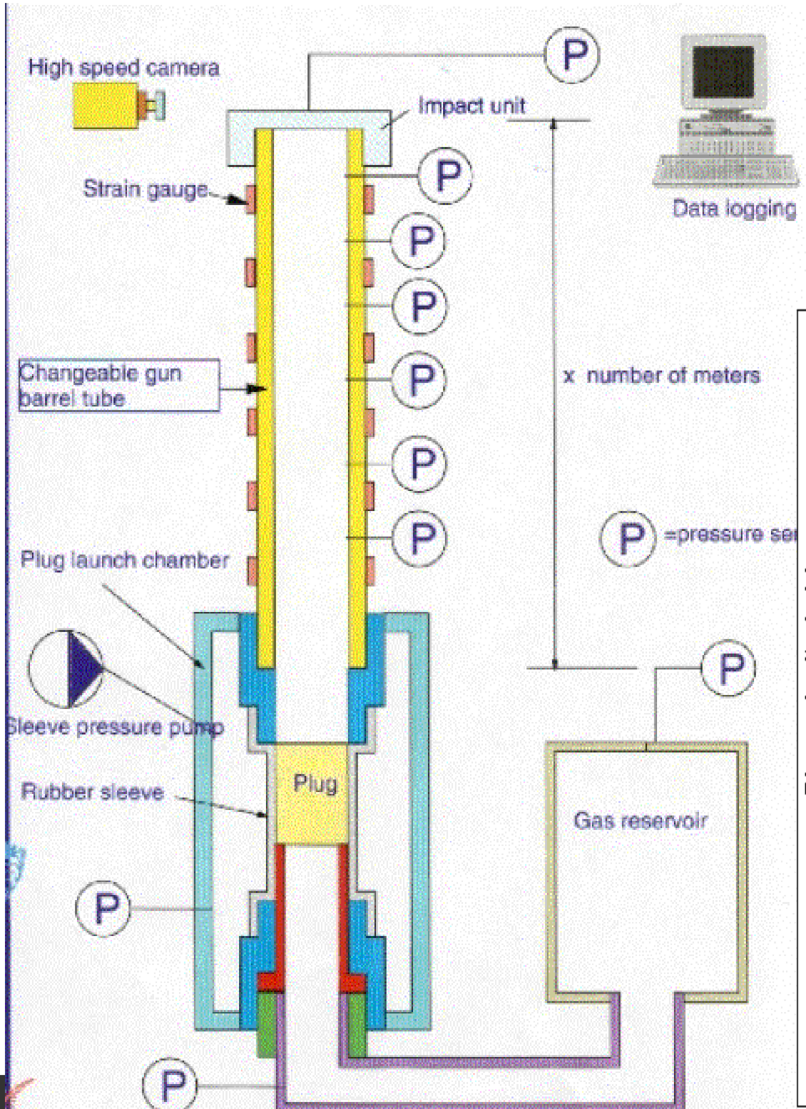
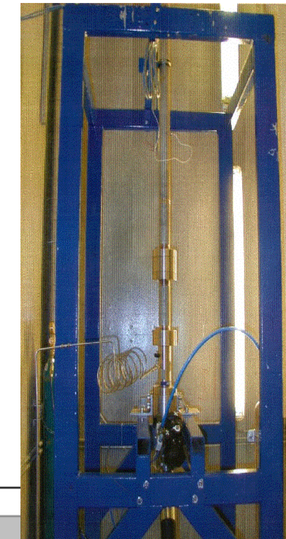
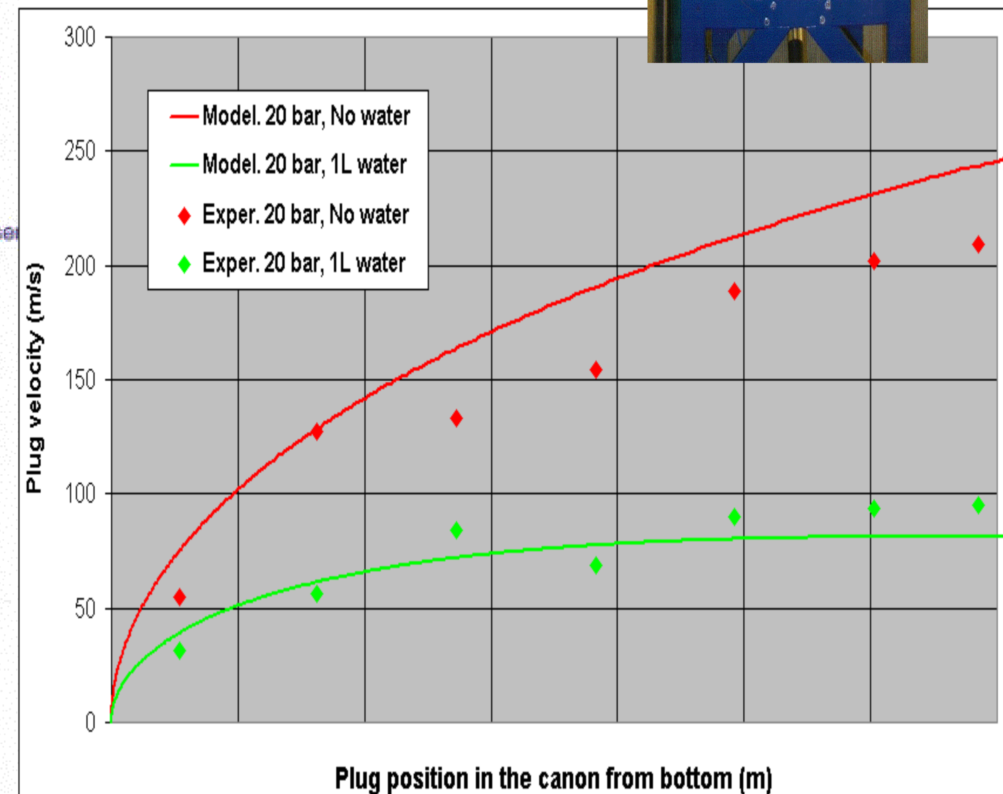
Large differential pressure
=> May cause projectiles (loosen plugs)!



Plug projectile exp. & modelling







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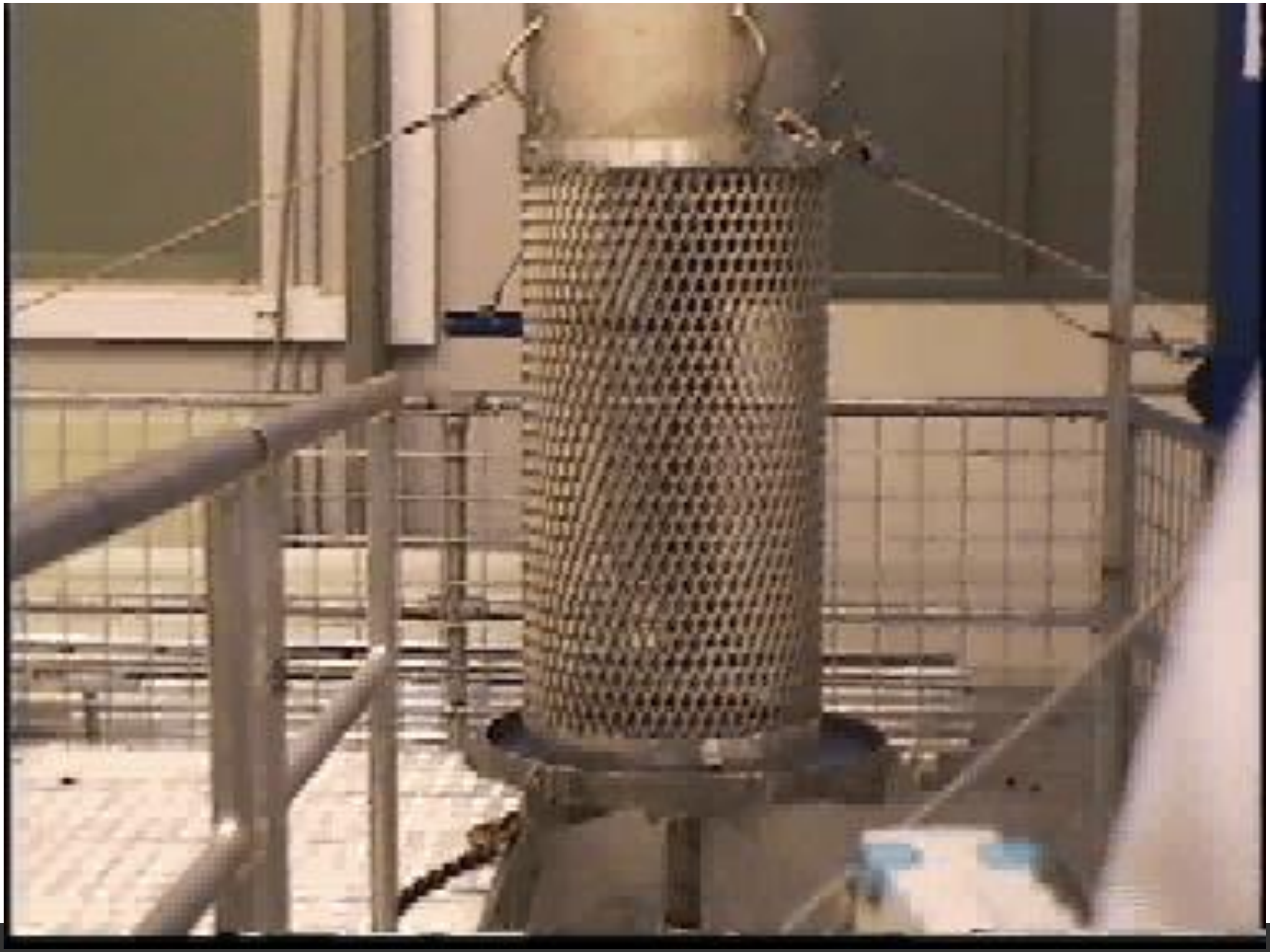
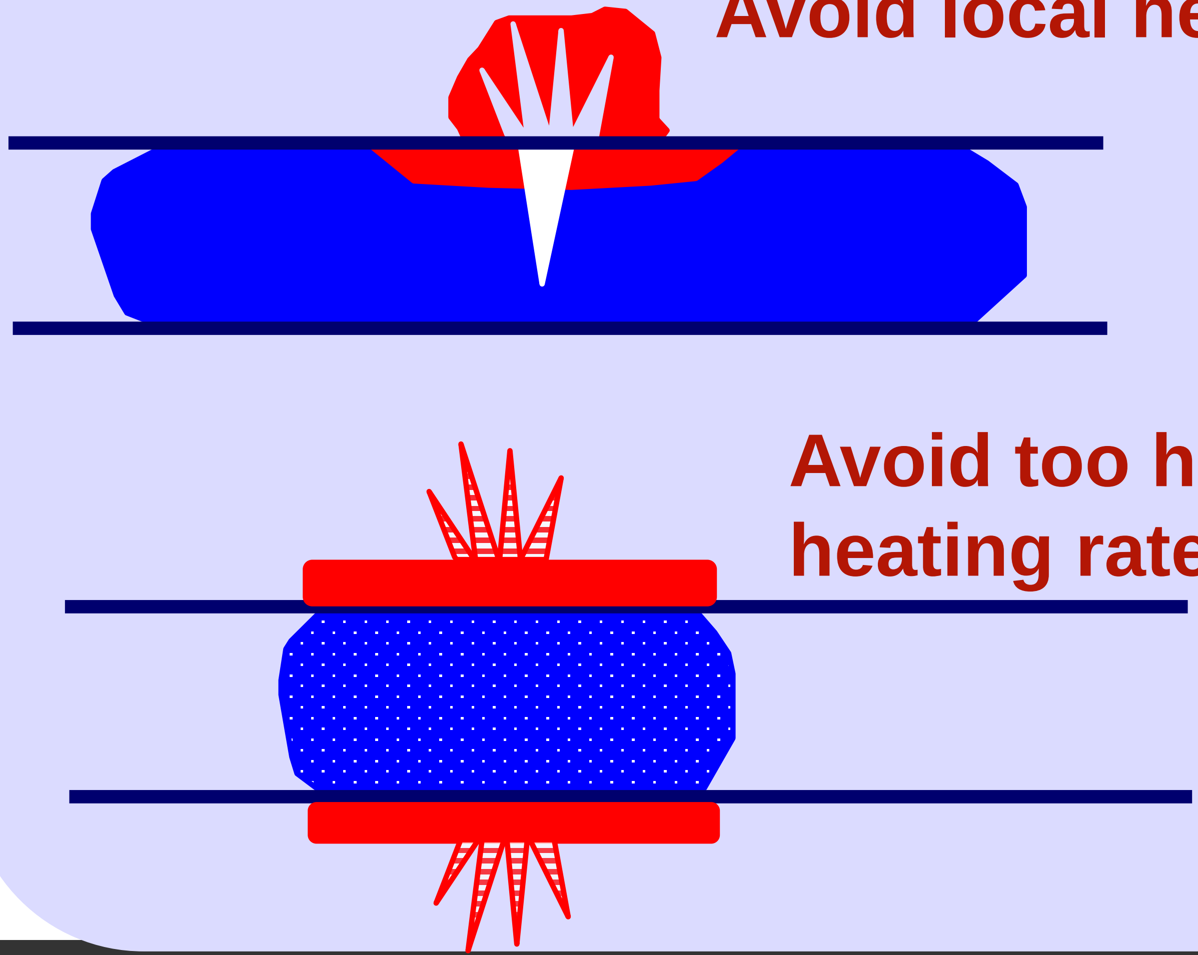
Hydrate Cannon experiments



Plug melting by heating

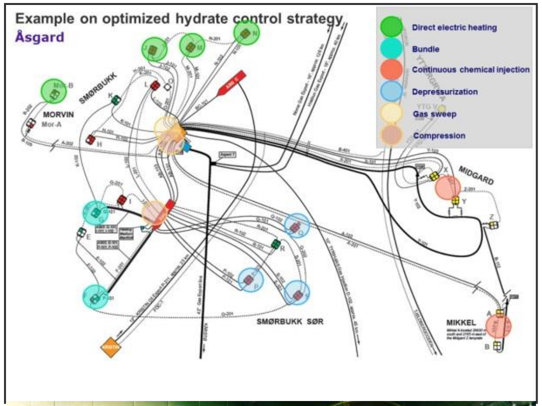


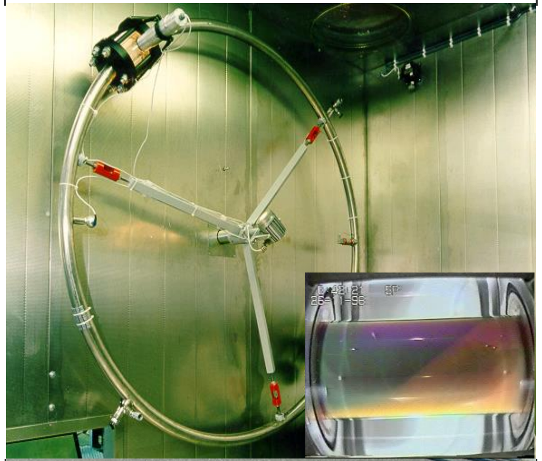
Avoid local heating

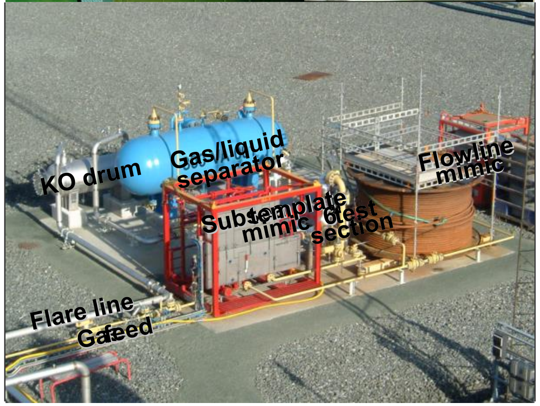
Avoid too high heating rate

Hydrate control in Statoil

- Statoil has over the past two decades had large efforts within hydrate control. Hydrate control - Statoil's distinctive technology portfolio.
- Large research projects and extensive operational experiences have lifted Statoil to the forefront with cutting edge hydrate control solutions.
- Statoil is world's largest subsea operator with over 500 wells and in excess of 100 production and injection flowlines. This has provided extensive first hand experiences on hydrate control issues.
- Statoil is a technology driven company with short ways to implement new hydrate control solutions.
- We continuously improve our operational strategies based on increased understanding on hydrate issues.







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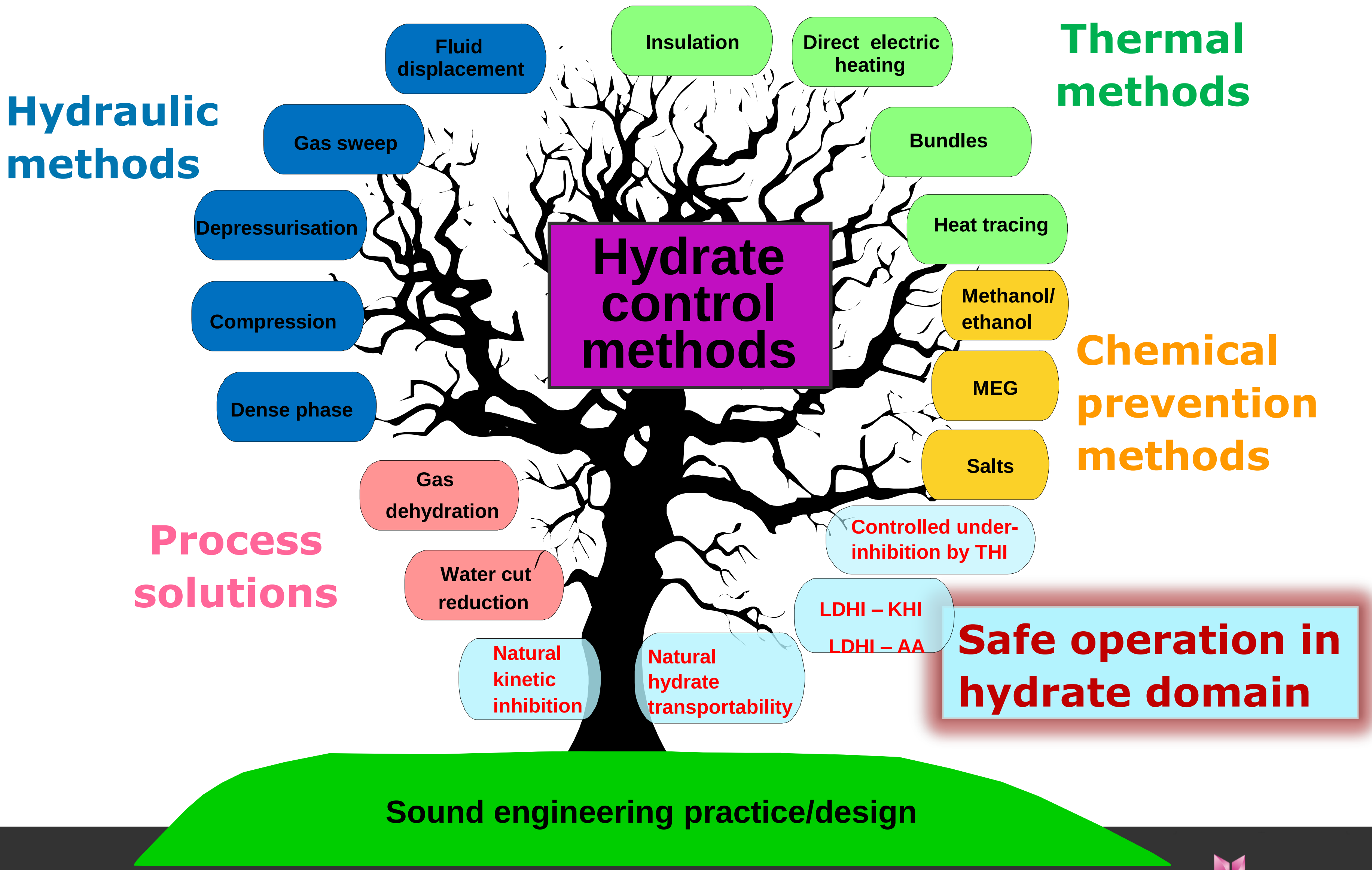
Hydrate control methods

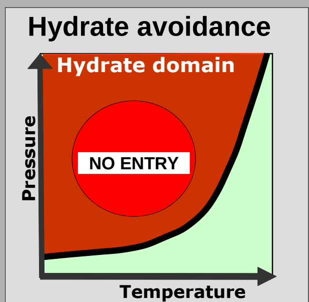


Thank you!

questions/comments?

Historical flashback on hydrate control

The old time	The new era of **hydrate management**



Field experience

R&D work

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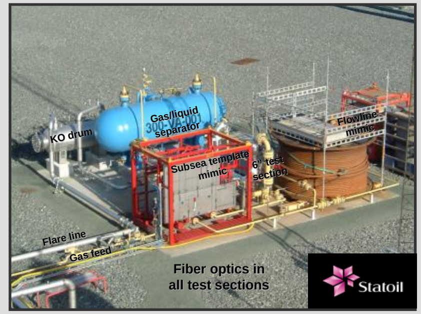
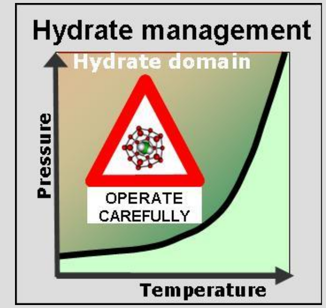




Continuous R&D work to enhance the understanding of hydrates and define improved solutions

2000 2002 2004 2006 2008 2014

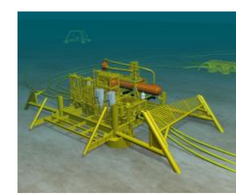
Large efforts to understand hydrate properties and behavior

Hydrodynamics, operation conditions and fluid properties are important for plugging risk assessment

Hydrate management concept introduced and gradually implemented

- Formation kinetics (induction time)
- Hydrate transportability
- Green chemicals
- Plugging risk assessment
- Risk based and tailor made

Continuous improvements – pushing the limits



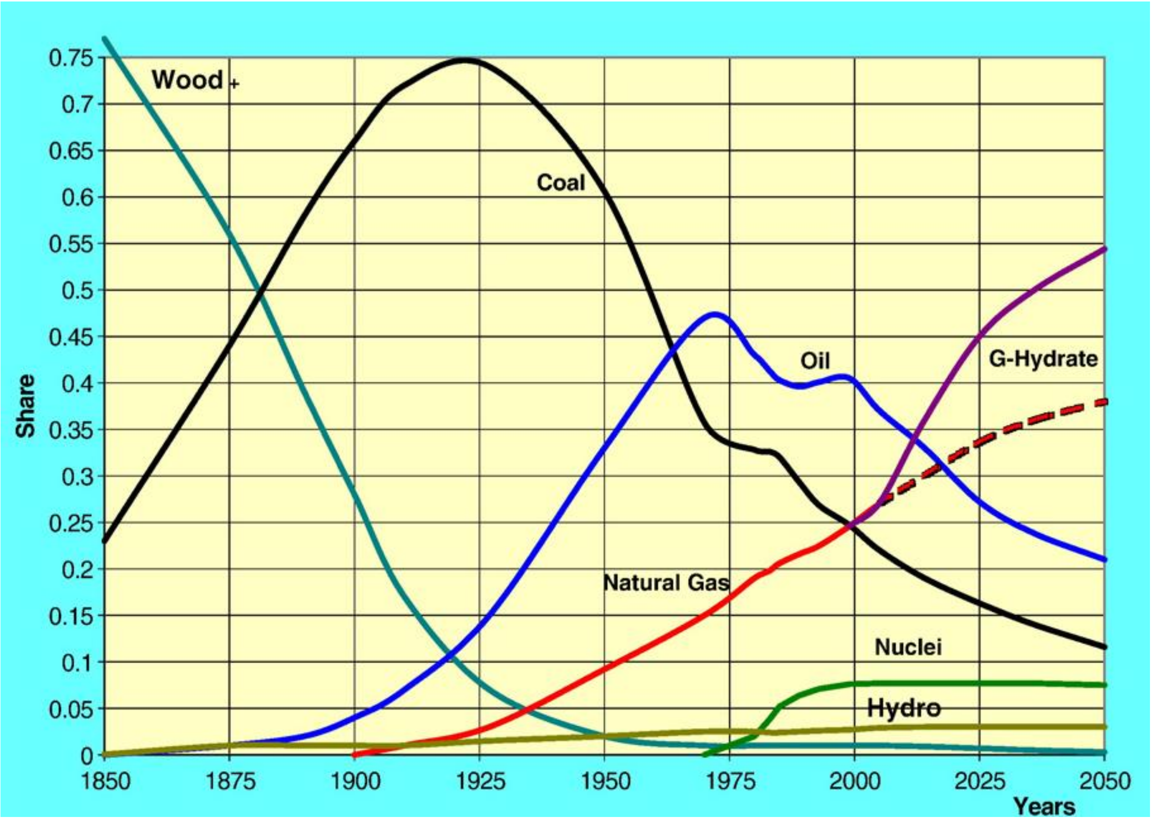
Statoil is a pioneer at
Direct Electrical Heating of Pipelines

- Primarily for hydrate control purposes
- Installed on 7 Statoil operated fields with multiple pipelines
  - Operational flexibility – "push the button"
  - Rapid start-up after shutdowns
  - No need for depressurization
  - End zones still need additional hydrate control measures
- Uniform heat input along the line
- Enables "single pipeline" tie-back
  - Tyrihans: 4 templates on a 43 km pipeline
  - Morvin: 2 templates on a 20 km pipeline
  - Fossekall-Dompap: 3 templates on a 26 km pipeline
- Developing new wet insulation materials
- DEH also recently selected by other operators

Plug melting by direct heating:

- Extensive studies have been performed at Statoil
- A comprehensive & rigorous mathematical model developed
- Guidelines and procedures developed

Natural gas hydrates – a potential new energy resource



[Y.F. Makogon et al. / Journal of Petroleum Science and Engineering 56 (2007) 14–31]

Estimated global resources in natural gas hydrates:

- From at least 100,000 TCF [source: Boswell & Collett, 2011]
- Global energy needs for the next 1,000 years

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