WHEN BOTH SHALL MEET: MANAGING INTEGRITY FOR H₂ AND CO₂ CONVERSION

In cooperation with
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R. Van-Elteren
T. Steinvoorte

presented by
Dr. Daniel Sandana
Principal Engineer
INVESTMENTS INTO HYDROGEN ARE GATHERING MOMENTUM

Announced clean hydrogen capacity through 2030


Breakdown of announced investments by maturity

INVESTMENTS INTO HYDROGEN ARE GATHERING MOMENTUM

Announced clean hydrogen capacity through 2030

Role of ‘Blue hydrogen’ in transition

Announced clean hydrogen capacity through 2030

- Cumulative production capacity
  Mt p.a.

Role of ‘Blue hydrogen’ in transition

- Without CCUS, the transition would become much more challenging
  - ~2.5 Mt blue H₂ by 2030 (SMR)
  - ~ 50 million tons CO₂
  - + CO & H₂S by-products
  - ‘CCUS is necessary’


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Retrofitting existing pipelines for \( H_2 \)

Connecting industrial clusters to an emerging infrastructure in 2030

Dedicated European Hydrogen Backbone can develop with a total length of approximately 11,600 km, consisting mainly of retrofitted existing natural gas pipelines. Regional backbones are expected to form in and around first-mover hydrogen valleys.

Growing network by 2035 covers more countries and enables import

The European Hydrogen Backbone will continue to grow, covering more regions and developing new interconnections across member states. Dedicated hydrogen storage facilities such as salt caverns, depleted fields and aquifers become increasingly important to balance fluctuations in supply and demand.

Mature infrastructure stretching towards all directions by 2040

The proposed backbone can have a total length of 39,700 km, consisting of approximately 69% retrofitted existing infrastructure and 31% of new hydrogen pipelines. Total estimate investment is expected to be between 43 and 81 billion euros.
Retrofitting existing pipelines for CO₂

“Transportation infrastructure to be built in the coming 30-40 years to be ~ 100 times > than current”
Conversion management

HOW DO I MANAGE THE INTEGRITY?

CAN I CONVERT MY EXISTING NATURAL GAS PIPELINE?

- Safely Managing the Transition of Pipelines to H₂, E.-Pepler M et al. World H₂ congress 2021
- Crack Management in Hydrogen pipelines, Sandana D et al., ICHS 2021
- Existing pipeline materials and the transition to hydrogen, Gallon N et al., PTC 2021

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Conversion management

**H₂**

**Hydrocarbon**

**CO₂**

- Material prop.? ✓
- Crack Management? ✓
  …Pre-existing vs new threats… ✓
- FFP / ERLs? ✓

- New IC threats? ✓
- IC Threat Severities? ✓
- Loss of containment behav.? ✓
Conversion management

…Hydrogen challenges

Interaction vs Steel Materials

…Hydrogen Embrittlement…

..Microstructure driven!...
(Not just grade!)

Don’t assume lower bound Properties!

Koyama et al.
Conversion management

...Hydrogen challenges

<table>
<thead>
<tr>
<th>Property</th>
<th>Effect of Hydrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength</td>
<td>$\leftrightarrow$ (?)</td>
</tr>
<tr>
<td>Ductility</td>
<td>↓</td>
</tr>
<tr>
<td>Fracture Toughness</td>
<td>↓</td>
</tr>
</tbody>
</table>
| Time-dependant crack threats     | ↑                  | (e.g. fatigue, SCC)
Conversion management

…Hydrogen challenges (?)

ASME B31.12 / EIGA / AIGA

Low grade

Relatively small diameter

Low utilisation
Conversion management

...Hydrogen

H₂ codes

- ASME B31.12 / EIGA / AIGA
- Low grade <=X52
- Relatively small diameter
- Low utilisation

Hydrocarbon NG pipelines (EU)

Caution! (SMYS vs AYS)
Conversion management
…Hydrogen

Hydrocarbon pipelines converted to H₂

Crack threats escalation
Pre-existing/New

FFP/ERL

Management (‘crack’)

✓ Understand ‘Materials’ DNA
✓ ID Crack baseline
✓ ID hard spot baseline
✓ ID high plastic deformation baseline

► Mat. Segmentation & Testing (Prop., CGRs)

✓ Monitor Cracks (service)
✓ Monitor high plastic deformation (service)
✓ Etc.

“ID material DNA, targeted material sampling & testing … at core of conversion strategies”

Crack Management in Hydrogen pipelines, Sandana D et al., ICHS 2021
Existing pipeline materials and the transition to hydrogen, Gallon N et al., PTC 2021
Conversion management

...CO₂ challenges

- Extension of Oil & Gas knowledge
- Higher Pp CO₂
- Escalation of IC?
- Water management(?)

- CO₂/H₂S corrosion

Hydrocarbon

CONVERSION

CO₂
Conversion management

...CO₂ challenges

- Sour cracking
- MR0175/ISO15156

- CO₂ + imp. H₂S, CO
- Escalation of EAC?
- Water management (?)
Conversion management

...CO₂ challenges

Fracture control (LoC)

- Dense CO₂
- Ductile running fracture (LoC)
- Crack arrestors
- Fracture toughness
- API 5L/ISO 3183... No mandatory requirements (hydrocarbon design)
Conversion management

...CO₂

Hydrocarbon pipelines converted to CO₂

Management

Pre-conversion

✓ ID Water Solubility thresholds
✓ Mat. segm. & fracture toughness testing
✓ Requirements for crack arrestors (Practical?)

Service

✓ Water management
✓ Monitor metal losses & cracks (operations)

Crack Management in Hydrogen pipelines, Sandana D et al., ICHS 2021
ILI strategies & challenges
Inspection strategies

...Hydrogen

RoMat-pgs

RoMat-DMG

EMAT

RoGeo-XT

RoGeo-XYZ

Conversion

Hydrocarbon

Material segmentation

Hard spots

Bending strain

Geometric

Bending strain

Cracks

H₂

Other tools for general IM!
Inspection strategies

...CO₂

RoMat-pgs

Cracks

EMAT

Material segmentation

CONVERSION

Corrosion Metal losses

Other tools for general IM!
ILIs in H₂

...Challenges

- Smallest
- Very mobile
- High Penetration
- Explosive
- Flammable
- Dry
- Operational

- Damage to electronic components
- Damage to magnets
- Damage to disc, cups
- Pipeline Safety, tool integrity
- Disc, Cup integrity (wear)
- Electrostatic discharge
- Damage to electronic components
- Flow control

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ILIs in \( \text{H}_2 \)

...Case study

- 10” x 10 km
- Service - Gaseous \( \text{H}_2 \)
- Installed – 1996
- Inspection practices for \( \text{H}_2 \) lines costly and time-consuming

- 2015 – ROSEN ILI MFL & geometric in \( \text{H}_2 \)
ILIs in $H_2$

...Case study

- European Union’s ATEX directives
  - Flameproof enclosure for the components
  - Pressurised enclosure for the electronics
  - Intrinsic safety with voltage-restricted electrical circuits

- Magnets protection
  - Protection against $H_2$

- Non-standard cups (different hardness)
  - Lower the risk of static electricity
  - Resistance to decomposition
  - Resistance to uneven wear

- Assessment of flow conditions
  - Standard set-up – $P_{\text{min}}$ of 435 psi.
  - $P$ of ~270 psi & flow rate of 11 MMscfd required.
  - Application of various bypass holes and notches to design for reduction of excessive velocity from pressure build-up in installations while still providing enough seal to propel the tool through the line.
ILIs in $H_2$

...Case study

- 100% sensor coverage (Geometry and MFL)
- 100% magnetisation levels (MFL)
- Overall Data quality acceptable for EL
  *(velocity spikes at installation)*
- No evidence of tool damage
- Minimum wear damage

Safely inspected in 2017
## ILIs in dense CO₂

...Challenges

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Affected components</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical degradation &amp; explosive decompression</td>
<td>Non-metallic – multiple e.g. cables, sensors, seals</td>
<td>Interaction with dense CO₂ Explosive decompression (end of ILI run)</td>
</tr>
<tr>
<td>High wear</td>
<td>Tool cup &amp; discs</td>
<td>Dry environments</td>
</tr>
<tr>
<td>Damage of electronic components</td>
<td>Electronic components</td>
<td>Build-up of electrostatic charge on tool due to movement of cups along pipe wall in dry environment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leads to high voltages generated between tool &amp; pipeline, resulting in a discharge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Depends on position and intensity of discharge</td>
</tr>
</tbody>
</table>
## ILIs in dense CO₂

**…Challenges**

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<tr>
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<th>Management</th>
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</thead>
<tbody>
<tr>
<td>Chemical degradation &amp; explosive decompression</td>
<td>Non-metallic – multiple e.g. cables, sensors, seals</td>
<td>Control of decompression rate &amp; material selection</td>
</tr>
<tr>
<td>High wear</td>
<td>Tool cup &amp; discs</td>
<td>Material selection or engineering design solutions e.g. use of support wheels, wear reinforced cups &amp; brushes.</td>
</tr>
<tr>
<td>Damage of electronic components</td>
<td>Electronic components</td>
<td>Development of conductive PU to minimise electrostatic build-up / protective shielding on delicate electronic components</td>
</tr>
</tbody>
</table>
## ILIs in dense CO₂

### Case studies

<table>
<thead>
<tr>
<th>Pipeline Design</th>
<th>Operations</th>
<th>Tool deployed</th>
</tr>
</thead>
<tbody>
<tr>
<td>24&quot; OD x 116 km</td>
<td>131 bar, 16°C</td>
<td>Geometric EGP &amp; Metal loss MFL</td>
</tr>
<tr>
<td>24&quot; OD x 120 km</td>
<td>134 bar</td>
<td>Geometric EGP &amp; Metal loss MFL</td>
</tr>
</tbody>
</table>

### Post-run

![Post-run image](image-url)
Conclusions

Integrity Management
…NG vs Hydrogen & CO₂…

...Understand your materials...

...Understand your Hot spots…
Hard spots, bending strain, geometric, etc.

...ILIs…
Challenges but NOT insurmountable

Storage
THANK YOU FOR JOINING!

presented by

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