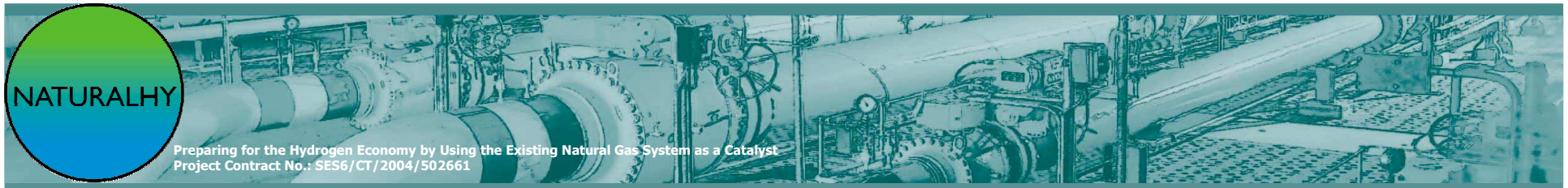

The value of the existing natural gas system for hydrogen, the sustainable future energy carrier (progress obtained in the NATURALHY-project)

Isabelle Alliat (Gaz de France)
Onno Florisson (N.V. Nederlandse Gasunie)

Barbara Lowesmith & Geoff Hankinson (Loughborough University)

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Presentation Breakdown

Preparing for the Hydrogen Economy by Using the Existing Natural Gas System as a Catalyst
Project Contract No.: SES6/CT/2004/502661

Project overview

Safety work

} Onno Florisson

Work on network durability — Isabelle Alliat

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Justification of NATURALHY

Preparing for the Hydrogen Economy by Using the Existing Natural Gas System as a Catalyst
Project Contract No.: SES6/CT/2004/502661

- Opportunity for “greening of natural gas”
- EU Directive 2003/55/EC:

  “*… taking into account the necessary quality requirements, biogas and gas from biomass or other types of gas are granted non-discriminatory access to the gas-system, provided such access is permanently compatible with the relevant technical rules and safety standards….* ”

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Objective

To determine the conditions under which hydrogen can be added to the existing natural gas system with acceptable consequences

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Hydrogen Impact

Preparing for the Hydrogen Economy by Using the Existing Natural Gas System as a Catalyst
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- Safety
- Integrity
- Performance of end user appliances
- Gas quality management

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Project Characteristics

Preparing for the Hydrogen Economy by Using the Existing Natural Gas System as a Catalyst
Project Contract No.: SES6/CT/2004/502661

- 39 Partners, 15 from the gas industry
- Financially funded by the European Commission (FP6)
- Budget 17.3 M€, EC grant 11 M€
- Start 1 May 2004, duration 5 years

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Partners Working on Safety

Preparing for the Hydrogen Economy by Using the Existing Natural Gas System as a Catalyst
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- Loughborough University (leader safety work)
- Leeds University
- Shell Hydrogen
- CEA
- National Grid
- UK HSE

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Objective of Safety Work

Preparing for the Hydrogen Economy by Using the Existing Natural Gas System as a Catalyst
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To assess the change in Risk to the public caused by introducing hydrogen into the natural gas pipeline network

Risk is Probability of Event x Consequences

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Experiments

Small Scale

- Laminar and turbulent burning velocity

Large Scale

- Gas build-up and explosions in domestic type room and in industrial enclosure
- Vapour Cloud Explosions in congested regions
- High pressure jet fires and pipeline fires

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Turbulent Burning Velocity

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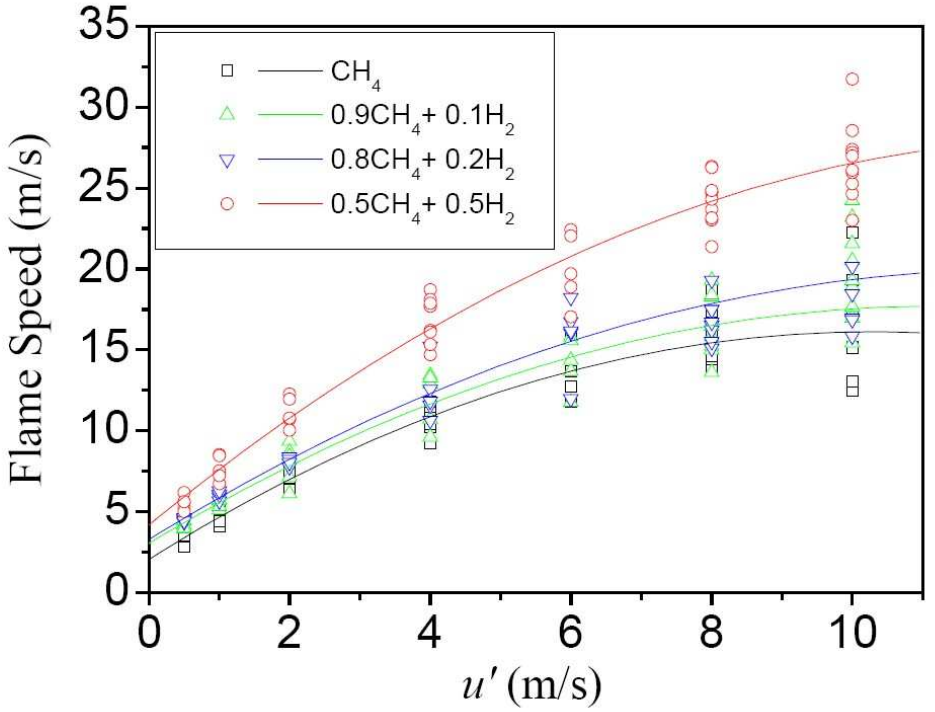
- Required for explosion models
- Over 700 experiments
- Range of H_2%, Equivalence Ratios and turbulence levels

Turbulent results, flame-speeds (at 30 mm radius) against r.m.s turbulent velocity for CH_4, 10, 20, & 50% H_2(vol.) 360K, 0.1 MPa, $\phi = 1$.



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Gas Build Up in Domestic Room

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10 Large Scale Experiments

- Pressures typical of upstream and downstream of the meter: 20 and 30mbar
- Size of leak from small (2mm) to large (10mm)
- Gas release upwards and upward cross flow ventilation as this is most likely to promote layering
- Varying gas composition: CH4 and 10, 20 and 50% H2 in CH4

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Typical Gas Accumulation in Domestic Room

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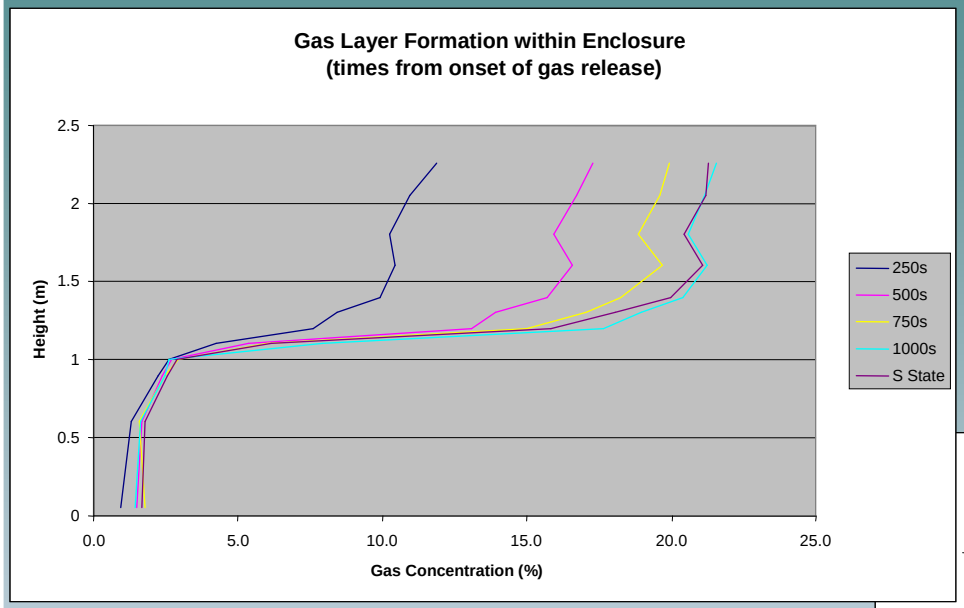
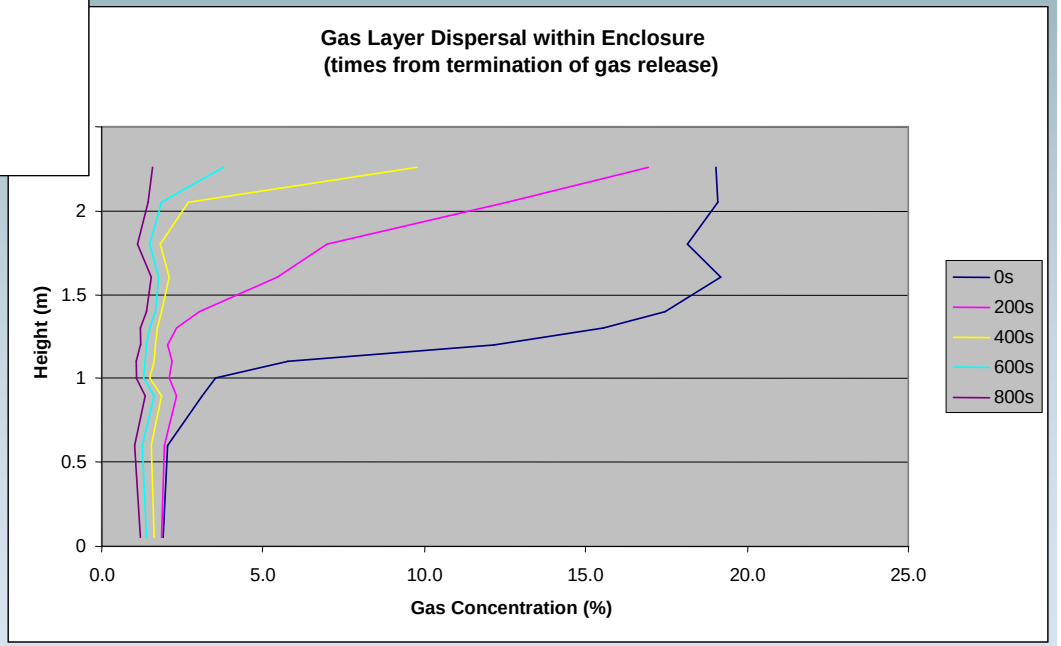


- Layer forms quickly and then increases in concentration

- When gas terminated, ventilation disperses layer



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Results Gas Build Up in Domestic Room

Still being processed but initial assessment suggests:

- Similar behaviour for H2/CH4 mixtures as for Methane – that is layered accumulation formed
- Evidence that the H2/CH4 mixtures result in increased buoyancy induced ventilation which helps lower the concentrations produced
- No evidence of separation of hydrogen from the gas mixture during gas accumulation

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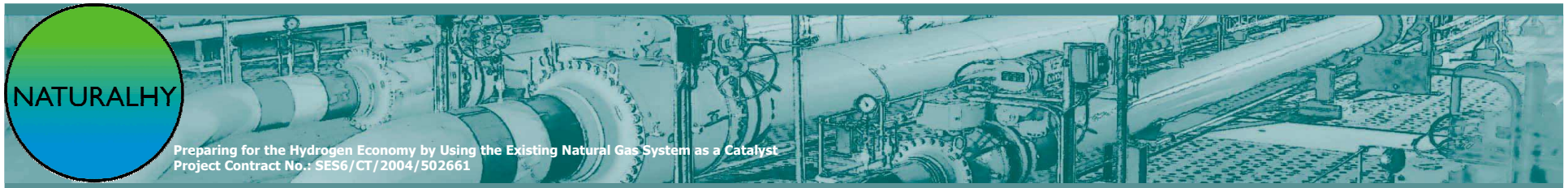

Preparing for the Hydrogen Economy by Using the Existing Natural Gas System as a Catalyst
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What is the impact of hydrogen on the durability of natural gas networks?

Gaz de France

Isabelle Alliat

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OBJECTIVES

- Effects of hydrogen on the durability of materials and components used in the natural gas transmission and distribution networks and end user devices
  - *How does H2 effect the initiation and growth of defects in pipes? In which conditions?*
  - *What are the H2 leakages in steel pipes? in PE pipes? in gas appliances?*
  - *Has H2 an ageing effect on PE pipes?*
  - *Are domestic gas meters reliable? Ageing effect?*

How much % of H2 is acceptable?

… damaging & safety …

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Transmission pipelines

State of the art

Gaseous H2 embrittlement of steels

- Degradation of steel ductility = more brittle
- Easier initiation of internal cracks (with or without applied stress)
- Ruptures by delayed failure under mechanical loading
- Reduced threshold stress intensity factor (K_{IH}) for cracks initiation
- Higher crack propagation rate under cyclic loading
  - = reduced fatigue lifetime

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Transmission pipelines
State of the art

- Materials for H2 pipelines :

  Recommendations and Practices

- API 914: **"Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants"**
- Hydrogen pipelines in operation
  - Air Liquide, Air Products, Praxair, NASA, etc.
- EIGA & CGA : "Hydrogen Transportation Pipelines"
  - Carbon steels = API 5L Grade X52 or lower
  - Stainless steels = 316L (304L)

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Transmission pipelines

Assess the effect of H2 on steels

- Scope = steels for pipes & welds & defects

- Mechanical strength and fracture behaviour
  - Fracture toughness
  - Burst resistance
  - Fatigue behaviour
- Deterministic and Probabilistic Approaches

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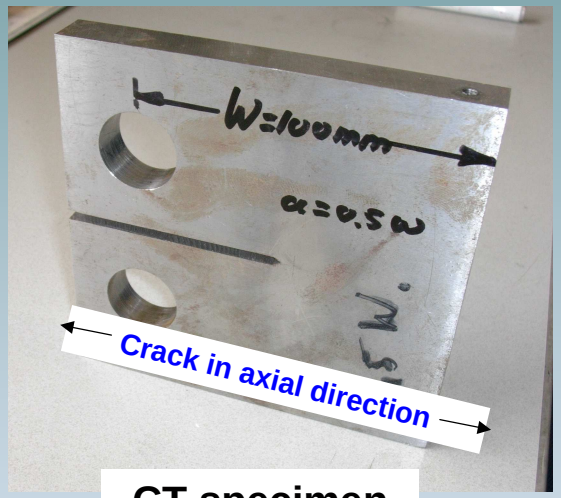
Transmission pipelines

Assess the effect of H2 on steels

- Experimental methodology

Machined sample

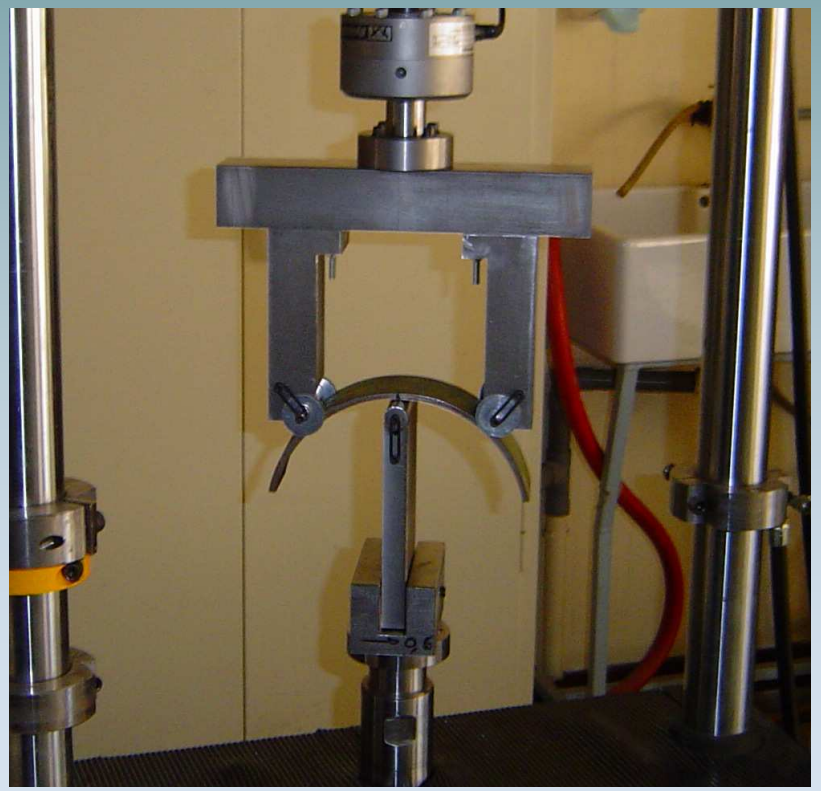


CT specimen

W=100 mm

a=0.5W

Tile cut in the pipes



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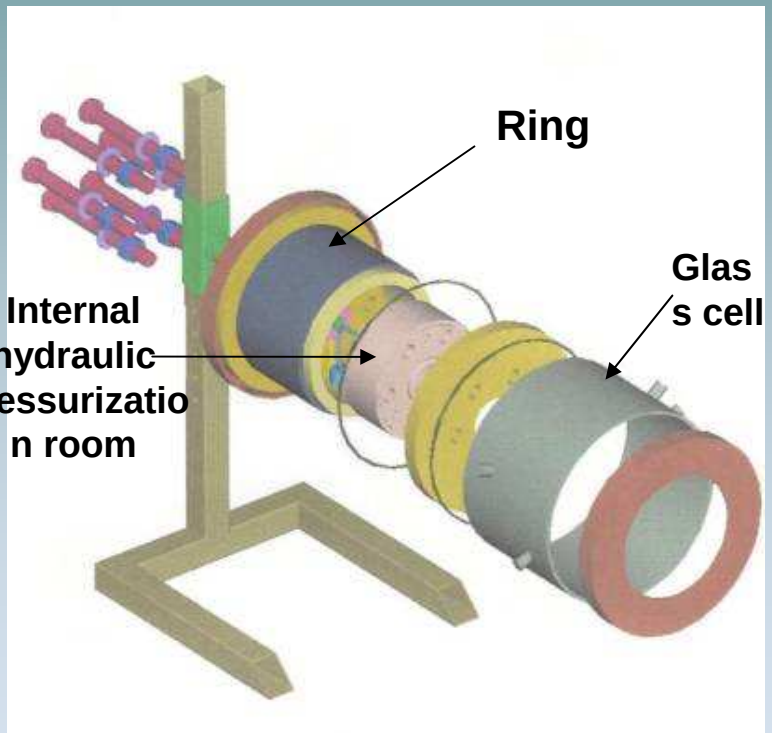
Transmission pipelines

Assess the effect of H2 on steels

- Experimental methodology

Part of pipes



Closed-end pipes

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Distribution network

Assess the permeability of PE

- State of the art
- Few works were published on H2 permeation
  - Coherence of published values of permeation …
- Quite thin literature on ageing of PE

- Work programme:
- Purpose = identify the leakage of gas and assess the potential risks % safety
- Scope = PE for pipes (PE80, PE100)
  & welds (electro-fusion)

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Distribution network

Assess the permeability of PE

- First results
- on bulk PE :

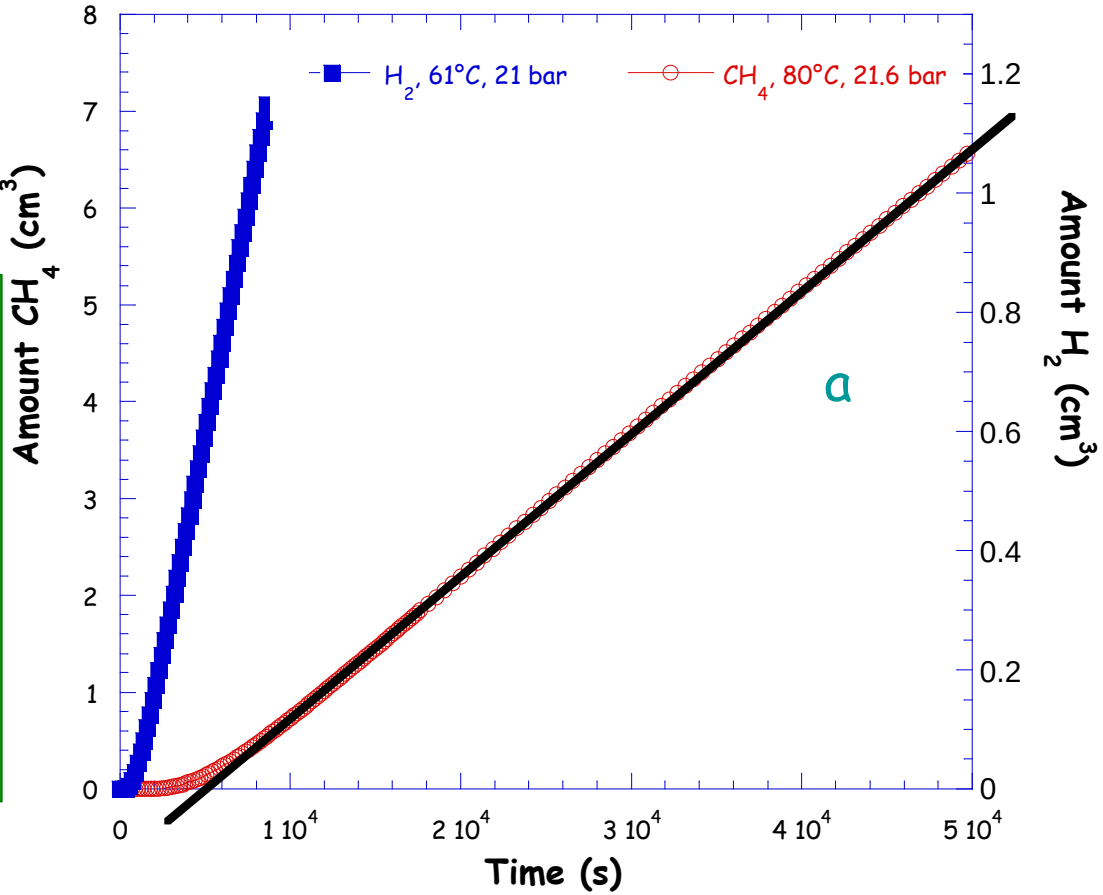
Calculated leakages:

Pipe of PE at 4 bar

Mixture 80%NG+20%H2 :

= 1,3 liter / km / day of H2

= 0,5 liter / km / day of NG



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Distribution network

Assess the reliability of gas meters

- Purpose = identify the leakage of gas (safety) and assess the metering
- Scope = domestic gas meters with polymer membranes
  - G4 (up to 6m^3/h) and G6 (up to 10m^3/h)
  - European manufacturers
    - Actaris
    - Elster
    - Kromschroeder
    - Nuovopignone

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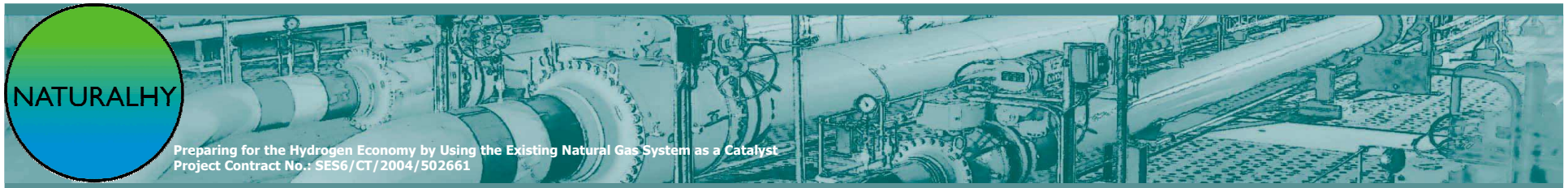

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Can we maintain effectively gas networks that include hydrogen?

Integrity Management of transmission grids

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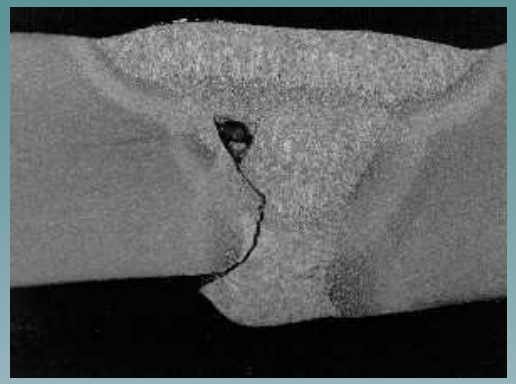
Transmission pipes
Threats, in more detail

Corrosion

- General
- MIC
- AC
- DC



Material Imperfections

- Weld defects
- Laminations

Mechanical damage (Third party)

- Dents
- Gouges

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Integrity Management

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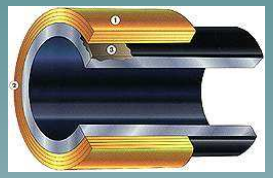

Repair & Mitigation Measures

Threat Identification

Integrity (PoF) & Consequence (CoF) Assessment

Risk Evaluation

Inspection & Monitoring

MFL Inspection

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Challenge in Naturalhy

Preparing for the Hydrogen Economy by Using the Existing Natural Gas System as a Catalyst
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Main deliverables:

- Improved inspection methods
- Improved repair methods
- Integrity Management Tool & Resource Allocation

Taking account of:

- Percentage of hydrogen in mixture
- Material of construction
- Operating conditions
- Age of pipeline, historical inspection data
- CP measurement data and level of protection
- Coating survey measurements

Translation of changed material properties towards decision-making on WHEN and HOW to INSPECT and REPAIR

Thank you for your attention

Isabelle Alliat (Gaz de France)

Onno Florisson (N.V. Nederlandse Gasunie)

www.naturalhy.net

Naturalhy@gasunie.nl

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