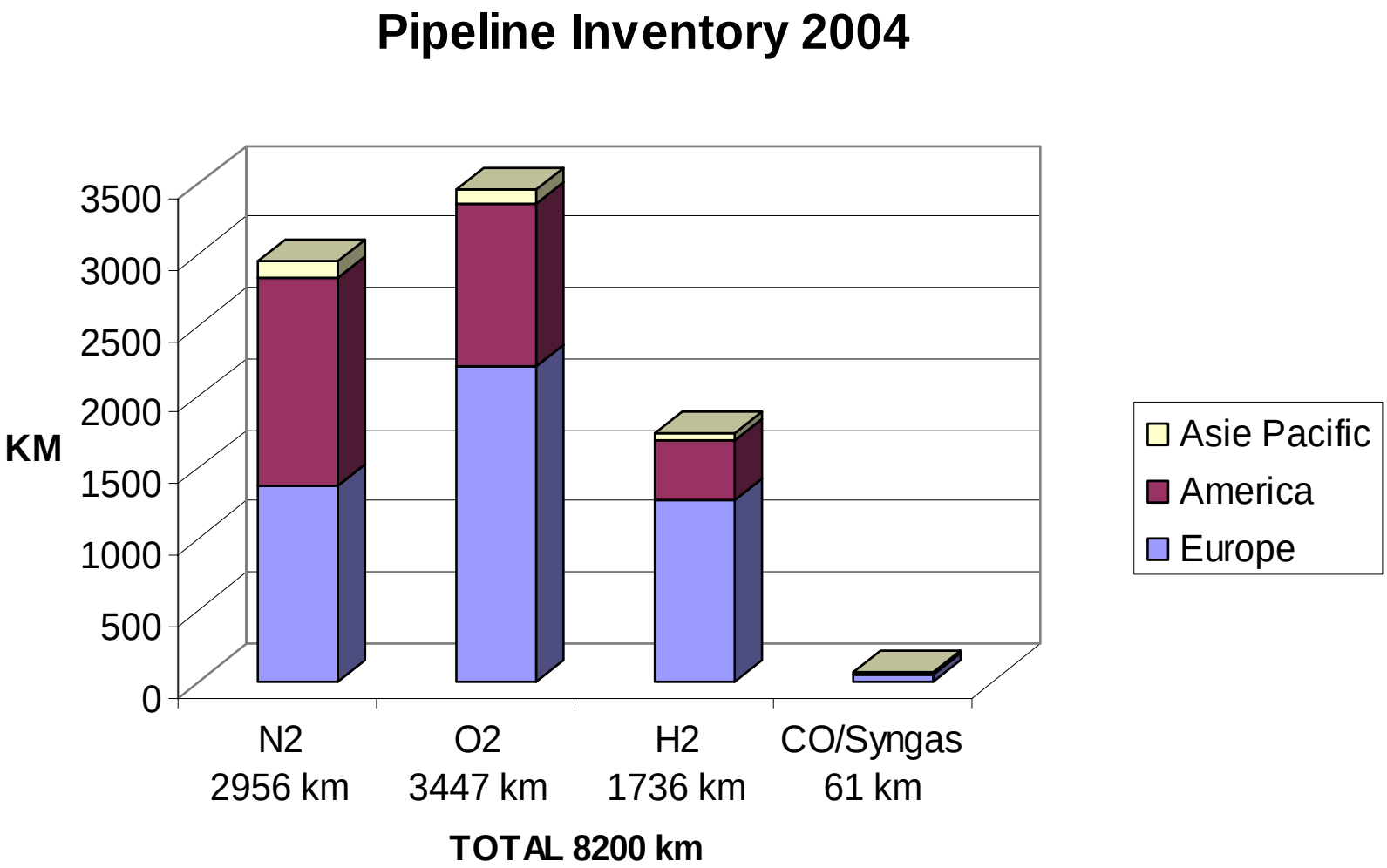

# *Questions and Issues on Hydrogen Pipelines*

## *Pipeline Transmission of Hydrogen*

**Doe Hydrogen Pipeline Working Group Meeting ■ August 31, 2005**

# Air Liquide Pipeline Inventory

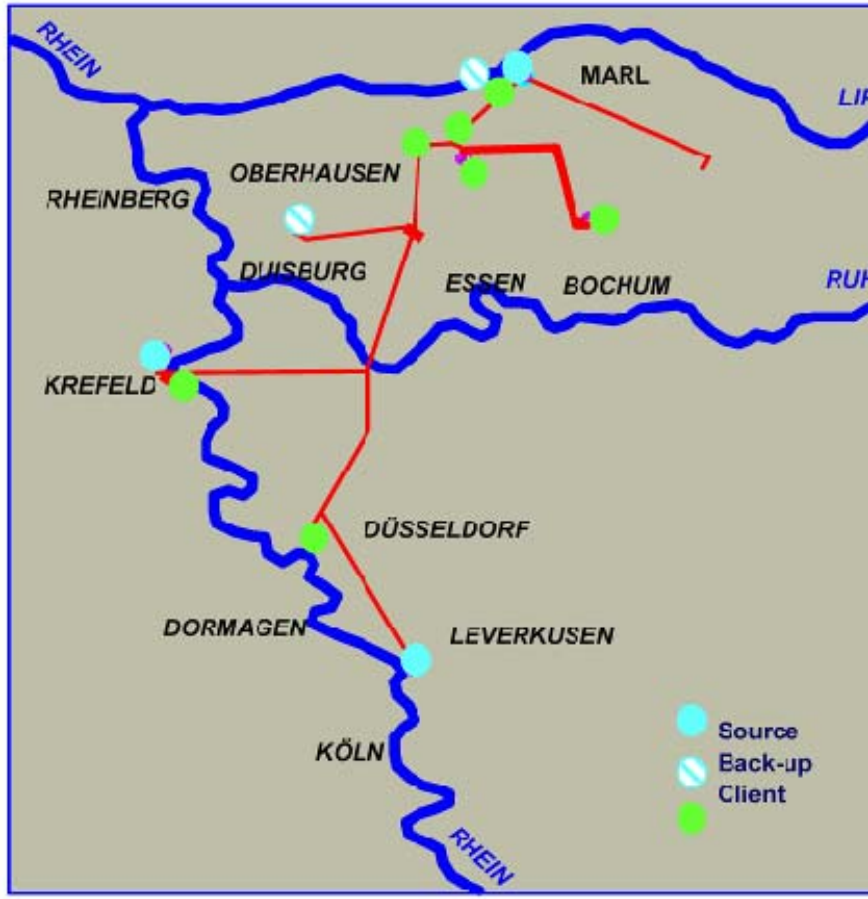
## Breakdown by gases



# Pipping of GH2 Pipeline

## Background

- FG 64 built in 50ies
- KP added in 70ies
- active mining area over total length
- length approx. 25 km
- incl. 150 expansion joints (EJ) and 40 foundations
- all damaged caused by mining influence payed 55% by mining company
- EJ in end position considered as damage

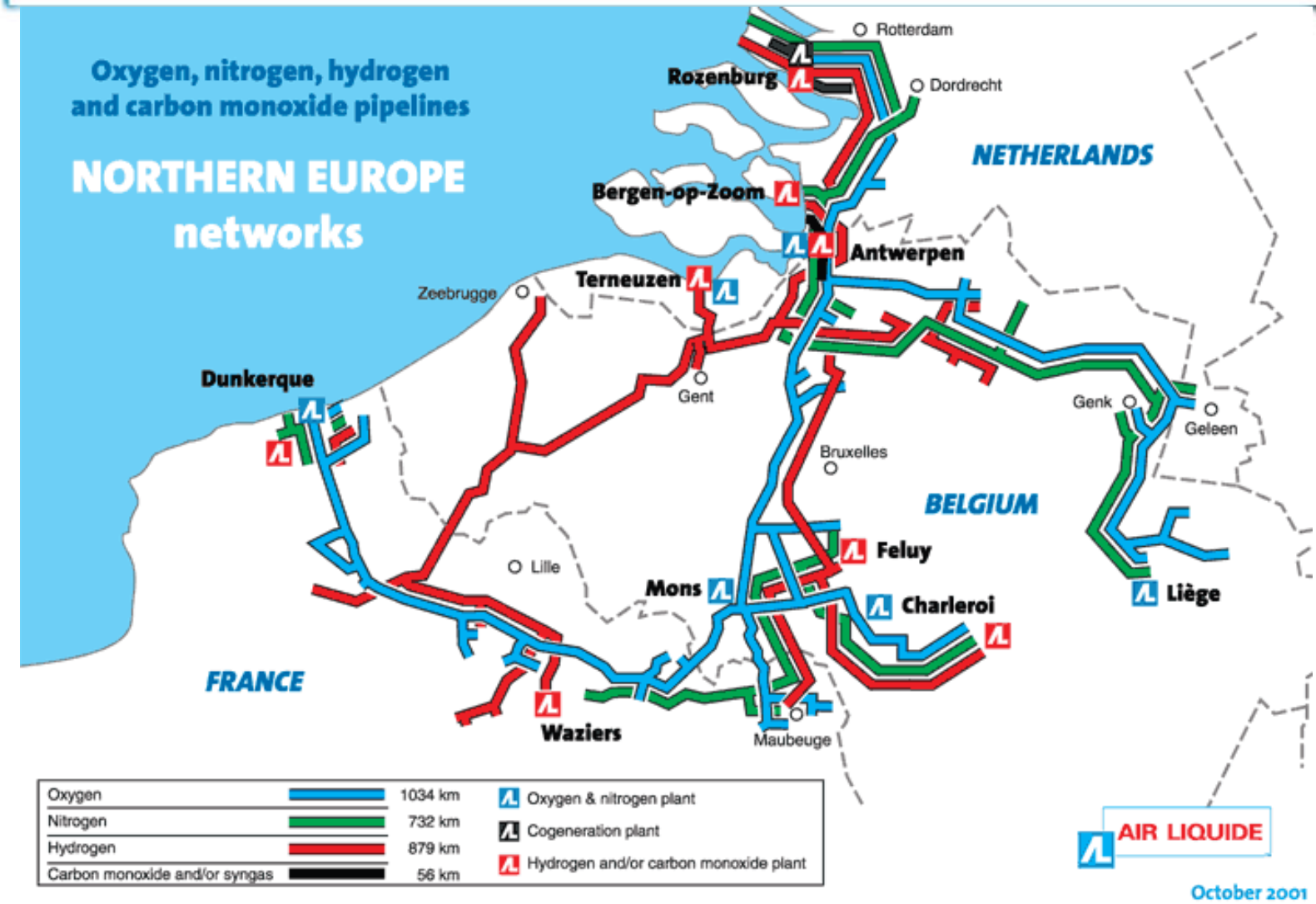


# 3. Special structures

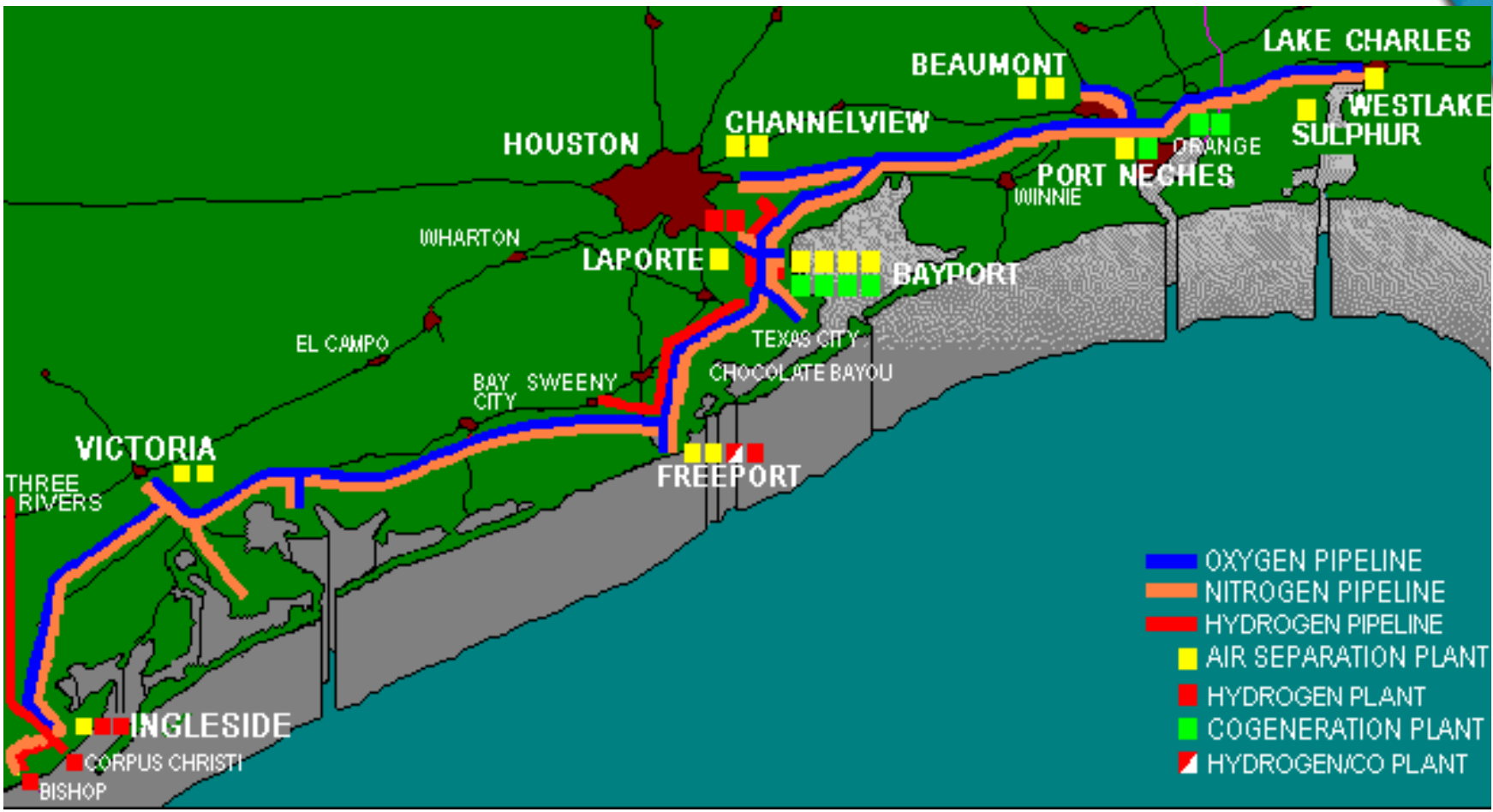
| | | |
|---|---|---|
| **River Crossings (culvert):** | 6 | (Rhein, Ruhr, Rhein-Herne-Kanal) |
| **River crossing (on bridge):** | 1 | (Rhein-Herne-Kanal) |
| **Motorway Crossings:** | 26 | |
| **Overground Pipelines:** | approx 21 km | |

# 5. Mining areas

# France & Netherlands



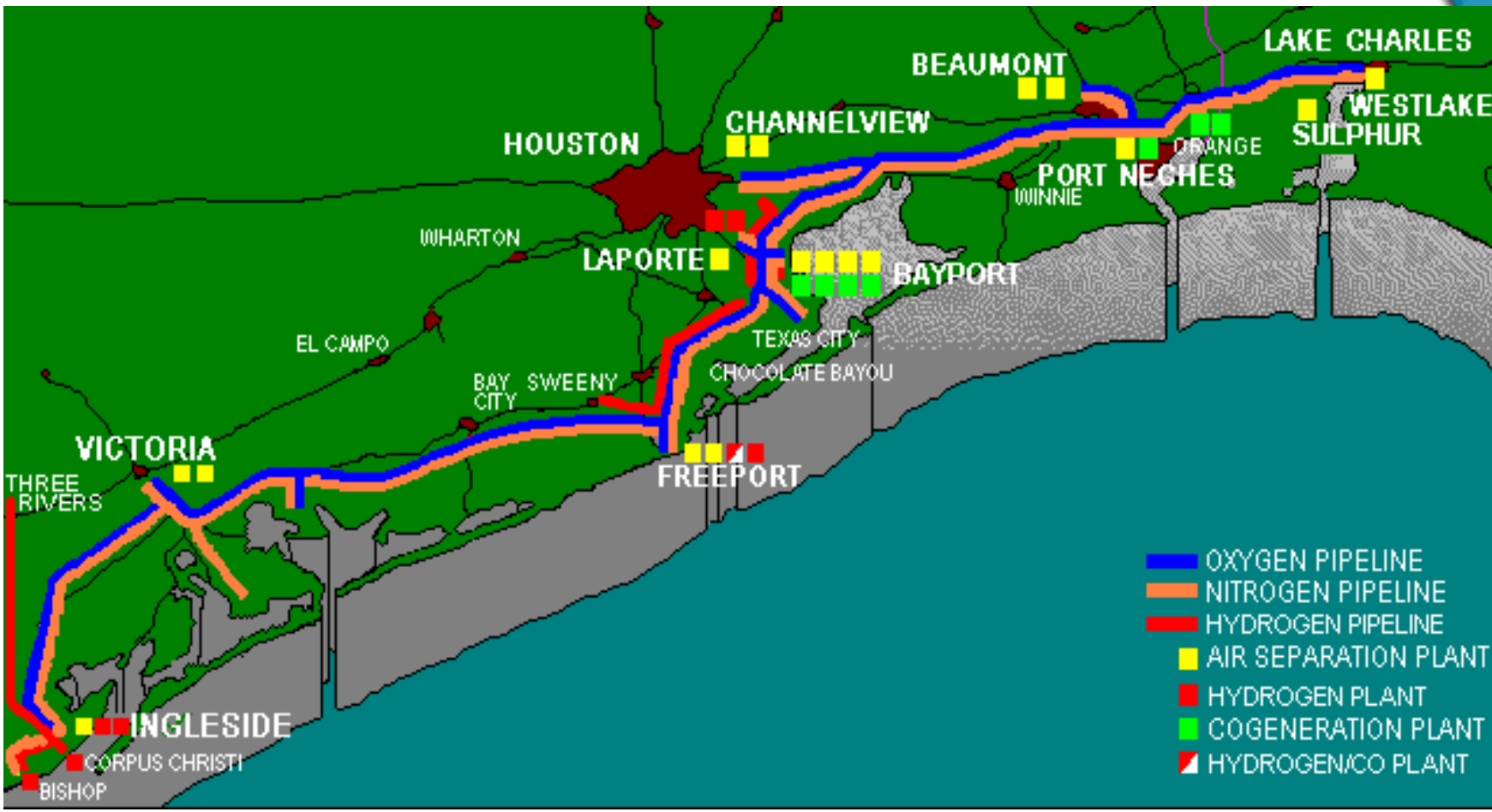
# Air Liquide Oxygen, Nitrogen , Hydrogen Pipelines



# Air Liquide Hydrogen Pipelines

| | Germany | France, Belgium | USA |
|---|---|---|---|
| Years H2 operation | <49 | <22 | *<17* |
| miles | 150 | 646 | 245 |
| Operating pressure | 250 psig | 1400 psig | 700 psig |
| Steel grade | <X42 | <X52 | *<X60* |
| Pipe manufacture | ERW | ERW | ERW |
| Welding | SMAW | SMAW | SMAW |
| Valve type | ball | ball | ball |
| Valve make | Audco | Argus | Cameron |

# Air Liquide Oxygen, Nitrogen , Hydrogen Pipelines



# Corpus Christi 8” H2 Pipeline (1998)

- Originally built as crude oil gathering pipelines (1940-1950) – 140 miles of 8 inch pipe
- Purchased by AL in 1998
- Intelligent pig inspection, cleaned, hydrotest
- Used in H2 service at 700 psig for 6 months
- Rupture because of corrosion 1998
- Derated to 350 psig, 65 miles still in service

# Freeport to Texas City 14” Pipeline

- Originally built as crude oil pipeline in 1979
- 34 miles, various grades and wall thickness
- Intelligent pig inspection, cleaned, hydrotest
- Original pipeline ball valves still in use for H2.
- Has been in service at 740 psig since 1996
- Successful repeat hydrotest in 2004
- No problems in service

# Steel Properties of Converted Pipelines

| | New pipe Spec. | Freeport-Texas City | Corpus Pipelines |
|---|---|---|---|
| Hardness | <250 HB | 225 | *178* |
| Carbon Equivalent | <0.43 | 0.63 | 0.325 |
| Grade | <X52 | *X60* | *Gr.B* |
| Sulfur | <0.015% | 0.015 | *0.036* |
| Phosphorus | <0.015% | 0.017 | *0.011* |
| Charpy Impact | >35J | >27J | 6J |
| Heat treatment | **Normalized** | NA | NA |

# Build VS. Buy

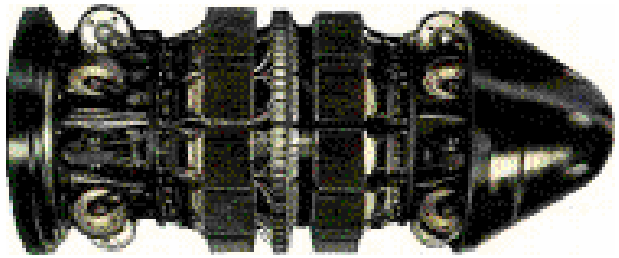
## FOR

- **Cost** – new transmission line averages $694,000 per km.
- **Easements** – major issue in industrial/urban areas
- **Schedule** – months vs. years

## AGAINST

- **Material** – will not match “ideal” H2 compatibility
- **Corrosion** – old pipelines, several fluids, corrosion?

# Pipeline Inspection Tools

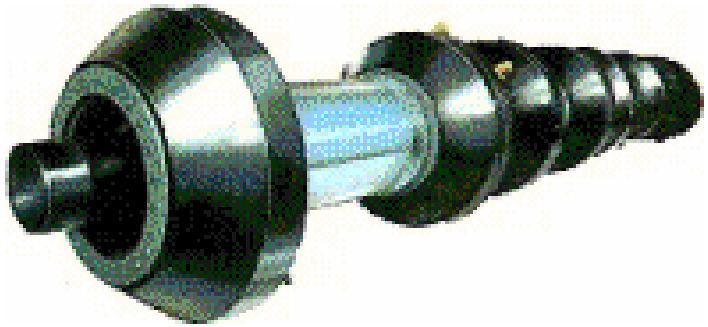


Smart Pigs can be introduced into operating pipelines and propelled by the gases or liquids being delivered. Smart Pigs for pipelines from 10” and larger have been developed.

Different technologies are used to locate defects in the pipeline wall.

Magnetic Flux Leakage (MFL) measurements can detect corrosion on thinning walls.

Ultrasonic sensors can detect external coating disbondment, cracks, dents and gouges.



The pigs contain data acquisition and storage devices. After the pig is recovered from the pipeline, the data can be downloaded. Analysis of the data reveals exact location of defects detected.

# Pipping of GH2 Pipeline

## Express Analysis of scan data

- ✔ 6 sections identified to be replaced immediately (pinholes)

section 4, 4380 m

| | |
|---|---|
| Wall thickness | 0,5 mm |
| length | 20 mm |
| width | 10 mm |

- leak relevant

section 4, 4415 m

| | |
|---|---|
| Wall thickness | 0,7 mm |
| length | 8 mm |
| width | 8 mm |

- leak relevant)

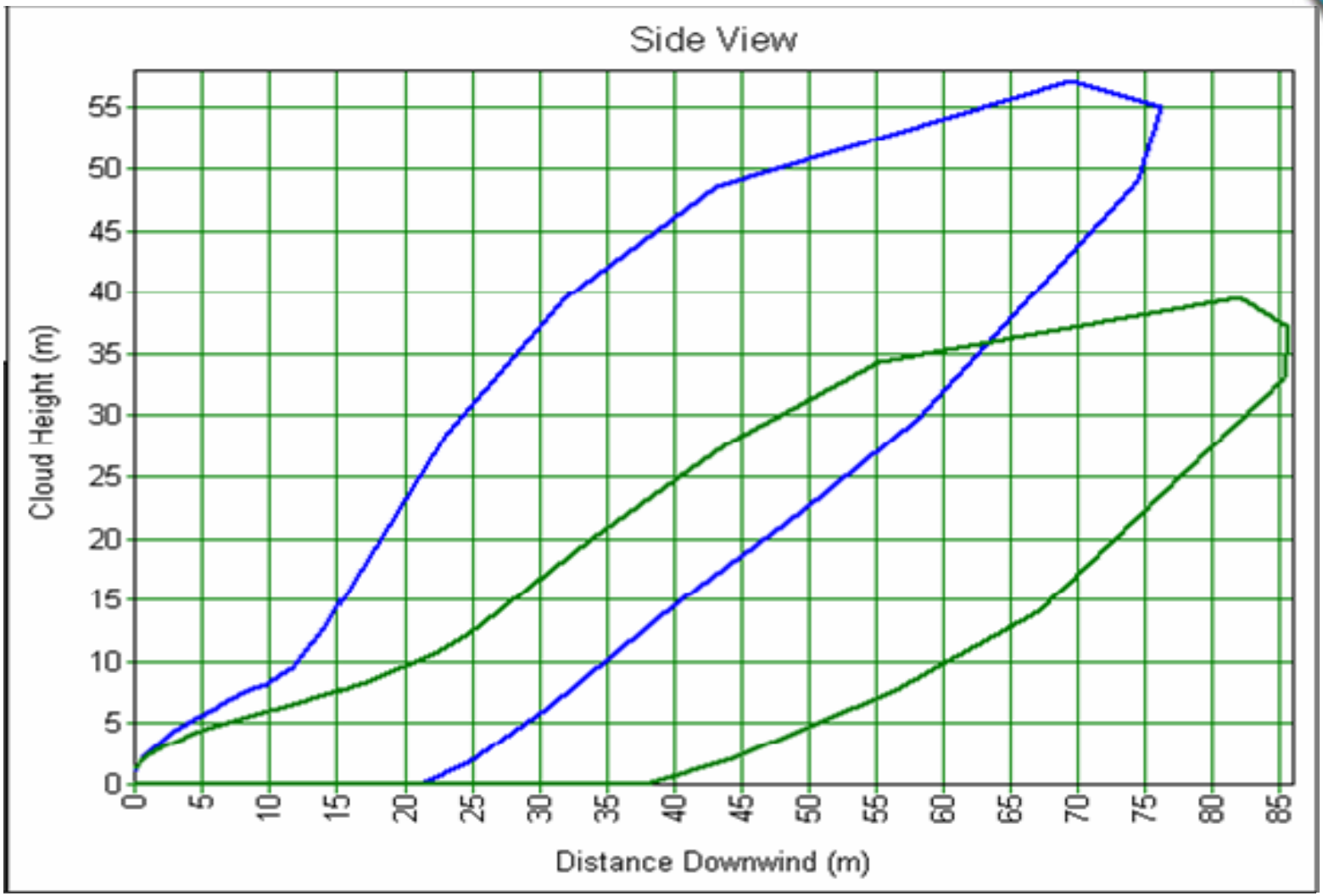
# Freeport H2 Supply to GM Fuel Cells

- Purified using pressure swing adsorbers
- Crude H2 purchased from Dow Chemical
- Compressed to 740 psig (lubricated reciprocal)
- Multi-stage vane type filtration for lubeoil removal
- <1 ppm CO, -300F dewpoint
- Fuel cells supplied through 1 inch pipeline

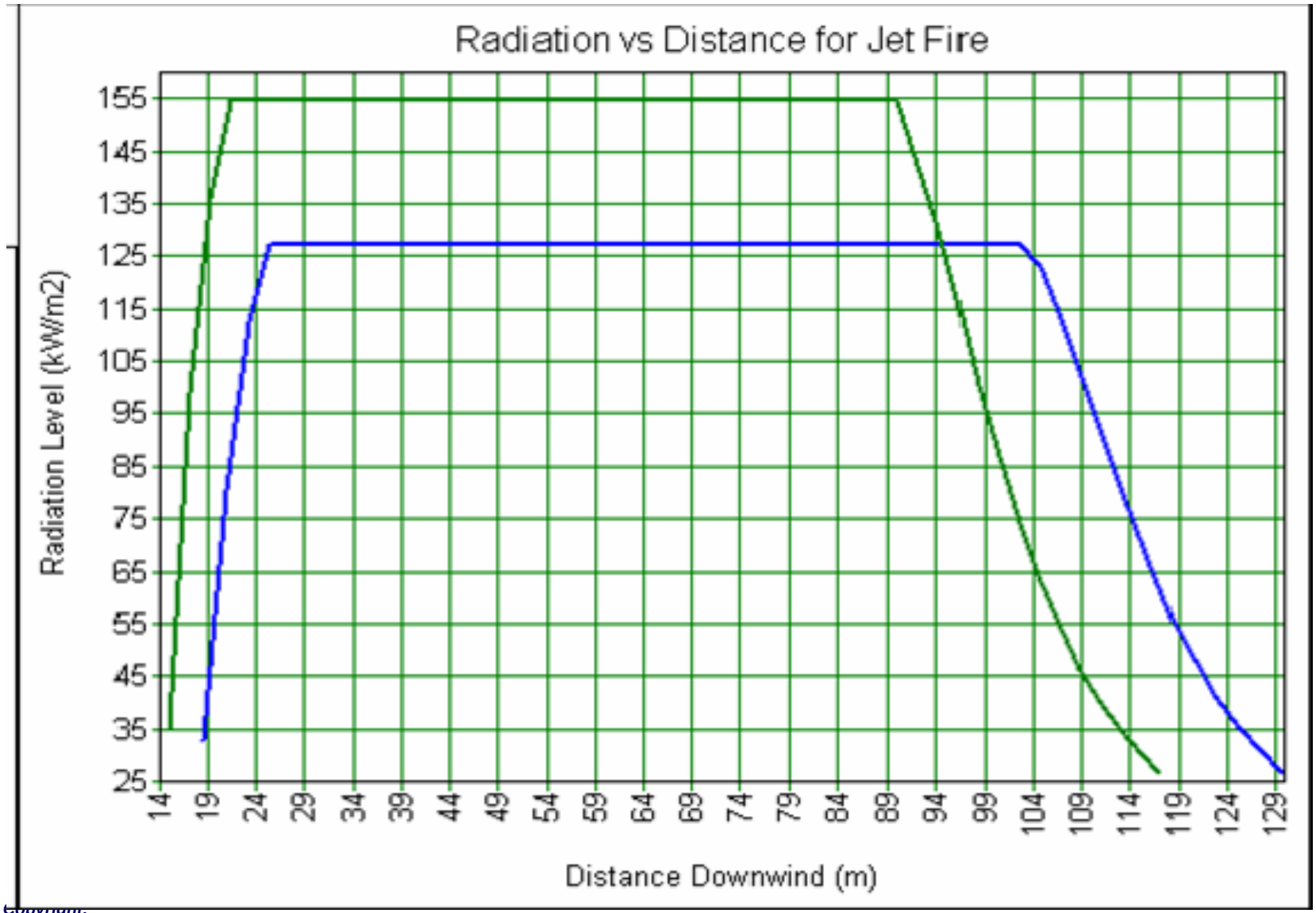
# Risk Analysis & Liability Concern

- Risk analysis is required for all H2 pipelines
- Commercial software available (PHAST, Canary)
- Evaluate full bore rupture and 1” puncture
- Assume that nearest valve is closed after 10 mins.
- Examine explosion and jet fire cases
- Quantitative analysis gives fatality risk
- Risk analysis may result in re-route or mitigation

# Plume Study



# Radiation vs. Distance



# Risk Study

| Full bore rupture Horizontal 3F | | | | |
|---|---|---|---|---|
| Effects | | Distance m | Area m2 | % fatality |
| Dispersion 1.5m Height 5D | | 41 | | |
| Thermal radiation kW/m2 | | | | |
| 13.4 | | 143 | 10593 | 1 |
| 18.2 | | 137 | 8416 | 10 |
| 22.8 | | 133 | 6999 | 30 |
| 26.6 | | 130 | 6104 | 50 |
| 31 | | 127 | 5175 | 70 |
| 38.7 | | 124 | 4200 | 90 |
| 52.5 | | 120 | 1590 | 99 |
| Maximum | 129 | 105 | 1182 | |

# LIKELIHOOD and ACCEPTABLE RISK

## Probability of Pipeline failure

| Probability of pipeline rupture year x km | |
|---|---|
| Full bore rupture | 6.50E-06 |
| Large leak | |
| Small leak Out corridor | 1.00E-04 |
| Small leak In corridor | 2.00E-05 |

## Acceptable risk (Netherlands advisory)

| Nederland Advisory Societal risk | |
|---|---|
| Nbs of people | Likelihood |
| 0.1 | 1.00E-01 |
| 1 | 1.00E-03 |
| 10 | 1.00E-05 |
| 100 | 1.00E-07 |

# Design & Operation

## --- Special Issues for $H_2$ Service

- H2 pipeline ruptures always catch fire
- Need a flare at pipeline vents & reliefs
- Small leaks hard to detect
- Valves, gaskets, fittings no real problem
- Odorization will be a challenge

# Conclusion

- ***Conventional pipeline materials have been successfully used for H2 up to 1400 psig***
- ***Existing pipelines can be converted to H2 service with some limits on stress and pressure***
- ***Current design of H2 compressors and H2 pipelines can supply fuel cells***
- ***Little experience with urban "distribution" pipelines***

Jim Campbell

Manager, Pipeline Construction

Air Liquide Process & Construction

Jim.campbell@airliquide.com