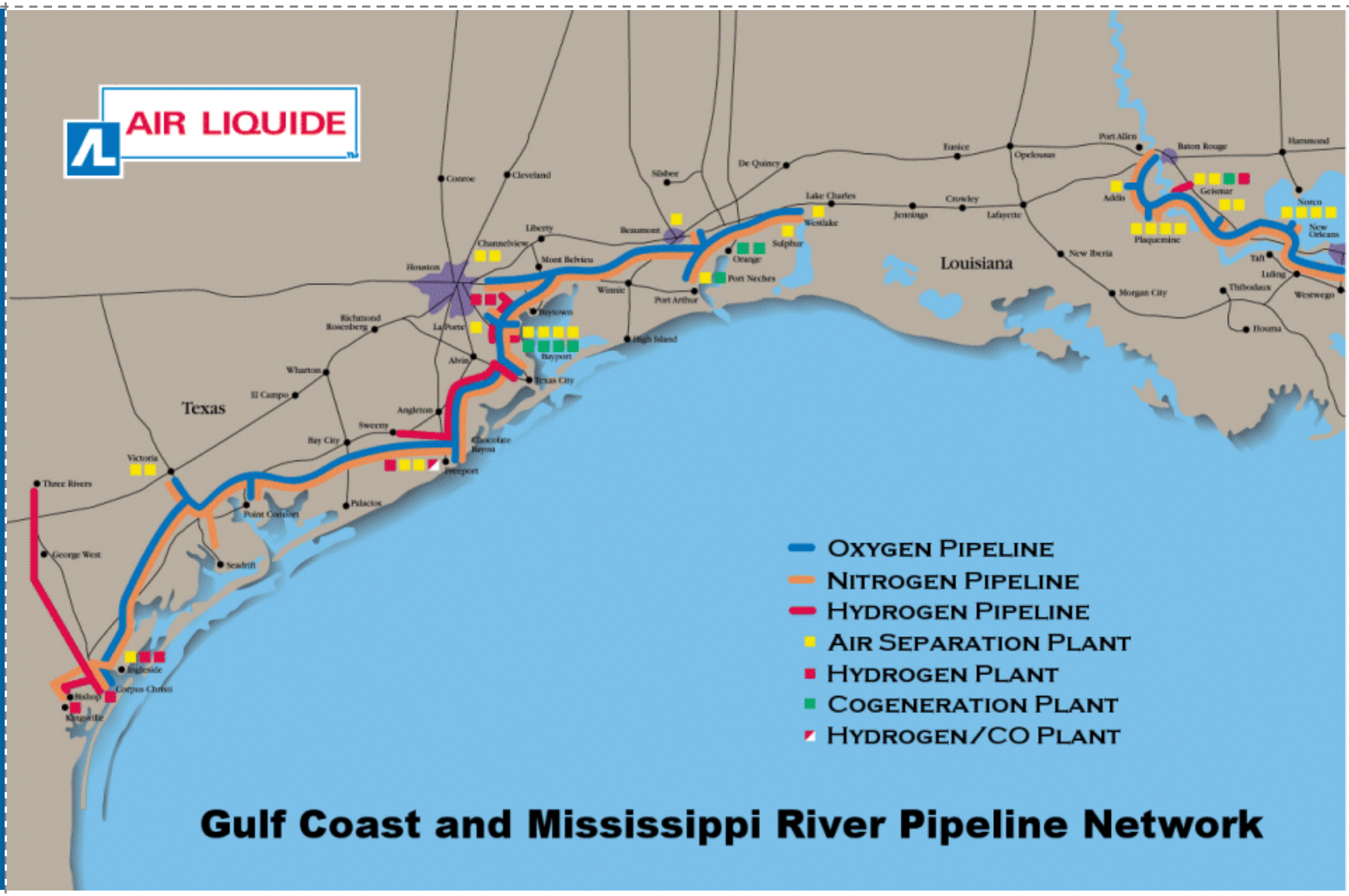
Conversion of Existing Hydrocarbon Pipelines for Hydrogen Service


AIR LIQUIDE
Texas
Louisiana
Houston
Cleveland
Conroe
Liberty
Channelview
Beaumont
Sibbee
De Quincy
Lake Charles
Westlake
Sulphur
Orange
Port Neches
Port Arthur
Winnie
Mont Belvieu
Baytown
Bayport
Texas City
High Island
Alvin
La Porte
Richmond
Rosenberg
Wharton
El Campo
Angleton
Sweeny
Bay City
Victoria
Three Rivers
George West
Seadrift
Point Comfort
Palacios
Chocolate Bayou
Freeport
Ingleside
Corpus Christi
Bishop
Kingsville
Eunice
Opelousas
Jennings
Crowley
Lafayette
Port Allen
Baton Rouge
Addis
Geismar
Plaquemine
New Iberia
Morgan City
Houma
Thibodaux
Lutling
Taft
Norco
New Orleans
Hammond
Westwego
OXYGEN PIPELINE
NITROGEN PIPELINE
HYDROGEN PIPELINE
AIR SEPARATION PLANT
HYDROGEN PLANT
COGENERATION PLANT
HYDROGEN/CO PLANT
Gulf Coast and Mississippi River Pipeline Network

Build VS. Buy

AIR LIQUIDE

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?
- **Risk concerns** – wall thickness, location, population

U.S. Pipeline Inventory

- 483,000 Km. Natural Gas Transmission
- 217,000 Km. Oil & Products Transmission
- 45,000 Km. Natural Gas Gathering
- 34,000 Crude Oil Gathering
- Diminishing oil production, many underutilized lines
- Oil pipelines more available than natural gas

Evaluation – 7 Steps

1. **Technical Documentation & Service History**
2. **Review of Legal Documentation** - Easements & Permits
3. **Visual Inspection** - walk the route
4. **Physical Inspection** - C.P. readings, depth of cover
5. **External Inspection** - excavate, check wall thickness
6. **Internal Inspection** - pressure test, “smart pig” inspection
7. **Risk Evaluation based on above data**

Documentation and Legal

- **Purchasing Data** –pipe specs., welding specs, when built
- **Mill test reports** – chemistry, tensiles, charpy impact
- **Service History** – oil, gas, contaminants
- **Annual Cathodic Protection Survey** – 850ma?
- **History of leaks and repairs**
- **Integrity Management data** – hydrotest, internal inspection
- **Easements** – product specific?

Metallurgical Evaluation

- Original certificates may be missing
- Pipeline may be in service
- On-line techniques > hot tap coupon, P.M.I. methods
- Need chemistry, tensiles, Charpy Impact data

Valves and Flanges

- Oil and natural gas valves may not hold hydrogen
- Replace flange connections with butt welds where possible
- Refurbish valves, refinish old flange faces
- Minimize compression tube fittings

Pressure Test and Internal Tool Inspection

- Hydrotest usually required for change of service
- Tool inspection required if pipeline condition is a concern
- Need to know minimum wall thickness for MOP

Risk Evaluation

- Acquire a population count along the route
- Evaluate potential damage from fire and detonation
- Risk calculations may indicate need for mitigation measures
- Metallurgy may require de-rating MOP <30 SMYS ?

Carbon Steel Properties for H2

	2005 IDEAL	1970's API 5L	1940's Grade B
Hardness	<250 HB	225	*178*
Carbon Equivalent	<0.43	0.63	0.325
Grade	<X56	*X60*	*Gr.B*
Sulphur	<0.01%	0.03	*0.036*
Phosphorus	<0.015%	0.03	*0.011*
Charpy Impact	>35J	>27J	6J
Heat treatment	**Normalized**	NA	NA

Conclusion

- Existing pipelines have been successfully converted to H2
- Needs careful metallurgical and risk analysis
- Cost is far lower than building new
- Conversion will be a major factor in the H2 infrastructure

Jim Campbell

Manager, Pipeline Construction

Air Liquide Process & Construction

Jim.campbell@airliquide.com