



**DOE Hydrogen Pipeline
Working Group Workshop**

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Hydrogen Pipeline Experience

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Hydrogen Pipeline – Scope of Presentation

- **Only those systems that are regulated by DOT in the US, DOT delegated state agency, or other federal regulatory authority.**
- **Cross property of third party and/or public properties for delivery to customers.**
- **Does not include in-plant or in-house hydrogen piping.**
- **Does not include piping (aboveground or underground) that delivers to a customer if all property is owned and controlled by Air Products and the customer.**

Pipeline Photos



**Concrete coated pipeline with floats
in Taft, Louisiana**

Pipeline Photos



Hydrogen pipeline - Mississippi River Crossing

Pipeline Photos



Multiple pipeline trench - Baytown, TX

Pipeline Photos



Horizontal bore of railroad

Pipeline Photos



Overview of North American Air Products Hydrogen P/L Systems

- **Approximately 350 miles of Hydrogen Pipelines in North America**
- **Major systems located in Texas, Louisiana, and California.**
- **These major networks account for 340 miles of the above total.**
- **Operating and maintaining portions of these systems since 1970.**
- **Currently developing two systems in Canada; one in Alberta and one in Ontario.**

Air Products H₂ P/L System – *West Gulf Coast*

- **System has numerous production facilities serving many customers in the PetroChemical and Refining Industry.**
- **System extends from Laporte, TX to near Lake Charles, LA.**
- **This system has approximately 228 miles of DOT regulated H₂ pipeline.**
- **Portions of this system operating since early 1970.**
- **Pipeline size is principally 8” and 10”.**

Air Products H2 P/L System – Louisiana

- **System is made up of two separate segments; one near New Orleans and the second extending from Plaquemine, LA to Taft, LA**
- **System has numerous production facilities serving many customers in the PetroChemical and Refining Industry.**
- **This system has approximately 100 miles of DOT regulated H2 pipeline.**
- **Portions of this system operating since early 1983.**
- **Pipeline size is principally 6”, 8”, and 12”.**

Air Products H2 P/L System – California

- **System has two production facilities serving numerous customers in the Refining Industry.**
- **System is located in the Los Angeles Basin and a portion is located in DOT Class 4 location.**
- **This system has approximately 12 miles of DOT regulated pipeline.**
- **Transportation agreement for additional 4 miles.**
- **Air Products has been operating portions of this system since 1995. A part of this system was acquired from others who operated it in hydrogen service since 1982.**
- **Pipeline size is principally 6”, 8”, and 10”.**

Overview of Worldwide Air Products Hydrogen P/L Systems

- **Additional existing networks in multiple worldwide locations.**
 - Rotterdam
 - Brazil
 - Thailand
 - Indonesia
 - South Africa
- **These networks total approximately 100 miles in length and in some cases multiple systems are contained within a network.**

Pipeline Standards and Regulations

- **CFR 49 Part 192 and as amended by delegated state agency.**
- **Air Products standards employ minimum design to Class 3 location except for very remote unpopulated areas and typically exceed the requirements of Part 192.**
- **Environmental Impact Studies designate additional design considerations.**
- **Local jurisdictions (City, Township, Parish, County, etc.) have imposed additional requirements beyond basic regulatory requirements.**

Typical Designs for Air Products Hydrogen Pipeline Systems

- Pipe sizes 4 to 12 inch diameter.
- Minimum depth of Pipeline is 3 feet (In most cases 4 feet).
- Operating pressures between 350 and 1900 Pounds per Square Inch (PSI).
- All current systems constructed using steel pipe.
- Majority of pipelines have operating stresses limited to 30% of SMYS (Specified Minimum Yield Strength).
- Routing of hydrogen pipelines carefully considered and include proprietary Risk and Consequence Analysis.
- Extensive use of automated EFV's (Excess Flow Valves). In excess of 30 EFV's in operation today.

Excess Flow Valve (EFV)



Pipeline Materials of Construction

- **Hydrogen pipelines constructed by Air Products have utilized carbon steel pipe with corrosion protective coatings.**
 - **Mild strength steels – API 5L X42 or X52**
 - **Weld procedures developed to API 1104 -
Typically SMAW with low hydrogen weld rods
100% radiography of all welds
Limit the hardness in the heat affected zone
Normally, PWHT is not needed to achieve acceptable weld hardness**
 - **Line pipe primarily coated with FBE although other coatings have been utilized for abrasion resistance.**
 - **These materials have been utilized by Air Products for hydrogen pipelines since 1970.**

Basis of Material Selection

- **Hydrogen gas can cause hydrogen embrittlement (HE) of steels.**
- **Best known, most studied HE service is wet H₂S (sour service) in the petroleum and petrochemical industries.**
- **NACE developed a standard (MR 0175) on the selection of metals in H₂S service in 1970's and this standard is recognized worldwide.**
- **MR 0175 allows use of carbon steel in wet H₂S service as long as the hardness is no more than 22 HRC.**
- **Applying the relationship between hardness and tensile strength this indicates a maximum tensile strength of 115 ksi.**

Basis of Material Selection (cont'd)

- **Based on MR 0175, as long as the hardness is less than 22 HRC or the tensile strength is less than 115 ksi, the steel will not suffer wet H₂S cracking or HE.**
- **Air Products believes that MR 0175 describes a much more severe HE environment than any of Air Products H₂ pipeline systems.**
- **Air Products material selection is based on the interpretation that if we adhere to MR 0175 hardness/strength criteria we will not be subject to HE.**
- **The use of the lower strength steels has not been a cost hindrance since Air Products employs a conservative approach with wall thickness because of concern of third party damage.**

Pipeline Operating Parameters

- **The pressure in Air Products hydrogen pipelines remains basically constant with minor fluctuations based on customer demand.**
- **Pipe size, compression equipment, valves stations, and custody metering stations determine flow capacity in the pipeline systems.**
- **Pipelines are monitored from central control location for each major system. Operators view live data from custody metering stations, production units, and EFV stations.**
- **Remote shutoff capability from these central control locations.**

Pipeline Maintenance

- **All preventive maintenance is performed in accordance with DOT 192 requirements.**
- **Air Products has not to date performed internal inspection of any of the H2 pipeline systems.**
- **Our systems are complex and were not designed to incorporate pigging at regular intervals.**
- **Since the H2 product in the pipelines is pure and dry there is little risk of internal corrosion.**
- **Air Products is basing its integrity management program on direct assessment techniques that are recognized in DOT 192 and ANSI B31.8S.**

Pipeline Conversion Experience

- **Air Products has converted a liquid products pipeline (DOT 195) that was built in the 1940's into H2 service.**
- **After extensive studies on the metallurgy of the pipeline Air Products decided to proceed with a project to convert the pipeline.**
- **Metallurgy experts had concerns over the composition of the 1940's carbon steel pipe material and the pipe manufacturing process.**
- **Extensive research was completed to understand the history of the pipeline and any previous replacement work. This included removal of pipeline segments for laboratory analysis.**

Conversion Experience (Cont'd)

- **Air Products developed a plan to replace pipe in sensitive areas and perform additional hydro testing of the existing pipeline.**
- **The plan included extensive legal review of the existing ROW documents.**
- **The key to successful implementation of the conversion plan was to follow all the recommendations of our proprietary Risk and Consequence Study.**
- **Numerous EFV's were installed in the pipeline system to limit exposure to 3rd parties.**

Conversion Experience (Cont'd)

- **A reduction in the allowable pressure was required and therefore a pressure reduction station and additional pipeline safety valves were installed.**
- **Air Products has converted two segments of this pipeline and has operated the first converted segment for more than 10 years.**
- **Air Products has no direct experience of converting Natural Gas pipelines into H2 service.**

Pipeline Cost Data

- **Cost of H2 pipeline installation is very dependent on the location (State, rural, street, etc.).**
- **Air Products cost data base is limited to construction of what is considered short lengths in the pipeline industry.**
- **ROW costs are variable and can add significant costs to a project.**
- **All Air Products H2 pipelines are private carrier status.**
- **Environmental permitting is having the biggest impact on pipeline cost at this time.**

Conclusion

- **Air Products has operated H2 pipelines since 1970 without a single pipeline incident that has caused injury to our employees or the general public.**
- **Air Products testified before US Congress in 2002 regarding its philosophy of systematically analyzing the risks and consequences and employing design and operating standards that exceed federal regulations.**
- **The Industrial Gas Community in association with the CGA and EIGA recently developed and published a document (CGA G-5.6) that compiles the collective safe experiences and practices for Hydrogen Pipeline Systems.**
- **Thank you for this opportunity to present this information regarding Air Products experience with H2 pipelines.**



Thank You !!!