

Blending of CNG with Hydrogen

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Hythane[®] Background

- Invented in 1989 by Frank Lynch and Roger Marmaro
- Studies and demonstrations through 1990s
- By 2003 extensive testing validated the “sweet spot” for heavy-duty Hythane[®] engines at 7% H₂ by energy (20% by volume)

California 2003

Montreal 1995



Hythane Summary

- 50% less NO_x with 7% H₂ by energy
- Improvement from Euro II (CNG) to Euro IV (Hythane) emissions reduction demonstrated in 2005
- Inexpensive and available now
- Reasonable range compromise
- Reasonable infrastructure costs
- Creates distributed hydrogen infrastructure
- Hythane System includes everything needed for reliability, safety, and carbon credit documentation

Hydrogen Properties

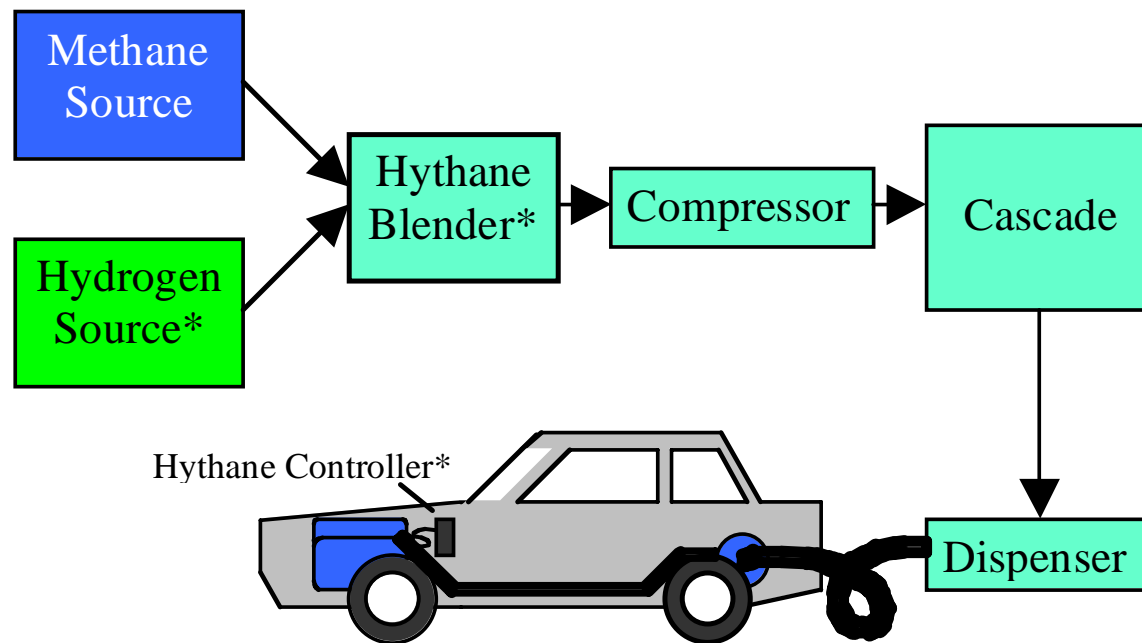
- Wide flammability range, more than 6 times wider than methane.
- Low ignition energy, about 20 times less than methane.
- High flame speed, about 8 times faster than methane.
- Powerful reducing agent and combustion stimulant

Hydrogen Sources

- Electrolysis and other 'exotic' water splitting
- Biological digestion - methane, too
- Industrial waste streams
- Gasification and reforming

Blending Low-Pressure Gaseous Methane and Hydrogen

Simplified Hythane Fuel Supply

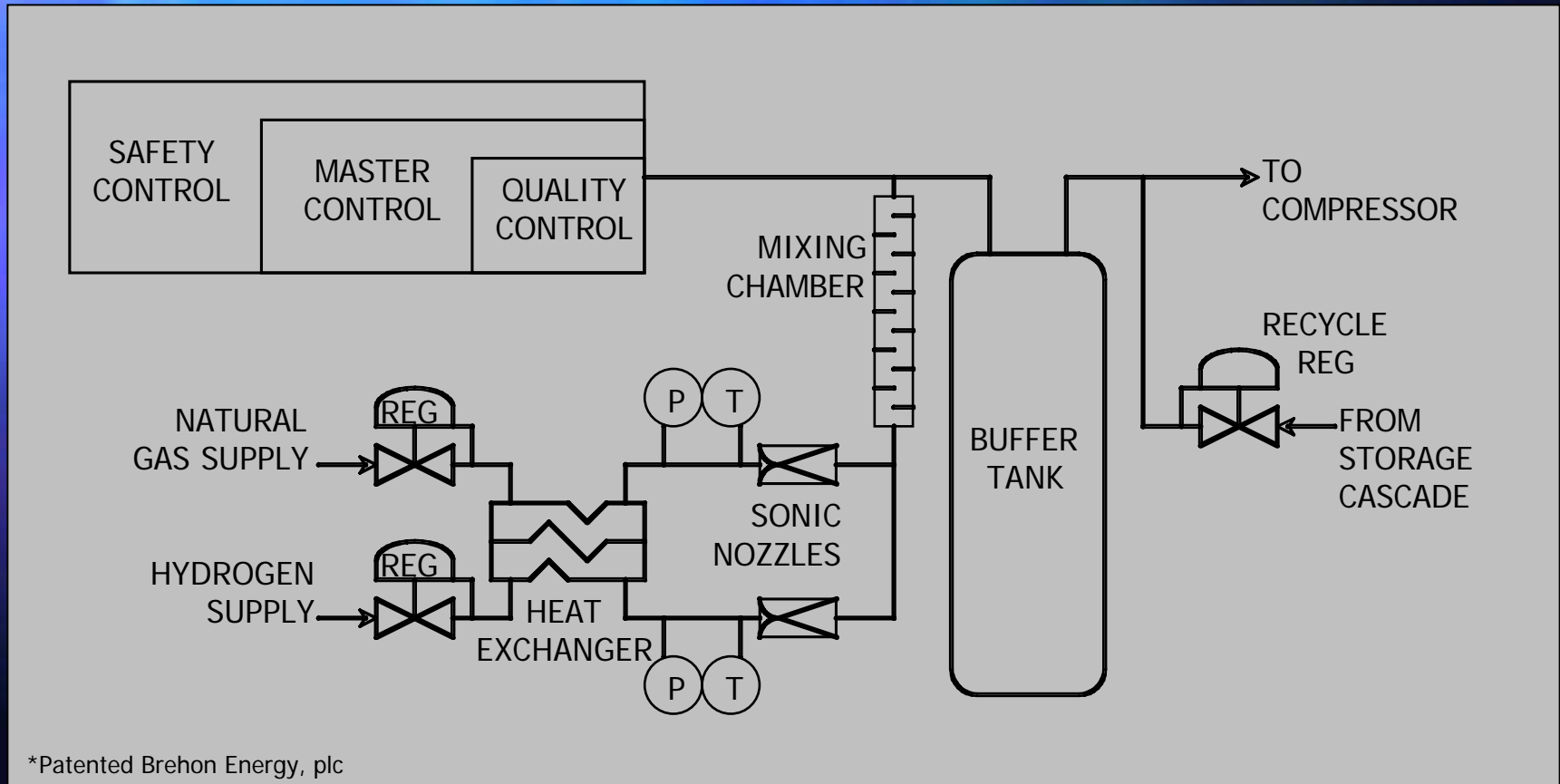


* Denotes additions to a standard CNG system

Blending Low-Pressure Gaseous Methane and Hydrogen

- As gases, hydrogen and methane are completely miscible
- Simple fluidic blending schemes provide the lowest-cost Hythane solution
- No additional moving parts added to conventional CNG compressor stations
- Only electronic devices are for supervision and quality control

Blending Low-Pressure Gaseous Methane and Hydrogen*



Blending Low-Pressure Gaseous Methane and Hydrogen

Hythane Company's blender (50 cfm capacity)



Compressor
(10 cfm
capacity)



Colorado
facility

Blending High-Pressure Gaseous Methane and Hydrogen

- Pumped LNG (LCNG)
- CNG or LNG, hydrogen, and Hythane all dispensed at one station
- Maintenance issues
- Quality control issues

Cryogenic Storage of Methane and Hydrogen Blends

- Homogeneous mixtures of liquid methane and hydrogen are not normally possible
- Brehon has patented a method using NASA perfected cryogenic storage techniques for mixing and storing a mixture of LNG and hydrogen
- Storage density is much higher than compressed gas mixtures, at much lower pressures

Hythane System

- Natural Gas Supply and Equipment
- Hydrogen Supply with Contingency Plan
- Failure Modes and Effects Analysis
- Hythane Blending with Quality Control
- Wireless Vehicle-Dispenser Communications
- Data Logging Service for Fleet Managers (Carbon Credit Documentation)
- Resource Optimization Software
- Optimized Engine Controllers with CNG Fallback