

# Demonstration of Hydrogen As A Viable Fuel in Underground Mines

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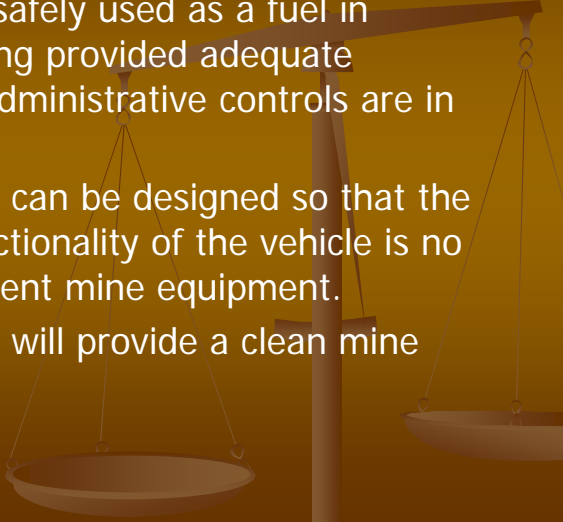
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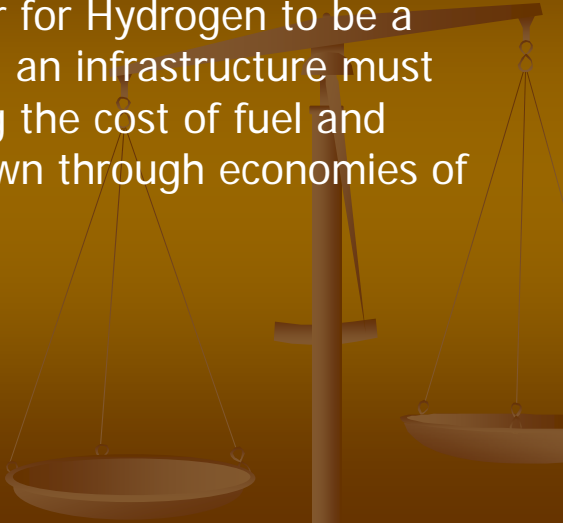
## How Can Hydrogen Become a Viable Fuel?

- The Risks of using H<sub>2</sub> must be managed.
- Vehicles using H<sub>2</sub> must be as Productive and Flexible as diesel equipment.
- The Benefit of using H<sub>2</sub> must be substantial.
- The Cost of conversion from diesel must be justifiable.

## The Goals of the Demonstration

- Hydrogen can be safely used as a fuel in underground mining provided adequate engineering and administrative controls are in place.
  - Hydrogen vehicles can be designed so that the operation and functionality of the vehicle is no different than current mine equipment.
  - Hydrogen vehicles will provide a clean mine atmosphere.
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## What the Demonstration Did Not Address

- COST – In order for Hydrogen to be a truly viable fuel, an infrastructure must develop to bring the cost of fuel and components down through economies of scale.
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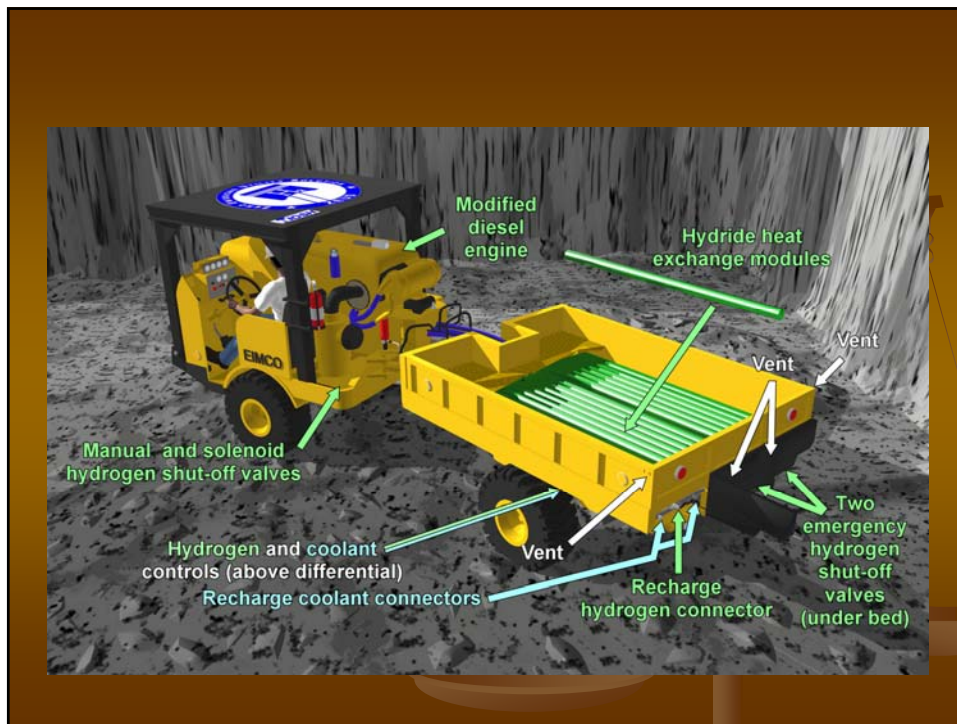
## The Demonstration Vehicle "ZEUS"



- EIMCO 975, 4 WD, 5 ton articulated truck
- CAT 3304, 70 KW Engine
- Parallel Induction and Spark Ignition Conversion
- Turbo Boost & After-cooler added.
- 8 Kg H<sub>2</sub> capacity
- Metal Hydride Storage
- Waste heat from engine and exhaust used to liberate H<sub>2</sub>

## Safety Systems & Controls

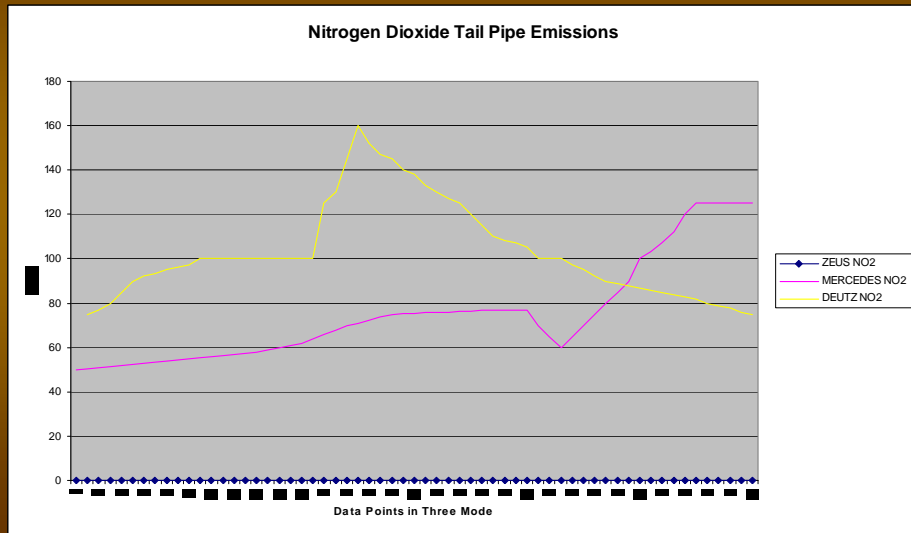
- Linear Fire Detection along entire fuel path
- Hydrogen Sensors in all enclosed areas with fuel lines – set to alarm at 25% LFL
- Collision sensor set to alarm at 8G in horizontal plane
- Fuel System over and under pressure alarm
- All Alarms result in engine shutdown, visual and audible alarm and isolation of fuel system.



## Ventilation Requirements

- Ventilation is needed to replace oxygen consumed by the engine and control the risk of Fire/Explosion from a catastrophic failure of the fuel storage system.
- Engine O<sub>2</sub> Consumption Requires ~5,000 CFM to maintain >20% O<sub>2</sub>.
- Potential catastrophic release requires 14,000 CFM to maintain H<sub>2</sub><LFL or, 5,000 CFM to maintain H<sub>2</sub><LEL
  - Mine Testing found the fuel supply could be reformulated to bring LFL requirement down to 5000 CFM

## Eliminates Toxic Emissions



## Operational Functionality

- 90 Hrs operating at Mine Site
- Wide Range of Duty Conditions
- Fuel Economy mirrored diesel consumption for fuel value
- Operating range on 8 kg (~25 liters diesel equivalent):
  - 20 km climbing 10% grades fully loaded
  - 100 km rolling terrain at 30 km/hr

## Hauling 4 Tons of Raise Bore Steel

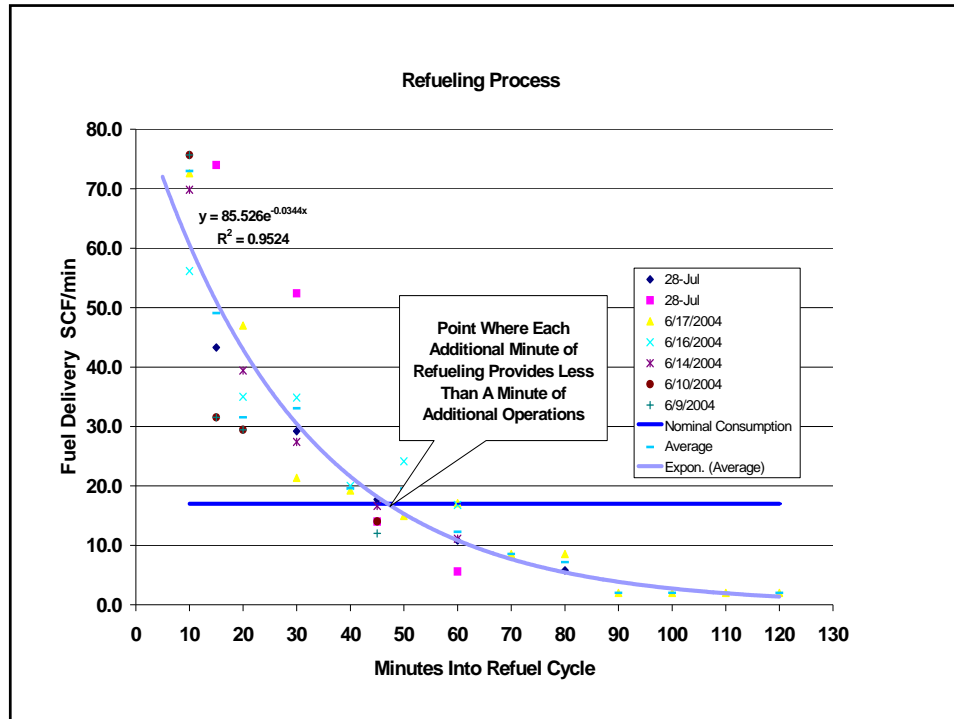


## Refueling

- Fuel Supplied from 100,000 scf Tube Trailer
- "Off the Shelf" CNG connections used
- Refueling Process Simple but Slow



Practical capacity of Metal Hydride ~75% of Absolute Capacity due to time .



## The Opportunities (Problems)

- Metal Hydride Storage system developed fatigue leaks in coolant jacket after ~ 1000 total hours of operation. – Repaired but design could be more robust
- An economical means to estimate the remaining fuel supply is needed. – Counting Engine Revolutions is too crude.
- Hydrogen Sensors need protection from dust and moisture.
- Hydride Formulation should minimize low temperature and pressure hydrides to reduce ventilation rates.
- For Combustion Applications, better fuel/air control is needed to improve efficiency.

## The Next Step

- NIOSH is looking for opportunities to continue refinement of the vehicle safety systems.

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