TECNOVERITAS®

Dedicated to innovation

An Hydrogen Fuelled Car

A TecnoVeritas Technology

White Paper

April 2010

The Hydrogen Properties

Density: 0.0899 kg/Nm^3 (gaseous); 0.0708 kg/dm^3 (liquid)
Boiling Point: 20.28 K
Melting Point: 14.02 K
Calorific Value: under 120 MJ/kg, higher 141.86 MJ/kg
Specific heat: Cp=14.99 J/(kgK), Cv=10.074 J/(kgK)

It is colorless, odorless and insipid;
It is not: toxic, contaminant, corrosive, radioactive and cancerous.
When used properly it is a fuel as safe as the other conventional fuels.

Hydrogen Energy

H_2 Mass [kg]	H_2 gaseous [Nm^3]	H_2 Liquid [kg]	Energy [MJ]	Energy [kWh]
1	11.12	14.12	120	33.33
0.0899	1	1.270	10.8	3.00
0.0708	0.788	1	8.495	2.359
0.00833	0.0926	0.1177	1	0.278
0.0300	0.333	0.424	3.6	1

Comparison with Other Fuels

	Hydrogen	Gasoline	Methane
Lower Heating Value (kJ/ Nm^3)	120	42	50
Gas Density (kg/ Nm^3)	0.090	-	0.72
Gas Energetic Density (MJ/ NM^3)	10.8	-	35.8
Liquid Density (kg/l)	0.071	0.73	-
Liquid Energetic Density (MJ/ Nm^3)	10.8	31.8	-
Flammability Limit (%)	4.75	1-8	5-15
Detonation Limit (%)	18.59	1.3	6-14
Minimal Activation Energy (mJ)	0.02	0.24	0.29
Flash Point	858	~600	813
Emissions ($mgCO_2/kJ$)	0	~80	~55
Toxicity	No	Yes	Yes

Other Interesting Values

1 kg of H_2 equals:
2.78 kg of gasoline
2.80 kg of diesel fuel
3 kg of natural gas

1 liter of H_2 liquid equals:
0.268 liters of gasoline
0.236 liters of diesel fuel

1 liter of H_2 (@ 350 bar) equals:
0.10 liters of gasoline
0.09 liters of diesel fuel
0.3 liters of natural gas (350 bar)

Electrolysis

An electrolyser with a performance of 85%, that produces 10 Nm3/h, has a consumption of 35.29 kWh and consumes 8.091 kg/h of water.

The TWINGO project driving ideas

Hydrogen should ideally be produced from a renewable source of electricity, originating a "green" utilization, with CO_2 emissions below 0.5 g/km.

Technologies available using Internal combustion engines

Low pressure: Otto Cycle, HCCI single or multi point injection in intake manifold, or low pressure direct injection;
High pressure: Diesel like late cycle direct injection with ignition assist; Diesel Pilot; Hot surface; Direct injection; Spark ignition; Injection into plasma.

Why the TWINGO project?

Hydrogen of Interesting Properties For ICE´s

Low ignition energy (1/10 of that for gasoline).
High flame speed (9 times that of gasoline).
Very broad flammability range (allowing unique potential for emissions control).
Lower volumetric energy density/high speed of sound.

Img 1 | The Twingo, a car fuelled by hydrogen

Hydrogen Engine Characteristics

Tendency to pre-ignite during compression.
Very fast burning rates.
Very low temperature combustion possible - Low NO_x.
Fuel injection system requires ~20% larger flow area as compared to CNG
For external mixing of fuel: Theoretical loss of up to 30% air flow due to volumetric displacement by H_2 in intake manifold/cylinder.

Engine technology roadmap

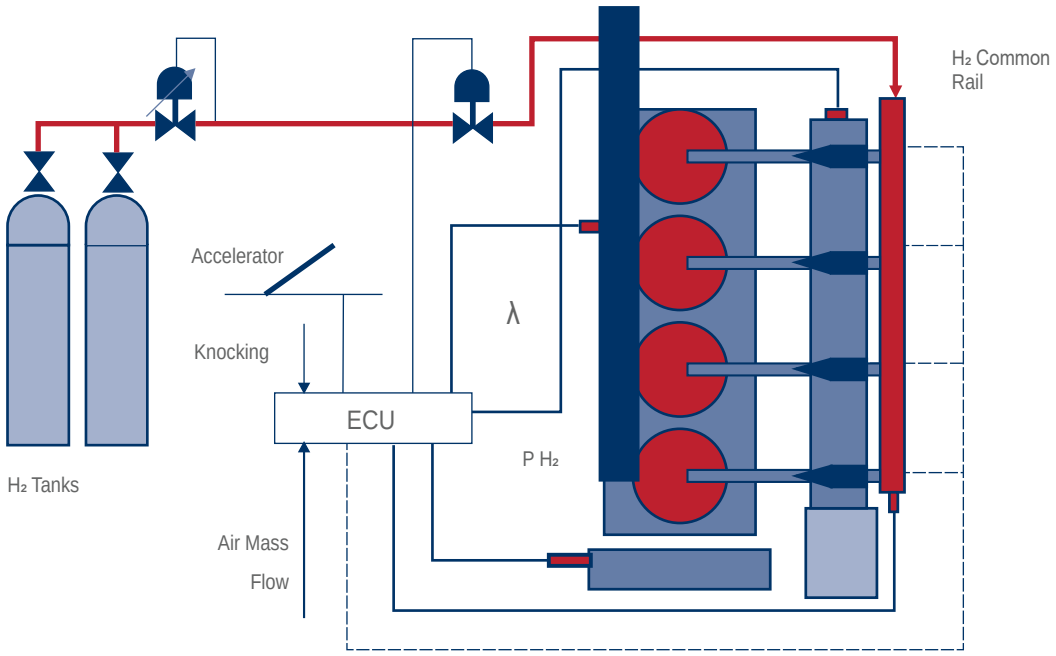
- Internal combustion engines (ICE) are very well developed and increasingly sophisticated;
- Internal combustion Engines can cope with low purity hydrogen, making it cheaper to produce;
- There is a pipeline of efficiency improving technologies that can still be used;
- Adapting high efficiency ICE's to hydrogen/natural gas mixtures or to hydrogen would result in very cost effective power plants for near to medium term.
- ICE development would be part of a long term H_2 roadmap.

TWINGO I.C.E.

Engine Particulars

- Cycle: Otto
- Swept Volume: 1149 cc.
- Maximum Usefull Power: 43 kW
- Maximum Engine Speed: 5250 RPM
- Maximum Torque: 145 Nm
- Electronic Multipoint Petrol Injection;
- Electronic Multiopoint Hydrogen Injection;

TWINGO Hydrogen Injection System



Img 2 | Hydrogen Injection System

Twingo Facts and Questions

Compressed Hydrogen
On board Capacity of H_2= 2 bottles of 10 dm^3@ 300 bar ~ 6 m^3
Millage for 6 m^3= 35 km urban trafic

Liquid Hydrogen
On board capacty of H_2= 1 Tank of 10 dm^3@ -263ºC ~1bar
Millage using full tank of LH_2= 1451 km

1m^3H_2 @PTN = 1.18 dm^3LH_2 (83.76 g @ NBP 20.268 K)
Minimum Liquefaction Work for 1 m3H2= 0.33 kWh (theoretical)
Practical: 1.1 kWh

To produce 1m^3/h from radiation of 1 kW/m^2, it is required a land area of (3.30/ Efficiency of the solar converting system) m^2 for solar collectors.

Assuming that the efficiency of conversion of a photovoltaic pannel system is only 19%, an area of 18.33 m^2 it is required for the production of 1m^3/h of hydrogen.

Assuming a time of production of only 6 hours a day, it would be possible to produce the H_2 required for a daily use of the TWINGO for a trip of 60 km.

Get you home mode: Once hydrogen storage ran out, then TWINGO is automatically changed over to Petrol.

Energy required for production of 1 kg of H_2= 53.354 kWh
Energy required for compression and handling of 1 kg H_2= 2.233 kWh

TWINGO comparative emissions

	Idling	1500 rpm	Hydrogen
Texhaust ºC	80.7	130.0	50.0
O_2 % v/v	8.88	0.94	1.16
CO_2 % v/v	8.89	14.7	0.84
CO % v/v	0.07	0.15	0.016
NO_x mg/m³	2.09	2.31	0.25
Particulate	-	-	0.00

The Twingo Project - Pictures

Img 3 | "Ann Arbour" Refilling Station

Img 4 | Hydrogen Fueled Twingo Emissions

Img 5 | The exhaust is only steam and condensed water!

Img 6 | The Twingo engine