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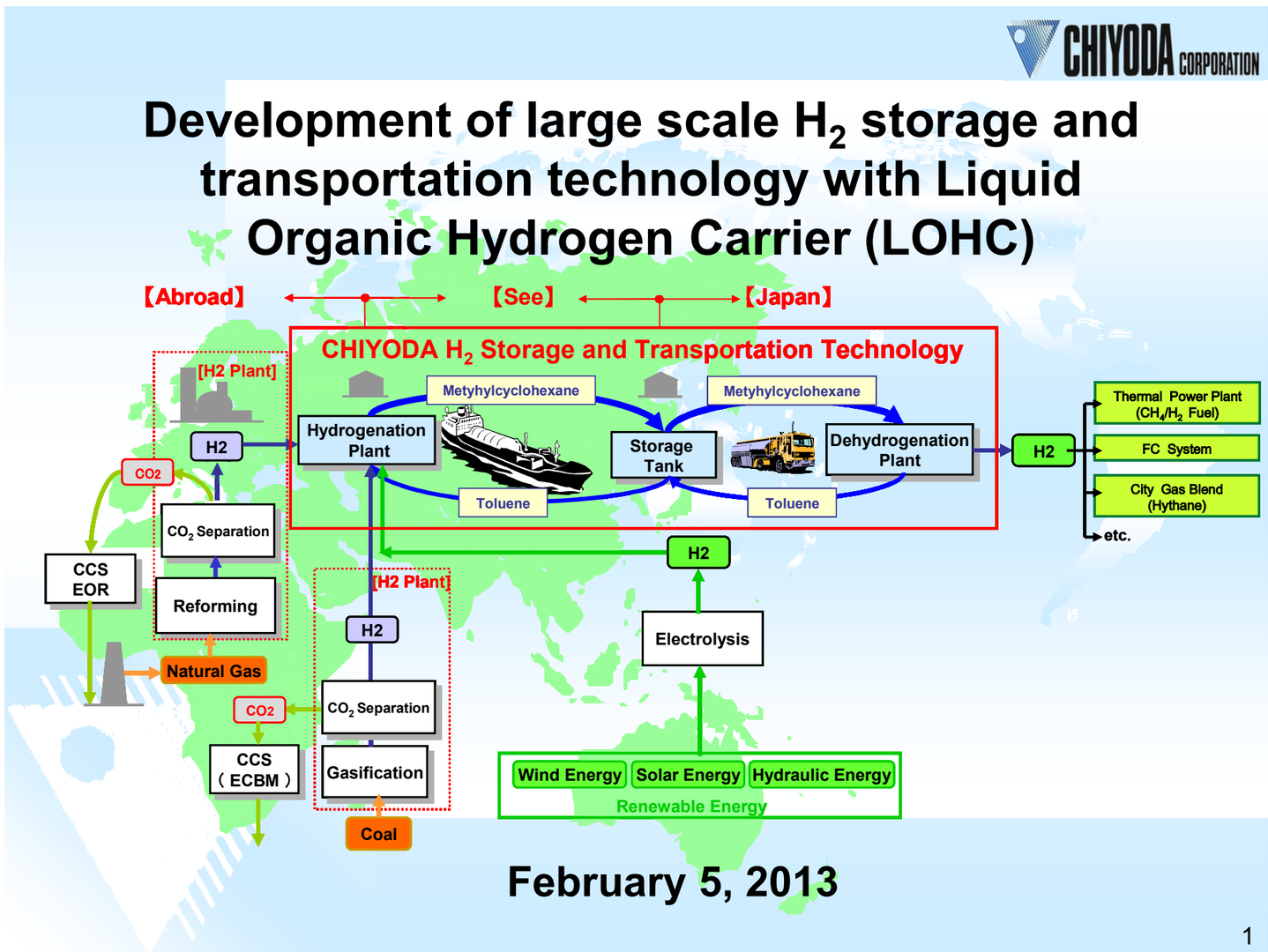
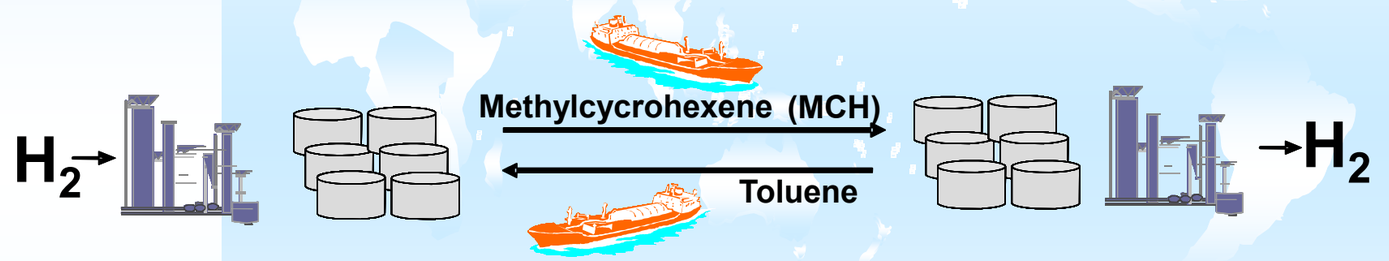
Development of large scale H_2 storage and transportation technology with Liquid Organic Hydrogen Carrier (LOHC)



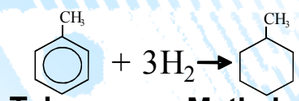
February 5, 2013

Organic Chemical Hydride Method

The Methylcyclrohexene(MCH) is considered one of the safety and economical hydrogen carriers because of the storage and transportation in the liquid phase under the ambient temperature and pressure.



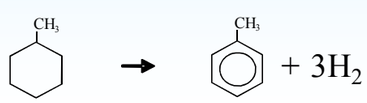
Hydrogenation → Storage → Transportation → Storage → Dehydrogenation



Toluene Methylcycrohexane

Δ H= + 205kJ/mol

Hydrogenation



Methylcycrohexane Toluene

Δ H= - 205kJ/mol

Dehydrogenation

Idea for Global Hydrogen Supply Chain

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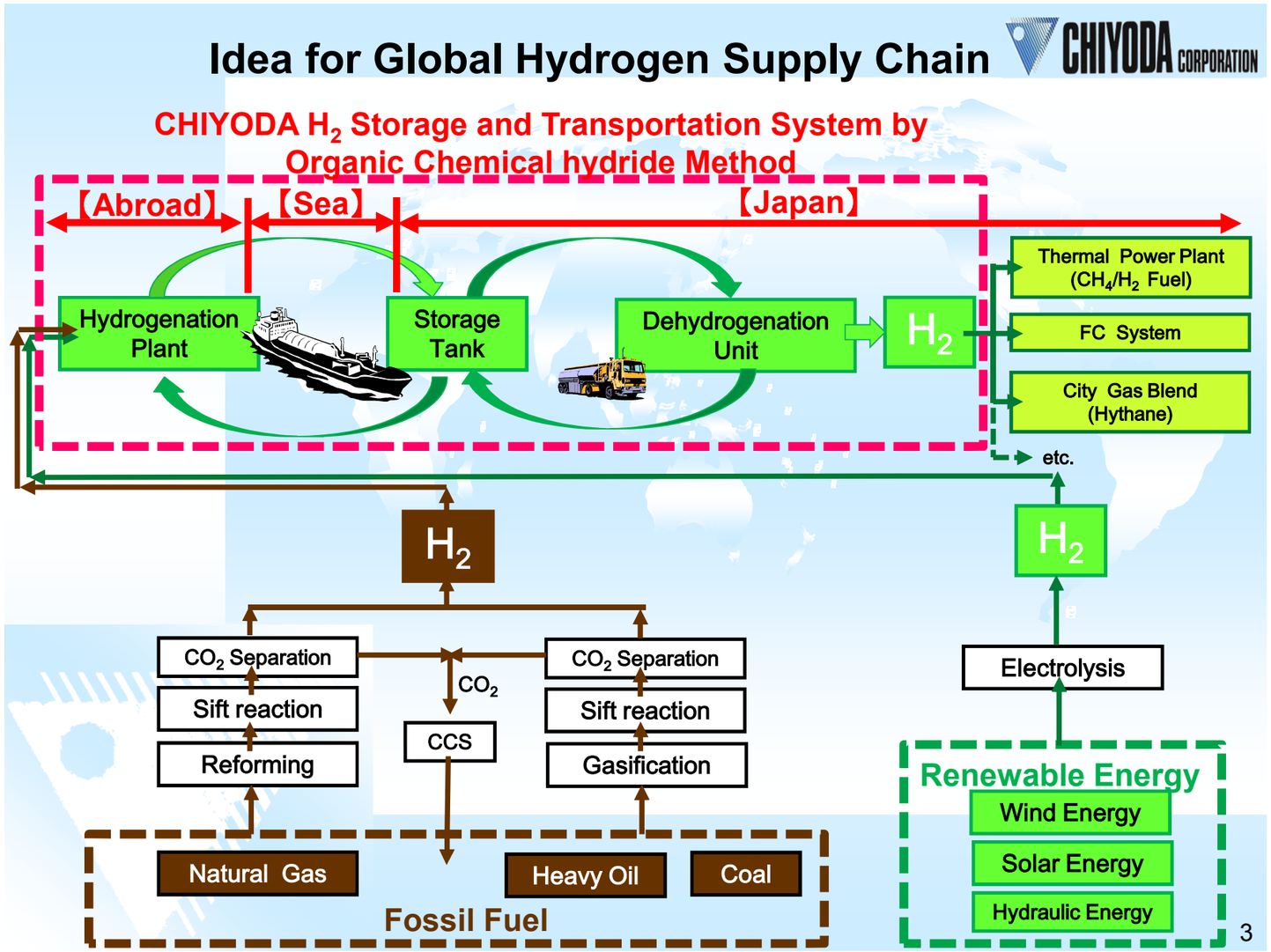

Hydrogen Storage Density

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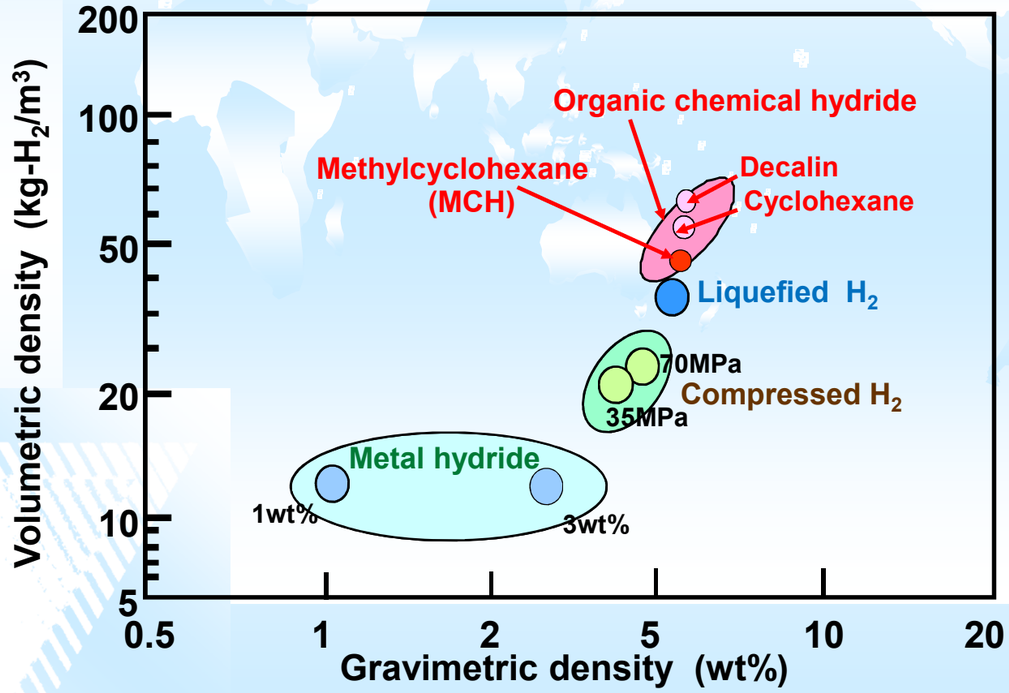
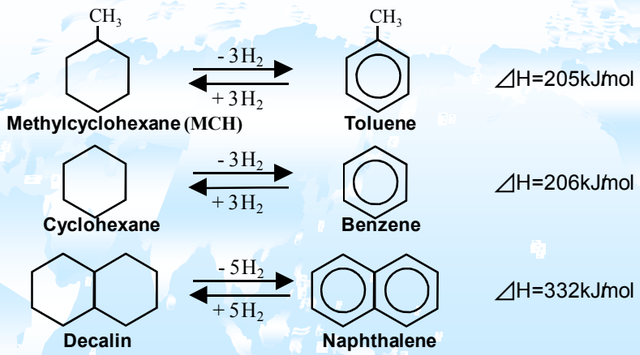
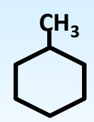
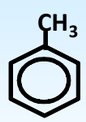
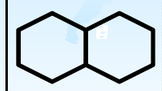
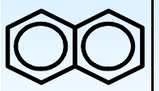
Liquid hydrogen and compressed hydrogen system have been proposed for the hydrogen transport and storage method. But in these systems, the very low temperature of around minus 250℃ or the high pressure of about 35MPa are required respectively.



Note: In the calculation of the gravimetric density, weight of container to storage liquid and compressed hydrogen is considered.

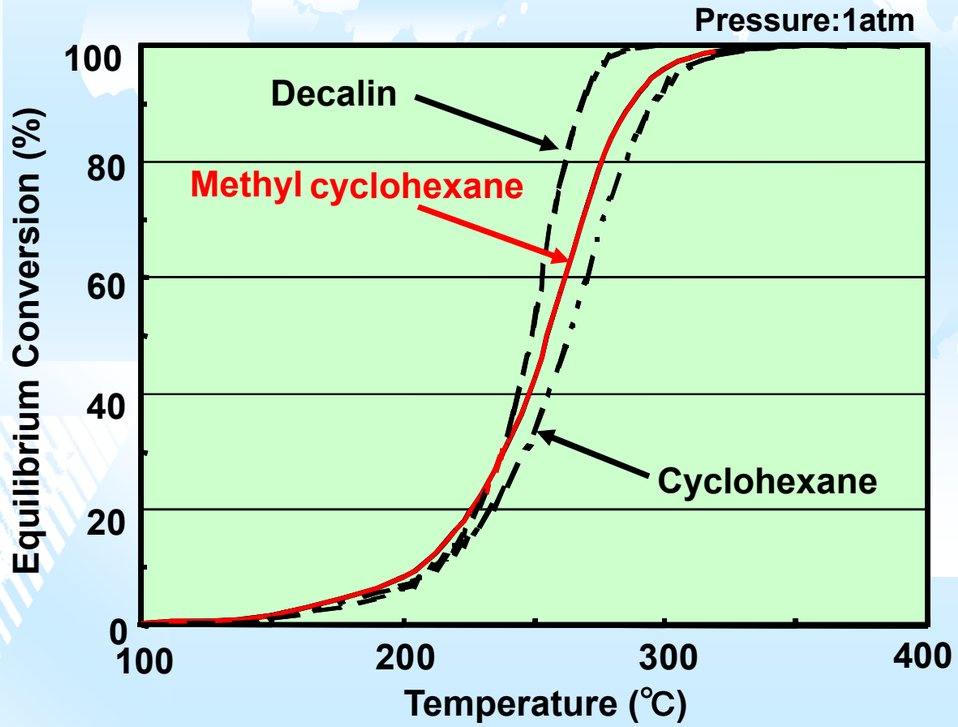
Comparison of Organic Chemical Hydride System



Property \ Organic Chemical Hydride System		MHC and Toluene System		Cyclohexane and Benzene System		Decaline and Naphthalene System	
		MHC	Toluene	Cyclohexane	Benzene	Decalin	Naphthalene
Chemical Formula							
Molecular Weight		98.19	92.14	84.16	78.11	138.3	128.2
State at room temperature		liquid	liquid	liquid	liquid	liquid	Solid
Density	(g/cm^3)	0.769	0.867	0.779	0.874	0.896	0.975
Melting Point	(℃)	−127	−95	6.5	5.5	−43.0,−30.4	80.3
Boiling Point	(℃)	101	111	81	80	194.6,186	218
Hydrogen Storage Density	(wt%)	6.2		7.2		7.3	
	(kg-H_2/m^3)	47.4		56		65.4	

Reaction Equilibrium for Dehydrogenation

To get 100% conversion of MCH, the reaction temperature should be set higher than 300℃. And the external heat supply for endothermic dehydrogenation reaction is required.



Characteristics of Dehydrogenation Catalyst

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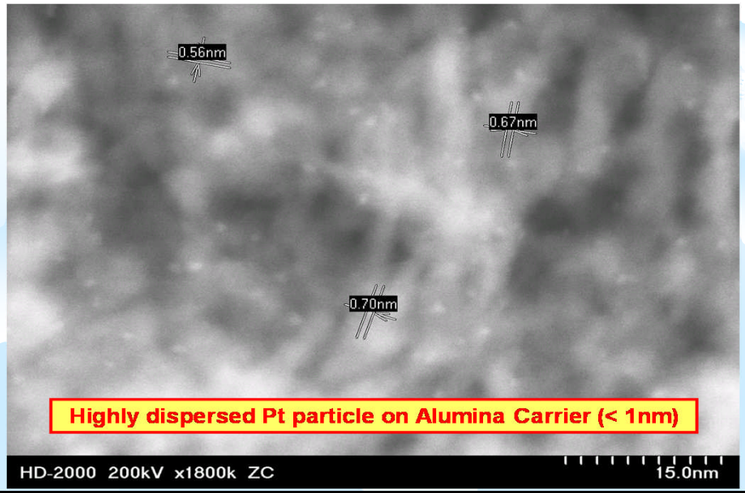
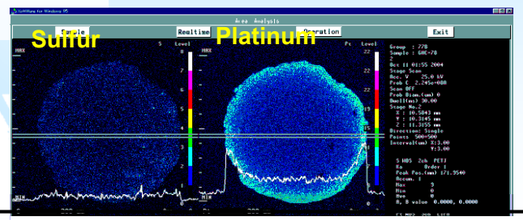
1.STEM Image

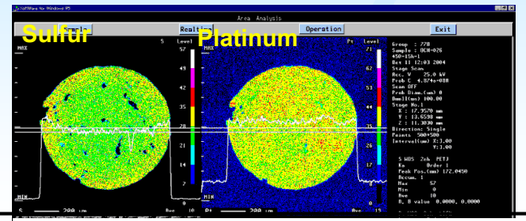


2.EPMA Observation

1）Ordinary egg shell type Pt/Al_2O_3 cat.



2）Developed Pt/Al_2O_3 cat. is uniform type



From the STEM image, it is observed that platinum clusters which have the size around 1nm are highly dispersed on alumina carrier.
Small amount of sulfur compound is intentionally added in the alumina support for our catalyst preparation.
As shown in EPMA analysis the sulfur compound is uniformly distributed with platinum.

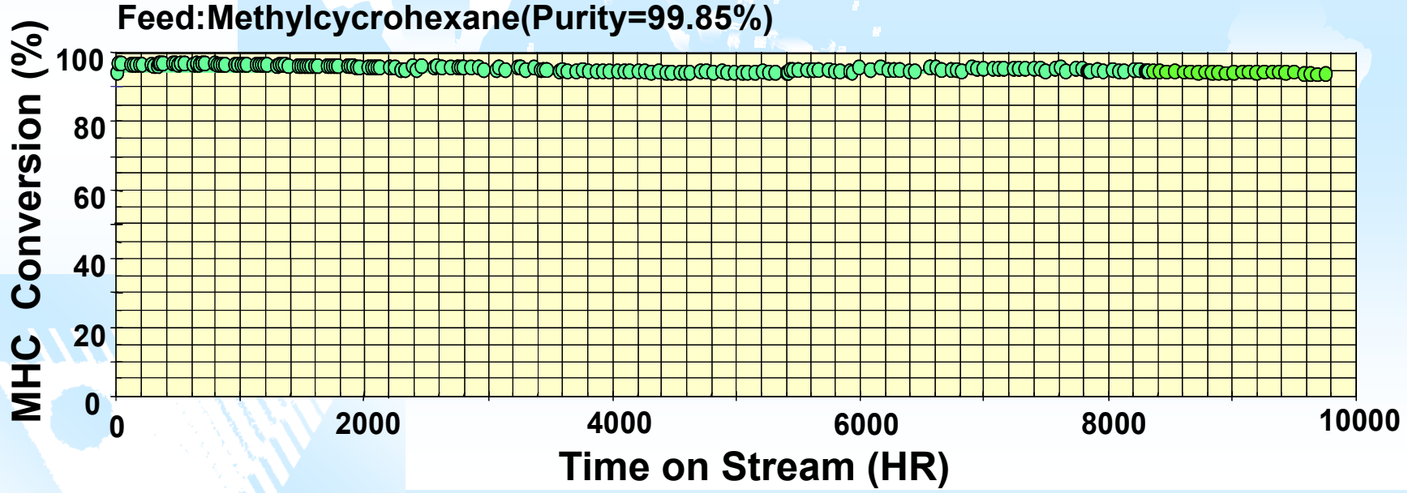
Results of Catalyst Life Test

Reaction Conditions

Temperature: 345→351℃
Pressurea : 0.3MPa
LHSV: 2.0h^{-1}
Feed:Methylcycrohexane(Purity=99.85%)

Catalyst performance

MCH Conversion: >95%
Toluene Selectivity : >99.9%
Catalyst life : > 8,000 (1year)



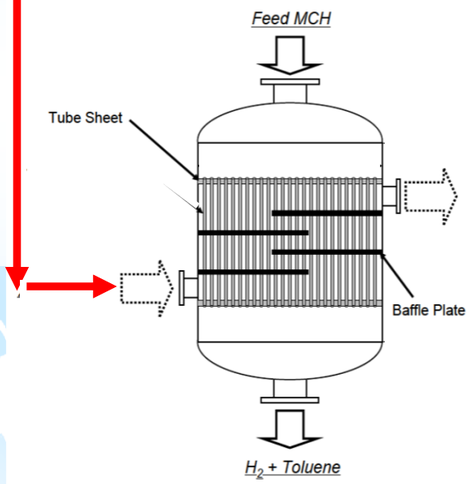
Idea of Hydrogen and Natural Gas Co-firing System for Power Generation

The external heat supply for dehydrogenation reaction is required to get hydrogen from MCH,

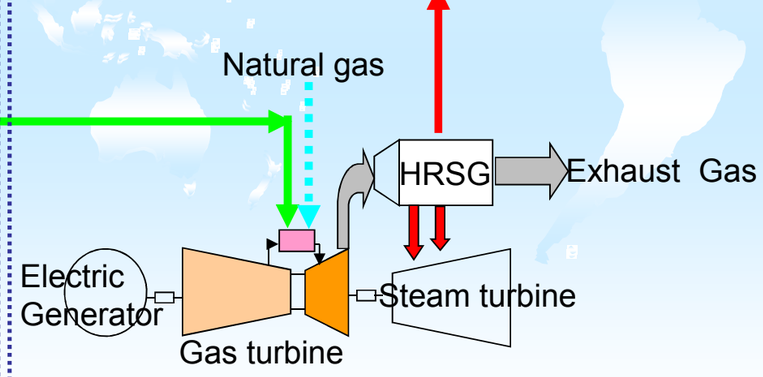
MCH Dehydrogenation Unit
(Heat-exchanger type Dehydrogenation Reactor)

Gas Turbine combined Cycle with H2 & NG Co-firing Unit

Heat（Utilization for Dehydrogenation Reaction）



Hydrogen



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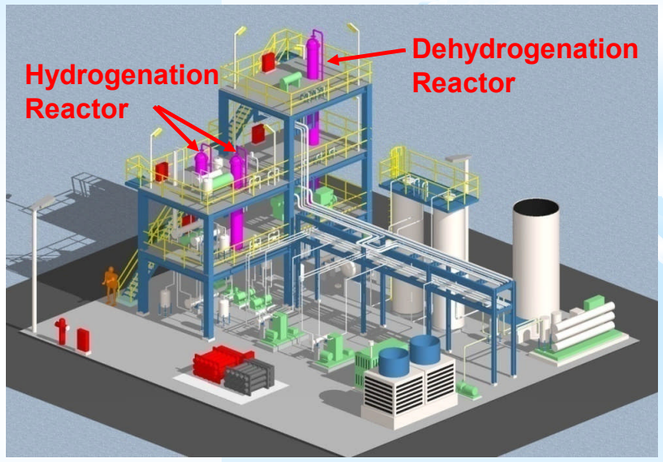
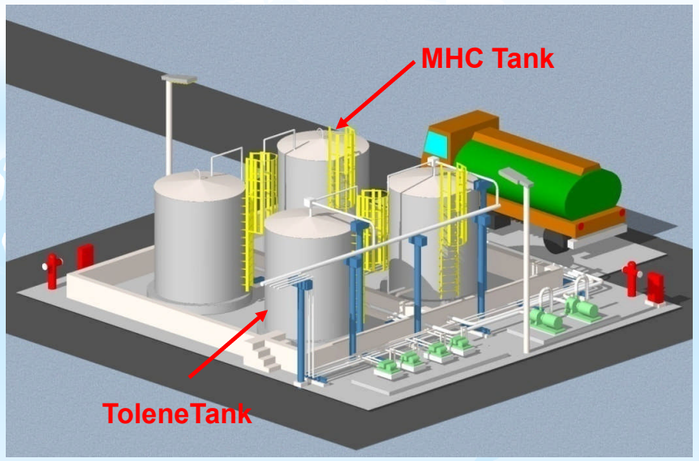
HRGS: Heat Recovery Steam Generator System

Image of Demonstration Plant





Operation of demonstration plant which has hydrogen production capacity is 50 Nm3/hr will be started at the end of this February.

Through this demonstration test the performance of our chemical hydoride system will be confirmed.

Conclusion

・Chiyoda have been proposed the H_2 supply Chain by Organic Chemical hydride (OCH) method as liquid organic hydrogen Carrier (LOHC) technology since 2005. The system can be applied to the storage and transportation of H_2 produced from both fossil fuel and renewable energy.

・In this technology, Toluene and Methylcyclohexane (MCH) system is employed, because this system can keep the liquid state in wide temperature range without any solvents.

・Novel dehydrogenation catalyst which is the key technology for the OCH method has been developed.

・Chiyoda will commence the demonstration test of total system of hydrogenation and dehydrogenation to established the technology for a large scale system in this February.

・Large scale H_2 storage and transportation technology will be established and ready for commercialization at the end of 2013.

Thank you for your kind attention !