



Hydrogen Vehicles and Fueling Infrastructure in China

Prof. Jinyang Zheng

Director of IPE, Zhejiang University

Director of Engineering Research Center for High Pressure Process

Equipment and Safety, Ministry of Education

Vice Director of China National Safety Committee of Pressure Vessels

Vice President of CMES-P.R. China

China Representative of ISO/TC197 and ISO/TC58



Content

- **Hydrogen Production**
- **CNG Refueling Station**
- **Hydrogen Refueling Station**
- **Shanxi HCNG Project**

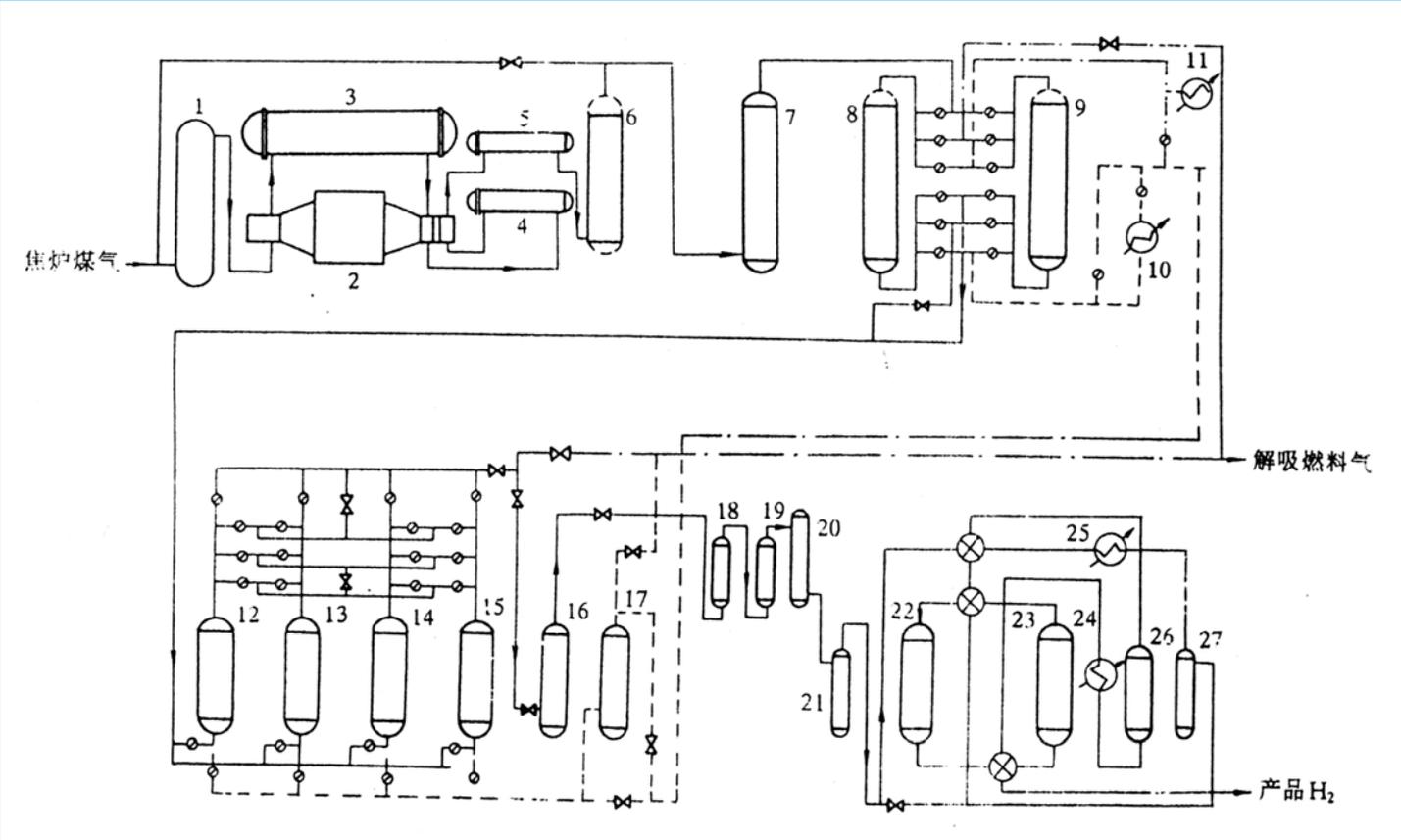


1、 Hydrogen Production

- **Hydrogen from Water
Electrolysis**
- **Hydrogen from Coke Gas**
- **Hydrogen from Natural Gas**
- **Hydrogen from Renewable Resources**
- **Hydrogen from Coal**



Safety and Regulatory Structure for CNG, CNG-H₂, H₂ Vehicles and Fuels in China



China produced 327 million tons of coke in 2008, which is about 60% of total production all over the world. It is estimated that there are 400m³ coke oven gas when producing 1 ton coke. We have a **huge resource of hydrogen**.



Safety and Regulatory Structure for CNG,CNG-H2,H2 Vehicles and Fuels in China

	Coke oven gas	H ₂	PSA inlet	PSA outlet	脱氧器出口	Hydrogen Product	尾气
Content (mol%)							
H ₂	52.3		53.19			99.999	25.45
CO ₂	2.00		1.96			-	3.13
N ₂	4.90		4.81			5×10 ⁻⁶	7.66
O ₂	0.10		0.10			1×10 ⁻⁶	0.13
CO	7.50		7.36			2×10 ⁻⁶	11.73
CH ₄	30.40		29.83	99.95		1×10 ⁻⁶	47.53
CnHm	2.80	99.99	2.75	0.05%	99.999	-	4.38
Flow rate (Nm ³ /h)							
H ₂	4360		4518				1357
CO ₂	167		167				167
N ₂	409		409				409
O ₂	8		8				7
CO	625		625				625
CH ₄	2534		2534	3161			2534
CnHm	233	158	233	1.6	3158	3000	233
Total	8337	158	8495	3163	3158	3000	5332
Pressure/kPa	15 ~ 20	15 ~ 20	1779	729	629	600	4.3 ~ 6.4

Hydrogen is about 50~60% in the coke oven gas.



1、 CNG Refueling Station

- At the end of 2007,there are 555 natural gas filling stations in P.R.China.
- However, it is far from enough.



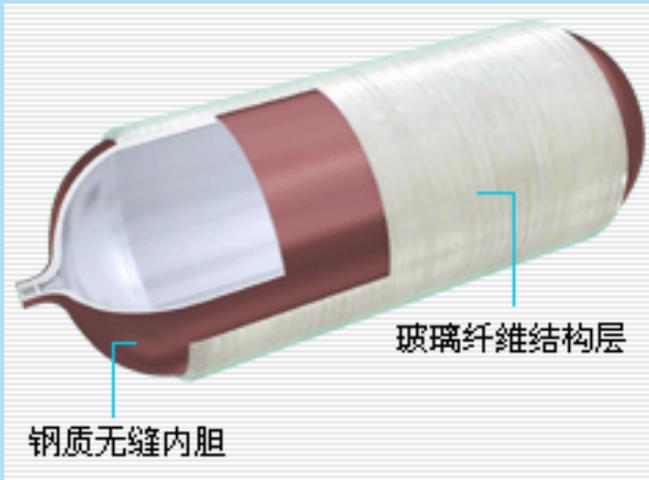


Safety and Regulatory Structure for CNG,CNG-H2,H2 Vehicles and Fuels in China





CNG Tanks





Safety and Regulatory Structure for CNG,CNG-H2,H2 Vehicles and Fuels in China



Reducing Valves for CNG



2、 Hydrogen Refueling Station

There are five hydrogen refueling stations in P.R.China, including 4 stationary stations.



Beijing Feichi



Shanghai Anting



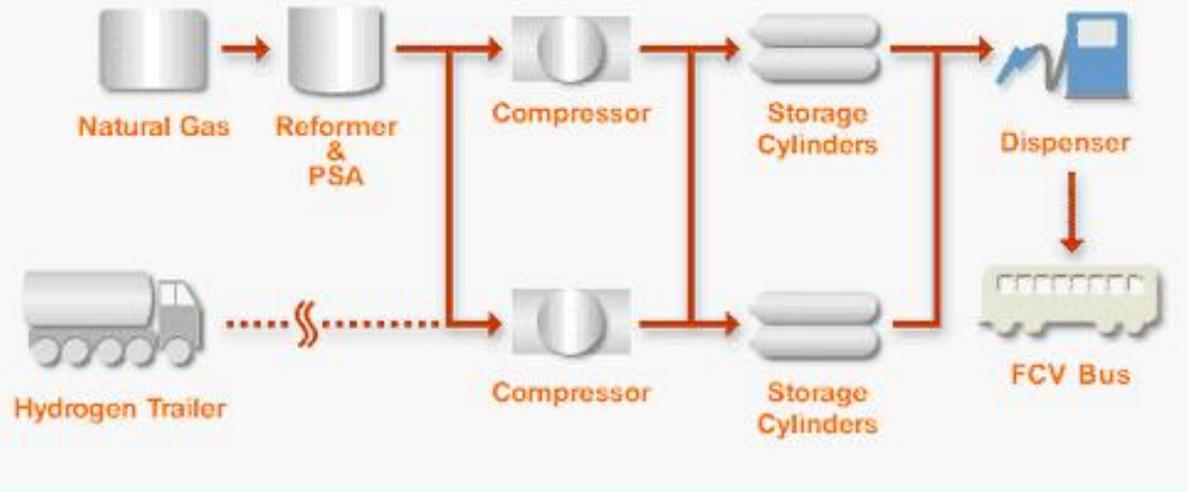
Beijing Huatong



Safety and Regulatory Structure for CNG,CNG-H2,H2 Vehicles and Fuels in China



■ City Gas Reforming Hydrogen Supply Facility Flow Sheet



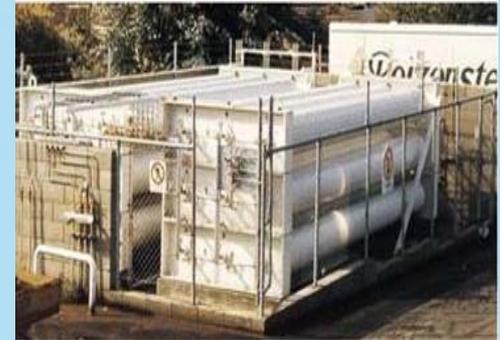


2.1 Hydrogen storage vessels

- Seamless pressure vessels are widely used in hydrogen refueling stations. 2.
- Designed, manufactured and inspected to ASME Boiler & Pressure Vessel Code, Section VIII, Division 1 or 2

Advantages

- No weld
- Avoid weld defects such as cracks, slag, etc.





Disadvantages

Susceptible to Hydrogen Embrittlement

Made from high strength steel with tensile strength over 800MPa

Difficult for online safety monitoring

Non-ability to detect hydrogen upon leakage and collect leaked hydrogen automatically.

Limit in Volume

Max diameter 610mm

Capacity 400-2000L

The higher the pressure, the smaller the capacity. The capacity is about 765L at 40MPa. In case of large amount of H₂ storage, it is required to use multiple vessels in parallel combined through removable stationary pipe supports, increasing the points of H₂ leakage.



Hydrogen Embrittlement

Chemical Composition of ASTM 4140

Steel	Cr	Mo	C	Mn	Si	P	S	Others
4140	0.93	0.20	0.40	0.83	0.31	0.009	0.014	-

Tensile Test Results of Smooth Coupon In High Pressure Nitrogen, and High Pressure Hydrogen

Steel	Medium	Strain rate/ s ⁻¹	Rp/ MPa	Rm/ MPa	Elongation/ %
4140	69MPa He	3.3×10 ⁻⁵	1235	1283	48
	69MPa H ₂		-	1228	8.8

Tensile Test Results of Notched Coupon In Air,High Pressure Nitrogen, and High Pressure Hydrogen

Steel	Medium	Strain rate/ s ⁻¹	Rp/ MPa	Rm/ MPa	Elongation/ %
4140	air	~4×10 ⁻⁴	642	1345	10
(Low strength)	69MPa He		-	1259	14
	69MPa H ₂		-	1074	7.1
(High strength)	69MPa He	~4×10 ⁻⁴	1235	2160	2.8
	69MPa H ₂		-	862	0.9

严重下降!

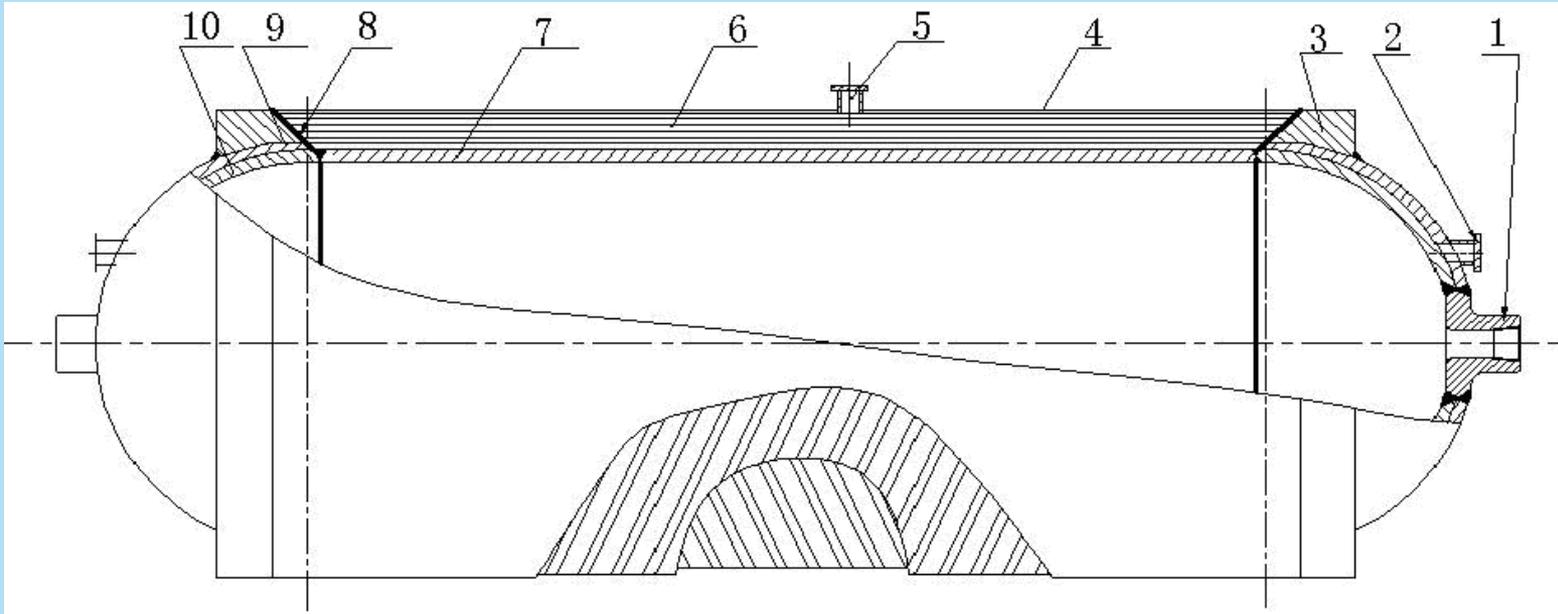


Stationary High-pressure Hydrogen Storage Vessels

In order to overcome the aforementioned disadvantages and decrease its manufacturing cost, a proprietary new type storage vessel, Multifunctional Layered High-Pressure Hydrogen Storage Vessels, were independently developed by IPE, Zhejiang University.

No.	1	2	3
Volume/m3	5.0	5.0	2.5
Pressure/MPa	42	47	77
Diameter/mm	1000	1000	700





- 1. End nozzle; 2. Head nozzle; 3. Reinforcing ring; 4. Protective shell;
- 5. Cylinder nozzle; 6. Layered shell; 7. Inner shell; 8. Slant weld;
- 9. Outer hemispherical head; 10. Inner hemispherical head

Multifunctional Layered High-Pressure Hydrogen Storage Vessels

Jinyang Zheng et al. High Pressure Steel Storage Vessels Used in Hydrogen Refueling Station. ASME Journal of Pressure Vessel Technology, 2008,130



Advantages :

- Feasible in Manufacturing Hydrogen Storage Vessels with Various Parameters
- Burst Resistant or Self-protected
- Random Dispersion of Defects or Cracks
- Feasible for Online Safety Monitoring
- Economical and Convenient for Manufacturing
- Not Susceptible to Hydrogen Embrittlement



Comparison between High Pressure Hydrogen Storage vessels

Item	Multi-functional H ₂ tank	Seamless compressed H ₂ tank
Materials	Steel sheet and flat steel ribbon tensile strength ≤ 540 MPa.	High strength thick steel tube, tensile strength > 720 MPa.
Manufacturing cost	Low material and manufacturing cost; overall heat treatment is not required.	NDT flow line, heat treatment furnace and high performance spinner are required.
Sensitivity to H ₂ embrittlement	Low material strength; low sensitivity to H ₂ embrittlement.	High material strength; potential of H ₂ embrittlement.
Failure mode	Bursting at overpressurization; 'Leak Before Burst' at operating pressure.	Bursting at overpressurization; difficult to fulfill 'Leak Before Burst' due to potential of H ₂ embrittlement at operating pressure.
Remote safety monitoring	Easy to fulfill remote real-time safety monitoring for multiple tanks by using 'only leak without explosion'.	Difficult to fulfill remote safety monitoring.



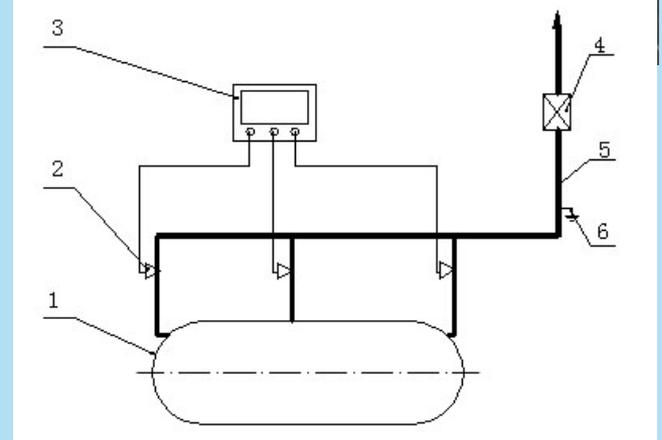
Comparison between High Pressure Hydrogen Storage vessels

Item	Multi-functional H₂ tank	Seamless compressed H₂ tank
Lead time	Easy processing and short lead time (3 months).	Imported and long lead time.
Weight	Heavy	Light
Capacity	No restriction of capacity.	Small capacity and many leak points.
Mode of installation	Horizontal or vertical as required.	Horizontal or vertical as required, but large floor area.
Resistance to shock	Multi-layered structure, with high resistance to shock.	Prone to external shock.
Intellectual property right	Own intellectual property right.	Have no intellectual property right and rely on importation.



Online Safety Monitoring System of High-pressure Hydrogen Storage Vessels

- The hydrogen sensor connected to the display and alarm instrument are set near the nozzles to monitor any leak of hydrogen automatically.
- When hydrogen leaks, the display and alarm instrument will roughly display the position of leakage point and will give alarm.
- The leaked hydrogen is vented through a pipe.
- The hydrogen flame arrester and antistatic device are used at the end of an escape pipe to prevent fire.



1. Vessel; 2. Sensor;
3. Display and alarm instrument;
4. Hydrogen flame arrester;
5. Vent pipe;6. Anti-static device



Safety and Regulatory Structure for CNG, CNG-H₂, H₂ Vehicles and Fuels in China



Outlet Pressure **75MPa**
Capacity **600Nm³/h**
Inlet Pressure **1.6MPa**



Capacity **375Nm³/h**



Safety and Regulatory Structure for CNG,CNG-H₂,H₂ Vehicles and Fuels in China



Dispenser parameters

Pressure

0-45MPa

Capacity

1-50Nm³/min

There is no factory who specializes in producing high pressure valves and pipes with pressure more than 35MPa



3、Shanxi HCNG Project

- **There are two sub-projects.**

+ **One for 30 heavy trucks, which are used to move coals from well to railway station. The distance is about 20km.**

20%hydrogen+80%CNG

+ **The other for furnace**

5%~30%hydrogen+70%~95%CNG

- **Resource of hydrogen:**

200,000m³/d Coke Gas through 10km pipeline with working pressure 0.2MPa

- **The project will be finished at the end of 2010.**



Acknowledgements

- **National basic research program of China (973 program)**
- **High-technology research and development program of China (863 program)**
- **Safety issues related to transport and storage of hydrogen fuels in northern climates (US DOT DTOS59-06-G-00048)**
- **National Natural Science Foundation of China**
- **National Key Technology R&D Program of China**
- **Doctoral Fund of Ministry of Education of China**
- **Wenzhou Huangsheng Pipe Industrial Co., Ltd., China**
- **University of Manchester**
- **Taiyuan University of Technology**
- **Northwest Institute of Nuclear Technology**



❑ <http://www.zjupe.com>

❑ Tel: 86-571-87952110

❑ Fax:86-571-87953393

❑ E-mail: jyzh@zju.edu.cn

❑ Address: Institute of Process Equipment, Zhejiang University,
38 Zheda Road, Hangzhou, P.R. China 310027

Thank you!