

# Research State of the Art and Knowledge Gaps in High Pressure Hydrogen Storage

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**Jinyang Zheng**

*Changjiang Scholar, Zhejiang University*

*Chair, SAC/TC31/SC8 Gas Cylinders/High Pressure Vehicle Fuel Tanks*

*Director, MOE Engineering Research Center for High Pressure Process Equipment and Safety*

*Vice Chair, National Technical Committee on Hydrogen Energy of Standardization Administration of China*



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- 1. High Pressure Hydrogen Storage Technology**
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# 1. High Pressure Hydrogen Storage Technology

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HP H<sub>2</sub> storage equipment is classified into vehicle tanks and stationary vessels:

- High pressure vehicle tanks

**Characteristics:** installed on and carried by vehicles.

**Requirements:** HP resistant, lightweight, and safe in use.

Technical route: composite tanks

- High pressure stationary vessels

**Characteristics:** fixed locations and user,

**Requirements:** HP resistant and safe in use.

**Applications:** HRS, power plant etc.

Technical route: Metallic or composite vessels

# 1. High Pressure Hydrogen Storage Technology

## Development Trends:

**Higher pressure**

**Lighter weight**



**70MPa high-pressure  
hydrogen refueling station**



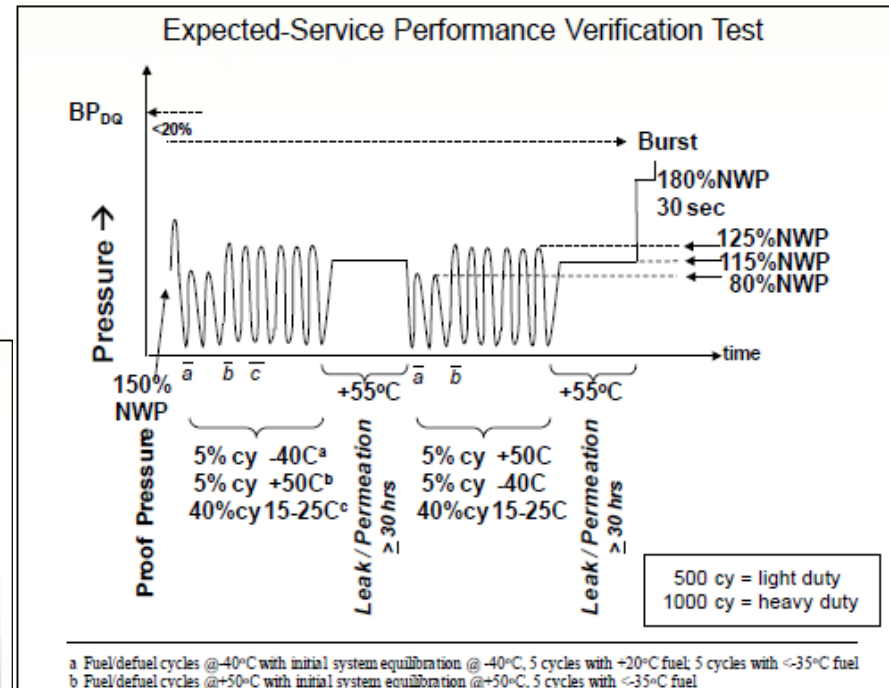
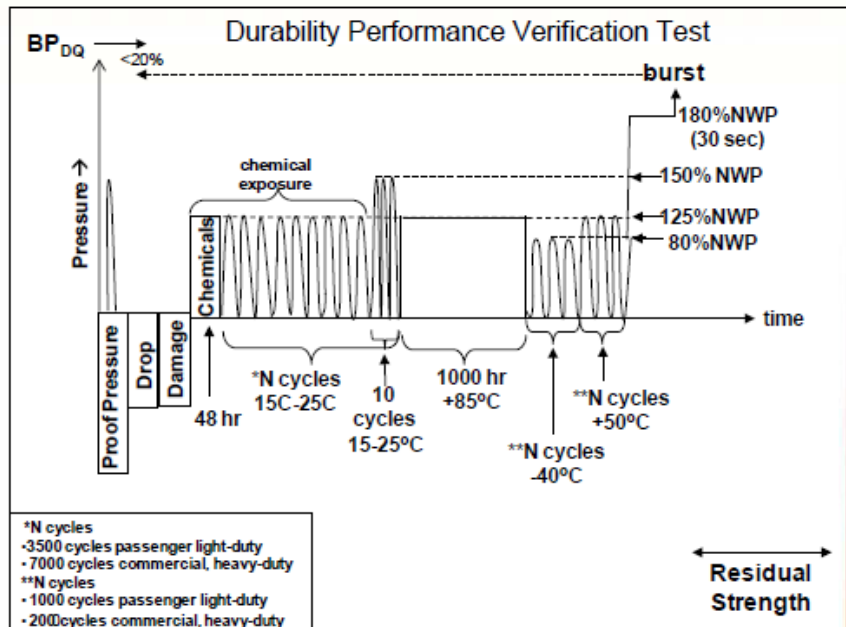
**Key components:**

**70MPa light-weight on-board HP H<sub>2</sub>  
storage tank**

# 1. High Pressure Hydrogen Storage Technology

## Trends:

Sequential test ☆  
hydrogen cycle test

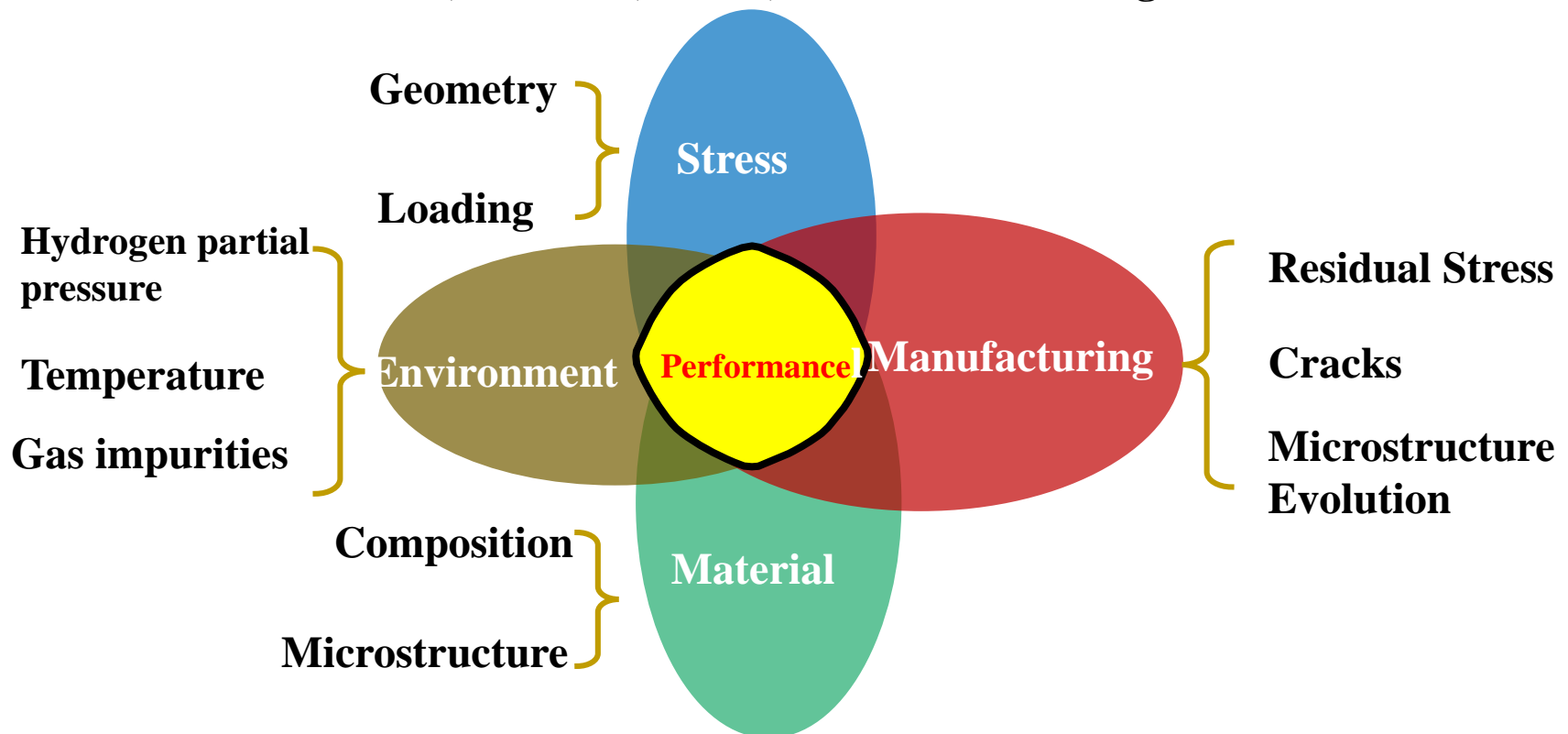


Pneumatic test(H<sub>2</sub>)

Hydraulic test

# 1. High Pressure Hydrogen Storage Technology

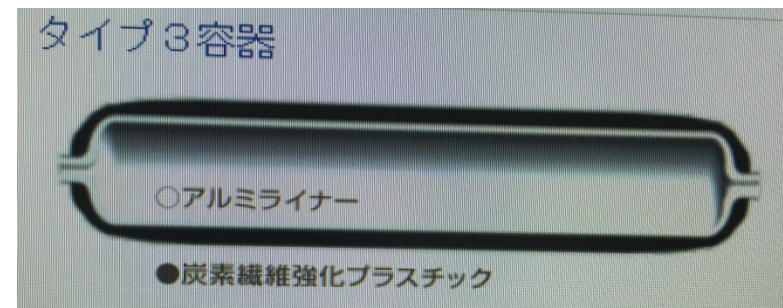
*Performance of Component/System in Contact With HP Hydrogen* is determined by the intersection of variables representing:  
Environment, Material, Stress, and Manufacturing Process.





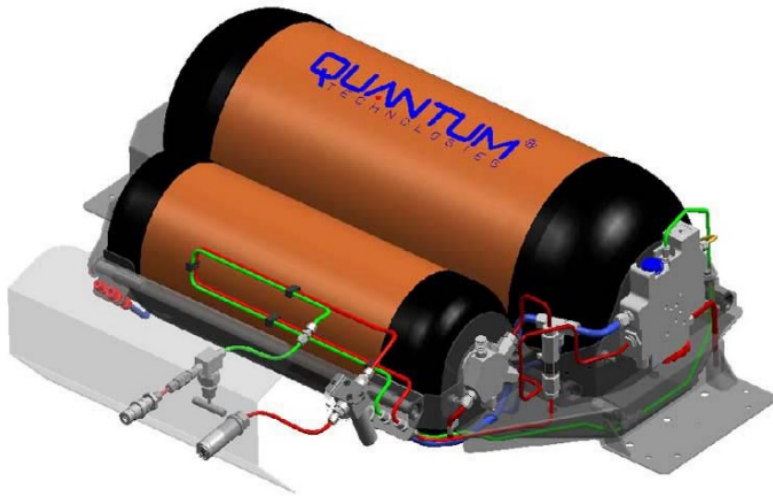
## 2. High Pressure Vehicle Tanks

### Type III Hydrogen tank



## 2. High Pressure Vehicle Tanks

### Type IV Hydrogen tank





## 2. High Pressure Vehicle Tanks

### Type IV Hydrogen Tank



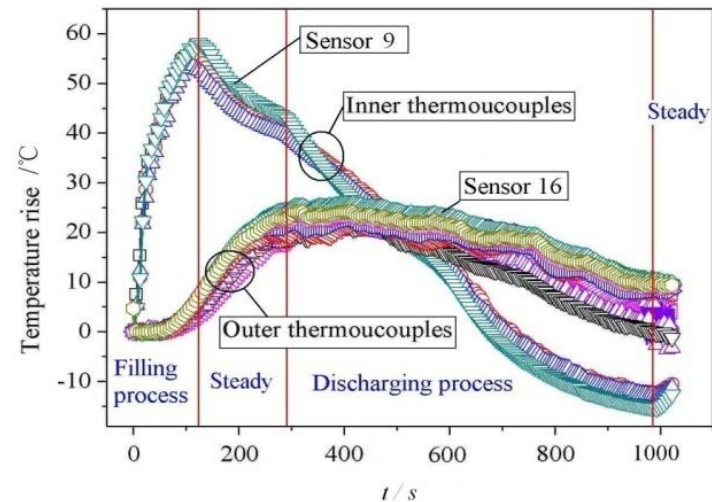
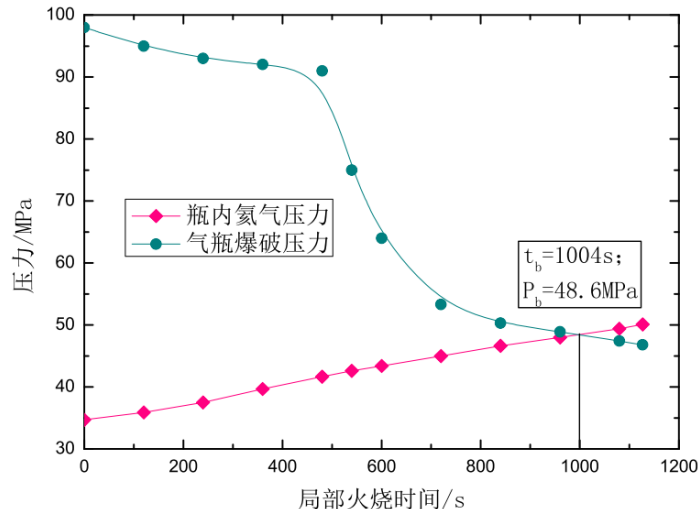
◆ pressure: 35 / 40 / 50 / 70 / 95 MPa

◆ volume: 29~539 L

## 2. High Pressure Vehicle Tanks

### What has been done

- prediction of burst pressure
- temperature rise due to fast filling (method for controlling the temperature)
- fire resistance prediction and optimization of fire protection
- blast wave due to burst



A decorative graphic consisting of overlapping yellow, red, and blue squares with a black crosshair.

## 2. High Pressure Vehicle Tanks

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### **Next steps**

- **temperature change during hydraulic or pneumatic cycle test**
- **effect of temperature variation on tank fatigue life**
- **effect of lower pressure on tank fatigue life (particularly the HDPE liner)**
- **Degradation mechanisms under extreme condition such as thermal shock(rapid temperature change during filling) , fire, etc.**

## 3. High Pressure Stationary Vessels

### 3.1 Seamless HP H<sub>2</sub> cylinder

Designed, manufactured and inspected to ASME BPVC VIII

**Advantage:** made from seamless steel tubes closed up on both ends - integral structure without welds.

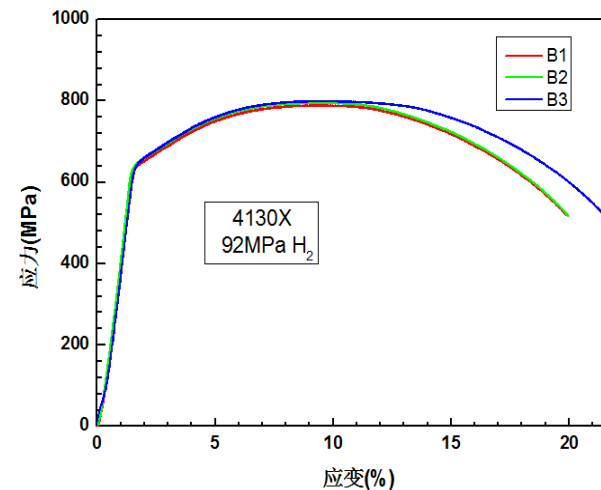
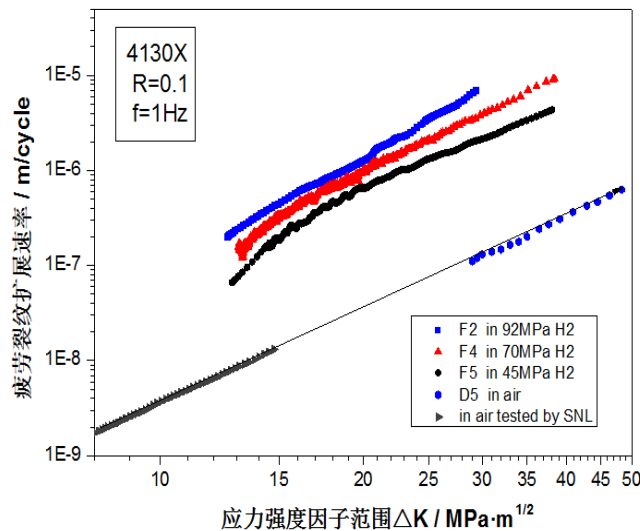


### 3. High Pressure Stationary Vessels

#### Disadvantages:

The Higher material strength, the more susceptible to hydrogen embrittlement:

Cr-Mo steel SA372



### 3. High Pressure Stationary Vessels

**Difficulty in online safety inspection: -**

**The safety can only be determined through regular inspection.**

**It is difficult to achieve online leakage inspection.**

**The capacity is restricted and points of leakage increase with its capacity:**

Max diameter	900mm
Capacity	400-3000L

The higher the pressure, the smaller the capacity. In case of large amount of H<sub>2</sub> storage, it is required to use multiple vessels in parallel combined through removable stationary pipe supports, increasing the points of H<sub>2</sub> leakage.

ASME Seamless Pressure Vessels for Stationary Storage of Gases







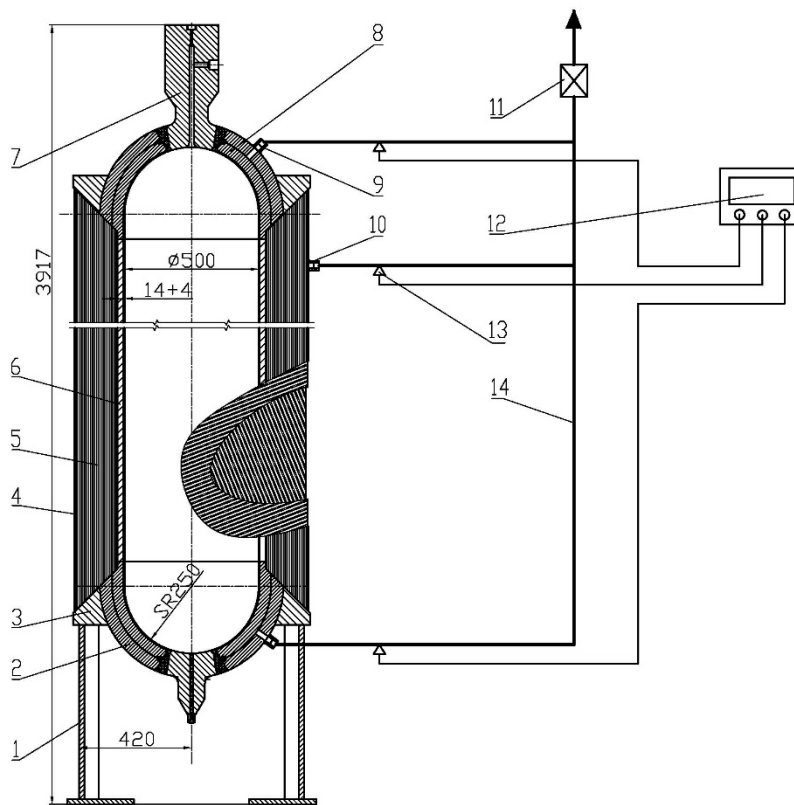
## 3. High Pressure Stationary Vessels

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### 3.2 Large volume multi-layered HP H<sub>2</sub> storage vessel

To overcome the disadvantages of seamless HP H<sub>2</sub> cylinders, We have developed a proprietary multifunctional steel layered vessel (MSLV), which have been used in several stations in China. MSLV is flexible in parameters, convenient in fabrication, easy in online leak diagnosis, low in cost.

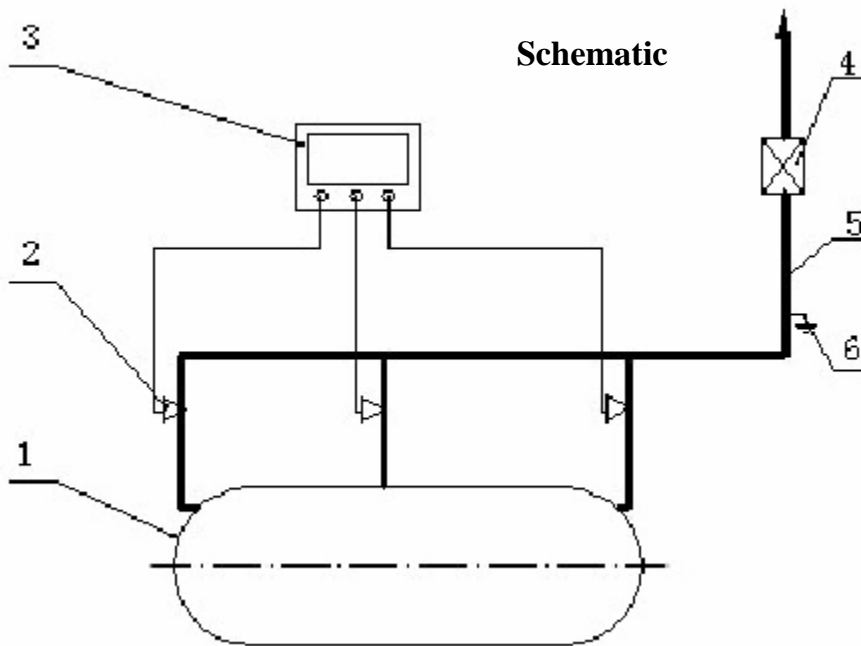
### 3. High Pressure Stationary Vessels



- 1 support
- 2 outer hemispherical head
- 3 reinforcing ring
- 4 protective shell
- 5 steel ribbon layer
- 6 inner shell
- 7 top nozzle support
- 8 inner hemispherical head
- 9 head nozzle
- 10 cylinder nozzle
- 11 hydrogen flame arrester
- 12 display and alarm instrument
- 13 sensor,
- 14 vent pipe

### 3. High Pressure Stationary Vessels

#### Online Diagnosis System



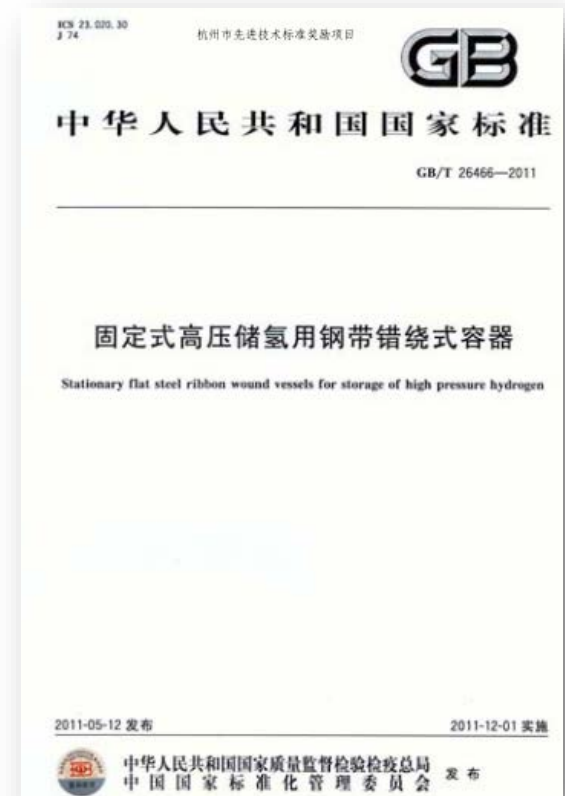
- 1、 Storage vessel
- 2、 Transmitter
- 3、 Indicator and alarm
- 4、 H<sub>2</sub> fire arrestor
- 5、 H<sub>2</sub> vent pipe
- 6、 Antistatic earthing device

### 3. High Pressure Stationary Vessels

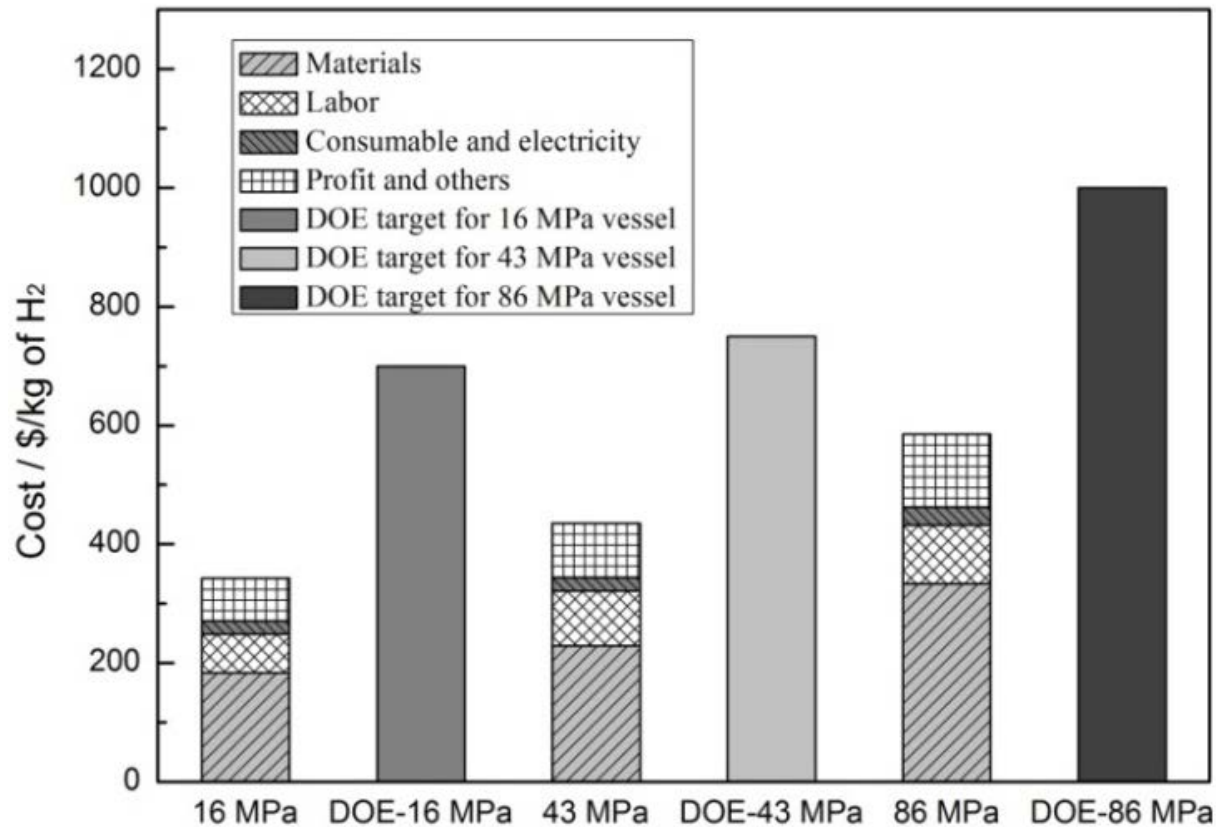
#### National standard

**GB/T 26466-2011 Stationary flat steel ribbon wound vessels for storage of high pressure hydrogen**

Max design pressure	100MPa
Operating temperature	-40-80°C
Max inner diameter of vessel	1500mm
Max length of vessel	25m



### 3. High Pressure Stationary Vessels



Comparison Between the Cost of MSLVs and The DOE Targets

### 3. High Pressure Stationary Vessels

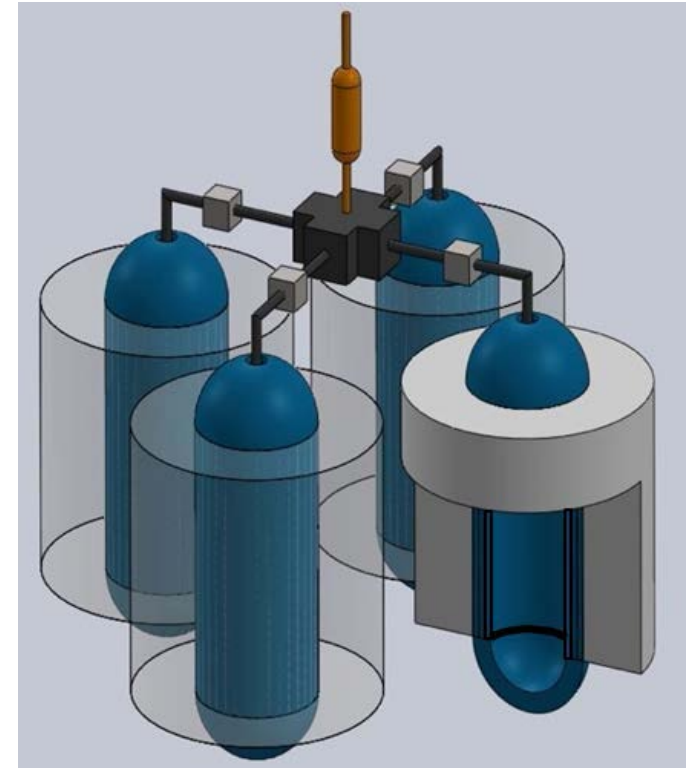


**Design Pressure/MPa** 20、25、42、47、77、98

**Volume/m<sup>3</sup>** 0.5、5.0、20.0、25.0



### 3. High Pressure Stationary Vessels



**Steel Concrete Composite Vessel-DOE Project**



## 3. High Pressure Stationary Vessels

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### 3.4 Next steps

- 1) **Material data for developing hydrogen-damage mechanism based methods for design of high pressure stationary vessels**
- 2) **Degrading mechanism of material/component/system in contact with high pressure hydrogen**
- 3) **Multi-physics approaches for coupled simulation of chemical/thermal transport, mechanical loading, microstructural evolution and distribution of properties in related to manufacturing process, to predict performance**
- 4) **Techniques for monitoring damage of high pressure stationary vessels**
- 5) **Nondestructive Evaluation method for aging of high pressure stationary vessels**



高压过程装备与安全创新团队2015新年全家福



A pair of hands is shown holding a small, realistic globe of the Earth. The globe displays the continents of North and South America in green, surrounded by blue oceans and white clouds. A single, translucent blue water drop is suspended in the air just above the top of the globe, as if about to fall. The background is a soft, out-of-focus light blue.

Thank you for your attention!

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