



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

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

- Zhejiang University is located in the coastal city Hangzhou, 180 km away from Shanghai.



Hangzhou(30°15'9.44"N, 120° 9'54.36"E) by Google Earth



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

- Hangzhou was honored as "the most beautiful and magnificent city in the world" by the Italian traveler Marco Polo.





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

- Zhejiang University was founded in 1897 as one of the oldest institutions of higher education in China. It has always been ranked among the few top universities in China, in terms of its comprehensive academic strength showed in teaching, research and social service.





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➤ With five campuses, namely Yuquan, Xixi, Huajiachi, Zhijiang, and Zijingang,





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

- 44,151 full-time students, including 24,983 undergraduates, 11,883 graduate students working for master degree, 6,050 doctoral candidates, 1,235 foreign students.





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1 Professor
3 Associate Professors
4 Postdoctoral
More than 20 candidates
for Ph.D and Master
degree



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- **CNG Vehicles**
- **Hydrogen Vehicles**
- **HCNG Vehicles**
- **Standardization Administration and Regulatory System**
- **Regulations and Standards for CNG, H2 Vehicles**
- **Case Study: Introduction to China Hydrogen Standards**



1、 CNG Vehicles

- **China implemented clean energy vehicle action in 1999.**
- **Natural gas vehicles mainly focus on CNG vehicle and will remain in the near future.**
- **The automotive industries and the whole society have reached a consensus on developing energy-conserving, environmentally-friendly vehicles.**
- **The CNG vehicles currently in use in China are mainly dual-fuel vehicles (CNG、 Oil).**
- **The main application is taxi and bus.**



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- Over the last five years, CNG vehicle has developed rapidly. the proportion of CNG taxis and buses in some of key promotion cities has reached over 50%.





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

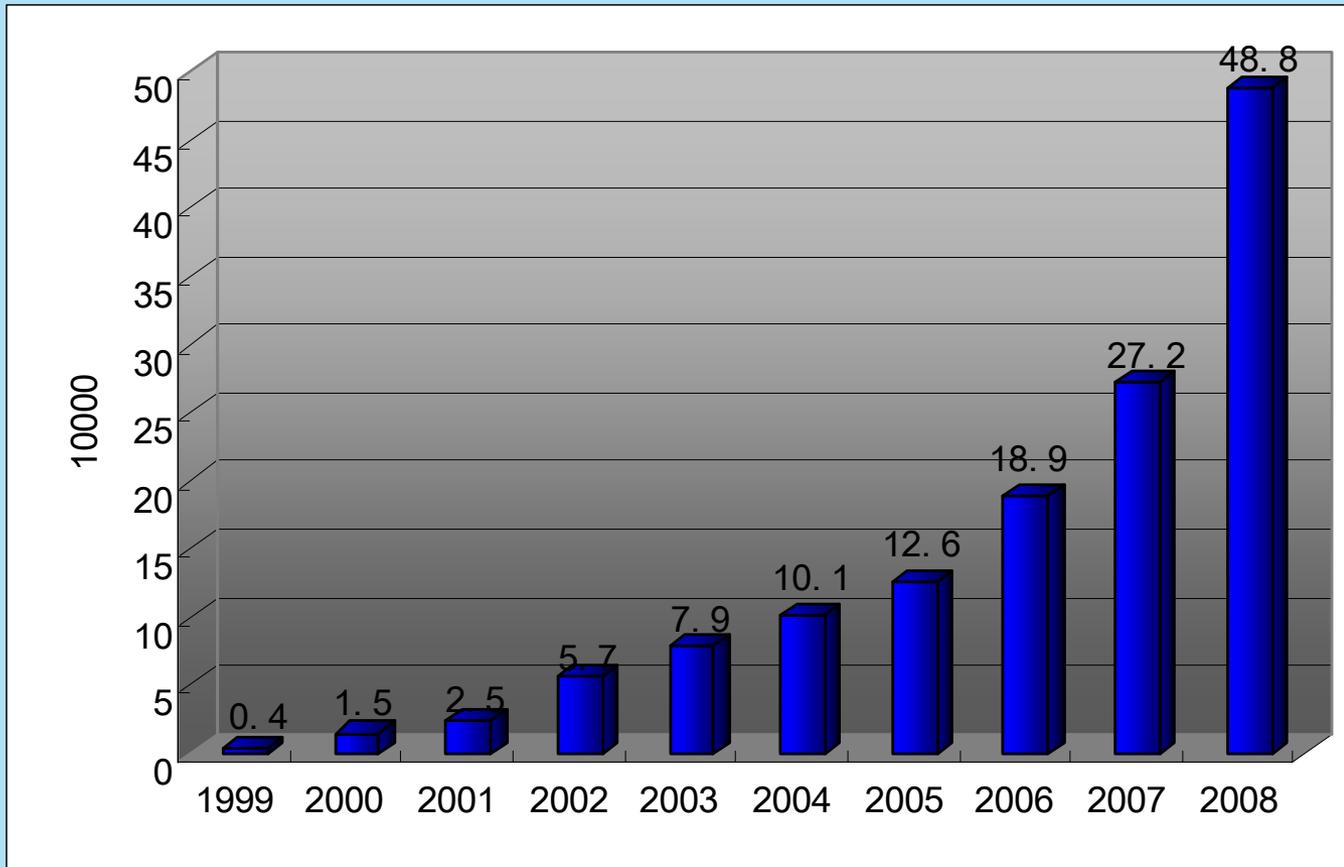


Figure 1 CNG vehicles development in China in recent ten years



Problems faced in the development of CNG vehicles

- CNG stations are not enough to supply CNG.
- Storage cylinders occupy a larger space. The nominal pressure is 20MPa. Vehicles only run about 200km per filling. It may be necessary to increase the pressure from 20MPa to 35 MPa to solve the problem.
- Compared with the diesel-powered vehicles, manufacturing costs of natural gas vehicle are higher.
- Natural gas vehicle engine requires high reliability for spare parts, because of high temperature.



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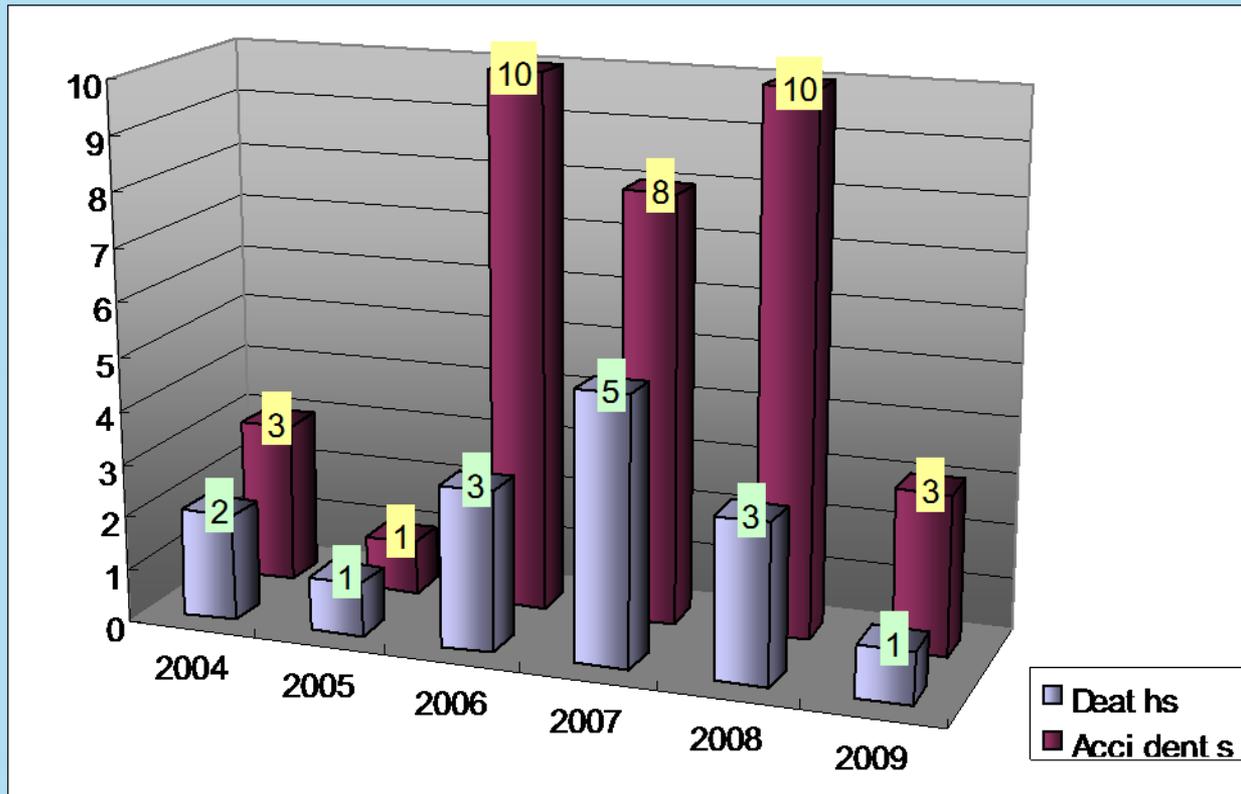


Figure 2 CNG accidents in the last six years in P.R. China



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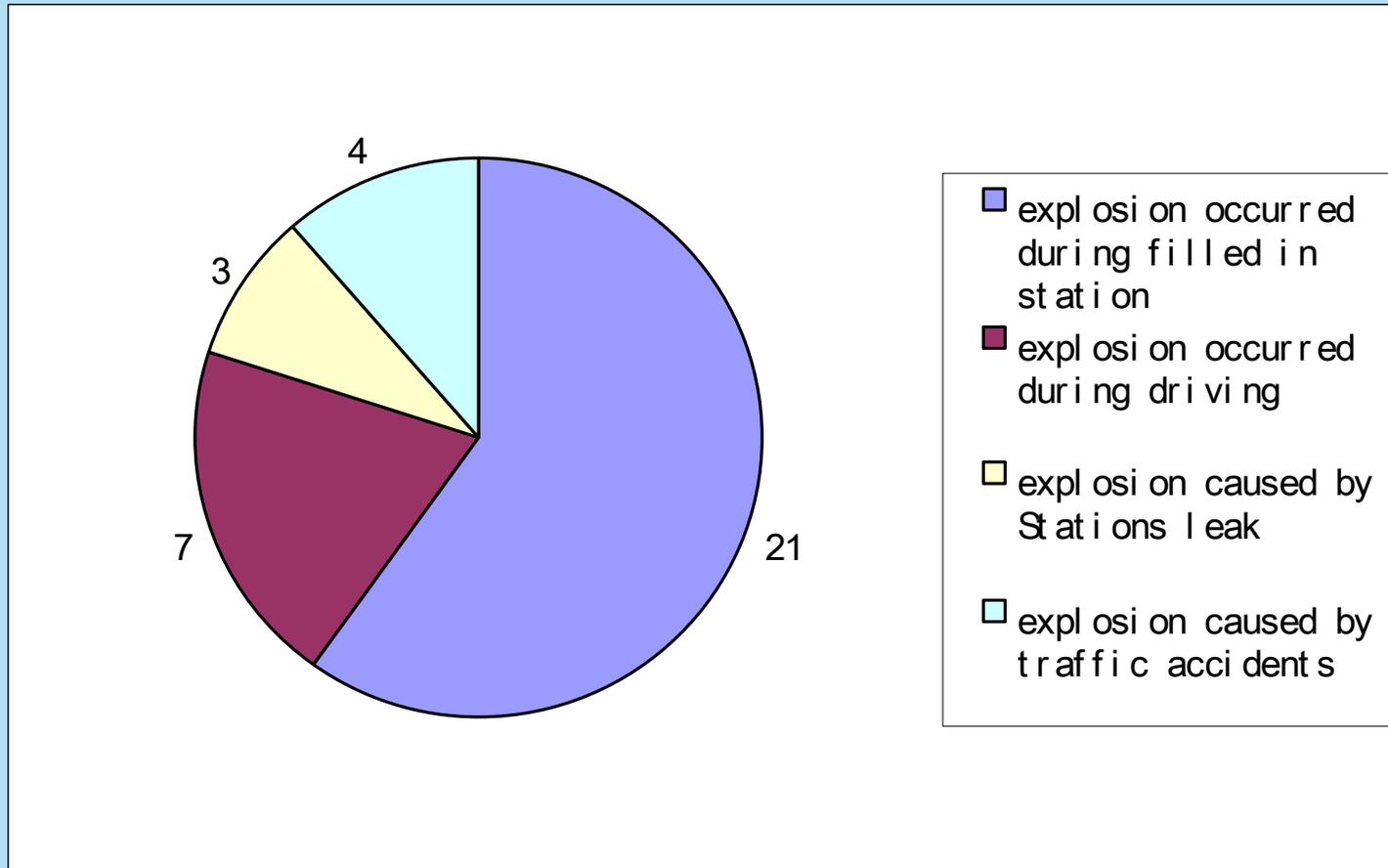


Figure 3 The Cause of the accidents



Types of CNG tanks Used In China

- **Type 1 Metal fuel tanks**
- **Type 2 Hoop wrapped composite tanks with a metal liner**
- **Type 3 Fully wrapped composite tanks with a metal liner**

Type 4 Fully wrapped composite tanks with plastic liner are not allowed to used In China





- **There are 4 serious explosion accidents of type 4 tanks in China.**
- **Service inspection of 12119 type 4 tanks in Beijing shows that only 32% meets the standard requirements. External damage, leakage during hydraulic test, crack, and blister were observed.**



blister



crack



- The coefficient of heat expansion of plastics is much larger than that of outer composite layer. Temperature change occurs during fast filling. So it is necessary to maintain a pressure not less than 2MPa in the tanks.



2、 Hydrogen Vehicles



Hydrogen Bus



Hydrogen Car

Type: **Hydrogen fuel cell, hydrogen engine**

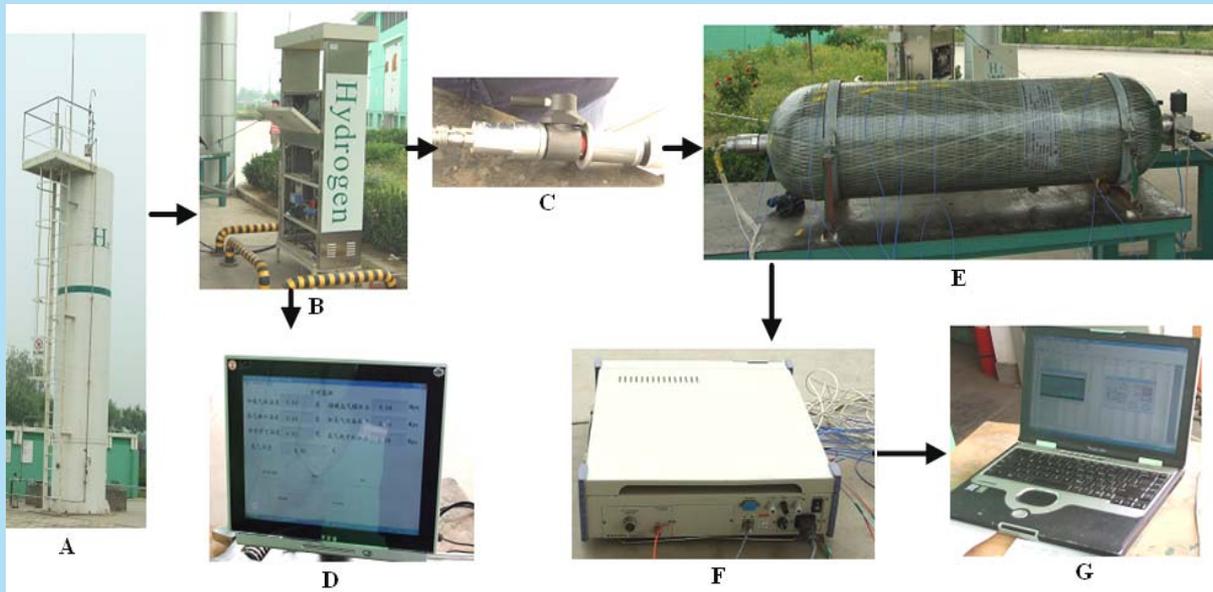


Fast Filling Test of Hydrogen

Filling time: 3 to 15 minutes

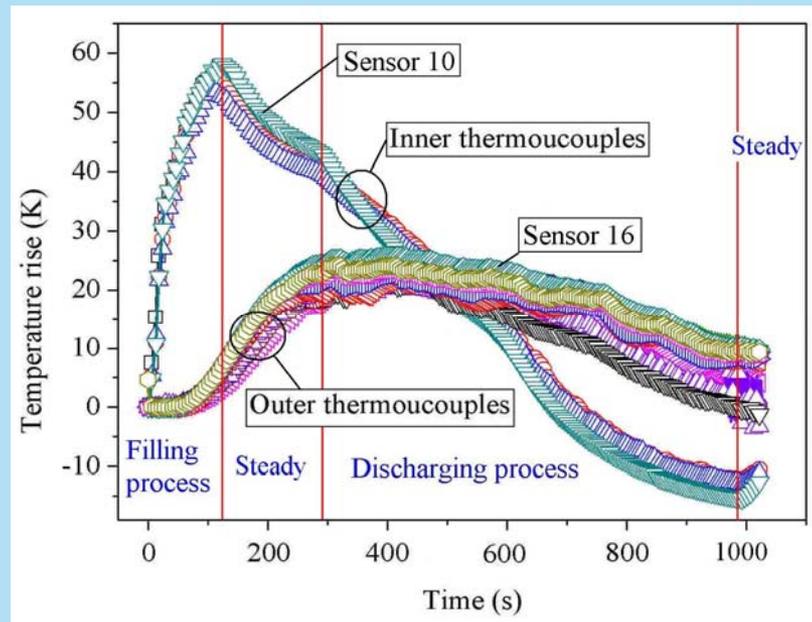
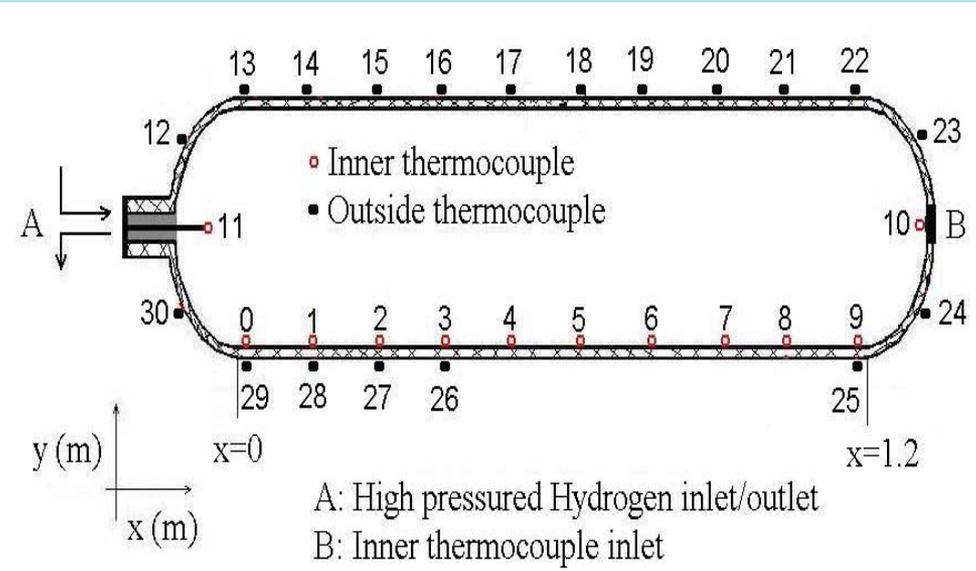
Hydrogen temperature might rise over 85°C during fast fill, which degrades the strength of composite cylinder.

Upper limit temperature is able to be under 85°C by choice of suitable measures, such as filling rate.





Experimental Studies

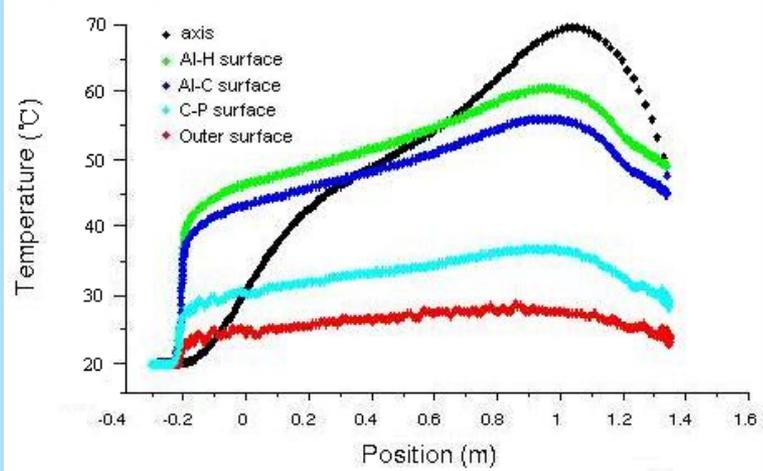
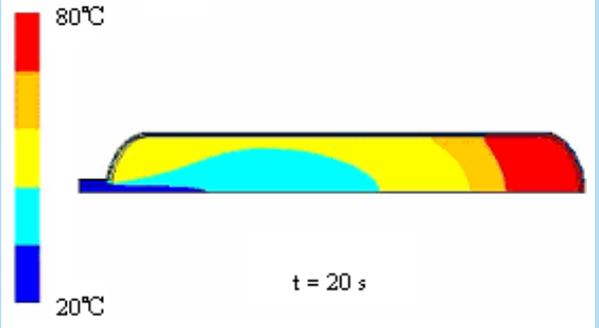


Thermocouple distribution in/out the cylinder

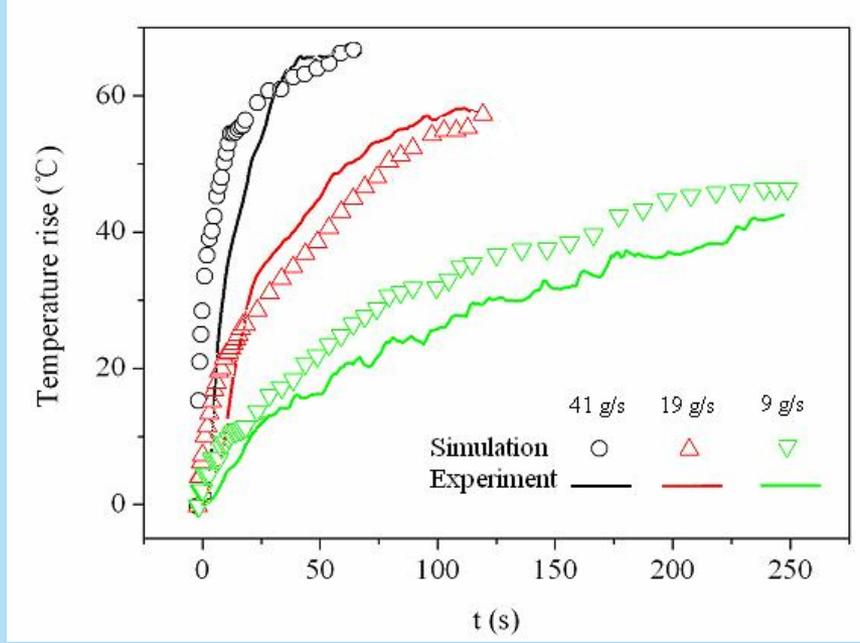
Value of temperature rise from all sensors in filling, steady and discharging process



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Axial Temperature Distribution

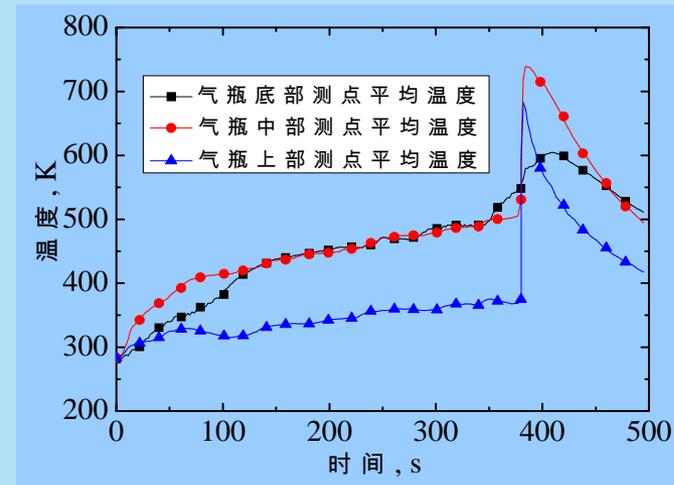


Comparison Between Measured Temperature Rise and Calculated ones

Bonfire test



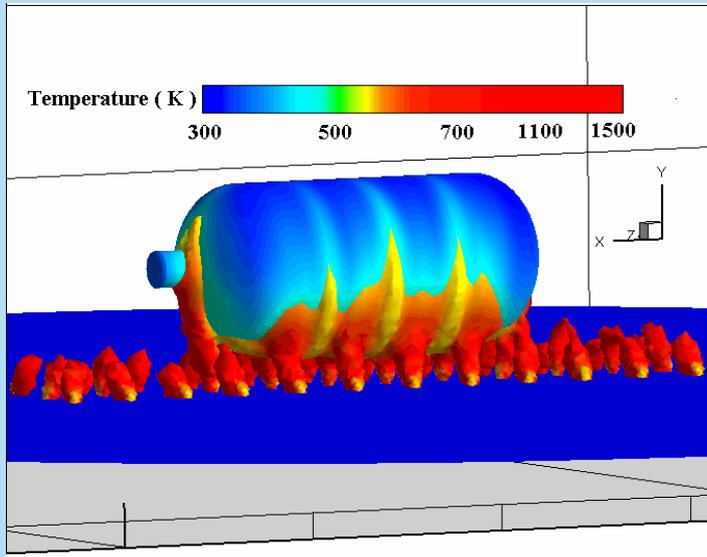
Bonfire test



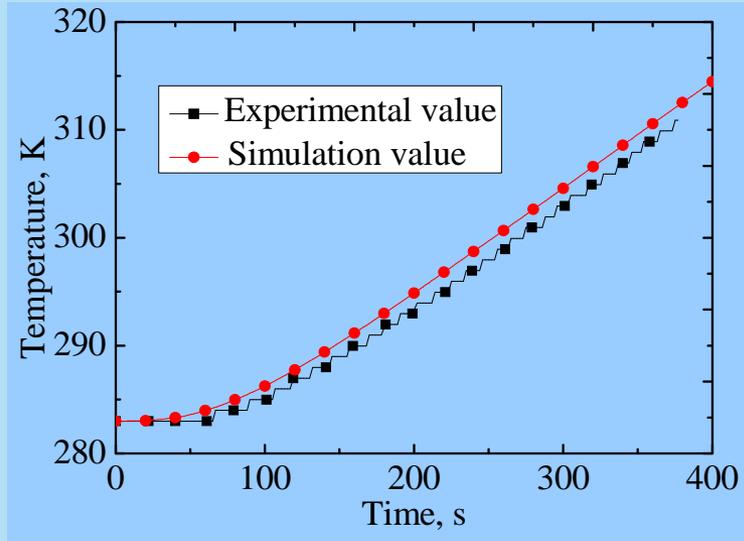
Temperature at different time



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Bonfire test simulation



Comparison Between Measured Temperatures and Calculated ones



Simulation on Leakage and diffusion of High Pressured Hydrogen

For wider use of hydrogen, the number of vessels will be greatly increased in hydrogen refueling stations or hydrogen fuel cell vehicles etc. Thus, accidents due to leakage of the vessel should be paid much attention.

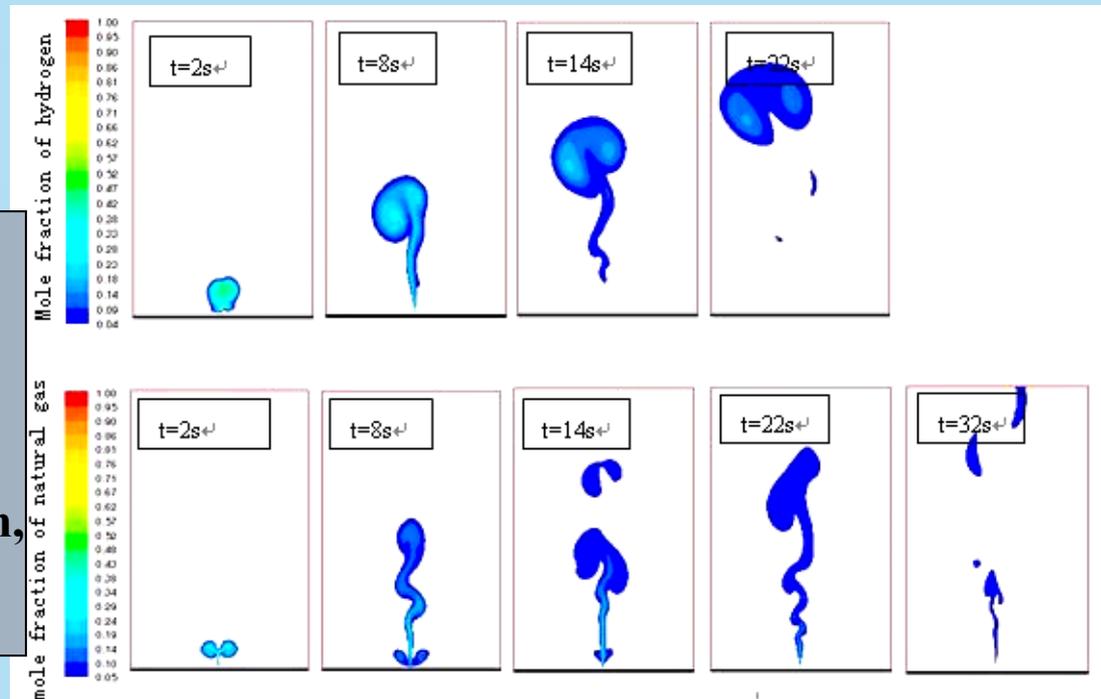
Because hydrogen exhibits some special properties such as high flammability and explosivity, the possibility of explosion will increase due to its storage tank failure. Therefore, it is crucial to understand the diffusion of hydrogen caused by leakage of high pressured storage tank. Since the experiment is not easy to carry out for high costs and dangerousness, numerical simulation can be an alternative.



Simulation on Leakage and diffusion of High Pressured Hydrogen

Numerical Studies on diffusion of High Pressured Hydrogen Due to Pipeline Failure

Yan-Lei Liu, Jin-Yang Zheng, et al . Numerical simulation on the diffusion of hydrogen due to high pressured storage tanks Failure. Journal of loss prevention, accepted



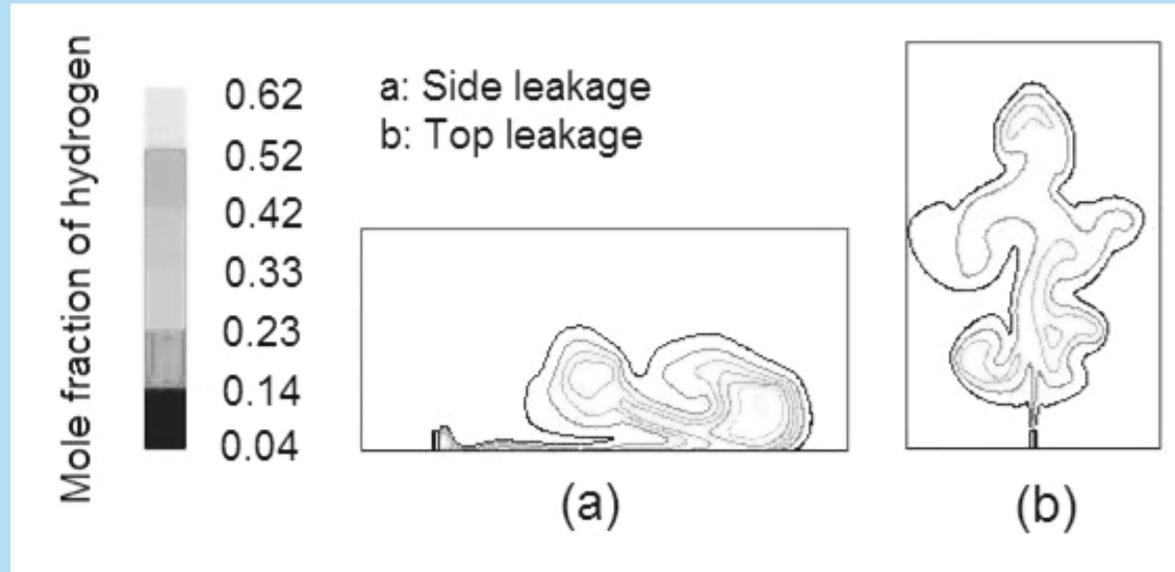
Diffusion of hydrogen and natrual gas due to pipeline failure



Simulation on Leakage and diffusion of High Pressured Hydrogen

Numerical Studies on diffusion of High Pressured Hydrogen Due to Storage Tank Failure

The dangerousness caused by hazard region is much larger to the ground when the leakage occurs at the side of the hydrogen storage tank than at the top.

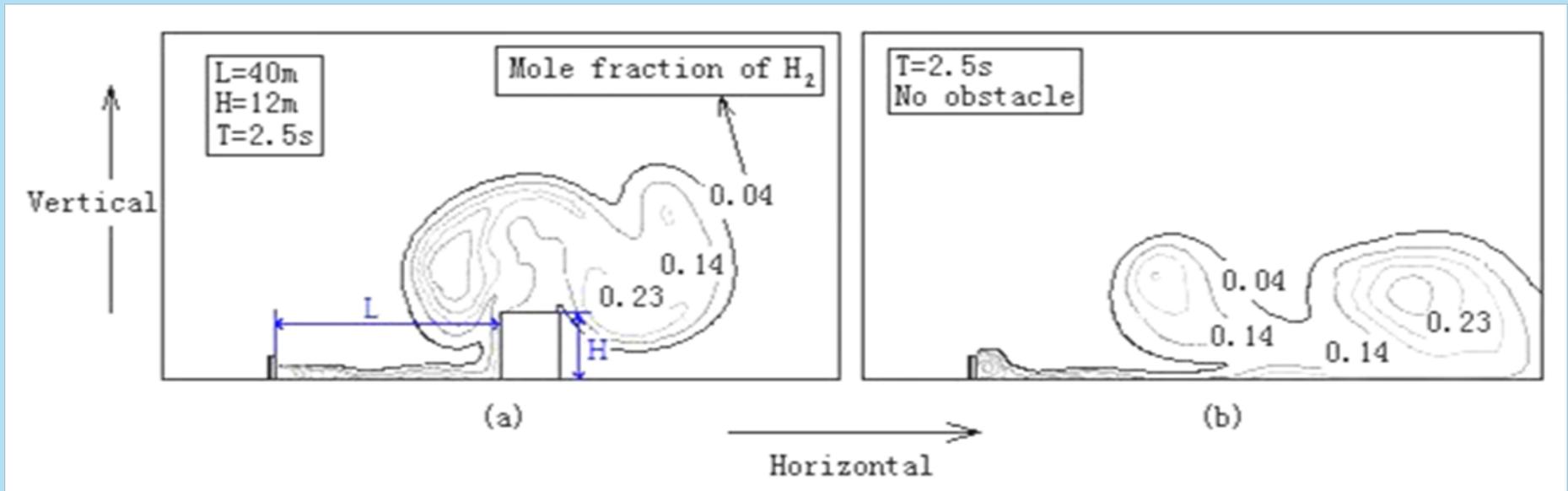


Mole fraction of hydrogen ($t=2.0s$) in the case of side leakage (a) or top leakage (b)



Simulation on Leakage and diffusion of High Pressured Hydrogen

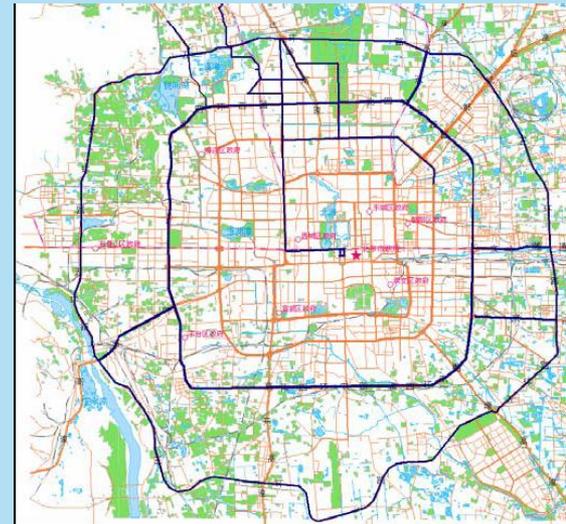
Numerical Studies on diffusion of High Pressured Hydrogen Due to Storage Tank Failure



Contours of mole fraction of H_2 in the case of obstacle (a) or no obstacle (b)



3、HCNG Vehicles



4 HCNG city buses were developed and demonstrated in Beijing. The range reached 15000km.



4、 Standardization Administration and Regulatory System

- **Standardization Law of P.R.C and its implementation regulations (enforced in 1989)**

- + **Nature of standards**

- Mandatory standards** the production, sales and import of products, provided they cannot show compliance with mandatory standards, are prohibited.

- Recommendatory standards**

- + **Standard categories**

- National standards**

- Industrial standards**

- Local standards**

- Enterprise standards**

- + **Standardization management**

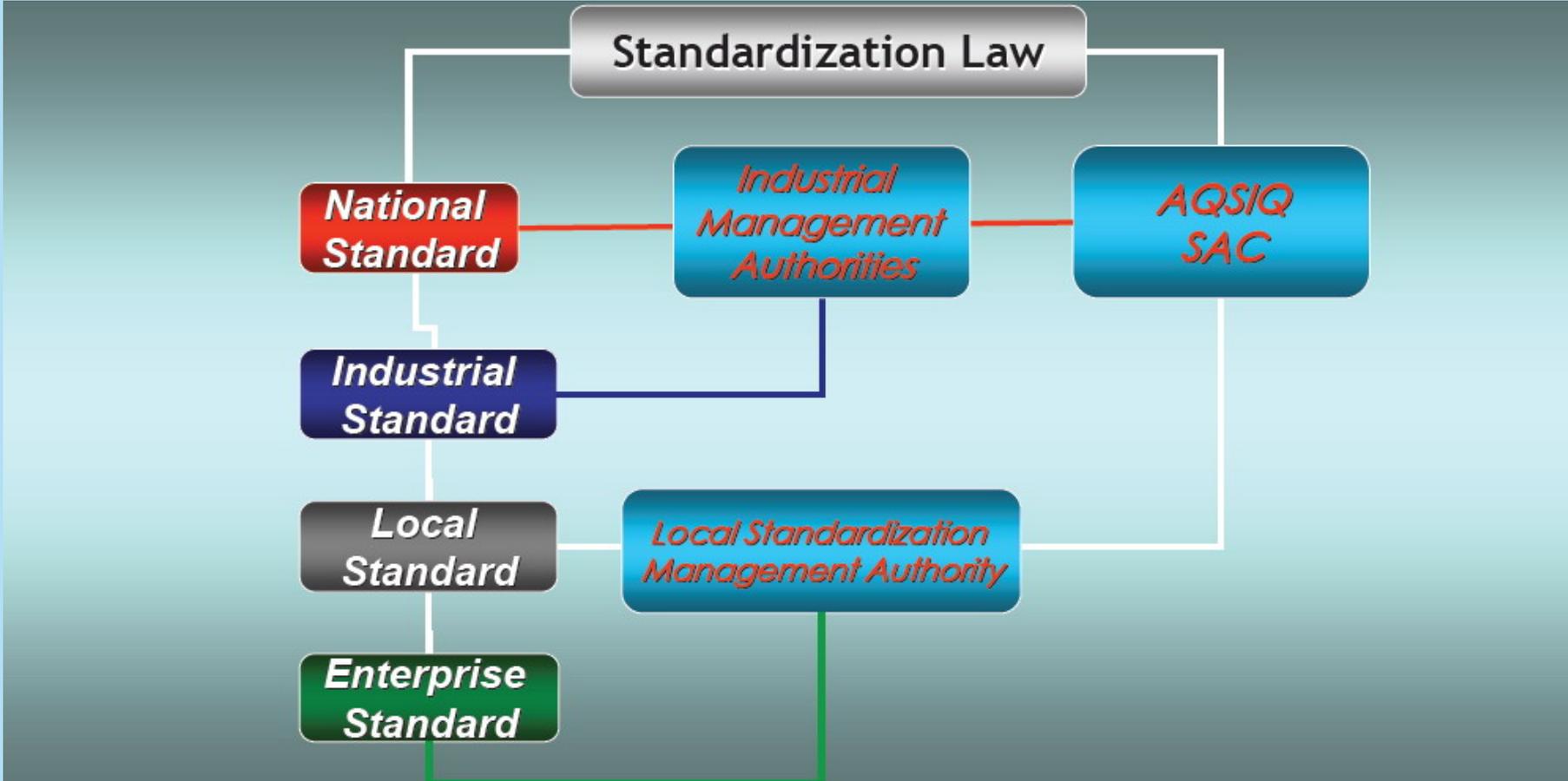
- National standards: General Administration Quality Supervision, Inspection, and Quarantine of P.R. China (AQSIQ) and Standardization Administration of P.R. China(SAC)**

- Industrial standards: authorities under the State Council, and submitted to relevant authorities for recording**

The introduction of International Standard and foreign advanced standards is encouraged.

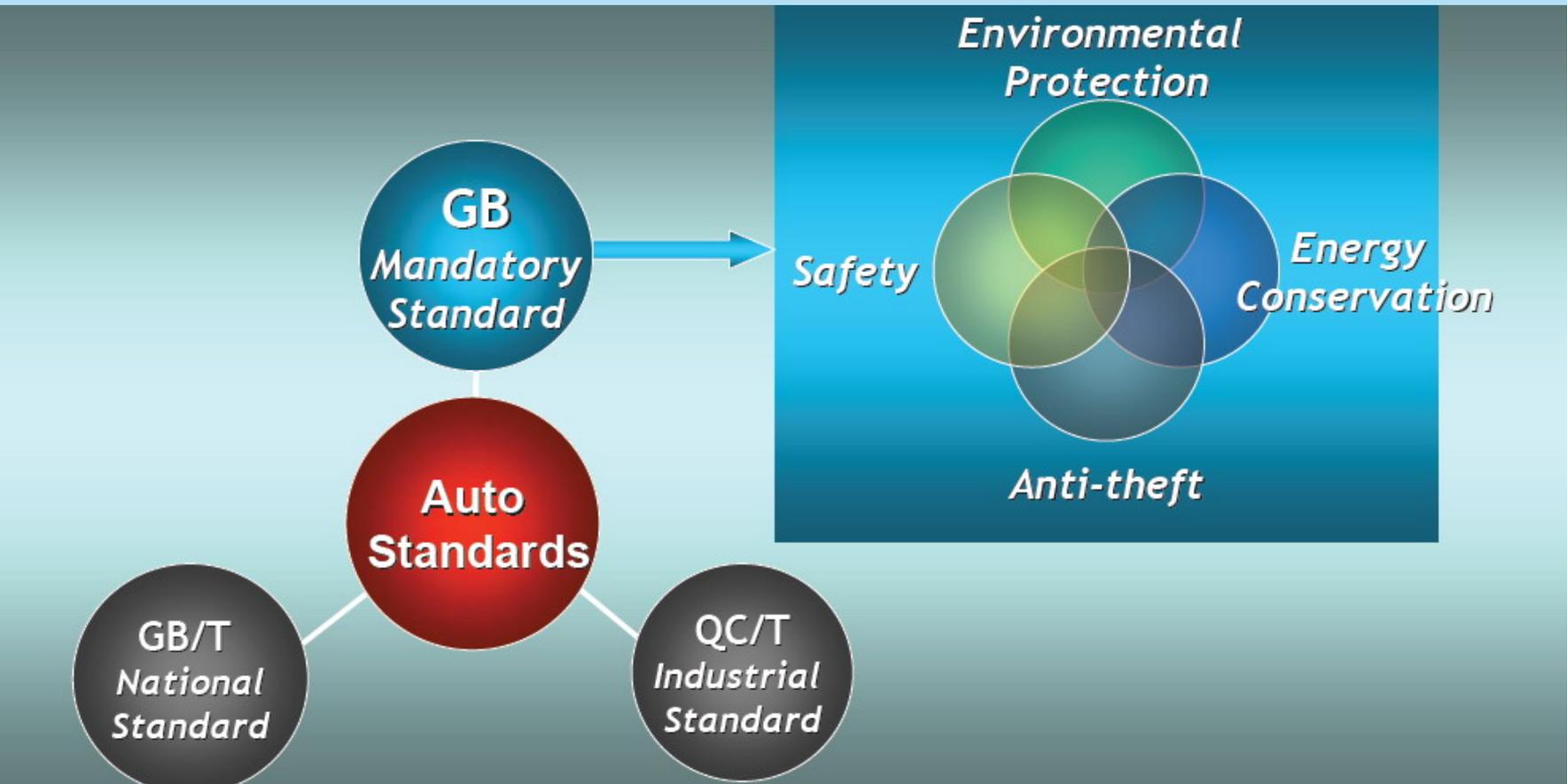


Safety and Regulatory Structure for CNG,CNG-H2,H2 Vehicles and Fuels in China





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





Regulations on safety supervision for special equipment

- **Boilers**
- **Pressure Vessels (including gas cylinders)**
- **Pressure Pipe**
- **Crane**
- **Passenger Transport Ropeway**
- **Escalator**
- **Factory Vehicles**
- **Large Entertainment Equipments**

Production (Including Design, Fabrication, Erection, Maintenance, Reconstruction), Use, Inspection, and Supervision



National Standardization Bodies Related to CNG, CNG-H2, H2 Vehicles

- 1、 SAC/TC309 National Technical Committee 309 on **Hydrogen Energy** of Standardization Administration of China (ISO/TC197 P Member)
- 2、 SAC/TC262 National Technical Committee 262 on **Boilers & Pressure Vessels** of Standardization Administration of China (ISO/TC11 P Member)
- 3、 SAC/TC31 National Technical Committee 31 on **Gas Cylinders** of Standardization Administration of China (ISO/TC58 P Member)
- 4、 SAC/TC114 National Technical Committee 114 on **Automotive Standardization** (ISO/TC22、 177 , P Member)



Standardization Administration Committee of the PR China (SAC)

SAC is authorized by the State Council and under the control of AQSIQ to exercise the administrative functions and carry out centralized administration for standardization in China. While relevant competent administrative departments of the State Council shall be assigned the responsibility of managing the work of standardization within their respective professional sectors. The competent administrative bureaus of standardization in the provinces, autonomous regions, municipalities, cities and counties shall execute unified administration of the work of standardization in their respective administrative regions. The provinces, autonomous regions, municipalities, cities and counties are also setting standardization departments in their governments. The SAC execute business administration of those province-level bureaus of technical supervision and execute directive administration in the system of under province-level bureau of technical supervision.



- **Major laws and technical policies related to motor vehicles motor vehicles**
 - + Law on Road Traffic Safety
 - + Law on the Prevention of Air Pollution
 - + Law on the Prevention and Control of Pollution From Environmental Noise
 - + Law on Conserving Energy
 - + Policy for the Development of Automotive Industry
- **Standards and technical regulations in China**
 - + No definition concerning technical regulation has been set out in the Legislation Law, which specifies the legal structure in China.
 - + Mandatory standards are used as technical regulations.
 - + Other standards are recommendatory ones.



5、 Regulations and Standards for CNG, H2 Vehicles

• Main regulations and standards for CNG vehicle

No.	Standards Name
1	Management practices for using vehicle converted to natural gas and liquefied petroleum gas vehicle
2	Certification scheme for natural gas and liquefied petroleum gas vehicle
3	Annual review approach for natural gas and liquefied petroleum gas vehicle
4	Liquefied petroleum gas and compressed natural gas vehicle-specific installation conditions for manufacturing enterprises
5	Conversion conditions of compressed natural gas and liquefied petroleum gas vehicle for business
6	Technical training and qualification of employees for natural gas and liquefied petroleum gas automotive
7	Regulations for compressed natural gas filling stations



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No.	Standards Number	Standards Name
8	GB 50156-2002	Code for design and construction of automobile gasoline and gas filling station
9	GB/T 19240-2003	Mounting requirements of special equipment for compressed natural vehicles
10	GB 19344-2003	Technique requirement and test method of leaking-safety of gas supply system on using gas vehicle
11	GB/T 19237-2003	Compressed natural gas dispenser for vehicle
12	GB 19533-2004	Periodic inspection and evaluation of steel gas cylinders for the on board storage of compressed natural gas as a fuel
13	GB/T 20734-2006	Mounting requirements for liquefied natural gas vehicle special equipment
14	GB/T 20735-2006	pressure regulator of CNG vehicles
15	GB/T 23335-2009	Natural gas vehicles - Engineering approval evaluation program



Main industrial standards for CNG vehicle

No.	Standards Number	Standards Name
1	SY 5853-1993	CNG cylinder safety management requirements for Petroleum industry
2	QC/T 257-1998	Natural gas vehicles - Engineering approval evaluation program
3	SY/T 0092-1998	Design code for compressed natural gas fueling station for vehicle
4	CJJ84-2000	Automotive Gas Station Technical Specifications
5	JB/T 10298-2001	The natural gas compressor for the vehicle gas station
6	QC/T 691-2002	Technical conditions for a single natural gas vehicle fuel engine
7	QC/T 692-2002	Technical conditions for gasoline / CNG dual-fuel engine



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No.	Standards Number	Standards Name
8	QC/T 245-2002	Technical conditions of special equipment for compressed natural vehicles
9	QC/T 694-2002	Technical conditions for diesel / CNG dual-fuel engine
10	JT/T 512-2004	Specification for the maintenance and inspection of compressed natural gas vehicle
11	AQ 3001-2005	Technology-separate and explosion-proof of gasoline gas filling station and light-fuel LPG tank of transportation by truck
12	AQ 3002-2005	Technology-separate and explosion-proof of auto gasoline gas filling portable device
13	QC/T 746-2006	High pressure pipelines for compressed natural vehicles
14	QC/T 674-2007	Solenoid valve of CNG vehicles



Situation of Hydrogen Energy Technology Standards in China

- Published hydrogen standards and codes:
 - + Industrial Hydrogen (GB3634)
 - + Pure hydrogen, High-Purity hydrogen and Ultrapure Hydrogen (GB/T7445)
 - + Technical Code on Safe Use of Hydrogen Gas(GB4962)
 - + Design Code on Hydrogen Gas Stations (GB50173)
 - + Technical Requirements on Water Electrolysis System for Hydrogen Production (GB/T 19774)
 - + Technical Requirements on Pressure Swing Adsorption System for Hydrogen Purification (GB/T 19773)



- Standards Being Developed
 - + Technical Code on Hydrogen Energy Automobile Refueling Stations (GB 50XX)
 - + Hydrogen Energy Terminology (GB/T XXXX)
 - + Fiber-reinforced high-pressure hydrogen cylinders with aluminum liner for land vehicle tanks
 - + Stationary flat steel ribbon wound vessels for storage of high pressure hydrogen
 - + Basic requirements for the safety of hydrogen systems



6、 Case Study: Introduction to China Hydrogen Standards

Design Code for Hydrogen Gas Stations (GB500177)

1. General
2. Terms
3. Overall Layout
4. Process Systems
(hydrogen production, compression, storage and filling)
5. Equipment Selection
6. Process Arrangement
7. Construction
8. Electric and Instrument Control
9. Lightning Protection and Earth
10. Water Supply and Drain and Fire Protection
11. Heating and Ventilation
12. Hydrogen Gas Piping



Technical Code on Hydrogen Energy Automobile Refueling Stations

1. General
2. Terms
3. Grade of Refueling Station
4. Site Selection
5. Overall Layout
6. Refueling Processes and Facilities
7. Fire Protection Facilities
8. Building Facilities
9. Water Supply and Drain
10. Electric Devices
11. Heating and Ventilation
12. Installation and Acceptance
13. Operation Management equipments

Appendix A: Classification of Explosion Hazardous Areas within Refueling Station

Appendix B: Classification of Civil Building Protection



Stationary flat steel ribbon wound vessels for storage of high pressure hydrogen

1. Scope

($\leq 100\text{MPa}$, D: 300 - 1500mm)

2. Reference Standards

3. Terms and Definitions

4. General

5. Materials

6. Design

7. Hydraulic test

8. Fabrication and Inspection

9. Marking, Packaging and Operation



Proposed Cooperation

Collaborate in the following areas Under the framework of energy cooperation between China and USA.

- **Seek opportunities to jointly apply for research funding from DOE , DOT , MOST, etc.**
- **Study of related standards and safety requirements, especially in the field of hydrogen embrittlement, fast filling, safety distance, etc.**
- **Develop International Standards, such as Hydrogen/CNG Stations, High Pressure Hydrogen Containers, High Pressure Hydrogen Supply Systems**
- **China is ready to be the Convener to develop international standard on HCNG station, Pressure Swing Adsorption. We would appreciate it very much if both USA and India could support China.**



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**



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Thank you!