Comparative Analysis of the Construction and Operation Status of Hydrogen Refueling Stations at Home and Abroad and the Classification of Hydrogen Refueling Stations in GB 50516-2010 "Technical Specifications for Hydrogen Refueling Stations"

Ke Pan¹*, Bingsheng Xu¹, Bo Wang¹, Chenhong Jin¹, Shan Hou¹

¹China National Institute of Standardization, Resource and Environmental Branch, No.4, Zhichun Road, Haidian District, Beijing 100191, China

*Corresponding author’s e-mail: panke@cnis.ac.cn

Abstract. This paper reviews and compares the construction and operation of hydrogen refueling stations in China, Japan, South Korea, and Europe, etc. This paper also analyzes the classification of hydrogen refueling stations in the current GB 50516-2010 “Technical Specifications for Hydrogen Refueling Stations” and puts forward suggestions for improvement. Reviews and reflections on hydrogen standardization of China have been made in this paper based on standardization status of hydrogenation station.

1. Introduction

Nowadays, with the rapid development of hydrogen industry, the construction of hydrogen refueling stations nationwide is progressing steadily. Japan's hydrogen industry infrastructure construction is currently in the leading position in the world, and its subsequent construction investment is still large. South Korea has made great efforts to develop the hydrogen industry. As a solution for its energy transformation, the construction of hydrogen energy infrastructure in South Korea is rapidly advancing. Comparing the construction and operation of hydrogen refueling stations of these two "neighbor countries" has great reference significance for China's domestic hydrogen industry. Europe has always been in the forefront of the world in the field of clean and renewable energy, and the construction of its hydrogen refueling station, as a new energy network layout, also has reference significance for China. Through the analysis it is clear that the current classification standard of hydrogenation station is out of date, which challenges standardization professionals in hydrogen industry of our country.

2. Construction and operation of hydrogen refueling stations in China

2.1. Geographical distribution

According to incomplete statistics, at present, there are about 144 hydrogen refueling stations in operation, under construction and are planned for construction in China, of which 53 are in operation, 2 have been built, and 89 are planned to be constructed.
2.1.1. Status of built and operational hydrogen refueling stations.

At present, the construction of hydrogen refueling stations in Guangdong, Shanghai, and Jiangsu is at the forefront of the country, with 15, 30 and 6 hydrogen refueling stations in operation respectively. Hubei, Liaoning, Hebei and other places are also accelerating the construction of hydrogen refueling stations.

2.1.2. Status of hydrogen refueling stations under planning/under construction

Shanghai and Guangdong are keeping their previous high momentum in construction, while Hebei, Inner Mongolia and other places are also beginning to exert efforts. It is expected that there will be more potential for various provinces in China in the future.
2.2. Time distribution
The wave of hydrogen refueling station construction in China started in 2017, boomed in 2018-2020, and it is still at the early stage of prosperity. Figure 3 shows the time distribution of the built hydrogen refueling stations in China:

Among them, the hydrogen refueling stations are classified according to the grading standard given in GB 50516-2010[1]. The grading distribution of hydrogen refueling stations built in different years is shown in Figure 4:

From 2006 to now, the hydrogen refueling stations in China are mainly third-grade stations, but hydrogen refueling stations above the second-grade have made a breakthrough in 2018, and the trend is increasing year by year.

2.3. Designed hydrogen storage capacity

The designed hydrogen storage capacity of hydrogen refueling stations that have been built and are operational in China varies from 80kg/d to 2000kg/d, of which the hydrogen refueling stations with
the storage capacity of 500kg/d and 1000kg/d take the majority. This means that these two hydrogen storage capacities are the current mainstream specifications internationally. In the future, there will be fewer and fewer newly built hydrogen refueling stations with the designed hydrogen storage capacity below 500kg/d. In the future, the designed hydrogen storage capacity of newly built hydrogen refueling stations will still be mainly distributed at 500kg/d, and some relevant parties will still be interested in hydrogen refueling stations with the storage capacity of more than 1000kg/d. This trend also mirrors the diversified trend of future hydrogen energy application scenarios.

2.4. Types of hydrogen refueling stations

2.4.1. Types of hydrogen refueling stations built and operational

Currently hydrogen refueling stations in China are mainly dedicated hydrogen refueling stations, and there are only a small number of petrol-hydrogen hybrid stations and petrol-hydrogen-electricity hybrid stations.

2.4.2. Types of hydrogen refueling stations planned for construction

New hydrogen refueling stations in the future will show a trend of hybrid types, such as petrol-hydrogen hybrid stations, gas-hydrogen hybrid stations, and petrol-hydrogen-electricity hybrid stations, etc.

2.5. Filling pressure and hydrogen storage method

At present, most hydrogen storage methods of hydrogen refueling stations in China are high-pressure gaseous hydrogen storage. The only low-pressure hydrogen storage hydrogen refueling station is the world's first low-pressure hydrogen storage hydrogen refueling station- Liaoning Xingcheng Hydrogen
Refueling Station; Yueyang, Hunan is planning to build a hydrogen refueling station employing liquid hydrogen storage method-Yueyang Green Chemical Plant hydrogen refueling station.

At present, the main hydrogen refueling stations built and operated in China are 35MPa, for example, RuGao Shenhua hydrogen refueling station, Shanghai Yilanjinshan hydrogen refueling station, Shandong Weichai hydrogen refueling station; the Inner Mongolia Wuhai chemical hydrogen refueling station have both 35MPa and 70MPa filling capacity.

3. Construction and operation of hydrogen refueling stations in Japan and South Korea

3.1. Number of hydrogen refueling stations

According to incomplete statistics, there are currently about 134 hydrogen refueling stations built, operated and are planned for construction in Japan, of which 115 are in operation and 19 are planned to be constructed; the total number of hydrogen refueling stations in operation and are planned for construction in South Korea is about 70, of which 32 are in operation and 38 are planned to be constructed.

3.1.1. Status of built and operational hydrogen refueling stations

In general, due to the early development of Japan's hydrogen energy industry, there are more hydrogen refueling stations in Japan than in South Korea.

3.1.2. Status of hydrogen refueling stations under planning
Figure 9. Comparison of the number of hydrogen refueling stations planned to be constructed in Japan and South Korea

There are currently more hydrogen refueling stations planned to be constructed in South Korea than in Japan.

3.2. Filling pressure

Figure 10. Distribution of filling pressure of hydrogen refueling stations that have been built and planned in Japan and South Korea

At present, the filling pressure of hydrogen refueling stations that have been built and operated in Japan and South Korea is mainly 70MPa. In addition, there are a few hydrogen refueling stations with both 35MPa and 70MPa filling capabilities. Statistics show that almost all hydrogen refueling stations planned to be constructed in Japan and South Korea are 70MPA hydrogen refueling stations.
3.3. Types of hydrogen refueling stations

At present, a considerable number of hydrogen refueling stations in Japan are mobile hydrogen refueling stations, which are closely related to their design and application scenarios. At present, a considerable number of hydrogen refueling stations in Japan are self-service hydrogen refueling stations in transportation hubs such as airports, which give full play to their convenient and instant hydrogen refueling function.

4. Construction and operation of hydrogen refueling stations in Europe

4.1. Number of hydrogen refueling stations

According to incomplete statistics, a total of 18 countries in Europe have built or are building hydrogen refueling stations.

4.1.1. Status of built and operational hydrogen refueling stations

At present, Germany, France, the Netherlands and other countries are "big users" of hydrogen energy in Europe [4]. Their hydrogen energy industry starts early, boasts strong strength, and enjoys rapid development. The number of hydrogen refueling stations and the development momentum of the industry in these countries are also consistent with each other.

4.1.2. Status of hydrogen refueling stations under planning
Germany and France will continue their traditional hydrogen power status for a period of time. Switzerland, Belgium and other countries are also gradually accelerating the pace of hydrogen refueling station construction.

4.2. Filling pressure

4.2.1. Vertical comparison
The vertical comparison shows that Germany, France, Switzerland and other countries are expected to continue their current refueling pressure distribution in the future; while some countries such as the Czech Republic and Italy are expected to change their refueling pressure significantly as the number of hydrogen refueling stations increases.

4.2.2. Horizontal comparison

(1) Status of built and operational hydrogen refueling stations

![Figure 15. Distribution of filling pressure of hydrogen refueling stations that have been built in European countries known currently.](image)

Among the countries with a large number of hydrogen refueling stations, Germany has built the hydrogen refueling stations with the filling pressure of 70 MPa mainly, France with 35 MPa mainly, and other countries with 70 MPa slightly more than 35 MPa.

(2) Status of hydrogen refueling stations under planning

![Figure 16. Distribution of filling pressure of hydrogen refueling stations under planning in European countries known currently.](image)

Among the currently known hydrogen refueling stations planned by European countries, France, the United Kingdom, Belgium and other countries mainly adopt the 35MPa type with several mixed pressure ones, while most of the other countries use 70MPa type with mixed pressure ones.

5. Viewing the classification of hydrogen refueling stations in GB 50516-2010[1] from the current status of hydrogen refueling station construction and operation

Table 1. Classification of hydrogen refueling stations in GB 50516-2010.

| Grade      | Hydrogen storage tank capacity (kg) | Total capacity G | Single tank capacity |
|------------|------------------------------------|------------------|---------------------|
| First-grade| 4000 < G ≤ 8000                    | ≤ 2000           |                     |
| Second-grade| 1000 < G ≤ 4000                  | ≤ 1000           |                     |
| Third-grade| G ≤ 4000                           | ≤ 500            |                     |
Table 2. Classification of hydrogen-gas hybrid stations GB 50516-2010.

| Grade     | Total capacity G | Single tank capacity |
|-----------|------------------|----------------------|
| First-grade | 1000< G≤4000     | ≤1000                |
| Second-grade | G≤1000          | ≤500                 |

Table 3. Classification of hydrogen-petrol hybrid stations GB 50516-2010.

| Petrol station grade | Hydrogen refueling station grade |
|----------------------|----------------------------------|
| First-grade          | (120 m3 < V ≤180 m3)             |
| Second-grade         | (60 m3 < V ≤120 m3)              |
| Third-grade          | (V ≤30 m3)                       |

GB 50516-2010 makes clear requirements for the classification of hydrogen refueling stations, hydrogen-gas hybrid stations, and petrol-gas hybrid stations. Figure 4 shows that according to the classification of hydrogen refueling stations in GB 50516-2010, there are currently very few hydrogen refueling stations of first-grade and second-grade in China, and third-grade hydrogen refueling stations takes the majority. This shows that this classification method is not able to pull the gradient for the domestic hydrogen refueling station currently, which weakens the significance of the classification. At the time when this standard was developed, the number of hydrogen refueling stations in China was still a single digit, and we took foreign technical indicators [5] by reference for the classification of hydrogen refueling stations. At present, the number of hydrogen refueling stations in China has already exceeded the three-digit number, and there are still more hydrogen refueling stations under planning. Therefore, in line with the reality of the industry development in China, a classification method that can pull the gradient of hydrogen refueling stations shall be the focus of future study.

In addition, it can be seen from Figure 7 that the main trend of hydrogen refueling stations in China in the future is to combine multiple energy sources such as petrol, hydrogen, electricity and even photovoltaics together. Therefore, in the future, it is necessary to further consider the classification method of multiple energy refueling stations. For example, in the current classification of hydrogen/petrol refueling stations, a petrol-hydrogen hybrid station can be classified as first-grade if either the petrol station or the hydrogen refueling station can reach second-grade. However, in fact, there are still no hydrogen/petrol refueling stations in China that can reach the first-grade. Therefore, the classification method of multi-energy hybrid refueling stations should be scientifically formulated considering various factors.

6. Conclusion

With policy support, technology development and infrastructure construction, hydrogen industry in China is on its way to blossom. Construction and operation of hydrogen refueling stations in China, Japan, South Korea, and Europe has great reference significance for China's domestic hydrogen industry, while we should also consider our own condition. The problem of GB 50516-2010 is also the epitome of the development of hydrogen standardization in China for more than ten years. Before 2017, the hydrogen industry has been in its infancy, and the hydrogen refueling stations mostly exist in the form of demonstration warfare. Therefore, in the past decade or so, technical indicators of China's hydrogen standards have been mostly based on international standards. In recent years, China’s hydrogen industry has been rapidly industrialized. The industry has higher and higher requirements for its own standardization level, thus the existing standards have become less and less "thirst quenching", to solve this problem, a large number of hydrogen group standards have been approved in the last year.
Hydrogen industry is an emerging sunrise industry. It is a test of the ability of standardization professionals to tailor the hydrogen energy industry to make a good standard system.

Notes
① The data in this article is as of late October 2020
② Due to the lack of relevant data on the types of hydrogen refueling stations in South Korea, this section only concerns hydrogen refueling stations in Japan.

References
[1] Chen L., Deng Y., Mao Z., etc. (2010). GB 50516-2010, Technical Specifications for Hydrogen Refueling Stations. China Planning Press, Beijing.
[2] Wang G., Yang Y., He G., etc. (2018) China Hydrogen Energy Industry Infrastructure Development Blue Book. China Quality Inspection press, Beijing.
[3] Mi S., Yu Z., Zhang W., etc. (2019). China Hydrogen Energy and Fuel Cell Industry White Paper (2019 Edition). China Hydrogen Energy Alliance, Beijing.
[4] Kang Y., Xiong X., Zhao M. (2020). The Main Points of EU Green Deal and Its Enlightenment to China. China Development Observation, 5:114-117.
[5] Cao X., Wei Z., (2020). Research on the Safety Technology of Hydrogen Energy Utilization and the Construction of the Standard System. Engineering Science in China,5: 1-8