



Research on Distributed LPG Small Storage Tank Gas Supply Device and System

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Abstract. LPG is still the gas source with the largest consumer population and the widest popularity in China. However, the existing cylinder gas supply mode has high operating management costs, and users generally have weak awareness of safety operations, lack professional safety management methods, and emergency response capabilities, which are prone to causing safety accidents such as leaks and explosions. Therefore, this article proposes a gas supply mode for LPG tank trucks with pumps to fill small storage tanks, namely the "distributed LPG small storage tank point supply method". Based on this gas supply mode and combined with existing "Internet of Things+" technology, an intelligent LPG small storage tank gas supply system has been developed.

Keywords: Distributed point supply; Intelligent LPG small storage tank; Gas supply system

1 INTRODUCTION

In recent years, with the development and changes in the national energy utilization pattern and situation[1], not only is there an urgent need for the transformation of gas supply methods for ordinary rural residents in suburban and township areas, but the rapid development of a large number of industrial enterprises (especially small and medium-sized enterprises, including schools, shops, etc.) that cannot be covered by gas pipelines has also generated personalized and intensive energy needs. However, currently, the main regulatory standards for the storage of liquefied petroleum gas in China include SY5985-2014 "Safety Regulations for Liquefied Petroleum Gas" [2], GB50028-2006 "Design Code for Urban Gas" [3], GB51142-2015 "Design Code for Liquefied Petroleum Gas Supply Engineering" [4], NB/T 47001-2009 "Form and Basic Parameters of Steel Liquefied Petroleum Gas Horizontal Storage Tanks" [5], NB/T 47042-2014 "Horizontal Containers" [6], etc. However, there is a lack of specific usage management requirements for the corresponding area and layout. Based on this, the usage mode of LPG tank trucks with pumps filling small storage tanks proposed in this article will provide a perfect solution for such users. At the same time,

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A. Rauf et al. (eds.), *Proceedings of the 3rd International Conference on Management Science and Software Engineering (ICMSSE 2023)*, Atlantis Highlights in Engineering 20,

https://doi.org/10.2991/978-94-6463-262-0_36

combined with existing "Internet of Things+" technology, an intelligent LPG small storage tank gas supply system will be developed.

2 DISTRIBUTED LPG SMALL STORAGE TANK POINT SUPPLY TECHNOLOGY

The distributed LPG small storage tank point supply method, as shown in Figure 1, has significant advantages such as short construction period, low investment, and flexible application. It can effectively improve domestic energy utilization efficiency and is one of the important carriers of distributed energy. This model requires the installation of small LPG storage tank gas supply systems near buildings such as rural areas, small residential areas, commercial and industrial users. The gas supply scale of the location of the small storage tank can be determined based on factors such as user category, gas consumption scale, and turnover days. Generally, the set effective volume can ensure that users use it for at least six months, and regular distribution of small storage tanks can be achieved through dedicated LPG tank trucks with pumps to achieve pipeline supply for LPG users.

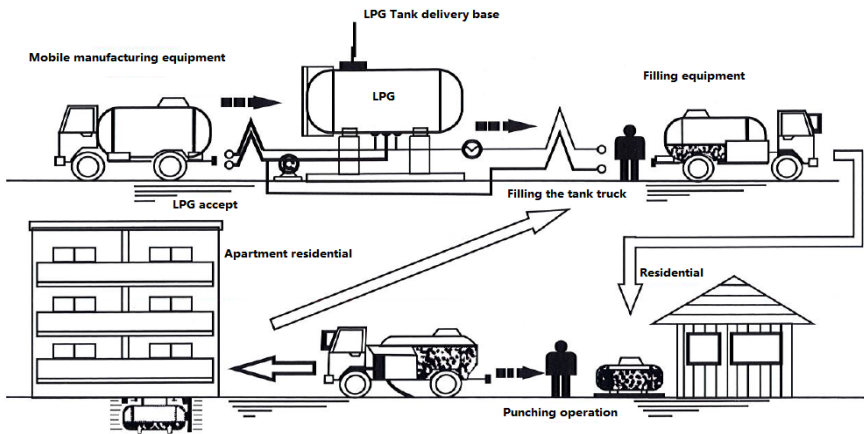


Fig. 1. Distributed LPG Small Storage Tank Point Supply Method

The main operating mode of the distributed LPG small storage tank point supply method is shown in Figure 2: Gas operating units generally issue delivery instructions to LPG tank trucks with pumps based on the distribution plan formulated by end customers every six months or the automatic feedback of liquid delivery demand signals from end customers supporting small storage tanks, After receiving the delivery order, the LPG tank truck with a pump is filled at the liquid source and transported by road to the location of the downstream LPG small storage tank as required to fill the small storage tank. After all filling tasks are completed, the LPG tank truck with a pump will empty and return to the liquid source for refilling in preparation for the next delivery order.

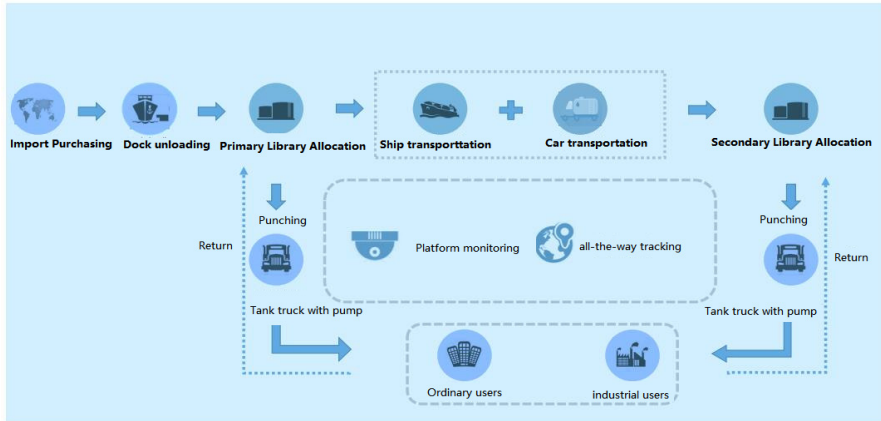


Fig. 2. LPG distribution process using small storage tanks

3 THE INTELLIGENT LPG SMALL STORAGE TANK GAS SUPPLY SYSTEM

The intelligent LPG storage tank gas supply system includes a small liquefied petroleum gas (commodity propane) (hereinafter referred to as LPG) tank car (hereinafter referred to as LPG tank car with pump), a small liquefied petroleum gas (commodity propane) storage tank (hereinafter referred to as LPG small storage tank), a manufacturing service platform, and a gas operation management platform.

3.1 Development of Small LPG Storage Tanks

3.1.1 Main Performance.

The LPG tank car with pump is designed, manufactured, and inspected in accordance with the standard T/CATSI 05005-2021 [7]"Small Liquefied Petroleum Gas (Commercial Propane) Tank Car with Unloading Pump". The tank is filled with LPG and permanently connected to the fixed chassis, equipped with unloading pumps, metering systems, unloading hoses, dedicated unloading joints, and other equipment. It is equipped with control devices and safety devices for road transportation of pressure tank vehicles unloading LPG to small LPG storage tanks.

3.1.2 Design Parameters.

The specification of the LPG small storage tank used in conjunction with the T/CATSI 05005-2021 standard tank truck with pump is 0.5m³、1m³、2m³、2.5m³、5m³ Five volume series, with loading capacities of 210kg, 420kg, 840kg, 1050kg, and 2100kg respectively. It has been learned that most foreign tank trucks with pumps choose 4*2 chassis, considering transportation efficiency and load-bearing capacity, the tank body specification of the tank truck with pump is integrated into a capacity of

5m³ (2.1 tons), 7.5m³ (3.15 tons), 10m³ (4.2 tons), 12.5m³ (5.25 tons), 15m³ Five specifications including (6.3 tons).

According to Article 7.4.5 of T/CATSI 05005-2021 "Small Liquefied Petroleum Gas (Commercial Propane) Truck Tank Car with Unloading Pump", the design pressure of the tank body should not be less than the maximum working pressure under any of the following working conditions, and should not be less than 1.76MPa; a) Working pressure for filling and unloading conditions; b) Saturated Vapor pressure (gauge pressure) of medium at design temperature.

Considering that the tank body is a container that operates under the influence of environmental temperature, the minimum environmental temperature is -40 °C. According to the provisions of Article 7.4.3 and 7.4.4 of T/CATSI 05005-2021 "Small Liquefied Petroleum Gas (Commercial Propane) Truck Tank Car with Unloading Pump", the design temperature of the tank body is taken as 50 °C, and the minimum design metal temperature is taken as -40°C.

According to Article 7.4.5.1 of T/CATSI 05005-2021 Small Liquefied Petroleum Gas (Commercial Propane) Tank Car with Liquid Unloading Pump, the filling capacity of the tank per unit volume shall be determined according to the gas Phase space of at least 5% left in the tank at 50 °C for liquefied petroleum gas (commercial propane), the density of liquefied petroleum gas (commercial propane) at this temperature, and the allowable carrying capacity of the tank car. In addition, the tank shall not be full of liquid at 60°C. Article 7.4.5.2 stipulates that the unit volume filling capacity of the tank body should not exceed 0.42t/m³. Therefore, the filling coefficient of the tank body is selected as 0.42t/m³.

3.1.3 Process Principles.

Due to the need for tank trucks with pumps to unload liquids at different unloading points, the liquefied petroleum (commercial propane) liquid in the tank body is basically in a state of 20% to 80% of the tank body volume. Additionally, it is necessary to consider the highway conditions in the area where small tank trucks are used to prevent accidents such as overturning during transportation. Therefore, this standard proposes a wave proof volume requirement based on the geometric volume of the tank body, which means that the geometric volume of the tank body should not exceed 7.5m³, Its wave proof capacity is not more than 3m³, However, the requirement for the effective area of the anti wave board should be appropriately relaxed, that is, not less than 40% of the cross-sectional area of the tank body. For tank volume greater than 7.5m³ With a wave proof capacity not exceeding 7.5m³, The effective area of the anti wave plate shall not be less than 70% of the cross-sectional area of the tank body, which is consistent with the anti wave volume requirements of GB/T 19905-2017. In order to prevent the absence of anti wave capacity, the standard also stipulates that the tank body should be equipped with at least one set of anti wave plates.

According to the characteristics of tank trucks with pumps, this standard divides the loading and unloading system into two parts: the filling system and the unloading system. Technical requirements are proposed for the filling and unloading systems respectively, and it is clear that the filling and unloading systems are composed of

three independent and connected devices. The setting requirements for the filling system are in accordance with the provisions of GB/T 19905-2017. The unloading system is divided into three parts according to functional requirements: liquid phase system, reflux system, and return gas system, and the setting requirements for each of the three sub systems are provided.

3.2 The composition and working principle of a fixed point unloading information management system

The fixed point unloading information management platform for tank trucks with pumps, as shown in Figure 3, relies on information technology such as electronic reading or electronic labels to manage the fixed point unloading system of small tank trucks produced by our unit, ensuring that the tank trucks with pumps cannot unload liquid into gas cylinders or fixed containers that are not included in the management. According to T/CATSI 05005-2021 "Small Liquefied Petroleum Gas (Commodity Propane) Truck Tank Cars with Unloading Pumps", its application scope is only limited to fixed small liquefied petroleum gas (commodity propane) storage tanks with limited filling devices, and the unloading object is limited to those containing liquefied petroleum gas (commodity propane) with pumps. The maximum identification distance should be set for the fixed point identification and tank identification pairing between the tank truck with a pump and a small storage tank. The fixed point pairing distance is <math><30\text{m}</math>, and the distance between the tank truck with a pump and the small storage tank exceeds 30m. The near field communication channel is disconnected. The tank car with a pump communicates with the electronic reading system of a small storage tank through a near-field communication channel. The tank car with a pump pairs the "car" and "tank" based on the electronic reading information transmitted through the near-field communication channel. After the "identification tank" pairing is successful, the unloading pump can be started for unloading. The matching distance between cans should be $\le 10\text{cm}$ and continuous reading should be maintained. The electronic reading distance exceeds 10cm, the reading fails, and the tanker with a pump cannot unload the liquid.

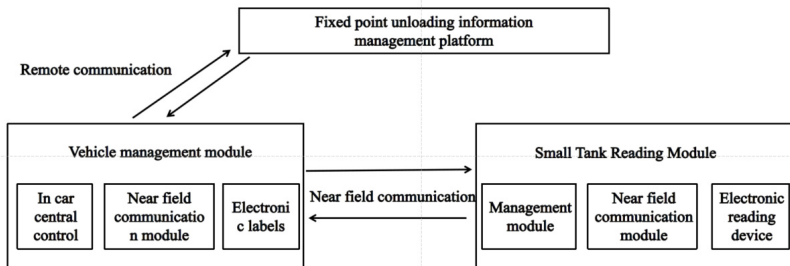


Fig. 3. Fixed point unloading information management system

3.3 Development of Manufacturing Service Platform

In order to prevent the problem of unloading liquids at non designated locations and illegally filling gas cylinders, electronic labels are installed on the unloading gun of tank trucks with pumps, and they can only be unloaded after being encrypted and closely paired with the electronic reading device of small LPG tanks to prevent illegal unloading. The management of the reading device is completed by the enterprise manufacturing safety management platform developed by the manufacturer of tank trucks with pumps.

The manufacturing platform can monitor the vehicle status in real-time based on the vehicle related information uploaded by the onboard central control terminal, and at the same time forward the relevant information to the operation management and other platforms according to relevant needs. The manufacturing platform can monitor the fixed-point filling of the designated tank car with pump and the designated small storage tank, without specific requirements for the implementation method. The electronic fence, directional identification, the Internet of Things Combination lock installed on the operation box door, the local communication identification authentication between the on-board central control terminal and the fixed pressure vessel tank and other methods can be supplemented as related auxiliary functions, and the unloading pump can only be started after the completion of the electronic communication identification between the tank car and the designated storage tank.

3.4 Development of Gas Operation Management Platform

To improve the intelligent and automated operation level of gas operating units, significantly reduce the operation and maintenance costs of stations, personnel, etc., and minimize the safety risks throughout the entire process of LPG filling, distribution, and use. Gas operation companies can choose to independently develop or rent gas operation and management platforms based on their own business volume and functions. The specific construction functions of the gas operation and management platform should include: 1) system management, generally operated by super administrators and tenants, managing some global configurations of the system; 2) Resource center, mainly responsible for driver management and ticket management; 3) Operation monitoring, used to view detailed information of tank trucks and tanks in real-time; 4) Vehicle monitoring, used to view vehicle trajectory, alarm information, etc; 5) LPG small storage tank monitoring is used to monitor the network status, station name, real-time monitoring data of LPG small storage tanks, monitoring data update time, real-time status of LPG small storage tank components, and to view the historical monitoring data of the selected LPG small storage tank within a specified time. The gas operation management platform will automatically send delivery instructions to the LPG pump tank truck according to the established delivery plan of the end user or when receiving automatic feedback from the end customer's matching small storage tank for liquid delivery. The LPG pump tank truck will fill in the liquid source after receiving the delivery instructions.

4 CONCLUSION

The distributed small LPG storage tank point supply technology and intelligent LPG storage tank gas supply system proposed in this paper are suitable for villages where the municipal gas pipeline is not laid outside the red line. Through the construction of small gas supply devices and intelligent micro pipe network systems in pilot villages, a centralized gas supply system for Economic security village pipelines is formed, creating pipeline gas supply conditions for villages. At present, pilot applications have been carried out in many provinces, and have received strong support from the governments of many pilot provinces. For example, Zhejiang Province has issued a pilot implementation plan, which proposes to pilot in Quzhou City, Lanxi County, and Anji County. After pilot applications in this province, by the end of December 2021, more than 50% of rural residents in the pilot area will use pipeline gas. The application results show that:

(1) Compared with the traditional LPG supply mode, the distributed LPG small storage tank point supply technology is flexible and innovative, which can reduce energy consumption by more than 40% and achieve significant energy-saving effects;

(2) This has greatly improved the intelligent and automated operation level of gas operating units, significantly reduced the operation and maintenance costs of stations, personnel, and other aspects, and minimized the safety risks throughout the entire process of LPG filling, distribution, and use.

5 PROSPET

The distributed LPG small storage tank point supply technology and intelligent LPG storage tank supply system proposed in this article provide a new mode for the supply of liquefied petroleum gas in China, especially for the diversification of clean energy supply methods in rural areas.

(1) According to the design principle of Intrinsic safety, the gas supply system adopts technical measures such as valve components with active and passive protection functions, IoT locks, anti-collision, leak prevention, misoperation prevention and interlock control devices, remote online monitoring, as well as technologies such as electronic fences, WIFI near station identification, two-way identification of vehicles and tanks, active safe driving, central control, and operation monitoring, with safe and reliable use effect. Satisfying the safe, convenient, and economic gas consumption needs of rural areas in China, achieving the goal of replicability and promotion.

(2) After market research and calculation, the number of potential users of intelligent LPG storage tank gas supply equipment in China has exceeded 150 million. According to the annual installation of 1 million residential users, one set of gas storage tank station is set up for every 100 households. In the next three years, residential users will need 60000 new gas storage tank stations, and non residential users will need 90000 sets, with a total market demand of over 150000 sets; According to the maximum configuration of one tank truck with a pump for every 30 gas storage tank stations, the demand for tank trucks with a pump in the next 3 years will exceed 5000

sets. Therefore, the project products have a broad potential market, with Zhejiang, Jiangsu, Anhui and other East China markets requiring over 20000 sets of gas storage tank stations and nearly 700 tank trucks with pumps in the past three years. The long-term market demand is guaranteed, and the market prospects are very broad.

The research content of this article comes from the national key research topic "Installation of Small Liquefied Petroleum Gas Storage Tanks". During the project research process, it received strong support from the National Ministry of Housing and Urban Gas Association. With the support of the National Ministry of Housing and Urban Gas Association, the distributed point supply and gas supply model proposed in this project has passed the "three new" technical review. We sincerely express our gratitude.

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