

Liquid State CO₂ Simulation Study of Storage Tank Storage Characteristics

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Abstract: Liquid CO₂ is formulated for Huang 3 well area of the fifth oil production Plant of Changqing Oilfield. Tank storage technology standard, the simulation study of the storage characteristics of the tank, through the study in the unloading, static storage, injection, tank in the process of the factors on the influence of the storage characteristics with the factors, combined with the actual field operation, develop a set of reasonable storage tank application technology, field application.

Keywords: Liquid CO₂, Simulation research, Static storage, Storage characteristics

1. Introduction

The production demand of this project comes from the need of improving oil recovery and maintaining steady production in Changqing Oilfield. In 2014, CNPC decided to carry out CO₂ in Huang District 3 of Changqing Oilfield. Drive (throughput) pilot test, currently, yellow 3 CO₂ Liquid CO₂ of the injection station. The supply is completely dependent on the car transport, the gas source source for Ningxia Delta Gas Development Technology Co., LTD., gas source in CO₂ Content of more than 99%, the comprehensive cost is higher. With the completion and operation of natural gas treatment plant, purification plant, Huang 3 comprehensive test station and other treatment station, CO₂ Will gradually enrich the source, can further improve the CO₂ The economic benefits of the drive. Yellow 3 CO₂ The design of the injection station mainly refers to the relevant data of Jilin oilfield, and the industry lacks the relevant standard guidance.

Therefore, four liquid CO₂ units have been built in the CO₂ injection station in Huang Area 3. The storage tank is the research object, according to the design parameters of the storage tank and the installation of the process pipeline. Simulation model of the storage tank to rationally optimize the liquid CO₂ through the simulation. Storage tank application technology solution, to form the liquid CO₂ Technical standards for storage and storage, to provide the relevant basis for static storage.

2. Research Methods

2.1. Numerical Calculation Method

This study uses a finite element method to solve the mechanical phenomena of the structural system containing the storage tank and its foundation under various external loads

The calculations for iteratively solving the above controlled equations are shown in Table 1.

Table 1. Numerical calculation model selection

types of models	Model selection
The control equation solves the model	immediate integration
Time integral model	The Newmark implicit integration scheme
Nonlinear convergence model	Newton-Raphson model

2.2. Mathematical Model of Gas Flow

2.2.1. Fluid Dynamic Conservation Equation

In the process of flow, the fluid follows the basic principles of fluid mechanics, namely the general law of mechanical motion, namely the three laws of fluid mechanics: namely the law of mass conservation, energy conservation law and the law of momentum conservation.

Among them, c_p is the specific heat capacity, T is the temperature, K is the heat transfer coefficient of the fluid, ST is the internal heat source of the fluid and the part of the fluid mechanical energy converted to heat energy, sometimes referred to as ST is a viscous dissipation term.

2.2.2. Turbulence Equation

The previously developed common turbulence models include zero-equation model, single-equation model, two-

side equation model, Reynolds stress transmission equation model (RSM), and algebraic stress model.

Zero Equation Model (mixed-length model)

$\overline{u_i' u_j'}$ The earliest turbulent closure method was proposed by Prandtl in 1925, which directly simulates the time average value in the Reynolds time average equation system, called the mixed length model, also called the algebraic equation model or the zero equation model. The model starts from a simple physical scenario of two analogies. The advantage of the mixed length model is intuitive and simple without additional turbulence characteristic differential equations.

(2) Single equation model (turbulent kinetic energy equation model)

Turbulent pulsation is a kind of energy, which is a part of

the overall kinetic energy (time-average kinetic energy plus pulsating kinetic energy), and thus obey the general transport theorem or conservation theorem, that is, has its convection, diffusion, generation and dissipation.

Kolmogorov and Prandtl have respectively proposed to determine the turbulent viscosity by solving the differential square of the turbulent characteristics (including the turbulent kinetic energy). In order to make the equation closed, the simulation assumption is used to reduce the third order correlation term order, and to express the second order term as a function of the average quantity. The basic idea here is to use gradient simulation. However, in a single-equation model, l still needs to be given by the empirical formula. The advantage of the single equation model over the mixed length model is to overcome the shortcomings of the latter, considering the turbulence energy experience effect (convection) and the mixing effect (diffusion), so it is more reasonable to give an expression for simple flow l , but for complex flow, l is difficult to give.

(3) The Reynolds stress equation model

$u_i' \phi_j'$ The stress model adopts another method of closed Reynolds time mean equation, which continues to derive the transport equation for the second order correlation term, and introduces the third order unknown (the time mean of the product of three pulsation values), and introduces the model for closed assumption. The simplified treatment of the higher-order terms is different, forming different stress equation models. At present, the second moment sealing method is more mature, which forms the Reynolds stress transmission (RSM) model. It uses second-order correlation quantities to simulate unknown third-order and other correlation quantities in Eq.

The Reynolds stress delivery model abandons the Boussinesq assumption and includes more physical processes; the advantage is that anisotropic effects, especially rotation, buoyancy, curvature, can perform the $k-\epsilon$ model in many cases. However, this model is too complicated for engineering application, and the computer storage and CPU time are used for 3 D problems. Second, the boundary conditions for each stress and flux component are difficult to define; many empirical coefficients are difficult to determine. Moreover, the simulation of the strain terms is still controversial.

(4) $k-\epsilon$ model

In the turbulent flow of turbulent kinetic energy k and turbulent diffusivity ϵ are two important parameters to describe the turbulent process, so often used in turbulence model is the standard $k-\epsilon$ equation model, which is a verified is considered empirical equation, which k equation is a relatively accurate equation, and ϵ is an empirical model equation derived. The standard $k-\epsilon$ model is a widely used hydrodynamic equation with relatively high accuracy:

$u_i u_j s^{-1} m^{-3} \mu, \mu_t G_k$ In the equation:, - -In the

following in x , Fractional velocity in the y -direction, m ; The density of the ρ — airflow, kg ; — The viscosity coefficients in laminar flow and turbulence, $Pa \cdot s$; - Changes in the turbulent kinetic energy due to changes in the shear force, $kg \cdot s^{-3} \cdot m^{-1}$; k -kinetic energy in turbulent processes, $M^2 \cdot s^{-2}$; The energy dissipation rate during ϵ — turbulence, $m^2 \cdot s^{-3}$; $C_1, C_2, C_\mu, \sigma_k, \sigma_\epsilon$ — the constant in the model, $C_1=1.44, C_2=1.92, C_\mu=0.09, \sigma_k=1.0, \sigma_\epsilon=1.3$.

The $k-\epsilon$ equation is the equation that contains these two important parameters. In fact, both the k and ϵ parameters have their own expressions. Turbulence intensity is a physical quantity characterizing the strength of fluid flow turbulence. Its empirical formula is:

$$I \equiv \frac{u'}{u_{avg}} \cong 0.16(Re_{D_H})^{-1/8}$$

When I is less than or equal to 1%, the turbulence intensity is often considered to be low intensity turbulence; when the intensity is greater than 10%, it is considered as high intensity turbulence.

The turbulent scale l is a physical quantity associated with the scale of large vortices carrying the turbulent energy. In a fully developed tube flow, l is limited by the size of the pipe, because the scale of the large vortex cannot be greater than the size of the pipe. The calculated relationship between L and the physical size of the tube is as follows:

$$l=0.07L$$

Where L is the size of the pipe. The factor 0.07 is based on fully developing the maximum of the turbulent mixing length, and for pipes with a non-circular cross-section, the value of L can be replaced by L with the hydraulic diameter L_H .

$$L_H = 4 \frac{A}{S}$$

A is the crossing area of pipeline; S is the contact circumference of fluid and solid.

The turbulent kinetic energy k can be expressed in terms of the turbulence intensity and the turbulent mean velocity.

3. External Environmental Impact Analysis

3.1. Analysis of The Pressure Influence in The Tank

(1) Under the static condition, the pressure in the tank is high, such as the gas temperature in the storage tank is basically unchanged with time, and the temperature rise of less than 2K is found in 2 MPa, 1.6MPa condition. Different tank pressure affects the initial value of the gas temperature greatly

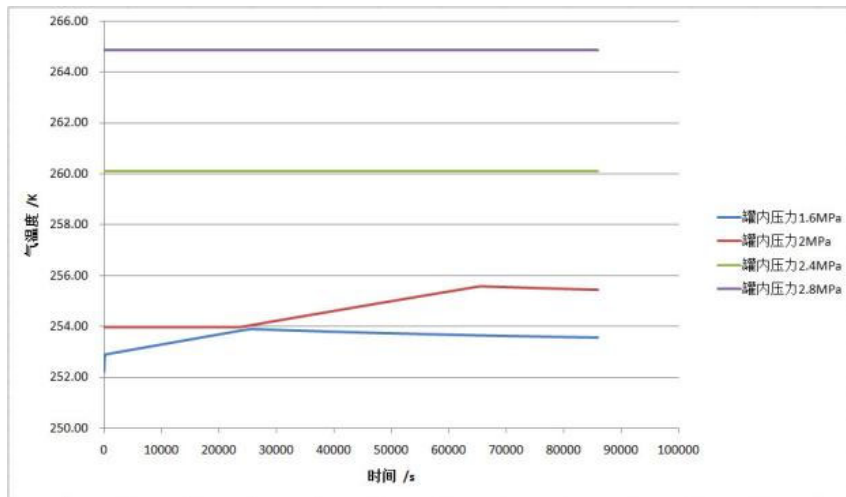


Figure 1. Change curve of tank pressure on gas temperature

(2) Under the static condition of setting, the liquid level in the storage tank increases slightly at the beginning, and then the change is very small with time. The liquid level in the pressure of the tank pressure of 2 MPa, 1.6MPa will be reduced to a certain extent in the middle and late stage, and the liquid level in the tank pressure of 1.6MPa will decrease relatively significantly

(3) Under the condition of static placement, the liquid accumulation in the storage tank under the tank pressure of 2 MPa, 1.6MPa will reduce the fluid accumulation pressure in the tank to some extent by 1.6MPa.

(4) Under the condition of static placement, the gas volume in the storage tank increases somewhat under the tank pressure of 2 MPa, 1.6MPa, and the gas pressure of 1.6MPa increases relatively significantly

3.2. Initial Temperature Impact Analysis

Under the static condition, the gas temperature in the storage tank is basically unchanged with time, and the initial temperature in the tank-18°C increased by less than 0.7°C in the middle and late period

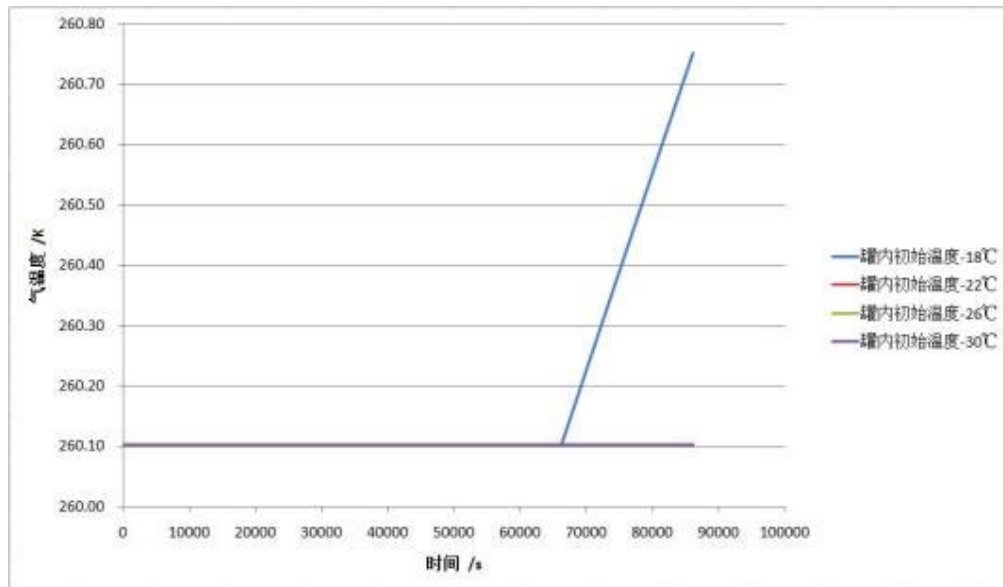


Figure 2. Change curve of the initial temperature influence on the gas temperature in the tank

Under static setting conditions, the liquid temperature in the liquid storage tank gradually increases over time; the lower the initial temperature in the liquid storage tank, the faster the liquid temperature increases

(3) Under the static setting conditions, the liquid level in the storage tank increases slightly at the beginning, and then the change with time is very small. The initial temperature in different tanks has very little effect on the liquid level

(4) Under the static condition, the liquid accumulation in the storage tank is basically unchanged with time, and the initial temperature in different tanks has very little impact on

the liquid accumulation

(5) Under the static setting condition, the gas volume in the liquid storage tank is basically unchanged with time, and the initial temperature in different tanks has a very little impact on the gas volume

3.3. Ambient Temperature Impact Analysis

Under the static conditions, the gas temperature in the liquid storage tank is basically unchanged with time, and the ambient temperature of 40°C is less than 0.7°C

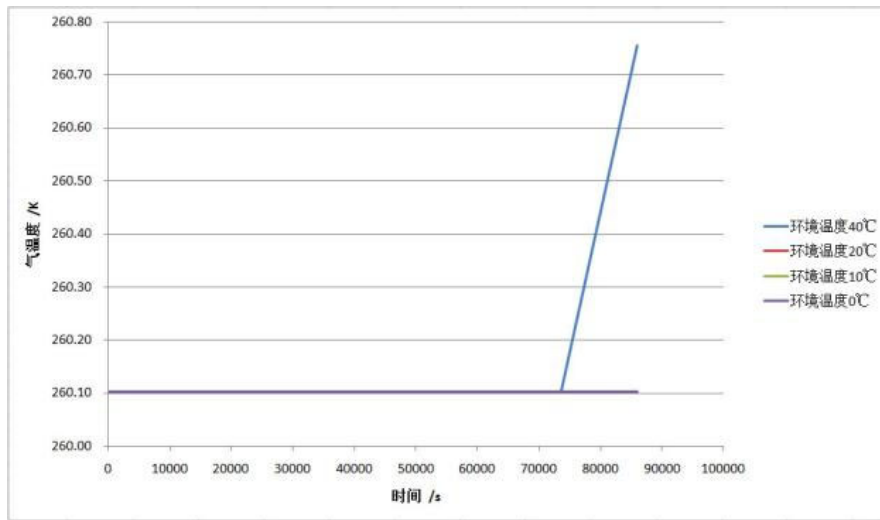


Figure 3. Change curve of ambient temperature influence on gas temperature

(2) Under the standing conditions, the liquid temperature in the reservoir tank increases gradually over time; the higher the ambient temperature, the faster the liquid temperature increases

(3) Under the static condition, the liquid level in the reservoir increases slightly at the beginning, and then the change is very small with time, and different ambient temperatures have very little impact on the liquid level

(4) Under the static condition, the liquid accumulation in the storage tank is basically unchanged with time, and different ambient temperatures have very little impact on the liquid accumulation

(5) Under the static setting condition, the gas volume in the liquid storage tank is basically unchanged with time, and different ambient temperatures have very little impact on the gas volume

3.4. Analysis of the Initial Liquid Level Effects

(1) Under the static conditions, the gas temperature in the initial liquid level of 2.3m and 2m liquid storage tank was basically unchanged with time, and the gas temperature in the initial liquid level of 1.5m and 1m increased to a certain extent in the middle and later stages.

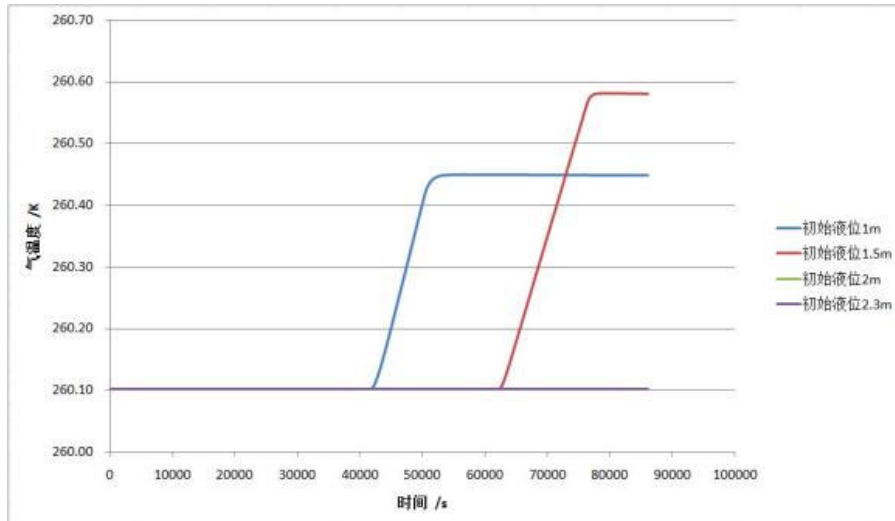


Figure 4. Effect curve of initial level on gas temperature

(2) Under the standing conditions, the liquid temperature in the reservoir tank increases gradually over time; the lower the initial liquid level, the faster the liquid temperature increases

(3) Under the static placement conditions, the liquid level in the liquid storage tank changes very little with time, and the impact of different initial liquid levels is also relatively small

(4) Under static conditions, the liquid accumulation in the reservoir changes very little with time, and the different initial levels affect less

Under static placement conditions, the gas volume in the liquid storage tank changes very little with time, and the influence of different initial fluid levels is also small

4. Simulation Results and Analysis

4.1. Effect of the C O content

(1) Under the static setting conditions, the gas temperature in the liquid storage tank is basically unchanged with time, and the different CO content has very little impact on the gas temperature, as shown in the figure below.

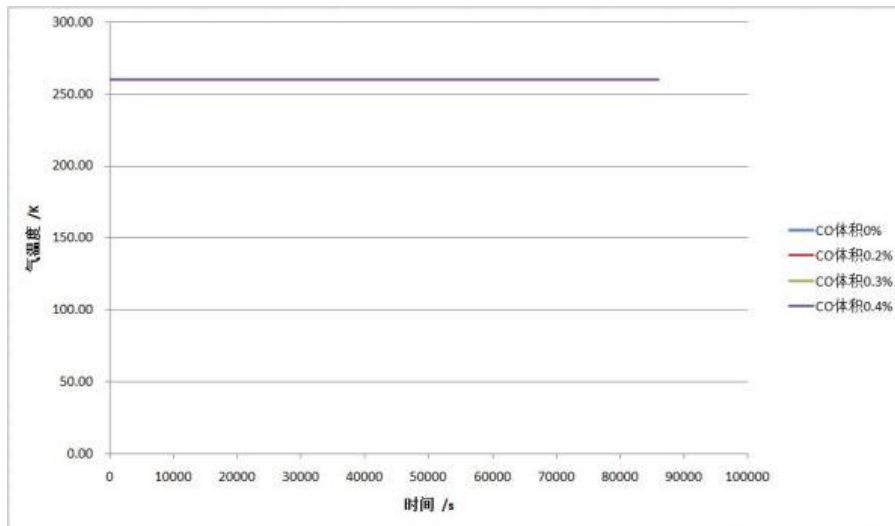


Figure 5. Effect curve of C O content on gas temperature

(2) Under the condition of static placement, the liquid temperature in the liquid storage tank gradually increases with time, and the different CO content has a very little impact on the liquid temperature

(3) Under the static condition, the liquid level in the reservoir is slightly increased at the beginning, and then the change is very small with time, and the different CO content has very little effect on the liquid level

(4) Under the static placement condition, the liquid accumulation in the liquid storage tank is basically unchanged with time, and the different CO content has very little impact

on the liquid accumulation

(5) Under the static placement condition, the gas volume in the liquid storage tank is basically unchanged with time, and the different CO content has very little impact on the gas volume

4.2. Effect of Methane Content

(1) Under the static setting conditions, the gas temperature in the liquid storage tank is basically unchanged with time, and the different methane content has a very little impact on the gas temperature, as shown in the figure below.

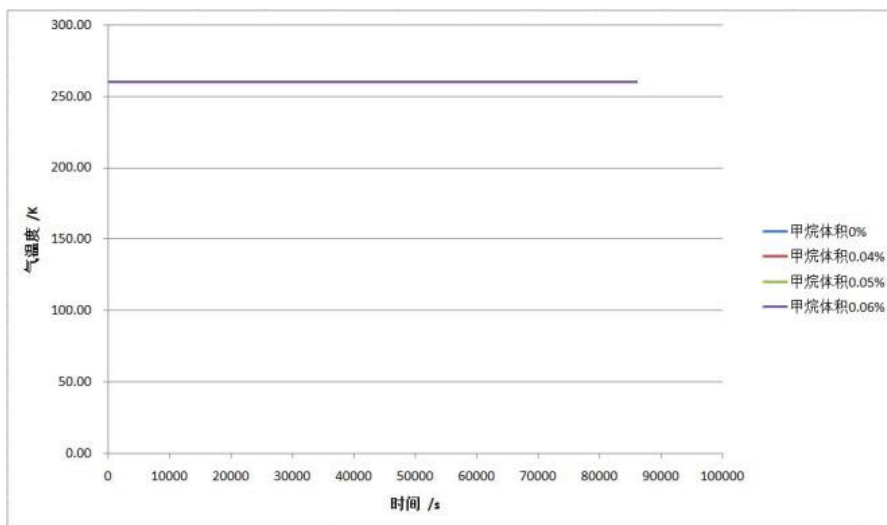


Figure 6. Effect curve of methane content on gas temperature

(2) Under the static setting conditions, the liquid temperature in the liquid storage tank gradually increases with time, and the different methane content has a very little impact on the liquid temperature

(3) Under the static condition, the liquid level in the storage tank increases slightly at the beginning, and then the change with time is very small, and the different methane content has very little effect on the liquid level

(4) Under the static condition, the liquid accumulation in the storage tank is basically unchanged with time, and the different methane content has very little impact on the liquid

accumulation

(5) Under the static placement condition, the gas volume in the liquid storage tank is basically unchanged with time, and the different methane content has a very little impact on the gas volume

4.3. Effects of Ethane Content

(1) Under the static conditions, the gas temperature in the liquid storage tank is basically unchanged with time, and the different ethane content has very little impact on the gas temperature, as shown in the figure below.

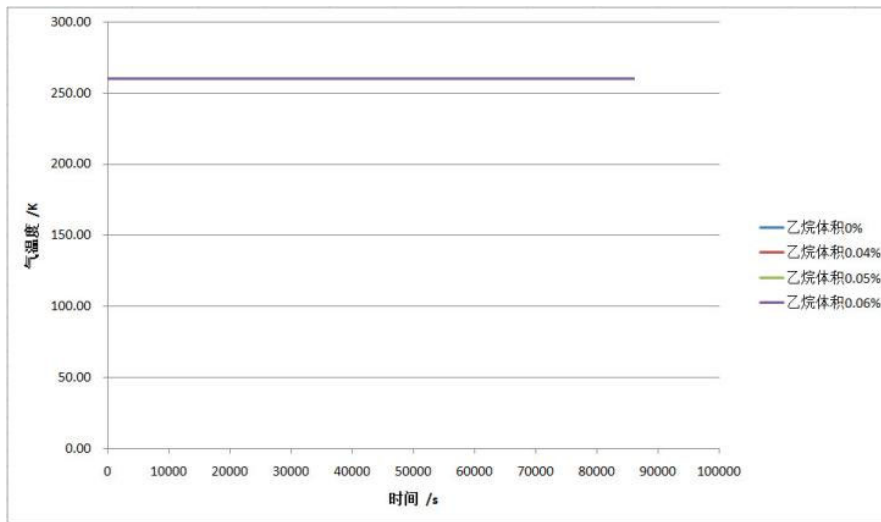


Figure 7. Effect curve of ethane content on gas temperature

(2) Under the static condition, the liquid temperature in the liquid storage tank gradually increases with time, and the different ethane content has very little effect on the liquid temperature

(3) Under the static condition, the liquid level in the reservoir increases slightly at the beginning, and then the change is very small with time, and the different ethane content has very little effect on the liquid level

(4) Under the static condition, the liquid accumulation in the storage tank is basically unchanged with time, and the different ethane content has very little impact on the liquid

accumulation

(5) Under the static placement condition, the gas volume in the liquid storage tank is basically unchanged with time, and the different ethane content has very little impact on the gas volume

4.4. Effect of Hydrogen Content

(1) Under the static setting conditions, the gas temperature in the liquid storage tank is basically unchanged with time, and the different hydrogen content has a very little impact on the gas temperature, as shown in the figure below.

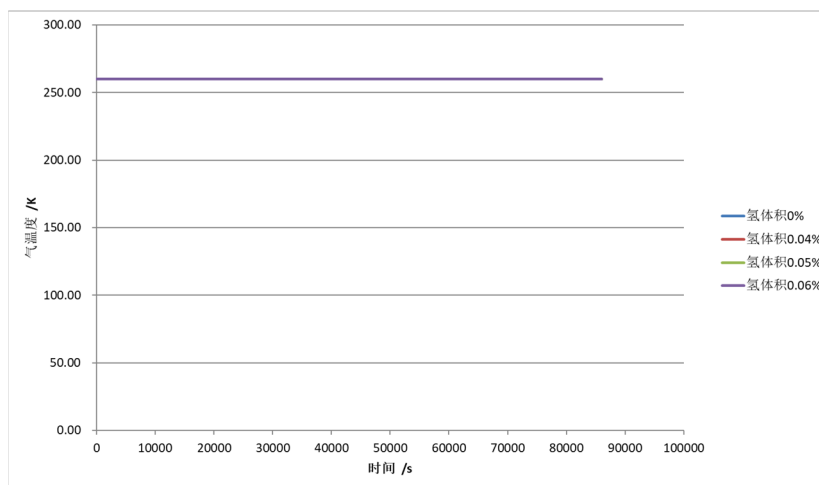


Figure 8. Variation curve of hydrogen content influence on gas temperature

(2) Under the static setting conditions, the liquid temperature in the liquid storage tank gradually increases with time, and the different hydrogen content has a very little impact on the liquid temperature

(3) Under the static condition, the liquid level in the reservoir is slightly increased at the beginning, and then the change is very small with time, and the different hydrogen content has very little effect on the liquid level

(4) Under the static condition, the liquid accumulation in the storage tank is basically unchanged with time, and the different hydrogen content has very little impact on the liquid accumulation

(5) Under the static placement condition, the gas volume in the liquid storage tank is basically unchanged with time, and the different hydrogen content has a very little impact on the gas volume

5. Conclusion

(1) The lower the tank pressure, about the greater the leakage and cooling, under extreme conditions (1.9MPa) can produce about 1.9% daily liquid loss. Therefore, it is recommended to maintain the tank pressure above 2MPa.

(2) When the environmental conditions (temperature, wind speed) are harsh, there is obvious evaporation in the tank in the storage process, which can lead to continuous liquid loss. Extreme temperature conditions can lead to about 1.24% liquid loss (40°C wind temperature), and about 0.55% liquid loss under extreme wind speed conditions (23 m/s wind speed). The ambient temperature is below 10°C. After the ambient temperature is lower than the liquid temperature, the tank no longer leaks cold, the liquid prevents heat to the

environment, and the liquid temperature gradually tends to the ambient temperature.

(3) Impurities (CO, methane, ethane) in the low content (maximum CO 0.4%, methane 0.06%, ethane 0.06%) have very little impact on the storage process, negligible in the engineering. When the impurity content exceeds 1%, it can have significant effects, and H₂, CO and methane can lead to a small decrease in daily evaporation rate (0.37% with 5% H₂, 0.34% with 5% methane and 5% ethane), and a small increase in daily evaporation rate (0.31% with 5% N₂ and 0.36% with 5% ethane).

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