

# Influence of Logging Instrument Drag on Temperature Distribution in Horizontal Gas Wells

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**Abstract:** In order to clarify the influence of the instrument's own drag on the temperature distribution in the horizontal gas wellbore in temperature logging. By constructing an indoor gas-liquid two-phase horizontal tube flow platform, the effects of the drag speed of the instrument on the temperature distribution in the wellbore were studied in the single-phase gas and gas-liquid two phases. In addition, during the process of instrument dragging, the influence of different perforation cluster opening methods and wellbore inclination on temperature distribution was also studied. The results show that the temperature fluctuation is reduced at higher drag speeds; Under a certain flow rate, the smaller the number of openings, the greater the influence of the instrument dragging inside the tube on the temperature distribution inside the tube; When the inclination angle is  $-5^\circ$ , the drag of the instrument in the tube interferes greatly with the temperature distribution. When the inclination angle is  $5^\circ$ , the drag of the instrument in the tube has less interference with the temperature distribution. This study provides more reference for the future temperature calculation model of horizontal wellbore and has important research significance.

**Keywords:** Temperature logging; tool drag speed; temperature profile; instrument response

## 1 Introduction

In shale gas mining, horizontal wells are a key and commonly used technique in mining technology. However, in the process of continuous exploitation of shale gas reservoirs, the pressure of the gas layer is reduced, and the formation water is continuously sucked into the horizontal wells, but cannot be completely discharged, which leads to the existence of gas-liquid two-phase flow in the horizontal wells. Due to the presence of water, this will affect the production of gas, and it will not be a good predictor of the output of each layer. At this stage, the Fuling shale gas field in the Sichuan Basin measures the gas production profile through the Sondex cable retractor or fiber-coil-coiled tubing fluid scanning imaging tool construction technology. This technology is owned by foreign countries and ensures that the wellbore is clean and completely removed when using this technology [1].

In vertical or near vertical wells, you can use the measurement of temperature changes in the wellbore to understand the flow under the well. As it penetrates into different strata, its temperature also changes, and the



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temperature of the fluid flowing into the wellbore also changes. Therefore, the temperature distribution parameters in the wellbore can effectively predict the downhole flow. In horizontal wells, because the horizontal wells are basically at the same formation depth, the temperature changes caused by the depth of the formation are minimal. Therefore, I want to know the temperature distribution in the wellbore, and understand the flow in the wellbore and the amount of gas produced through the temperature distribution [2]. It is necessary to consider all the factors in the wellbore that can affect the temperature parameters, such as the Joule-Thomson effect [3], the gas-liquid two-phase flow pattern, etc. In China, resistance or thermocouple sensors are generally used to measure parameters such as temperature distribution in horizontal wellbore, while foreign countries use distributed optical fiber temperature sensors to measure temperature parameters in wellbore [4].

Many researchers at home and abroad theoretically assume the hydrodynamics, thermodynamics and heat transfer equations and derive the wellbore multiphase flow temperature calculation model to explain the important production parameters such as the gas flow variation in the wellbore. Ramey established the energy equation of wellbore fluid flow by theoretical derivation, and obtained the temperature distribution calculation formula applicable to injection wells and production well [5]. Based on the energy conservation equation, Tarom et al. considered the influence of the Joule-Thomson effect and established a wellbore temperature field calculation model suitable for gas-liquid two-phase flow [6]. Frank et al. calculated the gas production in each section of the horizontal well by measuring the temperature distribution in the wellbore [7]. Based on the extended Bernoulli equation, Hagoort proposed an analytical method for temperature prediction of gas wells, which solved the effects of gravity, friction and wellbore heat loss, as well as two newly defined thermodynamic gas characteristics [8]. Hou et al. used an improved heat transfer model to analyze the wellbore temperature and proposed a new relationship between flow and convective heat transfer coefficient [9]. Cai and other distributed temperature sensors (DTS) monitor the horizontal well production layer by real-time measurement of the temperature profile, based on the mass, momentum and energy balance equations, a coupling model of wellbore temperature distribution in the horizontal wells considering the skin factor is established to predict the temperature distribution of the wellbore and analyze the factors affecting the temperature profile of the wellbore [10]. Ekaterina Wiktorski et al. used the C-Therm TCiTM Thermal Conductivity Analyzer to measure the thermophysical parameters of a typical wellbore component, particularly thermal conductivity, and applied it to the oil wellbore heat transfer model considering complex wellbore structures [11].

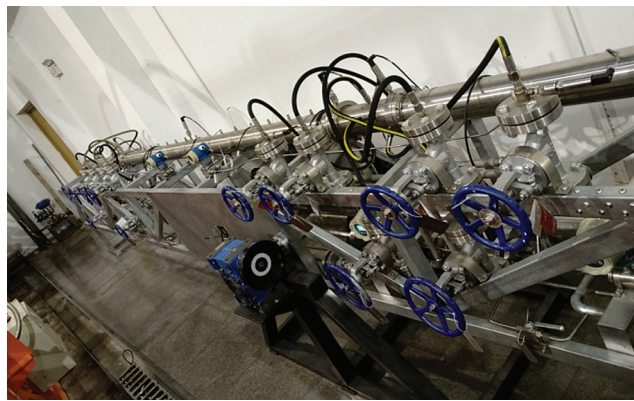
Li et al. applied a drift model between gas-liquid phase slip and non-uniform distribution of fluid along the wellbore section, combined with momentum conservation, energy conservation and wellbore heat transfer, and established a coupled model of gas wellbore temperature and pressure considering well deviation [12]. Mao et al. established a horizontal wellbore transient temperature prediction model based on unsteady two-dimensional convection-diffusion equation, and verified the validity of the model by using field temperature data [13]. Zhang et al. use distributed optical fiber temperature sensor (DTS) to measure temperature and pressure data in real time. Based on the fluid mass balance equation, momentum conservation and energy conservation, a horizontal well thermal model of the coupled reservoir and wellbore model is established, and the temperature and pressure profiles of the horizontal wellbore under specific conditions are solved iteratively [14]. Luo et al. proposed a comprehensive inversion method using data measured by distributed temperature sensors (DTSs). The forward temperature prediction model is used to simulate the temperature distribution of MFHW during each inversion iteration. A transient temperature prediction model based on mass, momentum and energy conservation is established [15–17].

It can be seen that the temperature parameter plays an important role in explaining the flow in the production or wellbore and the output profile in the wellbore production process. In the case of measuring the temperature distribution in the wellbore by means of a sensor, the influence of the

instrument itself on the temperature distribution in the wellbore during the measurement process should also be taken into account. By simulating the multi-phase flow in the actual horizontal wellbore to build an indoor gas-liquid two-phase horizontal tube flow platform, the process response of the instrument is tested to obtain the influence of the temperature distribution on the tube during the dragging process, and a more accurate temperature calculation model is established.

## 2 Experimental Device

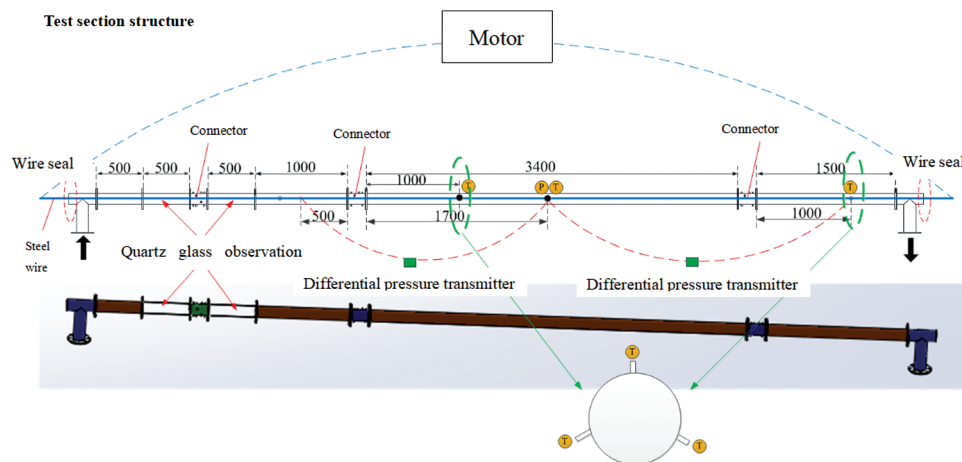
In order to simulate the on-site temperature profile test process, analyze the influence of the drag speed of the logging instrument on the temperature distribution law in the wellbore, and then establish a reasonable temperature profile test speed. A horizontal well gas-liquid two-phase flow simulation experimental device was built in the multiphase flow laboratory of Yangtze University. As shown in Fig. 1.



**Figure 1:** Photo of the test device

### 2.1 Test Section Layout

The arrangement of the experimental section of the experimental device is shown in Fig. 2. The test section pipeline is mainly composed of the main inlet, the outlet, the quartz glass observation section, the metal pipe section and the joint with the jet hole cluster. The test device has a total length of 10 meters, a pipe inner diameter of 115 mm, a temperature resistance of 90°C, and a pressure resistance of 3.5 MPa.



**Figure 2:** Schematic diagram of the test device

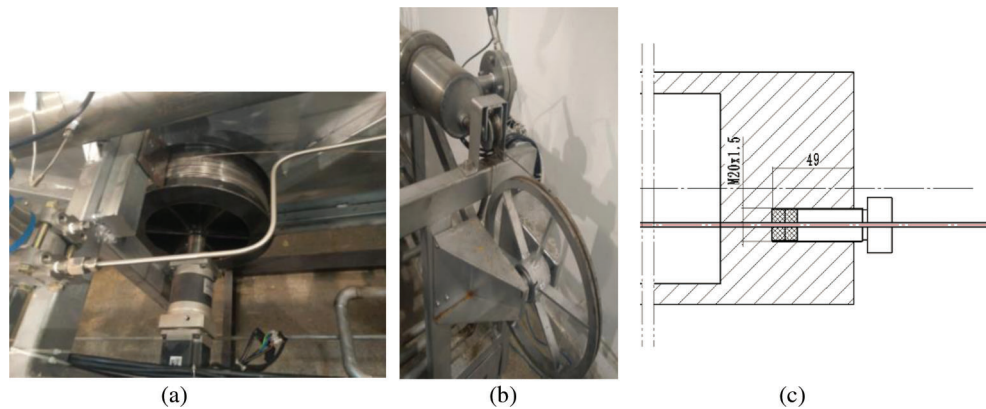
In the middle of the test section, the steel wire hanging from the test instrument is passed through, and the two ends are sealed by a dynamic sealing device for wire sliding. The wire can be slid in the pipe by the action of the servo motor at a set speed. The test instrument has a diameter of 40 mm and a length of 500 mm. After the mainstream of the gas-liquid two-phase fluid enters the test section through the inlet, it first enters the quartz glass observation section through a 0.5-meter straight metal pipe section. There are two sections in the quartz glass observation section, each of which is 0.5 m. The jet hole clusters are arranged between the two sections. The transparent quartz glass tube is used to observe the flow pattern change and the influence of the jet on the flow field, and then flow out from the outlet through the 6 m metal pipe section. A total of three jet-hole clusters are arranged in the test section, respectively, at a position of 1 m, 2.5 m and 6 m from the inlet, and a detachable replacement connection between each perforation cluster and the pipe. The number of perforation openings of the first, second, and third perforation clusters can be adjusted by switching valves, respectively. A total of 13 temperature sensors are arranged throughout the test section, which can measure the temperature distribution in the wellbore. The arrangement of each temperature collection point is shown in [Tab. 1](#) below.

**Table 1:** Temperature measurement point arrangement

Collection point	1	2	3	4	5
<b>Distance from entrance x(m)</b>	1.035	1.365	2.935	3.265	4.3
<b>Physical location</b>	Upstream of the first cluster perforating	Downstream of the first cluster perforation	Upstream of the second cluster perforation	Downstream of the second cluster perforation	Front the first cross section
<b>Collection point</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>
<b>Distance from entrance x(m)</b>	4.3	4.3	5	7.735	8.065
<b>Physical location</b>	After the first cross section	On the first cross section	Intermediate measuring points of two or three clusters perforation	Upstream of the third cluster perforation	Downstream of the third cluster perforation
<b>Collection point</b>	<b>11</b>	<b>12</b>	<b>13</b>		
<b>Distance from entrance x(m)</b>	9.1	9.1	9.1		
<b>Physical location</b>	Front the second cross section	After the second cross section	On the second cross section		

## 2.2 Tool Drag Mechanism

The horizontal well test device is equipped with a tool drag mechanism that can be moved by the wire rope at different speeds in the wellbore to simulate the downhole logging process. The tool drag mechanism mainly includes a servo motor mechanism capable of speed regulation, a wire disc, a runner and an end seal structure, as shown in [Figs. 3a–3c](#), respectively.



**Figure 3:** Tool drag mechanism (a) Servo motor and wire disc. (b) End sliding seal structure. (c) End sliding seal structure plan view

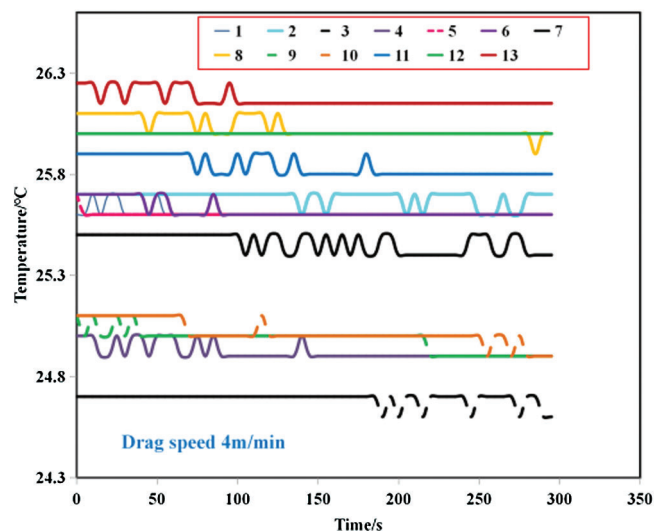
### 2.3 Experimental Method

The water temperature is normal temperature, the inlet pressure of the test is 3 MPa, the main inlet gas flow is 9600 m<sup>3</sup>/d, the water flow is 30 m<sup>3</sup>/d, and the valve is fully open before the jet hole. The flow rate of the jet orifice gas was controlled by 150 m<sup>3</sup>/h and the liquid flow rate (0 m<sup>3</sup>/h, 0.3 m<sup>3</sup>/h) by adjusting the valves in front of each mixer. After each working condition is stabilized, the flow pattern is photographed, and the test instruments are dragged at a speed of 4 m/min, 8 m/min, and 12 m/min, respectively, and the output values of each temperature sensor under each working condition are recorded.

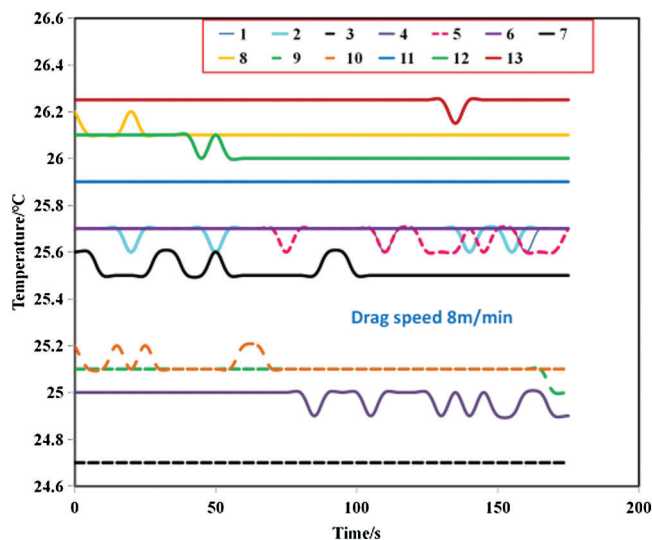
## 3 Experimental Results and Analysis

### 3.1 Influence of Drag Speed of Instrument on Temperature Distribution Law during Single-Phase Gas

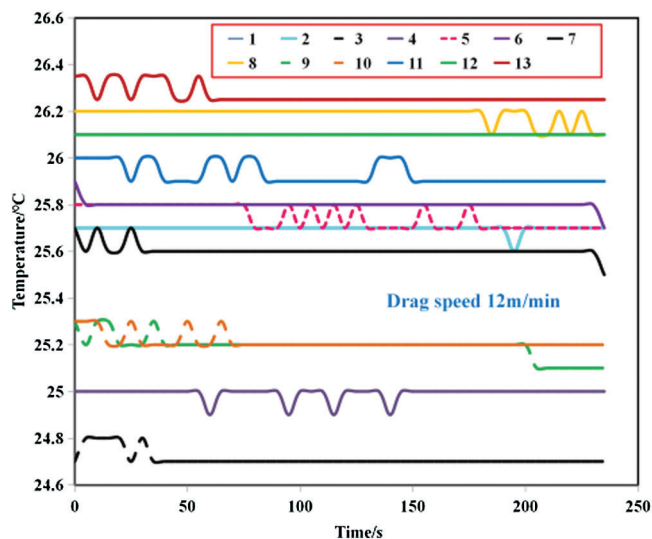
Under the regulation of the switch valve, the first cluster perforating, the second cluster perforating and the third cluster perforating open three holes respectively, namely (3, 3, 3). And the gas volume is 9600 m<sup>3</sup>/d. In the case of single-phase gas, the instrument is dragged at different speeds, and the temperature of each temperature measuring point changes with time during the dragging process of the instrument. As shown in Figs. 4–6.



**Figure 4:** Temperature variation of each temperature measurement point when the drag speed is 4 m/min



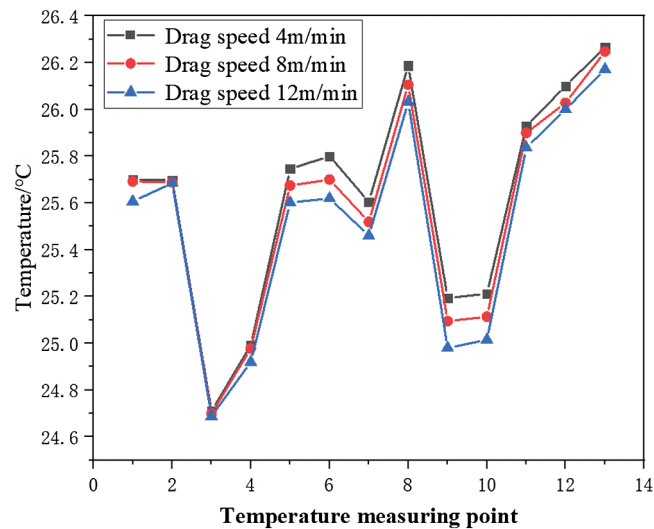
**Figure 5:** Temperature variation of each temperature measurement point when the drag speed is 8 m/min



**Figure 6:** Temperature variation of each temperature measurement point when the drag speed is 12 m/min

Keep the hole of the jet hole cluster in the way of (3, 3, 3), and the gas volume is 9600 m<sup>3</sup>/d. In the case of single-phase gas, the test instrument is driven at a speed of 4 m/min, 8 m/min and 12 m/min, respectively, and the average temperature change of each temperature measurement point in the horizontal tube. As shown in Fig. 7, the valley of the temperature distribution in the figure is due to the Joule-Thomson effect due to the flow of air from the perforation into the horizontal tube; As the drag speed increases, the average temperature of each temperature measurement point decreases, and the greater the drag speed, the more the temperature decreases. During the dragging process of the instrument, the airflow is disturbed by the instrument, and the hot and cold airflow will generate backflow in the wellbore, and alternately flow through the temperature sensor. The faster the instrument is dragged, the more cold air is carried, resulting in a decrease in the average temperature of each temperature measurement point.

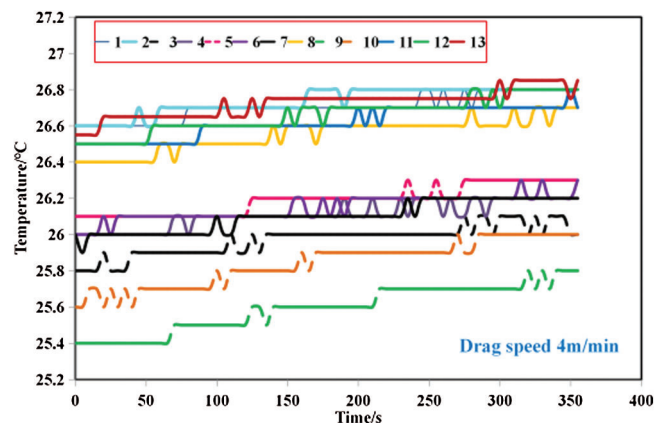




**Figure 7:** Effect of temperature on the temperature distribution in the wellbore at different drag speeds

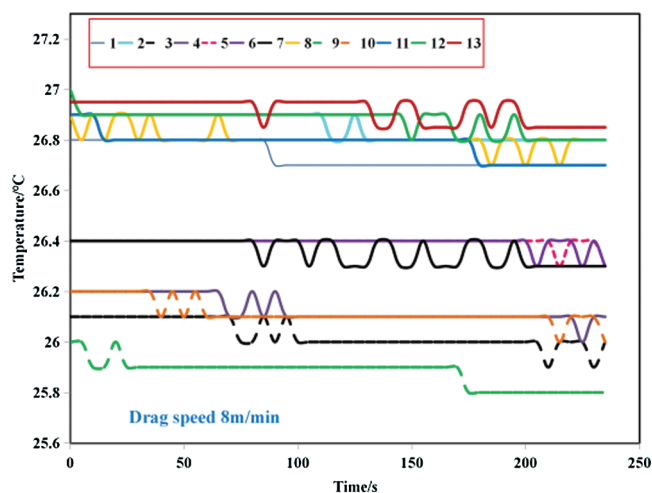
### 3.2 Influence of the Drag Speed of the Instrument on the Temperature Distribution Law during Gas-Liquid Two-Phase

The opening of the jet hole cluster is (3, 3, 3), the gas volume is 9600 m<sup>3</sup>/d, and the liquid volume is 7.2 m<sup>3</sup>/d. In the case of gas-liquid two-phase, the instrument is dragged at different speeds, and the temperature of each temperature measuring point changes with time during the dragging process of the instrument. As shown in Figs. 8–10. It can be seen from the figure that in the gas-liquid two-phase flow state, the influence of the drag speed on the temperature distribution is greater than that on the single-phase gas state. This is because the drag of the instrument in the pipe has a greater influence on the liquid flow, and the fluctuation of the liquid in the pipe is more severe, resulting in a change in the flow pattern.

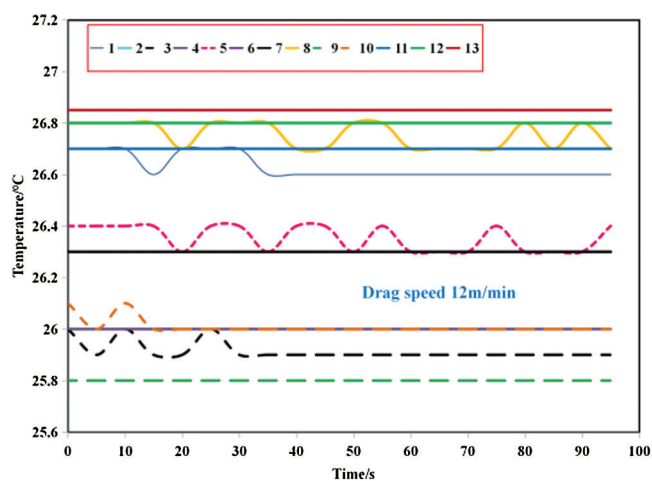


**Figure 8:** Temperature variation of each temperature measurement point when the drag speed is 4 m/min

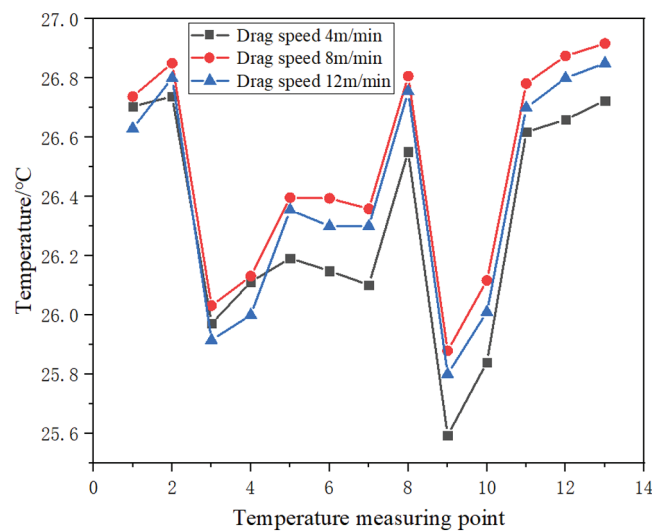
The opening of the jet hole cluster is (3, 3, 3), the gas volume is 9600 m<sup>3</sup>/d, and the liquid volume is 7.2 m<sup>3</sup>/d. In the case of gas-liquid two-phase, the test instrument is driven at a speed of 4 m/min, 8 m/min and 12 m/min, and the average temperature change of each temperature measurement point in the horizontal pipe. As shown in Fig. 11, it can be seen from the figure that in the gas-liquid two-phase flow, the gas flow from the perforation into the horizontal pipe produces a Joule-Thomson effect; In the



**Figure 9:** Temperature variation of each temperature measurement point when the drag speed is 8 m/min



**Figure 10:** Temperature variation of each temperature measurement point when the drag speed is 12 m/min



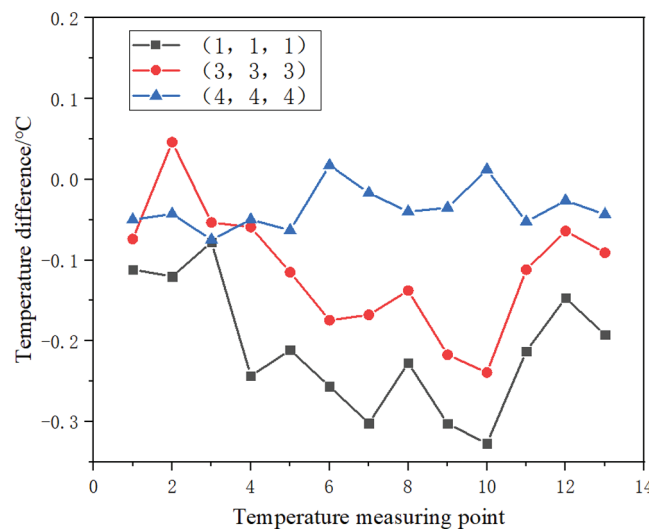
**Figure 11:** Effect of different drag speeds on temperature distribution in the wellbore



state flow of gas-liquid two-phase, the drag of the instrument will change the flow pattern inside the tube, causing the temperature to change. The drag speed of the instrument is increased, so that the fluctuation of the liquid in the tube is severe, so that the average temperature of each temperature measuring point is increased.

### 3.3 The Effect of the Opening Method on the Temperature Distribution under the Drag of the Instrument

Fig. 12 shows that the air volume is  $9600 \text{ m}^3/\text{d}$  when the instrument is dragged at a speed of  $4 \text{ m/min}$ . The opening modes of different jet hole clusters are (1, 1, 1), (3, 3, 3), (4, 4, 4), the temperature difference between each temperature measurement point in the horizontal tube and each temperature measurement point in the horizontal tube when there is no instrument drag in the tube, that is, the influence of the temperature on the horizontal tube when the instrument is dragged. As can be seen from Fig. 12, As the number of openings increases, the drag of the instrument has a smaller and smaller effect on the temperature inside the horizontal tube. This is because under a certain flow rate, the fewer the number of openings, the more serious the throttling effect, and the greater the influence of the instrument dragging inside the tube on the temperature distribution inside the tube. Therefore, in different opening modes, the influence of the drag of the instrument on the temperature distribution in the horizontal pipe should not be ignored, and this influence should be considered in the interpretation of the horizontal pipe temperature calculation model.



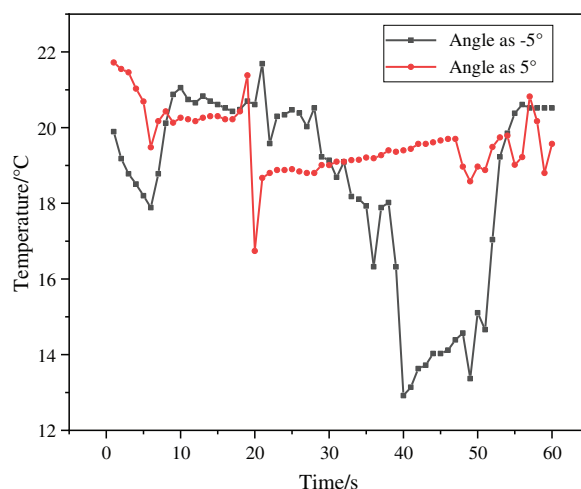
**Figure 12:** Effect of different opening methods on temperature distribution when the drag speed is constant

### 3.4 Drag Measurement Results under Different Inclination Angles

Under different inclination angles, the liquid flow rate is maintained at  $0.3 \text{ m}^3/\text{h}$ , the drag speed is maintained at  $4 \text{ m/min}$ , and the three jet stream clusters are opened with two holes. When changing the intake air amount, the change curves of temperature and pressure are shown in Fig. 13. It can be seen from the figure that when the inclination angle is  $-5^\circ$ , the drag of the instrument in the tube has a great interference to the temperature distribution. When the inclination angle is  $5^\circ$ , the drag of the instrument in the tube has less interference with the temperature distribution. This is because when the inclination angle is  $-5^\circ$ , the gas-liquid two phases in the horizontal pipe will generate slug flow, which will cause too much interference to the flow pattern due to dragging of the instrument, resulting in large fluctuations in the temperature distribution inside the pipe.

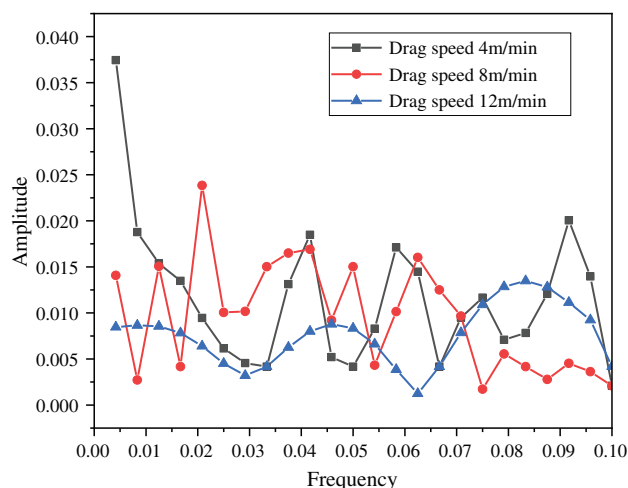
### 3.5 The Effect of Drag Speed on Temperature Disturbance

Select the temperature measuring point 7 in the horizontal pipe, keep the opening pattern of the jet hole cluster as (3, 3, 3), the gas volume is  $9600 \text{ m}^3/\text{d}$ , and the liquid volume is  $7.2 \text{ m}^3/\text{d}$ . In the case of gas-liquid



**Figure 13:** Instrument drag measurement results at different inclinations

two-phase, the test instrument was dragged at a speed of 4 m/min, 8 m/min and 12 m/min, respectively, and the amplitude analysis of the influence of temperature during the dragging process of the instrument was measured. As shown in Fig. 14, as the instrument drags faster, the amplitude of the temperature disturbance is smaller. When dragging at a lower speed, the temperature field is difficult to stabilize, the fluctuating frequency is high, and the amplitude is large; As the drag speed increases, the frequency and amplitude of temperature fluctuations decrease.



**Figure 14:** Effect of drag speed on temperature disturbance

#### 4 Conclusion

Through the construction of a gas-liquid two-phase experimental platform with adjustable perforation clusters, the influence of instrument drag engineering on the temperature field in the wellbore was studied by using the test process response experiment of the instrument, and the following conclusions were obtained.

1. The dragging of the instrument will cause the temperature field in the wellbore to fluctuate. The lower the drag speed, the higher the frequency fluctuation frequency. The influence of instrument drag on the gas-liquid two-phase flow state is greater than that of pure gas, which is characterized by higher temperature

fluctuation amplitude and frequency, and the temperature fluctuation is reduced at higher drag speed. Therefore, dragging at the highest possible speed while ensuring the temperature response.

2. The dragging of the instrument in different opening modes will also cause the temperature field in the wellbore to change. Under a certain flow rate, the fewer the number of openings, the more serious the throttling effect, and the greater the influence of the instrument dragging inside the tube on the temperature distribution inside the tube.
3. The drag of the instrument at different inclinations also affects the distribution of the temperature field in the wellbore. When the inclination angle is  $-5^\circ$ , the drag of the instrument in the tube interferes greatly with the temperature distribution. When the inclination angle is  $5^\circ$ , the drag of the instrument in the tube has less interference with the temperature distribution.

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**Conflicts of Interest:** The authors declare that they have no conflicts of interest to report regarding the present study.

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