Effect of Ignition Energy on Environmental Parameters of Gas Explosion in Semiclosed Pipeline

Chengwu Li, Zhen Qiao,* Min Hao, Heng Zhang, and Gen Li

ABSTRACT: In the processes of chemical production, storage, transportation, and utilization, when a gas explosion occurs, the postexplosion environmental parameters (environmental pressure, environmental temperature, and environmental humidity) are significant prerequisites for inducing secondary explosions and other derivative disasters. To investigate the variation and explore the influence of the law of ignition energy on gas explosions, experiments in a semiclosed pipeline under different ignition energies were performed. The results showed that there appeared a relatively obvious air backflow phenomenon at the opening end of the pipeline after gas explosions. The response relationship between the environmental pressure peak and ignition energy fit better with the linear function. Ignition energy had a comparatively large impact on environmental temperature. More specifically, when the ignition power was 275 W, the beginning moment of rise of the temperature was the earliest, the pressure rise rate was the fastest, and the temperature peak was the highest, and the temperature rise range after explosions was the largest, respectively, 3.05 s, 14.3 °C/s, 32.8 °C, and 8.66%. However, there was no strong causal relationship between explosion overpressure and environmental humidity. The research contributes to understanding the changing tendencies of environmental parameters during the whole process of gas explosions and analyzes the effect law of ignition energy on environmental parameters. Meanwhile, it can provide support to prevent and weaken secondary explosions and other derivative disasters and improve the safety production capacity of the chemical industry.

1. INTRODUCTION

With the overexploitation of fossil energy and the increasingly grave environmental problems, natural gas, as an alternative clean energy, has been widely used in industrial production and daily life. The main component of natural gas is methane, accounting for about 85%. However, methane is also flammable and explosive with a minimum ignition energy of 0.3 mJ. Therefore, in the processes of chemical production, storage, transportation, and utilization, when a gas leak occurs, it is extremely easy to cause gas explosions, and even induce more severe secondary explosions and multiple explosion accidents, which would result in huge economic and property losses, and personal casualties. Among them, environmental parameters after explosions are a prerequisite for evoking secondary explosions. To prevent, weaken, and investigate derivative disasters such as secondary explosions, it is necessary to conduct in-depth research on the variation of environmental parameters of gas explosions.

A small-scale pipeline explosion experiment is one of the major means for scholars to investigate gas explosions. Previous studies have primarily focused on characteristic parameters of gas explosion propagation, such as explosion overpressure, overpressure rise rate, flame temperature, and flame propagation speed. Moreover, turbulent fields in flame propagation have also been researched. However, continuous variations in the environmental parameters of gas explosions are rarely reported. Thereinto, Li et al. took methane concentration as an experimental variable to analyze variation features of environmental parameters during the whole process of gas explosions in the pipeline and discovered a relatively obvious air backflow phenomenon.

On the other hand, ignition source, as one of the three elements of combustion, is a significant factor affecting gas explosions. Van den Schoor et al. researched the influence of high-temperature ignition sources at different locations on gas explosions by using a closed spherical container. He obtains a conclusion according to experimental results that the lower is the fire source position, the greater is the explosion overpressure. Lv et al. explore the relationship between flame propagation...
velocity, explosion overpressure, flame thickness, and distance from an ignition source in the nonadiabatic open-ended steel pipe. Spitzer et al.33 discuss the effect of four different ignition sources on gas explosions.

To sum up, there is relatively little research on the continuous variation of environmental parameters after gas explosions and the response characteristics of ignition energy to them. Different ignition energies will lead to dissimilar degrees of gas explosions, resulting in different environmental parameters, thereby affecting the risk of derivative disasters such as secondary explosions. Therefore, it is necessary to explore the correlation between ignition energy and environmental parameters.

To solve the above problems, a small semiclosed pipeline gas explosion experimental system was established. The purpose of experiments was to understand the continuous change characteristics of environmental parameters (environmental pressure, environmental temperature, and environmental humidity) after gas explosions and to explore the influence laws of ignition energy on environmental parameters. The research can provide support for preventing and weakening derivative disasters such as secondary explosions, analyzing the causes of derivative disasters, and improving the safety production capacity of chemical enterprises.

2. EXPERIMENTAL DEVICES AND STEPS

2.1. Experimental Devices. To deeply investigate the continuous variation characteristics of environmental parameters in a semiclosed pipeline under different ignition energies at the whole process of a gas explosion, especially the later stage, a small gas explosion system was independently designed and built, as shown in Figure 1: Figure 1 A expresses the physical diagram of the experimental system and Figure 1B represents the sketch of the experimental system.

![Figure 1. Gas explosion experiment system.](image)

The gas explosion experiment platform consisted of four parts, namely the explosion chamber, the inflation system, the ignition system, and the data acquisition system. The explosion chamber was nested by a stainless-steel pipe and a quartz pipe. The specific dimensions of the two pipes were illustrated in Table 1. Moreover, one end of the stainless-steel pipe was sealed with a flange cover. And there were two small holes in the flange cover for inflation and ignition.

### Table 1. Specific Sizes of the Experimental Pipes

| Material    | Length (mm) | Outer Diameter (mm) | Wall Thickness (mm) |
|-------------|-------------|---------------------|---------------------|
| Stainless pipe | 800         | 160                 | 5                   |
| Quartz pipe  | 1200        | 155                 | 10                  |

The function of the inflation system was to charge a certain amount of methane gas into the explosion chamber, and its components included a high-pressure cylinder, a gas tank, valves, and a pressure gauge. The data acquisition system comprised three types of sensors and a storage recorder. Thereinto, three categories of sensors were pressure sensor, methane sensor, and temperature and humidity sensor, respectively. The information of the sensors was shown in Table 2. The storage recorder had 32 channels, the maximum sampling frequency if which was 1 MHz. Moreover, the sampling frequency of the pressure sensor used in the experiments was 100 Hz. The sampling frequency of the temperature and humidity sensor was 20 Hz.

The ignition system was pivotal to achieving different ignition energies. The system included heating wires, an ignition needle, and a voltage regulator. The heating wire was wound on the ignition needle, and different winding lengths indicated dissimilar resistance values. After electrification, the current flowed through the heating wire. Since the heating wire was pure resistance, the electrical energy was dissipated in the form of heat. Adjusting the length of the heating wire and the voltage of the voltage regulator could form different ignition powers, and ultimately achieve dissimilar ignition energies. For the convenience of expression, ignition power was applied in the following to replace ignition energy. In addition, the methane gas concentration used in experiments was 99.99%.

### Table 2. Parameters of the Experimental Sensors

| Sensor Type          | Monitoring Parameter | Measurement Range | Measurement Accuracy | Natural Frequency |
|----------------------|----------------------|-------------------|----------------------|------------------|
| Pressure sensor      | Environment pressure | 0–10 MPa          | 1%FS (full scale)    | >100 kHz         |
| Temp and humidity    | Environment temp     | 0–60 °C           | 0.5 °C               | >55 Hz           |
|                      | Environment humidity | 20–95%            | 5%                   |                  |
| Methane sensor       | Methane concn       | 0–100%            | 6% of true value     |                  |

### Table 3. Number of Experimental Groups

| No. of Group | R resistance/Ω | U voltage/V | formula | P power/W |
|--------------|----------------|-------------|----------|-----------|
| first        | 4.33           | 24          | \(P = \frac{U^2}{R}\) | 133       |
| second       | 3.71           | 24          |          | 155       |
| third        | 2.72           | 24          |          | 211       |
| fourth       | 2.32           | 24          |          | 248       |
| fifth        | 2.09           | 24          |          | 275       |

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temperature, and environmental humidity were monitored. Among them, environmental pressure was not the explosion overpressure researched in the conventional gas explosion experiments, which represented the gas pressure in the explosion chamber affected by a shock wave.

Two pressure sensors and one temperature and humidity sensor were applied for data collection. Among them, one pressure sensor was placed in the middle of the explosion chamber, and the other lay at the opening end of the explosion chamber. The purposes of those settings were to measure the changing tendencies of environmental pressures at different positions of the chamber and conduct comparative analysis. The temperature and humidity sensor was situated at the open end of the pipeline, the function of which was to collect the environmental temperature and environmental humidity data at the open end during the whole process of a gas explosion. Meanwhile, it could combine with the environmental pressure at the open end to collectively explore the variation law of the environmental parameters of the open end of the semiclosed pipeline after a gas explosion.

2.3. Operating Steps. The operating steps of gas explosion experiments could be divided into the following steps:

2.3.1. Assembly Equipment. According to the preset ignition power, a certain length of heating wire was wound on the ignition needle. Then, each equipment was assembled to build a gas explosion experiment system platform.

2.3.2. Air Tightness Test. Before the start of experiments, it was necessary to test the airtightness of the system. First, a
certain amount of compressed air was filled into the gas tank. Second, the open end of the semiclosed pipeline was sealed with PVC film. Third, after the pressure was stabilized, the valve between the gas tank and the explosion chamber was slowly opened to connect them. Finally, when the reading of the tank pressure gauge dropped to a certain value and remained unchanged for more than 3 h, the system could be regarded as having good airtightness.

2.3.3 Inflation. First of all, on the basis of the volume of the explosion chamber and the methane concentration (9.5%) at a gas explosion, the required amount of methane gas was roughly estimated in advance by using Dalton’s law of partial pressure. Next, the open end of the pipeline was sealed with PVC film. Then, the valve was slowly opened to fill the explosion chamber with methane gas. Finally, the methane sensor was applied to fine-tune the concentration of methane in the pipeline. When the rated concentration (9.5%) was reached, the methane sensor was removed.

2.3.4 Ignite Gas. The voltage regulator was turned on and the button was slowly rotated to the rated value. Different heating wire winding lengths and voltages corresponded to dissimilar ignition powers, which represented diverse ignition energy per unit time. When the temperature rose to a certain value, the gas ignited and exploded. The whole ignition process lasted about 5 s.

Figure 3. Environmental pressure in the third stage under dissimilar ignition powers: (A) 133 W; (B) 155 W; (C) 211 W; (D) 248 W; (E) 275 W.
2.3.5. Discharge of Waste Gas. After the whole measurement process was over, the ventilator was opened to discharge the waste gas. When the temperature of the explosion chamber decreased to room temperature and the gas was exhausted, the set of experiments was considered complete.

3. RESULTS AND DISCUSSIONS

3.1. Variations of Environmental Pressure. Figure 2 illustrates the change tendencies of environmental pressure at dissimilar locations in the semiclosed pipeline during the whole process of a gas explosion under different ignition powers. Obviously, the variation of the two test points in the first two stages was approximately similar, at which the pressure rose rapidly and then decreased quickly. However, there were comparatively remarkable differences between them in the third stage. Next, a detailed analysis was performed for each stage.

First, the environmental pressure at different test points both displayed a rapid upward trend in the first stage. The reason was that the explosion shock wave was generated in the process of gas explosions, the propagation of which led to a quick increase in environmental pressure. Whereas, in terms of the pressure value, test point 1 and test point 2 had significant distinctions. No matter how the ignition power changed, the environmental pressure at test point 2 was invariably greater than that at test point 1. The pressure was affected by the explosion shock wave, that is, it was proportional to explosion overpressure. The overpressure wave was inversely proportional to the propagation distance and the square root of the cross-sectional area. In other words, in the same pipe, the closer to the explosion source it was, the larger was the explosion overpressure, the greater the environmental pressure. Test point 2 lay in the middle of the pipe, while test point 1 was placed at the open end of the pipe. Therefore, the environmental pressure at test point 2 was always bigger than that at test point 1.

Second, in the second stage, environmental pressures were all reduced rapidly after reaching peak value. The cause of this phenomenon was that the gas in the chamber was exhausted after gas explosions, resulting in environmental pressure decreasing. Meanwhile, when the pressure dropped to the valley value, the relationship between pressures at different test points had changed; namely, the valley value at test point 1 surpassed that at test point 2. The closer it was to the location of the explosion source, the more intense the explosion, the more gas was consumed, and the smaller the valley value of pressure was. Furthermore, the shift in the relationship indicated a variation in the flow direction of the gas. That is to say, the gas initially flowed from the inside of the pipeline to the outside and gradually changed to transport from the external environment to the inside of the pipe.

Finally, in the third stage, the environmental pressures at the two test points were distinctly different. The differences were not only reflected in the size of the pressure value but also manifested in the shape of the curve. However, the variation amplitudes of pressures in the third stage were relatively small. Therefore, in order to more clearly highlight the distinctions between them, part of the third stage was deliberately intercepted for comparative analysis, as shown in Figure 3. The pressure at test point 1 increased after reaching the valley value. Nevertheless, after a while, there appeared an inflection point, which brought about a decline in the curve and eventually tending to stationary. In contrast, the pressure at test point 2 also showed a slight upward trend after reaching the valley value, but there was no inflection point. Instead, the increasing speed gradually decreased and ultimately stabilized. Moreover, no matter how the ignition power changed, the pressure at test point 1 basically exceeded that of test point 2. Whereas, the numerical gap between them had been narrowing over time.

After a gas explosion took place in a semiclosed pipeline, the internal gas was depleted, forming a negative pressure zone in the pipe. Under the action of atmospheric pressure, external gas flowed into the pipe, that is, the phenomenon of air backflow occurred. Besides, lots of water mist was observed in the quartz pipe. The essence of gas explosions was the chemical reaction between methane and oxygen. They reacted to forming water. Initially, water existed in the form of water vapor. When it came to the pipe wall or encountered cold air, water vapor liquefied into form droplets and released heat, further lowering the pressure in the pipe and exacerbating air backflow. Consequently, the environmental pressure at different locations showed a rise after reaching the valley value. As the pressure in the semiclosed pipeline rose, the air velocity at the open end of the pipe, namely the test point 1, gradually decreased. And finally, the pressure in the chamber tended to be atmospheric pressure. The appearance of pressure inflection point at test point 1 strongly demonstrated the above argumentation.

For the same test point, the variation of ignition power had a certain degree of influence on environmental pressure, as shown in Figure 4. Under different ignition powers, although the shapes of the pressure curve at test point 1 were approximately similar, the size of the pressure peak could still be significant reflecting the influence of ignition power, as shown in Table 4. Obviously, with the addition of ignition power, peak pressure also increased, and there was a positive relationship between peak pressure and ignition power. In order to more quantitatively describe the response characteristics between them, three common math-

### Table 4. Environmental Pressure Peak under Different Ignition Powers

| Ignition power (W) | Test point 1 | Test point 2 |
|-------------------|-------------|-------------|
|                   | 133         | 155         | 211         | 248         | 275         |
| 1                 | 0.04262     | 0.04877     | 0.0513      | 0.05936     | 0.06519     |
| 2                 | 0.07974     | 0.08171     | 0.08507     | 0.08945     | 0.09407     |

Figure 4. Variation laws of environmental pressures at test point 1.
matical equations were used for fitting, namely linear equation, power function equation, and logarithmic equation. Figure 5 illustrates the fitting effects of three types of equations. On the basis of the results, it was discovered that the fitting effect of the linear equation was the best, the correlation coefficient of which was 0.9417. Next was the power function equation, which had a slightly inferior simulation result, and the correlation coefficient was 0.9307. Because the correlation coefficient was only 0.8799, the fitting result of the logarithmic equation was the worst.

As shown in Figure 6, when the test point was converted to test point 2, the influence of the change of ignition power on environmental pressure was also primarily reflected in the magnitude of the pressure peak. As shown in Table 4, similar to test point 1, the peak values at test point 2 also increased with an increase of ignition power, and they were positively correlated. Likewise, peak values at test point 2 were also fitted. Figure 7 displayed the fitting effects of the linear equation, the power function equation, and the logarithmic equation on the pressure peak. Apparently, the imitative result of the linear equation was still the best, of which the correlation coefficient was 0.9616. Next was the power function equation, and its correlation coefficient was 0.9342. Because the correlation coefficient was 0.9222, the logarithmic equation had the worst effect. Compared with test point 1, the fitting effect of the linear equation was enhanced. By analyzing the above results, the following conclusions could be obtained. First, there was a positive linear correlation between the environmental pressure peak and ignition power at different positions in the semiclosed pipeline. Second, the closer it was to the explosion source location, the better was the linear relationship.

Ignition power represented the amount of heat released per unit time. Meanwhile, for a certain concentration of methane gas, the energy of converting ordinary molecules into activated molecules was definite. Therefore, from the perspective of the chain reaction mechanism, the larger the ignition power was, the greater the energy transmitted in unit time was, the more the number of activated molecules generated in unit time was, and the more activated molecules effectively collided. This led to the augmentation of molecules involved in the chain reaction, making the gas explosion reaction more complete and thorough, and ultimately resulting in an increase in environmental pressure peak. Moreover, the bigger the ignition power was, the shorter the time for the complete reaction of a gas explosion, and the less heat was lost through heat conduction and heat radiation through the tube wall. Thus, more energy was supplemented to the precursor shock wave, which further increased the pressure peak.34

3.2. Variations of Environmental Temperature. Figure 8 shows the variation tendency of environmental temperature with time. If only analyzed from the curve shape, the variation characteristics of environmental temperature under dissimilar ignition powers were approximately similar. First, within more than three seconds after experiments started, the temperature always remained unchanged. Then, the temperature represented a trend of rapid rise. After reaching the peak, the temperature gradually decreased and eventually stabilized. The influence of ignition power on environmental temperature was mainly reflected in the numerical size of curves and the change rate of curves.

First of all, during the temperature rise period, the effects of the ignition power on temperature principally embodied two
aspects, namely the beginning moment of rising and the average heating rate, as shown in Figure 9 and Table 5. It was observed that with the addition of ignition power, the beginning moment of rising shortened step by step, and the average heating rate gradually increased. Among them, when the ignition power was 133 W, the beginning moment of rising and average heating rate were 3.7 s and 10.28 °C/s, respectively. However, when the ignition power was 275 W, these two parameters were changed to 3.05 s and 14.3 °C/s, separately. The variation of the above data indicated that the ignition power had a relatively greater significant effect on the rising stage of temperature.

There were two main reasons for the rapid rise of environmental temperature at the opening end of the semiclosed pipeline. To begin with, according to the chemical reaction equation of methane and oxygen, as shown in formula 1, the full reaction of 1 mol methane and 2 mol oxygen would release 886.2 KJ heat, which brought about the temperature in the pipeline to rise rapidly. Secondarily, methane reacted with oxygen to generate water. The water produced initially existed in the form of water vapor. When it touched tube walls or cold air, it liquefied and released heat, causing a further increase in environmental temperature.

\[ \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + 886.2 \text{ KJ/mol} \]  

(1)

The larger the ignition power was, the more energy transferred to methane molecules per unit time, the more activated molecules that had effective collisions, the more molecules participated in the chain reaction, the more complete was the gas explosion, and the more heat was released. Therefore, with the increase of ignition power, the shorter was the beginning moment of rising, the greater was the average heating rate. Furthermore, the bigger the ignition power was, the shorter was the time for gas explosions to fully react, the less heat was lost through heat conduction and heat radiation through the tube wall, the more the energy was supplemented to the precursor shock wave was, the more apparent the positive feedback mechanism between the precursor shock wave and the flame propagation speed was, and the faster the flame propagation speed was. This was another main reason why ignition power was negatively correlated with the beginning moment of rising and positively correlated with the average heating rate.

Second, when the environmental temperature reached its peak, the peak value and the moment of temperature peak appearance were also greatly correlated with the ignition power. Figure 10 illustrates the moment of temperature peak appearance under different ignition powers. Obviously, there was a negative correlation between them, that is, with the increase of ignition power, the earlier the peak occurred. However, the relationship between the peak value and ignition power was just the opposite, as shown in Figure 11. More specifically, the peak value increased with the augmentation of ignition power.

Meanwhile, to quantitatively describe the response features between temperature peak and ignition power, linear equation, power function equation, logarithmic equation, and exponential were applied for fitting analysis. Figure 11 displays the fitting effects of dissimilar equations. Among them, the best simulation effect was the exponential equation, the correlation coefficient of which was as high as 0.9533. Next is the logarithmic equation, and its correlation coefficient was 0.9242. As the correlation coefficient of the power function equation was 0.9136, its fitting
Effect ranked third. The linear equation’s correlation coefficient was only 0.8837, which had the worst simulation results.

As mentioned above, the greater was the ignition power, the more were the activated molecules involved in the chain reaction, the more complete was the gas explosion reaction, and the more heat was released. Simultaneously, the larger the ignition power was, the shorter was the time for complete reaction of the gas explosion, and the less was the heat lost. Those reasons together led to the phenomenon that the greater was the ignition power, the greater was the peak environmental temperature.

Third, in the temperature descent period, the duration of temperature decline and average cooling rate with ignition power was expressed in Figure 12 and Table 6. The durations of temperature decline were basically positively correlated with the ignition power, namely, the cooling duration prolonged with the increase of the ignition power. For the average cooling rate, there was no remarkable monotonic relationship between it and ignition power. However, when comparing the rising and falling rates of temperature, it was noticed that the average rising rate was about twice the average cooling rate.

The drop in environmental temperature was due to the occurrence of air backflow. After gas explosions, the outside cold air moved into the pipe under the action of atmospheric pressure, causing the temperature measured at the open end to decline. The duration of temperature decline was associated with the peak temperature and air velocity. Owing to the pressure valley values at test point 1 being not very diverse under dissimilar ignition powers, the air reflux velocities at the open end were approximately equal. There was a positive relationship between peak temperature and ignition power. As a result, the bigger was the ignition power, the longer was the cooling duration.

Finally, when the environmental temperature tended to be stabilized, the change of ignition power would affect the temperature. However, since the change amplitude of this part was relatively small, it was deliberately intercepted. Meanwhile, it was compared with the room temperature in the previous few seconds, as shown in Figure 13 and Table 7. From Figure 13A, it was found that the stable temperature after explosions would increase with the increase of ignition power. Moreover, compared with the room temperatures before explosions, the environmental temperatures of the semiclosed pipeline after gas explosions had all increased. Among them, the increased amplitude of 275 W ignition power was twice as large as that of 133 W, which demonstrated that the greater was the ignition power, the greater was the increase in environmental temperature.

### Table 6. Environmental Temperature Parameters at Descent Period

| stage     | ignition power (W) | duration of temperature decline (s) | average cooling rate (°C/s) |
|-----------|--------------------|-------------------------------------|-----------------------------|
| descent   | 133                | 2.5                                 | 5.76                        |
| period    | 155                | 2.4                                 | 6.96                        |
|           | 211                | 2.75                                | 6.47                        |
|           | 248                | 2.8                                 | 6.57                        |
|           | 275                | 3.3                                 | 5.76                        |

3.3. Variations of Environmental Humidity. In section 3.2, it was mentioned that the liquefaction of water vapor to form droplets and release heat was one of the reasons for the rapid
increase of environmental temperature. To verify the above conjecture, the environmental humidity at the open end of the semiclosed pipeline was monitored. Figure 14 displays the variation tendency of environmental humidity with time. Obviously, the laws of humidity were approximately similar to that of temperature, which remained unchanged at first, next rose rapidly, reached the peak, then decreased quickly, and finally tended to be stable.

However, there existed some differences between temperature and humidity. First, as shown in Table 8 and Figure 14, the humidity peak changed in a wave shape with ignition power, and there was no significant monotonic relationship between them.

Second, the stable humidity after explosions basically did not vary with the increase of ignition power. The stable average humidity after explosions was 30.56%, which was an addition of 1.36% compared to the average humidity before the explosion, with little change.

Methane reacted with oxygen to generate water, whereas this water initially existed in the form of water vapor. When encountering cold air or touching the pipe wall, water vapor was liquefied to form small droplets, thereby increasing the humidity in the pipeline. There was no monotonic relationship between peak humidity and ignition power, which indicated that although the augment of ignition power could make the gas explosion more complete and thorough, it would not affect water production.

The environmental temperature data and environmental humidity data were collected by the same temperature and humidity sensor at the open end of the semiclosed pipeline. Therefore, the monitoring times of these two environmental parameters were totally identical. Taking time as the abscissa, the effects of the change of ignition power on the beginning moment of the rise of these parameters were explored, as shown in Figure 15. When the ignition power was relatively small, namely 133 W or 155 W, the initial rise moment of the temperature and humidity were substantially equal, which indicated that in the pipeline they changed simultaneously.

When the ignition power was 211 W, the initial rise moment of the temperature and humidity varied; that is, the temperature rose 0.3 s earlier than the humidity. Under the ignition power of 248 W, the gap between the onset of rise for each had widened to 0.55 s. That is to say, the rising beginning moment of temperature was 0.55 earlier than that of humidity. When the ignition power increased to 275 W, the gap between them further increased to 0.7 s. The greater ignition power led to the temperature displaying an upward trend earlier than the humidity. At the same time, the time gap between the upward trend of each increased with the augmentation of ignition power.

### 4. CONCLUSION

In this paper, experiments of gas explosion in a semiclosed pipeline under different ignition energies were performed to
research the continuous variations of environmental parameters (environmental pressure, environmental temperature, and environmental humidity) in the whole process of an explosion, especially in the later explosion period, and to investigate the influence of ignition energy (ignition power) on environmental parameters. The main conclusions were as follows:

(1) After a gas explosion in a semiclosed pipeline, a noticeable air reflux phenomenon appeared at the open end of the chamber. The occurrence of an inflection point in the later period of environmental pressure at test point 1, and the rapid decline trends of environmental temperature and humidity after reaching the peak all strongly proved the phenomenon.

(2) The influence of ignition energy on environmental pressure was mainly reflected in peak value. There was a positive linear correlation between ignition power and peak pressure. Meanwhile, the closer to the explosion was the source location, the better was the linear relationship.

(3) The change of ignition energy had a greater impact on the environmental temperature. Moreover, after gas explosions, the stable temperature at the open end significantly improved compared with the room temperature. The highest increasing extent of temperature could be reached at 8.66%. However, the degree of correlation between ignition energy and environmental humidity was not higher.
(4) When the ignition power was 275 W, the peak value of each environmental parameter was the highest. The peak pressure at test point 1, the peak pressure at test point 2, the peak temperature, and the peak humidity were 0.06519 MPa, 0.09407 MPa, 32.8 °C, and 47.4%, respectively.

Researching the correlation characteristics between ignition energy and environmental parameters is helpful to comprehensively understand the changing laws of environmental parameters, thus providing a theoretical basis for preventing, weakening, and investigating secondary explosions and other derivative disasters. Increasing the size of the experimental chamber, setting more measuring points, analyzing the kinetic process, and carrying out the numerical simulation to conduct more in-depth exploration of environmental parameters will be part of a follow-up study.

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Notes
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