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Study on the Law of Acoustic Emission Signal of PE Water Supply Pipe

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Abstract

Aiming at the lack of real-time characteristics of existing urban water supply pipeline leak detection methods, such as negative pressure wave method, the acoustic emission monitoring technology is used to conduct experimental research on pipeline leakage failure. Set up a leakage failure system for PE water supply pipelines, use a water pump to pass water into the pipeline system, artificially open 2mm, 4mm diameter leak holes, collect acoustic emission signals at 100mm, 200mm, 300mm, 400mm, 500mm away from the leak hole, and analyze the signal in the time domain Characteristic parameters and frequency spectrum rules. The frequency spectrum is obtained by fast Fourier transform of the acoustic emission signal in the frequency domain. The results show that the amplitude, energy count, and ringing count tend to increase with the increase of the leakage aperture, and with the increase of the monitoring distance. The main frequency distribution of 2mm and 4mm leak holes is similar, and the main frequency is stable in the range of 15.2KHz-64.24KHz.

Keywords

PE Water Pipe; Leakage; Acoustic Emission; Monitoring.

1. Introduction

With the continuous development of urbanization, the national economy has an increasing demand for water resources. As an important part of the urban water supply system, water supply pipelines can be called the main artery of the national economy [1]. However, because urban water supply pipelines are buried underground for a long time, there are many factors. Under the action of corrosion, cracking, third-party damage and other factors, pipeline leakage accidents occur from time to time, resulting in a great waste of resources and great economic losses [2][3]. The average leakage rate of water supply pipelines in my country is 16%, which is much higher than the leakage rate of only 7% in European and American countries [4].

For the detection of leaks in water supply pipelines, relevant scholars have conducted a lot of research. Bai Yongqiang et al. [5] used the acoustic signals collected at the two ends of the leak and combined with the propagation speed of the acoustic wave in the water supply pipeline to locate the leak in the pipeline. The research results showed that based on the use of cross-correlation analysis to locate the leak, The information after Fourier transform filtering is more accurate, and the leakage point obtained is more accurate. Ji Shuyao et al. [6] used power spectrum and HHT transform to extract typical frequency features for leak detection; the normalized energy of IMF component combined with BP neural network was used to classify and identify leak types. Experiments were conducted by collecting a large number of acoustic signals of different leak types, and it was confirmed that the scheme has a leak detection and classification accuracy rate higher than 95%. According to the negative pressure wave method, Li Zhonghu et al. [7] applied correlation analysis theory to leak detection and location of water supply pipelines. For the large amount of noise contained in the extracted leakage signal, it can be denoised by moving average filtering, wavelet analysis and other

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methods. The experimental results show that a reasonable selection of denoising methods based on actual conditions can effectively improve the accuracy of leak detection and positioning of water supply pipelines based on correlation analysis. Gu Xiaohong et al. [8] proposed a method to identify buried water pipe leakage based on acoustic emission sensors and ChiMerge rough set. This method first uses acoustic sensors to collect data, and then uses EMD (empirical mode decomposition method) and energy feature extraction. The combined method is used to establish a decision table, the decision table is discretized by ChiMerge algorithm, and finally the water pipe leakage is identified through rough set reduction. The experiment verifies the effectiveness of this method. Wang Qianlong et al. [9] used wavelet packet decomposition and reconstruction of the data signals collected by the two acoustic emission sensors to obtain different frequency band data, and performed cross-correlation analysis on the same frequency band of the two signals, and selected the time corresponding to the maximum value of the correlation coefficient into the positioning formula The location of the leak is obtained. The actual test results show that this method has a positioning accuracy higher than 94%.

The economic loss caused by the leakage of PE water pipes is huge. Aiming at the characteristics of buried PE water pipes that are not suitable for excavation, it is of very positive significance to carry out effective non-destructive monitoring on them. At present, there are many documents on pipeline leakage monitoring, but there are few studies on the application of acoustic emission to PE water pipe leakage monitoring. Acoustic emission technology has the advantages of strong real-time, high sensitivity, and strong integrity. The practicability of this technology has been extensively verified in the nondestructive detection of pipeline failures. This paper studies the leakage conditions of PE water pipes, collects its acoustic emission signals, analyzes the characteristic parameters of the signals, and summarizes its changing rules to achieve the purpose of real-time and effective monitoring of pipeline leakage failures.

2. Experimental part

2.1 Raw materials

PE water pipe (SDR11).

2.2 Instruments and equipment

Water pump

Full-information acoustic emission instrument: DS5-16C, supporting software DS5AE2020, Beijing Soft Island Technology Company.

2.3 Leakage experiment scheme under acoustic emission

In order to study the leakage failure of PE water pipes, this experiment builds a PE water delivery pipeline system, uses a water pump to deliver water into the pipeline, and opens 2mm and 4mm aperture leak holes above the pipeline, respectively, and collects 100mm, 200mm, 300mm, 400mm, and 400mm from the leak hole. The acoustic emission signal at 500mm, the experimental platform design is shown in Figure 1:

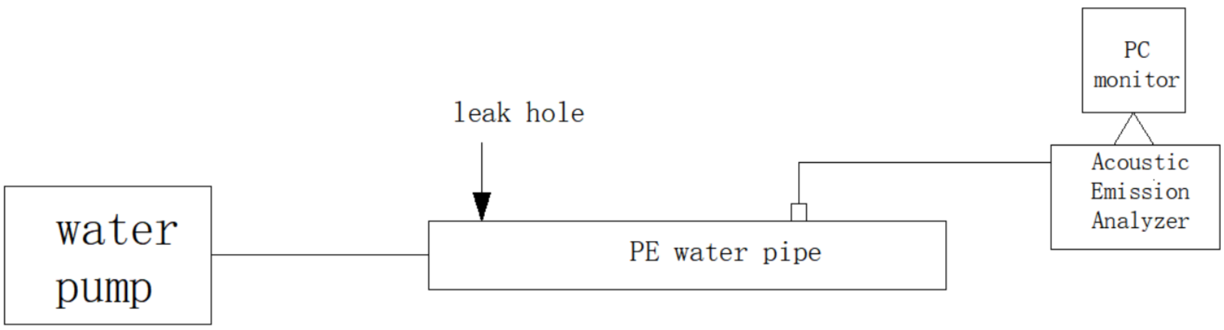

Figure 1. Leakage experiment platform

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2.4 Elimination of experimental environment interference

In order to minimize the interference of irrelevant factors on the experiment process, select qualified PE water pipes to be welded in accordance with the standard, ground the acoustic emission collection system and measure the environmental noise before the experiment. The final environmental noise acoustic emission signal amplitude is 3mV, which is in line with the acoustic emission collection. The use of the system requires that the water pump be kept as far away from the test site as possible during the experiment, the noise of the water pump is shielded, and the temperature of the experiment environment is kept at room temperature.

3. Results and analysis

When the PE water pipe leaks and fails, due to the pressure in the pipe, the fluid will be continuously ejected outwards, and the molecular chains and crystals at the leak hole will also undergo structural changes, which continuously generate acoustic emission signals that are collected by the sensor. The acoustic emission signal collected in this experiment is a continuous signal. The parametric analysis method is one of the most commonly used methods to analyze acoustic emission signals since 1950. This method uses several simplified characteristic parameters with time as the horizontal axis to characterize acoustic emission signals, including amplitude, ring count, and energy count, And other characteristic parameters. This experiment selects amplitude, energy count, and ringing count as the research objects, and their definitions and uses are shown in Table 1 [10][11][12].

Table 1. Characteristics, definitions and uses of acoustic emission characteristic parameters

Parameter	Definition	Features and uses
Amplitude	The maximum amplitude value in the waveform of an acoustic emission signal.	What is reflected is the size of the event, which has nothing to do with the size of the threshold, and its size determines the detectability of the event.
Energy count	The area under the envelope of the signal detection wave can be divided into total count and count rate.	Reflect the relative energy and relative intensity of the event.
Ring count	The number of oscillations of the signal crossing the threshold can be represented by the total count and the count rate.	Reflect the intensity and frequency of the acoustic emission signal.

3.1 Analysis of the variation law of acoustic emission characteristic parameters of PE water pipe leakage

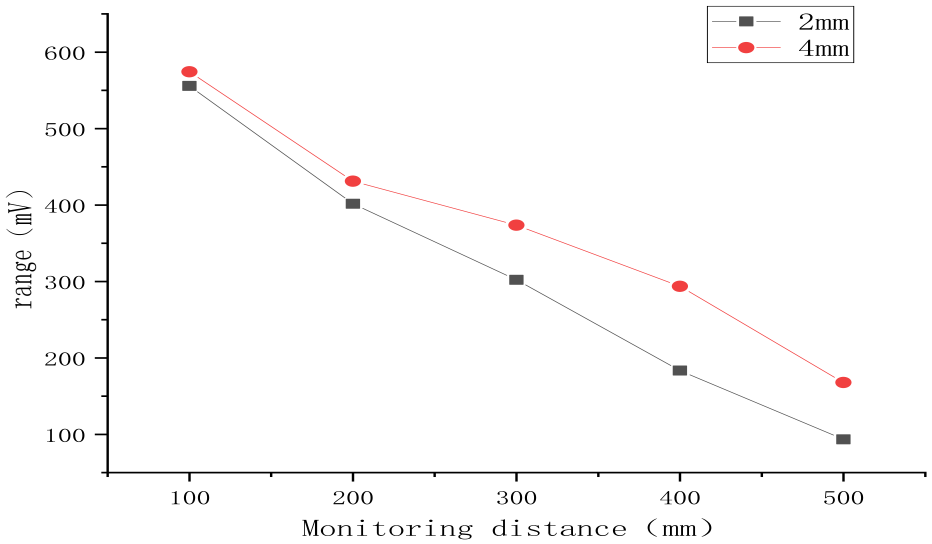

Figure 2. Schematic diagram of the variation trend of amplitude with monitoring distance

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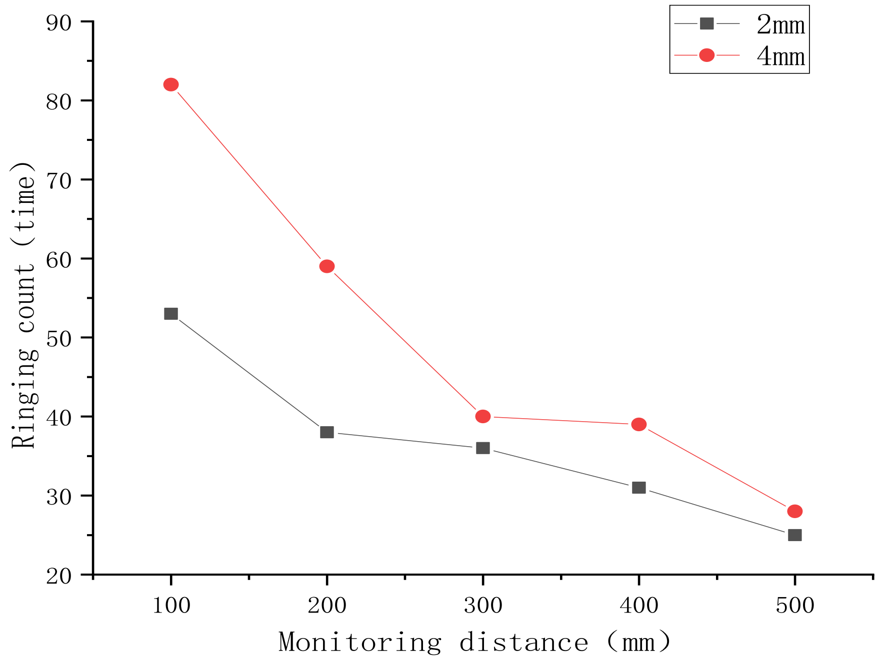

Figure 3. Schematic diagram of the change trend of ringing count with monitoring distance

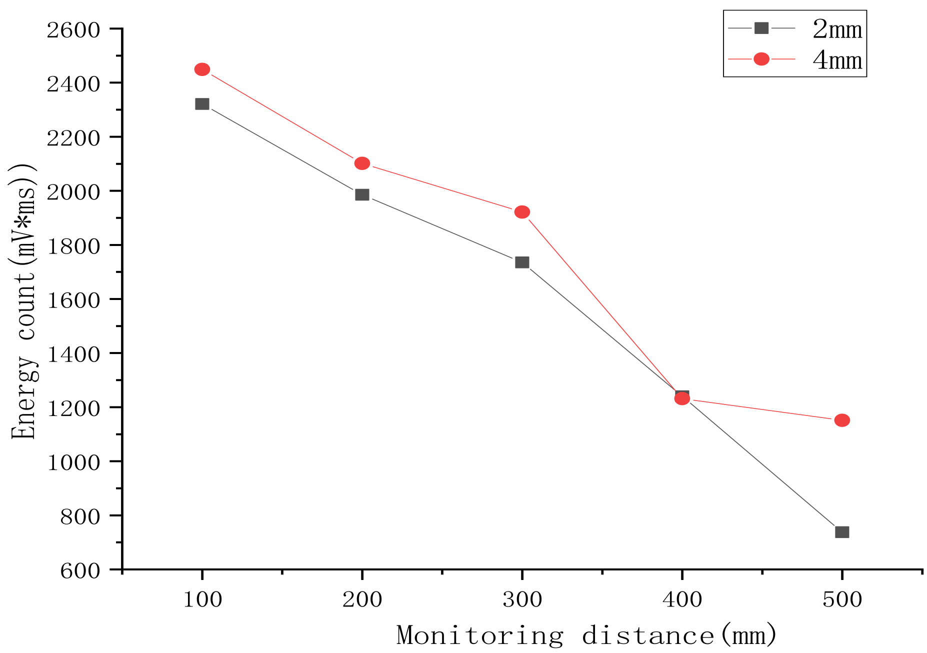

Figure 4. Schematic diagram of the change trend of energy count with monitoring distance

Figure 2, Figure 3, Figure 4 are respectively the acoustic emission signal amplitude, ringing count and energy count change trend graph with the monitoring distance, from the figure, the following rules can be obtained:

(1) Under the same monitoring distance, as the leakage aperture increases, the acoustic emission signal amplitude, energy count, and ringing count characteristic parameters increase accordingly. This is because the pipeline leakage acoustic emission signal is caused by the friction of the fluid leakage on the hole wall. Caused by crystal vibration, within a certain period of time and the fluid environment in the tube is stable, the larger the diameter of the leak hole, the greater the leakage, the more serious the friction on the hole wall, the stronger the acoustic emission signal, and the larger the characteristic parameters. The change of the monitoring distance does not affect this law.

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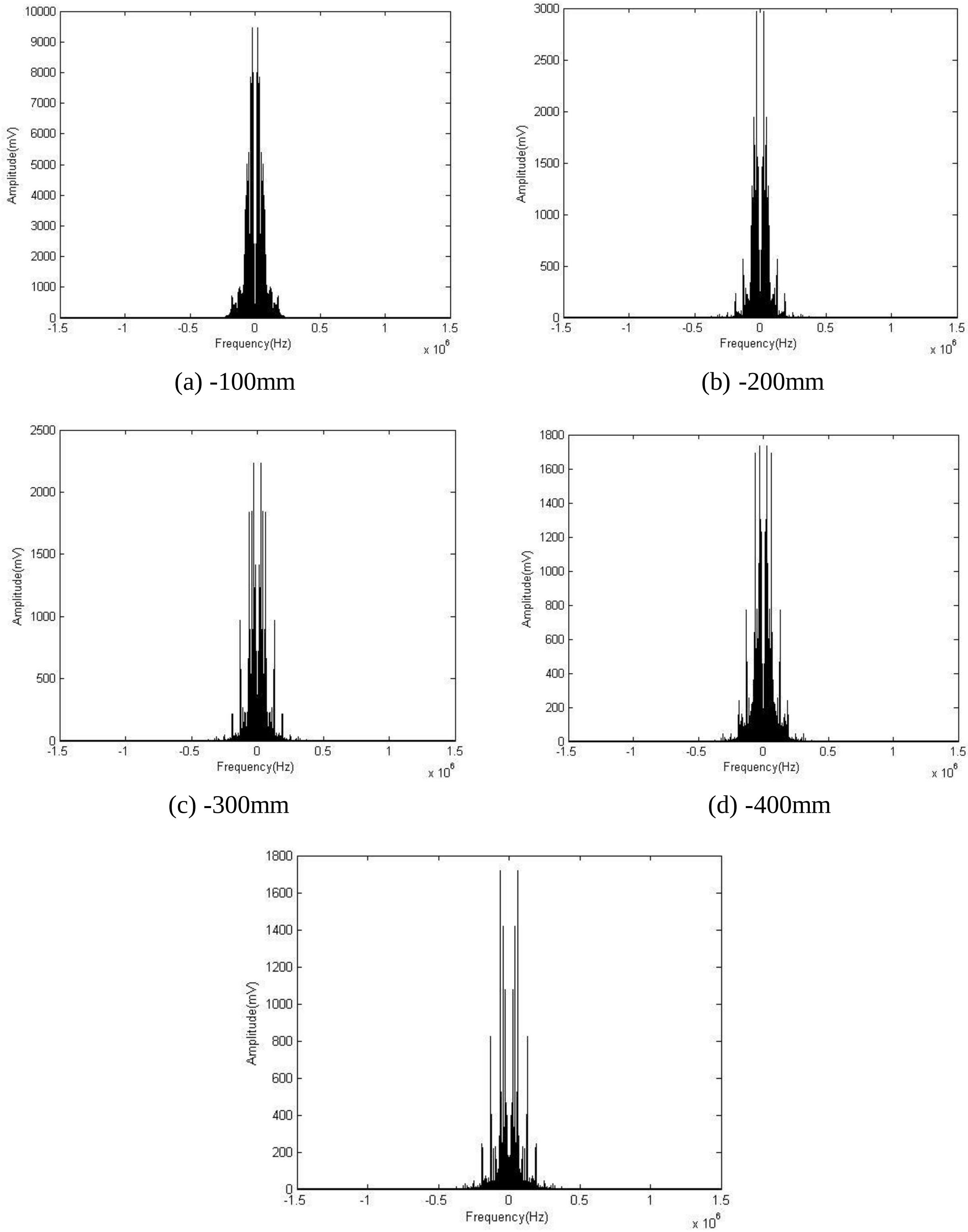
(2) Under the same leakage aperture, the characteristic parameters of acoustic emission signal amplitude, energy count, and ringing count show a decreasing trend with the increase of the monitoring distance. This is due to the high attenuation of PE pipes, and the factors of the pipe material and even the surrounding environment The acoustic emission signal will be attenuated and the signal strength will be weakened, so that the characteristic parameters of the acoustic emission signal are smaller, and the change of the leakage aperture does not affect this law.



(a) -100mm

(b) -200mm

(c) -300mm

(d) -400mm

(e) -500mm

Figure 5. The frequency spectrum of the acoustic emission signal of PE pipeline leakage failure

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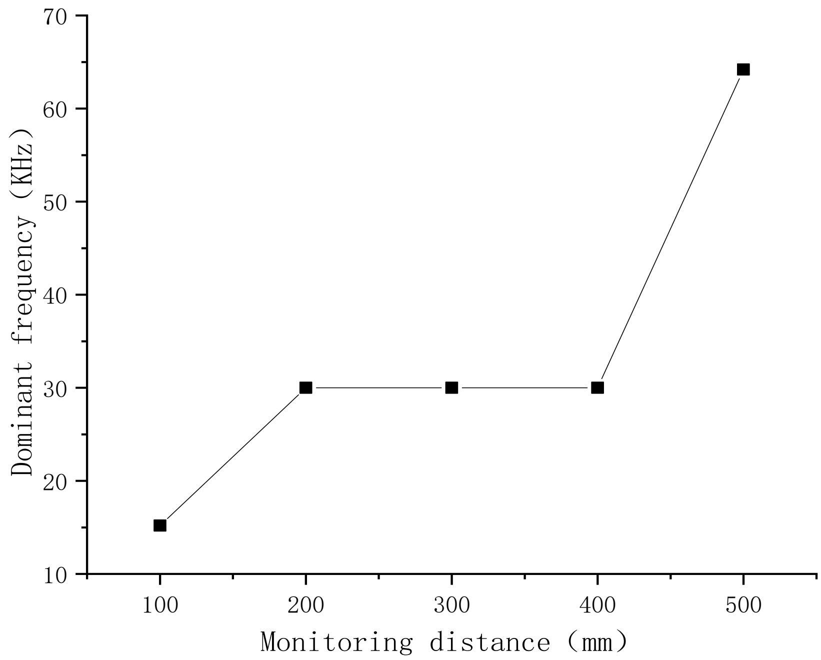

Figure 6. Schematic diagram of main frequency distribution of acoustic emission signal

3.2 Analysis of the change law of the acoustic emission spectrum characteristic parameters of PE water pipe leakage

After many experimental data analysis, it is concluded that the change of the leakage aperture does not affect the distribution of the main frequency of the acoustic emission signal, so this article only conducts a frequency spectrum analysis on the 2mm leakage hole to study its main frequency distribution.

Figure 5 and Figure 6 show the frequency spectrum and main frequency distribution of PE pipeline leakage acoustic emission signal. It can be seen from the figure:

(1) During the leakage process, the main frequency is distributed in the range of 15.2KHz-64.24KHz, and the overall distribution is relatively stable. This is that during the pipeline leakage process, the fluid in the pipe is generally stable, and the frequency of acoustic emission events generated by the leakage is stable, so the main The frequency distribution is relatively stable.

(2) Through calculation, the average main frequency under each monitoring distance is 33.688KHz. Compared with the main frequency under each monitoring distance in the figure, the main frequency under the monitoring distance of 200mm-400mm is more stable than that at the monitoring distance of 100mm and 500mm.

4. Conclusion

In this paper, by opening 2mm and 4mm leak holes on PE water pipes, collecting the acoustic emission signals at different distances from the leak holes, and analyzing the characteristic parameters of acoustic emission-amplitude, ringing count and energy count, the acoustic emission signal is analyzed. Spectrum analysis, get the following conclusions:

(1) The larger the leakage aperture, the greater the leakage flow rate within a certain period of time, and the stronger the acoustic emission signal generated by the friction of the leakage hole wall by the fluid, which makes the characteristic parameters of the acoustic emission signal-amplitude, ringing count, and energy count larger.

(2) Under the same leakage aperture, due to the high attenuation of the PE pipe, the acoustic emission signal attenuates higher as the distance increases, causing the amplitude, ringing count, and energy

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count to decrease as the monitoring distance increases. The change of the leakage aperture does not affect this law.

(3) Because the fluid in the pipe is relatively stable during the leakage process, the main frequency of the leakage process is stable within the range of 15.2KHz-64.24KHz, and does not change with the aperture and the monitoring distance.

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