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Research on Calculation Method of Annular Leakage Rate based on Variable Conservation Method

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Abstract: The annular leakage rate is the most important parameter to measure the failure of gas well barrier units. At present, there are two methods that can be applied to calculate the leakage rate of offshore gas wells: safety valve method and nozzle flow method. However, applying these two methods to the calculation of annular leakage rate has encountered a problem of poor adaptability. In order to enhance the accuracy of leakage rate calculation results and improve the reliability of judging gas well integrity through annular leakage rate, this article summarizes an annular rate calculation method based on variable conservation method.

Keywords: Calculation Method of Annular Leakage Rate; Variable Conservation Method; Gas Well Barrier Device.

1. Background

The safety valve method and the nozzle flow method actually do not have a specific scope of application, but the incorrect parameter values limit these two methods to a certain operating condition in order to obtain relatively close results [1-3]. Under the correct parameter values, the above two methods can be applied to all well conditions. However, in on-site measurement, there are many parameters that are difficult to measure or cannot obtain relatively accurate values, which makes it difficult to use the safety valve method and the nozzle flow method in practical on-site applications [4]. Taking the safety valve method as an example, due to the relatively long injection time of the annulus protection fluid, there is no accurate measurement and record of how much annulus protection fluid has been injected several times, as well as the leakage of the wellbore annulus protection fluid. Currently, it is difficult to determine the height of the liquid level in the wellbore, which results in the inability to obtain the annulus volume parameter, which is extremely important for the safety valve leakage calculation model [5]. For the mouth flow method, as it is based on the isentropic relationship between the wellhead pressure relief pipeline and the annular leakage during pressure relief balance, it is necessary to test the data from the annular pressure well pressure relief test to pressure balance. However, in practical operation, due to the consideration of maintaining production and ensuring safety, most of the time, the pressure relief of the annulus is not tested until the pressure relief balance is reached. Instead, the pressure relief valve is closed for various reasons before the pressure relief balance is reached, resulting in the lack of key data (pressure relief balance pressure) during use and the inability to use the nozzle flow method.

2. Calculation Method for Conservation of Change

In order to solve the problem of incomplete on-site test data and records, a method is proposed that can approximate the annular leakage rate without the need for complete pressure relief/recovery test data.

Due to the long time required for pressure relief/pressure recovery testing, it usually takes more than 24 hours to obtain a relatively stable value. Therefore, in order to minimize the impact on production, many on-site pressure relief/pressure recovery tests do not achieve complete pressure relief balance before pressure recovery. Instead, pressure recovery is carried out before reaching balance. For the test data in this situation, consider it from the perspective of flow conservation. Select a pressure point A in the pressure relief test, and the cumulative time from this point to the end point B of the pressure relief test is t1. In the pressure recovery test, select point C with the same pressure level as point A. The cumulative time from the beginning B of the pressure recovery test to point C is t2.

During the pressure relief process, the change in gas volume in the annulus is provided by two parts: one is the discharge volume of the pressure relief pipeline, and the other is the leakage volume of the annulus leakage. During the pressure recovery process, the change in gas volume in the annulus is only provided by the leakage rate at the bottom of the well. It is believed that the difference between the release amount of the pressure relief pipeline and the leakage amount of the annulus during the process of reducing the pressure level from A to B during pressure relief is the same as the leakage amount of the annulus during the process of increasing the pressure level from B to A during pressure recovery.

In real situations, changes in annular pressure can cause changes in the pressure at the leakage point, including at both ends of the relief pipeline, and changes in pressure difference can affect the flow rate, accompanied by changes in temperature. Due to the fact that risk level determination does not require completely accurate calculation values, in order to simplify the calculation, the influence of temperature on the results is ignored, and the leakage rate is considered as a constant value, that is, the annular leakage rate during the pressure relief process is considered to be the same as the annular leakage rate during the pressure recovery process (equivalent to taking the average value within a specific time range).

When using the conservation of flow method, the key is to obtain the discharge capacity of the pressure relief pipeline. There are currently two approaches:

(1) Direct measurement method for pressure relief pipelines

The simplest and most accurate method for obtaining relief flow is to directly measure it through the relief pipeline. At present, pressure relief pipelines generally use 3/8-inch or 1/4-inch pipelines to discharge into atmospheric ignition or backup tanks, and the flow rate can be measured by installing a flowmeter. However, due to limitations such as on-site operations or tubing tree structure, it is not easy to achieve.

(2) Simplified flow calculation method

When it is difficult to obtain on-site discharge flow data, a simplified flow calculation method can be used for calculation. When using the small hole model for pressure relief pipelines, the actual data that needs to be obtained is the pipeline inlet pressure, wellhead temperature, and pipeline outlet pressure, which are relatively easy to obtain data. When simplifying the calculation model, the decrease in pressure during the pressure relief process is approximately linearized, and the mean of points A and B is used as the inlet pressure.

3. Conclusion

This article mainly studies the calculation method of annular leakage, analyzes the existing underground safety valve method and nozzle flow method, and indicates that the safety valve method is suitable for wells with low annular pressure and can release pressure to a lower pressure value; The nozzle flow method is only applicable to wells with high annular pressure values and cannot be released to lower pressure values or with low pressure drop. Based on this, a widely applicable variable conservation calculation method is proposed.

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