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Optimization and Experimental Study of Foaming Agent based on Yan 694 Well Area

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Abstract

In the gas well drainage and gas recovery process, foam drainage gas recovery has become one of the main technologies with its advantages of easy construction and quick effect, but it is necessary to consider the influence of different construction environments (different salinity in formation, different condensate, different bottom well temperature) on its performance, so a single foaming agent has a poor effect on on-site construction, and different agents need to be designed and selected for different environments. In this paper, on the basis of clarifying the mechanism and properties of the foaming agent, the development of the foaming agent was carried out for the well area, the compatibility and thermal stability of the foaming agent and the water sample were investigated, and according to the field investigation, the foaming and drainage design was made, the foaming effect of different foaming agents was evaluated, the selected foaming agent was used for the bubble drainage test, the influence of different factors on the performance of the foaming agent was studied, its foaming and foaming ability under different conditions were revealed, and it was pointed out that the X-PP-2301 foaming agent conformed to the technical indicators of the well area. It was used as a foaming agent in the Yan 694 well area, which provided a theoretical and experimental basis for the optimal design, which was helpful to stabilize production and increase efficiency in the well area.

Keywords

Drainage Gas Production; Foam Drainage; Foam Drainage Agent Selection; Indoor Screening Experiments.

1. Overview of Drainage Gas Recovery

1.1 Mechanism of Foam Drainage

Foam drainage gas recovery technology uses specific surfactants to form gas-water foam fluid, which significantly reduces density and surface tension and improves gas recovery efficiency of gas wells. It not only changes the flow characteristics of gas-liquid two-phase motion in the wellbore, but also brings the effusion out of the wellbore more efficiently and reduces the bottom hole back pressure, which is of great significance for improving the recovery rate on site.

1.2 Properties and Types of Foaming Agent

1.2.1 Performance of Foaming Agent

(1) Strong foaming ability: a large amount of foam can be quickly generated at low gas flow rate, which can effectively reduce the density of water column. A small amount of foam can be added to

form a large amount of foam in the bottom water, so that the liquid density can be greatly reduced, so that it can be easily pushed to the wellhead by air flow;

(2) The strength of the bubble film formed by the foam is large: when the foam discharge agent molecules reach a certain concentration around the bubble, the strength of the bubble film formed is high, the thickness of the internal water film increases, so that the foam has a large water carrying capacity and long-term stability, and the amount of water carried increases ;

(3) Foam stability is moderate: it can maintain stability during long-distance transportation, which can effectively avoid water loss caused by foam rupture, and will not cause excessive defoaming in the separator.

(4) Anti-condensate oil and high salinity capacity: Adapt to complex well conditions, maintain its foaming performance and foam stability, and ensure continuous and efficient gas drainage.

1.2.2 Types of Foaming Agent

Foam drainage agents can be divided into several types according to their chemical properties and uses : Anionic foam drainage agents are known for their good foaming ability and wide application range.

In water, most of the active anions can be dissociated by anionic foaming agents such as sodium dodecyl benzene sulfonate (ABS), so the foam system is stable. Organic amine-derived salts are one of the classic components of cationic foaming agents and play an important role in foaming. Non-ionic foam drainage agent is famous for its superior electrolyte resistance and stability in various water quality environments. Amphoteric surfactants combine the characteristics of anions and cations, usually exhibit different ionic properties under different acid-base conditions, and have good biodegradability and low toxicity. Polymer foam drainage agent is favored for its relatively large molecular weight and excellent surface activity. Special types of foaming agents have more excellent functions, such as fluorine surfactants, silicon surfactants, etc., which can reduce surface tension.

1.3 Performance Evaluation Methods and Indexes of Foaming Agent

According to the application experience of foaming agent, the ability of foaming, foam stabilization and liquid carrying was determined. This paper mainly introduces the following three evaluation methods :

(1) airflow method

The air flow method refers to an experiment to measure the foaming ability and water content of the foaming agent solution during the air flow stirring process. The foam height is regarded as the index of foaming ability, and the water content after foam stabilization under the action of defoaming agent is regarded as the index of foam water carrying capacity. At the same time, the time required for the foam height to decay to half of the original is measured as a measure of foam stability.

(2) Roche Mill 's method

Roche foam instrument is a kind of instrument similar to wellbore structure, which is actually a simulation equipment. Under the conditions specified in the test, the height of the foam in the tube was formed by taking 200ml of the foaming agent solution from the bottom of the Rogowski tube and measuring the two heights at the beginning and 3 minutes (or 5 minutes). The initiation reflects the foaming ability of the foaming agent, and the difference indicates the stability of the foaming agent.

(3) Waring Blender stirring method

In this way, the performance of the foaming agent can be accurately measured. During the test, the test solution was added to the measuring cup, stirred at a constant speed for 60 seconds, and stopped to record the generated foam volume V to evaluate the foaming ability of the solution. Observe the gradual deposition of the liquid from the foam and record the time required for the liquid volume to reach 50 ml to evaluate the stability of the foam.

2. Optimization and Application of Foaming Agent

2.1 Indoor Screening Experiment

2.1.1 Experimental Research Ideas

In the drainage process of deep gas wells, foaming agent and foam stabilizer need to have good foaming and foam stabilizing ability, and ensure that the compatibility of treatment agent and formation water is good, and make it have certain salt resistance, calcium ion resistance and magnesium ion resistance.

In the study, the electrolyte ion base with strong polarity should be selected first to enhance the salt resistance. At the same time, zwitterionic surfactants with good foam stability and surfactant molecules rich in multiple polar points are given priority. In addition, new surfactants synthesized from natural and easily degradable raw materials should be developed and utilized. Next, the synergistic effect between surfactants is used to reduce the surface tension, thereby enhancing the repair ability of the surface film. Finally, the strength and elasticity of the surface film can be further improved by the interaction of surfactant molecules at the gas-liquid interface.

Therefore, a single surfactant lacks applicability in complex field applications, and must be compounded according to different environments to meet on-site drainage needs. In this paper, according to the different water production conditions of gas wells in Yan 694 block, the experiments carried out mainly include : the foaming ability of foaming agent and its liquid carrying capacity under normal temperature and high temperature conditions. Firstly, the changes of foaming performance and liquid carrying capacity of foaming agent were measured after adding a certain amount of condensate oil in high temperature environment. Secondly, the thermal stability of the foaming agent was analyzed to evaluate its performance under high temperature conditions. Finally, the effects of different concentrations of foaming agent solution on foaming ability and liquid carrying capacity were discussed in order to understand the performance of foaming agent under various conditions more comprehensively.

2.1.2 Research Methods and Instruments

The indoor screening experiments done in this paper also evaluate the screening from the ability of foaming, foam stabilization and liquid carrying.

(1) Evaluation of foaming ability and foam stability of foaming agent.

1) The basic principle of the foam measurement method is to dump 200 mL of surfactant solution from a height of 900 mm onto the liquid surface of the same solution, and then measure the height of the foam at 30 seconds and 5 minutes, respectively.

2) The instruments and reagents required include : foam foaming force test equipment (shown in Figure 2-1), a measuring cylinder with a scale with a capacity of 500 ml, a constant temperature water bath with a circulating water pump (temperature 65 ° C), and a reagent made from a mixture of chromic acid and sulfuric acid. Under stirring conditions, concentrated sulfuric acid (density of 1.83 g / mL) was slowly added to an equal volume of potassium dichromate saturated solution. In addition, a timer or a common stopwatch is required.

3) measuring steps

a.The glass instruments used in all experiments were contacted with a mixture of chromic acid and sulfuric acid overnight, and then washed with distilled water until there was no acid, and then washed 2-3 times with the solution to be tested.

b.The solution was prepared, and the final well water sample was taken, and the foaming agent solution of the corresponding concentration was prepared according to the product description. During the preparation of the solution, the stirring should be slow to prevent the formation of foam, and then the temperature was kept in a constant temperature water bath for 30 min at the test temperature. At the same time, the water pipe of the constant temperature water bath is connected with the inlet and outlet of the foaming pipe to open the circulating water pump.

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c.A 200 mL constant temperature foaming agent solution was measured with a measuring cylinder, and slowly poured into the liquid filling funnel along the wall.

d.The foaming tube is also slowly poured into the 50 mL constant temperature foaming agent solution along the wall.

e.Open the filling funnel suspension to make the solution flow at a uniform speed, and start the s table at the same time.

f.The foam volume was observed 30 seconds after the solution in the liquid funnel was flowed, and then the foam volume was observed at 3 minutes and 5 minutes, respectively. If there is a low-lying at the upper center of the bubble, the reading is recorded according to the arithmetic mean between the center and the edge.

g.After the solution foam disappears, the c ~ f step is repeated for parallel experiments.

h.result representation.

The results are expressed as the number of ml or height of the formed foam at 30 seconds, 3 minutes and 5 minutes after the liquid flow stops, and the corresponding curve can be drawn if necessary. The arithmetic mean value of the repeated measurement results was used as the final result. The difference between the repeated measurement results should not exceed 15 mL.

Fig. 1. Measuring device for foaming force and foam stability of foaming agent

(2) Determination of liquid carrying capacity of foaming agent

1) Determination principle : By introducing a certain flow rate of gas into the test solution, a foam is formed. After the set time, the volume of the liquid (including oil and water) carried in the foam was recorded as a measure of the liquid carrying capacity of the foaming agent.

2) Instruments and reagents : The required instruments include a foaming tube and a foam collector (see Fig.2-2), a super thermostat with 0.5 accuracy, a float flowmeter with a flow accuracy of 10 mL / min, a stopwatch, 500 mL and 1000 mL beakers, 20 mL and 100 mL measuring cylinders, wet gas flowmeters, and petroleum ether and nitrogen with a boiling point range of 60-90 °C.

Fig. 2 Liquid carrying capacity measuring device for foaming agent

3) measuring steps

a.The water sample was taken from the final gas well, and the foaming agent was added according to the concentration required by the experiment, and slowly stirred to ensure its uniform mixing.

b.190 mL of foaming solution and 10 mL of petroleum ether (or condensate oil) were added to the foaming tube, and the temperature was kept constant for 30 minutes at the temperature required for the experiment.

c.During the experiment, nitrogen was introduced into the test solution at a pressure of 0.05 MPa and a flow rate of 60 mL / min.

d.After 15 minutes of ventilation, the volume of the liquid (including oil and water) carried by the foam was measured and the experiment was repeated until the difference between the two measurements did not exceed 2 mL.

e.result representation: The amount of liquid carried by the foam is expressed as the number of milliliters carried every 15 minutes. The value of the difference between the liquid carrying capacity of the foam in the two measurement results is not more than 2 mL, and the arithmetic average value is calculated as the final measurement result.

2.1.3 Comparative Analysis of Foaming Effect of Foaming Agent

Four kinds of foaming agents UT-11C, HY-3K, HS-PP-D and X-PP-2301 were selected to evaluate the performance of three kinds of field water samples FX1, FX4 and Yan 2108-3 with different salinity and ion content. Among them, UT-11C and X-PP-2301 are conventional foaming agents, HY-3K is nano-foaming agent, and HS-PP-D is a foaming agent containing corrosion inhibitor. Foaming and foam stability are shown in Table 1.

Table 1. Test results of foamability and foam stability of foaming agent

Field water sample	Added foaming agent	Initial bubble height, mm	5min soaking height, mm
yan2108-3	UT-11C	70	35
	HY-3K	100	70
	HS-PP-D	140	90
	X-PP-2301	170	140
FX1	UT-11C	180	170
	HY-3K	190	190
	HS-PP-D	210	200
	X-PP-2301	220	220
FX4	UT-11C	150	90
	HY-3K	140	90
	HS-PP-D	160	80
	X-PP-2301	150	80

It can be seen from the test results of the foaming power of the foaming agent in the above table that the foaming and foam stability of X-PP-2301 are the best, followed by the foaming and foam stability of HS-PP-D, and the performance of the other two foaming agents is more general.

2.1.4 The Influence of Different Factors on the Performance of Foaming Agent

(1) Effect of temperature on foaming and foam stability of foaming agent

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The stability of foam is closely related to temperature. Under the condition of low temperature and high temperature, the decay process of foam shows a significant difference : in the low temperature environment, when the foam is discharged through the liquid to make the liquid film reach a certain thickness, the foam will enter the metastable state, and the decay mechanism is mainly caused by the diffusion of gas. Relatively speaking, under high temperature conditions, the viscosity of the liquid decreases, resulting in an increase in the rate of liquid discharge. In addition, the upper part of the foam usually presents a convex shape, and this curved liquid film is extremely sensitive to evaporation. With the increase of temperature, the movement rate of molecules in the film increases, and the evaporation rate also increases. As a result, the speed of liquid film thinning increases, which eventually leads to the burst of foam. At the same time, the increase of temperature will also cause the change of surface film properties and reduce its surface viscosity.

The effect of 0.5 % X-PP-2301 on the foaming ability and foam stability of water sample Yan 2108-3 at different temperatures was determined by the experiment, as shown in Fig. 3.

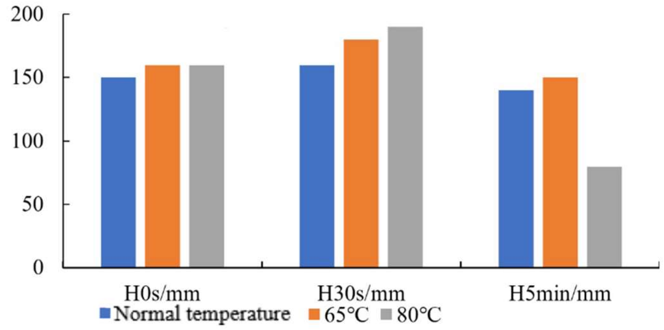

Fig.3 Effect of temperature on foaming ability and foam stability

According to the data in Fig.3, the increase in temperature leads to a gradual increase in the initial foam height, while the foam height shows a downward trend at 5 minutes. This phenomenon can be attributed to the increase of foam expansion volume caused by the increase of temperature. However, with the passage of time, the water in the liquid film gradually evaporates, making the liquid film become weaker and more fragile, eventually leading to its rupture, resulting in a decrease in the stability of the foam. Because the on-site construction temperature is about 65 °C, the follow-up experiment unified experimental temperature is 65 °C.

(2) Effect of concentration on foaming and foam stability of foaming agent

By changing the concentration of X-PP-2301 foaming agent, the effects of 0.5 % and 1 % X-PP-2301 on the foaming ability and foam stability of water samples FX1, FX4 and Yan 2108-3 were measured at 65 °C, as shown in Fig. 4 and Fig. 5.

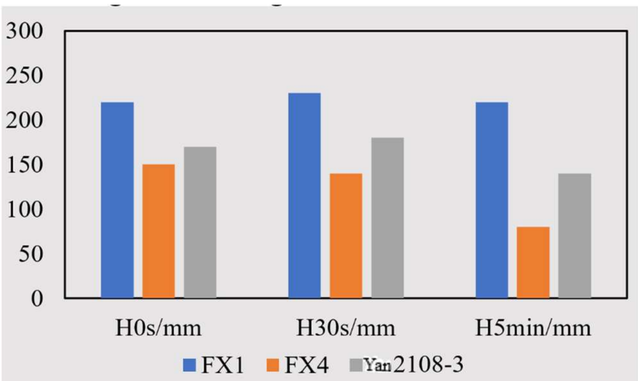

Fig.4 Effects of 0.5 % X-PP-2301 on foaming ability and foam stability of water samples

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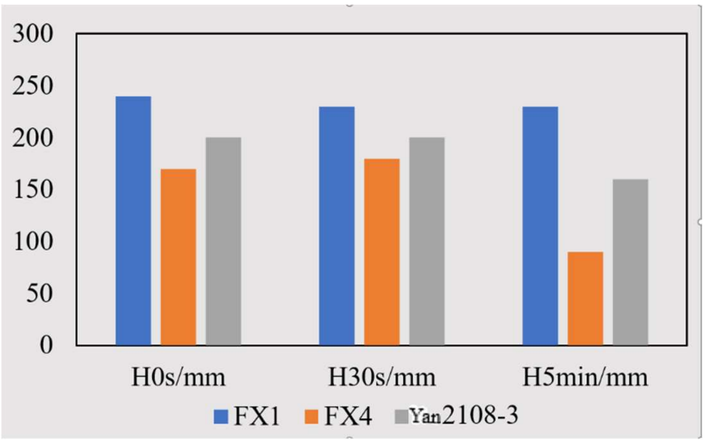

Fig.5 Effects of 1 % X-PP-2301 on foaming ability and foam stability of water samples

It can be seen from the figure that increasing the initial bubble height of the foaming agent concentration increases to meet the technical requirements, and the 5min bubble height will also increase to meet the technical requirements (initial bubble height ≥ 120mm, 5min bubble height ≥ 70mm). It can be concluded that with the increase of concentration, the foaming ability and foam stability of foaming agent will increase.

(3) Effect of salinity on foaming and foam stability of foaming agent

In the experiment, water samples with different salinity were used to test the foaming ability and foam stability of 0.5 % X-PP-2301 under different salinity. The results are shown in Fig.6 and Fig.7.

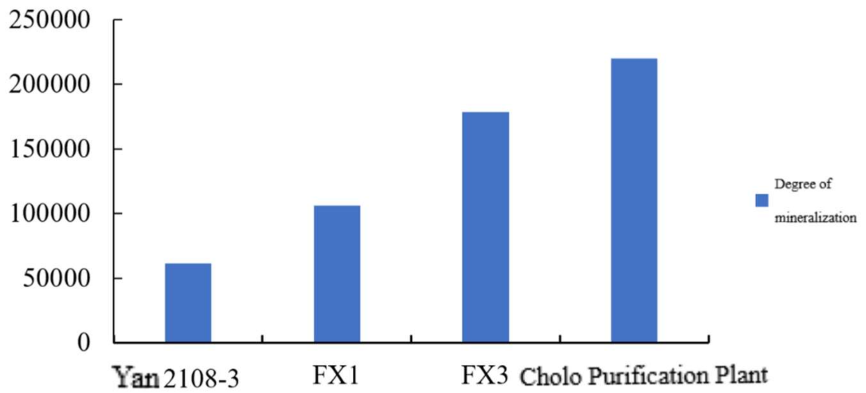

Fig.6 Water samples with different salinity

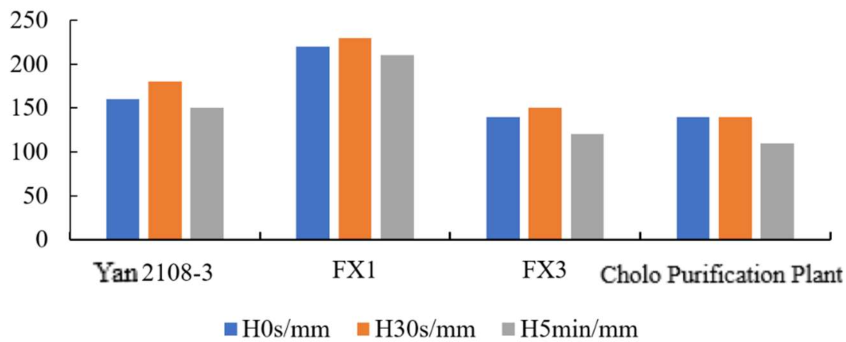

Fig. 7 Foaming ability and foam stability of 0.5 % X-PP-2301 under different salinity water samples

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It can be observed from the figure that as the salinity decreases, the initial height of the foam and the ability to stabilize the foam within 5 minutes are improved. X-PP-2301 exhibits the characteristics of zwitterionic surfactant, and its effect is small when the salinity is low. However, as the salinity increases, the electric double layer of the foam liquid film will be compressed, resulting in a thinning of the liquid film, thereby reducing the stability. This shows that X-PP-2301 foam drainage agent has excellent salt resistance.

(4) Effect of condensate oil on foaming and foam stability of foaming agent

The foaming ability and foam stability of 0.5 % X-PP-2301 on water sample Yan 2108-3 under different condensate oil content at room temperature were determined by experiment. The results are shown in Fig. 8.

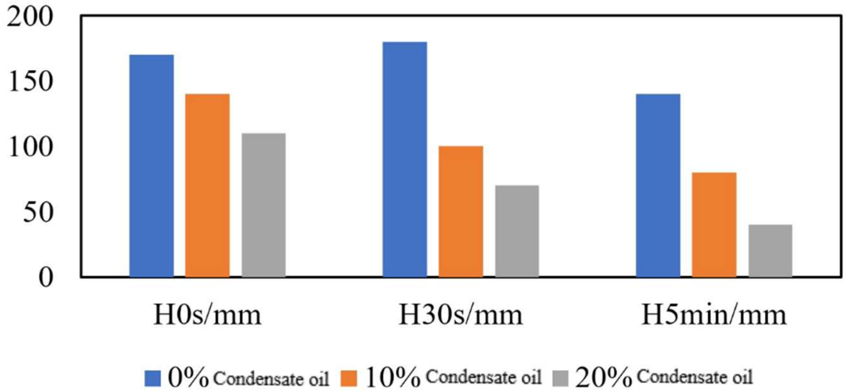

Fig.8 Effect of condensate oil on foaming ability and foam stability

As a natural defoaming agent, condensate oil can significantly destroy the stability of foam. It can be observed from Fig.2-8 that the height of the foam is high and quite stable when no condensate oil is added. With the gradual increase of condensate oil content, its defoaming ability also increases, and the foam height and stability show a downward trend. The reason why condensate oil can destroy foam stability is that condensate oil will diffuse in the foam liquid film and squeeze out the liquid in the original liquid film, thus forming a layer of oil film. The oil film is unstable and prone to rupture. It is worth noting that X-PP-2301 exhibits certain anti-condensate oil properties.

2.2 Evaluation of Application Performance of Preferred Foaming Agent

2.2.1 Thermal Stability Evaluation

250 ml of foaming agent prepared by 0.5 % X-PP-2301 and water sample Yan 2108-3 was placed in a constant temperature water bath at 90 °C and an oven at 110 °C, respectively. After heating the sample for 4 hours, the foaming ability and foam stability of the foaming agent before and after heating were measured. The specific results are shown in Table 2.

Table 2. Foaming ability and foam stability of foaming agent before and after heating

Temperature environment	Reagent concentration	Initiation	30s	5min
Preheating	0.5	170	180	140
After heating at 110°C for 4h	0.5	180	200	60
After heating at 90°C for 4h	0.5	190	210	70

It can be seen from Table 2 that after constant temperature heating for 4h, the initial bubble height is higher than that before heating, but the bubble height at 5min is lower than that before heating. It can

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be seen that the foaming ability of the foaming agent is enhanced and the foam stability is reduced after constant temperature heating.

2.2.2 On-site Water Compatibility Experiment

The high salinity water sample FX3, the low salinity water sample Yan 2108-3 (Ma Wu 41 + Ma Wu 22 + Shan 2 + Shan 1 + He 8) and the foaming agent X-PP-2301 were used to prepare the foaming agent solution, and the temperature was kept at 90 °C for 4 hours. Take out and observe its state. The experimental results are shown in Figure 9 and Figure 10.

Fig.9 (a) High salinity water samples without reagent photos

Fig.9 (b) Photos of high salinity water samples with reagents

Fig.10 (a) High salinity water samples without reagent photos

Fig.10 (b) Photograph of adding chemicals to high salinity water samples

The results of compatibility experiments showed that X-PP-2301 foaming agent could be completely dissolved in formation water samples, and the viscosity of the mixed solution remained unchanged without precipitation or stratification. After being kept in a static state for 4 hours, the mixed solution still showed good fluidity and no new precipitation was produced. It can be seen that the foaming agent has good compatibility with formation water.

2.3 Result and Discussion

As the temperature gradually increases, the initial foam height of the foaming agent solution gradually increases, but after 5 minutes, the foam height gradually decreases. In addition, with the increase of the concentration of foaming agent, its foaming ability and foam stability are enhanced. However, with the increase of salinity, the foaming ability and foam stability of foaming agent show a decline. It is worth noting that increasing the concentration of foaming agent solution can significantly enhance the foaming ability and foam stability of high salinity water samples. When the foaming agent solution does not contain condensate oil, the height of the foam is high and extremely stable ; however, with the increase of condensate oil content, the defoaming ability gradually increased, while the foaming ability and foam stability showed a downward trend. The foaming agent exhibits good thermal stability, can meet the technical requirements, and is completely dissolved in the formation water sample. After 4 hours of static constant temperature at 110 ° C and 90 ° C, the mixed solution showed good compatibility with formation water. The foaming ability and foam stability of X-PP-2301 for high salinity water samples were better than those of other foaming agents, and all of them could meet the technical indexes.

Based on the above indicators, the indicators of X-PP-2301 foam discharge agent meet the technical indicators, so X-PP-2301 foam discharge agent was selected as the main foam discharge agent to carry out foam discharge operation in 694 well area.

3. Conclusion and Foresight

(1) In this paper, the mechanism of foam drainage is briefly described. The key is to improve the drainage effect by reducing the density of gas-water mixture. Based on the composition, performance and type of foam drainage agent, several commonly used performance evaluation methods are introduced.

(2) Through indoor screening experiments, it is determined that X-PP-2301 foam drainage agent has good foaming, foam stabilization and liquid carrying capacity in Yan 694 well area. The X-PP-2301 foam drainage agent and the water sample of Yan 694 well area were prepared into a solution for performance evaluation. It has good effect on thermal stability and compatibility with field water.

(3) The system provides a great guiding significance for the drainage of Yan 694 well area and similar environment. In the future research, it is expected that some scholars will continue to study the mechanism of foam drainage, consider the behavior and influencing factors under different geological conditions more comprehensively, narrow the gap between indoor screening experiment and field application, and improve the efficiency and reliability of foam drainage process.

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