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# New Progress in Application of Temporary Plugging and Diversion Technology

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***Abstract:*** *Temporary plugging and diversion technology is simple in operation, low in overall cost, good in adaptability under different target conditions and low in construction risk. It has been widely used in Hydraulic fracturing in China. In the process of Hydraulic fracturing, timely and appropriate temporary plugging agent can effectively plug the fully transformed area, retransform the incomplete transformed area, increase the fracture contact area, improve the fracture complexity, finally realize the full coverage of the transformed section, improve the operation efficiency, and ultimately create economic benefits. The application examples of temporary plugging diversion technology in the three well conditions of refracturing well, casing variable well and infill perforation well are analyzed and summarized. The characteristics of fracturing curve and microseismic monitoring show that the microseismic events increase in most of the well reconstruction section after temporary plugging, and the improvement effect is obvious.*

***Keywords:*** *Hydraulic fracturing, Encryption perforation, plugging, transition direction*

## 1. Introduction

In recent years, major breakthroughs were made in China shale gas exploration and development, [1], compared with the reservoir conditions of foreign high-yield shale gas blocks, domestic shale reservoirs generally have the characteristics of large horizontal stress difference. During fracturing, low-stress zones will be preferentially fractured, Due to the poor controllability of horizontal bedding fracture extension; the complexity and extension area of fracture are far from the design requirements. [2]. Shale gas reservoirs without fracturing are not economically viable, In order to form multidirectional complex fractures and ensure the effect of reconstruction, it is necessary to refine the shale reservoir, Reasonable measures can be taken to promote the fracturing fluid to enter more perforating clusters evenly, change formation stress conditions and complicate the in-situ stress near the original fracture, so as to improve the opening degree of each perforating cluster and the overall fracture coverage in the horizontal well section.

According to the classification of the location and target, temporary plugging technology can be divided into temporary plugging technology at crack mouth and temporary plugging technology in crack. The stimulation mechanism of these two kinds of technology is described, The application examples of three well conditions of refracturing well, casing variable well and infill perforation well are analyzed and summarized.It provides reference for reducing cost and increasing efficiency of shale oil and gas and tackling key engineering problems.

## 2. Stimulation Mechanism

The technology is simple, the comprehensive cost is low, the adaptability of reservoir transformation and steering under different formation conditions is good, the construction risk is low, and it has been widely used in fracturing construction in China. However, it is necessary to optimize the operation program of temporary plugging diversion according to the characteristics of different formation conditions and process modes, so as to realize the control of diverting in clusters and finally realize the improvement of fracturing effect.

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### *2.1 Temporary Plugging Technology at Crack Mouth*

There are differences in reservoir physical properties and fracture development degree in different fracturing stages of horizontal Wells. In conventional fracturing process, sections with good reservoir physical properties and low fracture pressure will be forced open first. When there is a large interlayer stress difference or large span thin interbedded reservoirs in fracturing, Put in high performance temporary plugging agent for one or more times at the right time, forming high-strength filter cake at the perforation hole and fracture, realizing the temporary plugging and turning of the fracture near the well zone, opening up the perforation cluster that has not been fully transformed, and naturally optimizing the distribution of fluid inflow in each fracturing stage. The efficiency of perforating cluster reconstruction can be improved in two aspects: reducing unused area by opening new fractures in the insufficient position of horizontal production interval and promoting the uniformity of perforating cluster opening degree. The implementation of this technology does not depend on any downhole tools, only needs to optimize the timing, number and quantity of temporary plugging agent in the construction process to realize the control of the number, spacing and scale of cracks in each section, without increasing the construction time.

### *2.2 Temporary Plugging Technology in Crack*

The new fracture opening point, fracture initiation orientation, fracture length and extension track are all related to the stress state within the range of each section of the horizontal well. The stress state of the reservoir is the superposition of in-situ stress field and induced stress field. In the fracturing process, temporary plugging and diversion measures are adopted to plug the main fracture that is extending and control the length of the main fracture. The continuous increase of net pressure in the main fracture will lead to fracture at the weak fracture stress position, which will generate new fractures at this point and promote the formation of secondary fractures, thereby improving fracture morphology and promoting fracture complexity on the whole. At the same time, the continuous increase of net pressure will increase, and when the induced stress difference is large enough, the original in-situ stress state of the reconstructed position will change, and the stress field may be reversed, eventually opening new micro-cracks or forming new branch fractures. Microseismic monitoring shows that temporary plugging in crack can greatly increase the swept volume of fracturing.

## 3. Technology Analysis

The technology is simple, the comprehensive cost is low, the adaptability of reservoir transformation and steering under different formation conditions is good, the construction risk is low, and it has been widely used in fracturing construction in China. However, it is necessary to optimize the operation program of temporary plugging diversion according to the characteristics of different formation conditions and process modes, so as to realize the control of diverting in clusters and finally realize the improvement of fracturing effect.

### *3.1 Refracturing Well*

Statistics show that about one-third of all Wells in the U.S. are re-fractured, The effect of primary fracturing in domestic main oil field now is not obvious [4]. Conventional refracturing is often ineffective because old fractures are repeatedly opened and extended without opening or forming new fractures, and this refracturing does not increase the frac sweep volume [5].

The temporary plugging and diversion technology can plug the old fractures and open the new fractures in the re-fractured Wells. According to the theory of fracture mechanics, segments and clusters with low fracture pressure will have priority to fracture initiation. The design needs to calculate the location of fracture initiation and determine the sequence of fracture initiation segment and cluster according to the physical property and stress state of the target layer, In actual construction process combined with micro seismic events response, timely delivery of temporary plugging material into the objective layer within the high permeable zone or cracks is extended, produce filter cake bridging, plugging high permeable zone within this section or has full transformation area, the high stress area or region reform, and create new cracks and improve the spread of proppant distribution, implementation layer and interlayer fracture shift for many times, Finally, a complex fracture network is formed to greatly increase the swept volume of fracturing and improve the hydraulic fracturing effect.

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### *3.2 Casing Variable Well*

Casing deformation often occurs in horizontal shale gas Wells during fracturing [6]. In the process of fracturing, casing deformation often occurs in horizontal shale gas Wells [6]. In this case, downhole operation accidents such as obstruction and blockage are likely to occur during the operation of bridge plug, which will affect the project progress and increase the operation cost. Due to the influence of casing deformation, the bridge plug can not be fixed in the design position. As a result, the untransformed well section below the casing deformation section cannot be transformed, and the reserves of the untransformed well section cannot be utilized, As a result, the final effect of volumetric fracturing of shale gas horizontal Wells becomes worse.

It is suitable for casing with serious deformation and large influence length [7]. The unmodified well section below the casing deformation section can be reformed to effectively improve the utilization of resources. Before fracturing, the unmodified well section below the casing deformation section can be perforated without bridge plug. During fracturing, according to the real-time monitoring response of microseismic, temporary plugging materials are put in several times according to the selection of the machine to seal the fractured horizon and open new fractures in the unmodified well section below the casing deformation section. However, when there are too many stages, more holes need to be plugged, resulting in poor reliability.

### *3.3 Infill Perforation Well*

In shale gas development, the new concept of controlling reservoir volume by fractures has been widely accepted. At present, the core of the "close cutting" shale gas fracturing concept widely recognized at home and abroad is to increase the number of perforations in horizontal Wells. The cluster spacing of shale gas horizontal well reconstruction has been reduced from 20 ~ 30 m to about 10m [8], but the shortening of cluster spacing intensifies cluster effect and directly increases the difficulty of all clusters to open. In the horizontal well with general fracturing, the edge cluster fracture extension is good, while the middle cluster fracture extension is limited. Statistics from production profile tests show that approximately 21% of all perforating clusters are still "inactive" after extensive fracturing, meaning that they do not contribute to the production of a well, indicating that there is significant potential to improve the conductivity of horizontal Wells.

Through multiple temporary plugging diversion, more adequate secondary fracturing is performed on the incomplete perforation affected by stress shadow, which makes the horizontal section of infill perforation more uniform, more likely to produce interconnected fracture network, higher complexity of fracture, and stronger overall reconstruction degree. 181/5000

Reconstruction steps: the fracturing fluid will first open the formation to make the main fracture open, and the engineer will pump fine particles into the temporary plugging agent to form temporary plugging bridge at the end of the main fracture to stop the extension of the end of the main fracture. Under the action of higher net pressure in the fracture, multiple secondary fractures are opened on the weak stress surface of the main fracture. At this time, coarse particle temporary plugging agent is pumped to form temporary plugging bridge at the entrance of the main fracture, and the fully opened perforation hole is blocked, so that the fracturing fluid is diverted to the incomplete perforation cluster, and the new main fracture and secondary fracture are opened. After fracturing, the temporary plugging agent degrades naturally within a short time and is discharged with the flowback fluid.

## 4. Examples of Application

Due to casing deformation, pumping 100mm bridge plug could not be in place in well W1. Therefore, combined fracturing of section 4 and 5 of the well was selected. According to logging data, the horizontal stress difference of fractured layer was calculated to be between 3.5-6.2mpa, with an average of 4.5mpa. The stress field simulation results show that the additional net pressure above 5MPa can realize the in-seam steering. Combined with laboratory experiment and fracture simulation, 40/60 mesh and 80/100 mesh particle compound temporary plugging agent was designed. When 180 kg of compound particle size temporary plugging agent is put into the early stage of the second stage fracturing, the reaction pressure of the field construction curve increases rapidly (46-54 MPa) by 8 MPa. In the case of similar construction displacement, the construction pressure of stage 2 is larger than that of stage 1, indicating that it is the extension of different cracks and the formation of new artificial cracks. Based on the microseismic monitoring, the microseismic events increase in most fracturing

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stages after temporary plugging, and the event points gradually cover the reconstructed well section, and the uniform reconstruction effect is obvious. It can be seen that the input of compound particle size temporary plugging agent can reduce the construction cost and play an effective role in sealing the fractured horizons, opening new fractures and improving the degree of longitudinal and transverse transformation.

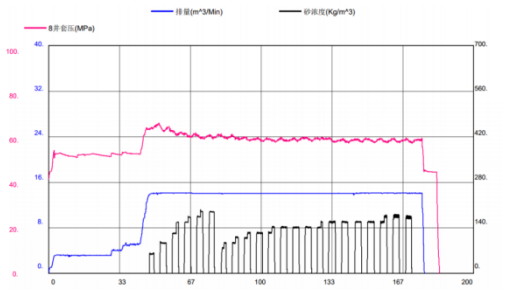

*Fig. 1: Pressure curve of stage 1 well W1*

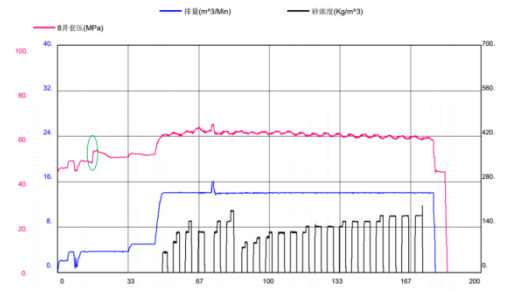

*Fig. 2: Pressure curve of stage 2 well W1*

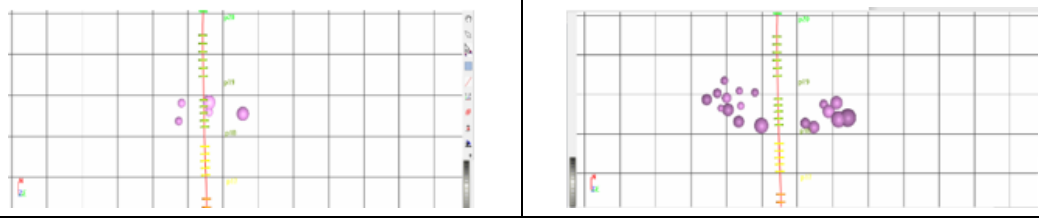

*Fig. 3: Monitoring map of microseismic in well W1*

In the 13th section of well Y1, 6 clusters were perforated, with a total of 96 holes spaced at 8m. Compound particle size temporary plugging agent was put in twice: 200 kg of fine particle temporary plugging agent was put in the first time, followed by 100 mesh of high-quality quartz sand, and 175 kg of coarse particle temporary plugging agent was put in the second time. The field construction curve shows that the pressure response of the two temporary plugging agents is obvious: the construction pressure rises as a whole and rises rapidly, the bridge plug is temporarily blocked at the end of the main crack in the far well zone, resulting in the end of the main crack stop extending, and multiple secondary cracks are formed on both sides of the main crack. Fracture plug temporarily enables fracturing fluid to be diverted to other perforation clusters to form new main fractures and branch fractures.

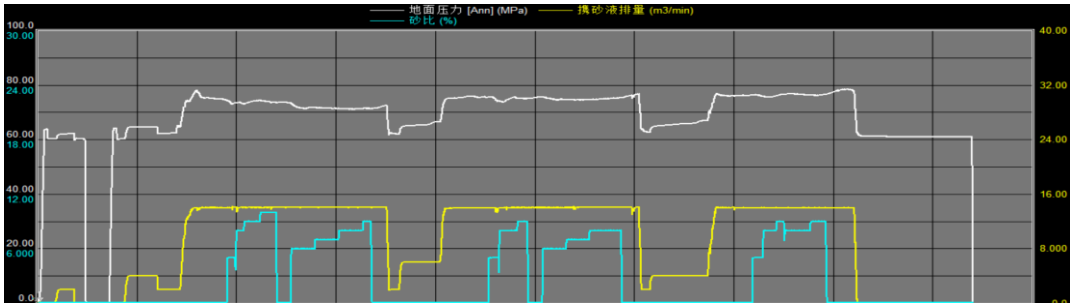


*Fig. 4: Construction pressure curve of well Y1*

Well W3 was re-fractured, and the temporary plugging diversion was designed for three times. After plugging, the fracturing pressure increased and new fractures were obviously generated. Before and after the second plugging, the construction pressure ladder is obvious at the same displacement, which is caused by the temporary plugging agent migration and temporary plugging in the cracks and the pressure opening of new cracks. With more temporary plugging agent into the deeper crack, the temporary plugging area is more and more dense, and the construction pressure is higher and higher. When the construction pressure reaches a certain value, the new crack is opened, the pressure drops, and the crack extends along the new direction. Based on the microseismic monitoring, the density of microseismic events shows that the target segment has been fully reconstructed after the temporary plugging diversion, and the microseismic events on both wings are evenly distributed, indicating that the temporary plugging diversion agent can optimize the fracture morphology, and the design of the temporary plugging time is accurate.

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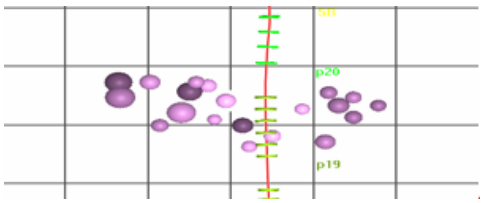


*Fig.5: Microseismic monitoring map of well W3*

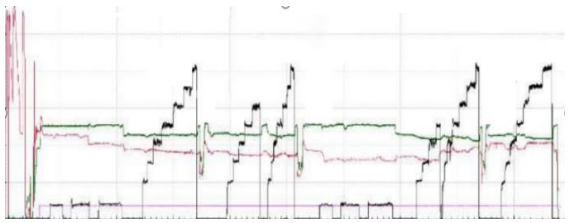

*Fig. 6: Construction pressure curve of well W3*

## 5. Conclusion

1. Optimization of temporary plugging fracturing technology according to different reservoir conditions and specific construction conditions can effectively improve the transformation effect, achieve fracture uniformity and complexity, and achieve economic benefits.

2. In order to avoid the adverse situations such as sand sensitivity and temporary plugging failure before temporary plugging, the type and size of temporary plugging material should be optimized, the amount of temporary plugging agent should be rationally designed and the plugging agent can be pumped to a predetermined position to ensure the plugging effect. The timing of temporary plugging agent can be more accurately determined by on-site micro-seismic wave monitoring technology.

3. After temporary plugging, the construction pressure increases obviously, which is the necessary condition to realize fracture diversion and form complex fracture morphology.

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