

# Application of Stratified Indicator Curve in Optimization of Injection Well Adjustment Scheme

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**Abstract.** Sashing oilfield has entered the high water cut development stage, and the oil recovery has been obviously improved under the guidance of constantly improving subdivision water injection technology. However, some layers cannot be used effectively under conventional water injection conditions due to factors such as the development condition of oil layers. The stratified indicator curve can clarify the starting pressure of each water injection layer and the variation law of water absorption capacity of different layer under the same pressure conditions, which can effectively guide the injection test adjustment or pressurized water injection of multi layers, and shallow profile control or plugging with fine selection of strong water absorption layer. The stratified indicator curve has a good site application effect, and is of great guiding significance for optimizing the adjustment scheme of injection wells and improving the development degree of oil layers.

## 1. Introduction

There are 2667 water injection wells in Sashing development zone, of which 2362 are stratified wells, and the stratified injection rate is 88.6%. The average number of segments for stratified wells is 3.4, the average number of layers is 7.2, and the thickness of sandstone is 9.1m [1]. It can be known from the water absorption profile of 337 wells that the number of absorption layers is only 41.2% of the perforated layers, and the thickness of sandstone with absorption accounts for 48% of the total perforated thickness.

## 2. Some problems in the process of injection well adjustment

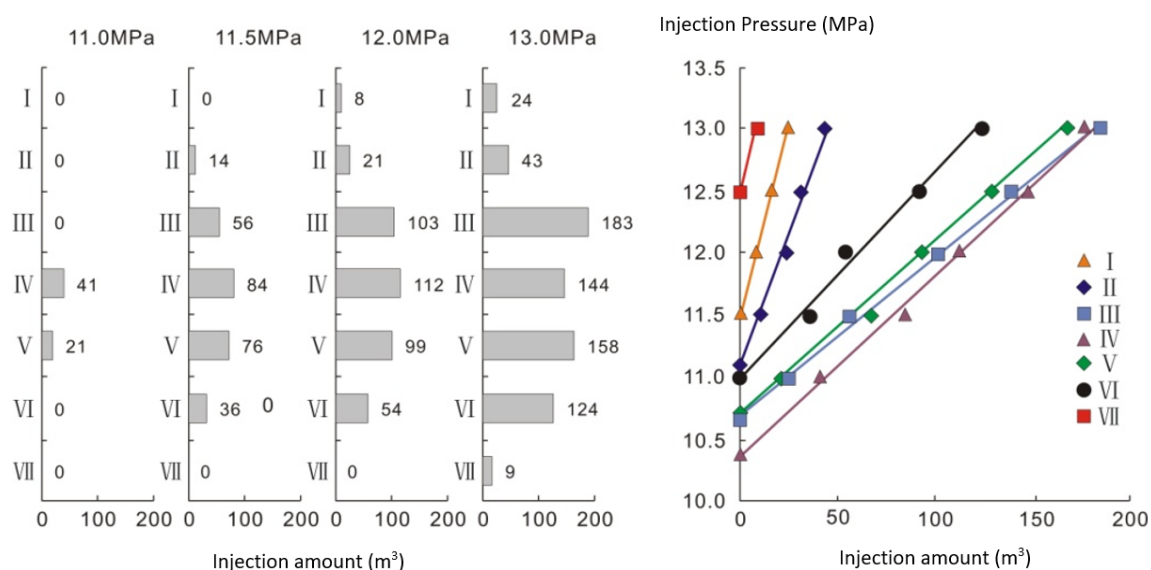
Firstly, with the increase of the number of subdivision layers, especially six or seven layers, it's difficult to ensure the injection quality of all layers. Secondly, for some perforated multi-player producing zones with Sa, Up and Ago oil layers, the starting pressure of each layer has a big difference due to the long length of perforated layer, which resulting in the poor development of reservoir[2]. Thirdly, the previous determination of the main absorption layers is based on the static data and the isotopic absorption layer, but it is hard to determine the "actual" high permeability layer when the absorption information of multiple layer is similar.

Therefore, the accurate analysis data is needed, not only to clarify the starting pressure of each injection layer, but also to reflect the variation law of absorption capacity of different layers under the same pressure or the same layer under different injection pressure.



### 3. Introduction of stratified indicator curve

The test of stratified indicator curve is to put the nozzle or net with the same aperture into each layer and measure the stratified indicator curve. The difference of starting pressure and absorption capacity can be known by the curve characteristic, thus to find the "actual" high permeability layer, and determine the properties of each layer. According to Figure 1, it can be found that under the same injection pressure, the absorption capacity of layer III and layer V is the strongest, and it should be restricted. The absorption capacity of layer VII is the worst, and the starting pressure is the highest, therefore, it is difficult to complete the injection allocation [3].



**Figure 1.** Schematic diagram of stratified indicator curve

### 4. Application of stratified indicator curve in injection well scheme adjustment

#### 4.1. Judge the absorption capacity of each layer and guide the optimization of distribution scheme

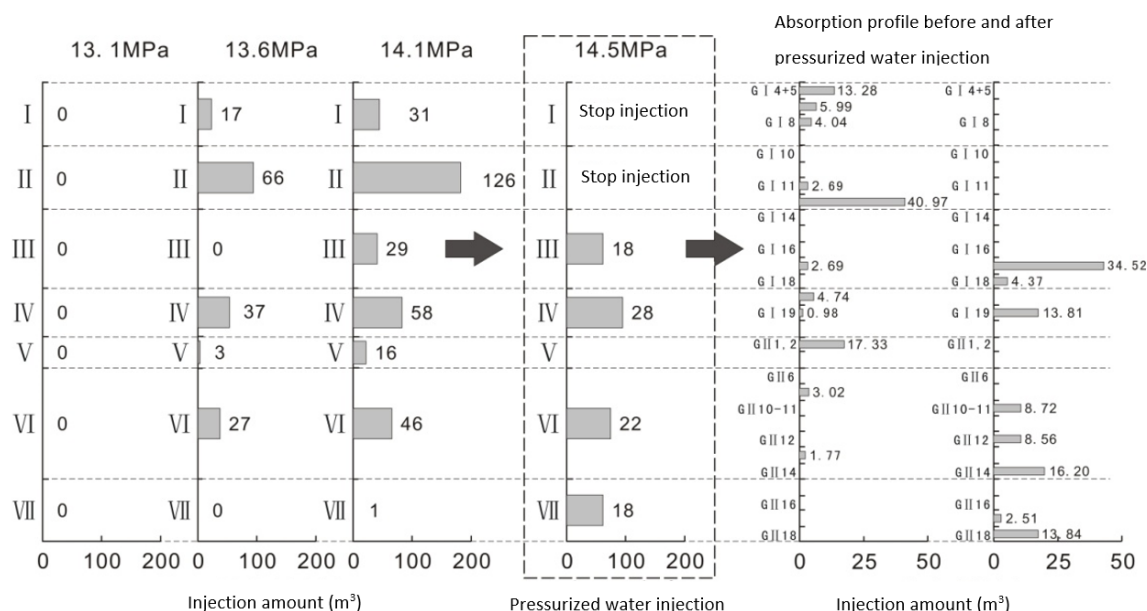
Based on the analysis of the indicator curve and under the condition of overburden pressure, if every layer can be injected, it is indicated that the pressure can be increased by increasing injection pressure and exchanging nozzle. The pressure should be re-determined and the stratified nozzle be adjusted according to the field test indicator curve, to complete the original injection scheme. The adjustment of the stratified nozzles shall use the data of indicator curve and nozzle loss curve, increase the pressure difference of the high absorption layer, and increase the injection pressure of the whole well under the condition of not overlying the rock pressure, and enlarged the nozzle of poor oil layer [4].

#### 4.2. Judge the starting pressure of each layer and guide the pressurized water injection

Through the analysis of the indicator curve, if the layer cannot be developed or a poor layer is developed, it indicates that the pressure cannot be increased any more. This requires the use of pressurized injection method, which is to plug the high permeability layer, only strengthen the injection for the low permeability layer, especially the "low permeability layer" at the bottom. In this way, a new perforation top can be formed, the low permeability layer is developed [5].

As shown in Figure 2, it can be known that layer VII cannot be developed under the injection pressure 14.1MPa, which is close to the overburden pressure 14.3MPa, thus that layer VII cannot be developed by increasing the injection pressure. However, the layer II has a strong absorption capacity, and it should be restricted. And then stop injecting water into layer II and I to increase the overburden pressure from 14.3MPa to 14.7MPa. After the adjustment, the whole well was injected with water at

14.5 MP, and the layer VII could be injected with 18m<sup>3</sup> water. According to the isotope absorption profile before and after the pressure increase, the strong absorption layer was effectively suppressed, and multiple absorption layers were newly added. The whole well absorption layer ratio increased from 37.9% to 58.6%, and the sandstone absorption thickness ratio increased from 41.5% to 61.4%, which greatly improved the absorption and increased the extent of oil layer development.

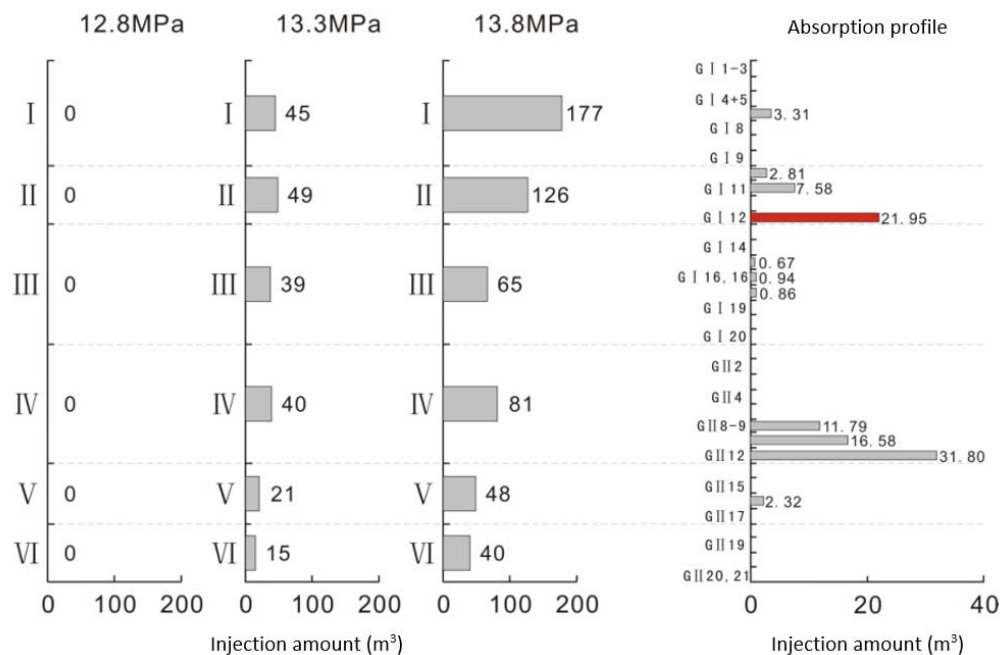


**Figure 2.** Schematic of pressurized water injection

#### 4.3. Judge the "actual" strong absorption layer and guide the selection of profile control layer

For high absorption layers with large interlayer difference, relying only on controlling the amount of water injected cannot alleviate the contradiction between the layers, so the shallow profile control technology should be applied to control the high permeability layer. In the past, the profile selection mainly referred to the absorption profile data, and there was no on-site measured stratified indicator profile data. The empirical analysis was the main method. Through the stratified indicator curve, a more comprehensive and true understanding of the water-absorbing capacity of each layer can be gained and the high water absorption layer can be determined. This well selection principle has a more scientific basis.

As shown in Figure 3, the stratified indicator curve shows that the layer GI1-3-GI9 and GI10-I12 have a strong absorption capacity, and the absorption accounts for 56.4% of the whole well. It is preliminarily determined that the two layers can be used as the profile control layer. Judging from the isotope data, the layer GI10-I12 has a large interlayer difference. The layer GI12 is a dash layer, and the relative absorption is as high as 22%. Therefore, the layer GI10-I12 and layer GI12 is determined to be the profile layer based on the stratified indicator curve and isotope profile data. But if according to the original judgment method, the profile control target layer should be determined as GII1-II12 and GII12.



**Figure 3.** Schematic diagram of target layer selection by stratified indicator curve

## 5. Field application

The structure of Sashing development zone is complex, multiple patterns co-exist, oil layer development is not balanced, thin and poor reservoirs has not been developed for a long time, and the interlayer contradiction is very prominent. The increase of annual water-cut reaches 1.42%, and the natural decline is as high as 9.84%. In order to improve the injection conditions and the development effect, 22 injection wells were selected to test the stratified indicator curve. According to the injection contradiction reflected in the curve, the adjustment of the corresponding water injection scheme was carried out and a significant effect was achieved.

### 5.1. Further optimization of injection scheme

The stratified injection method has been implemented according to the actual indicator curve and the starting pressure, and the amount of water absorption increased significantly, and the daily water injection rate of 36 low absorption layers increased from 620 m<sup>3</sup> to 1845m<sup>3</sup>. The strong absorption layers are limited strictly through the scheme reorganization, and the daily water injection rate of 41 high absorption layers is reduced from 3024 m<sup>3</sup> to 360 m<sup>3</sup>.

### 5.2. Water absorption profile has been significantly improved

By analyzing the absorption capacity of each layer reflected by the indicator curve, the profile development has been improved significantly after plugging. The absorption ratio of sandstone has reached 75.5%, which has increased by 8.6%. The layer structure of injection wells is improved, the absorption ratio of thin layers ( $\leq 1\text{m}$ ) increases, and the absorption thickness ratio of sandstone increases from 34.9% to 51.9%; the absorption ratio of thick layers ( $\geq 2.5\text{m}$ ) is controlled, and the absorption thickness ratio of sandstone declines from 100% to 58%.

### 5.3. Block development has been significantly improved

The daily production of 45 connected oil wells with no stimulation increased from 157.2 tons to 201.7 tons, and the increase of daily production was 44.5 tons. Besides, the water cut decreased from 86.5% to 85.2%, with a drop of 1.3%, and the development effect was significantly improved.

## 6. Conclusion

1. Through the actual stratified indicator curves, the starting pressure of each layer can be obtained, and the absorption capacity difference of each layer can be analyzed, which can find out the "actual" high permeability layer.

2. According to the information reflected by the indicator curve, the adjustment scheme of injection well, and the selection of layer to be plugged and profile controlled can both be optimized. The stratified indicator curve is of great guiding significance for improving the quality of water injection and development degree of the reservoir.

## Acknowledgments

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