Study on SEC Reserve Evaluation Method for Low Permeability Reservoirs

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Abstract: SEC reserves assessment is an important indicator to measure the development potential of oil companies. Based on the evaluation of SEC reserves, this paper summarizes the dynamic evaluation methods of SEC reserves, including analogy method, volume method, decline method, material balance method and reservoir simulation. Among them, the decline method is the most commonly used method, which has the characteristics of easy prediction of production and economic life cycle. Therefore, this paper discusses how to choose the decline method, the initial output and the determination method of the decline rate.

1. Introduction
SEC reserves assessment rules are the reserves assessment criteria that must be followed by oil companies listed in the United States. SEC reserves dynamic evaluation is the main work in reserves evaluation. The dynamic assessment is mainly as follows. By using the dynamic data of oilfield, such as production, decline rate, time, pressure, water cut, price, etc., the future of oilfield is evaluated through certain calculation methods, including reserves, recoverable reserves, economic recoverable reserves, economic life span, etc. It stipulates the calculation criteria and evaluation rules of oil and gas reserves. According to this criterion, the major oil companies can calculate their own reserves increase or decrease. Oil companies will disclose their reserves in the United States, which will directly affect their next development potential. The SEC reserves criterion divides the remaining economically recoverable reserves into three categories: proven reserves, estimated reserves and possible reserves. According to SEC criterion, reserves assessment can be divided into two categories: static parameters (including oil area, effective thickness and recovery) and dynamic parameters (including initial production, decline rate and drilling plan). This paper mainly analyses the dynamic parameters.

2. Characteristics and evaluation principles of low permeability lithologic reservoirs

2.1 General characteristics of low permeability lithologic reservoirs
Lithologic reservoirs are formed by abrupt changes in physical or lithological properties of reservoir rocks under the action of sedimentation or diagenesis, which are shielded or surrounded by non-permeable rocks. According to incomplete statistics, lithologic and stratigraphic reservoirs account for about 40% of China's onshore oil and gas exploration, which is the most potential field in China. Low permeability reservoirs at home and abroad generally have the following characteristics. Firstly, low porosity, low permeability and low natural productivity. Conventional production can not even produce oil, it must be properly reformed to achieve commercial productivity. Secondly, crude oil has the characteristics of low viscosity, low density and good properties. Thirdly, the reservoir has
poor physical properties, poor sorting, fine grain size and high cementing content. Fourthly, the interaction between sandstone and mudstone is obvious, the thickness of sandstone is unstable and the interlayer heterogeneity is strong. Fifth, the flow of fluid has the characteristics of non-Darcy seepage.

2.2 Principles of reserve evaluation by dynamic method
The dynamic production time is more than one year, which proves that the reserves can be exploited. The dynamic method is mainly used to evaluate the reserves. The main evaluation methods of dynamic method are decline method, such as time method and monthly production, cumulative production method and monthly production, cumulative production method and water content, cumulative production method and oil content, cumulative production method and water-oil ratio, average single well curve method, etc. Reserve evaluation by dynamic method is carried out according to oil (gas) field level and reserve evaluation. If there is a big gap between the evaluation results of two-stage units, the oil fields should be compared and analyzed to explain the reasons. If the production decline law of an oil field changes abnormally in an oil field or a development unit, we can evaluate reserves according to the following conditions. Firstly, if the increase of overall reserves is caused by infilling well pattern and comprehensive adjustment, the correction of decline rate can refer to the decline rate of the stable period of the oilfield. Secondly, if the infilled well pattern is limited to a part of the development unit, we can separate the dynamic data of the infilled well pattern block from the data of the development unit. For the infill well pattern part, the reserves are evaluated by referring to the decline rate of infill adjustment scheme or representative well group decline rate. For the original well pattern area, the dynamic method is also used to re-evaluate reserves. Thirdly, if the law of oil field decline is not obvious, we can use the average single well production decline rate to evaluate.

3. SEC reserve dynamic reserve assessment in low permeability reservoirs

3.1 Initial production
For reservoirs with low initial production and decline rate, the higher the initial production value, the higher the evaluation results. For example, in a block of Hezhuang oilfield, the initial domestic production takes 7.6 tons of oil per day at the initial stage of production test, while the average daily production of single well is 4.7 tons for old wells. Then the remaining economic recoverable reserves decreased to 1325,000 tons from 3013,000 tons calculated domestically. However, for reservoirs with high initial production and high decline rate, it is not that the higher the initial production, the better the evaluation results. For example, the initial output is 6 t/d to 60 t/d, respectively. Suppose that the daily production of a single well decreases to 5 t/d after one year. The higher the initial production, the greater the corresponding decline rate, and the smaller the residual economic recoverable reserves calculated. Detailed data are shown in Figure 1. Therefore, we should reasonably select initial production according to reservoir type, development characteristics and understanding of decline law. The reserves at different initial rates are shown as the Table 1.
3.2 Decline curve theory

For oil and gas fields that have been in decline stage, Arps based on actual production decline data. Arps makes statistics and analysis, and theoretically puts forward three types of decline, including exponential, hyperbolic and harmonic.

First, the Alps exponential decline curve formula.

Formulas for yield change: \( Q_t = Q_i e^{Di t} \)  
Formula 1

Formulas for calculating cumulative production:

\[ N_p = \frac{Q_i - Q_t}{Q_i} \]
Formula 2

Formulas for calculating technically recoverable reserves:

\[ N_R = \frac{Q_i - Q_s}{Q_i} \]
Formula 3

Second, Alps hyperbolic decline curve formula.

Formulas for yield change: \( Q_t = Q_i (1+nD_i t)^{1/n} \)  
Formula 4

Formulas for calculating cumulative production:

\[ N_p = \frac{Q_i}{(1-n) N_i} \]
Formula 5

In style:

\( N_p \) is cumulative oil production, 10\(^4\)t.
\( N_R \) is a technically recoverable reserve, 10\(^4\)t.
\( D_i \) is the instantaneous decline rate at the beginning of decline, 1/a.
D is the decline rate of a year, 1/a.
Qa is the abandoned oil production of the reservoir, 10^4 t/a.
Qi is the annual oil production at the initial stage of decline, 10^4 t/a.
Q is the production of oil in a year of declining period, 10^4 t/a.
n is a decreasing index.

3.3 Decline type judgment
According to the linear relationship between yield and time or between yield and cumulative yield, we can judge the type of decline. Generally speaking, the relationship curve between yield Q and time t is drawn in semi-logarithmic coordinate system. If the relationship is linear or near linear, it can be judged as exponential decline type, as shown in Figures 2 and 3. Otherwise, the relationship curve between Q yield and Np cumulative yield is drawn in semi-logarithmic coordinate system. If the relationship is linear or near linear, it can be judged as the type of harmonic decline. If neither of them is linear or near-linear, it can be judged as hyperbolic decreasing type.

Figure 2: Q-t diagram of different decreasing types
Figure 3: Q-Np diagram of different decreasing types

3.4 Depression rate and reservoir permeability
According to the analysis of decline rate and permeability data of 68 low permeability reservoir development units in Jilin Oilfield, we can get the statistical relationship between decline rate and permeability of low permeability reservoir, as shown in Figure 4. Generally speaking, there is no obvious relationship between decline rate and permeability. The reason is that the decline rate changes with the development status, which is closely related to the development effect of the reservoir. If the development status of each development unit (including the number of wells opened, water injection policies and measures reformation) remains unchanged, there should be a certain correlation between reservoir permeability and decline rate. That is, the decline rate increases with the decrease of reservoir permeability.

Figure 4: Relationship between decline rate and permeability in 68 low permeability reservoirs of Jilin Oil
4. Conclusions
In dynamic evaluation of SEC reserves, we should determine the corresponding evaluation methods according to reservoir types. Different evaluation methods are selected according to different development stages of reservoir blocks. We should grasp it flexibly according to the specific conditions of the reservoir. After dynamic evaluation of reservoir blocks, it is necessary to analyze the evaluation results and compare the results obtained by various evaluation methods. Only when the remaining economically recoverable reserves are consistent with the actual development, the dynamic evaluation results can be credible.

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