Application analysis of isotope water absorption profile in ternary test of second class weak alkali

Hongdi Zhang *
Daqing Oilfield Co., Ltd. No.6 Oil Production Plant Test Brigade, Heilongjiang, Daqing 163000, China

*Corresponding author Email: Zhanghongdi@petrochina.com.cn

Abstract. In the weak alkali ASP flooding test of Pu II 4 - 9 reservoir in the second area of north east block of lamadian oilfield, the original well pattern of strong alkali ASP test area was used for backward development of Pu II 4 ~ 9 reservoir. According to the analysis of isotope water absorption profile results, the production degree of blank water flooding reservoir was obviously higher than that of strong alkali ASP test at the same stage. In this paper, the principle of isotope water absorption profile reflecting the utilization degree is analyzed, and it is considered that poor water quality is the reason for the large difference of utilization degree in test areas, and the feasible methods to reduce this kind of influence are put forward, and the corrected utilization degree in test areas is given.

Keywords: Ternary test of weak alkali in second-class reservoir: Water absorption profile; Degree of use; discrepancy.

1. Introduction
In the weak alkali ASP flooding test of Pu II 4 ~ 9 reservoir in the second area of North East Block of Lamadian Oilfield, the well pattern of the original strong alkali ASP test area was used to develop Pu II 4 ~ 9 reservoir. The test area was put into production in April 2016, with 45 injection wells and 62 oil wells in total, and the production was basically completed in November.

2. The raising of questions
In the first half of 2017, the water absorption profile test was carried out for wells in the test area. The statistical results of the profile show that the effective thickness of oil layer is 92.6% and the sandstone is 89.8%. Compared with the water flooding stage of strong alkali ASP flooding test, the production ratio of effective thickness is 9.1 percentage points higher and that of sandstone is 11.0 percentage points higher. Compared with the production degree of various sand bodies, the weak alkali ASP flooding test is also significantly higher than the strong alkali test (Table 1).
Table 1. Comparison of water drive degree of different sand bodies in strong and weak alkali ternary test area

| Mining horizon          | River sand(%) | Main sheet sand(%) | Non-main sheet sand(%) | Outer surface layer(%) |
|-------------------------|---------------|--------------------|------------------------|------------------------|
| Pu II 4 ~ 9 oil layers  | 93.1          | 89.3               | 87.2                   | 60.9                   |
| Sa III 4-10 oil layer   | 84.2          | 81.6               | 56.1                   | 46.6                   |

By comparison, the oil layer in weak alkali ternary test area has a strong development, poor alkali ternary test area, strong plane heterogeneity of weak alkali, great difference in development thickness and permeability between wells, and the coefficient of variation of plane permeability is greater than 0.7, which is slightly larger than that in strong alkali ternary test oil layer. Vertically, the longitudinal heterogeneity of Pu II 4 ~ 9 intervals is strong, and the coefficient of variation of interlayer permeability is 0.778, which is higher than that of strong alkali ternary test area (table 2); The water absorption index of weak alkali ternary test area is 0.574m³/d.m.MPa, which is lower than that of strong alkali ternary test area by 29.7 percentage points. Through analysis, it is determined that the isotope water absorption profile used in weak alkali ternary test area is not suitable for statistical test area production, which leads to high oil layer production degree.

Table 2. Comparison table of reservoir development in strong and weak alkali ternary test area

| Mining horizon          | Sandstone thickness(m) | Effective thickness(m) | Permeability (μm²) | Variation coefficient of permeability | Number of sedimentary units |
|-------------------------|-------------------------|------------------------|--------------------|--------------------------------------|----------------------------|
| Pu II 4 ~ 9 oil layers  | 10.7                    | 8.2                    | 0.476              | 0.778                                | 4                          |
| Sa III 4-10 oil layer   | 11.7                    | 8.8                    | 0.676              | 0.732                                | 5                          |

3. Analysis of problems

3.1. Principle of statistical utilization degree of isotope water absorption profile
Radioisotope carrier method is a method to study the state of oil production and water injection and the technical state of oil and water wells by using artificial isotope as tracer, which is realized by using natural gamma logging tool and necessary construction and measurement process. Tracing refers to adding isotope tracer into injection fluid of water injection well, which moves along with the movement of fluid substance. By tracking and measuring tracer, the injected fluid is "traced" to judge and calculate the path, destination and flow rate of fluid flow, so as to achieve the purpose of evaluating injection state and oil-water well conditions. Generally, radionuclide releasers are used to carry radionuclide carriers and release them at a predetermined well depth. The carriers and injected water in the wellbore form an activated suspension, which is absorbed when the formation absorbs water. Because the particle size of radionuclide carrier (microsphere) is larger than the pore throat of the formation, the water of activated suspension enters the formation, while the radioactive carrier is filtered on the surface of the borehole wall formation. The water absorption of the stratum is directly proportional to the amount of isotope carrier filtered on the corresponding well wall of this stratum and the radioactive intensity of the carrier. At this time, the measured gamma curve is compared with the natural gamma curve before releasing nuclide, and the amplitude difference between them in the corresponding water absorption layer reflects the water absorption condition of this stratum. This is the basis for interpretation of injection profile logging data by isotope logging tracing method. I131 isotope is widely used in the test area, and the carrier particle size is 600-900 μm. The existing isotope oil layer thickness and oil layer suction should be considered when calculating the oil layer production degree. As shown in fig. 1, the effective thickness of injection well 10-PS2606 is 9.4m, and the production thickness calculated according to the water
absorption profile is 8.2m, so the oil layer production degree of this well is calculated to be 87.2%, and the oil layer suction of Pu II 4-9 is relatively large.

![Figure 1. 10-PS2606 water absorption profile data June 2017](image)

3.2. Reasons for the high degree of utilization
By observing the test data of the comparative test area in 2008 and 2017, it is found that the water absorption profile in 2017 shows that the boundary of the water absorption area is rather vague, and the whole well absorbs water, with a production degree of 100%. It is found that the water absorption of many layers is small, which does not conform to the production characteristics of oil layers. Through analysis, it is considered that this phenomenon is mainly caused by contamination of isotope particles (Figure 2). Due to the poor surface activity of tracer, unclean water quality of injected people, poor wall of pipe string and other factors, isotope particles failed to percolate to the formation surface along with water flow, but adhered to the isotope curve, resulting in the illusion that it has nothing to do with water injection rate, that is, isotope "adsorption contamination".

One is the impact of water quality. Since the test was carried out, the water pipe in the factory network was used for injection, and the water quality was poor without advanced treatment. The suspended solids and oil content both exceeded the assessment indexes of suspended solids and oil content of injected sewage of 20mg/L (Table 3).

Second, the influence of tubing and casing. After the oil pipe and casing are corroded, the micropores developed in the corroded layer can also be adsorbed, and the adsorbed microspheres are not easily washed away by water. The test area is the secondary utilization of well pattern, and the strong alkali ASP flooding is developed and used for the first time, and some oil pipes are old pipes, so both oil pipes and casing pipes may affect isotope test results.

| Sampling time | Suspended matter(mg/L) | Oil content(mg/L) |
|---------------|------------------------|-------------------|
| 2017.4.13     | 37                     | 53.6              |
| 2017.4.25     | 49                     | 90.1              |
| 2017.5.3      | 92                     | 153.7             |
| 2017.6.8      | 32                     | 46.3              |
| 2017.6.14     | 25                     | 50.4              |
| 2017.6.19     | 23                     | 41.5              |
| 2017.8.1      | 36                     | 55.4              |
| 2017.10.18    | 40                     | 81.8              |
4. Countermeasures for high production degree of oil layer

4.1. Reduce the particle size of tracer carrier

According to current research results, isotope microspheres are related to factors such as downhole density and viscosity of injected water. The diameter of isotope microspheres should not be too large, because the larger the particle diameter, the worse the carrying capacity of injected water, the faster the settling speed of particles, and the greater the probability of contamination of water injection string and downhole tools.

\[ V_p = \frac{D^2 (\rho_B - \rho_w)}{18 \mu} \]

In which:
- \( V_p \) —— Sedimentation velocity of particles
- \( D \) —— Diameter of particles
- \( \rho_B \) —— Density of microspheres
- \( \rho_w \) —— Underground density of injected water
- \( \mu \) —— Viscosity of injected water

Considering that the carrier with small particle size is selected when the oil layer is particularly well developed, for the high permeability pore channel layer, the isotope carrier will enter the depth of the formation with the injected water in a short time. When the instrument detects with the water flow, it is beyond its range and cannot be detected, thus causing the illusion that the formation does not absorb water, while the flow meter test results show that it absorbs water. Therefore, it is recommended to reduce the particle size of the carrier when testing the injection wells with smaller oil layers and poor development in the test area.

4.2. Reduce the adsorption of tubing and casing

To solve the scaling and corrosion problems on casing, scraping can be enhanced during operation. At present, 21 heavy plugging operation wells in the test area have been enhanced scraping and descaling, and the influence of contamination is reduced by comparing the water absorption profiles before and after (Figure 3). Combined test areas are all layered pipe strings, and most of the oil pipes are the problem of reusing old pipes, so it is suggested that reusing old pipes should not be used downward at about 30m above the target layer.
Figure 3. Comparison of water absorption profile effect of Pu II 4 ~ 9 reservoir before and after scraping with 8-PS2616

4.3. Treatment of isotope interpretation results

4.3.1. Screening from the shape of water absorption profile. From the water absorption profile, it can be seen that the oil layers with relative absorption less than 5% are mostly affected by contamination, but it is obviously unreasonable to give the result that the oil layers are used (Figure 4). Therefore, the units with relative absorption less than 5% are eliminated when the water absorption profile results of the test area are counted.

Figure 4. Water absorption profile of 8-PS 2632 Pu II 4 ~ 9 reservoir Test time: May 2017

According to the test results of water absorption profile in the test area in 2017, the sedimentary units are divided into 60 units with relative water absorption less than 10%, accounting for 43.8% of the water absorption units, and the sandstone thickness is 97.3m, accounting for 29.0% of the water absorption interval thickness (Table 4).
Table 4. Statistical table of unit number and thickness of oil layer with different water absorption ratio in test area

| Relative water absorption ratio I(%) | Number of units | Unit proportion(%) | Sandstone thickness(m) | Sandstone thickness ratio(%) | Absolute water absorption(m³) | Relative inhalation ratio (%) |
|------------------------------------|-----------------|--------------------|------------------------|-----------------------------|-------------------------------|-----------------------------|
| 10≥I                               | 60              | 43.8               | 97.3                   | 29.0                        | 74.9                          | 6.5                         |
| 30≥I>10                           | 37              | 27.0               | 86.8                   | 25.8                        | 143.4                        | 12.5                        |
| 50≥I>30                           | 13              | 9.5                | 50                     | 14.9                        | 196.1                        | 17.1                        |
| 70≥I>50                           | 14              | 10.2               | 46.4                   | 13.8                        | 292.2                        | 25.5                        |
| I>70                               | 13              | 9.5                | 55.5                   | 16.5                        | 438.3                        | 38.3                        |
| Total                              | 137             |                    |                        |                             | 1145.0                       |                             |

From statistics, it can be found that the proportion of units with relative absorption less than 10% is the highest, and the classification of these layers is refined. There are 18 units with relative absorption less than 2%, accounting for 13.1% of the water absorption units; There are 24 with relative water absorption between 2% and 5%, accounting for 17.6% of water absorption units. There are 15 with relative water absorption between 5% and 8%, accounting for 10.9% of water absorption units. There are 3, which are more than 8%, accounting for 2.2% of water absorption units. It can be seen from the analysis results that there are 42 units with relative intake less than 5%, with less intake and more layers.

4.3.2. Screening from unit injection intensity. According to statistics, the production degree of the whole area is 92.6%, which is nearly 10% higher than that of similar reservoirs. According to the relative water absorption of profile interpretation, the water absorption strength of each unit is counted. Among 110 units with developed effective thickness, the effective thickness ratio of units with water absorption strength less than 0.5 m³/d.m is 11.6%, and the number of units is 10.9% (Table 5). According to the field experience, units with water absorption intensity less than 0.5 m³/d.m can be considered as not absorbing water. If this part of oil layer should be removed from production, the production degree of the test area is close to that of other blocks, so units with water absorption intensity less than 0.5/d.m can be eliminated when counting oil layer production.

Table 5. Classification table of water absorption strength of each deposition unit in the test area

| Water absorption strength (m³/d.m) | Effective thickness (m) | Thickness ratio (%) | Number of units (pieces) | Proportion of water absorption unit(%) |
|-----------------------------------|------------------------|---------------------|--------------------------|---------------------------------------|
| Less than 0.5                     | 29.9                   | 11.6                | 12                       | 10.9                                  |
| 0.5-1                             | 31.9                   | 12.4                | 12                       | 10.9                                  |
| 1-2                               | 21.1                   | 8.2                 | 12                       | 10.9                                  |
| 2-4                               | 75.2                   | 29.2                | 28                       | 25.5                                  |
| 4-6                               | 35.6                   | 13.8                | 13                       | 11.8                                  |
| 6-8                               | 12.8                   | 5.0                 | 6                        | 5.5                                    |
| Greater than 8                    | 50.8                   | 19.7                | 27                       | 24.5                                  |

4.4. Application effect
According to the statistics of reservoir producing degree in water flooding stage in the test area, the producing ratio of effective thickness of reservoir is 78.7%, and that of sandstone is 74.6%. Among them, the river sand utilization ratio is 79.9%, the main sheet sand utilization ratio is 77.4%, the non-main sheet sand utilization ratio is 35.3%, and the surface layer utilization ratio is 47.3%. Compared with the strong alkali test area, the utilization degree is close, and the non-main sheet sand utilization degree is quite different, which is influenced by the heterogeneity of the test area (Table 6).
Table 6. Comparison of water drive degree of different sand bodies in strong and weak alkali ternary test area (after adjustment)

| Test area name           | Degree of utilization(%) | Effective reservoir | Malmstone River sand | Main sheet sand | Non-main sheet sand | Outer surface layer |
|-------------------------|--------------------------|---------------------|-----------------------|----------------|---------------------|--------------------|
| Class II strong alkali  |                          | 83.5 78.8           | 84.2                  | 81.3           | 56.1                | 46.6               |
| Second-class weak base  |                          | 78.7 74.6           | 79.9                  | 77.4           | 35.3                | 47.3               |
| Differential value      |                          | 4.8 4.2             | 4.3                   | 3.9            | 20.8                | -0.7               |

5. Some understandings
(1) The injection profile interpretation of weak alkali ternary test area in class II reservoir is affected by contamination, and the utilization degree of profile interpretation results is high;
(2) Screening through water absorption profile shape and unit injection intensity to reduce the influence of contamination on reservoir production statistics;
(3) After isotope interpretation results are corrected, the production ratio of effective thickness of oil layer and sandstone in the test area is 78.7% and 74.6%, which is close to that in the strong alkali test area.

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