# The use of a ranking system in the selection of acid compositions (AC) for effective treatment of the near-wellbore formation zone (TWZ)

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***Abstract.*** This analytical work is based on the methodology and principles of integral assessment and point digitalization of the main eight qualitative and quantitative parameters of acid compositions (AC), characterizing the quality, efficiency and prospects of their use at specific (preselected by experts) development targets confined to the carbonate reservoirs of the Tournaisian, Vereian and Bashkir tiers.

***Keywords:*** acid composition, carbonate reservoirs, dissolving capacity, fluid compatibility, ranking.

## Introduction

Selection of optimal formulations of multicomponent acid compositions for various conditions of specific development objects and fields is a relevant and significant topic for solving technological challenges of PJSC "Tatneft". For effective primary acid treatments, an individual selection of acid formulations is required. The expected end results of the work are the ranking and targeted selection of AC recipes for specific horizons of development objects, the creation of a digital library of acid composition recipes. It is planned to integrate the library into the design and automated selection system for AC. The technological goal is to reduce the negative impact of adsorption layers, high-quality contact with the rock, the absence of emulsion

and sludge complexes, and intensification of oil production. Scope: acid methods and technologies TWZ carbonate reservoirs in the fields of PJSC "Tatneft".

**The purpose of laboratory studies**

The purpose and result of laboratory test studies for the selected eleven ACs based on this scientific approach was the substantiation and selection of the three best acid compositions in terms of a complex of physicochemical properties with reference to a specific geology (lithology) of reservoirs and properties of formation fluids (water, oil).

**Materials and methods**

Based on this methodological approach, a conceptual scheme for the selection of AC formulations for the digital library of PJSC "Tatneft" has been determined. This scheme is based on the analytical results of large-scale test studies for eleven ACs based on the developed methodology for scoring control parameters and physicochemical properties of acid compositions. The essence of the technique is to translate the absolute values of physical and chemical properties into a ten-point scale, to determine the "significance" of each property with further ranking of the formulations by the highest sum of points. According to the three best ACs in physical and chemical properties with reference to geology and reservoir fluids, a recommendation for well testing is given.

The developed methodological approach is recommended for further detailing, development and generalization of the digital library for new promising ACs, based on the principles of "machine" learning, chemoinformatics and a statistical base for laboratory research with the formation of a design system for new ACs with predetermined physical and chemical properties.

On the basis of the experimental studies carried out, a point ranking of the values of the physical and chemical properties of acid compositions was carried out (tab. 1-3).

For this, the absolute values of physical and chemical properties were converted into a 10-point scale, where $X_{min}$ = 1, and $X_{max}$ = 10. Values between $X_{min}$ and $X_{max}$ are scored in proportion to the absolute values.

On a five-point scale, the significance of each of the physicochemical properties is determined, depending on their influence on the results of acid treatment, while the base value is 1, the maximum is 5.

For the final point ranking, the sum of the products of significance and points for each acid composition is taken.

The point ranking is based on the degree of importance of physical and chemical indicators, namely, the points of physical and chemical indicators are considered with the following significance:

- 5 – total solubility;
- 4 – compatibility with reservoir oil in the presence of iron ions (sieve analysis);
- 4 – compatibility with reservoir oil (sieve analysis);
- 3 – compatibility with reservoir oil in the presence of iron ions (phase separation);
- 3 – compatibility with reservoir oil (phase separation);
- 2 – surface tension at the border with the hydrocarbon carrier;
- 2 – contact angle of wetting at the boundary with the rock surface;
- 1 – acid corrosion rate.

Statistical processing of the data of physical and chemical indicators was carried out taking into account the regulatory boundaries approved in the technical and technological conditions (TTC):

1) surface tension at the border with the hydrocarbon carrier: 0.10-35.10 mN/m;

2) the contact angle of wetting at the boundary with the surface of the rock: 10.0-30.1$^{o}$;

3) acid corrosion rate: 0.10-0.31 g/($m^2$· h).

Analyzing the data in tables 1-3 according to this principle, choose AC.

Table 1 – Ballistic ranking of physical and chemical properties for the Tournaisian stage of field № 1 using statistical processing taking into account regulatory requirements (TTC)

| Physiochemical properties | Recipe № 1 | Recipe № 2 | Recipe № 3 | Recipe № 4 | Recipe № 5 | Recipe № 6 | Recipe № 7 | Recipe № 8 | Recipe № 9 | Recipe № 10 | Recipe №1 1 | "Significance" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reservoir oil compatibility (phase separation) | 9 | 9 | 9 | 8 | 8 | 10 | 6 | 10 | 9 | 10 | 10 | 3 |
| Reservoir oil compatibility (sieve analysis) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 4 |
| Compatibility with formation oil in the presence of iron ions (phase separation) | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 9 | 9 | 3 |
| Compatibility with reservoir oil in the presence of iron ions (sieve analysis) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 4 |
| Total solubility | 5 | 10 | 5 | 2 | 1 | 1 | 1 | 7 | 7 | 2 | 1 | 5 |
| Acid corrosion rate | 6 | 8 | 6 | 6 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 1 |
| Surface tension at the interface with a hydrocarbon carrier | 9 | 9 | 9 | 9 | 9 | 10 | 10 | 8 | 10 | 9 | 10 | 2 |
| Contact angle of wetting at the boundary with the rock surface | 4 | 5 | 5 | 7 | 6 | 4 | 7 | 7 | 4 | 9 | 6 | 2 |
| Points total | 188 | 217 | 190 | 176 | 170 | 174 | 168 | 212 | 206 | 189 | 180 | |
| Place in the ranking of acidic compounds | 6 | 1 | 4 | 8 | 10 | 9 | 11 | 2 | 3 | 5 | 7 | |

Figure 1 shows a diagram with the values of the sum of the points of the recipes AC in descending order (tested with oil from the Tournaisian stage of the field № 1).

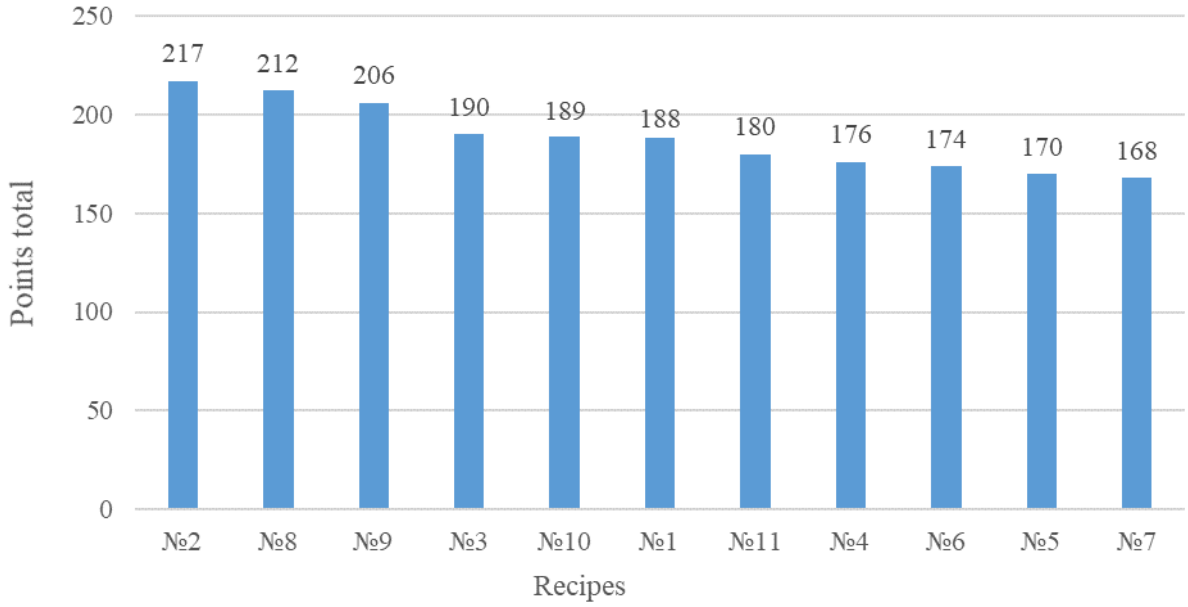


Figure 1 – AC recipe sum scores in descending order

Table 2 – Ballistic ranking of physical and chemical properties for the Vereya stage of the field № 2 using statistical processing taking into account regulatory requirements (TTC)

| Physiochemical properties | Recipe № 1 | Recipe № 2 | Recipe № 3 | Recipe № 4 | Recipe № 5 | Recipe № 6 | Recipe № 7 | Recipe № 8 | Recipe № 9 | Recipe № 10 | Recipe № 11 | "Significance" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reservoir oil compatibility (phase separation) | 10 | 10 | 9 | 8 | 7 | 6 | 9 | 10 | 9 | 9 | 8 | 3 |
| Reservoir oil compatibility (sieve analysis) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 4 |
| Compatibility with formation oil in the presence of iron ions (phase separation) | 10 | 10 | 10 | 8 | 10 | 8 | 10 | 10 | 8 | 10 | 10 | 3 |
| Compatibility with reservoir oil in the presence of iron ions (sieve analysis) | 10 | 8 | 8 | 7 | 10 | 7 | 6 | 10 | 10 | 10 | 10 | 4 |
| Total solubility | 5 | 10 | 6 | 3 | 1 | 2 | 3 | 8 | 8 | 2 | 2 | 5 |
| Acid corrosion rate | 6 | 8 | 6 | 6 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 1 |
| Surface tension at the interface with a hydrocarbon carrier | 9 | 9 | 9 | 9 | 9 | 10 | 10 | 8 | 10 | 9 | 10 | 2 |
| Contact angle of wetting at the boundary with the rock surface | 4 | 5 | 5 | 7 | 6 | 4 | 7 | 7 | 4 | 9 | 6 | 2 |
| Points total | 197 | 218 | 193 | 169 | 173 | 155 | 177 | 217 | 205 | 189 | 182 | |
| Place in the ranking of acidic compounds | 4 | 1 | 5 | 10 | 9 | 11 | 8 | 2 | 3 | 6 | 7 | |

Figure 2 shows a diagram with the values of the sum of the points of the recipes AC in descending order (tested with oil from the Vereisky stage of the field №2).


Figure 2 – AC recipe sum scores in descending order

Table 3 – Ballistic ranking of physical and chemical properties for the Bashkirian stage of the field № 3 using statistical processing taking into account regulatory requirements (TTC)

| Physiochemical properties | Recipe № 1 | Recipe № 2 | Recipe № 3 | Recipe № 4 | Recipe № 5 | Recipe № 6 | Recipe № 7 | Recipe № 8 | Recipe № 9 | Recipe № 10 | Recipe № 11 | "Significance" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reservoir oil compatibility (phase separation) | 10 | 10 | 9 | 8 | 7 | 6 | 9 | 10 | 9 | 9 | 8 | 3 |
| Reservoir oil compatibility (sieve analysis) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 4 |
| Compatibility with formation oil in the presence of iron ions (phase separation) | 10 | 10 | 10 | 8 | 10 | 8 | 10 | 10 | 8 | 10 | 10 | 3 |
| Compatibility with reservoir oil in the presence of iron ions (sieve analysis) | 10 | 8 | 8 | 7 | 10 | 7 | 6 | 10 | 10 | 10 | 10 | 4 |
| Total solubility | 7 | 10 | 10 | 5 | 1 | 1 | 3 | 6 | 4 | 2 | 3 | 5 |
| Acid corrosion rate | 6 | 8 | 6 | 6 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 1 |
| Surface tension at the interface with a hydrocarbon carrier | 9 | 9 | 9 | 9 | 9 | 10 | 10 | 8 | 10 | 9 | 10 | 2 |
| Contact angle of wetting at the boundary with the rock surface | 4 | 5 | 5 | 7 | 6 | 4 | 7 | 7 | 4 | 9 | 6 | 2 |
| Points total | 207 | 218 | 213 | 179 | 173 | 150 | 177 | 207 | 185 | 189 | 187 | |
| Place in the ranking of acidic compounds | 3 | 1 | 2 | 8 | 10 | 11 | 9 | 4 | 7 | 5 | 6 | |

Figure 3 shows a diagram with the values of the sum of the AC recipe scores in descending order (tested with oil from the Bashkirian stage of the field № 3).

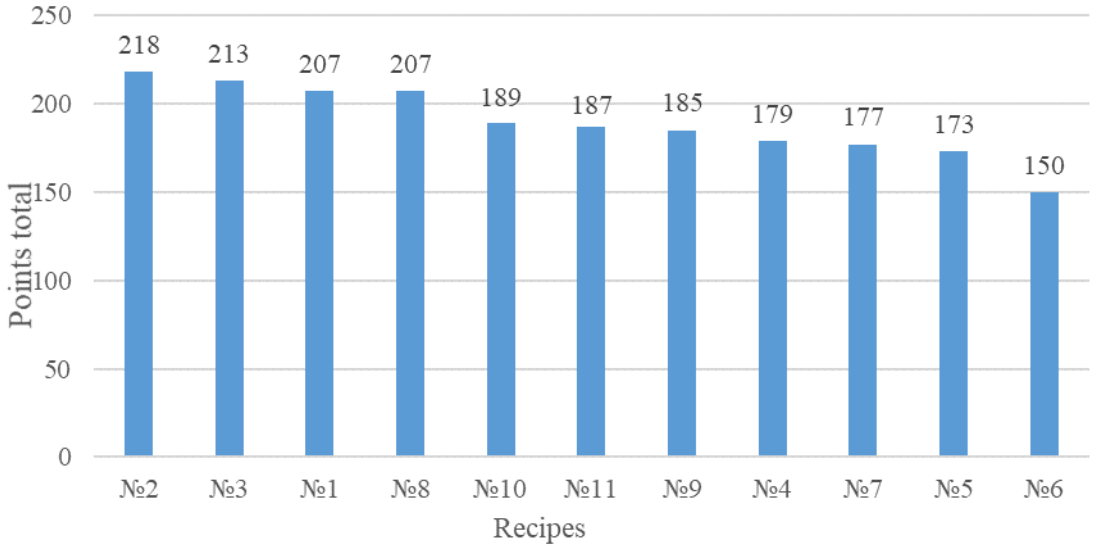


Figure 3 – AC recipe sum scores in descending order

**Conclusions and recommendations:**

1) On the basis of a joint analysis of specialists from the TWZ laboratory and the TWZ department of the UGTM, a method has been developed for a point assessment of the basic physical and chemical properties and parameters of acid compositions and compositions.
2) Statistical processing of the results of a large array of laboratory analyzes was carried out for eight qualitative and quantitative parameters, taking into account their expert significance on a five-point scale of eleven AC.
3) Based on the adopted methodology, an examination of the selected ACs was carried out, which made it possible for the first time to integrally digitize and rank AC, taking into account the peculiarities of the lithology of carbonate reservoirs and the properties of native fluids of a number of specific objects of development of PJSC "Tatneft".
4) Thus, for the first time on a scientific basis, ranked digitization of AC quality was obtained (three best in terms of integral parameters were identified) with reference to a specific development object (Bashkir, Tourney), which is the beginning of the conceptual scheme for the selection of AC recipes and the development of a digital library at PJSC " Tatneft ".
5) The developed methodological approach is recommended for further detailing, development and generalization of the digital library for new promising ACs, based on the principles of machine learning, chemoinformatics and a statistical base for laboratory

research with the formation of a design system for new ACs with predetermined physicochemical properties.