Improving the method and equipment of thermo-acidic pulsation treatment

M Ya Khabibullin\textsuperscript{1}, G S Dubinskiy\textsuperscript{2,3}, P M Malyshev\textsuperscript{1}, A R Safiullina\textsuperscript{1}, A A Karimova\textsuperscript{1}

\textsuperscript{1} Ufa State Petroleum Technological University, Branch of the University in the City of Oktyabrskiy, 54a, Devonskaya St., Oktyabrskiy, Republic of Bashkortostan, 452607, Russian Federation
\textsuperscript{2} Ufa State Petroleum Technological University, 1, Kosmonavtov st., Ufa, Republic of Bashkortostan, 450062, Russian Federation
\textsuperscript{3} State autonomous scientific institution “Institute of strategic research of the Republic of Bashkortostan", 129/3, October avenue, Ufa, Republic of Bashkortostan, 450075, Russian Federation

E-mail: m-hab@mail.ru

Abstract. Initially, the method of thermo-acid pulsation was intended for heavily drained wells. But, as practice has shown, it can also be successfully used in the processing of wells of other categories, and depending on the diameter of the production string and the diameter of the reactor (jacket), the acid flow can be changed. A reactor with a diameter of 114 mm is usually used, but for 114 or 127 mm of the production string, a reactor with a diameter of 48 or 88 mm, respectively elongated, can be used to maintain the required capacity in order to accommodate the right amount of magnesium chips. The efficiency of acid treatment operations by pulsing is greater than the efficiency of thermo-acid treatments according to the results of calculations of both the increase in oil production and the duration of the wells at increased production.

1. Introduction
Initially, the method of thermo-acid pulsation was intended for heavily drained wells. But, as practice has shown, it can also be successfully used in the processing of wells of other categories, and depending on the diameter of the production string and the diameter of the reactor (jacket), the acid flow can be changed. A reactor with a diameter of 114 mm is usually used, but for 114 or 127 mm of the production string, a reactor with a diameter of 48 or 88 mm, respectively elongated, can be used to maintain the required capacity in order to accommodate the right amount of magnesium chips.

2. Results and discussion
The tip (Figure 1a), despite the simplicity of its design, nevertheless had a significant drawback: valve opening was associated with the tolerance from the shank to the bottom. In the conditions of sand occurrences, when sand accumulates during the operation of the wells at the bottom, the descent of the liner all the way to the bottom is associated with the danger of sticking pipes. Therefore, a new special tip was proposed and introduced [1-3]. The main part of this tip is a fitting, the channel of which is
closed by a magnesium rod (Figure 1c).
Good results were obtained by the introduction of the acid pulsation method, which involves the use of a special tip in which the nozzle channel is completely closed by a magnesium rod (Figure 1b) [4, 5].

Figure 1. Tip reactors for acidic and thermo-acidic treatment of wells by pulsation: a – tip reactor for thermo–acid pulsation; b – tip for acid impulse; c – universal tip reactor for acidic and thermo–acidic pulsation; g – cone with magnesium rod (discharged into the well during repeated processing); 1 – pump–compressor pipe; 2 – valve ball; 3 – valve seat; 4 – coupling; 5 – connecting pipe; 6 – persistent branch pipe; 7 – valve body; 8 – coupling; 9 – reactor; 10 – magnesium chips; 11 – filter (grill); 12 – pipe sub; 13 – coupling; 14 – perforated pipe tip; 15 – saddle for cone with magnesium core; 16 – connecting pipe (sub); 17 – insert fitting; 18 – magnesium rod; 19 – fitting body.

The tip is lowered into the well on tubing until the perforated pipe is installed against the production object (in this case, the pipe does not need to abut the bottom). Then, the acid solution is poured into the tubing string, which is retained in it due to the magnesium channel blocking the nozzle channel. As a result of the reaction, the magnesium rod dissolves in the acid solution, after which the latter rushes through the released channel of the nozzle and the perforated nozzle into the filter, creating a so-called acid impulse, i.e. an increase in the injection rate under the influence of hydrostatic pressure is achieved. The pressure created in this case at the bottom of a heavily drained well contributes to a much greater penetration of the active acid solution into the formation compared to conventional acid treatment.

The design of this device has the following advantages:
- the fitting opens without the use of a lifting tractor;
- the acid treatment process can be carried out in wells having a sump (pocket below the filter zone) of considerable length;
- if there is a sand plug or construction of objects on the face there is no danger of sticking pipes.

The length of the magnesium rod is selected according to our nomogram (Figure 2), which was based on laboratory studies of the dissolution of a magnesium rod 10 mm long and 10 mm in diameter (placed in a cartridge-like insert) in a 15% hydrochloric acid solution [6–8]. When constructing the nomograms, we proceeded from the calculation that the complete dissolution of the magnesium rod should occur no earlier than the complete filling of the pipes with an acid solution (at the end of the
latter).

Given the length and diameter of the tubing lowered into the well, the volume of the acid solution is determined.

Further, setting the rate of acid solution discharge into the tubing (controlled by the valve opening on the tank truck), the pipe filling time and the length of the magnesium rod are found. So, in this case, at a drain rate of 1 l/s, the pouring time is 53 min, and the rod length is 17 mm.

A significant drawback of the method of acidic pulsation (as well as thermoacid) is the limitation of the volume of the acid solution by the capacity of the deflated tubing.

It should be noted that it is often advisable to use a larger volume of solution. Therefore, a method of multiple acid impulses without extracting tubing from wells was proposed and implemented. For the application of this method, a universal tip reactor is proposed (Figures 1c and 1d).

3. Experimental

Conducting multiple pulsations became possible because the set of the new reactor has a number of cone seats, installed in series in tubing (in Figure 1, only one saddle 15 is shown); moreover, the diameter of the hole in each seat located above is greater than that of the seat located below. After a single acid impulse, a cone is thrown into the tubing (Figure 1, d), which overlaps the seat hole. The hole of the cone is filled with magnesium rod 18. Then one can again fill the acid solution in the tubing, etc. (as with a single acid impulse). This operation can be repeated several times using pre-installed saddles and each time throwing the corresponding cones with magnesium rods (their length in all cases is determined by the nomogram shown in Figure 2) [9].

With repeated pulsation, the number of pulses is determined based on the selected volume of the acid solution and the volume of the solution that can be placed in descended pipes. The latter is determined by the left side of the nomogram, shown in Figure 2. For example, for 500 m of 73-mm pipes, the volume of acid solution that can be used for one pulse will be no more than 1.75 m³. If during the acid treatment it is advisable to use 3.5 m³ of the solution, then the pulses will be determined as the quotient of dividing 3.5 by 1.75 and will be equal to two.

In heavily drained wells, it is advisable to first conduct thermo-acid pulsing (especially if paraffin oil was extracted from it). For this, a universal tip reactor can be used (Figure 1c). After thermo-acid pulsation, acid pulsation can be carried out as many times as needed without lifting pipes. To do this, first install the required number of saddles 15 in the tubing (Figure 1c) and cast a cone with a magnesium rod before each acid pulse treatment (Figure 1d).

![Figure 2. Nomogram for determining the length l of the magnesium rod (for suspension data - the length L and the diameter of the tubing), at which it is completely dissolved only after the filling of the tubing with a given volume of acid solution V (at a certain filling rate of pipes)](image-url)
When using a conventional filling head, the piston-like movement of the solution in the pipes caused periodic air breakouts to the wellhead. At the same time, the air carried away the acid solution, so it was necessary to periodically stop pouring the solution into the pipes.

A special casting head is proposed (Figure 3). The external 73 mm branch pipe 2 has a branch 3 for draining the acid solution into the tubing 6, and the internal 48 mm pipe 1 serves to evacuate the air displaced into the atmosphere.

![Figure 3. Universal wellhead for acid and thermo-acid pulsation treatment of wells: 1 – pipe with a diameter of 48 mm; 2 – pipe with a diameter of 73 mm; 3 – tap with a diameter of 73 mm; 4 – landing clutch; 5 – faceplate; 6 – tubing; 7 – production casing; 8 – guides for drainage of acid solution](image)

After the pipes are lowered and the said head is installed on them, an acid solution is drained through branch 3. Once in the annular space, the solution first flows along the guides 8, and then along the walls of the tubing 6. The displaced air occupies a central position and is removed through the pipe 1. As a result of the introduction of such a head, there is no loss of time to drain the acid solution into the pipes, as well as loss of the latter due to emissions (together with air); contamination of the wellhead and ensures the safety of workers engaged in pulse acid treatment.

In order to establish the effectiveness of pulsed thermo-acid treatments in comparison with simple thermo-acid operations, the probability of successful operations is determined. At the same time, the asymmetric distribution of wells by efficiency was aligned using the Charlier distribution [10].

The results of calculating the probability of successful outcomes for pulsed thermo-acid treatments are given in the table, where the likelihood of the effectiveness of conventional thermo-acid treatments calculated above is also indicated for comparison.

| Table 1. Operational efficacy probability |
|------------------------------------------|
| Operations                      | According to calculations of |
|                               | flow rate increase | duration of the well at an increased flow rate |
|                               | Thermo-acid conventional | Thermo-acid pulsed | Thermo-acid conventional | Thermo-acid pulsed |
| Highly efficient               | 9                  | 22                  | 7                      | 11                      |
| Efficient                      | 11                 | 34                  | 20                     | 23                     |
| Ineffective                    | 80                 | 44                  | 73                     | 66                     |
4. Conclusion
It should be noted that a comparison of the two groups of numbers may be valid provided that the difference in their means is not significant. These groups of numbers were processed, as a result of which it was found that the combination represented by them is different. As can be seen from the table, the efficiency of operations on acid treatments by pulsing is greater than the efficiency of thermo-acid treatments according to the results of calculations of both the increase in oil production and the duration of the wells at increased production.

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