RESEARCH ARTICLE

Algorithm thermo chemical reactions for improved oil recovery

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Abstract

With the purpose of well-bottom zone cleaning from contamination and enhancement of well production of oilfield "Gunasli", a quite new method of simulation of oil production using thermo chemical reaction is proposed by us. To determine basic components of the thermo chemical reaction for well- bottom zone treatment, the algorithm is worked out for the first time.

The essence of effect of thermo chemical reaction is in the fact that as a consequence of the liberation of thermal energy, surface stress in formation is reduced, the effectiveness of well- bottom zone treatment thank to thermal effect is enhanced, the oil relative permeability is increased , the oil density is reduced and the reservoir is cleaned from interstitial contamination.

A novelty of the proposed algorithm is the solving of practical problems in area of well-bottom zone treatment using thermo chemical reaction taking into account of well's operational conditions, as well as reservoir's physicochemical and geology factors. Proposed algorithm possesses a valuable importance for increasing of well production using thermo chemical reaction.

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Introduction

The problem of increasing productivity operated wells - one of the main problems in the oil industry. This problem involved numerous scientific institutions and experts. Currently developed various technologies designed to increase oil production is mainly aimed at overcoming the hydrodynamic forces. The interaction of forces, such as physic-chemical, quantum mechanical, molecular, surface and other phenomena not yet fully understood.

The results of basic research in the field of heat treatment of bottom whole zone (CCD) show that the main factors contributing to the restoration and increase permeability of the formation consist of:

● cleaning of asphalt - resin - paraffin deposits (AFS) and substances with high molecular weight, accumulated in the CCD. As a result of the high temperature on the above reservoir, paraffin are melted and then dissolve. Subsequently, the reaction products are carried with the formation fluid at development wells. The result is shown in Fig. 1.1 shows that as the temperature raise to 100C organic deposition solubility increases 4 times;

● changing the wettability of the surface of the CCD rocks in the direction of increasing the permeability for the oil phase;

● thermal pulse, promoting detachment of inorganic deposits on the surface of the contaminated zones capillary penetration treatment fluids into the far zone when pumping, and brings them to the surface during the development;

● Destruction of the blocking plugs, which is the reason for reducing the permeability of the CCD;

● Creation of new cracks.

According to the method of heat delivery methods of thermal processing of the CCD are divided into two groups:

♥ Heat delivery by means of heated liquids or gases (delivered in CCD heated gas, hot water, hot oil, steam);

♥ Methods using the heat source from neighboring wells (hot oil or hot water).

By way of obtaining heat CCD processing methods can be divided into three groups:

►electric method (getting heat into the CCD by means of an electric heater);

► Method of internal combustion (CCD receiving heat from fuel combustion or fuel in conjunction with chemical reagents delivered (pumped) to the surface;

► Thermo chemical method (CCD receiving heat by an exothermic reaction).

Existing methods of thermal treatment of the bottom hole zone:

1. Electricity and processing Beneficiation zone. The use of electro-thermal processing is one of the processing methods bottom-hole zones. For the electro-thermal processing of used electric heater with a voltage of 250V and 70A AC power. Electric Descends into the well, solvent injected into the CCD. Paraffin dissolved in a hot solvent. However, the method Electro thermal processing zones has some drawbacks, it is not used deep wells and low economic efficiency, so little used. His Improvement continues to this day.

2. Processing CCD using steam, hot water and hot oil. Bottom whole treatment using water vapor is one of the methods used in the early stage of operation of the well. The source of the vapor is a steam plant. Installation is normally mounted on the vehicle chassis (PUF Mobile setting) to quickly jump from one to the other hole. When processing well water vapor is injected into the production tubing. Molten dispersed hydrocarbons (oil, water and gas), and makes with the formation fluid for processing surface. Thermal using heated steam has a major drawback - usually form water-resistant cork difficult to destroy emulsions and in some cases water accelerates the formation

of the lens during use after processing. It used in the same way to process using hot water from nearby wells or oil reservoir near the source. This method helps reduce the cost of treatment because they do not use special equipment, but the effectiveness of this method is much less than the efficiency of steaming hot because hot water temperature is much less than the steam temperature.3. Internal combustion method. Internal combustion method is the formation of the thermal energy from the combustion of fuel is reduced, or a combination of the reduced outside down hole chemicals and fuel. This method is called - a method of Moshe (Moser) [1]. The method used in 1943-1975gg. in the wells of the United States of America Wyoming fields and fisheries in Baku 1965-1980gg. for processing CCD with reservoir depth of 550 - 950m.

Technology method consists in filling the well with a mixture of water, solvent or oil, then pumped fuel mixture which includes air and gasoline, and ignites at helping special equipment. As a result of the combustion of gasoline and air, heated mixture of water and oil to a temperature of 170-210 0F (77-100 0C) about 5-7 gallons / hour (19-26,5l / h). The disadvantage of this method is the high degree of danger due to the fact that the mixture of gasoline vapor and air can cause fire and explosion.

There is one more an invention relating to a method of internal combustion, patent RU 2209960 C2 (2003) [6]. The invention involves a new method of cleaning bottom hole zone allows to process organic and inorganic deposition using gas mixture HCl, HF and CO2, CO, N2, formed by the decomposition of the primary generating substances HCl and HF. The advantage of this invention is that under the influence of high temperature and high pressure process large area CCD.

The disadvantage of this invention is that as a result of rapid combustion at high pressure is formed short time. The sharp increase in pressure and temperature leads to disruption of the casing and the cement ring wells.

4. The method of use of the exothermic reactions. The heat released during the exothermic reaction can be used for the heat treatment zone bottom hole. However, for many reasons, both in technical and in economic, some only exothermic reactions (after study) applied. Chemical reactions used to process bottom hole zone can be divided into five groups:

1) The reaction of calcium carbide (CaC2) with water;

2) Reaction of dry alkaline water;

3) Reaction of alkali metal and aluminum;

4) The reaction of compounds of the alkali and alkaline earth metals, Al, Si with water;

5) Reaction of aluminum, magnesium HCl acid.

5.Metod use of heat as a result of reaction with water CaC2 .If interaction with water CaC2 large amount of heat released by the following reaction scheme:

$$CaC2 + H2O \rightarrow C2H2 + Ca\ (OH)\ 2 \downarrow + Q \downarrow, \quad (1)$$

In theory one pound (0,454 kg) CaC2 reacts with water, whereby the amount of heat released about 840 BTU (1954 kJ). Carrying TXP requires strict performance standards of fire and explosion, as is formed as a result of an explosive mixture of C2H2 mixing with air.

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Generated by the reaction of the dry alkali (NaOH) with water. In the process of dissolution of the dry, solid caustic (NaOH) in water, we get a huge amount of heat. This resulting heat is used to clean the wax in the stacks optional tubing, and equipment in the well. About 420 BTU (977KDzh) is formed by dissolving in water 1pound NaOH. If more than 4 reconstruction pound NaOH in 1 gallon of water, the amount of heat generated per pound NaOH 1 will decrease and the net heat for the quantitative ratio of water and NaOH 3.8 pound NaOH required

for 1 gallon of water. The cost of this method is greater than the cost of using the method CaC2. As a method of using CaC2, a method of using a dry alkali reaction with water is theoretical in nature, which is not applied in practice [2,3,4].

Fig. 1. *Effect of temperature on the solubility of the wax in some solvents and oil.*

7. A method of using the heat of reaction of aluminum and NaOH. In some fields, this method is used to separate some organic substances and deposited with the method of dissolving the NaOH in water, a method of using the reaction of aluminum and NaOH. Technology of this method is as follows: in the well, translated into the water, descend of NaOH, then descend the aluminum powder, the reaction takes place Al and NaOH. The resulting reaction produces Natri alumina, CO2 and H2 gas. The heat released by mixing 0,2 pound (0,091kg) aluminum powder with 0,8 pound (0,363 kg) of water and 1620 BTU. A method for obtaining heat from the reaction of NaOH and is used in aluminum wells having a small depth.

8. Method of using the heat produced in the reaction admixture of alkali metals and alkaline water. The authors of the patent RU 2073696 C1 (1997), [3,5,6] proposed a method for thermal cleaning and paraffin asphatin, the heat released by the reaction of alkali and alkaline earth metals with water. The composition of this impurity may be the following metals include Al, Ca, Mg, Si, or alkali metals. Water reacts with the aluminum and the alkali metals according to the following reaction:

$$Al + H2O \rightarrow Al(OH)3 + H2\uparrow + Q,$$

$$Ca + H2O \rightarrow Ca(OH)2 + H2\uparrow + Q, \quad (2)$$

This method has already been applied to the wells in Tyumen and Redleninpetrolgas.

The method of using the heat produced in the reaction mixture of alkali and alkaline earth metals with water, has a high efficiency of cleaning and bottom zone intensification of oil inflow, but at the same time has great difficulties associated:

* Production and storage of mixtures of aluminum and alkali metals because these metals have high activity by reacting with oxygen and humid air (highly flammable);

* Difficult to control the negative impact of gel hydroxyl, formed during the reaction.

Rationale for the development and practical application of a completely new method of using the heat released during the reaction of Mg and hydrochloric acid HCl.

Studying the experience of developing the exploitation of oil deposits in Russia, Vietnam, Kazakhstan, Bahrain and Azerbaijan has allowed the identification of the reasons for characterizing the decrease in well production of oil fields namely:

quantities, ie, reduction of the natural permeability oil reservoir is due to its pore clogged after when exposed to sea water;

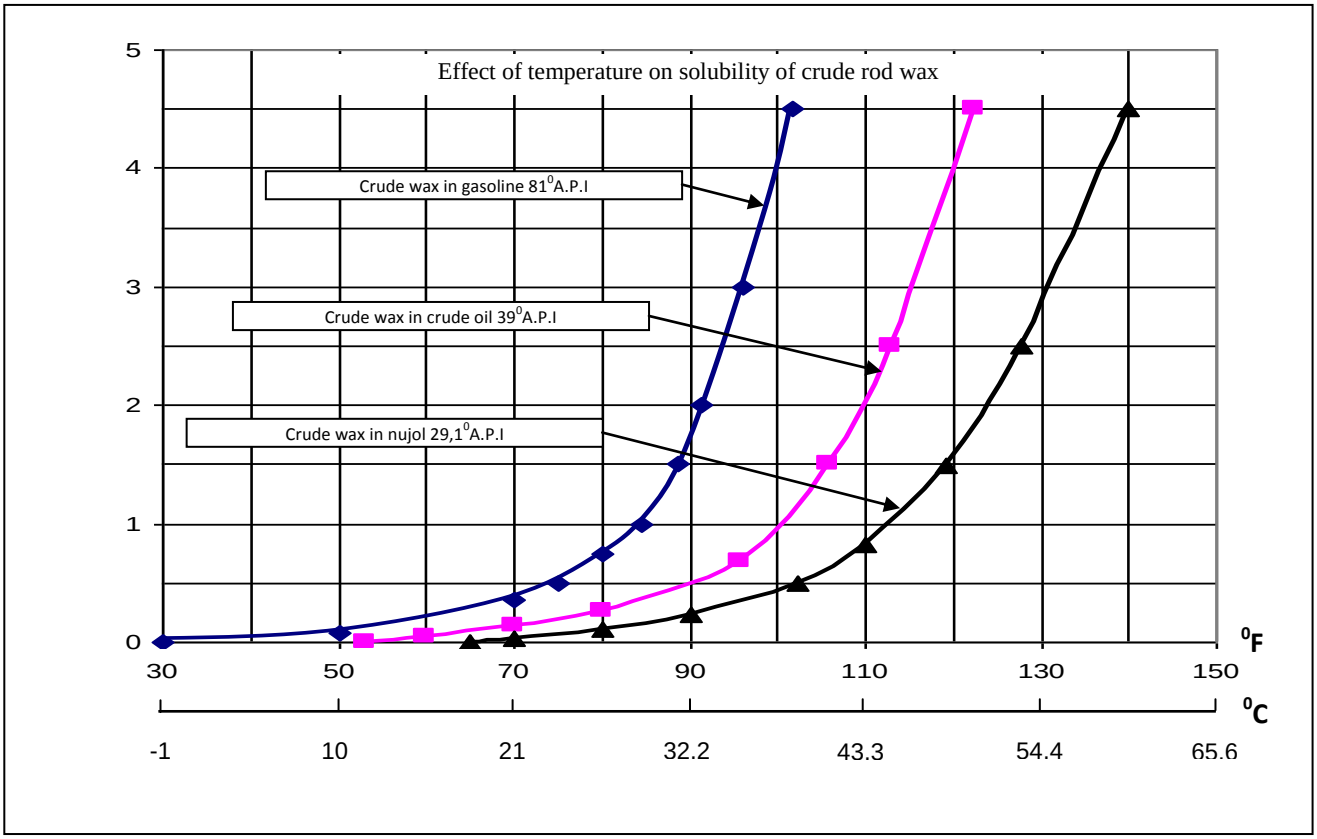
● swelling clay materials contained in the rocks that form the collector (39.0% silt and 33.2% clay fractions);

● blocking action of water due to capillary and surface phenomena occurring in the pore space;

● complications with the development of wells after drilling, work over and RIR, starting well after the temporary stop for operational reasons

● blocking the action of water, due to the capillary and surface phenomena occurring in the pore space as a result of the mutual displacement of immiscible liquids intense flooding;

● in the phenome-non of adhesion of the fundamental role played by the electric force, in particular, the phenomenon of formation of the electrical double layer and TP.



● Reduction in well productivity as a result of their killing sea water, accompanied by its absorption in significant

Many scientists from Russia, Azerbaijan, Vietnam, Kazakhstan and other countries felt that during the processing of the CCD thermal methods, depending on the conditions, you need to add some auxiliary special agents, such as temperature stable inhibitors, reagent - HDBM, which increases the capacity of penetration of the acid into the rock and demulgator to prevent formation of an emulsion of oil, water, and alkali compounds prevent precipitation of iron compounds. The authors of these patents used the catalysts that can increase the rate of reaction and HCl Mg, darning time of processing. These catalysts are mixtures of metals, mostly Al and other metals at a very low dose, metals such as Si, Cu, Mg, Zn, the amount of these additives is equal to 1 ÷ 2% weight relative to Mg.

Furthermore, the authors use proposed buffer liquid, which consists of 11% NaHSO4 solution and 5% Na2CO3 solution after injection into the bottom zone of the reservoir in the condition of high fluid temperature this buffer releases CO2 gas through the following reaction:

$$Na2CO3 + 2NaHSO4 = 2Na2SO4 + H2O + CO2 \uparrow, (3)$$

Table 1. *Estimated number of components for the thermo chemical reaction.*

Expressing gratitude to the scientists and experts in the field for their great work, at the same time to note that they are from our point of view is not adequately examined the influence of various factors on the effectiveness of the thermo-chemical reaction, namely:

* Area of coverage and the volume of the treated area, depending on the effective capacity of the reservoir;

* Porosity and permeability of the formation, the amount of magnesium required for the reaction;

* Magnesium liquid composition fluidity and volume of the buffer liquid for the safety of the work;

* The final temperature of the reaction, the amount of gas produced is H2, the technology of thermo chemical reactions and the formation of the CCD, etc.

Moreover, in their work place has at least 30-40% error compared to the heat balance equation.

We have to study formation of oil fields Gunesli in 2014-2015. We have shown that for a long time working wells are observed change their properties as compared to the initial selection. In general, it notes that the time development of gas content value formation of deposits in oil producing wells is reduced, the gas density increases, the volume ratio is decreased, which leads to increased density and molar mass of the oil reservoir [4,7].

It is known that an analytical study of the thermodynamic processes occurring in a porous medium, greatly complicated in cases when it is necessary to take into account the temperature difference between the solid skeleton of the porous body and its saturated liquid or gas. Given these characteristics, we believe that the study of thermo chemical processes in porous media must be considered:

Initial matmerialy	**reagent Weight** **kq**	**Cv0** **KJ / kg**	**The amount of heat supplied with the starting materials** **(Qv = m. Cv0.298), kJ**
1	2	3	**4**
Mg	1000	0,983898	**293.201,6**
HCl	3050	0,791365	**719271,6**
H2O carrier solution consisting	24500	4,182630	**30537381,6**
Buffer solution (diesel liter = 4000 * 0.78 = 3120kg)	3120	2,0	**1859520,0**
Starch	200	2,0	**119200**
antifoam agent	20	2,0	**11920**
In total	**31890**		**33 540 494,8**

● The temperature difference between the heat of the porous body (solid skeleton of the porous body) and saturating it with liquid;

● Temperature ranges deposits metering values;

● wetted surface of the porous volume of the medium;

● Volume reservoir for thermo chemical reactions;

● Heat loss;

● Boundary conditions for the transition criterion from one mode to another;

● mixed convection in the medium;

● the effect of temperature thermo chemical reaction on the viscosity of liquids.

Furthermore, to solve problems for practical use thermo chemical reaction must take into account rock surface wetting area, the temperature difference between the reaction and thermo chemical Seam temperature, porosity and permeability of reservoir rock, the diameter of the production tubing, power effective formation.

It should be noted that in the literature yet no more accurate research in this area.

We believe that the establishment and definition of new principles that describe the dynamics in fractured and classic reservoirs of these deposits, in solving the problem of enhanced oil recovery, will help eliminate the use of EOR techniques and designed for conventional porous (carbonate, sand etc .) reservoirs. Many experts at the hydrodynamic calculations unduly rely only on the simple concept of the conventional modes of reservoirs, without taking into account that deposits are mainly developed with a significant manifestation gravitational- capillary forces, including the operation of all types of processes impregnation and drainage. In addition, fluid flow into the cracks and simultaneous fluid flow in fractured matrix systems based on the principles of a radically symmetric flow.

Essence of the thermo chemical reaction is that as a result of the exothermic reaction releases a certain amount of heat energy. Due to heat exposure reduces the surface tension in the formation, improves the effectiveness of treatment of bottom hole zone increases relative permeability oil reservoir and is cleared from the pore-clogging ingredients.

The algorithm to determine the main components of the thermo chemical reaction to process the CCD to increase well productivity. The proposed thermal reaction looks like:

$$Mg + 2\ HCl = MgCl2 + H2 \uparrow + Q, \quad (1)$$

where Q exothermic (by dissolving 1 kg of magnesium in hydrochloric acid stands 18, 9 MJ of heat).

In the presence of the following second reaction begins in the formation of CaCO 3 content of a minor:

$$CaCO3 + 2HCl = CaCl2 + CO2 + H2O + Q, \quad (2)$$

To solve the problem initially make up the material balance for 1 reaction with 15% hydrochloric acid, we obtain the following data (Table 1).

Table 2. *Material balance for only one reaction with 15% hydrochloric acid*

Coming	**kq**	**%**
1.Mg	1000	3,47
2.HCl	3050	10,60
3.H_2O	24500	85,16
4. Starch or CMC	200	0,70
5. Defoamer	20	0,07
In total	28 770	100

For this write process heat balance equation:

$$Q1 + Q2 + Q3 + Qr = Q4 + Q5 + Qp \quad (3)$$

Where: Q1, Q2, Q3, - the amount of heat supplied from Mg, HCl, H2O;

Qr -thermal reacti

Q4, Q5, Qp - the amount of heat carried away MgCl2, H2 and loss.

Based on the heat balance equation determines the estimated amounts of the components for the thermo chemical reaction. Thermal calculations starting components at concentrations of 15% HCl solution and water in the composition of the technical solution of starch + + + buffer defamer presented in Table 1.

Calculation of the amount of heat carried away with the reaction products - Is represented heat consumption in *Table 3.*

The products obtained after reaction	The weight of the products obtained	kg Cv0 = Cpo-R	KJ / kg.
1	2	3	4
$MgCl_2$	4050	0,791365	3205,0
H_2	83,300	14,234830	1185,7
H2O carrier solution consisting	24500	4,182630	102474,4
Buffer solution (diesel = 4000litr * 0.78 = 3120kg)	3120	2,0	6240,0
Starch	200	2,0	400,0
antifoam agent	20	2,0	40
in total			113545,1

The amount of heat being vacated by calculation is ot1kg

Mg = (18.800 KJ.)

ΔT = Qpu / Σmi. (Cv0) I (4)

Then create a temperature gradient:

ΔT = 18800 000 kJ / 113545,1KDzh / 0C = 165,6 = 166 0C

After the reaction mass temperature is equal to:

166 (0C) + 200C = 1860C

The volume of gas released by the reaction is determined by the formula:

〖 〗 _ V (1) = (P_0 V_0 T_1) / (P_1 T_0), (5)

where - under normal pressure, MPa;

- The volume of gas emitted under normal conditions, l;

- Under normal temperature, K;

- Bottom hole temperature, K;

- Bottom-hole pressure, MPa.

〗 〖V _ (0) M / μ * 22,4, (6)

where - mass of the gas, kg;

- the molar mass of the gas, kg / mol.

In the study of thermo chemical processes in a porous medium, it is necessary to take into account the temperature difference between the solid skeleton of the porous body and fills it with liquid. To determine the heating of the porous body (in this case using magnesium) proposed the following formula:

N = S (Ť -T1), (7)

where N - thermal capacity flow, heating the porous body unit volume, S - wetted surface in a unit volume of the porous medium, the temperature T generated by the reaction, T1 - porous body temperature.

Given that the temperature ranges of metering values fundamental deposits of 120-160 0C, 80-1100S Lower Miocene, Lower Oligocene 120-140 0C. Then, for the foundation:

T1 = 0,0238 * N 51.04 (8)

Where H - the depth of the well of the filter, m.

For the Lower Miocene and Oligocene:

T1 = 0,034 * N 11.64 (9)

The following formula is proposed to determine the surface wetting of the porous medium volume

S = Dak * m * m in n / k (10)

Where take - the inner diameter of the production string, cm, m - porosity,% Bn - layer production factor%, to - permeability in Darcy.

The volume of the reservoir for the thermo chemical reaction is determined by the following formula:

V = S h (11)

Where h is the effective seam thickness, m.

It is known that the reaction 24,3g-atom Mg consumed 73 g mol-HCl (2 * 36.5 g mol = 73g) (see Table. Mendeleev). At 100g Mg required 300,4g HCl (100 * 73 / 24.3). Clearly, 100g 12% - strength solution of HCl contains 12g HCl. Then 3004 g HCl 2503,3g will contain a 12% HCl solution (300.4 * 100/12 = 2503,3g). According to the heat balance equation of heat loss from the heated water and HCl is from 10 to 15% of the heat of reaction. To determine the amount of magnesium in order to conduct the thermo chemical reaction in the well serves the following formula:

W = 1,15 * V * (Tr - Ts) * S / 4520 (12).

where Tb - the temperature of the reaction,

Ts - face temperature,

C is the specific heat of the aqueous solution of magnesium chloride kcal (P = 0.75).

4520 kcal of heat that is released by 1 kg of magnesium. [4]

We first propose a completely new algorithm for solving practical problems in the field of processing of the CCD using thermo chemical reactions. We proposed algorithm takes into account the real state of the wells, taking into account the physic-chemical and geological formation factors. Thanks to a new algorithm could resolve the case by determining the amount of magnesium for the treatment of IPF for CCD using thermo chemical reactions.

References

1. 1.Bendiksen, K., Malnes, D., Moe, R., Nuland, S. (1991). The dynamic two fluid model. OLGA - 17 theory and applications. Prod. Engine, 6: 171-80.
2. Patent RU 2 168 008 (1999)
3. Patent RU 2073696 C1 (1997)
4. Patent of Azerbaijan Republic. № I 2003, 0118, Baku-2003
5. Patent US 1,657,628
6. Patent US 1,657,631
7. Patent RU 2167284 C2 (2000).