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(54) **Title**: METHOD FOR THE ADDITIONAL DEVELOPMENT OF DEPLETED NATURAL HYDROCARBON DEPOSITS

(57) **Abstract**: The present invention relates to oil-gas industry, specifically - to additional development of depleted natural hydrocarbon deposits. Under the proposed method: the deposit is prepared for additional development; at least one injection well is created and/or used to pump at least one working agent into the deposit for the purpose of obtaining hydrogen, oxygen and methane homologs and further extracting the natural hydrocarbons remaining in the stratum; at least one working agent is injected until the predetermined formation pressure is achieved in the deposit; at least one production well is created and/or used; extraction of formation fluids is started after the specified formation pressure is reached in the deposit; water, hydrocarbons, hydrogen, oxygen and carbon dioxide are recovered from the extracted formation fluids; the extracted water and unreacted carbon dioxide are directed to at least one injection well for reinjection into the deposit. The proposed method is suitable for all types of depleted natural hydrocarbon deposits. It permits: firstly, not only burying carbon dioxide underground, but also utilizing it for production of hydrogen, oxygen and methane homologs in the stratum; secondly, further extracting the oil, gas and condensate remaining in the stratum; thirdly, not only incurring costs, but also generating revenue from the sale of the above-mentioned products.

Method for the Additional development of Depleted Natural Hydrocarbon Deposits

TECHNICAL FIELD

The present invention relates to the oil-gas industry, specifically to development of depleted natural hydrocarbon deposits.

Natural hydrocarbon deposits are generally understood to include gas, gas condensate, oil, oil and gas condensate, gas condensate and oil, and gas hydrate deposits.

The inventors have excluded gas hydrate deposits from further consideration as they are not currently under commercial development.

We will consider deposits with the word "oil" in their name to be oil deposits, since maximum oil extraction is the primary problem to be solved when developing such deposits.

BRIEF SUMMARY AND PRIOR ART

Modern methods used to develop natural hydrocarbon deposits under are not very efficient. Gas losses during gas deposit development amount to 10-20% and more. While, condensate losses, during gas condensate deposit development, reach as high as 70% (Vuktyl field). The average level of oil extraction from Russian oil fields is only approximately 30% [Bokserman A.A.: Oil recovery and renewal. // Nefteservis Analytical Magazine, No. 3 (11), p. 24-26, 2010].

Oil extraction in developed countries is usually more efficient, since many oil companies strategically strive to achieve an average of approximately 70% oil extraction [Surguchev M.L. Secondary and tertiary methods of increasing oil recovery from strata. Moscow: Nedra. 1985. 308 p.]. However, published data on all oil fields in the world are not available.

Nevertheless, based on the above, it is safe to say that increasing the efficiency of natural hydrocarbon deposit development, which eventually comes down to the development of depleted deposits, is one of the current challenges faced by the oil and gas industry both in Russia and all over the world.

Another equally important challenge is related to environmental protection through reducing carbon dioxide emissions into the atmosphere.

The proposed invention aims to address these two challenges.

There already exists a method of using depleted gas deposits for underground gas storage. Numerous implementation examples of this method can be found around the world. In Russia, the most characteristic example is the conversion of the Khadumskaya deposit at the Severo-Stavropolskoye field to an underground gas storage [Varyagov S.A. Scientific and Engineering Problems Encountered during Creation and Operation of Severo-Stavropolskoye Underground Gas Storage. / Materials of international conference "Underground Gas Storage: Reliability and Efficiency" (Moscow, October 11-13, 2006): 2 volumes. Volume 1, p. 93-109. – Moscow: Gazprom Information and Advertising Center, LLC, 2007, - 190 p.].

Depleted gas condensate deposits are also converted for this purpose. Examples of this in Russia are the Kushchevskoye field in the Krasnodar Territory, the Sovkhoznoye field in Orenburg Region, and the Kanchurinsko-Musinskiy underground gas storage facility in the Republic of Bashkortostan.

Recent research has been conducted on natural gas injection into depleted oil deposits. The purpose of these activities is to create underground gas storages and at the same time improve the oil recovery factor in depleted oil deposits. Examples of such fields in Russia are the Yelshano-Kurdyumskoye, Peschano-Umetskoye, and other fields [Khan S.A. Program of underground gas storage activities in the Russian Federation for 2005-2010. / Materials of international conference "Underground Gas Storage: Reliability and Efficiency" (Moscow, October 11-13, 2006): 2 volumes. Volume 1, p. 57-65 – Moscow: Gazprom Information and Advertising Center, LLC, 2007, - 190 p.]. The essence of using this method in depleted natural hydrocarbon deposits is as follows:

The user of subsurface resources utilizes the available wells at the depleted deposit for the purpose of gas injection into the stratum for storage and gas extraction during use..

However, at times additional wells have to be drilled for the purpose of underground gas storage. In this case, they serve the same functions during the gas extraction and injection cycles.

Conversion of a depleted gas condensate deposit to an underground gas storage facility has an additional positive effect in the form of gas condensate appearing in the extracted product. This is the condensate that was deposited in the stratum and began evaporating partially into the dry gas pumped into the depleted reservoir.

When a depleted oil deposit is converted into an underground gas storage facility, the residual oil to a certain degree is dissolved in the injected gas (depending on pressure and temperature conditions), i.e. the formation of the underground gas storage results in an increase in the final oil recovery.

Operation of an underground gas storage facility requires retrofitting the existing field infrastructure, including installation of an additional compressor plant with higher capacity and pressure compared the one already available at the field.

Underground gas storage imposes more requirements for monitoring of gas injection and recovery process as well as possible gas leaks from storage.

This method has the following drawbacks:

The method is designed to cover only seasonal or daily gas consumption peaks and does not solve the problem of environmental protection, as proposed by this disclosure.

The method in question increases the load on the Earth's atmosphere, because the compressors used to pump the gas into the stratum (and deliver it to the consumers) release a considerable amount of carbon dioxide.

The majority of depleted natural hydrocarbon deposits are located far away from the cities and towns that need underground gas storage. Therefore, this method cannot be used in such cases.

There is already difficulty in recovering large volumes of low-pressure gas remaining in the strata of depleting Urengoyskoye, Medvezhye and Yamburgskoye fields in Western Siberia, as it is uneconomical to deliver this gas into long distance pipelines.

In such cases, use of low-pressure gas for local production of electric energy, methanol and other products is considered as a possible recovery method [Lapidus A.L., Golubeva I.A., Krylov I.F., Zhagfarov F.G.: Comprehensive natural gas processing into chemical products and engine fuels. // Special issue of the Gas Industry magazine, 633/2009, p. 112-115].

The drawback of this method is that it does not allow for the recovery of large volumes of low-pressure gas due to lack of consumers for the final products. Besides, even local consumers impose limitations on the pressure of the gas delivered to them.

The earlier mentioned method of injecting gas into depleted oil deposits for the purpose of improving oil recovery can be considered as a prototype for this disclosure. However, the drawbacks of the above analogues apply to the prototype as well.

As for depleted gas deposits, the method of carbon dioxide injection into such deposits is considered to be the prototype [Galis H., Cawley S., Bishop S., Todman S., Gas F. CO2 injection into depleted gas reservoirs // J. Petrol. Techn. 2010. No. 7, p.76-79].

The specific features for implementation of this method are similar to those characteristic of underground gas storage. However, the differences are as follows:

- carbon dioxide rather than gas is injected into the stratum; therefore, a source of carbon dioxide is necessary,

- only the injection cycle takes place, without subsequent extraction of carbon dioxide.

The prototype method has the following drawbacks:

The method is designed for carbon dioxide disposal only, i.e. it does not provide for additional development of the gas deposit.

The method is unprofitable both in terms of capital and operating costs. It will only become widespread when the emission penalties exceed the costs of underground disposal of carbon dioxide. However, this is not a very efficient way to protect the environment.

Similar remarks apply to possible attempts to dump carbon dioxide into depleted gas condensate and oil deposits. Moreover, oil deposits will likely be less attractive, since their field infrastructure is mainly designed for low pressures and compressor facilities are rarely used.

The authors were led to the idea of the proposed invention by the research results on the genesis of oil and gas. Initially, a model was validated regarding the global circulation of water in nature, whereby water transfers carbon dioxide from the atmosphere to the depths of the Earth during the descent phase (thus explaining the origin of natural hydrocarbons [Barenbaum A.A. Oil and gas deposit formation mechanism // Reports of the Academy of Sciences. 2004. Volume 399. No. 6. p. 802-805].

Cycles of laboratory experiments has been performed in recent years. This invention is based on the results of those experiments.

DESCRIPTION OF DRAWINGS

Fig. 1 is schematic diagram illustrating an experimental plant diagram, in accordance with the present disclosure;

Fig. 2 is an illustration of chromatograms of gases produced in reaction (1) with low (A) and high (B) hydrogen output, in accordance with the present disclosure;

Legend: a – hydrogen; b – methane; c – isopentane. At high output the hydrogen peak surpasses the methane peak.

DETAILED DESCRIPTION

Experimental Evidence

The invention is based on the results of laboratory experiments related to the genesis of natural hydrocarbons in the depths of the Earth.

The experiments included passing an aqueous solution of carbon dioxide, simulating meteorological water, through a porous bulk medium, simulating Earth crust rocks with typical terrigenous and carbonaceous composition. An admixture of iron-bearing compound (iron turnings, powdered iron oxide and dioxide etc.) was added to the model media as catalyst. The experiments were conducted at room temperature and atmospheric pressure at the outlet of the laboratory device.

A simplified diagram of the laboratory unit developed for this purpose is shown in Fig. 1. The illustrated components are labelled as follows: 1 – reaction column with a heating element, 2 – mixer, 3 – accumulating separator, 4 – gas chromatograph, 5 – carbon dioxide cylinder, 6 – pressure reducer, 7 – adjustable valve, 8 – pressure gauge, 9 – recirculating pump, 10 – flow meter, 11 – pH meter.

The unit comprised of a reaction (or reactor) column (1), filled with bulk model substance. Water with the specified dissolved carbon dioxide concentration was supplied to the reaction column inlet from a mixer (2). Upon exiting the reaction column the fluid was delivered to an accumulating separator (3) where gaseous reaction products were separated from it for subsequent analysis by a gas chromatograph (4). A 20 litre tank capable of withstanding pressure up to 15 atmospheres served as the mixer. A carbon dioxide cylinder (5) was used to prepare the solution. Carbon dioxide concentration in the solution was adjusted through pressure and the duration of water saturation with carbon dioxide in the mixing unit.

Both distilled water and artesian well water were used in the experiments. The pressure of carbon dioxide supplied to the mixer varied from 1 to 12 atmospheres. This made it possible to control the flow rate of the solution through the reaction column. The reaction column is designed as a 1 meter long piece of plastic tube with inner diameter of 19 mm. On the outside of the tube an electric heating coil was installed for heating in separate experiments. Field chromatograph "Khromoplast-001", designed for the measurement of hydrogen, methane, ethane, propane, isobutane, butane, isopentane and pentane content in the gas mixture, served as a gas analyzer. The analyzer had two chromatographic columns of various lengths, which allowed the determination of hydrogen and the above mentioned gases with the accuracy of ~0.01%.

The experiments showed that passing an aqueous solution of carbon dioxide through the model medium resulted in water decomposition with generation of hydrogen and oxygen. Generation of methane (CH_4), ethane (C_2H_6), butane and isobutane (C_4H_{10}) was also observed. Fig. 2 shows the chromatograms of gases produced in reaction (1) with low (A) and high (B) hydrogen output. The following spikes are identified in the chromatograms: a – hydrogen, b – methane, and c – ethane. In case of high output the hydrogen spike overlaps the methane spike.

The output of hydrogen and hydrocarbon gases as reaction products were considerably influenced by the carbon dioxide concentration in the aqueous solution, flow rate of the solution through the reaction column, the pressure in the reaction column, as well as the catalyst type and amount.

The experiments proved the performance capacity of the proposed laboratory device. In particular, they showed that a process of water decomposition in the presence of carbon dioxide and rocks with catalytic properties accompanied by polycondensation synthesis of oil and gas series hydrocarbons and generation of hydrogen and oxygen is occurring in sedimentary rocks in the Earth's crust.

The inventors have observed that the results of the experiments can be described by the following equation:

$$nCO_2 + 4(n+1)H_2O = C_nH_{2n+2} + (3n+1)H_2 + (3n+1)O_2$$

Despite low pressures and temperatures (room temperature and pressure of 10-15 atmospheres at the reaction column outlet) as well as the relatively small length of the reactor column, hydrogen output reached up to 10%, while methane and isobutane output amounted to fractions of a percent.

Therefore, the results of laboratory experiments corroborate the oil and gas genesis model described in [Barenbaum A.A. Oil and gas deposit formation mechanism // Reports of the Academy of Sciences. 2004. Volume 399. No. 6. p. 802-805]. At the same time the experiments showed that hydrogen and oxygen are generated in the depths of the Earth as a result of water decomposition. Presence of a catalyst causes separation of carbon from carbon dioxide in the aqueous solution. This carbon together with hydrogen from the water then participates in the hydrocarbon synthesis reaction.

Due to the common mechanism for the genesis of hydrocarbon and the formation of hydrogen and oxygen, it is possible to substantiate a method for additional development of both oil and gas fields which is targeted at reducing man-made carbon dioxide.

The objective of this invention is to create a method for the additional development of depleted oil and gas deposits that would permit the additional extraction of residual gas, oil and condensate reserves as well as hydrogen, oxygen and hydrocarbons synthesized in the stratum by means of man-made carbon dioxide disposal.

Under the proposed method for the additional development of depleted natural hydrocarbon deposits, the deposit is prepared for additional development.

A 3D geological, and subsequently – a 3D gas-hydrodynamic model of the productive stratum is built for the natural hydrocarbon deposit in question. The 3D hydrodynamic model of the stratum is adapted to the actual well operating conditions and the deposit development monitoring data.

Taking into account the chemical reactions occurring in the stratum, a series of forecast calculations is carried out using the adapted 3D hydrodynamic model of the stratum to identify the best option (from the engineering and economic standpoint) for additional development of the deposit in question, including for the injection of the working agent.

The best (optimal) option for additional development is selected based on the specified optimality criterion – for example, net present value (NPV).

It is advisable to create a computer model of the entire additional development process based on the available data, selecting the optimal parameters.

The optimal well distribution pattern, well operation modes and target average formation pressure dynamics are determined for the best additional development option.

The retrofitting and well workover activities necessary to adapt the field to operate under the higher pressures required for injecting the working agent are carried out.

An aqueous solution of carbon dioxide can be used as the working agent. Alternatively carbon dioxide can be injected into the most flooded parts of the deposit in a gaseous form. Another possibility is to alternate injection of water plugs and gaseous carbon dioxide into the stratum. If necessary, injection options can be combined.

At least one injection well is created and/or used to pump at least one working agent into the deposit for the purpose of obtaining hydrogen, oxygen and methane homologs and further extracting the natural hydrocarbons remaining in the stratum. Also, at least one working agent is injected until the specified/predetermined formation pressure is achieved which is necessary for the reaction to occur and for additional hydrocarbons to be extracted from the deposit.

Then at least one production well is created and/or used. Extraction of formation fluids is started after the specified/predetermined formation pressure is reached in the deposit. Water, hydrocarbons, hydrogen, oxygen and carbon dioxide are recovered from the extracted formation fluids. The extracted water and unreacted carbon dioxide are directed to at least one injection well for reinjection into the deposit.

The proposed method can be implemented as a continuous process. Water and/or carbon dioxide can be used as the working agent. A possible option is to use a catalyst when injecting the working agent. If no catalysts are present in the material composition of the deposit rocks, the selected catalyst is added to the aqueous solution of carbon dioxide or water injected into the stratum. Known substances used as catalysts in Fischer-Tropsch hydrocarbon synthesis and hydrogen generation by methane conversion serve as catalysts.

Implementation of the method described has certain specific features when applied to the three main types of depleted natural hydrocarbon deposits – gas, gas condensate and oil.

The method for the additional development of depleted gas deposits involves the use of the existing field infrastructure, including gas wells; carbon dioxide injection into the stratum not only for the purpose of its underground disposal, but also to enable renewal of hydrogen, oxygen and natural gaseous hydrocarbons in the stratum and for additional extraction of low-pressure gas remaining in the stratum; use of some of the available wells as production wells and the rest – as injection wells; carbon dioxide injection in the form of an aqueous solution through injection wells; extraction of low-pressure gas, hydrogen and methane homologs synthesized in the stratum, and water from the production wells; separation of the extracted products on the surface; delivery of gaseous products to the consumers after processing, and reinjection of the extracted water and unreacted carbon dioxide into the stratum through injection wells.

If necessary, the existing well stock is supplemented by drilling new production and injection wells, including use of horizontal drilling technologies; carbon dioxide is pumped into all or some of the injection wells in a gaseous form; the proposed method is implemented by alternating injection of water plugs and gaseous carbon dioxide into the stratum; the process of additional development of the gas deposit is monitored using known hydrodynamic and geophysical methods, including analysis for ^{14}C isotope content.

The proposed method for the additional development of depleted gas condensate deposits involves the use of the existing field infrastructure; availability of a carbon dioxide source; carbon dioxide injection into the stratum not only for the purpose of its underground disposal, but also to enable renewal of hydrogen, oxygen and natural gaseous hydrocarbons in the stratum and additional extraction of low-pressure gas and condensate deposited in the stratum; use of some of the available wells as production wells and the rest – as injection wells; carbon dioxide injection in the form of an aqueous solution through injection wells; extraction of low-pressure gas and gas condensate dissolved in it, condensate deposited in the stratum and displaced by the injected aqueous solution of carbon dioxide, methane homologs synthesized in the stratum, hydrogen and oxygen generated as a result of water decomposition, and water from the production wells; separation of the extracted products on the surface; delivery of gaseous products to the consumers after processing and recovery of unreacted carbon dioxide, and reinjection of the extracted water with new portions of carbon dioxide, unreacted carbon dioxide and water into the stratum.

If necessary, the existing well stock is supplemented by drilling new production and injection wells, including use of horizontal drilling technologies; carbon dioxide is pumped into all or some of the injection wells in a gaseous form; the proposed method is implemented by alternating injection of water plugs and gaseous carbon dioxide into the stratum; filtration flow directions are changed and flow and input profiles are adjusted in production and injection wells to improve the sweep efficiency; the process of additional development of the gas condensate deposit is monitored using known hydrodynamic and geophysical methods, including analysis for ^{14}C isotope content.

The proposed method for the additional development of depleted oil deposits involves the use of the existing field infrastructure, including production and injection wells, and carbon dioxide injection into the stratum not only for the purpose of its underground disposal in the oil deposit, but also to enable renewal of natural hydrocarbons, hydrogen and oxygen in the stratum and additional extraction of oil and gas remaining in the stratum; putting all wells previously decommissioned due to flooding or asset unprofitability back into operation; carbon dioxide injection in the form of an aqueous solution through injection wells; recovery of residual oil and gas dissolved in it, water, unreacted carbon dioxide, methane homologs synthesized in the stratum as well as hydrogen and oxygen generated; separation of the extracted products on the surface; delivery of oil and gas products to the consumers after processing and recovery of unreacted carbon dioxide, and reinjection of the extracted water with new portions of water, carbon dioxide and unreacted carbon dioxide into the stratum.

If necessary, the existing well stock is supplemented by drilling new production and injection wells, including the use of horizontal drilling technologies; carbon dioxide is pumped into all or some of the injection wells in a gaseous form; the proposed method is implemented by alternating injection of water plugs and gaseous carbon dioxide into the stratum; filtration flow directions are changed and flow and input profiles are adjusted in production and injection wells to improve the sweep efficiency; the process of additional development of the gas deposit is monitored using known hydrodynamic and geophysical methods, including analysis for ^{14}C isotope content.

DESCRIPTION OF EMBODIMENT

There are minor differences in the proposed method for the additional development of depleted hydrocarbon deposits depending on the deposit type. Therefore, we will use the most general case – a depleted oil deposit – to provide an example of its implementation.

We assume that field infrastructure (including wells) as well as a source of carbon dioxide and equipment for its injection into the stratum is available.

In this case the characteristic features of implementation of the proposed additional development method will be as follows.

Prediction calculations are performed using the created 3D model of the stratum in 3D multi-component arrangement, taking the chemical reactions occurring in the stratum according to the above-mentioned equation into account. The optimal option of additional development of the oil deposit by carbon dioxide injection into the stratum is identified.

The available wells are divided into the production well stock and injection well stock. This predefines their position in the oil productive area.

According to the additional development project, an aqueous solution of carbon dioxide is pumped into the least flooded parts of the deposit through some of the injection wells and gaseous carbon dioxide is pumped into the most flooded parts of the deposit through the rest of the injection wells.

The injected working agent maintains formation pressure and forces the oil remaining in the stratum towards production well bottoms.

Carbon dioxide in aqueous or gaseous phase begins dissolving in the oil as well as in the residual water. As a result, oil and residual water volume is increased, leading to higher oil mobility. This creates conditions for filtration of some of the oil remaining in the stratum towards production well bottoms due to movement of the water front with carbon dioxide dissolved in the water.

Working agent injection and displacement of the above-mentioned gaseous and liquid fluids towards production well bottoms causes the production wells to produce oil along with injected and residual water with carbon dioxide dissolved in it as well as some of the unreacted carbon dioxide.

According to the results of laboratory experiments, hydrogen and oxygen generated by water decomposition in the presence of natural catalysts as well as methane homologs synthesized in the stratum appear in the production well products.

As seen from the above, the proposed underground carbon dioxide disposal method is different from the traditional one. Specifically, the injected carbon dioxide first performs the function of a useful agent by participating in additional extraction of oil and gas remaining in the stratum, and even more importantly – in hydrogen and oxygen generation and in the extraction of synthesized methane homologs. It becomes just a "buried" gas only when extraction of the above-mentioned products drops to an unprofitable level.

Products extracted from production wells undergo field processing. Oil and water are recovered from the liquid phase. Oil is delivered to the consumers, and water is reinjected into the stratum. Hydrogen, oxygen, methane homologs and unreacted carbon dioxide are recovered from the gaseous phase. Hydrogen, oxygen and methane homologs are delivered to the consumers, and carbon dioxide is reinjected into the stratum with the water. If needed, catalysts are introduced into the carbon dioxide solution injected into the stratum together with additional amounts of water and carbon dioxide.

Where necessary, the existing well stock is supplemented by drilling new production and injection wells, including use of horizontal drilling technologies.

If the oil deposit is heavily flooded, carbon dioxide is injected in a gaseous form.

Depending on the degree of flooding as well as zonal and stratified heterogeneity of the stratum in terms of porosity and permeability, the proposed method is implemented by alternating injection of water plugs and gaseous carbon dioxide.

If there is zonal and stratified heterogeneity of the stratum in terms of porosity and permeability, filtration flow directions are changed and flow and input profiles are adjusted in production and injection wells, respectively, to improve the sweep efficiency.

The process of the additional development of the oil deposit is monitored using known hydrodynamic and geophysical methods (including analysis for ^{14}C isotope content which allows identifying natural and synthesized methane homologs) as well as 3D computer modelling methods.

The proposed method for the additional development of oil (gas and gas condensate) deposits supplemented with the process of underground carbon dioxide disposal in the stratum is based on the traditional equipment and technologies used to extract gas and liquid products and inject working agents in the form of gaseous and liquid fluids.

The scientific aspect of the method is validated by the results of laboratory experiments carried out by the authors in the course of researching oil and gas genesis mechanisms.

Actual data that can be viewed as proof of the practical feasibility of the proposed method can be found in [Šmigaň P., Greksak M., Kozankova J. et all. Methanogenic bacteria as a key factor involved in changes of town gas stored in an underground reservoir // FEMS Microbiology Ecology. 1990. V.73. P.221-224.]. The authors of this work provided data on chemical composition of so-called town gas pumped into and extracted from Lobodice (the Czech Republic) underground gas storage created in a water-bearing stratum. The gas injected into the storage contained 20% CH_4, 20% CO_2+CO, and 55% H_2. However, when the gas was extracted half a year later, its composition was different: CH_4 – 40%, CO_2+CO – 12% and H_2 – 37%. The methane content in the extracted gas increased twofold as compared with the injected gas over half a year, with an almost equal decrease of the total carbon dioxide and monoxide content.

The hydrogen content also dropped, which is most likely an indication of leakage of this mobile and very light gas from the trap in the water-bearing stratum of Lobodice gas storage. The authors of the cited research refer to life activity of underground methane-producing bacteria as a possible reason for the changes in the injected gas composition. However, the results of laboratory experiments carried out by us provide a more natural explanation of the above data.

As for hydrogen leakage, it is quite common in the nature. This phenomenon is described in numerous publications, for example – in the materials of the Russian national conference on the issues of the Earth degassing with international participation. For instance, see [Larin N.V., Larin V.N., Gorbatikov A.B. Circular structures created by hydrogen underflows. / Materials of the conference "Earth degassing: geotectonics, geodynamics, geofluids, oil and gas, hydrocarbons and life". October 18-22, 2010, Moscow, p. 284-288]. The authors describe numerous cases of hydrogen escaping to the day surface. The concentrations of hydrogen measured at the seepage locations reach up to 2% at the depth of up to 120 cm. As a result, the authors consider it possible to use hydrogen extracted from deep wells for power generation.

The above reference proves the fact of hydrogen genesis in the depths of the Earth without artificial stimulation of the corresponding process.

Therefore, the proposed method for the additional development of oil deposits allows complete or partial recovery of expenses on underground carbon dioxide disposal through additional extraction of low-pressure gas, residual oil and condensate, hydrogen, oxygen, and methane homologs synthesized in the stratum.

The known prototype method of using depleted gas or gas condensate deposits for the underground disposal of carbon dioxide is unprofitable and does not even provide for extraction of gas and condensate remaining in the stratum. Use of depleted oil deposits for underground carbon dioxide disposal has not yet been considered by anyone due to the deterrents mentioned above.

The proposed additional extraction method offers the following advantages:

- it is suitable for all types of depleted natural hydrocarbon deposits,

- it compares favourably with the prototype since it permits:

firstly, not only burying carbon dioxide underground, but also utilizing it for production of hydrogen, oxygen and methane homologs in the stratum;

secondly, further extracting oil, gas and condensate remaining in the stratum;

thirdly, not only incurring costs, but also generating revenue from the sale of the above-mentioned products.

CLAIMS:

1. The method for the additional development of depleted natural hydrocarbon deposits, according to the said method:

- the deposit is prepared for additional development;
- at least one injection well is created and/or used to pump at least one working agent into the deposit to obtain hydrogen, oxygen and methane homologs and further extracting the natural hydrocarbons remaining in the stratum;
- at least one working agent is injected until the predetermined formation pressure is achieved in the deposit;
- at least one production well is created and/or used;
- extraction of formation fluids is started after the predetermined formation pressure is reached in the deposit;
- water, hydrocarbons, hydrogen, oxygen and carbon dioxide are recovered from the extracted formation fluids;
- the extracted water and unreacted carbon dioxide are directed to at least one injection well for reinjection into the deposit.

2. The method according to claim 1, wherein the preparation of the depleted deposit for additional development comprises collection of information on the state of the deposit, creation of 3D geological and hydrodynamic models, adaptation of the 3D hydrodynamic model to the actual production history, performance of optimizing prediction calculations with selection of the best additional development option and determination of the optimal well operating parameters and pattern; retrofitting and well workover activities necessary to adapt the field to operation under higher pressures; determination of the required formation pressure based on the optimal engineering and economic parameters of the process using the created model.

2. The method according to claim 1, wherein the method is implemented as a continuous process.

3. The method according to claim 1, wherein water and/or carbon dioxide is used as the working agent.

4. The method according to claim 1, wherein a catalyst is used when injecting the working agent.

5. The method according to claim 4, wherein the catalyst is added to the aqueous solution of carbon dioxide or water injected into the stratum.

6. The method according to claim 4 or claim 5, wherein the known substances being used as catalysts in Fischer-Tropsch hydrocarbon synthesis and hydrogen generation by methane conversion serving as catalysts.

7. The method according to claim 1, wherein existed well stock can be optionally supplemented by drilling new production and injection wells, including use of horizontal drilling technologies.

8. The method according to claim 3, wherein carbon dioxide is pumped into all or some of the injection wells in a gaseous form.

9. The method according to claim 1, wherein the method is implemented by alternating injection of water plugs and gaseous carbon dioxide into the stratum.

10. The method according to claim 1, wherein filtration flow directions are changed and flow and input profiles are adjusted in production and injection wells.

11. The method according to claim 1, wherein process of additional development of the gas deposit is monitored using known hydrodynamic and geophysical methods, including analysis for ^{14}C isotope content, as well as 3D computer modelling methods.

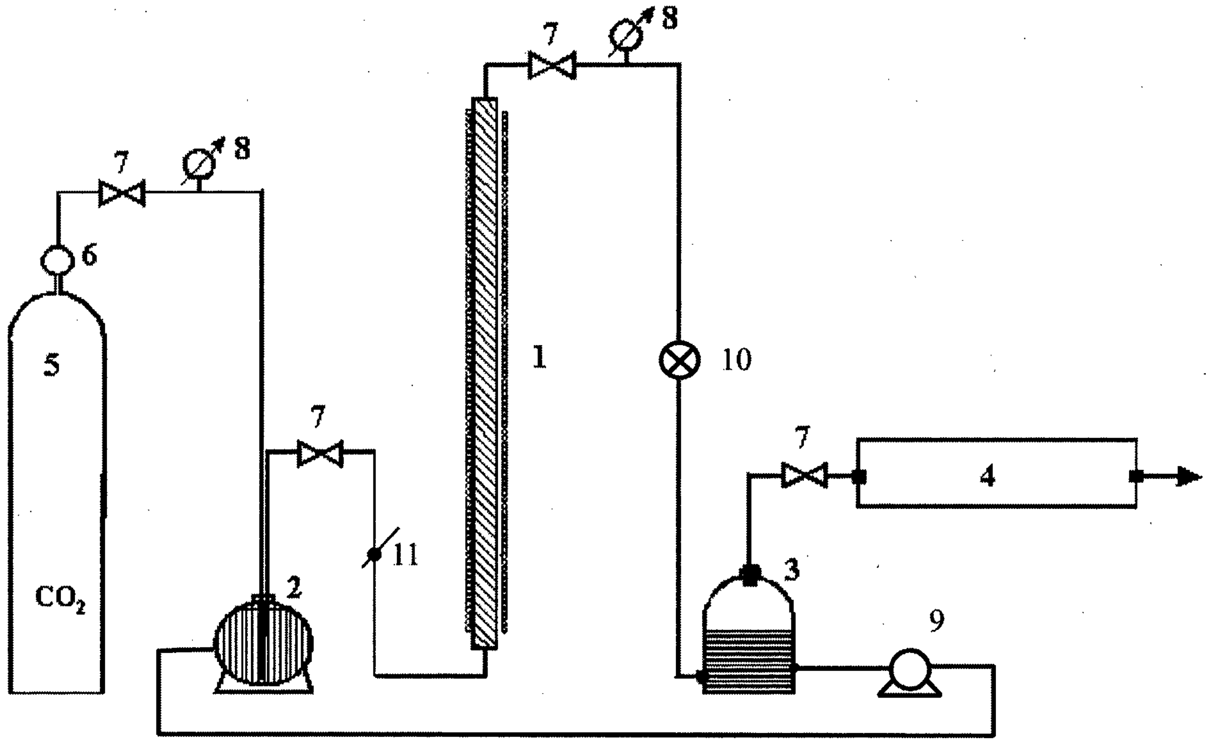
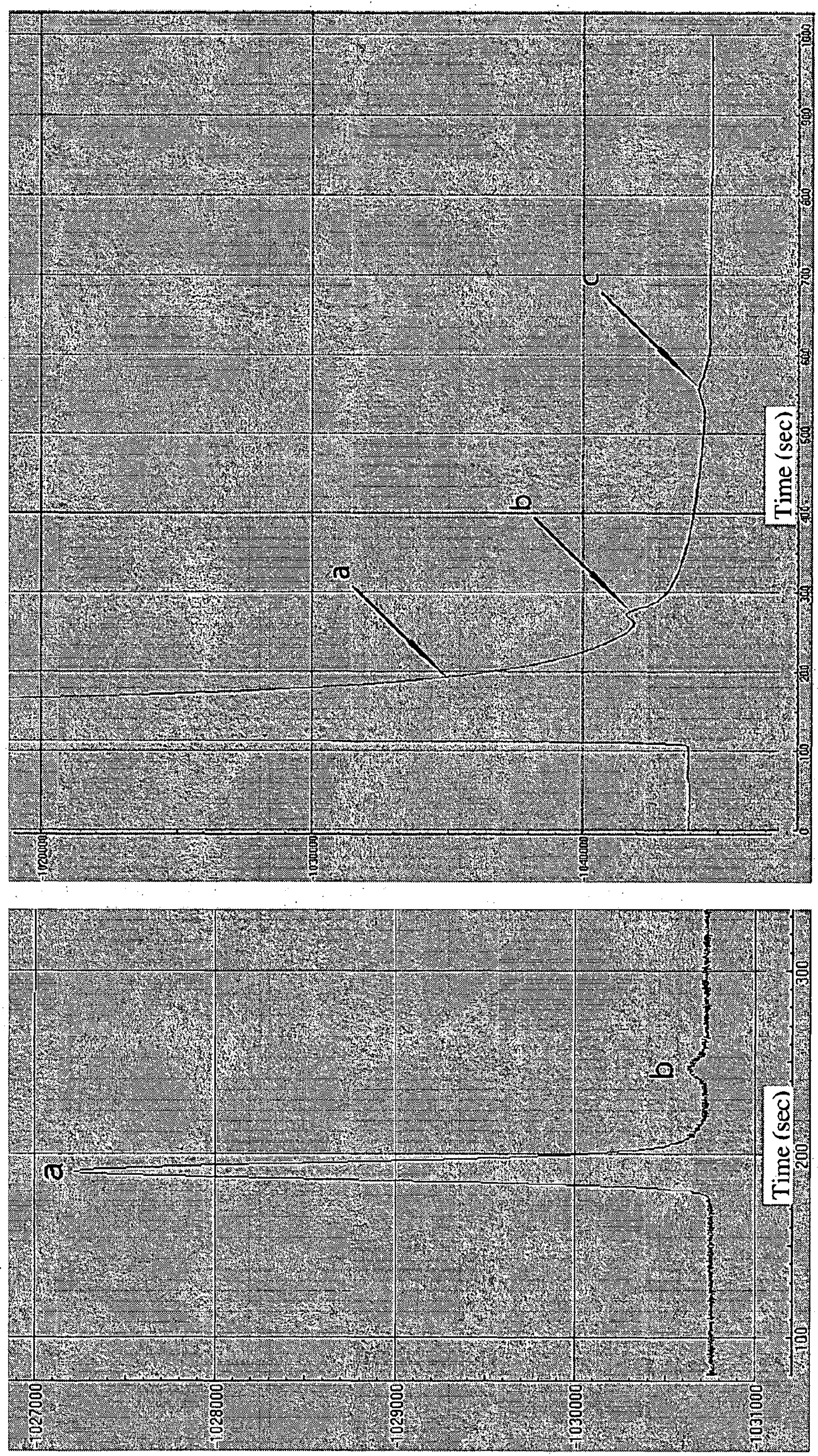


Fig. 1



b

a

Fig. 2