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Increasing Oil Reserve Using Secondary Recovery Methods

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Abstract

The paper presents some secondary methods applied in Romania to increase the oil recover. Special attention is given to chemical and thermal methods, injection of microbial solutions, mining, CO_2 injection and horizontal drilling. The paper put in evidence the very good results obtained in the application of thermal methods. The paper presents also the problems and difficulties met during the secondary recovery process implementation and development and the solutions applied to solve them.
The last chapter of the paper presents the perspectives of using in the next future some of these methods in Romania. Depending on the new technical and economical conditions there are very good perspective for water injection and for steam injection.

Key words: *secondary oil recovery, oil reserve, water injection, steam injection, thermal methods.*

Introduction

An oil reservoir is produced first using his own energy and that is why this is called primary method. In this phase the oil rate and the production decline is high, but the recovery factor is generally low, 5 – 25%. Due to the diminution in time of the reservoir's energy, it is necessary to supplement it using different methods. Starting this moment, the secondary exploitation methods are applied [1, 2].

In the last years the number of new discovered oil reservoirs was very small, and the only solution for increasing oil reserves was to apply secondary recovery methods. In Romania those projects for field application of secondary recovery methods have been implemented since 1970 – 1980 [3].

Classification of Secondary Recovery Methods

The secondary recovery methods can be classified in two main groups: conventional and unconventional methods. Conventional methods includes: water injection, gas injection (hydrocarbon gas), infill drilling. Unconventional methods includes: chemical methods, CO_2 injection, thermal methods, mining, microbial EOR, nitrogen injection, and horizontal drilling.

Depending of the kind of the injected agent being used, the chemical and thermal methods may define different secondary methods such as:

Chemical methods: polymer injection, alkali and active agent injection, micellar solutions injection, solvent injection.
Thermal methods: in situ combustion, steam injection (cyclic and continuous), hot water injection.

The infill drilling and water injection are the most used in the world and are applied since over 100 years, but the final recovery factor is relative low, about 20 – 30 %.

To increase oil reserve the best methods are thermal methods which can lead to a significant increase of oil recovery such as of 15 – 30 % for hot water injection, and 40 – 60 % in case of steam injection or in situ combustion. CO_2 injection process can lead also to an important increase of oil reserves up to 20 – 30 % but in this case but is necessary to have CO2 sources near oil reservoir.

In case of horizontal drilling, the increase of recovery factor is about 10 – 25 %; by mining the recovery factor can be 20 – 40 %, but in case of pit exploitation the final recovery factor can reach 60 – 80 %. For microbial EOR the increase of recovery is only 5 – 15 % but has the advantage is presented by the very simple operation.

The chemical methods, as micellar solution injection and polymer injection, were considered as a great potential in the last years of the XX century, but their applicability is low because of high cost for chemicals, work program and poor results obtained in the field applications.

The best results are obtained when 2 or 3 secondary recovery methods are applied simultaneous or consecutive, when the effects of synergism are spectacular. The methods which can be applied together are, for instance: steam injection with horizontal drilling, hot water injection with short term in situ combustion for reaction wells, in situ combustion with water injection (wet combustion and water injection in burnt area) and/or horizontal drilling, water injection with M.E.O.R., hot water injection with alkali or active agent injection, steam injection with water injection, CO_2 injection with water injection, etc.

In case when 2 or 3 secondary recovery methods are applied consecutive, the recovery is called tertiary but essentially this is not the case of a tertiary recovery methods.

Secondary Recovery Methods Applied in Romania

In Romania were applied conventional and also unconventional recovery methods for reservoirs with different geological and physical properties.

Among conventional methods, infill drilling was applied to all oil reservoirs, water injection was applied to more than half of oil reservoirs and gas injection was poorly applied, at experimental level, because of the absence of gas. Although water injection was the most used method, the results obtained were under expectations for many reservoirs, generally because of the field operation errors. Besides, in the last 15 – 20 years the water injection was frequently applied as residual water injection, this fact was lead to a decline of this method. The potential for water injection in present is still high [3].

The unconventional secondary recovery methods applied in Romania are:
Chemical methods: micellar solutions injection, alkali or active agent solutions injection and polymer injection applied as experiments but also at industrial level: polymer injection for Meoţian Drăgăeşti and alkali injection for Dacian Băicoi;

- Thermal methods: in situ combustion, steam injection (cyclic and continuous) applied experimentally and industrially, and hot water injection only experimentally at Meoţian Şotânga and Meoţian Oteşti reservoirs;
- Microbial E.O.R. was applied only as experiment;

- Mining methods was applied experimentally and industrially;
- CO_2 injection was applied experimentally at Meoțian Bradu – Albota;
- Horizontal drilling was applied experimentally and industrial for many reservoirs.

Table 1. Data about unconventional oil recovery applied in Romania .

Method	Field tests			Commercial processes			Results evaluation
	Number of fields	Number of experiments	Period of time	Number of fields	Number of processes	Period of time	
Cyclic steam injection	14	26*	1963 – 2007	3	-	1966 – 2007	Good results
Continuous steam injection	5	5	1964 – 2001	4	4	1967 – 2007	Medium efficiency
In – situ combustion	26	70	1964 – 1997	11	11	1967 – 2007	Good technical results
Hot water injection	2	2	1996 – 1998	-	-	-	Inconclusive
Polymer flooding	3	5	1974 – 1980	1	1	1974 – 1990	Poor results
Alkaline flooding	4	4	1979 – 1993	1	1	1979 – 1993	Poor results
Micelar flooding	3	3	1985 – 1992	-	-	-	Inconclusive
Microbial EOR	9	31*	1978 – 1992	-	-	-	Inconclusive
CO_2 injection	1	1	1976 – 1980	-	-	-	Good results
Mining	3	4	1951 – 1994	1	1	1951 – 2007	Poor efficiency
Horizontal drilling	6	7*	1993 - 2003	5	16*	1995 - 2007	Good results

*) Number of wells used to apply he method

The statistical data about secondary recovery processes applied until now in Romania are presented in table 1. According with these data, 70 field experiments were performed and 11 industrial processes for 26 oil reservoirs with different geologic and physic parameters. The best results were obtained using in situ combustion processes [4].

From the results obtained by in situ combustion, it is worth to mention:

- In situ combustion process from Panonian Suplacu de Barcău which has the longest burning front in the world (10 – 12 km) and the biggest oil production, 1200 – 1400 to/day and a cumulative of over 30 millions tons;
- In situ combustion was applied with good technical results at reservoirs lied at depths greater than 1000 m: Helvețian Băbeni (1100 m) and Helvețian Țicleni (1400 m);
- In situ combustion was applied with good technical results for reservoirs with light oil (Drader Ochiuri, Drader Moreni, Meoțian Poseşti), or for oil with high content of wax (Sarmațian Moineşti, Solonț and Dofteana), but with poor results for a continuous in situ combustion process and medium results for a short term in situ combustion process.

The majority of unconventionally secondary recovery methods can lead to an increase of recovery factor with 20 – 40 % and the shortening of exploitation time by enhancing of extraction rhythm. Despite of these advantages, the secondary recovery methods are not very used in Romania and in the world, due to:

- Initial investments are very costly and need long time (1,5 – 2 years) to be realized, specially for steam injection and in situ combustion;
- High volume of workover which lead to high operation costs
- Complex management of exploitation process;
- Long duration and high financial resources needed for laboratory tests, field experiments and design;
- Great inertia of these methods, the first results of an industrial process being notable after 2 – 5 years and pay out time is 3 – 10 years.

Perspectives of Secondary Methods in Romania

In order to establish perspectives for secondary recovery methods for oil reservoirs in Romania is necessary to mention some new and specific conditions:

- The knowledge about reservoirs improved through seismic 2D and 3D and complex geophysical investigation;
- The equipments and installations with very good performances and high quality chemicals are available;
- Availability of efficient supervision and design of secondary recovery processes by using chemical tracers and blocking gels (for water injection, hot water injection, steam injection, chemical solution injection);

No political pressures but legal restriction for environment and oil resources.
Some difficulties for applying secondary recovery methods in Romania are due to investments level, complex supervision and the long period of time until the production increases.

Following are presented some general recommendations for the application of secondary recovery methods in Romania:

1. Almost all the oil reservoirs existing in Romania have a low level of reservoir energy (reservoir pressure), so is very important to restart a water injection process;
2. *Microbial E.O.R* (M.E.O.R.) can be used for reservoirs with good physical and geological characteristics and also for reservoirs under water injection. Because in the last 20 years M.E.O.R. was significantly improved, it is necessary to perform field tests. The laboratory researchers achieved at I.C.P.T. Câmpina were proved that Sarmațian Cartojani reservoir is a good candidate for this method [6].
3. *Steam injection* – cyclic and continuous – for reservoirs with appropriate parameters using steam generators of high technical performances or cogeneration of electrical power. It is recommended to start the giant project for development and intensification of steam injection for Levantine (2+3) Moreni reservoir where steam injection is designed for a production period of 30 – 50 years were the oil reserve will increase by 12 – 16 million of tons. For this reservoir it is possible to apply steam injection – cyclic and continuous – together with in situ combustion (short term combustion), with hot water injection and with horizontal drilling.
4. *In situ combustion*, mainly short term combustion can replace cyclic steam injection due to his better technical and economical efficiency, low environmental problems, rapid reaction and facile operation mode [7]. It is possible to apply this process at Levantine Moreni, Drader Ochiuri Vest, Drader Dealu Batran and Sarmatian Ghimpati reservoirs
5. *Hot water injection* has a big potential for heavy oil reservoirs and has the easiest technical program. The reservoirs most suitable for this process are Moreni, Videle, Balaria, Blejesti, Talpa, Silistea, Otesti, etc [3, 8].
6. *Burnt gas injection* from chemical plants existing in the nearby of oil reservoirs. This gas

contains more than 90 % CO_2 and the candidate reservoirs are: Calinesti – Bradu – Albota with gas from ARPECHIM Pitesti, Bradesti with gas from DOLJCHIM Craiova, Babeni with gas from OLTCHIM Ramnicu Valcea and offshore fields from Black Sea with gas from Midia Navodari. Burnt gas injection has the advantage of reducing of air contamination from industrial plants.

7. *Horizontal drilling and cvasiorizontal* [3, 9] particularly to massive reservoirs from Moesic Platform (Cretaceous from Blejesti, Talpa, Corbii Mari, Balaria) and Meotian, Helvetian and Oligocene reservoirs from Moreni, Ochiuri, Strambu, Babeni, Bogati Colibasi and other reservoirs with high dip. A special case is Oligocene Moreni Nord reservoir using horizontal wells drilled from "free salt" areas in vertical plane to avoid salt difficulties (drilling and production).
8. *Mining* is possible to apply for reservoirs with a depth less than 400 m. the candidate reservoirs being: Levantine 1 Moreni, Dacian Superior Moreni Nord, Dacian Ochiuri, Meotian Posesti and Sarmatian Ghimpati.

Conclusions

Romanian specialists had an important contribution to the worldwide development and improvement of secondary oil recovery methods.

Romania has good specialists with strong theoretical and practical background to encourage application of secondary recovery methods.

As presented above, the secondary recovery methods have a good potential of applicability in the near future in Romania.

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Creşterea rezervelor de țiței prin aplicarea metodelor de recuperare secundară

Rezumat

Aplicarea metodelor de recuperare secundară a țițeiului constituie o soluție sigură de creştere a rezervelor şi de intensificare a exploatării zăcămintelor de țiței. De aceea în România s-au realizat numeroase cercetări teoretice şi de laborator, precum şi experimente de şantier privind aplicarea metodelor de recuperare secundară, respectiv metodele chimice (injecția de soluții micelare, de polimeri şi de soluții alcaline sau tensioactive), metodele termice (combustia subterană, injecția de abur şi injecția de apă fierbinte), injecția de CO_2, metodele petrominiere, metodele microbiologice, injecția de azot, forajul orizontal şi altele. Cele mai spectaculoase rezultate au fost obținute prin combustie subterană care a fost aplicată la 26 zăcăminte de titei din Romania.

Dupa un scurt capitol introductiv, în lucrare este prezentat potențialul de creştere a rezervelor de țiței pentru principalele metode de recuperare, precum şi câteva realizări romaneşti în acest domeniu. In capitolul final sunt prezentate unele zăcăminte din Romania la care se pot aplica în viitor metode de recuperare secundara.