

# Energy-efficient technology for recovery of oil reserves with gas injection

**Yu A Kotenev, V Sh Mukhametshin, Sh Kh Sultanov**

Ufa State Petroleum Technological University, 1, Kosmonavtov St.,  
Ufa, Republic of Bashkortostan, 450062, Russian Federation

E-mail: [vsh@of.ugntu.ru](mailto:vsh@of.ugntu.ru)

**Abstract.** Improving energy efficiency of hydrocarbon extraction processes at any stage of development of oil deposits is a prioritized field of work for oil industry of any region. Prospects of using complex technologies to harness hydrocarbon potentialities are shown on the example of two pilot projects for Pre-Urals foreland basin (Russia) and south Iraq. Application of gas technologies on Tereklynskoye (Russia) and Zubair (Iraq) fields will allow reducing the capital spending and increasing the oil recovery of each of the objects under consideration by at least 8-10% in comparison with depletion drive. For Tereklynskoye oil deposit, there are provisions to use natural gas as it comes from the major gas pipeline as a displacement agent. In Zubair field, gas injection may be arranged by means of gas delivery from a nearby gas deposit with high formation pressure. A prospect of creating a network of underground gas storage facilities in depleted reefogenic oil deposits of Pre-Urals foreland basin allows combining solution of the problem of energy security of the region with that of the problem of increasing oil recovery rate for depleted oil deposits to design values and above. Arrangement of underground gas storage facility is seen also as a strategic potential for further development of the area surrounding the field.

## 1. Relevancy

Under current economic conditions, driven mostly by the fall in prices of hydrocarbon stock, one significant factor that inhibits development of oil and gas industry is limitation in available energy resources. It is connected to a number of causes, such as depreciation of key assets of oil producers and oil refineries, excessive energy consumption of processes and many others. A problem of directing the Russian oil and gas industry to an energy-saving development route has been relevant for quite some time already. Improvement of energy efficiency is, undoubtedly a necessary measure, however, search for energy efficient technologies has to be linked to concrete geological, field and process conditions.

## 2. Objectives and Goals

Our country has vast stock and resources of natural gas, thus creating prerequisites for its use as a displacement agent. Many researchers noted a significant deterioration in conditions of the oil production resource potential, which will directly drive intensification of research and creation of programs with the aim to switch to more technically-complex processes [1-5]. At that, some of them share an opinion that using the hydrocarbon gas as a fuel may and shall become a transitional phase on the way of wide adoption of renewable energy sources [6-8]. Predictions for development of the global economy, in particular those describing fuel and energy sector, witness to an acute necessity for



development of this field in the next two or three decades; creation of a system of basic underground gas storage facilities (UGSF) may become one of its components and strategic tasks [9-11].

### 3. Methods and materials

The prime task is to use hydrocarbon gas instead of traditional flooding method, first and foremost, at the assets where flooding efficiency is nil or minimal. Among such assets are deposits confined to buried Lower Permian reef masses of Pre-Urals foreland basin. In the region, there are 27 reefogenic deposits discovered, 13 of them are oil deposits and 6 are oil and gas deposits. Specifics of geological, physical and morphological properties of the reefogenic deposits determine the technology of their development characterized with a sequence of three main modes: volumetric expansion (elastic) drive, dissolved gas drive and gravity drive. Such an arrangement is implemented on the vast majority of deposits of this type. As a result, actual oil recovery is very low and on average does not exceed 30%.

Currently, most deposits are largely depleted; the recoverable resources are mostly extracted (Table 1). Utilization factor of the recoverable resources varies from 0.1 to 0.99, averaging at 0.74. Though 12 deposits the utilization factor varies from 0.83 (Muraptalovskoye) to 0.99 (Ishimbayskoye), averaging at 0.95. For these deposits, the total reserves amount to 120 million tons at the average oil recovery factor (ORF) of 0.28. Further development of such deposits with the depletion drive becomes unprofitable.

**Table 1.** Characteristics of depletion of reefogenic deposits of the Pre-Urals foreland basin

FIELD	Nature of saturation	Year of commissioning	Oil recovery rate, design, fraction	Oil recovery factor, current, fraction	Utilization factor, fraction
Vvedenovskoye	oil	1954	0.37	0.37	0.99
Ozerkinskoye	oil	1961	0.29	0.28	0.98
South-Vvedenovskoye	oil and gas	1956	0.35	0.33	0.97
Kumertauskoye	oil and gas	1961	0.28	0.27	0.97
Tereklynskoye	oil	1957	0.26	0.24	0.94
Staro-Kazankovskoye	oil	1953	0.37	0.32	0.86
Grachevskoye	oil	1957	0.32	0.32	0.99
Muraptalovskoye	oil and gas	1971	0.24	0.20	0.84
Ishimbayskoye	oil	1932	0.32	0.32	0.99
Kartashevskoye	oil	1948	0.31	0.31	0.98
Stolyarovskoye	oil and gas	1951	0.36	0.34	0.94
Kusyapkulovskoye	oil	1935	0.10	0.08	0.77
Kazlairskoye	oil and gas	1967	0.25	0.18	0.72
Shamovskoye	oil	1989	0.13	0.09	0.67
Allakayevskoye	oil	1958	0.30	0.19	0.63
Mayachnoye	oil and gas	1969	0.30	0.05	0.15
Salavatskoye	oil	1988	0.28	0.04	0.12
Kungakskoye	oil	1942	0.28	0.03	0.12
Lemezinskoye	oil	1988	0.26	0.03	0.10

Works for implementation of gas drive in Ishimbay region of Bashkortostan started in 1970s. The first design document for arranging a UGSF in a depleted oil deposit was drafted by specialists of Soyusnefteotdacha and VNIIGAZ in 1987. However, the project has never been implemented.

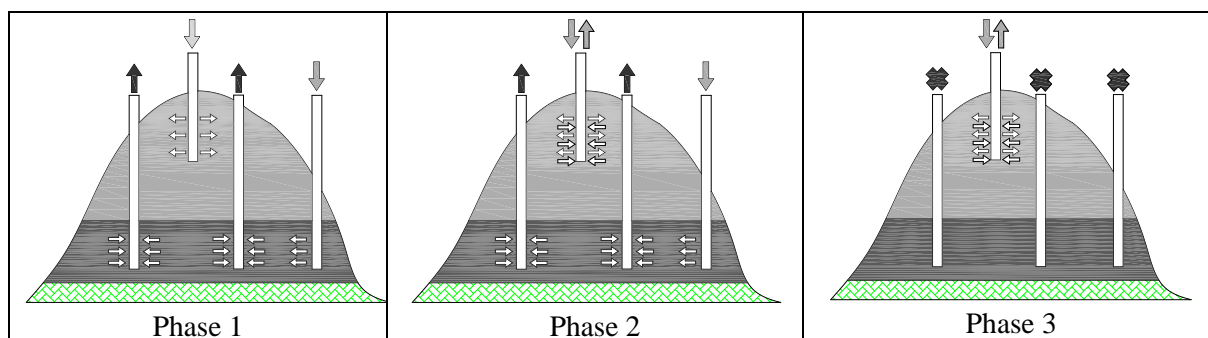
Reefogenic deposits of Pre-Urals foreland basin are the best fit to be operated as UGSFs, due to geomorphology of these objects: a closed nature of the natural reservoir, large volumes in a limited

area, presence of regional impermeable bed (Kungurian salt-bearing section) and availability of a well-developed gas transportation system near the fields.

Currently, a field most prepared to conversion into a UGSF is the Tereklynskoye oil field: most of the old well count is abandoned; 38 wells of the new well stock were drilled, including 9 gas injection wells; a project of further development has been drafted, based on the technology of additional recovery of residual oil reserves while creating a UGSF. Additional oil production may amount to 0.7-0.8 million tons, which corresponds to increase in oil recovery by 8.0-10.0%. The active volume of the UGSF is estimated at 430 million m<sup>3</sup> of gas, buffer storage capacity would be 220-250 million m<sup>3</sup>.

The proposed technology involves three consecutive phases (Figure 1). At the first phase, gas is bypassed into central and south-western crest of the mass from a major gas pipeline (MGP) under a pressure of up to 5.6 MPa until the pressure difference between the MPG and the deposit is minimized. After that, pilot oil production proceeds with cyclic injection of high-pressure gas with the aim to refine the parameters of the hydrodynamic model created. The duration of this phase is about 7-8 years [1, 6-8].

The second phase is a preparatory one to a complete development of the UGSF. Within the boundaries of this phase, the cyclic gas injection is performed with the help of a compressor unit in volumes that provide the highest efficiency of oil displacement with gas and the oil production itself happens. The second phase is the longest. As per preliminary calculations, in the conditions of Tereklynskoye deposit it would last for about 25 years. During this period, the main volume of residual recoverable oil reserves is deemed to be extracted. At the final stage of this phase the volume of injected gas increases up to 430 million m<sup>3</sup>, while production of liquid is reducing.



**Figure 1.** A principle diagram of technology implementation

At the third phase, production of liquid is stopped and the deposit is used as a UGSF with a cyclic mode of injection and withdrawal of gas.

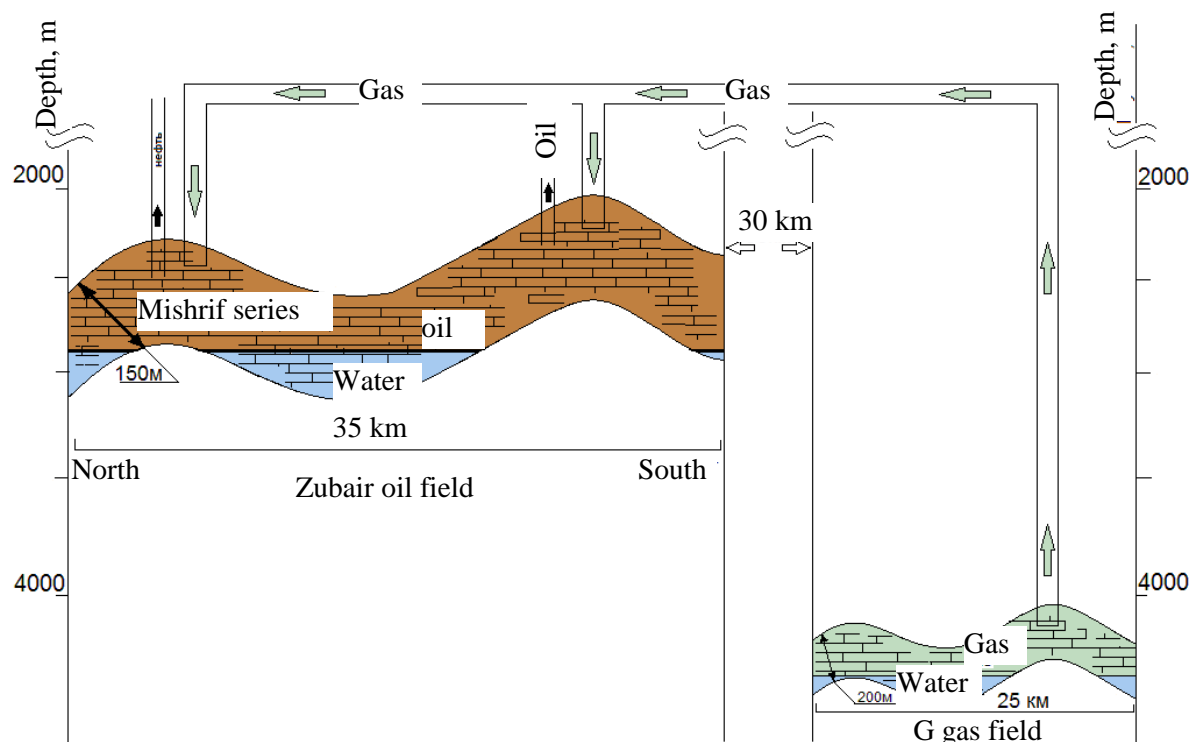
In Pre-Urals foreland basin, there are 7 depleted reefogenic oil deposits that are promising for implementing this technology. An active volume of UGSFs for these objects would in total amount to 7-8 billion m<sup>3</sup>, expected additional oil recovery is 10-12 million tons.

Another variant of applying gas technologies to increase the oil recovery efficiency is center-to-edge gas injection; let us consider it on the example of one of fields in the south of Iraq. Analysis of geological features of oil deposits and presence of natural gas deposits in the region, as well as criterion analysis of efficiency of gas injection allowed justifying a compressorless gas injection for oil recovery at the Zubair deposit [9-15].

Implementation of center to edge gas injection into the productive Mishrif series at the Zubair deposit provides for bypassing gas from the nearby G deposit characterized by a high formation pressure, i.e., there will be no need for compression (Figure 2).

Difference between the average hypsometric levels of the oil and the gas deposits in 2000 m (corresponding to a difference of formation pressures in 20 MPa), sufficient available gas reserves, as well as a short distance between the fields (about 30 km) allows for arrangement of a compressorless transport of gas into the oil reservoir.

Analysis of fluid samples taken from 4 wells has shown that under such rheological conditions it is possible to increase oil recovery by gas injection. The average values of the oil properties are given in Tables 2 and 3.



**Figure 2.** A principal diagram of implementing a compressorless gas injection at the Zubair oil reservoir

**Table 2.** Properties of in-place oil of Zubair deposit

Saturation pressure, MPa	19.0-23.0
Viscosity, mPa·s	1.7-2.5
Gas content, m <sup>3</sup> /m <sup>3</sup>	1.26-1.35

**Table 3.** Main components of gas at the Zubair deposit and the G deposit

Components	Content, % vol	
	Zubair deposit	Gas deposit (G)
Nitrogen System	0.15	0.06
Carbon dioxide	0.19	3.96
Methane	10.22	86.84
Ethane	5.46	4.26
Propane	3.58	2.00
i-Butane	1.11	0.46
n-Butane	3.33	0.73
i-Pentane	1.33	0.18
n-Pentane	1.30	0.17

#### 4. Conclusions

Redevelopment of reefogenic oil deposits of Pre-Urals foreland basin with a prospect of creating a network of underground gas storage facilities in the depleted formations allows combining solving the problem of energy security of the region with solving the problem of increasing oil recovery rate for

depleted oil deposits to design values and above. Arrangement of underground gas storage facility shall also be seen as a strategic potential for further development of the area surrounding the field.

Taking the above into account, the idea of creating a training, scientific and production testing grounds at Tereklynskoye field is very timely and relevant; it will help resolve the pressing economic and social issues in the region by:

- increased oil recovery of the depleted oil deposit;
- increased efficiency of operation of the gas distribution system during the seasonal peaks in gas consumption;
- perfection of innovative technologies aimed at increase of oil recovery and intensification of oil production;
- use of experience obtained at the testing grounds for further development of depleted reefogenic oil deposits;
- arrangement of facilities for work experience internship of students of oil and gas universities.

The technological calculations completed for the Zubair oil field has shown that its daily oil production would be strongly dependent on the rate of gas injection. When injecting 1 million m<sup>3</sup>/day of gas, the oil production would increase by 40%, while when injecting 2 million m<sup>3</sup>/day and 3 million m<sup>3</sup>/day it would increase by a factor of 2.4 and 3.3 respectively.

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