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Applications of the Enhanced Recovery Methods to Saudi Oil Fields

M. H. Sayyouh and M.S. Al-Blehed
Petroleum Engineering Department, College of Engineering, King Saud University, P.O.Box 800, Riyadh 11421, Saudi Arabia.
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Abstract. Based on the analysis of data obtained from 186 Saudi formations, the possibilities of applying different enhanced oil recovery (EOR) methods were investigated.

It was found that the most suitable technical methods applicable to Saudi oil fields are the miscible processes using gases. A new technology should be developed in order to be able to apply any of the enhanced recovery methods involving chemicals and heat. A study of the economical feasibility of these methods should also be performed.

Introduction

According to the latest published data, the original oil-in-place in Saudi Arabia is about 700 billion barrels. Only about 250 billion barrels, or 35% of total oil-in-place, can be produced by conventional production methods. More than 90 billion barrels, as much as twice the proven reserve of the USA and Canada combined, can be added to the country's proven reserve if only 20% out of the 450 billion barrels left in-place can be produced through enhanced oil recovery methods.

The screening guides for enchanced oil recovery methods should be used as a first step in evaluating a given reservoir for enhanced recovery. Many screening guides have been suggested for the application of EOR methods, according to field and laboratory results [1-5, 6; pp. 172-180, 7, 8; pp. 626-628, 9-11]. The use of preferred criteria can be helpful in selecting suitable methods that may be economically attractive [4]. The main objective of this study was to investigate the possible EOR methods that can be applied to Saudi oil fields.

Application of Enhanced Recovery Methods to Saudi Oil Reservoirs

In applying any EOR method to a given reservoir, it is important to evaluate properly the different reservoir parameters. Oil viscosity, API gravity, reservoir pressure and temperature, formation thickness, porosity, permeability, connate water saturation and salinity, rock clay sensitivity and heterogeneity are the most important factors that influence and limit the applicability of EOR processes. Another very important factor is reservoir geology. Geological conditions such as bottom water, shale barriers, gas caps, etc., can invalidate a favourable screening criterion. In the following, only the aforesaid parameters are considered for the Saudi reservoirs.

Two approaches were proposed in a previous study by the authors [1]. the first approach states that the reservoir should be evaluated individually, whereas the second approach indicates that the screening guides should be used to select the best enhanced oil recovery method for a given reservoir.

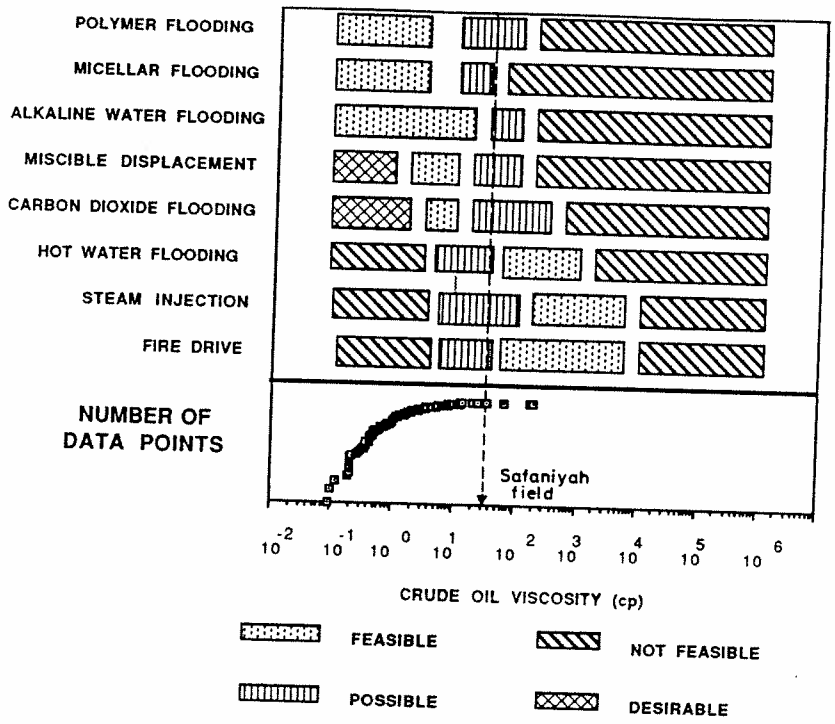

Fig. 1. Saudi crude oil viscosity ranges for different e.o.r. methods

Chemical flooding

Enhanced oil recovery by chemical solutions is best applied to reservoirs with medium gravity crude oils viscosity as shown in Fig. 1. Figure 1 shows that polymer, micellar and alkaline flooding processes are applicable to reservoirs which contains crude oil viscosities up to 10 cp.

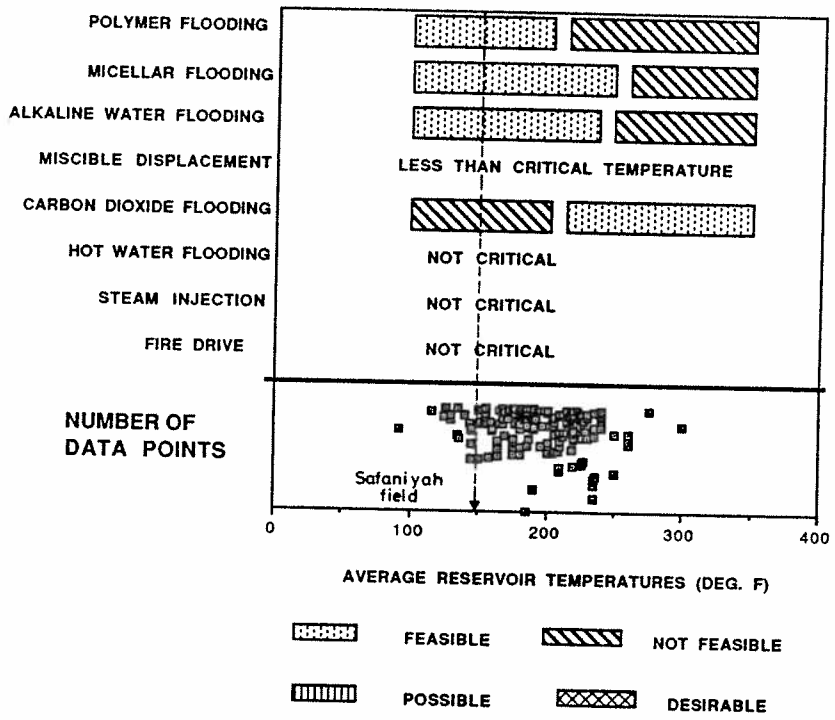

Fig. 2. Average saudi reservoirs temperature limitation for different e.o.r. methods

Most chemical enhanced oil recovery methods are applicable preferably to sandstone reservoirs. Reservoirs having extensive fractures and/or extreme reservoir heterogeneity are not practical candidates because of the resulting early breakthrough of the injected chemical slug. This is also true for the other EOR methods. The reservoir temperature should not exceed 250°F as shown in Fig. 2. However, extensive research is going on today in order to develop chemicals such as surfactant and polymers that can be used in reservoirs with higher temperatures. Fortunately Fig. 2 and 3 indicate also that Saudi reservoir temperature and pressure range from 140 to 240°F and from 2000 to 5500 psia, respectively, which means that the chemical methods are applicable at these ranges.

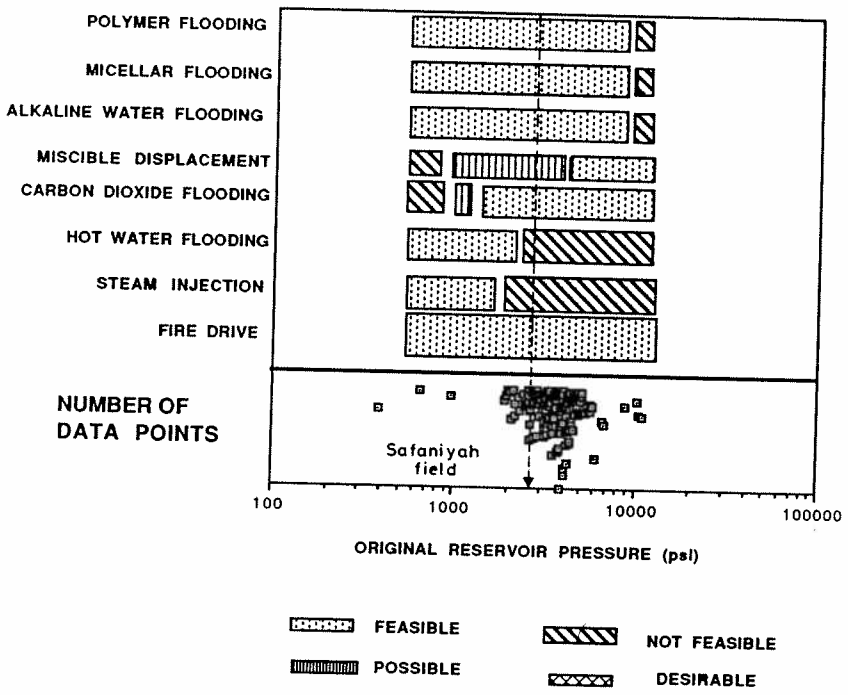

Fig. 3. Original saudi reservoirs pressure limitation for different e.o.r. methods

The reservoirs of Saudi Arabia are characterized by high salinity of the formation waters as shown in Fig. 4. This will put a serious limitation on the use of micellar and polymer floods. The high salinity of the formation water may reduce the integrity of the chemical slug. Therefore, for applying chemical methods to Saudi oil reservoirs, the chemicals should be chosen such that the adverse salinity effects can be minimized. In all cases, each reservoir must be evaluated individually.

Miscible displacement

The miscible displacement process consists of displacing oil by injecting a solvent slug which is completely soluble in oil. The solvent slug is either liquid hydrocarbon such as naphtha and alcohol or liquified petroleum gas (LPG) such as butane and propane. There are three types of miscible displacement process: **(1)** miscible slug process, in which a slug of liquid hydrocarbon is driven by gas, natural gas or water, **(2)** enriched gas process, in which an enriched gas slug is driven by lean gas or lean gas and water, and **(3)** high pressure gas process, in which a lean gas is injected under high

pressure. This process is applicable to reservoirs containing highly volatile oil, and is sometimes called "vaporizing gas drive".

Fig. 1 shows that enhanced oil recovery by CO_2 and miscible methods are feasible under Saudi reservoir conditions. Fig. 3 also shows the feasibility of Saudi original reservoir pressure for carbon dioxide flooding. The serious limitation on the use of CO_2 in Saudi Arabia is its availability. Although, it is expected that a considerable amounts of CO_2 is generated from power plants and refineries, its storage and transportation will be economically questionable.

Thermal flooding

The term "thermal" EOR is used when heat is applied to the reservoir rock and fluid is driven by either steam, hot water injection or in situ combustion. In the first case, heat is externally generated at the surface and injected into formation, while in the case of in situ combustion heat is generated within the formation. The steam injection process takes two forms: **(1)** steam flooding involving continuous injection, and **(2)** cyclic steam stimulation, involving intermittent steam injection and oil production. In situ combustion can take two forms: forwad combustion (either dry or wet), and reverse combustion. The latter is seldom used. the increase in oil recovery, due to the application of heat to the reservoir rocks, is obtained mainly through reduction in oil viscosity and hence increase in sweep efficiency.

Fig. 1 shows that the range of Saudi crude oil viscosities, limits the use of some of the thermal methods. However, thermal recovery is being considered for higher gravity crudes than had been considered feasible in the past. Steam flooding has been very successful in light oils of over 20 field tests [12]. In situ combustion has been more successful in lighter oils than in very heavy oils. Fig. 5 shows that some of the thermal methods may be applicable to some of the Saudi oil reservoirs.

Laboratory Design Under Saudi Reservoir Conditions

The design of an EOR technique for a specific Saudi reservoir is basically related to the screening guides that can be developed as follows: The range of Saudi crude oil viscosity is from 0.1 to 10 centipoise as shown in Fig. 1. The limits for Saudi porous medium permeability, and porosity can be determined from Figs 5 and 6. These limits are from 1 md to 1500 md for permeability and from about 10% to 30% for porosity. However, laboratory experiments have to be designed and carried out based on the actual reservoir conditions. Since there is considerable variation in porosity and permeability, the selection of a suitable porous medium to represent Saudi reservoirs is not clear cut. The connate water salinity conditions of Saudi reservoirs place some restrictions on the laboratory design of the EOR methods by chemicals. To ensure optimal displacement efficiency, the injected chemical solution slug must have an optimum salinity that gives minimum residual oil.

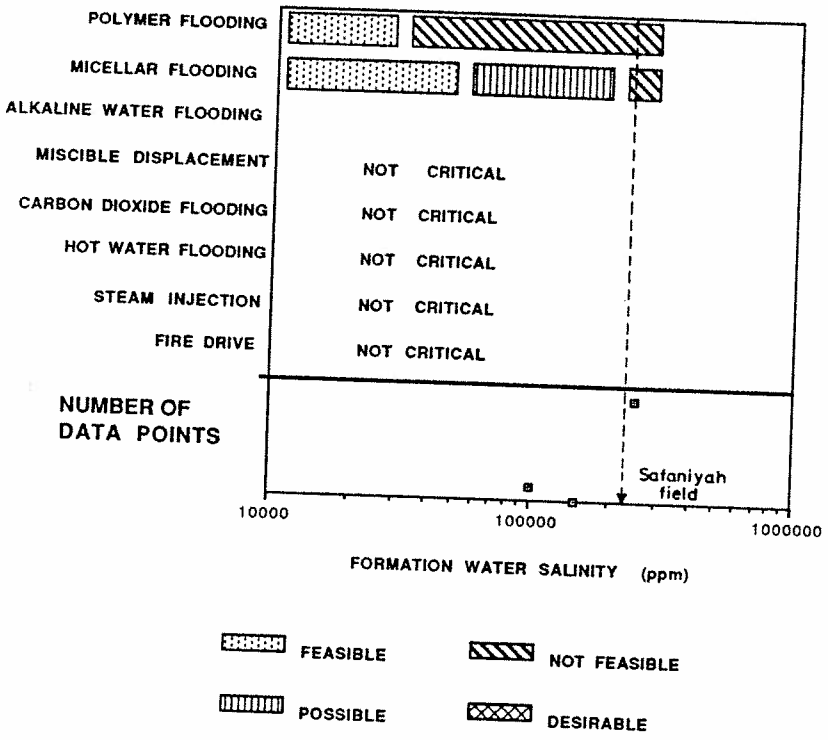

Fig. 4. Feasibility of e.o.r. methods to saudi formations water salinity

Economic Analysis and Field Application Example

According to Safaniyah field data shown in Figs 1–6 (as indicated by the vertical dashed line), the proposed methods to be applied to this field are miscible displacement and alkaline flooding. Micellar flooding can be applied, however, if a new technology can be developed to overcome the serious effects of salinity.

Economical factors can overshadow physical ones in commercial oil production. Even if provisions are made to improve recovery by increasing displacement and sweep efficiencies, cost to accomplish this cannot be higher than added oil value. Any economical evaluation should take into consideration oil recoverable, oil prices, cost (operating and capital), discount factor, inflation rate, tax rate and depreciation. The higher the crude price, the more feasible to recover oil from linear deposits using effective but costly methods [13].

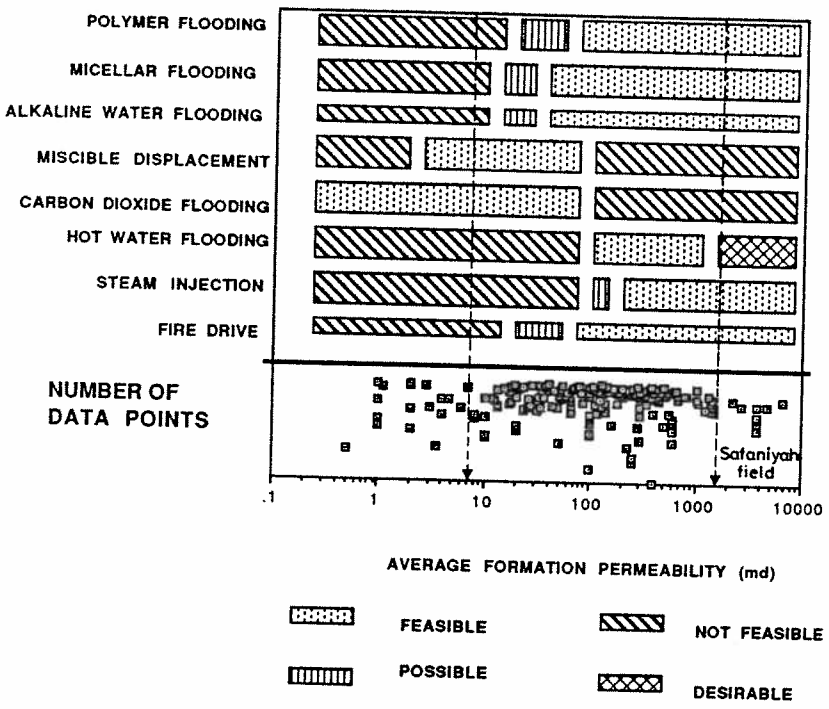

Fig. 5. Saudi reservoirs formation permeability guides for applying e.o.r. methods

Conclusions

The miscible flooding processes using suitable and available gases are the most suitable technical EOR methods applicable to Saudi oil reservoirs. Chemical flooding may be applicable but a new technology should be developed in order to be able to apply any of the chemical EOR methods. Thermal EOR techniques may be effective in Saudi reservoirs under special conditions. However, economical feasibility investigations of using these methods under the Saudi reservoirs conditions must be carried out.

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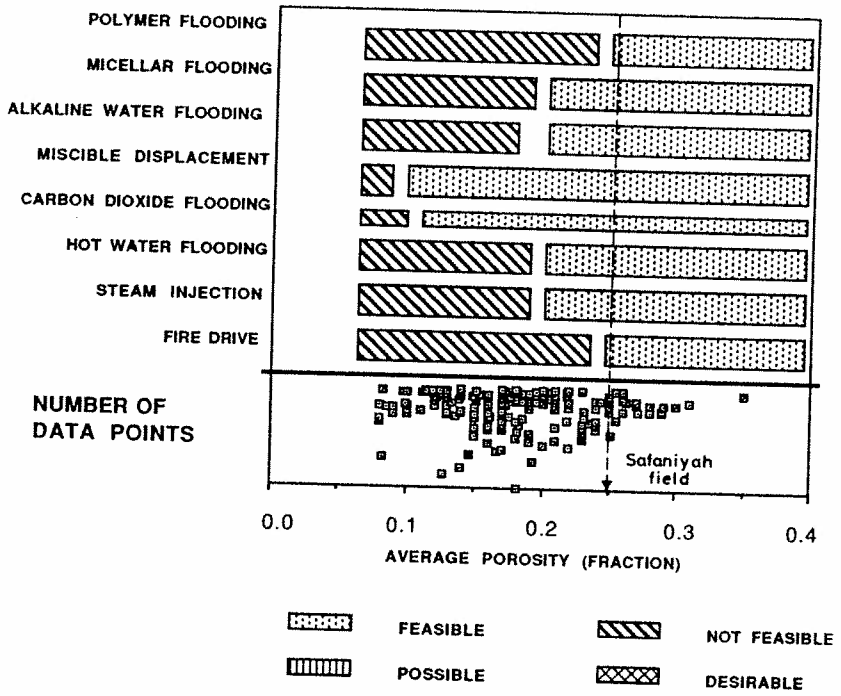

Fig. 6. Saudi reservoirs formation porosity guides for applying e.o.r. methods

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تطبيقات طرق الاستخلاص المُحسَّنْ لحقول الزيت السعودية

محمد حلمي صيوح ومحمد سعود البليهد

قسم هندسة النفط، كلية الهندسة، جامعة الملك سعود، ص.ب ٨٠٠،
الرياض ١١٤٢١، المملكة العربية السعودية

ملخص البحث. بناءً على تحليل ودراسة المعلومات التي تم الحصول عليها من ١٨٦ طبقة سعودية تمَّ استنباط احتمالات تطبيق طرق الاستخلاص المُحسَّنْ لمكامن النفط السعودية. ولقد وجد أن أنسب الطرق التي يمكن تطبيقها لحقول النفط السعودية هي العمليات الامتزاجية باستعمال الغازات. ويجب التوصل إلى تكنولوجيا جديدة لكي نتمكن من تطبيق طرق الاستخلاص المُحسَّنْ باستخدام الكيماويات. ويجب دراسة الإمكانية الاقتصادية لتطبيق هذه الطرق.