DETERMINATION OF OIL RECOVERY FACTOR BY USING WATER INJECTION-LABORATORY TEST METHOD

by
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I. INTRODUCTION

Oil production limit that is usually followed by decrease of oil productivity in old fields is a major problem and can't be avoided. This case happened when cumulative oil production has approached primary recovery method. Decrease of the action of native reservoir energy is followed by drastically increase of production of water (saturation almost 100 %).

In relation to this, a method is needed to obtain the additional oil recovery. Water injection method is one of the solutions to solve oil production problem that happened in old fields. It is expected that by using water injection method, productivity and oil recovery in old fields can be improved. Water that is used as the fluid injected into reservoir to improve oil recovery is sea water. How far oil recovery can be improved by using water injection method, is determined by a laboratory research. Before carrying out water injection laboratory test; one has to know what the main points that play important role in determining the optimal oil recovery by water injection method. These are: firstly, reservoir data, secondly, formation water and sea water analysis, thirdly, determination of physical fluid and rock properties, next, the displacement of water injection process to obtain the additional oil recovery and standard operational procedure. The main focus of this paper is " Determination of Oil Recovery Factor By Using Water Injection-Laboratory Test Method ". Hopefully, the contents of this paper give extremely valuable and useful information not only for LEMIGAS as Research and Development Centre for Oil and Gas Technology, but also for the oil industry or the Department of Petroleum Engineering of the universities in Indonesia.

II. BASIC PARAMETERS

This section explains what basic parameters play important role, that are needed to support the determination of oil recovery by water injection method in EOR laboratory, Exploitation Division of Lemigas. These are as follows:

- Samples : core, oil, formation water and sea water.
- Reservoir data : reservoir pressure and temperature.
- Rock properties : permeability and porosity.
- Fluid properties : oil density, water specific gravity.
- Chemical : formation and sea water.

III. LABORATORY TESTS

To determine oil recovery factor by using water injection, laboratory test method involves several main stages as follows:

1. Formation water and sea water analysis.
2. Determination of physical fluid and rock properties.
3. The displacement of water injection process.
4. Standard operational procedure.
5. Determination of oil recovery factor.

IV. THE DISPLACEMENT PROCESS

Secondary recovery of oil deals essentially with the flow of oil and water in a porous reservoir rock. The relative flow rates determine the efficiency of the process. The process by which water occupies pore space formerly filled by oil is called the displacement process. Briefly, the displacement process is dependent upon the nature and characteristics of the water involved, the physical characteristics of the reservoir, certain physical relationship between the fluid and the reservoir rocks. One of the basic equation used in fluid displacement work is the fractional flow formula of Buckley-Leverett. The simplified equation for linear flow of water is:

$$f_w = \frac{1}{1 + \frac{K_o}{K_w}\frac{u_w}{u_o}}$$

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where:

Fw = fraction flow
Ko (mD) = oil permeability
Kw (mD) = water permeability
w (cp) = water viscosity
o (cp) = oil viscosity

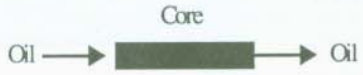
This equation states that the fractional flow depends solely upon the relative permeability-saturation characteristics of the porous system and upon the fluid viscosities.

Thus, the curve of fractional flow (fw) should be plotted against water saturation. The process of water injection to improve oil recovery by using core media that is carried out in EOR laboratory, is described schematically in Figure 1 below:

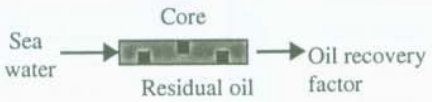
a. Formation water saturation.

Formation water (FW) is injected into core up to saturation 100 %.

b. Determination of connate water saturation (Swc).



Oil is injected into the core, so that the whole core is filled by oil totally. From this stage, connate water saturation data will be obtained.



c. Water injection

Before carrying out water injection, it must be considered that the sea water used as injected water into to the core must be compatible with formation water. Oil recovery factor can be determined after water injection process done.

V. STANDARD OPERATIONAL PROCEDURE

It is very important to prepare laboratory standard operational procedure (see Table 1 for the main points mentioned above that will be tested.

Table 1
Laboratory Standard Operational Procedure for Water Injection Laboratory Test

No.	Types of analysis	Analysis / method	Equipment	Standard
1	Determination of chemical compositions and physical water properties.	- Chemical composition	Water analysis laboratory	API - RP 45
		- Water spesific gravity	Spesific gravity tool	API - RP 45
2	Measurement of physical core properties.	- Porosity	Helium Gas expansion porosimeter	API recommended practise no. 40, supported by ISO 17025
		- Permeability	Digital gas permeameter	API recommended practise no. 40, supported by ISO 17025
		- Oil density	Densitometer	API - RP 45
3	Water flooding	- to determine oil recovery by water injection laboratory test	Water flooding equipment	Petroleum Production Handbook, Vol. II, by Thomas C Frick.

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VI. LABORATORY TEST RESULTS

This section describes the obtained result of laboratory tests. The results of determination of chemical composition and physical water properties for each formation water and sea water can be seen in Table 2 and Table 3. While the results of physical fluid properties tests were shown in Table 4 and physical rock properties tests in Table 5. Section IV has described the displacement process of the additional oil recovery by using water injection method schematically that consists of three types of work descriptions, these are: formation water and sea water analysis, connate water saturation (Swc) and determination of oil recovery factor by using water injection method. Based on the results of water injection laboratory test, the obtained data for core # 3 are as follows:

- Connate water saturation (Swc) = 35.86 %.
- Oil effective permeability (Ko) = 66.9973 mD.
- Residual oil saturation (Sor) = 28.98 %.
- Water effective permeability (Kw) = 40.0821 mD.
- Oil recovery factor (%) = 100 - Swc - Sor

Table - 6.1
Formation water analysis

Total Dissolved Solids	21,053.0	mg/L (Calc.)	Sp. Gr.	1.0151	at 60°F/60°F
Total Dissolved Solids	22,380.0	mg/L (Evap.)	pH	8.40	
Resistivity	0.190	Ohm-meters @ 125°F (Calc.)	Hydrogen Sulphide	Nil	
	-	Ohm-meters @ 77°F (Meas.)	Total Equiv. NaCl Conc.	19,686.8	mg/L

Constituents	meq/L	mg/L	Constituents	meq/L	mg/L
Sodium	341.45	7,852.3	Chloride	311.55	11,046.6
Calcium	1.41	28.3	Bicarbonate	26.94	1,643.7
Magnesium	5.25	63.9	Sulphate	5.84	280.6
Iron	0.10	24.3	Carbonate	3.78	113.3
Barium	0.00	0.0	Hydroxide	0.00	0.0
Total Cations (excl. Fe)		7,968.8	Total Anions		13,084.2

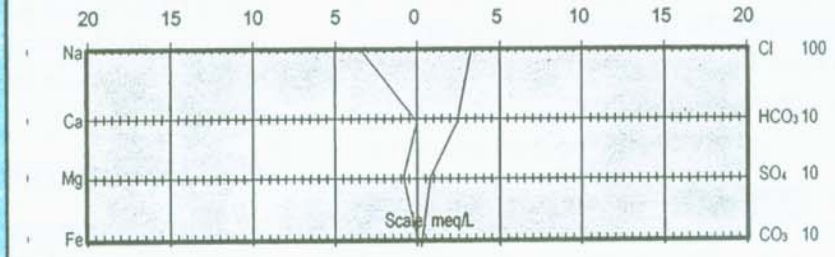
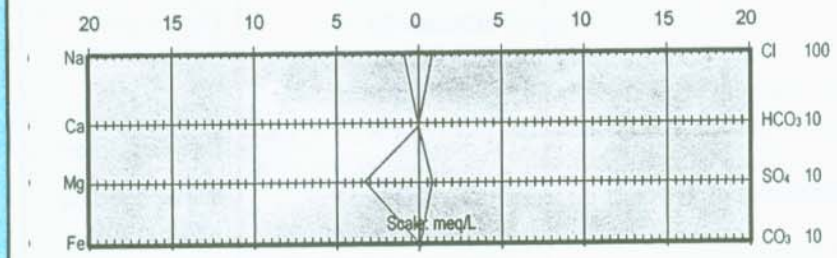


Table 3
Sea water analysis

Total Dissolved Solids	8,402.2.	mg/L (Calc.)	Sp. Gr.	1.0078	at 60°F/60°F
Total Dissolved Solids	9,070.0	mg/L (Evap.)	pH	8.00	
Resistivity	0.410	Ohm-meters @ 125°F (Calc.)	Hydrogen Sulphide	Nil	
	-	Ohm-meters @ 77°F (Meas.)	Total Equiv. NaCl Conc.	8,360.3	mg/L

Constituents	meq/L	mg/L	Constituents	meq/L	mg/L
Sodium	115.10	2,647.0	Chloride	130.65	4,632.5
Calcium	1.62	32.4	Bicarbonate	1.59	97.0
Magnesium	28.89	351.3	Sulphate	13.37	642.0
Iron	0.05	0.0	Carbonate	0.00	0.0
Barium	0.00	0.0	Hydroxide	0.00	0.0
Total Cations (excl. Fe)		3,030.7	Total Anions		5,371.5



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= 100 - 35.86 - 28.98

= 35.16% (see Figure 2).

VII. CONCLUSIONS

1. Water flooding is a secondary recovery method in which water is injected into a reservoir to obtain the additional oil recovery by movement of reservoir oil to a producing well after the reservoir has approached its economic productive limit by primary recovery methods.
2. To obtain accurate data, optimum and reliable result, it is very important and valuable to carry out a sequence of stages from initial until final stage of data preparation for water injection laboratory test, including:

- Formation water and sea water analysis.
- Determination of physical fluid and rock properties.

Table 4
Measurement of physical fluid properties

OIL		SEA WATER		FORMATION WATER	
Density (gr/cc)	Viscosity (cp)	Density (gr/cc)	Viscosity (cp)	Density (gr/cc)	Viscosity (cc)
0.8453	0.8328	1.0072	0.3507	1.0145	0.3610

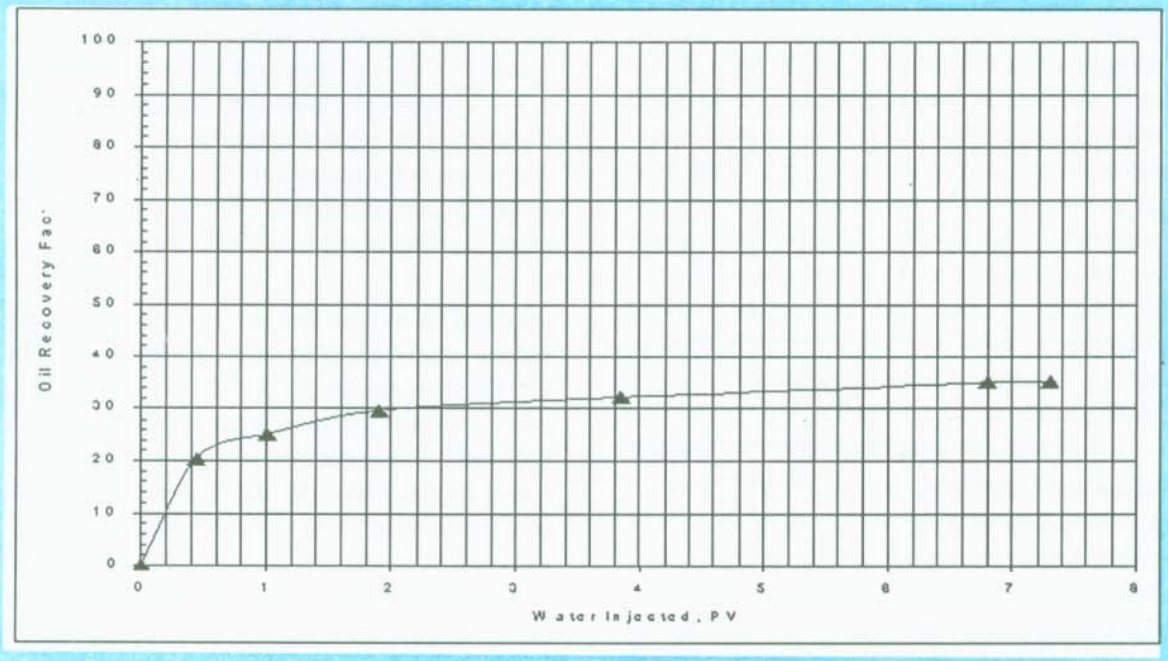
Table -5
The Results of Basic Paramater Measurement and Identification of the analyzed core

No scale

Field		
Sample Number		
Depth, m.		
Length, cm	=	7.6120
Diameter, cm	=	3.8180
Acre, cm^2	=	11.4430
Bulk Volume, cc	=	87.1044
Core Weight, gr	=	171.9500
Grain Volume, cc	=	63.5400
Pore Volume, cc	=	23.5520
Air Permeability, mD	=	287.0000
Porosity, %	=	27.0300
Grain density, gr/cc	=	2.7060

LM : Bounds, lthy-ltbrn, csl, algae, moldic, Mot-5mmvugs.

Figure 2
Influence of Sea Water Injection on Enhanced Oil Recovery



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- The displacement of water injection process.
- Standard operational procedure.
- Water flooding.

3. Based on the result of laboratory tests for core # 3, the value of oil recovery factor obtained was 35.16 % by using water injection method and the residual oil saturation (Sor) value was 28.98 %.

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