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In preparation of the study, x core plugs are drilled. Determination of basic parameter and identification of core plug sample are carried out following the API – RP 40. For example, the tests of physical properties, i.e. grain density (gr/cc), weight, grain volume (cc), pore volume (cc), porosity (%), and air permeability (Ka, mD).

C. *Measurement of interfacial tension and phase behaviour test*

Spinning drop interfacial tensiometer is the equipment used for determining interfacial tension between liquids – it has the capability to measure interfacial tension as low as 10^{-4} dyne/cm – following:

$$IFT = \frac{(10^6 \pi^2 \Delta \rho d^3)}{(8 n^3 P^2)}$$

where

IFT : interfacial tension, dyne/cm

$\Delta\rho$: difference of fluid density, gr/cm

d : dropping width, cm

n : bias index

P : period, msec.

D. *Phase behaviour test*

Effectiveness of surfactant that is usable in enhanced oil recovery is not only determined by interfacial tension factor but is also influenced by phase behaviour and adsorption of surfactant concentration in pore media/core. To study the type of phase behaviour formed when oil, surfactant, and formation water are mixed, it is necessary to test:

a. Phase behaviour of oil - surfactant - formation water blend

b. Phase behaviour of oil - surfactant - cosurfactant - formation water blend

E. *Adsorption*

Effectiveness of surfactant to reduce interfacial tension and to improve oil recovery is affected by adsorption of surfactant in pore media. In this study, surfactant with x % concentration is dissolved into formation water. The surfactant solution was then placed into a beaker glass that contains a bit of crushed core. After 9 hours immersion, concentration of surfactant in the solution was determined by using ultra violet spectrophotometer. The difference of initial surfactant concentration (x %) and a certain concentration of surfactant in the solution (y %) is the concentration of surfactant adsorbed by pore media (z %).

IV. PROCESS OF SURFACTANT FLOODING LABORATORY TEST

The stage of surfactant flooding laboratory tests process to improve oil recovery is schematically described in Figure – 4.1 below:

a. Formation water saturation

Formation water (F_w) is injected into core plug up to water saturation of 100 %.

b. Determination of connate water saturation (Swc).

Oil is injected into the fully water saturated core plug so that the core is partially saturated by oil. From this stage, connate water saturation data is obtained.

c. Determination of oil recovery factor by formation water injection

By injection of formation water into core, some of oil existing in the core is displaced and is produced. Recoverable oil is recorded. The remaining amount of oil in the core is the residual oil saturation (S_{or}).

d. After water flooding, the surfactant flooding takes place. Recoverable oil is recorded.

In this main step, surfactant solution at the certain concentration is injected into core plug letting the surfactant solution contacts formation water within the plug. Since surfactant has a function of reducing oil-water interfacial tension, the residual oil that is trapped in the pore media can be displaced by the surfactant solution and be produced. Fluid that comes out from core, is a mixture of oil, surfactant, and formation water. Sampling is carried out for five analyzed samples: S1 (0.5 PV), S2 (0.5 PV), S3 (1 PV), S4 (1.5 PV), and S5 (2.0 PV). Due to the nature of the phase, it is very difficult to measure the volume of the recovered oil visually. As stated before, the surfactant tends to be dissolved by oil and mixed within it. To obtain the real oil volumes, infra red spectrophotometer (IR) is used.

e. Calculation of oil recovery factor after surfactant flooding.

V. STANDARD OPERATIONAL PROCEDURE

It is very important to prepare laboratory standard operational procedure for the seven main points that will be tested. Each stage in implementation of surfactant injection laboratory test to improve oil recovery should fulfill laboratory standard operational procedure, such as American Petroleum Institute (API), and Petroleum Production Handbook, supported by ISO 17025. Application of laboratory standard operational procedure for the required laboratory test (see Section III) will en-

Table - 5.1
Laboratory standard operational procedure for surfactant injection laboratory test

No.	Types of analysis	Analysis / method	Equipment	Standard
1	Determination of chemical compositions and physical formation 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
3	Fluid (oil and surfactant) physical properties	- Density and - Viscosity	Densitometer Viscosimeter	API - RP 45 API - RP 45
4	Measurement of interfacial tension	- Interfacial tension	Spinning Drop Interfacial Tensiometer	Spinning Drop Interfacial Tensiometer Manual Book and Interfacial Tension Phenomena in Enhanced Oil Recovery Book.
5	Phase behaviour test	- Phase behaviour test	Test tube	Theory of Microemulsion book
6	Water flooding	- to determine oil recovery factor by water injection	Water flooding equipment	Petroleum Production Handbook, Vol. II, by Thomas C Frick.
7	Surfactant flooding	- to determine oil recovery factor by surfactant injection	Surfactant flooding equipment	Petroleum Production Handbook, Vol. II, by Thomas C Frick, and EOR Reprint Series No. 23

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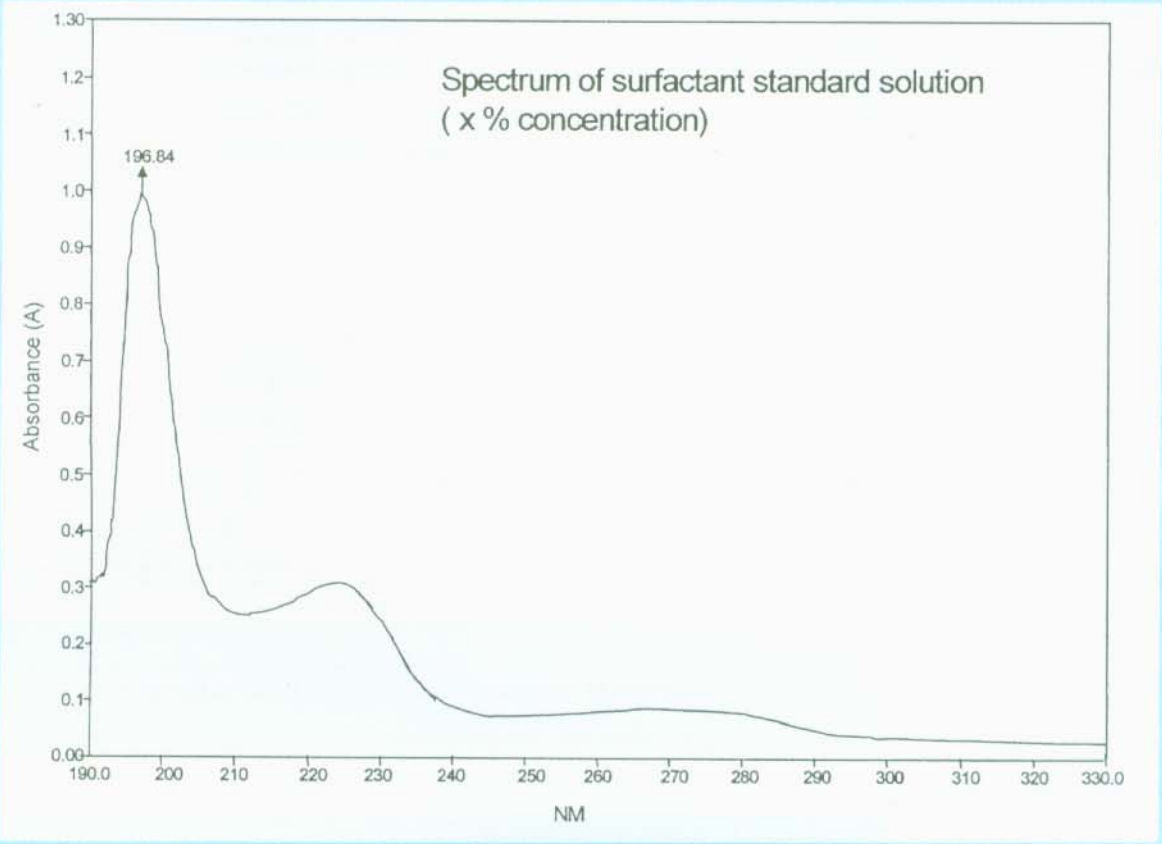

Figure – 6.1
Spectrum of surfactant standard solution (x % concentration)

sure that the obtained analysis result will be accurate. Table - 5.1 shows the standard operational procedure, that contains the seven types of analysis, equipment, method and the used standard for surfactant injection laboratory test.

VI. LABORATORY TEST RESULTS

This section describes the obtained result of the seven analyzed main points (mentioned in Section III) sistematically. The obtained results of the seven analyzed main points are as follow :

1. Formation water analysis.
2. Determination of physical fluid and rock properties.
3. Measurement of interfacialtension.
4. Phase behaviour test.
5. Adsorption test (see Figure – 6.1 and Figure - 6.2)

As mentioned in Section – 3.5 enhanced oil recovery by using surfactant injection method is affected strongly by adsorption of surfactant factor in pore media. Figure – 6.1 indicates the spectrum of surfactant standard solution (x % concentration), whereas the spectrum of surfactant solution after 9 hours immersion is presented in Figure – 6.2. The difference between the two concentrations produces a concentration of y % surfactant adsorbed by pore media. After doing water flooding process, it is followed by surfactant adsorbed by pore media. After doing water flooding process, it is followed by surfactant injection into media pore (core). How tremendous influence of surfactant injection on oil recovery factor in pore media (core) can be seen in Figure – 6.3 . This figure is as an example of enhanced

oil recovery laboratory test result by using surfactant injection method.

VII. CONCLUSIONS

1. Surfactant flooding is a tertiary recovery method in which surfactant solution with certain concentration is injected into a reservoir oil to a producing well after the reservoir has approached its economic productive limit by secondary recovery (water injection) method.

2. To obtain accurate data, optimum and reliable results, it is very important and valuable to carry out a sequence of stages from initial until final stages of data preparation for surfactant injection laboratory test, including:

- Formation water analysis.
- Determination of physical fluid and rock properties.
- Measurement of interfacial tension.
- Phase behaviour test.
- Adsorption of surfactant in pore media.
- Water flooding.
- Surfactant flooding.

3. Seven types of work descriptions (mentioned in Section – 7.2) are completed by laboratory standard operational procedure and even supported by ISO 17025.

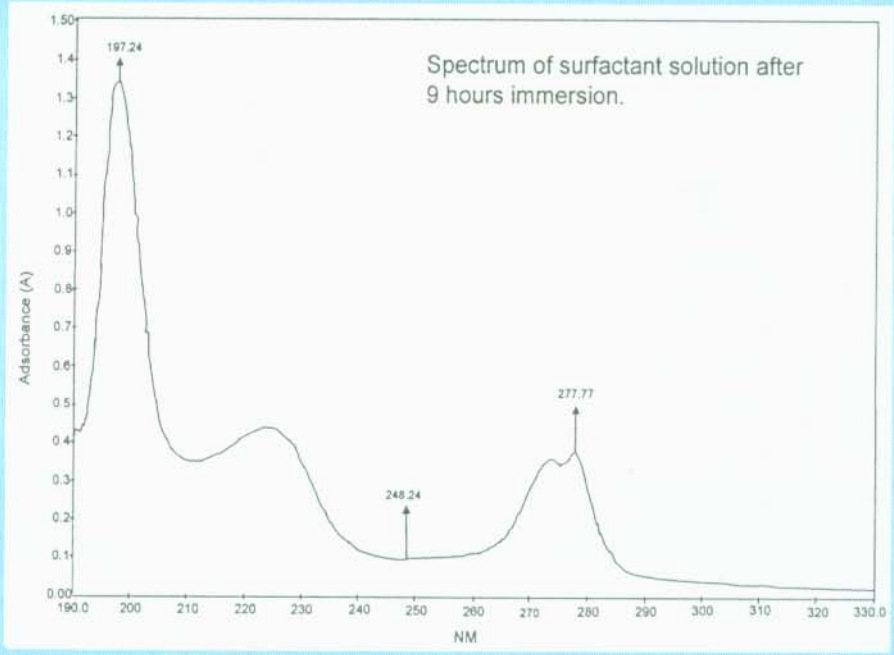

Figure – 6.2
Spectrum of surfactant solution after 9 hours immersion

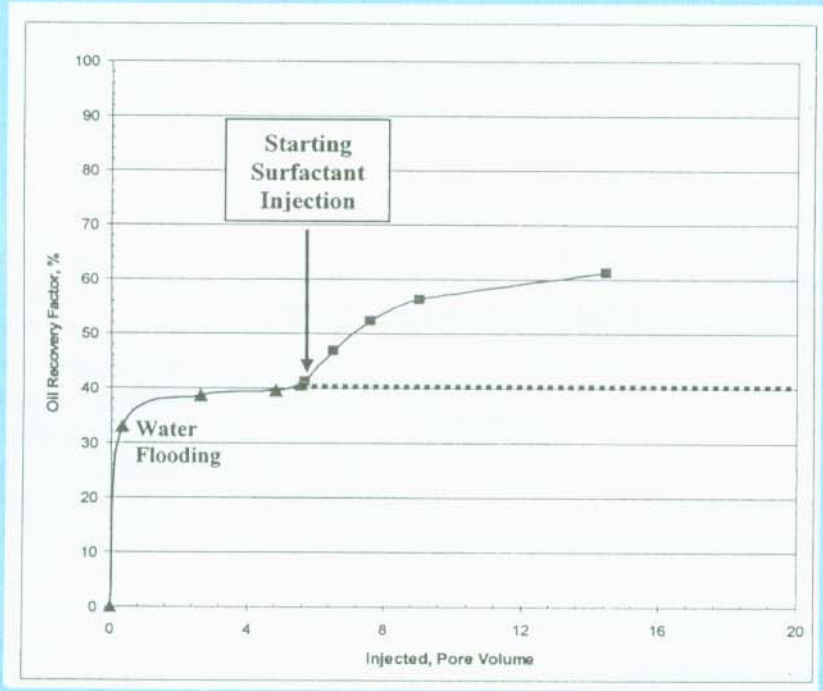

Figure - 6.3
Influence of surfactant injection on enhanced oil recovery

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