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USING A WEIGHT METHOD FOR LABORATORY FLUID PRODUCTION MEASUREMENTS

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ABSTRACT

Fluid production measurements are important in oil/brine unsteady-state relative permeability tests. Test accuracies and costs depend upon the measurement methods employed. Manually recording oil and brine volumes captured in collection tubes can be tedious, especially when the test fluids don't separate easily. Automated techniques are desired to increase the resolution of produced volume measurements and to minimize errors.

This paper describes the construction and use of a weight method for separating oil and brine test fluids and for recording produced fluid volumes during two-phase unsteady-state flow tests. The separator consists of two collection chambers. Chamber weights are monitored during tests by electronic balances. Fluid volumes are calculated from chamber weight changes. The separator works well when the density of each fluid is constant throughout a test and the densities of the two fluids are different. Separator measurements are fast even when the fluids separate slowly. The system can be configured for tests with backpressure. Because volume calculations are rapid, the number of data points recorded during a test is limited only by the balance response and data acquisition times. Examples of data from tests using the separator are presented.

BACKGROUND

The technique employed to measure brine and oil production versus time data during an unsteady-state relative permeability test affects the accuracy of the results. Typically, oil and brine volumes are collected in a series of graduated collection tubes at several times during the test. Obtaining a number of good measurements immediately after water breakthrough is critical and often very difficult. Recording the fluid volumes in collection tubes can be tedious, especially when the brine and oil do not readily separate.

An automated method of recording fluid production volumes during unsteady-state tests is required. Several measurement systems are available commercially that monitor fluid production within a separator by measuring the position of the interface between the two fluids. Another technique is to take advantage of the difference in fluid densities to monitor production. This technique has been applied in several laboratories[1-3] for liquid production measurements. Other investigators have reported a similar approach for gas and liquid production measurements.[4,5]

PRINCIPLE OF OPERATION

Figure 1 is a schematic of a system for automating unsteady-state oil and brine volume measurements. The apparatus consists of two collection vessels, U1 and U2, that are placed downstream from the core plug which is being flooded with oil or brine. U1 is a closed vessel, initially filled with brine. A drop of brine flows from U1 to U2 for each drop of fluid that enters U1. Each drop of brine that leaves U1 is captured in U2. A film of oil in U2 prevents the brine in U2 from evaporating. As long as the densities of the brine and oil test fluids are constant and the brine density is greater than that of the oil, the produced fluid volumes can be calculated at any time during the test from the change in U1 and U2 weights as described in the following calculations:

Let
V_o = oil volume, cm^3
V_w = water (brine) volume, cm^3
ρ_o = oil density, g/cm^3
ρ_w = water density, g/cm^3
$\Delta W1$ = weight change for U1, g (compared to previous weight)
$\Delta W2$ = weight change for U2, g (compared to previous weight)

As oil and brine are produced from the core plug,

$$\Delta W1 = \Delta V_o(\rho_o - \rho_w) \tag{1}$$
$$\Delta W2 = (\Delta V_o + \Delta V_w)\rho_w \tag{2}$$

From eqs. 1 and 2,

$$\Delta V_o = \Delta W1/(\rho_o - \rho_w) \tag{3}$$
$$\Delta V_w = [\Delta W2/\rho_w] - [\Delta W1/(\rho_o - \rho_w)] \tag{4}$$

Typical Oil/Brine Application

Assume that an unsteady-state oil/brine relative permeability test is to be performed using an oil of 0.86 g/cm^3 density and brine of 1.00 g/cm^3 density. The difference in densities is 0.14 g/cm^3. Assume further that fluid volumes are to be resolved to the nearest 0.1 cm^3. The required accuracies of the weight measurement devices are calculated from eqs. 3 and 4:

$$\Delta W1 = 0.1\ cm^3(-0.14\ g/cm^3) = -\ 0.014\ g/0.1\ cm^3 \text{ of oil} \tag{5}$$
$$\Delta W2 = 0.1\ cm^3(\ 1.00\ g/cm^3) = \ 0.100\ g/0.1\ cm^3 \text{ of oil or brine} \tag{6}$$

From the results of eqs. 5 and 6, the weight measurement devices should be capable of resolving weights to 0.01 g. If the plug pore volume is 25 cm^3, the volume capacity of U1 should be at least 25 cm^3, and the weight measurement device from which U1 is suspended should be capable of measuring weights to at least 25 g. If 100 pore volumes of brine are injected during the test, U2 should have a volume capacity of at least 2,500 cm^3, and the weight measurement device which U2 rests upon should be capable of measuring weights to at least 2,500 g. The weight measurement devices should also be able to accommodate the weights of the two containers. Inexpensive digital electronic balances are available with resolutions to 0.001 g and weight capacities in the several thousand gram range. Balances with digital output options can be interfaced with laboratory computers for electronic data logging.

In Fig. 1, a coil is shown in the tubing which runs from the coreholder to the oil collection vessel. The flexible, coiled tube allows the oil collection vessel to move in the vertical direction with a minimum of interference. The stiffness of the tubing has an effect on the weight change displayed by the balance. The effect of the tubing stiffness can be measured early in the coreflood when oil alone is injected into the oil collection vessel. When only oil is flowing into the separator, weight changes in the oil and brine collection vessels are both indicative of oil production. The effect of tubing stiffness on weight changes within the oil collection vessel can be calculated and can be corrected for in subsequent oil volume determinations. A similar analysis can be performed when the oil collection vessel is attached to the brine collection vessel by another coiled tube.

When the oil and brine collection vessels are connected in a closed fashion, tests can be performed at elevated temperatures and pressures with live fluids by placing backpressure on the flow system. Figure 2 shows an example in which the oil collection vessel is placed within a heated environment with backpressure while the brine collection vessel is placed downstream from the backpressure regulator at an ambient temperature condition. The performance of the backpressure regulator is enhanced because only single-phase brine flows through the regulator. The brine collection vessel can also be placed upstream from the backpressure regulator in the heated environment. When tests are conducted at elevated temperature and pressure conditions, appropriate corrections for fluid density changes are required, depending upon where in the flow system weights are measured.

ADVANTAGES AND LIMITATIONS

A major advantage of the separator design is that the system can be used to measure timed-volumes of produced fluids even when the fluids do not separate easily because the technique is based on weight measurements rather than interface level measurements. Figures 3 and 4 are oil and brine production versus time plots from an unsteady-state test in which the separator was used. Water breakthrough is clearly evident from the data, so the test operator does not have to be present to observe when breakthrough occurs.

Advantages of the weight method for monitoring liquid production include the following:

- Low cost. Inexpensive digital electronic balances of appropriate resolution and weight capacity are currently available with digital output and weigh-below options. Collection vessels can be fabricated from plastic materials for low-pressure tests. Metallic gas sample cylinders can be used for tests with elevated fluid pressures and temperatures.
- Accuracy. Produced fluid volumes can be resolved to 0.01 mL when appropriate instruments are selected. Depending upon the sampling frequency, hundreds to thousands of oil and brine volume data sets can be recorded during a test. The plethora of data, particularly before and after water breakthrough, is useful when curve-fitting techniques such as JBN[6] or Jones and Roszelle[7] graphical techniques are employed to analyze results.
- Simplicity. Operator skill requirements are greatly reduced using this technique compared to those of other methods in which fluids are collected in graduated tubes and interface levels are visually determined.
- Unattended operation. An operator does not have to stay with the equipment during an experiment when a computer is used for acquiring pressure, time, and production measurements. The system offers a high degree of automation.
- Emulsion measurements. The weight method can resolve oil and brine volumes even when the fluids separate slowly.

Some of the limitations of the system include:

- Vibration. The balances must be placed in an environment which is free from vibrations. The separator and balances should be shielded from fluctuating air flows. This requires the construction of wind screens when the separator vessels are placed in forced-air ovens.
- Temperature. Temperature capabilities of digital balances are limited. A balance cannot be placed directly in an oven during a high-temperature test.
- Balance induced time delays. Some electronic balances use comparator circuitry to ensure that the weight is stable before displaying a weight measurement. During high-injection-rate tests or in a windy environment, the time delay as the balance tries to distinguish a consistent

weight can be a nuisance. This problem can be minimized by selecting balances with very fast measurement times or through bypassing the comparator circuitry.

- Production of fines, varying fluid densities, and production of a third phase. Because the method bases volume measurements on weight differences, large errors may result in measurements when appreciable fines are produced, or when the densities of the fluids change because of phase changes or temperature instabilities. Tests must be designed to minimize these occurrences.

CONCLUSIONS

Production measurements from unsteady-state tests can be automated using a technique in which produced volumes are calculated from separator weight changes. The separator works well when the density of each fluid is constant throughout a test and the densities of the two fluids are different. Separator measurements are fast even when the fluids separate slowly. The system can be configured for tests with backpressure. Because volume calculations are rapid, the number of data points recorded during a test is limited only by the balance response and data acquisition times. The system allows a high degree of automation.

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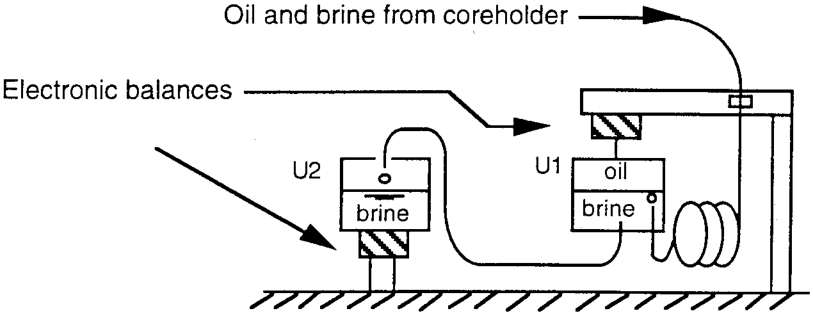


FIGURE 1. - Fixture for measuring oil and brine fluid volumes during unsteady-state corefloods.

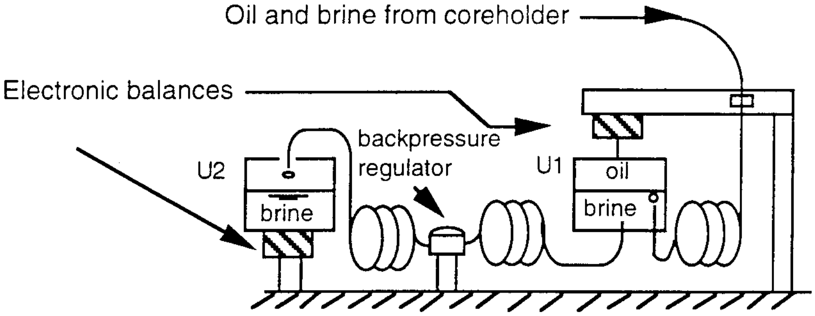
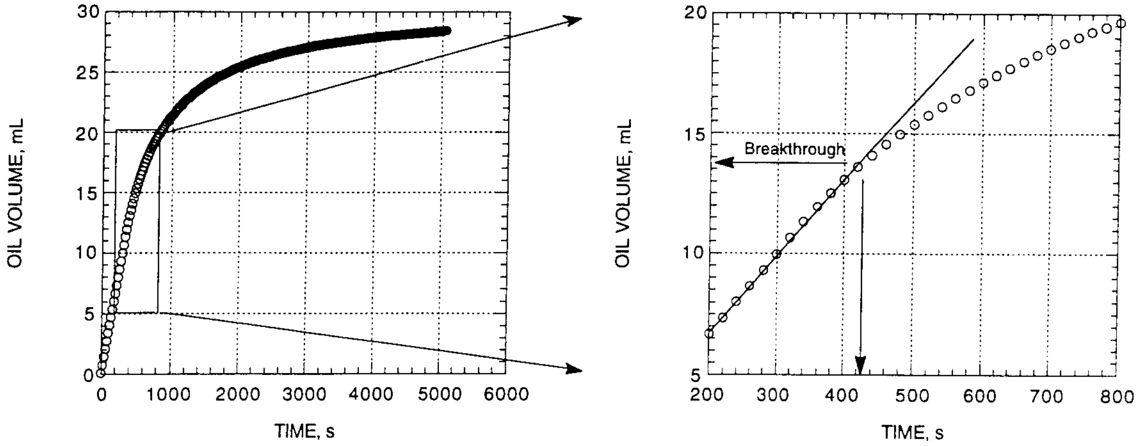
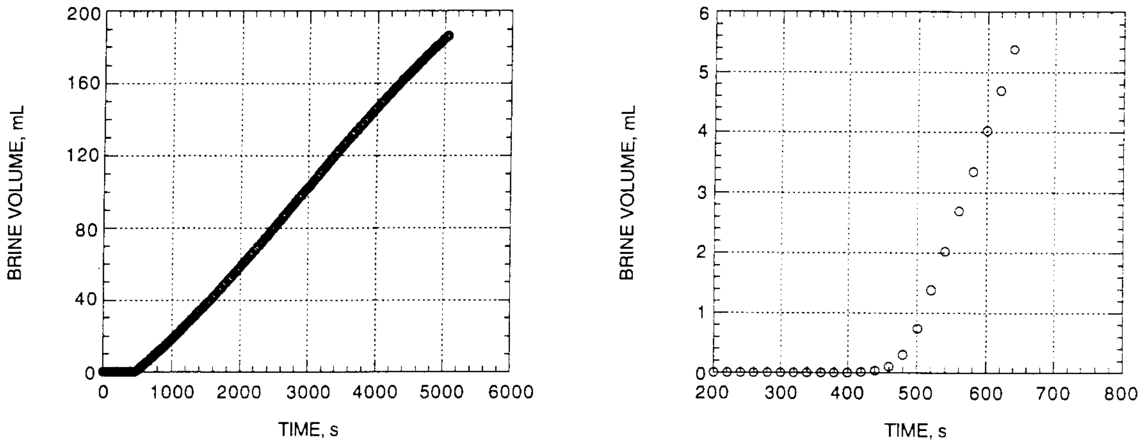


FIGURE 2. - Weight method oil/brine system with backpressure.



(a) (b)

FIGURE 3. - Oil production versus time from unsteady-state test (a) entire data set and (b) showing breakthrough.



(a) (b)

FIGURE 4. - Brine production versus time from unsteady-state test (a) entire data set and (b) showing breakthrough.