Author's Reply to Discussion of A Prediction Technique for Immiscible Processes Using Field Performance Data

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Liu's proposed method of plotting N_p vs. $\ln(N_p/W_p)-N_p/W_p$ to extrapolate cut vs. cumulative production plots is not based on a firm theoretical foundation. The main objective of the proposed method is to make long-range forecasts from very early performance data.

If the prediction technique is to rely on field permeability characteristics of a waterflood, then one must allow sufficient performance data to develop the appropriate trend. Field-based relative permeability characteristics of a waterflood implicitly include a measure of effective vertical and horizontal sweep efficiencies. These efficiencies cannot be reflected unless all producing layers have exhibited breakthrough. Low water cuts (below 50%) are indicative of breakthrough in subcomponents of a layered system. If one believes in the concept of frontal advance theory, then at breakthrough of all layers, water cut must be above 50% (above the point of inflection of a fractional-flow curve). Thus, applying any procedure to use water-cut data below 50% is to represent the behavior of the reservoir prematurely and can lead to erroneous projections.

The formulation suggested by Liu uses $E_R=mX+n$ as a starting point and substitutes cumulative water cut $F_w=W_p/(N_p+W_p)$ for instantaneous water cut, $f_w=W_p/(W_p-N_p)$. This assumption is not valid because it requires a constant f_w throughout the life history. The relationship between F_w and f_w has a shape similar to that between cumulative recovery and f_w, as shown below:

$$E_R=mX+b,$$

$$N_p=NmX+bN,$$

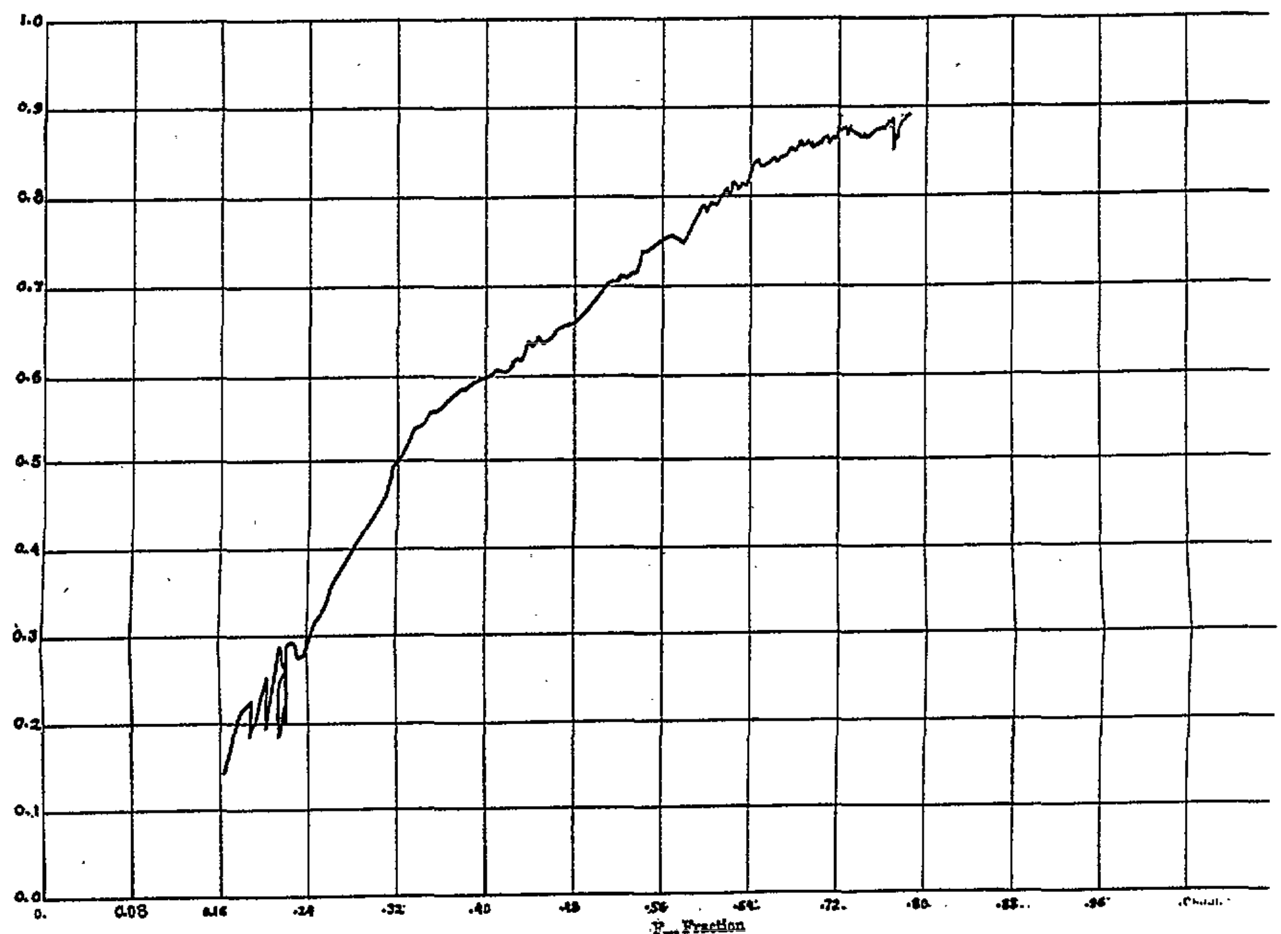

Fig. R-1—Cut-vs.-cumulative-production plot of a waterflood in Long Beach, CA.

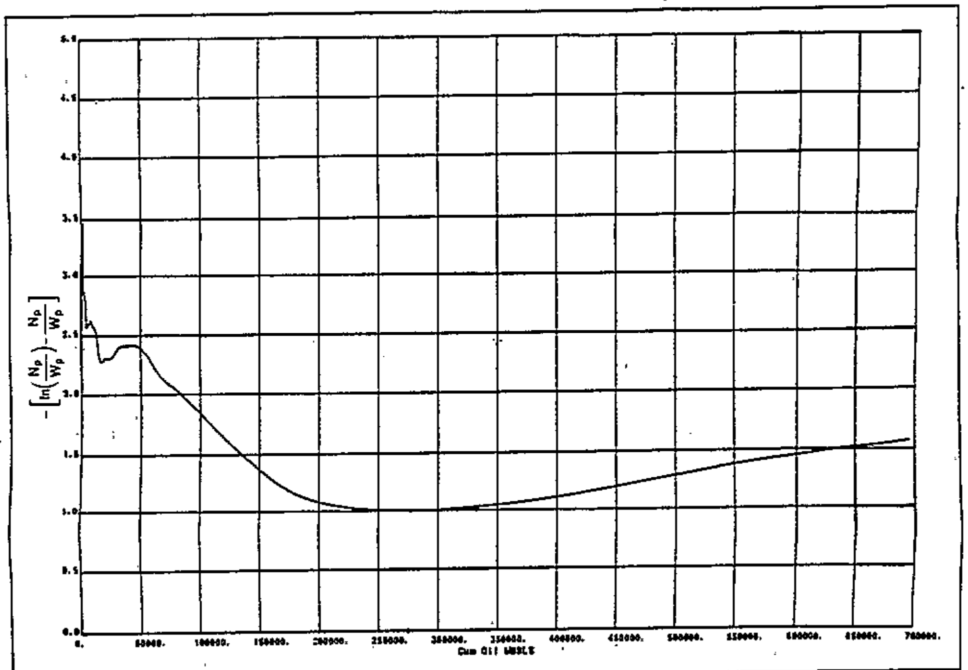

Fig. R-2—f_w/F_w plot for the waterflood.

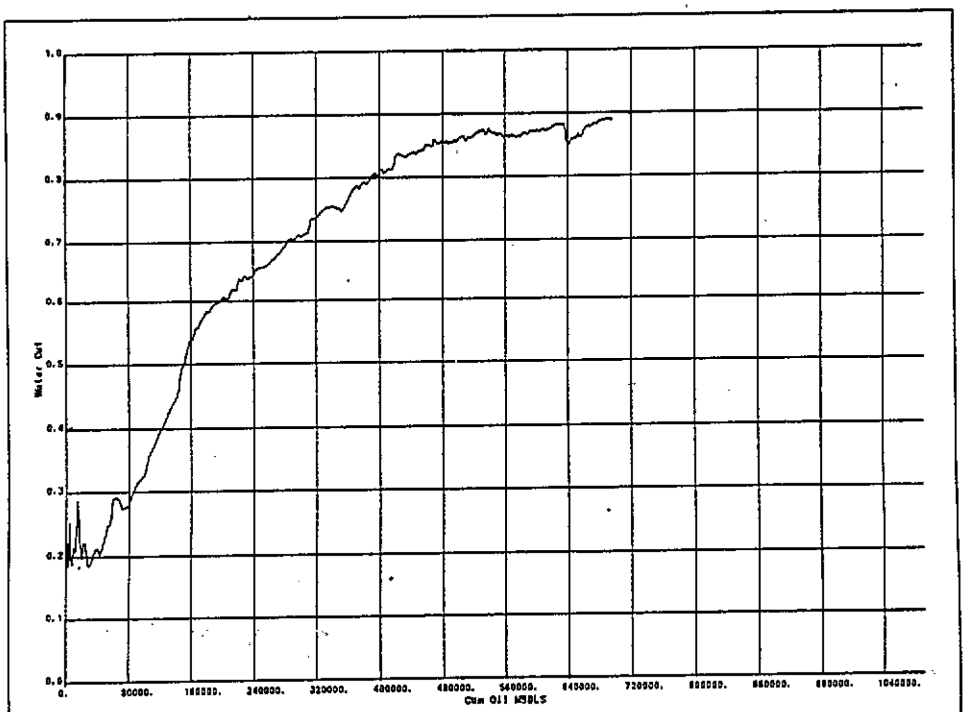

Fig. R-3—Proposed plot for the waterflood.

$F_w = 1-(N_p/q_i\Delta t)$ (assuming constant injection rate), and

$F_w = \alpha X+\beta$,

where $\alpha=-Nm/q_i\Delta t$ and $\beta=-Nb/q_i\Delta t+1$.

A typical cut-vs.-cumulative-production plot for a mature waterflood is shown in Fig. R-1. Corresponding F_w vs. f_w is plotted in Fig. R-2. Note the nonlinearity of the plot. Also, the plot proposed by Liu is shown in Fig. R-3. There is a definite change in trend starting at cumulative oil production of 32×10^8 bbl [5.1×10^8 m^3] corresponding to a cumulative cut of 50%. Extrapolation of early data would definitely have resulted in an erroneous projection. This can also be inferred from a plot of $Z=\ln(N_p/W_p)-(N_p/W_p)$ vs. N_p, where the minimum point corresponding to $dZ/dN_p=0$ occurs at $N_p=W_p$ or $F_w=0.5$, which further delays the projection process.

SI Metric Conversion Factor

bbl × 1.589 873 E−01 = m^3

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