CHAPTER IX

EVALUATION OF OPTIMUM PRODUCTION RATE

It was found in the previous chapters that the maximum allowable oil production rate had insignificant effect on the ultimate oil recovery of a reservoir produced under natural depletion process. However, it does affect on the time to reach ultimate oil recovery. The surface information obtained routinely can, therefore, be used as a tool for indicating the threshold rate for that particular reservoir. The term threshold rate refers to the smallest maximum allowable oil rate or the smallest plateau rate that will give optimum ultimate oil recovery. The derivative plot of flowing tubing head pressure has proved in chapter VIII that it is capable of identifying the threshold rate.

The benefit of having the well producing at its threshold rate instead of its maximum capacity is to avoid the problems that might occur in association with production at a very high rate. Those problems include, for instance, water conning and sand problem.

The application of the derivative plot of flowing tubing head pressure to a reservoir producing with a natural depletion process will be shown in this chapter. In this case, the conventional formulations which require subsurface information are not used for predicting the behavior of the reservoir. Only surface information which is routinely available during the production period will be used. The surface information is used to improve time for reaching ultimate oil recovery of this particular reservoir.

The reservoir starts to produce at plateau oil production rate of 500 STB/D. Observations are made to surface information including oil rate, Figure 9.1, GOR, Figure 9.2, and flowing tubing head pressure, Figure 9.3. The well has produced for 100 days with the rate of 500 STB/D. Therefore, these figures are plotted up to the first 100 days of production. The first order derivative of flowing tubing head pressure with respect to producing time is plotted against producing time, as shown in Figure 9.4. After 100 days of production, the value of the derivative was still at -5 and increased at much lower rate. It was, therefore, decided that the plateau oil production rate of 500 STB/D was still too low. The plateau oil production rate consequently was increased to 800 STB/D. The well was then allowed to produce at this plateau and the derivative plot was further extended (Figure 9.5). The derivative plot of this later portion increased more rapidly and reached the zero value at about 300 days. It is, therefore, concluded that for this well, the optimum plateau rate should be equal to 800 STB/D.

For this example, it can be shown that the plateau rate of 800 STB/D is actually the optimum plateau rate by verification runs as results shown in Figure 9.6. In this figure, the plateau rate of 500 STB/D gives the oil recovery fractions which are lower than the other plateau rates. Hence, the plateau rate of 500 STB/D is not the optimum one. This same figure also demonstrates that after the plateau rate was changed from 500 to 800 STB/D, and the well was produced until reaching abandonment, the optimum ultimate oil recovery is obtained. This is concluded from the fact that the oil recovery curve of the plateau rates of the plateau rates of 500 and 800 STB/D almost coincides with the oil recovery fraction curves of the high plateau rates (1,000 and 1,500 STB/D) which ensures the maximum ultimate recovery.

The verification stated above cannot be done when the method is applied to real data. Therefore, for real data application, one can rely only on the first order derivative plot of flowing tubing head pressure.

From this example, it could be seen that the close monitoring of the plot of the first order derivative of flowing tubing head pressure can be used to identify the optimum plateau rate. In case that the plot of the first order derivative of flowing tubing head pressure does not have tendency to approach zero rapidly, a plan to increase production rate should be considered. The magnitude of increasing production rate should be monitored by the plot of the first order derivative of flowing tubing head pressure again. After the increasing of production rate, the plot of the first order derivative of flowing tubing head pressure should approach zero within relatively short period. It should be noted here that the optimum plateau rate is the variable being sought and can be used in controlling the flowing well. When the flow rate is below the optimum plateau rate, the optimum flow rate is the rate at which the well is produced at its full capacity under the flowing tubing head pressure constraint.

It should also be noticed that when applying the method to the real data, the rate may not be abruptly changed to higher rates. In this case the rate must be gradually increased.

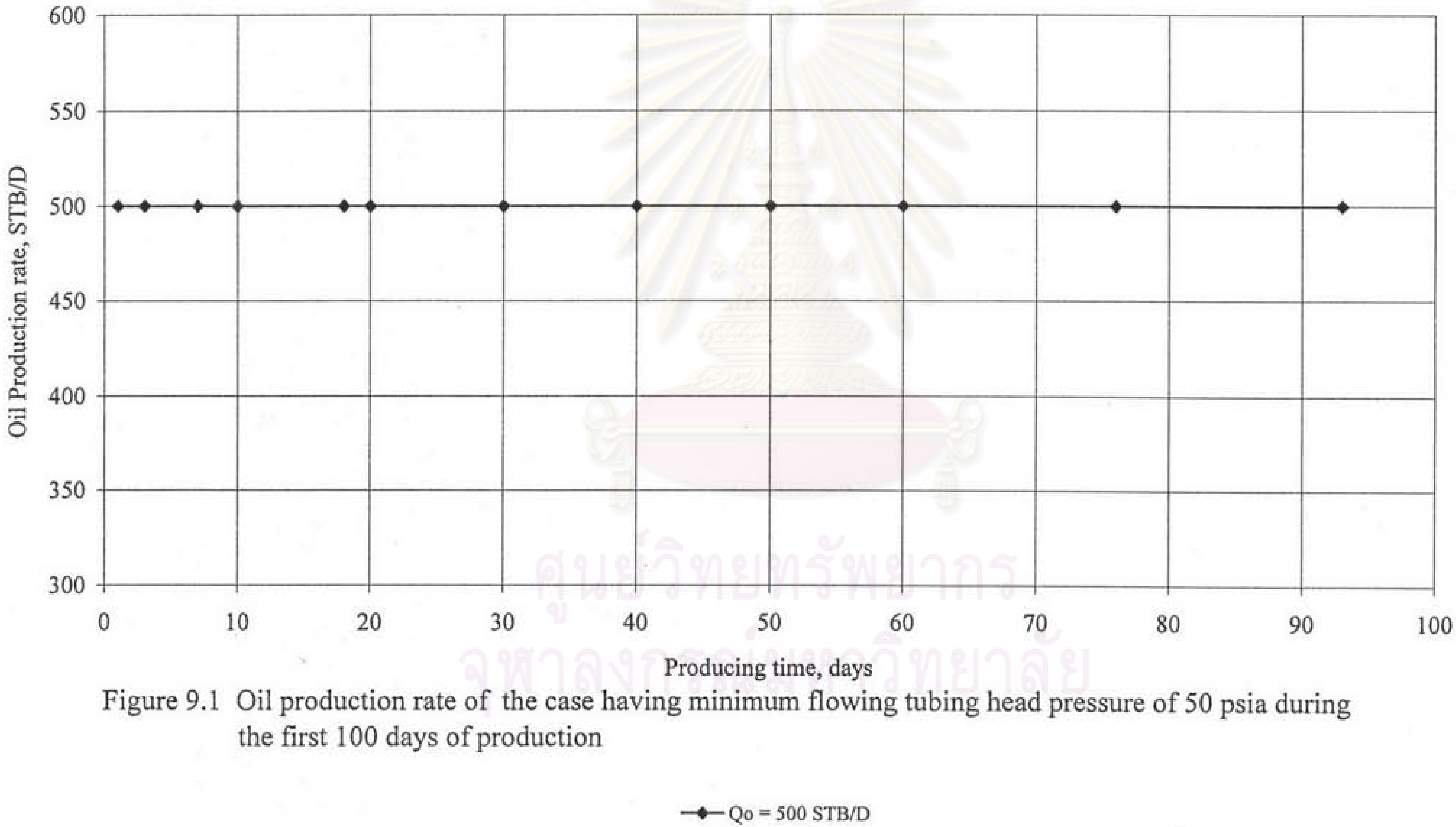

Figure 9.1 Oil production rate of the case having minimum flowing tubing head pressure of 50 psia during the first 100 days of production

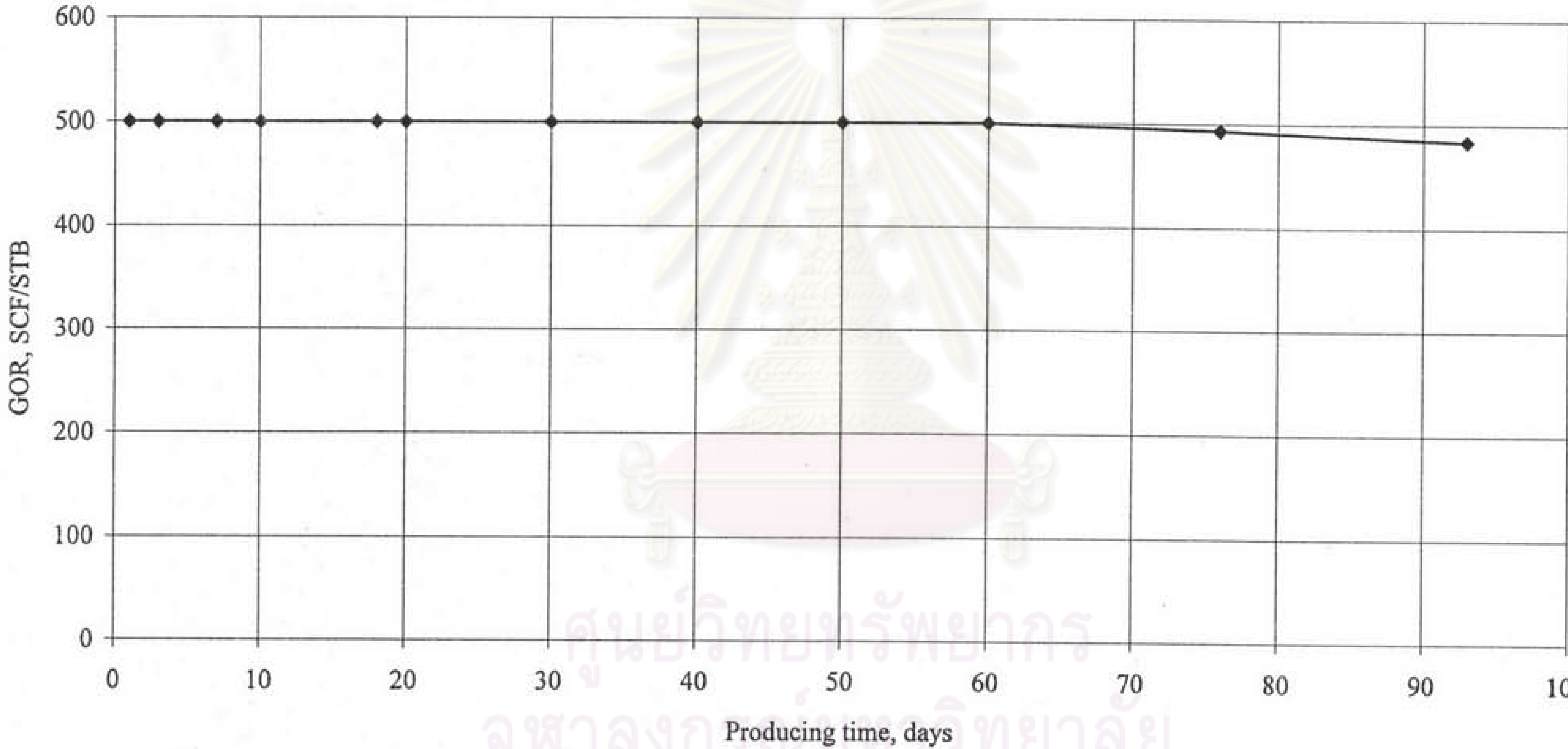

Figure 9.2 GOR of the case having minimum flowing tubing head pressure of 50 psia during the first 100 days of production

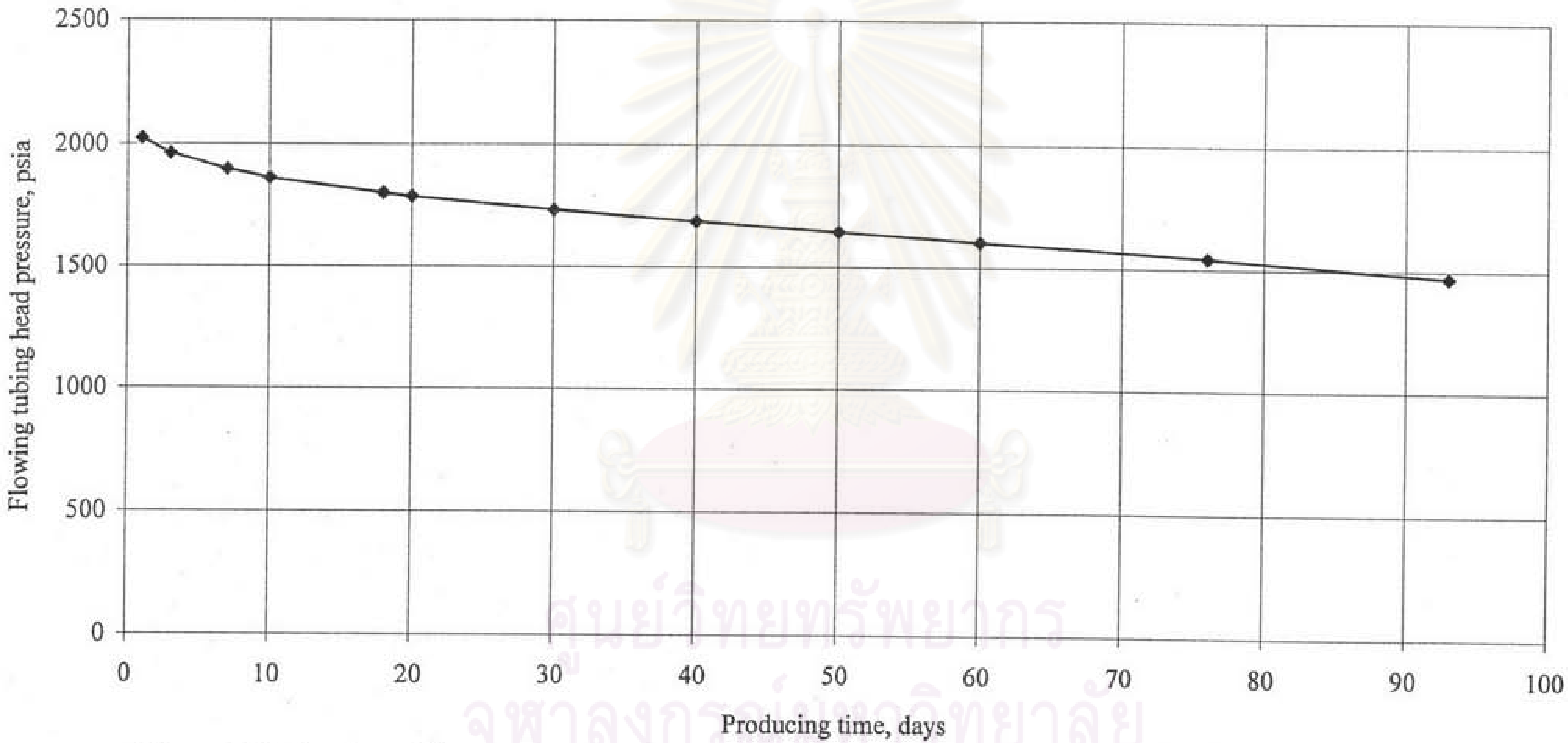

Figure 9.3 Flowing tubing head pressure of the case having minimum flowing tubing head pressure of 50 psia during the first 100 days of production

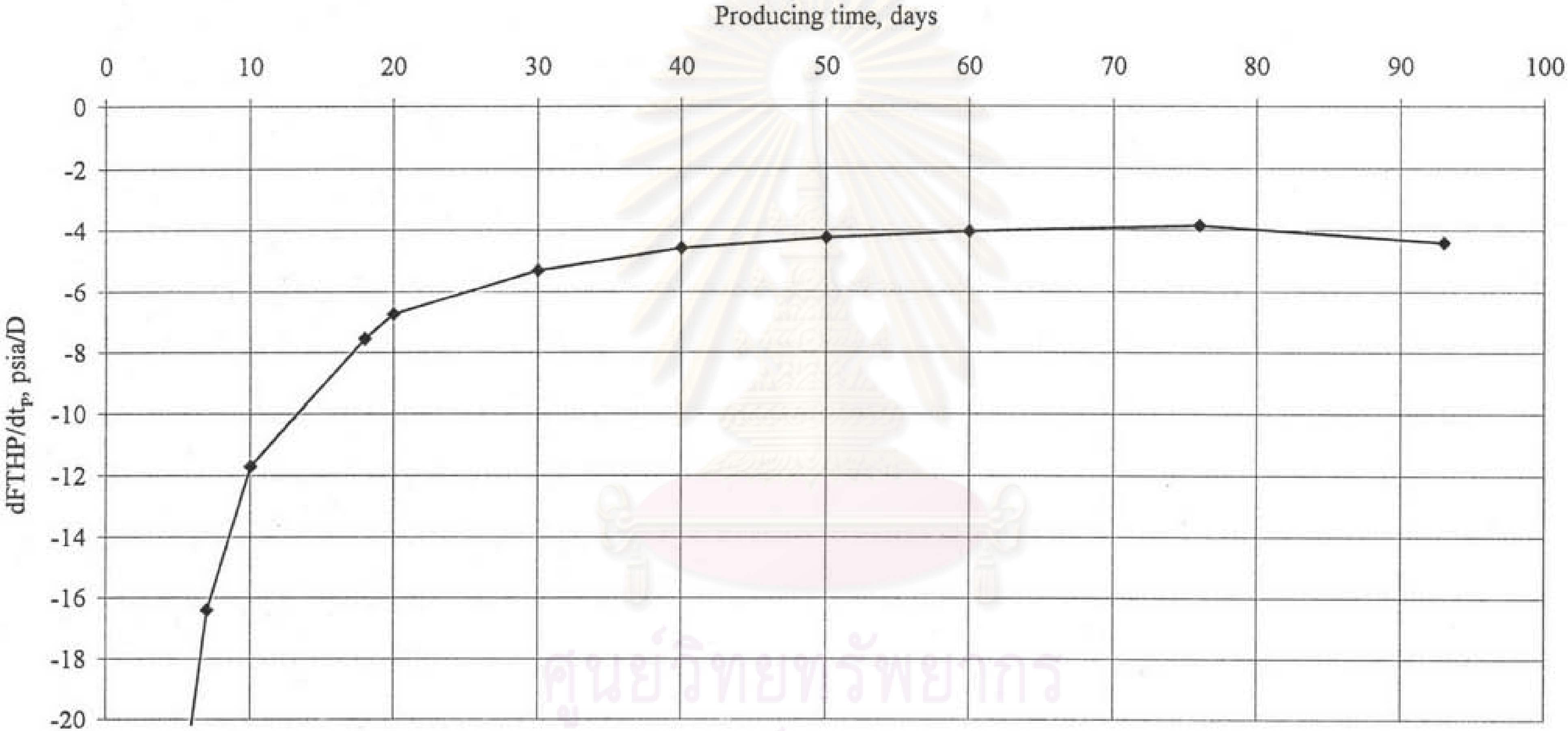

Figure 9.4 The first order derivative of flowing tubing head presssure with respect to time of the case having minimum flowing tubing head pressure of 50 psia during the first 100 days of production

—◆— Qo = 500 STB/D

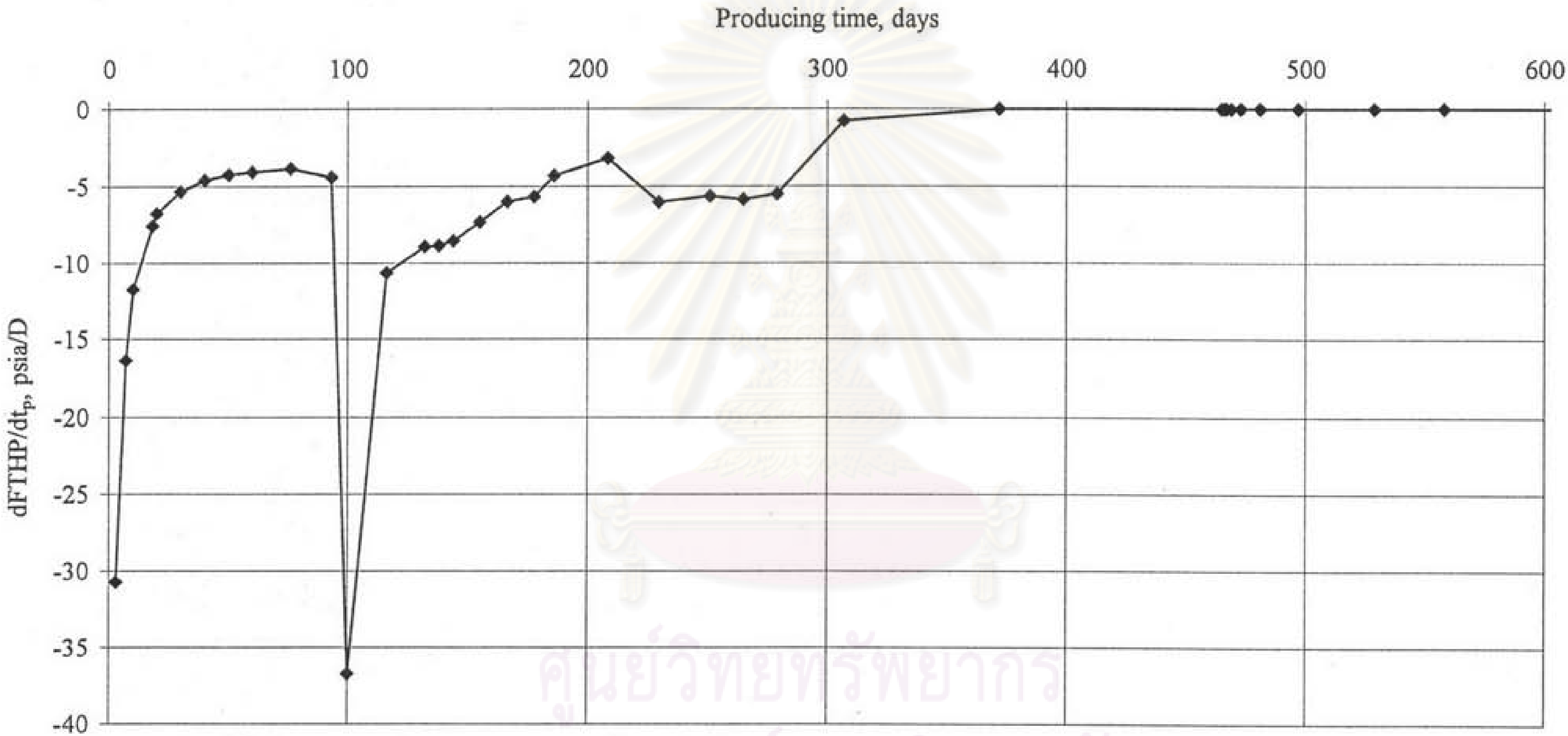

Figure 9.5 The first order derivative of flowing tubing head presssure with respect to time of the case having minimum flowing tubing head pressure of 50 psia

Qo = 500 STB/D and increased to 800 STB/D

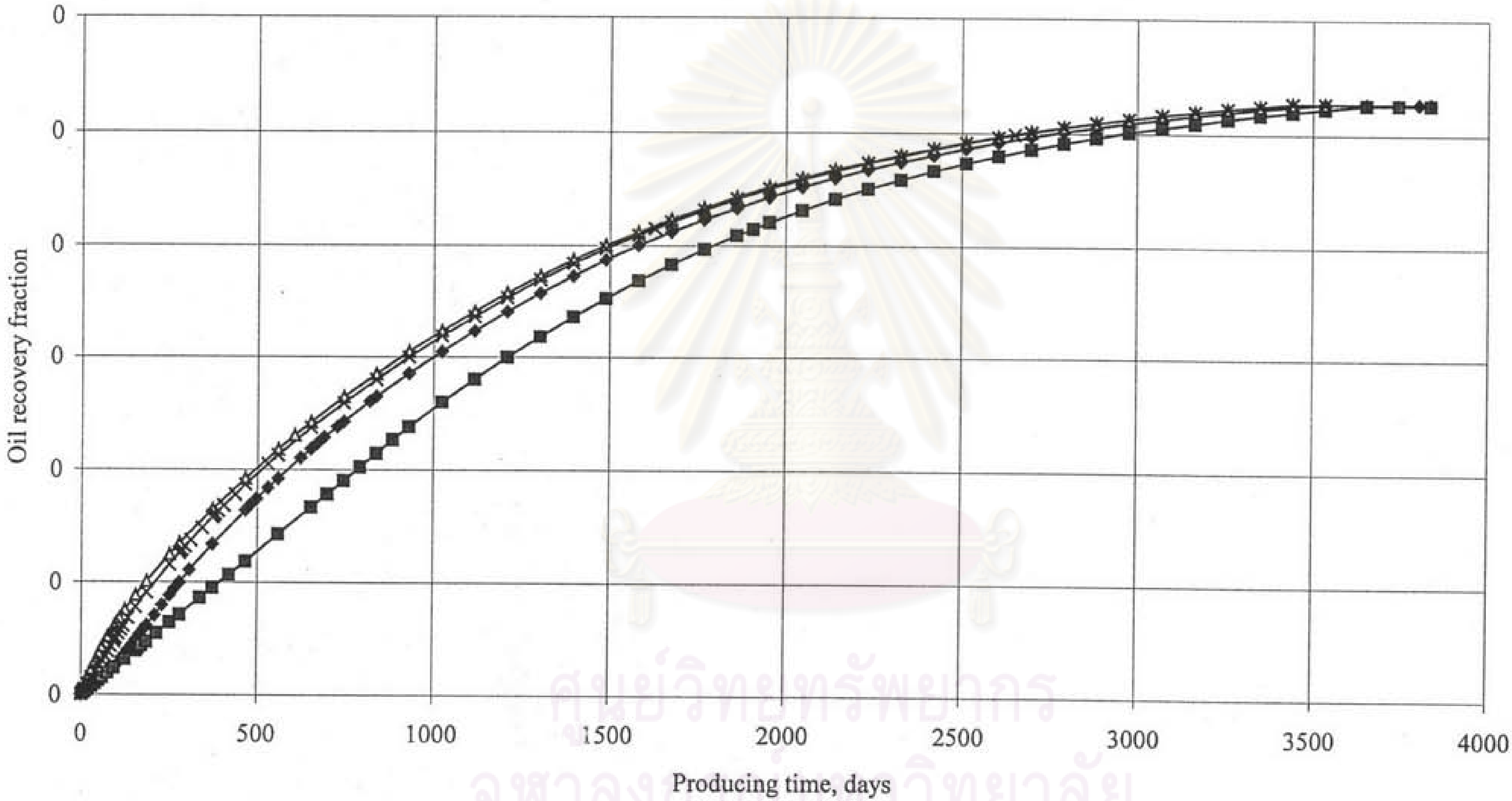

Figure 9.6 Oil recovery of the case having minimum flowing tubing head pressure of 50 psia

Maximum allowable oil rate

—◆— Qo = 500 STB/D and increased to 800 STB/D —■— Qo = 500 STB/D —▲— Qo = 1500 STB/D —✕— Qo = 1000 STB/D