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USE OF TEMPERATURE DATA IN GAS WELL TESTS

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Abstract:

Temperature measurements in front of sand face during gas production or well shut in might be used to estimate wellbore storage which represents one of the most important factors that affects pressure transient analysis. Pressure and temperature are changed depending on downhole flow rate; however, the pressure changes significantly while the temperature changes slightly. In gas producing well, the temperature might change due to two factors. The first factor is heating effect resulting from frictions through perforations. The second one is called Joule-Thomson effect or cooling effect.

This paper is focused on the explanations of pressure drop through the perforations due to friction and the cooling effects resulting from gas expansion after well shut in.

Key word: Temperature, Friction Heat, Joule-Thomson Effect.

Introduction:

Pressure transient analysis is one of the techniques that are used for reservoirs characterization. Theoretically, wellbore storage coefficient (C) can be estimated based on the analysis of the pressure in the early time portion of a test. Unfortunately, some times, it is difficult to calculate wellbore storage coefficient because of the wellbore storage itself. The well bore storage effect delays the formation pressure response and distorts the early portion of pressure data. The problem becomes more difficult as many factors including wellbore storage, skin factor, and reservoir heterogeneity affect pressure response. Therefore, detecting the end of wellbore storage might have uncertainty. As a result, many attempts have been done to determine wellbore storage effect using data corresponds to the volume of the wellbore and the type of fluid inside the

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wellbore.

Pressure derivative techniques are used during the last 30 years to figure out the problems the wellbore storage. These techniques increased significantly the probability of certainty level for the wellbore storage coefficient. But, recently, temperature transient data are used to determine the end of the wellbore storage effect.

It has been observed that the temperature in front of the sand face is equal to the static reservoir temperature before the beginning of production (new well). As the well starts to produce by a certain production rate, the temperature of the sand face increases due to the heating effect resulted from the friction pressure through the reservoir and perforations until it reaches a certain value (higher than static reservoir temperature), this temperature is called flowing bottom hole temperature. If the well is closed, the temperature starts to increases to a certain value for a short period due to the JULIO-THOMSON effect caused by gas expansion. And then declines slightly toward the static reservoir temperature.

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Temperature effects during transient test. There are two thermal effects that cause increasing or decreasing the temperature of the gas during production and shut- in.

1- Frictional heating effect:

During production the gas temperature is control by fractional heating effect which is resulted from heat transfer to the gas due to the friction of flowing gas through the reservoir and perforations. The temperature changes essentially proportional to pressure drop. From reservoir towards wellbore, since reservoir fluid travels a long distance and pressure decreases gradually, frictional heating has the dominate effect compare to JT effect. Effect of permeability on temperature behavior is shown in fig (1).

It is easy to conclude that temperature increases in low permeability reservoir more than high permeability. Low permeable reservoir has less and thin channels that allow fluid to flow toward the well bore, while high permeable reservoir has great and wide channels. Thus a great pressure drop due to friction with the porous media might happen through low permeable reservoir. The higher pressure drop reservoir the more heating effect and the higher temperature. The same situation has been observed through the pressure transient analysis especially using (Tiab Direct synthesis) as shown in fig. (2, 3).

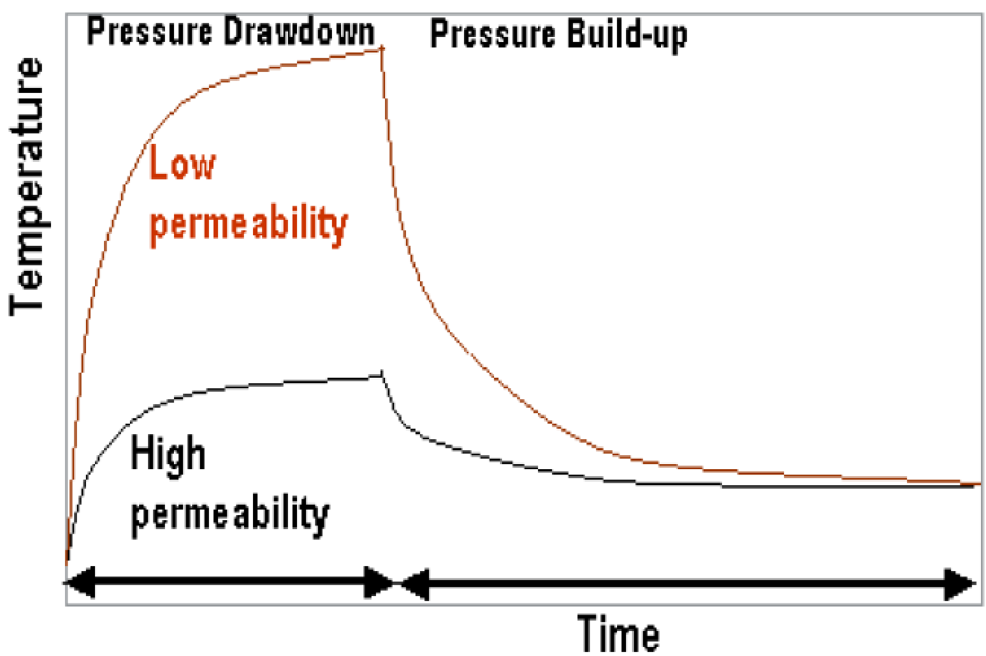

Fig (1) effect of reservoir permeability on frictional heating effect during flow assuming no JT cooling effect

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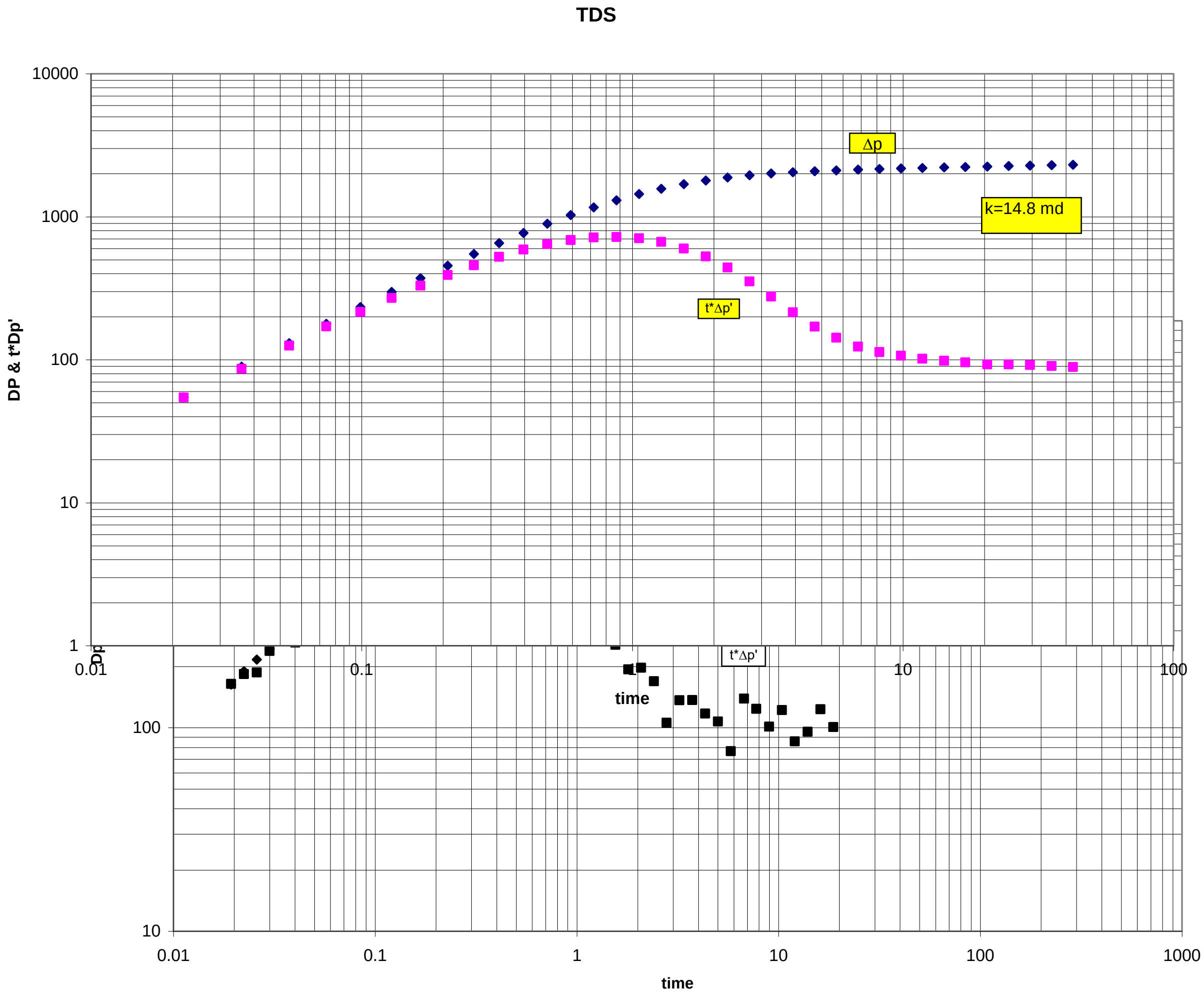

Fig. (3) high Permeability

In near wellbore region, since any throttling or reduction caused by perforation or damaged zone causes significant extra pressure drop which leads to increase the amount of heat transferred to the gas. The increment in gas temperature depends on the amount of heat transfer to the gas which depends on the friction pressure resulted in the perforation. There are many experimental equations which try to calculate the pressure drop through perforation.

$$\Delta P_f = \frac{0.000134 \rho q_o{}^2}{C_d^2 d_o^4}$$

qo= flow rate through perforation (gal/min).

C_d= discharge coefficient (dimension less).

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d= perforation diameter (inch).

ΔP_f= friction pressure (Psi).

ρ= fluid density (lbm/gal).

From the above equation, the pressure drop through the perforation depends mainly on gas flow rate and the diameter of the perforation.

2- JOULE THOMSON Effect.

In physics, the Joule–Thomson effect or Joule–Kelvin effect or Kelvin–Joule effect describes the temperature change of a gas or liquid when it is forced through a valve or porous plug while kept insulated so that no heat is exchanged with the environment This procedure is called a throttling process or Joule-Thomson process At room temperature, all gases except hydrogen, helium and neon cool upon expansion by the Joule-Thomson process. The change in temperature per unit pressure is called Joule-Thomson coefficient, μJT which is derived as:

$$\mu = \left(\frac{\partial T}{\partial P}\right)_h$$

For an ideal gas, the Joule- Thomson coefficient is zero meaning that when an ideal gas expands at constant enthalpy, there is no temperature change while as real fluid expands, cooling occurs if μJT is positive and warming occurs if μJT is negative fig (4).

Typically, for natural gases up to pressure of 5000-7000 Psia, μJT is positive during production and it ranges from 0.01 to 0.06 f^o per Psia. At higher pressure, above 8000 Psia , μJT might be negative for gas and raising gas temperature during flow.

Analysis of temperature transient for gas wells

For gas producing wells, both the Joule-Thomson cooling effect and frictional heating effect are main factors causing the inflow temperature of the fluid to be different from the geothermal temperature at the depth. This implies that flowing well temperature can be either higher or lower than static reservoir temperature depending on which phenomenon is more dominant. In pressure build-up test, the early time pressure and temperature data are affected by wellbore storage in which

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There is a down hole flow rate from reservoir toward wellbore. During wellbore storage, flow rate decreases within a short period of time approaching a zero value causing μJT cooling effect to be vanished. This will cause a sharp increase in temperature in the early time pressure build up due to inexistence of JT cooling effect. A typical wellbore temperature behavior during flow and shut-in is depicted in fig. (5) When wellbore storage effect ends and there is no downhole flow rate, wellbore temperature decrees gradually due to radial thermal heat transfers between wellbore and reservoir. As a result, bottom hole temperature starts cooling down over shut-in time and showing a decreasing trend.

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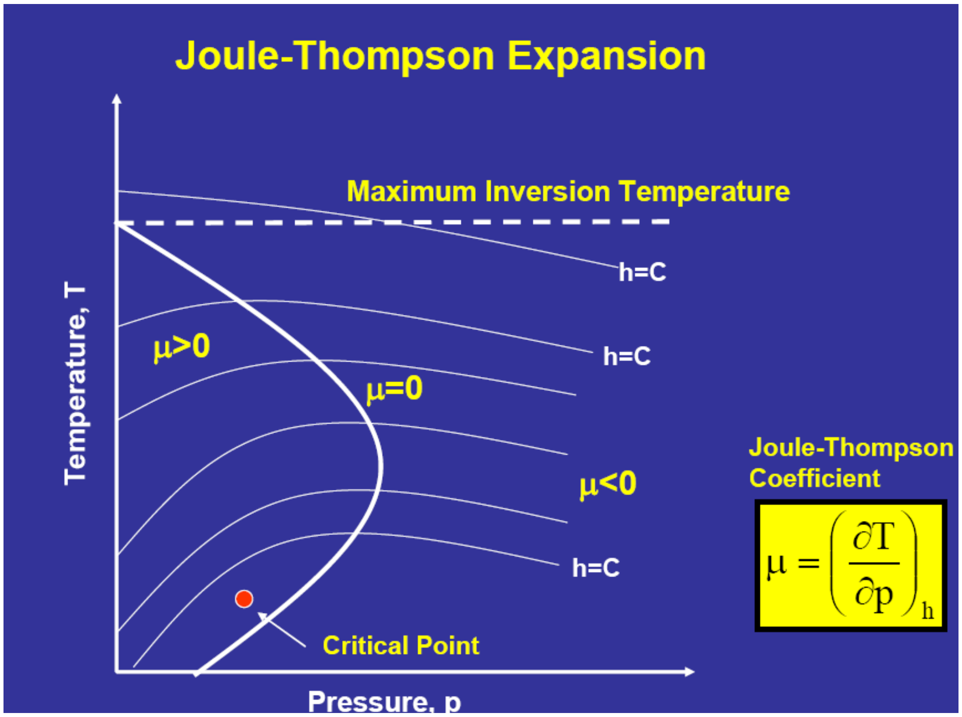

Fig.(4).Depending on the JT operating conditions, lower back pressure has the potential to reduce cooling load.

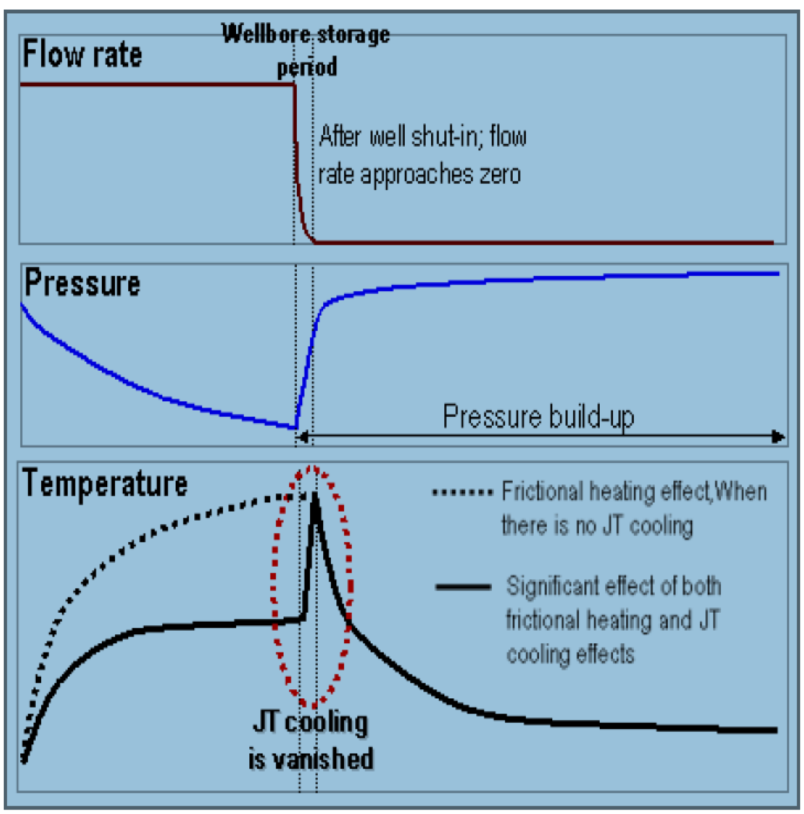

Fig (5): evaluation of JT cooling and frictional heating effects on wellbore temperature during flow and shut-in for gas wells.

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Field example

Case 1: For vertical gas well with large open hole producing interval: in this case the well-produced in different production rate, this flow rate increased with time. As shown in fig. (6). in these figures we can observed the flowing temperature continues to increase indicating a dominate fractional heating effect associated with a small JT cooling effect. Implying there is no significant extra pressure drops around wellbore. For build –up test temperature transient data can be also used to detect end of wellbore storage region. As shown in fig. (7).

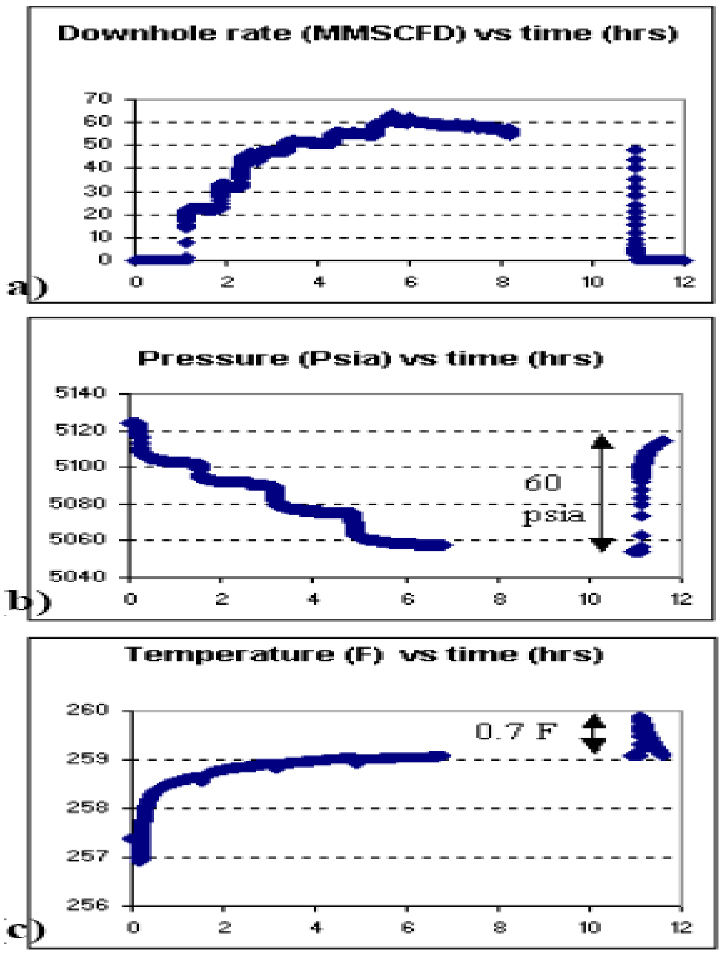

Fig. (6) Flow After Flow and Pressure Build Up Test for Case 1 During Flow.

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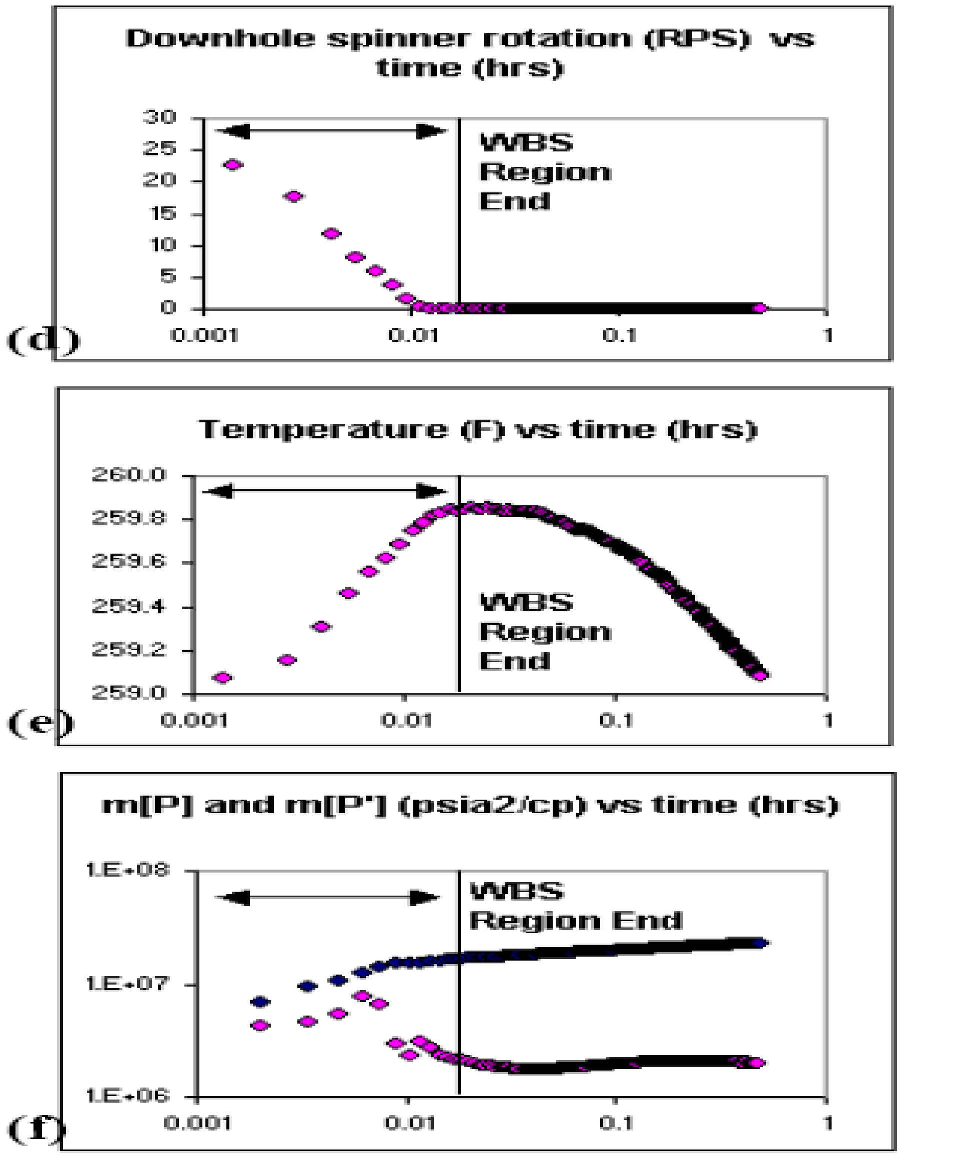

Fig. (7) Flow After Flow and Pressure Build Up Test for Case 1 During Build Up

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In this figures temperature and pressure derivative versus shut- in time are plotted when the well is shut-in, JT cooling is vanished and temperature start to increase sharply. When WBS end and downhole flow approach a zero value, frictional heating effect is also diminished. At this time well bore temperature starts declining due to heat conditions with near wellbore region. Therefore, for gas wells during build-up test, the WBS start when temperature starts increasing sharply and it end when temperature decreasing.

Case 2: vertical perforated gas well: in this case the well-produced in different production rate, this flow rate increased with time. As shown in fig. (8). in these figures we can observed the flowing temperature has significant increase indicating a high fractional heating effect generating by low permeable zone fig. (8, 9). Temperature behavior during build – up as shown in fig. (8, 9) has jumped in temperature indicating that wellbore storage end. We can observe that wellbore storage duration is accurate more than interpretation of pressure derivative.

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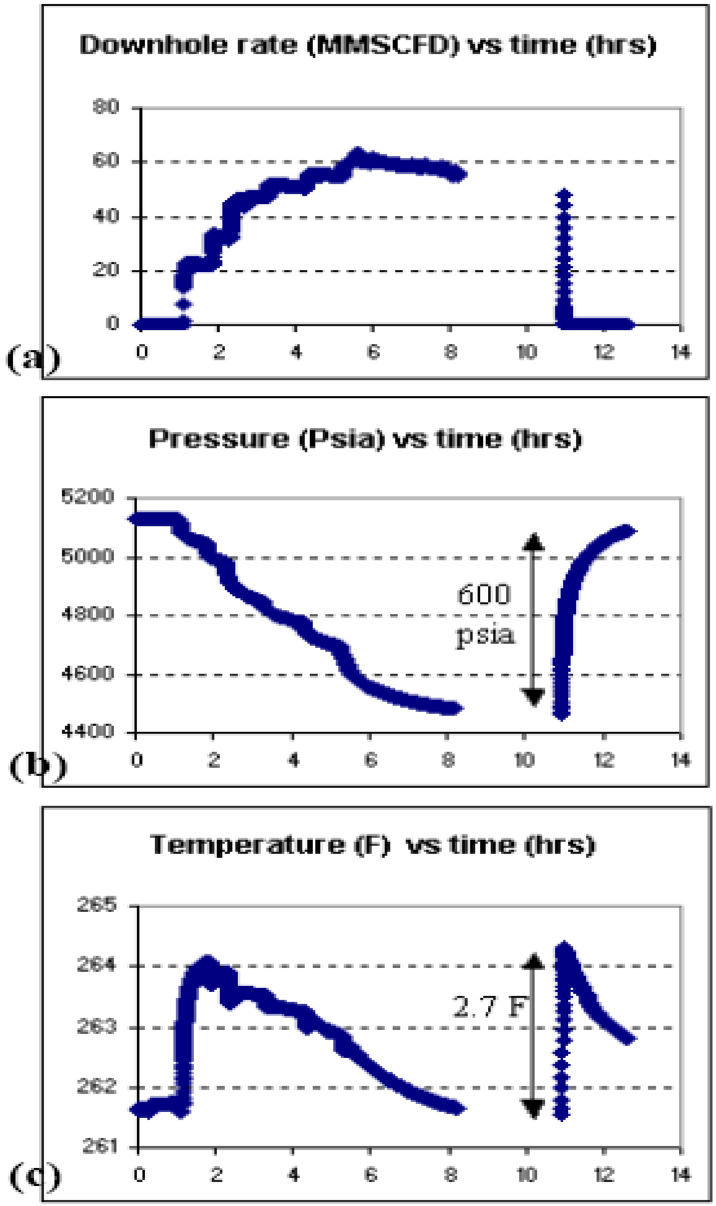

Fig. (8) Flow After Flow and Pressure Build Up Test for Case 2 During Flow.

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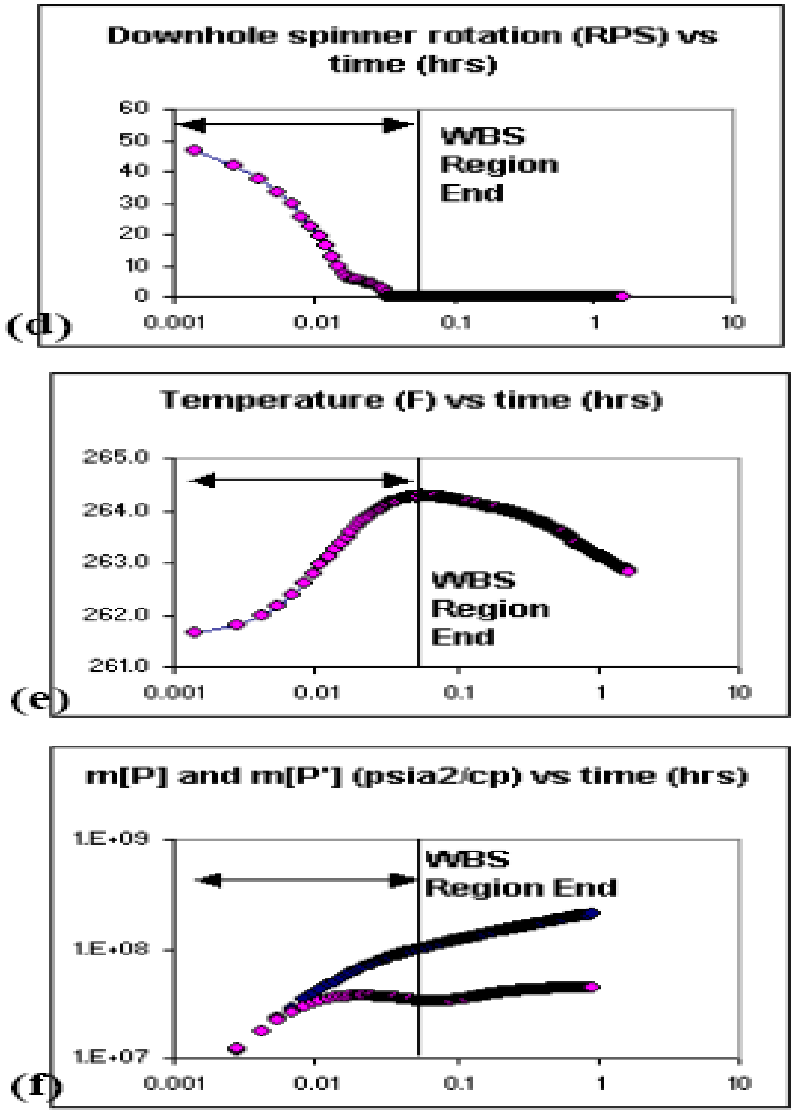

Fig. (9) Flow After Flow and Pressure Build Up Test for Case 2 During Build-Up.

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