Well Test Interpretation

SKM4323

CONVENTIONAL INTERPRETATION METHODS

Azmi Mohd Arshad

Department of Petroleum Engineering

WEEK 04

Pressure Buildup – Horner's Method

- Most of the information from a well test comes from interpreting the pressure buildups.
- Interpreting a drawdown test is limited by the flow rate fluctuations inherent to production.
- The zero flow rate that corresponds to pressure buildups does not cause this type of problems.

Pressure Buildup – Horner's Method…/2

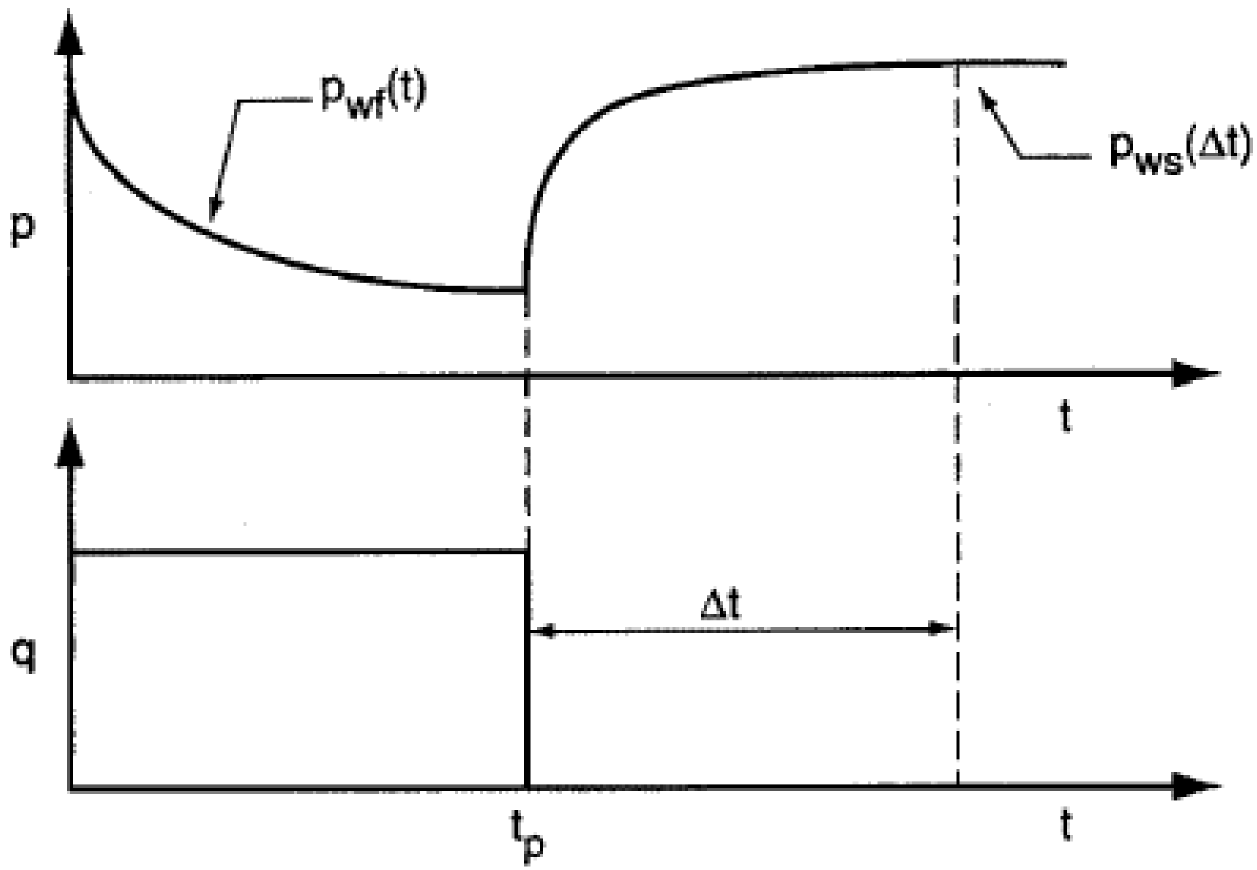

Fig. 4.2

Pressure Buildup – Horner's Method…/3

- Pressure buildup is analyzed using the flow rate superposition principle mentioned before:

$$p_i - p_{ws}(\Delta t) = [p_i - p_{wf}(t_p + \Delta t)] - [p_i - p_{wf}(\Delta t)] \qquad \textbf{(4.14)}$$

- The variations in flowing pressure are given by equation (4.3) once the wellbore storage effect has ended. Replacing the two right-hand terms of equation (4.14) by the semi-logarithmic expression of radial flow (equation 4.3) gives:

$$p_i - p_{ws}(\Delta t) = \frac{qB\mu}{4\pi kh} \ln \frac{t_p + \Delta t}{\Delta t} \qquad \textbf{(4.15)}$$

Pressure Buildup – Horner's Method…/4

Which is written:

- in practical US units

$$p_i - p_{ws}(\Delta t) = \frac{162.6\ qB\mu}{kh} \log \frac{t_p + \Delta t}{\Delta t} \tag{4.16}$$

- in practical metrics units

$$p_i - p_{ws}(\Delta t) = \frac{21.5\ qB\mu}{kh} \log \frac{t_p + \Delta t}{\Delta t} \tag{4.17}$$

Pressure Buildup – Horner's Method…/5

Interpretation

- Equations (4.15) to (4.17) show that the bottomhole pressure varies linearly versus log $(t_p + \Delta t) / \Delta t$.
- If the value of pressure measured at the bottom of the hole is plotted versus the logarithmic of $(t_p + \Delta t) / \Delta t$, on a graph, once the wellbore storage effects has ended a straight line with a slope of m can be observed:

$$m = \frac{162.6\ qB\mu}{kh} \quad \text{(in practical US units)} \qquad \textbf{(4.18)}$$

$$m = \frac{21.5\ qB\mu}{kh} \quad \text{(in practical metric units)} \qquad \textbf{(4.19)}$$

Pressure Buildup – Horner's Method…/6

Interpretation

- As with drawdown, the value of slope m is used to compute the reservoir's **kh**:

$$kh = \frac{162.6\ qB\mu}{m}$$ (in practical US units) **(4.20)**

$$kh = \frac{21.5\ qB\mu}{m}$$ (in practical metric units) **(4.21)**

Pressure Buildup – Horner's Method…/7

Interpretation

- The **skin** value is computed from the difference between:
  - the value of the pressure recorded after 1 hour of buildup on the semi-log straight line (Fig. 4.3):

$$p_i - p(1\,h) = -\frac{162.6\,qB\mu}{kh}\log(t_p + 1)$$

  - and the value of the pressure at shut-in time:

$$p_i - p_{wf}(t_p) = -\frac{162.6\,qB\mu}{kh}\left(\log t_p + \log\frac{k}{\phi\mu c_t r_w^2} - 3.23 + 0.87\,S\right)$$

Pressure Buildup – Horner's Method…/8

Interpretation

- Subtracting the two expressions term by term, the skin can be deduced:

$$S = 1.151\left(\frac{p_{1h} - p_{wf}(t_p)}{m} + \log\frac{t_p + 1}{t_p} - \log\frac{k}{\phi \mu c_t r_w^2} + 3.23\right) \quad \text{(US)} \qquad \mathbf{(4.22)}$$

$$S = 1.151\left(\frac{p_{1h} - p_{wf}(t_p)}{m} + \log\frac{t_p + 1}{t_p} - \log\frac{k}{\phi \mu c_t r_w^2} + 3.10\right) \quad \text{(metric)} \qquad \mathbf{(4.23)}$$

- The term log $(t_p + 1) / t_p)$ is usually negligible compared to the other terms

Pressure Buildup – Horner's Method…/9

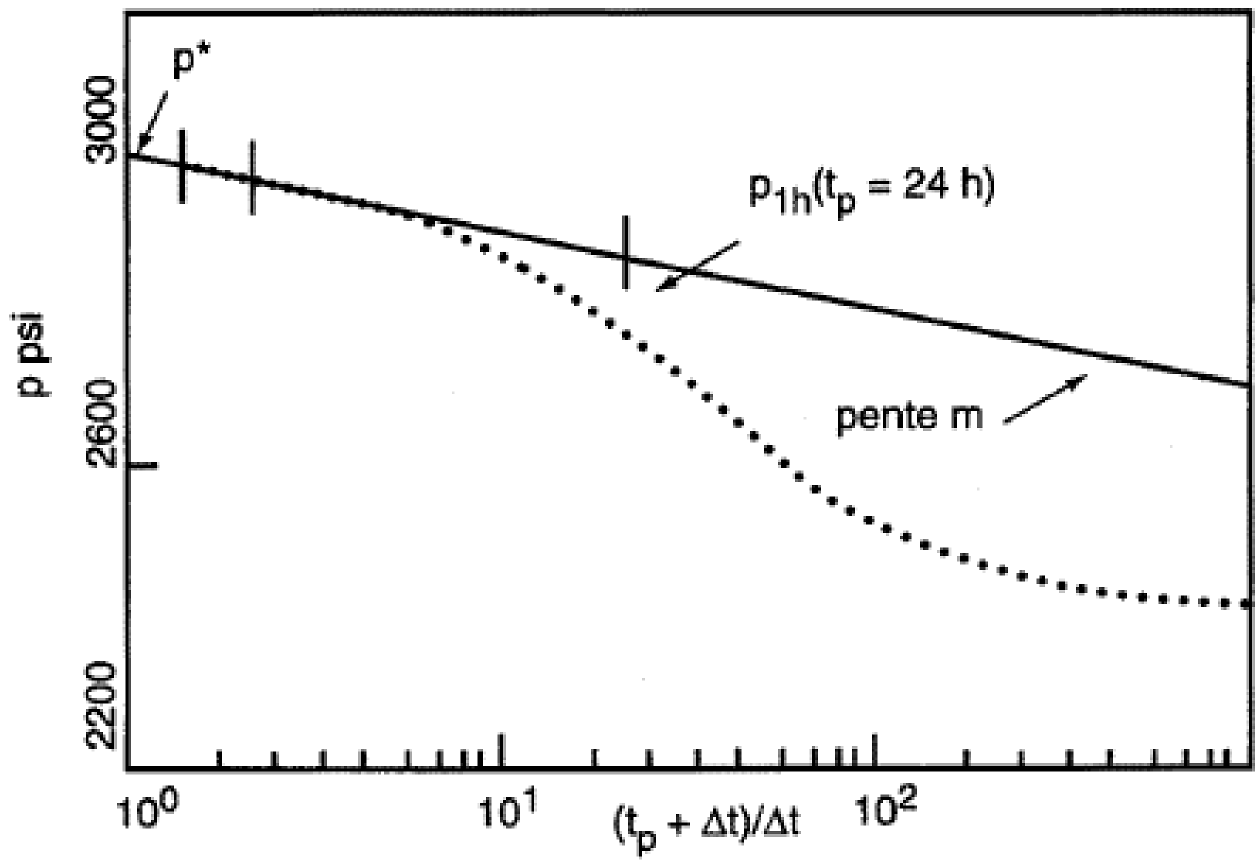

Fig. 4.3

Pressure Buildup – Horner's Method…/10

Interpretation

- If the pressure buildup was continue indefinitely, the bottomhole pressure would be equal to the initial reservoir pressure.
- The initial reservoir pressure can be read on the pressure buildup for

$$\Delta t = \infty,\ \text{i.e,}\ \frac{t_p + \Delta t}{\Delta t}$$

- This pressure value is called the extrapolated pressure and is written p*.
- It is equal to the initial reservoir pressure in most initial test.

Example 2

(In-class workshop)

Pressure Buildup – MDH Method

- If t_p is large compared to Δt:

$$t_p + \Delta t \approx t_p$$

- Equation (4.15) becomes:

$$p_i - p_{wf} = -\frac{qB\mu}{4\pi kh}(\ln \Delta t - \ln t_p)$$

- The bottomhole pressure varies linearly versus pressure buildup time.
- This means that during buildup the pressure drop due to previous production is disregarded

Pressure Buildup – MDH Method…/2

- Figure 4.4 illustrates this interpretation method developed by Miller Dyes and Hutchinson, i.e. the MDH method:
  - the real pressure buildup is Δp;
  - the pressure buildup dealt with the MDH is Δp_{MDH}.

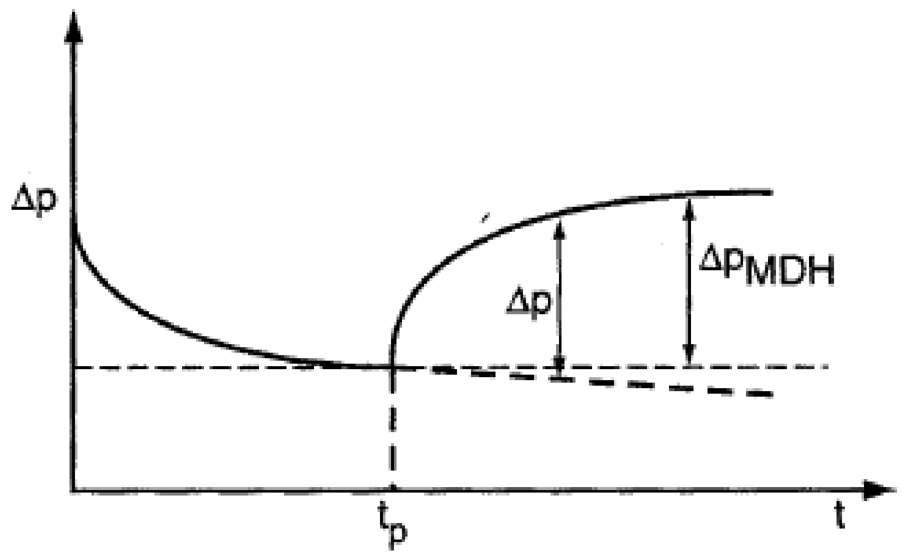

Fig. 4.4

Pressure Buildup – MDH Method…/3

- The difference between Δp and Δp_{MDH} is negligible when Δt is small compared to t_p, i.e.:
  - at the beginning of buildup;
  - after a long period of constant flow rate.

Pressure Buildup – MDH Method…/4

Interpretation

- The pressure varies linearly versus the logarithm of time. By plotting Δp_{MDH} versus Δt, a semi-log straight line with a slope of m (Fig. 4.5) can be seen once the wellbore storage effect has ended;

$$m = \frac{162.6\ qB\mu}{kh} \quad \text{(in practical US units)} \tag{4.24}$$

$$m = \frac{21.5\ qB\mu}{kh} \quad \text{(in practical metric units)} \tag{4.25}$$

Pressure Buildup – MDH Method…/5

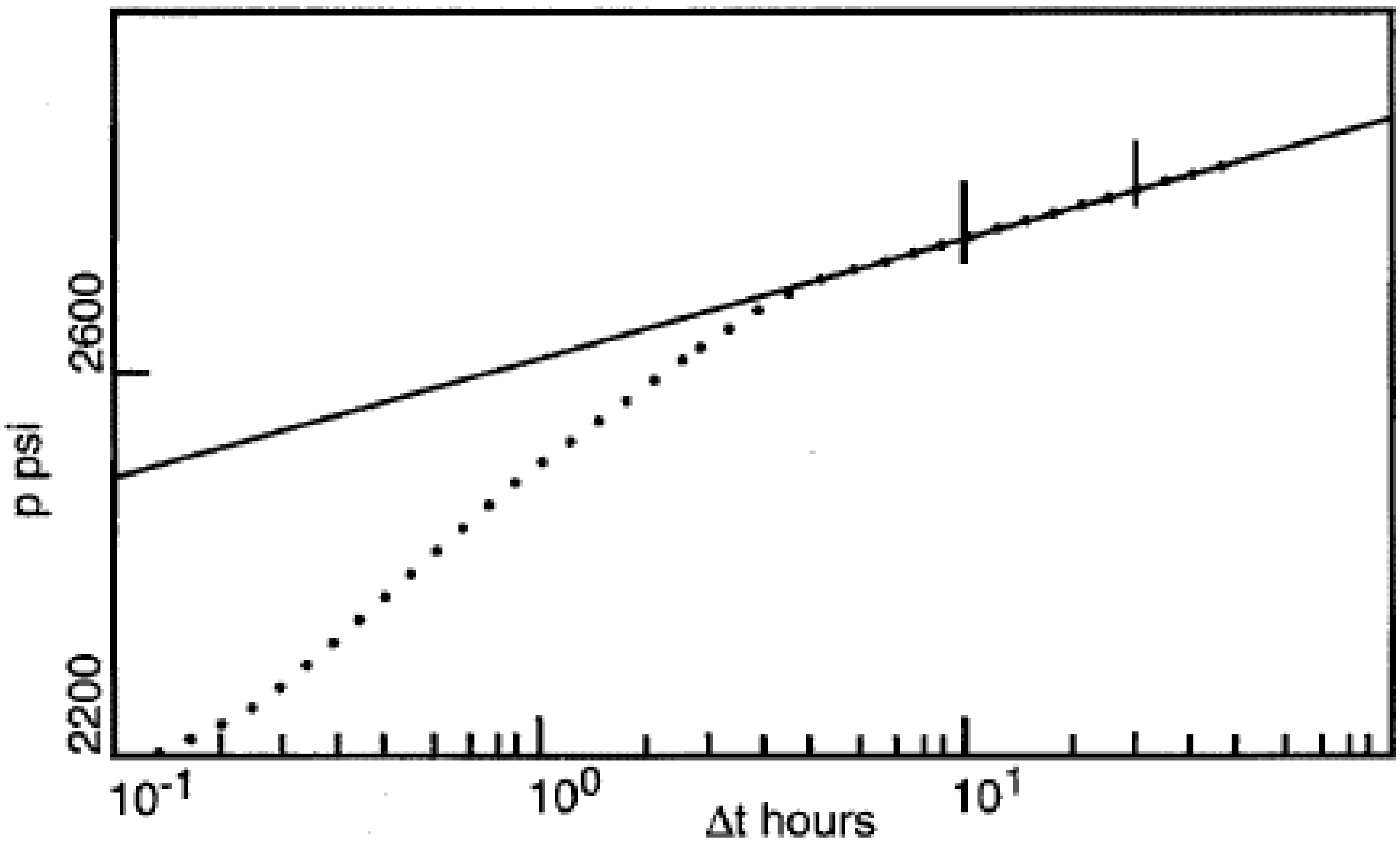

Fig. 4.5

Pressure Buildup – MDH Method…/6

Interpretation

- The slope is used to compute the reservoir's **kh**:

$$kh = \frac{162.6\ qB\mu}{m}$$ (in practical US units) **(4.26)**

$$kh = \frac{21.5\ qB\mu}{m}$$ (in practical metric units) **(4.27)**

Pressure Buildup – MDH Method…/7

Interpretation

- The skin is computed the same way as in the Horner method:

$$S = 1.151\left(\frac{p_{1h} - p_{wf}(t_p)}{m} - \log\frac{k}{\phi\mu c_t r_w^2} + 3.23\right) \quad \text{(US)} \quad \mathbf{(4.28)}$$

$$S = 1.151\left(\frac{p_{1h} - p_{wf}(t_p)}{m} - \log\frac{k}{\phi\mu c_t r_w^2} + 3.10\right) \quad \text{(metric)} \quad \mathbf{(4.29)}$$

Pressure Buildup – MDH Method…/8

Interpretation

- The advantage of this method is that it is very simple, however it has two major drawbacks:
  - it can not be used to find the extrapolated pressure;
  - it can be used only for values of Δt that are small compared to t_p.
- When production time is short or close to Δt (initial tests on a well), the last buildup points are located under the theoretical semi-log straight line in the MDH representation (Fig. 4.6).

Pressure Buildup – MDH Method…/9

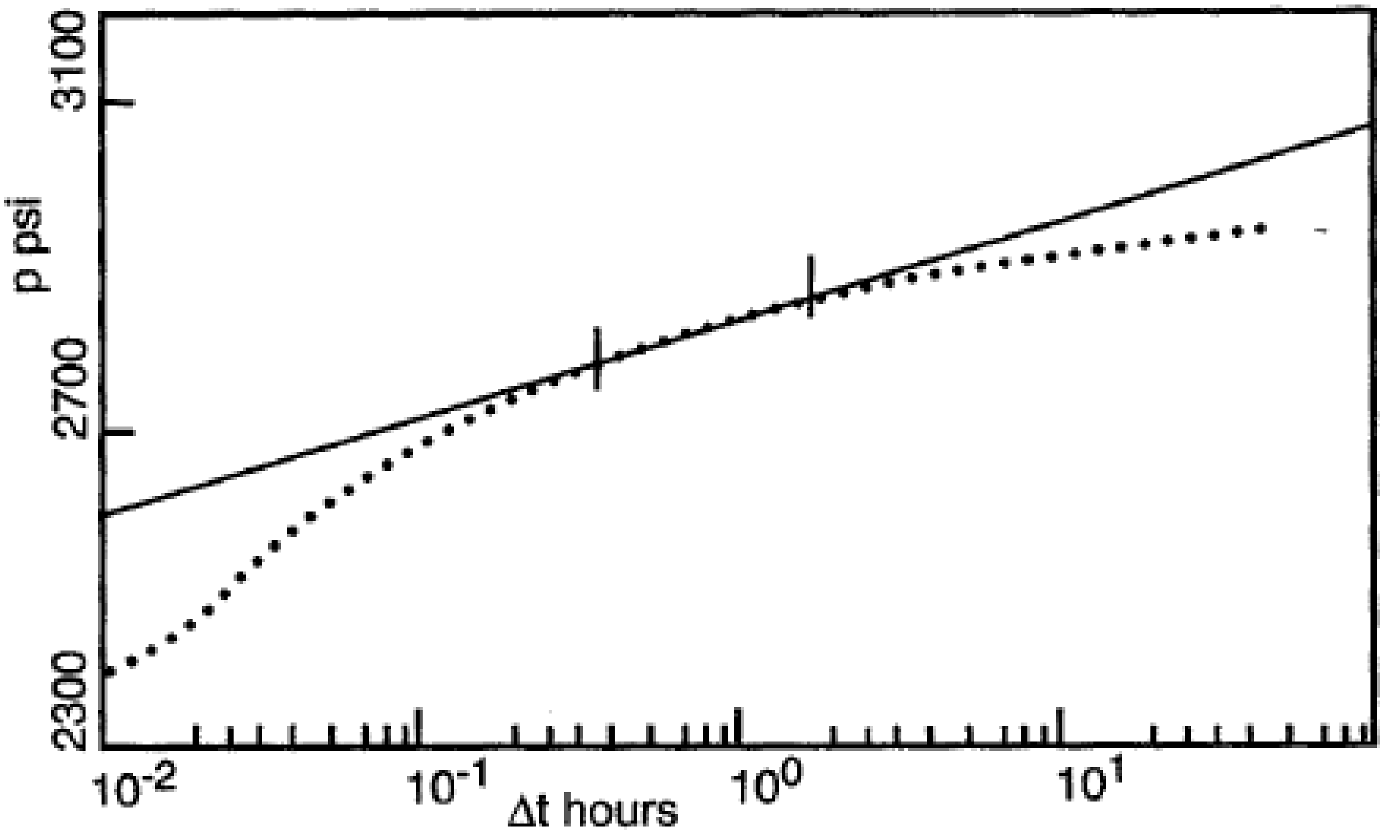

Fig. 4.6

Example 3

(In-class workshop)

References

1. Bourdarot, Gilles : Well Testing: Interpretation Methods, Éditions Technip, 1998.
2. Internet.