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# The Interpretation of DST Data for Donghae-1 Gas Field, Block VI-1, Korea

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**Abstract**−Donghae-1 gas field is located in Ulleung basin at offshore Ulsan, Korea, and its recoverable reserve is expected to be 170 to 200 BCF (Billion cubic feet). The field was confirmed to have potential gas and condensate reserves from an exploration well in 1998 and two appraisal wells in 1999. This field consists of five zones, with an average reservoir depth of about 7,000 to 8,000 ft. In this study, we have performed an analysis of Gorae V DST (Drillstem test) #2 for testing B4 zone which has the biggest reserves and Gorae V-1 DST #2 for testing B3 and B4 zones simultaneously among DST data achieved in a total of 11 zones at three wells. The pressure and flow rate recorded from two tested zones were used to obtain the reservoir characteristics and the well productivity. For pressure transient test data, we carried out the analysis of reservoir permeability, skin factor, wellbore storage effect and barrier effect by using the Horner plot and type curve matching methods. Also, with the deliverability test data, we estimated the absolute open flow which is the maximum flow rate of the gas well, and extracted the correlations representing production rate with reservoir pressure. According to the analysis, Gorae V DST #2 of B4 zone has a permeability and skin factor of 37 md (Millidarcy), 4.54, and Gorae V-1 DST #2 of B3 and B4 zones has 23 md and 21.0, respectively. It was also found that the wellbore storage effect was not significant for the two wells tested. From the deliverability test analysis, the AOF (Absolute open flow) of the Gorae V DST #2 is 152.8 MMSCFD (Million standard cubic feet per day), and that of the Gorae V-1 DST #2 is calculated to be 68.2 MMSCFD.

Key words: DST, Donghae-1 Gas Field, Pressure Transient Test, Deliverability Test, AOF

## INTRODUCTION

Offshore exploration activities for oil and gas in Korea were begun in 1969, and since then, KNOC (Korea national oil corporation) has found some gas and condensate. However, Donghae-1 gas field is the first commercial gas reservoir, which is located at 60 km away from Ulleung basin to Ulsan. This field has been confirmed to have GIIP (gas initial in place) of 250 to 300 BCF, and recoverable reserve is expected to be 170 to 200 BCF.

The Donghae-1 gas field is located at the southwest margin of the Ulleung basin as shown in Fig. 1, and its water depth is about 150 m. It is connected to Korean straits toward the southwest, and close to the continental slope in the north. The oceanic floor around the drilling point is quite flat with small variation of water depth and topography, but the maximum water depth is 190 m near the drilling location in the westerly direction.

The structure of Donghae-1 gas field is one of enechelon fold accompanied by major strike-slip fault running NE-SW in the middle of the Ulleung basin. The structure is open toward the strike-slip fault; however, thick canyon-fill shale of 10.5 Ma (Million years) plays a major role of a seal to the southeast.

Referring to the timing of the structure formation of the Late Miocene, gas migration into the structure probably occurred around 5.5 Ma. As shown in Fig. 2, Donghae-1 reservoir is subdivided into several reservoir zones by intervening shale layers. These shale layers are relatively thick and continuous, and deposited in shallow

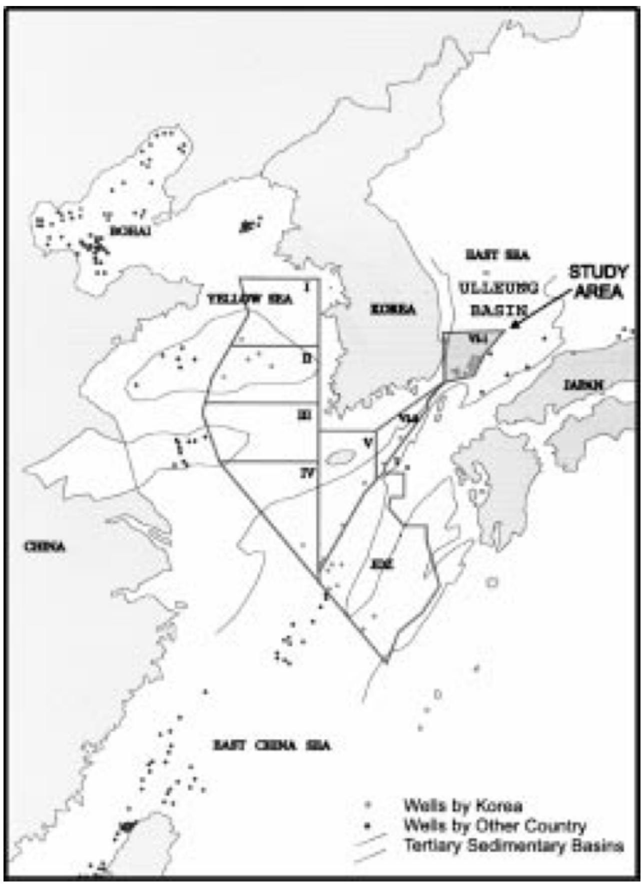


**Fig. 1. Location map of Block VI-1.**

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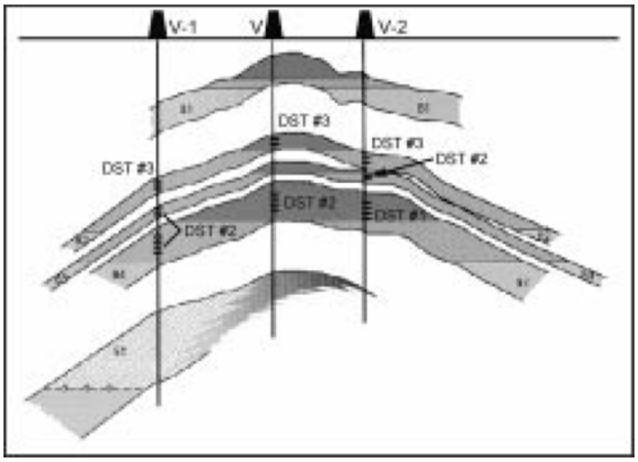


**Fig. 2. Sectional view of Donghae-1 gas field.**

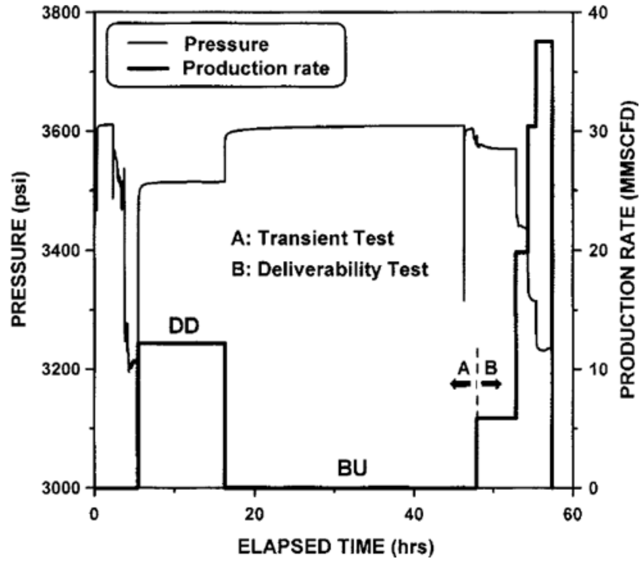


**Fig. 3. Pressure and flow rate for Gorae V DST #2.**

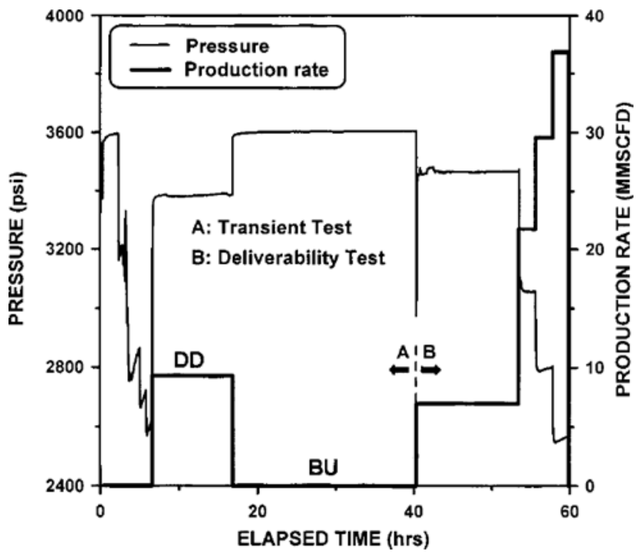


**Fig. 4. Pressure and flow rate for Gorae V-1 DST #2.**

marine environment.

The Donghae-1 gas field was confirmed to have a potential for gas and condensate from an exploration well in 1998, and two appraisal wells were drilled to the same structure in 1999. Gorae V-1 appraisal well is located at 1,100 m toward the southwest from the Gorae V and its total depth is 2,650 m. Gorae V-2 well is located at 880 m toward the northeast from the Gorae V and its total depth is 2,700 m.

A drillstem test was conducted over 11 zones of three wells for the Donghae-1 gas field as shown in Fig. 2, and gas was produced from seven zones among them (Table 1). In this study, we have analyzed two zones: Gorae V DST #2 and Gorae V-1 DST #2 [Sung et al., 2000].

## DATA ACQUISITION AND METHODOLOGY

Summarizing the data of 7 DSTs, gas was produced mainly from B2, B3 and B4 zones, and net pay thickness is proven to be 48 ft, 28.3 ft and 100 ft, respectively. Because the boundaries between the B3 and B4 zones were uncertain from the seismic and logging data, the B3 and B4 zones were perforated simultaneously to identify a communication between the two zones.

The DSTs were conducted by main drawdown (DD) and main buildup (BU) after one or two short cycles of DD and BU at the beginning. After the pressure transient test was completed, an additional flow after flow test or modified isochronal test was conducted.

In the case of Gorae V (DST #2), the pressure transient test consists of the main DD period, which produces 12.188 MMSCFD for 11 hours, and the main BU for 30 hours as shown in Fig. 3. After the transient test, the flow after flow test was conducted by producing 5.838, 19.849, 30.423 and 37.545 MMSCFD for 5, 2, 1 and 2 hours, respectively. For Gorae V-1 DST #2, the testing process is similar to Gorae V DST#2, i.e., the main DD produced 9.268 MMSCFD for 10 hours and the main BU for 24 hours as pre-

**Table 1. Summary of DST for Donghae-1 gas field**

| DST no. | V #2 | V #3 | V-1 #2 | V-1 #3 | V-2 #1 | V-2 #2 | V-2 #3 |
|---|---|---|---|---|---|---|---|
| Layer | B4 | B2 | B3, 4 | B2 | B4 | B3 | B2 |
| Gauge depth (ft) | 8366.1 | 7685.8 | 7868.4 | 7781.3 | 8014.1 | 7923.9 | 7843.4 |
| Gauge no. | 10613 | 10613 | 10019 | 10019 | 10851 | 10851 | 10722 |
| Net pay (ft) | 103.7 | 51.7 | 137.4 | 48.4 | 92.7 | 28.3 | 42.3 |
| Test interval (ft) | 7890-8366 | 7708-7907 | 7909-8448 | 7822-7995 | 8058-8242 | 7968-8123 | 7889-8038 |
| Date | 18-07-98 | 23-07-98 | 08-04-99 | 14-04-99 | 21-05-99 | 27-05-99 | 02-06-99 |

**Table 2. The recorded pressure and production rate**

| | Gorae V DST #2 | | | | | Gorae V-1 DST #2 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | P (psi) | Δt (hrs) | ∑Δt (hrs) | Q (MMSCFD) | | P (psi) | Δt (hrs) | ∑Δt (hrs) | Q (MMSCFD) |
| DD | 3191.71<br>3591.54 | 0.30 | 0.30 | | DD | 3422.41<br>3373.38 | 0.31 | 0.31 | |
| BU | 3591.54<br>3610.83 | 2.00 | 2.30 | 0.0 | BU | 3373.38<br>3595.44 | 2.01 | 2.32 | 0.0 |
| DD | 3490.77<br>3221.79 | 3.16 | 5.46 | | DD | 3327.25<br>2634.95 | 4.26 | 6.58 | |
| DD | 3221.79<br>3514.81 | 10.81 | 16.27 | 12.188 | DD | 2634.95<br>3387.06 | 10.21 | 16.79 | 9.268 |
| BU | 3514.81<br>3609.08 | 29.99 | 46.27 | 0.0 | BU | 3387.06<br>3604.56 | 23.50 | 40.29 | 0.0 |
| DD | 3316.26<br>3592.31 | 1.62 | 47.89 | | DD | 3169.52<br>3464.85 | 13.13 | 53.42 | 6.957 |
| DD | 3592.31<br>3567.14 | 4.95 | 52.84 | 5.838 | DD | 3464.85<br>3054.90 | 2.17 | 55.59 | 21.731 |
| DD | 3493.55<br>3427.84 | 1.47 | 54.31 | 19.849 | DD | 3054.90<br>2796.68 | 2.21 | 57.80 | 29.58 |
| DD | 3427.84<br>3314.98 | 1.02 | 55.33 | 30.423 | DD | 2796.68<br>2568.97 | 2.03 | 59.83 | 36.815 |
| DD | 3314.98<br>3236.62 | 2.09 | 57.42 | 37.545 | | | | | |

DD: Pressure drawdown period, BU: Pressure buildup period.

sented in Fig. 4. Also, the flow after flow test produced 6.957, 21.731, 29.580 and 36.815 MMSCFD for 13, 2, 2 and 2 hours, respectively. Since the recorded data are enormous, we summarized the representative pressures and flow rates of each period (Table 2).

## RESULT AND DISCUSSION

### 1. Pressure Transient Analysis

The solution of an appropriate flow equation for the target reservoir is essential for the pressure transient analysis. In this study, a homogeneous, infinite acting system is assumed, and its analytical solution in dimensionless form for the gas flow equation is written as Eq. (1) [Govier, 1975]:

$$\Delta\Psi_D(r_D, t_D) = -\frac{1}{2}\mathrm{Ei}\left(\frac{r_D^2}{4t_D}\right) \quad (1)$$

where Ψ is a pseudo-pressure introduced by Al-Hussainy, Ramey and Crawford [1966] to linearize the non-linear gas flow equation, and it is defined by Kirchhoff integral transform, that is, $2\int^p \frac{p}{\mu z}dp$.

The Horner method is based on an approximate solution of Eq. (1) for a transient period, namely, $t_D<0.25\, r_D^2$:

$$\Delta\Psi_D = \frac{1}{2}(\ln t_D + 0.80907) \quad (2)$$

Generally, DST consists of two periods of BU and DD, and Eq. (2) can be applied by using the principle of superposition. The resulting equation in dimensional form is the following [Govier, 1975]:

$$\Psi_{ws} = \Psi^* - m\log\left(\frac{t_p+\Delta t}{\Delta t}\right) \quad (3)$$

$$m = \frac{1.632\times10^6 q_{sc} T}{kh} \quad (4)$$

When Eq. (3) is plotted on semi-log paper with $\Psi_{ws}$ vs. $(t_p+\Delta t)/\Delta t$, a straight line appears with a slope of m and an intersection of $\Psi^*$.

Using the above equations and input data of Table 3 [Chair et al., 1989; Park and Kim, 1993], the analysis of Gorae V DST #2 is performed by the transient pressure test data of section A in Fig. 3, and the data is plotted on $\Psi_{ws}$ vs. $\log(t_p+\Delta t)/\Delta t$ in Fig. 5. From the straightline section of 0.1056 hours to 1.9667 hours, the slope is $3.440\times10^6$ psi$^2$/cp/one-log-cycle and the resulting permeability is

**Table 3. Input data for DST analysis**

| | Gorae V DST #2 | Gorae V-1 DST #2 |
|---|---|---|
| Gas gravity | 0.658 | 0.630 |
| Gas compressibility | 2.33e-4 psi$^{-1}$ | 2.36e-4 psi$^{-1}$ |
| $CO_2$ concent | 1.5% vol. | 2.0% vol. |
| Gas viscosity | 0.020 cp | 0.020 cp |
| Gas z-factor | 0.935 | 0.943 |
| Pay thickness | 103.77 ft | 137.40 ft |
| Water saturation | 34.00% | 32.10% |
| Wellbore radius | 0.51 ft | 0.51 ft |
| Total compressibility | 1.59e-4 psi$^{-1}$ | 1.65e-4 psi$^{-1}$ |
| Porosity | 14.40% | 14.62% |
| Temperature | 680.7 °R | 676.1 °R |

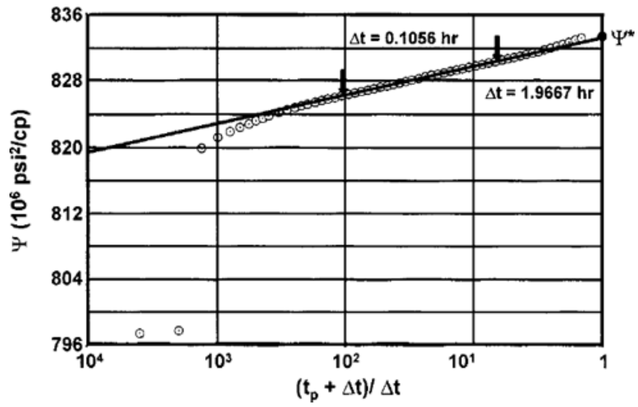


**Fig. 5. Horner plot analysis for Gorae V DST #2.**

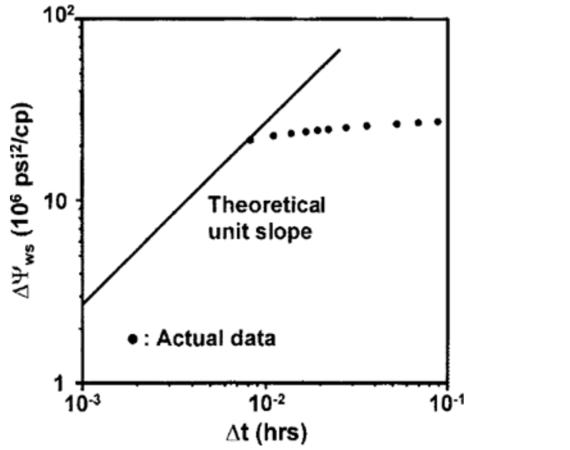


**Fig. 6. Investigation of wellbore storage effect for Gorae V DST #2.**

37.96 md by using Eq. (4). If shut-in time $\Delta t$ is much greater than the producing time $t_p$, then $(t_p+\Delta t)/\Delta t$ is close to 1.0. Therefore, the original static pressure $\Psi^*$ can be obtained with an x-axis value of 1.0 by extrapolating the straightline section. In the case of Gorae V DST #2, $\Psi^*$ is $833.4\times10^6$ psi$^2$/cp, which is converted to a pressure of 3608.79 psi.

Well testing data should theoretically have a straight line in the semi-log graph, but the field data show a deviation at the early stage of buildup due to the skin effect as well as wellbore storage effect. The additional drawdown of pressure by skin effect is caused by partial completion, mud infiltration during drilling, turbulent flow, liquid condensation, etc. However, each factor causing the skin effect is not separable with the DST data, and hence, we used total skin or apparent skin. In the meantime, the wellbore storage effect is caused by fluid compressibility inside the tubing and also the volume of the wellbore itself.

In order to examine the skin effect for the early time data (before shut-in time $\Delta t$ of 0.1056 hour) of Fig. 5, the equation used to calculate the skin factor by DST data is described at Eq. (5) [Gringarten et al., 1979], where $\Psi_{1\,hr}$ represents the value at $\Delta t$=1 hour on straightline, that is, $829.6\times10^6$ psi$^2$/cp.

$$s'=1.1513\left[\frac{\Psi_{1\,hr}-\Psi_{wf(\Delta t=0)}}{m}+\log\frac{t_p+1}{t_p}+\log\left(\frac{k}{\phi\mu_i(c_t)_i r_w^2}\right)+3.23\right] \quad (5)$$

Apparent skin factor (s') was estimated as 4.64 with the permeability and slope of m obtained by Horner plot analysis. This positive value of skin factor means that the formation near the wellbore is damaged but not serious.

Another reason for the deviation from straightline in the early stage of the Horner plot in Fig. 5 is the wellbore storage effect, and its theoretical basis is as follows. This is a phenomenon that occurs at the very early stage of buildup; its equation is presented in a logarithmic form as Eq. (6) [Horne, 1995].

$$\log\Delta\Psi_{ws}=\log\Delta t+\log\frac{2357q_{sc}T}{\mu_i C} \quad (6)$$

When Eq. (6) is plotted on $\log\Delta\Psi_{ws}$ vs. $\log\Delta t$, a straight line with slope of 1.0 appears. Thus, the wellbore storage effect should be considered seriously if the actual data show a slope of 1.0 [Ramey, 1992]. As can be seen in Fig. 6, Gorae V DST #2 does not have a slope of 1.0, which means that the wellbore storage effect is not significant. In order to prove this, we calculated the wellbore storage effect timerm ($t_{wb}$) by using Eq. (7) [Govier, 1975].

$$t_{wb}=\frac{36177\mu\, V_{wb}\, c_f}{kh} \quad (7)$$

From the calculation, the wellbore storage effect disappears in the extremely short time at 0.0021 hour, and it can be negligible.

Since there is an uncertainty in choosing the straightline section from actual data in the Horner plot, various analysis methods are used in general, of which the type curve matching method is the most useful technique. The type curve is a graphical representation of the analytical solution of an appropriate flow equation for the target reservoir. The main idea of type curve matching is drawing both the field data and the selected type curve on a log-log paper which has the same grid size and matching the two curves for the whole data including the early time section.

Because the solution of the type curve matching includes skin factor and wellbore storage as boundary conditions, these variables can also be calculated together with reservoir characteristics. Once matching is completed, permeability is then estimated by using Eq. (8) [Horne, 1995].

$$(\Delta\Psi_D)_m=\frac{(\Delta\Psi)_m kh}{1.417\times10^6 q_{sc}T} \quad (8)$$

Meanwhile, we used the pressure derivative type curve with conventional $\Psi$ curve for a more precise analysis, which has $(d\Delta\Psi_{ws}/d\Delta t)\,\Delta t$ instead of $\Delta\Psi_{ws}$ in the y-axis [Bourdet et al., 1989]. When this method is applied, the analysis is much more accurate because the flow regime is clearly shown as illustrated in Fig. 7.

Based on the aforementioned theory, the matching for the analysis of Gorae V DST #2 has been performed except the data after 1.9667 hours. In order to apply type curve matching for the buildup data, equivalent shut-in time $\Delta t_e$, namely, $(t_p\,\Delta t)/(t_p+\Delta t)$ was utilized, which is useful in analyzing the buildup data [Agarwal, 1980; Sabet, 1991]. In this analysis, type curve matching was performed by non-linear regression with matching parameters of skin factor and permeability neglecting the wellbore storage effect. The resulting permeability and skin factor are 37.46 md and 4.50, respectively, which is almost identical to the Horner analysis results.

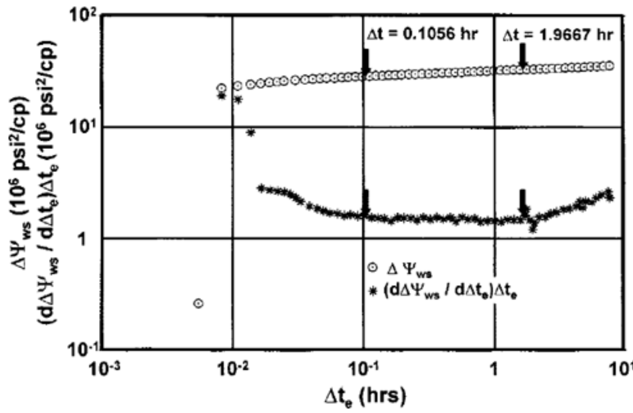


**Fig. 7. Type curve matching analysis for Gorae V DST #2.**

In the case of using the pseudo-pressure derivative curve, when the effect of pressure drop during flow period reaches the reservoir boundary it will cause the pressure behavior to be pseudo-steady or steady state. After this time, the curve starts to deviate from straight-line at the latter part of the pseudo-pressure derivative curve.

As shown in Fig. 7, the pseudo-pressure derivative curve of Gorae V DST #2 tends to incline after 1.9667 hours. This indicates that it is either the pressure behavior reaching the reservoir boundary or other barrier effect within the system. Whether or not this appearance is caused by reservoir boundary effect can be confirmed by calculating the radius of investigation.

The radius of investigation means the area experiencing pressure drop during the flow period and can be computed by Eq. (9) [Horne, 1995].

$$r_{inv.}=0.029\sqrt{\frac{kt}{\phi\mu c_t}} \tag{9}$$

Gorae V well (B4 zone) has a distance of 1722.4 ft away from the nearest outer boundary regardless of the inclination of the zone; this distance is much greater than the radius of investigation of 853.92 ft which is calculated by Eq. (9). Therefore, the upward tendency of the latter part in the pseudo-pressure derivative curve is considered to be a barrier effect within the system, rather than a boundary effect. Furthermore, in order to re-examine the above, we applied extended Muskat method, that is, a trial and error method to search for the average reservoir pressure in a graphical manner at a reservoir reaching pseudo-steady state condition.

For this investigation, the pressure difference ($\bar{p}_R-p_{ws}$) vs. shut-in time ($\Delta t$) was plotted on log-log paper by using original static pressure ($\bar{p}_R$) calculated previously in Horner analysis (Fig. 8). If the latter part shows a straight line, then the system is considered to have reached pseudo-steady state. However, the data of Gorae V DST #2 do not show a straight line, and thus the pressure effect is not experienced by the outer boundary, which is the same result in the estimation of the radius of investigation.

The transient pressure data (section A of Fig. 4) of Gorae V-1 DST #2 were analyzed in a similar manner to Gorae V. As the result plotted on Fig. 9, permeability was 23.26 md, and original static pressure was 3604.23 psi. For the investigation of wellbore storage effect, the early stage of buildup data appearing in Fig. 9 does not have a slope of 1.0 shown in Fig. 10. In addition, the calculated wellbore storage effect time $t_{wb}$ was 0.0051 hour, which indicates that wellbore storage effect disappeared in a very short time. Thus, the deviation of the early stage of the buildup data is likely to be due to the effect of total skin, rather than the wellbore storage. On the other hand, unlike Gorae V, Gorae V-1 DST #2 has a considerable skin factor of 21.0, meaning that the flow was disturbed by wellbore damage due to mud infiltration or liquid condensation.

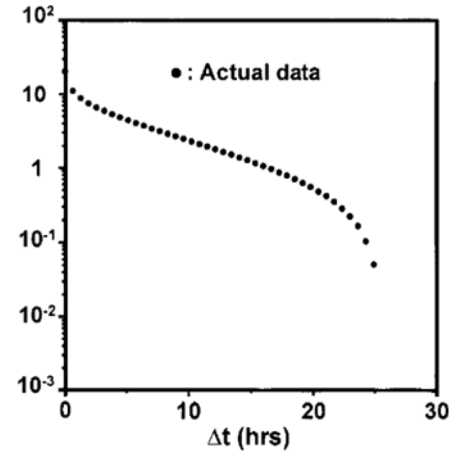


**Fig. 8. Extended Muskat analysis for Gorae V DST #2.**

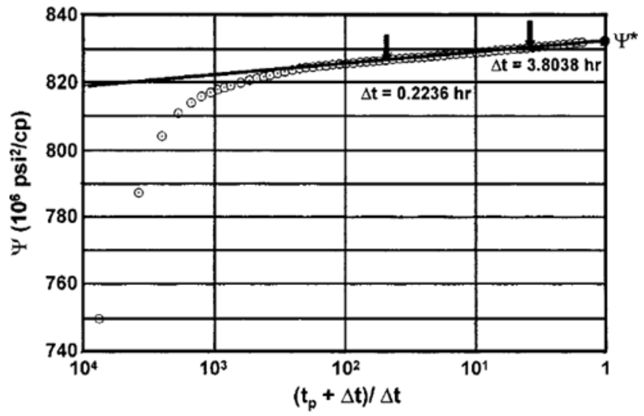


**Fig. 9. Horner plot analysis for Gorae V-1 DST #2.**

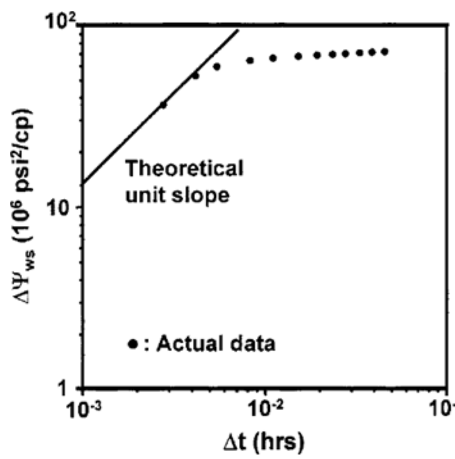


**Fig. 10. Investigation of wellbore storage effect for Gorae V-1 DST #2.**

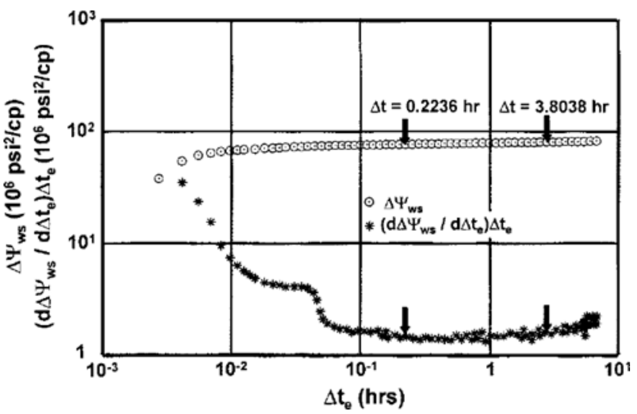


Fig. 11. Type curve matching analysis for Gorae V-1 DST #2.

In the case of applying the type curve matching method for Gorae V-1, the estimated permeability and skin factor are 22.98 md and 21.0, respectively (refer to Fig. 11). Note that these values are very similar to the Horner results. As shown in Fig. 11, the data also has a tendency to rise at the latter part of the derivative curve. As a result of radius of investigation of 638.94 ft, which is shorter than the distance of the outer boundary of 1886.5 ft, and showing no straight-line in extended Muskat plot, it is thus found to be the effect of the impermeable barrier within the system, rather than boundary effect.

**2. Deliverability Test**

The analysis of deliverability test data is based on Eq. (10) [Donohue and Ertekin, 1986].

$$q_{sc}=\frac{0.703\times10^{-6}kh(\bar{p}_R^2-p_{wf}^2)}{\mu Tz\left(\ln\frac{r_e}{r_w}-0.75\right)} \quad (10)$$

Considering the turbulent flow effect, this can be written as

$$q_{sc}=C'(\bar{p}_R^2-p_{wf}^2)^n \quad (11)$$

where n is ranging between 0.5 and 1.0 depending on turbulent or laminar flow. C' is a constant representing the properties of both fluid and reservoir such as viscosity, permeability, temperature, and net pay thickness.

Flow after flow test data of Gorae V were first analyzed. Average reservoir pressurerm ($\bar{p}_R$) was used as original static pressure of 3608.79 psi estimated by Horner method with the flowing bottomhole pressure ($p_{wf}$) which is the final pressure of each flow period in the deliverability test (section B in Fig. 3). The calculated values of ($\bar{p}_R^2-p_{wf}^2$) vs. flow rate for four stages were plotted on log-log graph shown in Fig. 13. Using four points on the plot, we obtained a straight line called the stabilized deliverability line with a slope of 1/n. From this slope and Eq. (11), n is 0.865 andrm C' is 0.000107. The value of n is closer to 1.0 (laminar flow), and hence the tested flow rate is estimated to be proper to the reservoir capacity. In addition, when sandface pressure ($p_{wf}$) is 0 psi in Eq. (11), the flow is a maximum production rate which represents gas well potential. The AOF of Gorae V DST #2 was calculated as 152.8 MMSCFD, whereas for Gorae V-1 DST #2 in Fig. 14, the values of n and C' were 0.885 and 0.0000345, respectively, and AOF was estimated as 68.2 MMSCFD.

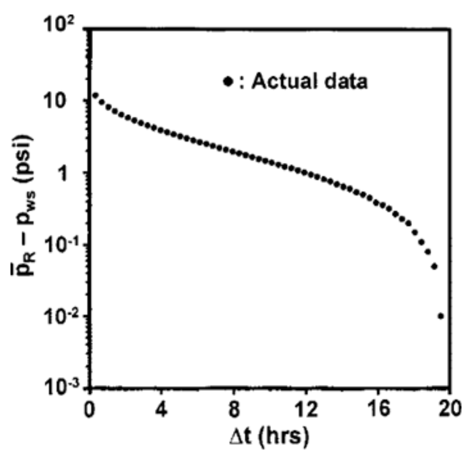


Fig. 12. Extended Muskat analysis Gorae V-1 DST #2.

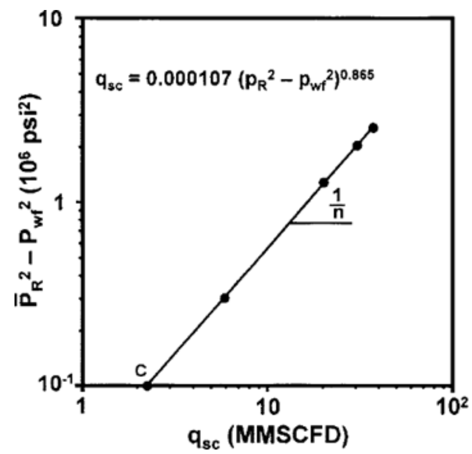


Fig. 13. Deliverability analysis of flow after flow testing data for Gorae V DST #2.

## CONCLUSION

This study shows interpretation procedures and results of DST data of Gorae V and Gorae V-1 in Donghae-1 gas field, Korea. The

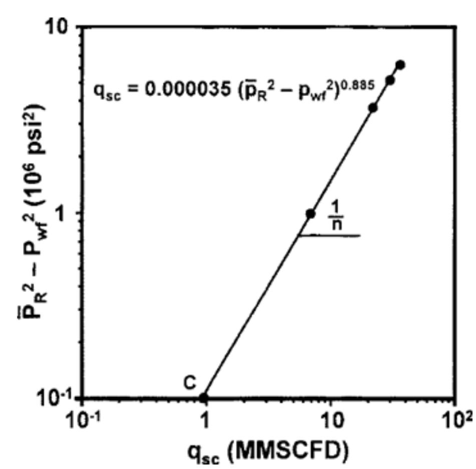


Fig. 14. Deliverability analysis of flow after flow testing data for Gorae V-1 DST #2.

transient pressure test data were interpreted by using a Horner plot and type curve matching methods. The flow after flow test data were analyzed by drawing a stabilized deliverability line to obtain gas productivity as well as well potential. From the results, the following conclusions were drawn:

1. The formation permeabilities of the B4 zone calculated by Horner method and type curve matching by using a pseudo-pressure derivative curve of Gorae V DST #2 data are 37.96 and 37.46 md, respectively. The permeabilities of the B3/B4 zone from Gorae V-1 DST #2 are 23.26 and 22.98 md, respectively.

2. Skin factor was estimated to be 4.50 for Gorae V and 21.0 for Gorae V-1. The reason for a substantially large value in Gorae V-1 is considered to be due to the wellbore damage by mud infiltration during drilling or liquid condensation which causes a disturbance in the flow of gas.

3. From the analysis of the early stage of the buildup period, the wellbore storage effect and wellbore storage time were investigated. It is found that the wellbore storage effect is not significant in both wells studied. The calculated wellbore storage times are 0.0025 and 0.0051 hour for Gorae V and Gorae V-1, respectively, noting that the wellbore storage effect disappears in a very short time.

4. In the analysis of the later stage of the buildup period for examining the slight increase in the pressure derivative curve, both wells of Gorae V and Gorae V-1 did not experience it by the outer boundary. Therefore, this phenomenon is considered to be a barrier effect rather than a boundary effect.

5. Finally, the interpretation of deliverability test data yields well productivity and also absolute open flow of 152.8 and 68.2 MMSCFD for Gorae V and Gorae V-1, respectively.

## ACKNOWLEDGMENT

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## NOMENCLATURE

C : wellbore storage coefficient
C' : deliverability coefficient
c : compressibility [$psi^{-1}$]
Ei : exponential integral function
h : net pay thickness [$ft^3$]
k : permeability [md]
m : Horner plot slope [$psi^2$/cp/cycle]
n : deliverability exponent
p : pressure [psi]
$p^*$ : extrapolated pressure [psi]
q : gas flow rate [MMSCFD]
r : radius [ft]
s' : total skin factor
T : temperature [°R]
t : time [hour]
V : volume of wellbore [$ft^3$]
z : gas deviation factor

**Greek Letters**

$\phi$ : porosity
$\Psi$ : pseudo-pressure [$psi^2$/cp]
$\mu$ : viscosity [cp]
$\Psi^*$ : extrapolated pseudo-pressure [$psi^2$/cp]

**Subscripts**

D : dimensionless
e : equivalent
f : fluid
g : gas
i : initial
inv. : investigation
m : matching point
o : outer boundary
p : producing
R : reservoir
sc : standard condition
t : total
w : wellbore
wb : wellbore storage
wf : wellbore flowing
ws : wellbore shut in

**SI Metric Conversion Factors**

| | |
|---|---|
| cp×1.0 | E-03=Pa·s |
| ft×3.048 | E-01=m |
| $ft^3$×2.831685 | E-02=$m^3$ |
| md×9.869233 | E-04=$\mu m^2$ |
| psi×6.894757 | E+00=kPa |
| $psi^{-1}$×1.450377 | E-01=$kPa^{-1}$ |
| °R×5/9 | =K |

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