Fig. 2 - Agarwal, Al-Hussainy and Ramey type-curve.

Fig. 3 - McKinley type-curve.

Fig. 4 - Earlougher and Kersch type-curve.

\[
\frac{1}{0.000295} \quad t_D = \frac{kh}{\mu} \cdot \frac{\Delta t}{C} \cdot \frac{md \cdot ft}{cp} \cdot \frac{hr}{bbl/psi}
\]

**Fig. 5 - New type-curve for wellbore storage and skin effects ("Gringarten" type curve).**
Fig. 6 - Dimensionless time at approximate end of unit slope.

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Tom BLASINGAME | t-blasingame@tamu.edu | Texas A&M U.
Fig. 7 - A comparison between different approximation criteria for the start of the semi-log straight line.

Fig. 8 - Build-up type-curve for a well with wellbore storage and skin effects.


Fig. 12 - Comparison between type-curves.

Fig. 14 - Example test data set.
Fig. 15 - Log-log analysis of test data set.
Data from SPE 008205.

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SPE 8205

A COMPARISON BETWEEN DIFFERENT SKIN AND WELLBORE STORAGE TYPE-CURVES FOR EARLY-TIME TRANSIENT ANALYSIS

by Alain C. Gringarten, Member SPE-AIME, Dominique P. Bourdet, Pierre A. Landel, and Vladimir J. Kniazeff, Member SPE-AIME, FLOPETROL

This paper was presented at the 54th Annual Fall Technical Conference and Exposition of the Society of Petroleum Engineers of AIME, held in Las Vegas, Nevada, September 23-26, 1979. The material is subject to correction by the author. Permission to copy is restricted to an abstract of not more than 300 words. Write SPE, P.O. Box 3317, Dallas, Texas 75267.
A COMPARISON BETWEEN DIFFERENT SKIN AND WELLBORE STORAGE TYPE-CURVES FOR EARLY-TIME TRANSIENT ANALYSIS


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conductivity fracture was found to yield a one-fourth
unit slope straight line (as is proportional to \( \frac{q}{\phi} \))
Radial flow \( \left( \frac{q}{\phi} \right) \) spherical
flow \( \left( \frac{q}{\phi} \right) \) pseudosteady
flow \( \left( \frac{q}{\phi} \right) \) function of \( \Delta P \) also exhibit dis-


However, for the analysis to be correct, all of the
parameters of the theoretical model must be
found in the actual well test data, and all reults
from specific analytical methods employed by the
model
must be consistent. Specifically, if, for instance,
wellbore storage effects, all the points on the
unit slope log-log straight line must also be located
on a straight line passing through the origin when
the plot is presented versus \( \log \Delta t \) in Cartesian coordinates,
and vice-versa. Similarly, in the case of a vertical
fracture of infinite conductivity, the points on the
half-unit slope log-log straight line must line up
in a \( \log \Delta t \) vs Cartesian plot. The new applies to
all other flow regimes, and, in particular, the
proper semi-log straight flow used in "conventional"
analysis methods can only be used for the points that
exhibit the fluid flow typical shape on the log-log
plots.

Two types of plots are therefore useful in well
interpretation:

1. A log-log plot of all test data, which is
   used to identify the various flow regimes,
   and to select the most appropriate wellbore
   storage model (Diagnostic Plot). Such a plot
   should be made prior to any analysis, pro-
   vided, of course, that the necessary data
   are available (namely, the time and pres-
   sure at the start of the test);

2. Specialized plots as needed, that are
   specific to each flow regime identified on
   the diagnostic plot (as in \( q \) vs \( \Delta P \), \( q \) vs \( \Delta t \),
   \( q \) vs \( \Delta t \), etc.), and only contain appropriate
   parameters of the test data.

In order to provide quantitative reservoir
information, the log-log plot of the test data
must be matched against a type-curve from a
theoretical model that includes the various
features identified on the actual data. For a given
theoretical model, however, not all type-curves are
equivalent.

Depending upon the choice of dimensions, pressure
and time parameters, one type-curve may be easier
or more convenient to use than another. Different
graphs of the same type-curve data are common in
the literature to illustrate the differences in pressure
for an infinite conductivity vertical fracture.

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (1)
\]

where \( L \) is the fracture radius, then as

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (2)
\]

in Ref. 1, and versus

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (3)
\]

In Ref. 1, it is shown that the type-curve for
producing time effects in pressure buildup
analysis is better suited for late time analysis,
whereas the latter is more efficient for early time
analysis.

In the same way, the type-curve for a horizon-
tally fractured well was first presented in terms of
\( \log \Delta t \) versus

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (4)
\]

where \( L \) is the fracture radius, then as

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (5)
\]

versus the same \( \text{fracture length} \quad L = \frac{L_H}{L} \quad (6)
\]

Another example concerns the finite conduc-
tivity vertical fracture, for which a first type-
curve \( a \) was produced as \( \log \Delta t \) versus \( \log \Delta P \) (Ref. 3).
This type-curve was subsequently redrafted as \( a \)

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (7)
\]

where \( \text{fracture length} \quad L = \frac{L_H}{L} \quad (8)
\]

represents the dimensionless fracture conductivity.
Another useful presentation would be in terms of
\( \log \Delta t \) versus

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (9)
\]

where \( \text{fracture length} \quad L = \frac{L_H}{L} \quad (10)
\]

represents the dimensionless fracture conductivity.

In general, type-curve matching is easier when
all the theoretical curves on the type-curve graph
merge into one single curve where the actual well
data are simply matched (Matching of type-curve)
and different graphs of the same type-curve data are common in
the literature to illustrate the differences in pressure
for an infinite conductivity vertical fracture.

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (11)
\]

where \( \text{fracture length} \quad L = \frac{L_H}{L} \quad (12)
\]

and are the modified Bessel functions of the
first and second kind of integer order, respectively.

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (13)
\]

is used for positive skin calculations.
The negative skin situation is approximated by
evaluating \( \xi \) at \( r = r_s \) or \( r = r_e \), but for dimensionless
time and storage constant based on the effective
radius, \( r_g \), respectively, \( \tau_r \) and \( \tau_r \).

As mentioned earlier, wellbore storage effects
(\( \tau_r \) and \( \tau_r \)) cause different pressure responses
than the transmissibility group.

All calculations were made for zero skin and,
so a number of type-curves were

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (14)
\]

on the basis that this group

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (15)
\]

was used to represent the pressure response
than the transmissibility group.

Instead of matching \( a \) to data in minutes
on the \( q \) axis, we match the

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (16)
\]

and \( \Delta P \) in psi on the \( q \) axis. As we start

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (17)
\]

the raw data graph parallel to the \( q \) axis until a good
match is obtained, and then we plot the

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (18)
\]

and \( \Delta P \) in psi on the \( q \) axis. As we start

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (19)
\]

the raw data graph parallel to the \( q \) axis until a good
match is obtained, and then we plot the

\[
\text{fracture length} \quad L = \frac{L_H}{L} \quad (20)
\]
when a "reservoir" match is attempted with data from a stimulated or damaged well.

The last comparison shown on Fig. 13 concerns the type-curve for finite conductivity vertical fractures with wellbore storage, published by Timco and Samaniego. C_f is the dimensionless fracture conduc-
tivity, equal to the ratio of the time on the right side of Eq. 16 to the time on the left side of Eq. 6. In Fig. 13, C_f is given by Eq. 14 and 15, respectively. C_f is obtained as a function of C_f from Eqs. 9 and 10. The curves from Ref. 19 shown in Fig. 13 correspond to C_f = 0.25 values between 4 and 6, and C_f = 1.0 values between 6 and 8. They are in good agreement with the corresponding C_f = 0.25 curves in Fig. 5 at long times (after the semilog approximation becomes valid), and at very early times, during storage flow. At intermediate times, however, they differ greatly. This exam-
ple illustrates well what was pointed out in the be-
ginning of the paper: data from a specific time 
range cannot be used to predict the system behavior in a later time range, unless additional knowledge on the well is available. Analyzing finite conductivity early time data with an infinite conductivity model should yield erroneous results.

**Example Analysis**

The use of the type-curve presented in this paper is illustrated with the following example calculation on a well shown on Fig. 14, pertinent reservoir and pressure data are given in Table 1:

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<td>C</td>
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A log-log plot of the data is presented in Fig. 14. At the initial pressure was not available, log-log analysis was first attempted with build-up data graphed as P_i (t) vs log(t) in Fig. 14. A good match, not shown, was designed with all the data points falling on the C_f = 0.25 curve indicating no little stimulation, and the match of the data at time t = 5.5 hrs. Selecting a match point:

P_i = 200 psig, C_f = 0.65, t = 5.5 hrs, k = 1.0

and using the pressure data for computing h yields:

\[ h = \frac{141.3}{m} \times \left( \frac{P_i}{C_f} \right) = 141.3 \times \frac{200}{0.65} = 4095 \text{ ft} \text{ (1251 m)} \]

The time the match was used to compute the wellbore storage coefficient (for C_f = 0.25), So unit slope log-
log straight is available as:

\[ C_f = \frac{1.32}{m} \text{ Match} \]

\[ C_f = \frac{4095}{1.32} = 3081 \text{ psig} \]

C_f is much greater than that computed from well 
block data. The dimensionless wellbore constant is calculated as:

\[ C_f = \frac{0.5}{C_f} = 0.5 \times 3081 = 1540.5 \]

The skin can then be obtained from the curve match:

\[ S = \frac{0.5}{C_f} = \frac{0.5}{0.65} = 0.769 \]

The last equation indicates a highly stimulated well, which is not consistent with the curve match. Pro-
cedural differences between the OM and Horner plots that were shown on Fig. 16. Straight lines can be clearly 
identified on both plots. The slopes are different, respectively, 38 and 71.5 log[1/g]. The OM analysis yields:

\[ S = 0.15 [\text{Match}] \]

\[ S = 0.15 \times 3081 = 462.1 \text{ psi-yr} \]

This is an excellent agreement with the Horner analysis results. The final conclusion was that the re-

cervoir was probably fissured, with natural fractures communicating with the well as a result of acidification.

The rough behavior of the reservoir is identi-
cial to that of a homogeneous reservoir with a single infinite conductivity vertical fracture, with a fracture half length equal to:

\[ x_f = 2 \text{ psig} = 50 \text{ ft} (15 m) \]

A log-log plot of the data is presented in Fig. 14. At the initial pressure was not available, log-log analysis was first attempted with build-up data graphed as P_i (t) vs log(t) in Fig. 14. A good match, not shown, was designed with all the data points falling on the C_f = 0.25 curve indicating no little stimulation, and the match of the data at time t = 5.5 hrs. Selecting a match point:

P_i = 200 psig, C_f = 0.65, t = 5.5 hrs, k = 1.0

and using the pressure data for computing h yields:

\[ h = \frac{141.3}{m} \times \left( \frac{P_i}{C_f} \right) = 141.3 \times \frac{200}{0.65} = 4095 \text{ ft} \text{ (1251 m)} \]

The time the match was used to compute the wellbore storage coefficient (for C_f = 0.25), So unit slope log-
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\[ C_f = \frac{1.32}{m} \text{ Match} \]

\[ C_f = \frac{4095}{1.32} = 3081 \text{ psig} \]

C_f is much greater than that computed from well 
block data. The dimensionless wellbore constant is calculated as:

\[ C_f = \frac{0.5}{C_f} = 0.5 \times 3081 = 1540.5 \]

The skin can then be obtained from the curve match:

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