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Modern Palacio-Blasingame Type Curve Method to Determine Well Production Characteristics and Reserves in Fields in Indonesia

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ABSTRACT - Well production characteristics and reserves are critical parameters in field development planning and production optimization. In general, well production characteristics are obtained through well testing, followed by plotting and extrapolating flow rate against time, commonly referred to as the cumulative production curve. Conventional decline curve analysis models production decline under constant bottom-hole pressure during boundary-dominated flow periods. However, this approach is inadequate for analyzing data obtained during transient flow periods and requires substantial time and cost when applied to large fields with numerous wells. The modern Palacio-Blasingame type-curve method enables the integration of daily production data with reservoir information by accounting for variations in bottom-hole pressure and changes in gas pressure–volume–temperature characteristics as reservoir pressure declines. This approach enhances the accuracy of well performance evaluation and reserve estimation, provides a more comprehensive understanding of reservoir dynamics, improves efficiency by reducing analysis time and associated costs compared with the conventional decline curve methods.

Keywords: decline curve analysis, type curve, Palacio-Blasingame type curve, production characteristics, reserves.

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INTRODUCTION

Producing from hydrocarbon reservoirs naturally leads to a reduction in average reservoir pressure and changes in flow mechanisms, which results in a progressive decline in production rate. This decline is generally subtle during early development but becomes increasingly significant as the field matures (Taghavinejad et al., 2021; Wang et al., 2022). Decline-curve analysis (DCA) has long been a standard approach for evaluating well performance and forecasting recovery by fitting historical production trends. Two primary categories are generally recognized: classical curve -fitting and type-curve matching (Ahmed 2018).

Among the classical methods, the Arps decline model remains one of the most widely used tools for reserve estimation and forecasting. It is expressed as:

$$qt=\frac{qi}{(1+b\ Di\ t)^{1/b}} \quad (1)$$

where qi is the initial production rate, Di is the initial decline rate, and b is the decline exponent (Arps 1945; Wang et al., 2022). Despite its simplicity and long-standing use, the Arps model often fails to capture dynamic reservoir behavior. To address these limitations, stochastic formulations (Liu et al., 2021) and Bayesian frameworks that incorporate variable bottom-hole pressures (Zhang et al., 2020) have been developed to better represent uncertainty and transient effects.

As a complementary approach, type-curve analysis provides a theoretical representation of flow solutions matched with production data. The general formulation is:

$$\frac{Pi^2-Pwf^2}{q}=\frac{141{,}2\ B\ \mu}{k\ h}\left[\ln\left(\frac{t}{\theta\mu Ctrw^2/k}\right)+s\right] \quad (2)$$

where Pi is the initial reservoir pressure, Pwf is bottom-hole pressure, q is production rate, k is permeability, h is reservoir thickness, s is skin factor, B is the formation volume factor, μ is viscosity, ϕ is porosity, Ct is total compressibility, and rw is the wellbore radius (Palacio & Blasingame 1993; Zhao et al., 2022).

Type-curve techniques have been further refined for complex reservoirs system, including fractured and unconventional formations, and have recently been integrated with machine-learning algorithms to handle large variable-rate production datasets (Zhou et al., 2019; Guo et al., 2021; Li et al., 2023). Advanced applications such as the Palacio–Blasingame method incorporate pseudo-pressure normalization and material balance pseudotime, enabling more accurate analysis of nonlinear gas properties and variable bottom-hole pressures in vertical, horizontal, and fractured wells (Lv et al., 2025; Wang et al., 2020).

Despite these advancements, the adoption of modern type-curve and decline-curve techniques remains limited in Indonesia. Most local studies continue to rely on Arps-based methods, even though reservoir heterogeneity, limited well-tested data, and complex production histories are common challenges (Maurenza et al., 2023; Widarsono 2013). A systematic application of the Palacio–Blasingame approach under Indonesian field conditions is therefore essential for improving the reliability of reserve estimates and supporting more strategic development decisions.

METHODOLOGY

The modern Palacio–Blasingame type-curve method was applied to analyze production data from a gas field in Indonesia. This approach integrates material-balance concepts, pseudotime, and normalized production rates to construct diagnostic plots, including rate, rate integral, and derivative curves. These diagnostic functions are subsequently matched with type curves to estimate key reservoir parameters such as permeability, skin factor, drainage radius, and reserves under variable bottom-hole pressure conditions.

Compared with conventional decline-curve analysis, the Palacio–Blasingame approach provides higher accuracy by incorporating pressure -dependent PVT properties and accounting for variations in flowing pressure during both transient and boundary-dominated flow regimes. The method is applicable to various well configurations, including vertical, horizontal, and hydraulically fractured wells, where production data are often influenced by complex flow behaviors. The overall workflow, which includes calculating material balance pseudotime, normalizing production data, generating diagnostic functions, and performing type-curve matching, is illustrated in Figure 1. The methodology employs several simplifying assumptions. The reservoir is considered slightly compressible and closed, with rock and fluid properties assumed to be homogeneous within the drainage area. The producing well is modeled as near-vertical with circular drainage boundaries, and production is treated as predominantly single-phase. These assumptions are consistent with the theoretical foundations of the Palacio–Blasingame method and help ensure that the estimated parameters remain representative of the reservoir system under investigation.

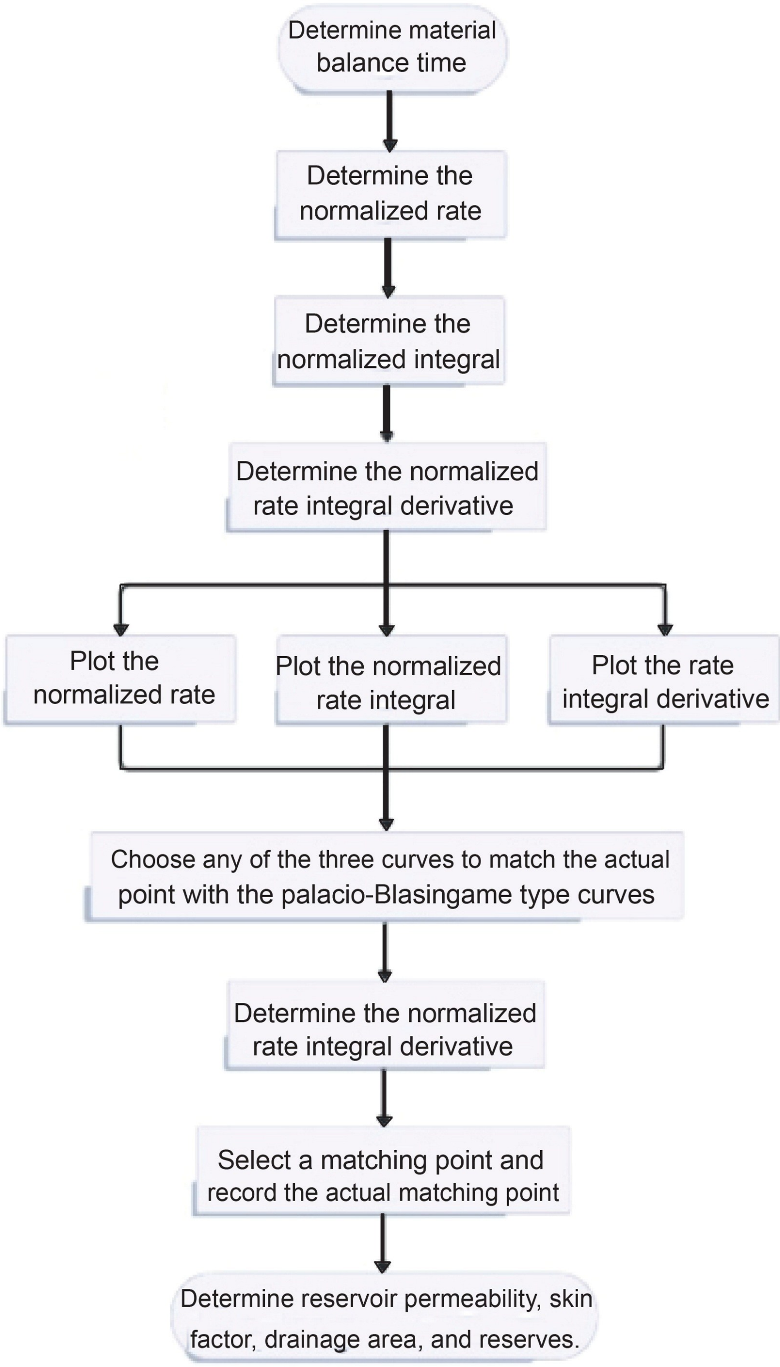

Figure 1. Workflow of the Palacio–Blasingame type-curve method for production data analysis.

RESULT AND DISCUSSION

The example well analyzed in this study is an oil producer with cumulative output of 6.31 MMbbl as of April 2019. The input reservoir and production parameters used in the analysis are summarized in Table 1, while the well production performance is shown in Figure 2.

Table 1. Reservoir and production parameters of the example well

Parameters	value	unit
Well depth	7051	ft
Tubing size	3,5	in
Initial pressure, p	2797	psi
Reservoir thickness, h	304	ft
Oil formation volume factor, B	1,61	m^3/sm^3
Total compressibility, Ct	0,05	1/MPa
Viscosity, μ	0,43	mPa-s
Porosity, ϕ	0,1980	
Well radius, rw	0,1869	ft
Initial water saturation, S_{wi}	0,15	
Residual oil saturation, S_{or}	0,3	

Diagnostic plots, including the normalized rate, rate integral, and derivative, are presented in Figure 3. These functions are essential for identifying flow regimes and provide the foundation for type-curve analysis. The type-curve match is shown in Figure 4, yielding an estimated ultimate recovery (EUR) of 9.77 MMbbl and a remaining reserve of 3.46 MMbbl. Additional reservoir parameters derived from the matching process are listed in Table 2, further confirming the applicability of the Palacio–Blasingame method to field production data.

Table 2. Estimated reservoir parameters and reserves from type-curve analysis.

Characteristic	Value	Unit
Permeability, k	42,74	mD
Effective well radius, r_{wa}	0,07	ft
Skin factor, s	0,79	
Drainage radius, r_e	741	ft
EUR	9,77	MMbbl
RR	3,46	MMbbl

Although the single-well case demonstrates the method applicability, validation using multiple wells or comparison with benchmark decline models such as Arps or Fetkovich would strengthen the conclusions. Such benchmarking would highlight the improvements in accuracy and efficiency gained by incorporating variable pressure and pressure dependent PVT effects, factors not captured in conventional decline-curve methods that assume constant bottom-hole pressure.

Figure 2. Production performance of the example well

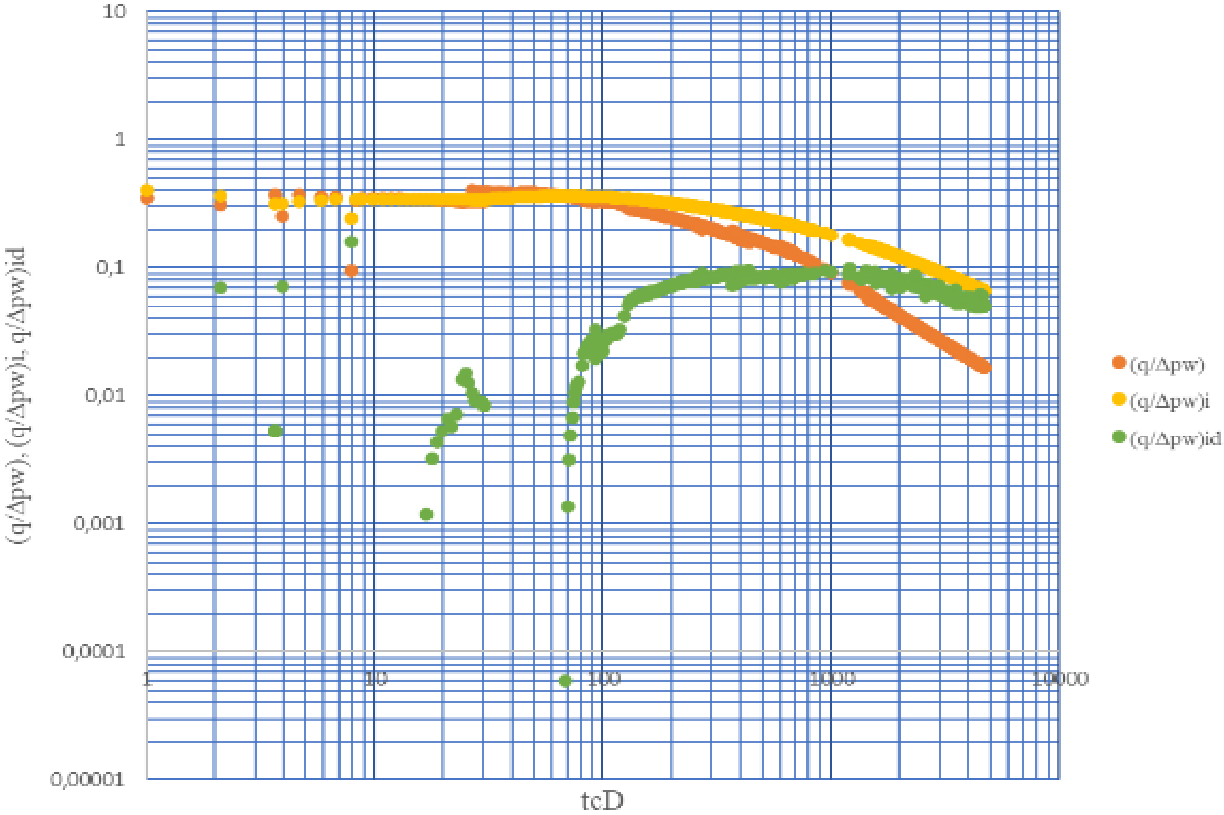

Figure 3. Diagnostic functions plotted against material balance time.

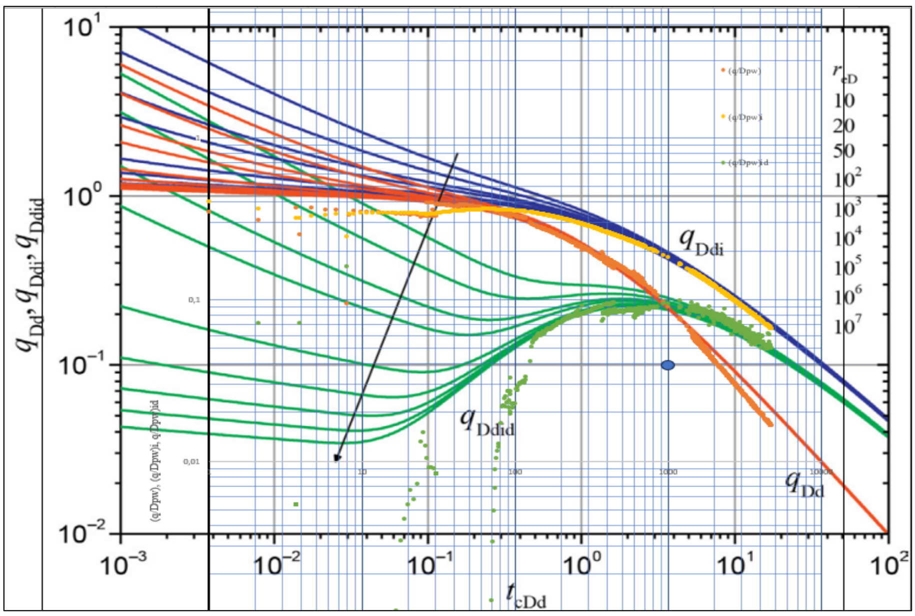

Figure 4. Type-curve matching between field data and Palacio–Blasingame model.

A deterministic sensitivity analysis was performed by varying porosity, viscosity, and total compressibility by ±10% of their baseline values. The results show that EUR is most sensitive to porosity, exhibiting approximately ±12% change, followed by viscosity with about ±8%, and compressibility at ±4%. These findings are visualized in Figure 5, which presents a tornado chart ranking the relative influence of each parameter on reserves estimation. To ensure clarity for international readers, consistent units were used throughout the study. Field units (ft, psi, stb) were applied as the primary basis, with conversions to SI units summarized in Table 3. This approach minimizes ambiguity and facilitates interpretation across diverse technical backgrounds.

Table 3. Conversion between field and SI units used in this study

Parameter	Field Unit	SI Unit
Pressure	1 psi	0,006895 MPA
Length	1 ft	0,3048 m
Viscosity	1 cP	1 mPa.s
Formation Volume Factor	1 rb/stb	0,1781 m³/m³
Rate	1 stb/day	0,159 m³/day
Volume	1 stb	0,159 m³

The limitations and assumptions of the methodology must also be acknowledged. As outlined in the methodology section, the analysis assumes slightly compressible, closed reservoirs with homogeneous properties and near-vertical well geometries. In practice, deviations such as heterogeneity, natural fracturing, or irregular boundary conditions may reduce predictive accuracy. For instance, extensive fracturing can lead overestimation of drainage radius, while heterogeneity may bias permeability estimates. Recognizing these limitations underscores the need for careful application of the method and, where possible, calibration with alternative analytical models or well-testing data.

Overall, this study demonstrates that the Palacio –Blasingame type-curve method provides reliable estimates of reservoir parameters and reserves while reducing both time and cost compared to conventional well testing approaches. Its effectiveness, however, is maximized when supported by sensitivity analysis, benchmarking, and a thorough understanding of the underlying assumptions.

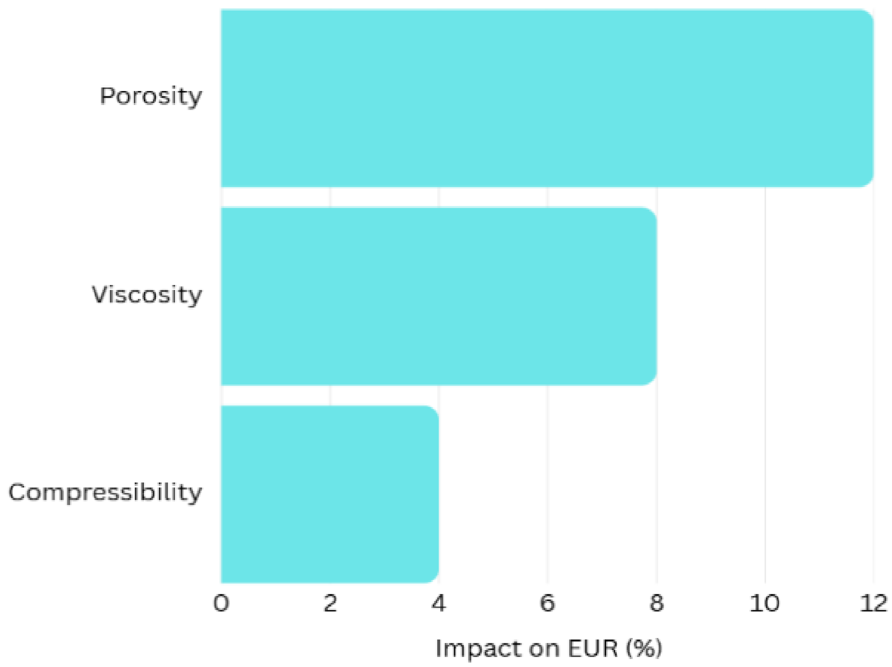

Figure 5. Tornado chart showing EUR sensitivity to ±10% variations in porosity, viscosity, and compressibility

CONCLUSION

This study demonstrates the applicability of the Palacio–Blasingame type-curve method for production data analysis. When applied to an example oil well, the method yielded an estimated ultimate recovery (EUR) of 9.77 MMbbl and a remaining reserve of 3.46 MMbbl. Compared with conventional well testing, it offers practical advantages by reducing evaluation time by several weeks and lowering costs by eliminating extended shut-ins and expensive surface tests. The sensitivity analysis indicates that porosity exerts the strongest influence on EUR, causing approximately ±12 percent variation, followed by viscosity at about ±8 percent and compressibility at roughly ±4 percent. These results highlight the importance of accurate reservoir and fluid characterization for robust reserve estimation. Despites its advantages, the method relies on several simplifying assumptions, including slightly compressible, closed, and homogeneous reservoirs with near-vertical well geometries. Deviations from these assumptions, such as heterogeneity, natural fractures, or boundary effects, may reduce predictive accuracy and should be carefully considered in practical applications. Broader validation across multiple wells, along with benchmarking against traditional decline-curve models, is recommended to enhance confidence in the methodology and expand its applicability to field-scale reserve assessments.

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GLOSSARY OF TERMS

Symbol	Definition	Unit
BHFP	Bottom hole flowing pressure	
EUR	Estimated Ultimate Recovery	
PVT	Pressure Volume Temperature	
RR	Remaining Reserve	
p	Reservoir pressure	psi or MPa
p_{wf}	Well flowing pressure	psi or MPa
h	Reservoir thickness	ft
B	Formation volume factor	Bbl/stb or m^3/sm^3
C_t	Total compressibility	1/psi or 1/MPa
μ	Viscosity	cP
ϕ	Porosity	Fraction or percent
r_w	Well radius	ft
r_e	Drainage radius	ft
S_{wi}	Initial water saturation	
S_{or}	Residual oil saturation	
k	Rock permeability	mD
r_{wa}	Apparent well radius or effective well radius	ft
s	Skin factor	
bbl	US barrel	
q	Volumetric flow rate	Bbl/day or m^3/day
t_c	Material balance time	
$q/\Delta p$	Normalized rate	
$(q/\Delta p)_i$	Normalized rate integral	
$(q/\Delta p)_{id}$	Normalized rate integral derivative	
t_D	Dimensionless time	
t_{cD}	Dimensionless material balance time	
q_{Dd}	Dimensionless decline flow rate	
q_{Ddi}	Dimensionless decline flow rate integral	
q_{Ddid}	Dimensionless decline flow rate integral derivative	

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