Gas Field Production Data Analysis: The Truth, the Whole Truth and Nothing but the Whole Truth*

Christopher Evans[1]

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[1]RISC Advisory, Jakarta, Indonesia (Chris.Evans@riscadvisory.com)

Abstract

Gas Field Production Data Analysis has advanced significantly in recent years with advanced techniques such as Flowing Material Balance and Rate Transient Analysis, etc., providing additional tools to characterize gas reservoirs and estimate their ultimate recovery. These advanced techniques would not have been possible without the advent of permanent downhole gauges and automated flowing tubing head pressure measurements. As a result, today's reservoir engineers have a veritable plethora of production data on which to characterize gas reservoirs and estimate their ultimate recovery. However, data sets are not always examined to their fullest potential, and more often than not, this occurs due to a singular approach to analysis, rather than application of multiple mutually exclusive analysis.

This article discusses how to combine traditional and more advanced production data analysis techniques to gain insight into gas fields, ranging from tight gas reservoir to conventional reservoirs under active water drive. Such insight is not obtained from brute force application of one size fits all techniques, but understanding the appropriate combination of techniques is likely to characterize gas reservoirs in place volumes and estimate their ultimate recovery. This integration is essential in narrowing uncertainties in the reserves and resources estimation process of fields, in particular the SEC reliable technology criteria, helping operators and investors to make decisions with confidence.

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decisions with confidence

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Contents

The author acknowledges the assistance of IHS in providing the Production Diagnostics, Flowing Material Balance and Composite Analytical plots in this presentation.

Key Thought of the Presentation

Insight is gained from understanding. It is not likely to be obtained from brute force application of one size fits all techniques, but by using an appropriate combination of techniques that illuminate the underlying physics of the reservoir at hand.

"Tech support says the problem is located somewhere between the keyboard and my chair."

Data Driven Production Modelling

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Safest technique in the business! It is the minimum assumption route through the subject of reservoir engineering concerning the basic understanding of the physics of reservoir performance.

Data Driven Models	Simulation Driven Models
Independent of geological models	Dependent on facies-driven geological models
Immune to petrophysical cutoffs	Sensitive to petrophysical cutoffs
See only connected GIIP	Sees all GIIP whether connected or not
Less degrees of freedom in the solution space	Greater degrees of freedom in the solution space
Data will tell you what's going on!	***Relying on the model to tell you what's going on!***

The Tools and Workflow

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It is unusual not to have FTHP (dynamic data) and good reservoir management practices will have regular pressure build ups (static data).

Production, static and dynamic pressure, PVT and completions data is all that is needed to utilize the tools available.

The Tools

- Log Diagnostic plots:
  - Identifies transient vs Pseudo Steady State (PSS) flow
- Static Material Balances:
  - P/Z plots mislead, Cole and Havlena Odeh plots don't
  - Analytical aquifer models such as PSS Fetkovich do not require an explicit geological description
- Flowing Material Balance (P/Z**):
  - Integrate FTHP/FBHP
  - Clearer visualization of additional energy sources
- Rate Transient Typecurves:
  - Can discriminate between aquifer and multi-tank support under certain circumstances
- Simple Analytical Models:
  - Pressure and rate history matching drawing from GIIP and reservoir architecture results of the above tools, closes the analysis loop

The Workflow

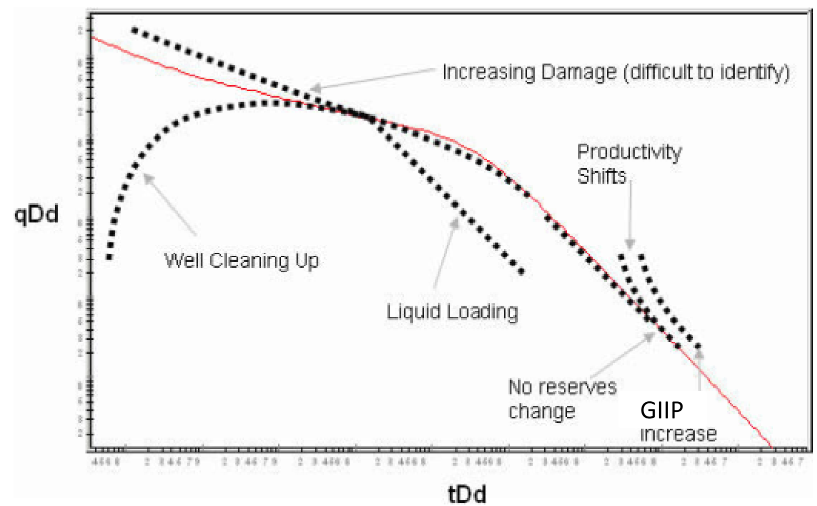
- Step (1) Data quality and diagnostics:
  - Data quality control
  - Diagnostic plots
  - Identification of flow regime(s)
- Step (2) Interpretation and analysis:
  - Drive mechanism and multi-tank behaviour, aquifer characterisation, reservoir architecture
  - GIIP estimation
- Step (3) Modelling, history matching and forecasts:
  - Building simple analytical models utilising material balance, FMB and Typecurve results
  - History match rate and pressure, verify GIIP and reservoir architecture
  - Generate forecasts

Data QC and Diagnostics

More often that not, only after model(s) generate non sensical results, do people realise the importance of Data QC and Diagnostics.

- In reality, there are two types of data: good or bad, and some of the bad encountered:
  - Pressures not corrected to reservoir datum
  - FTHP and rate trends inconsistent
  - Physically impossible outliers included
  - Production misallocation
- Bad data does not improve with more complex analysis
- Log-Log Diagnostics provide the insight into reservoir architecture and drive mechanism(s):
  - Productivity shifts
  - Early time vs late time behavior
  - Rate sensitivity behavior
  - Particularly useful if there have been shut-in periods

Productivity Diagnostics



Discriminating Between Additional Sources of Energy

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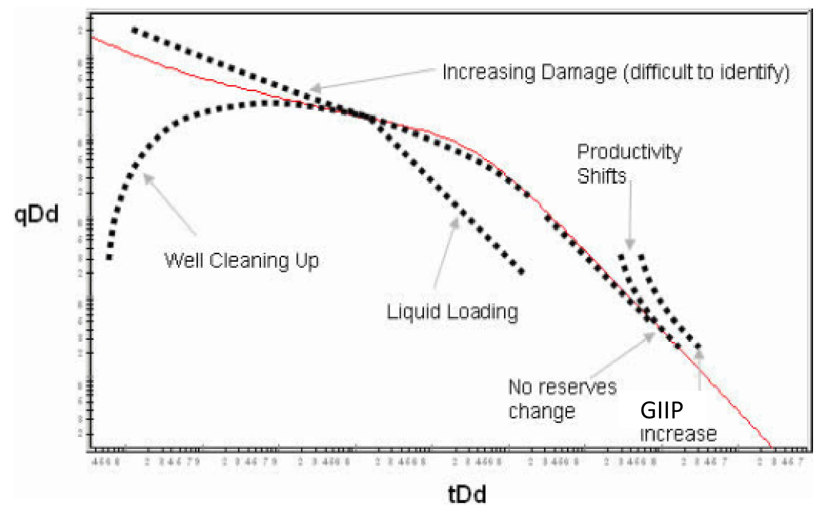
Being able to discriminate between potential sources of additional energy is crucial for reservoir management.

Is it possible to use Production Data Analysis to determine if additional energy is aquifer and/or multi-tank pressure support?

- Lets look at an example of integrating static material balances and RTA Typecurves where flowing data and field shut-in data is available
- Static Material Balance Cole diagnostic plots indicate additional sources of energy
- Typecurve for vertical well in a uniform reservoir indicates repeated productivity shifts, but once well is back on production the shifts are parallel to unit negative slope line
  - The repeated productivity shifts parallel to the negative unit slope line indicate increasing GIIP with time suggesting multi-tank behavior
  - After periods of shut in the Typecurve trend parallels the unit negative slope line i.e. volumetric depletion drive

Productivity Diagnostics



Putting it All Together

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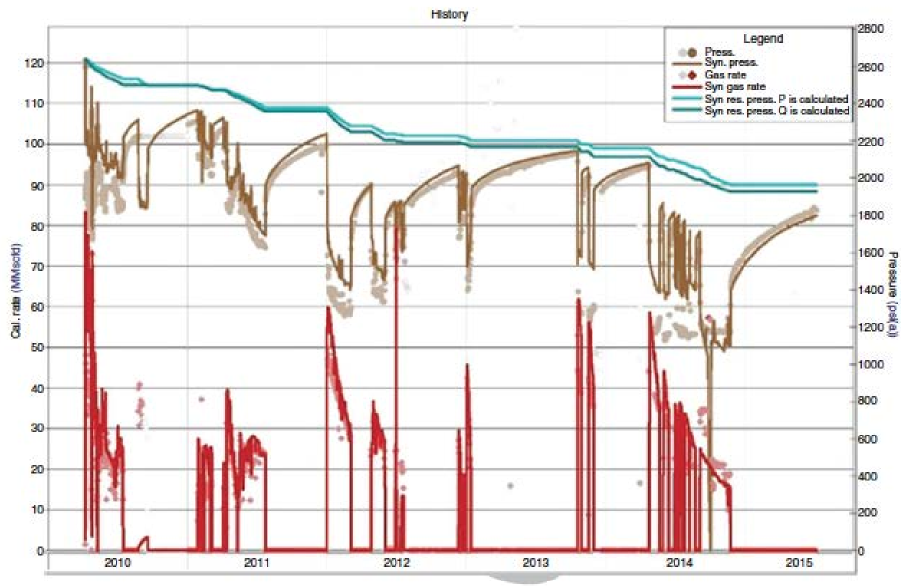
Let's put all the points together to illustrate the workflow that captures GIIP estimation and forecasting.

- Step (1) Data quality and diagnostics:
  - P* static pressures discarded, last known PBU data utilized
  - Static build up pressures overlay FMB derived P/Z** pressures
- Step (2) Interpretation and analysis:
  - Multi-tank behavior is characterized on a FMB plot by repeated offset transient 'stems' that fail to merge to a single P/Z** depletion line
  - Analysis of this early time data using FMB provides an estimate of the volume connected to the wellbore
- Step (3) Modelling, history matching and forecasts:
  - Simple composite analytical model to represent the multi-tank system
  - This consists of a wellbore in the centre of a small tank which is surrounded by and connected to a larger tank with lower permeability

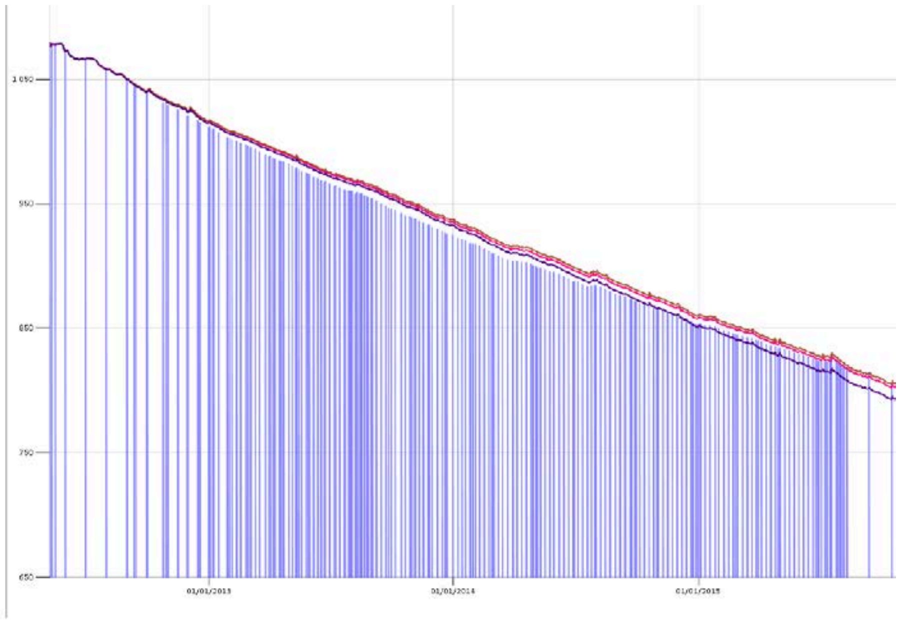


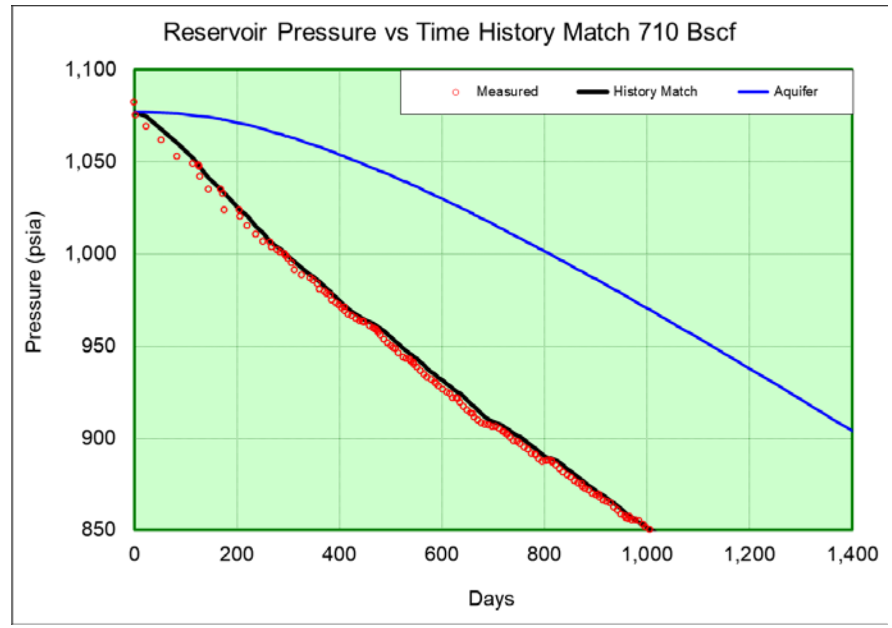
- Whilst it is tempting to draw a line of "best fit" through the FMB data, this fails to identify multi-tank behaviour and may lead to a misunderstanding of how the field will physically produce

The Price of Getting it Wrong

Gas field under active waterdrive. 1000+ multi-realisations based on a HM P50 case to derive P10 and P90 GIIP.

Subsequent premature water breakthrough ended production 2 years earlier than P90 forecast.





Multi-realisation P90 to P10 GIIP range 836 to 867 Bscf i.e. 3% range of uncertainty in GIIP with less than half the GIIP produced…

In this example analytical methods based on production created a most likely (P50) GIIP outside the multiple realisation history matched range

Forcing the wrong initial model to fit the data failed to identify the best solution or the range of outcomes!

Rigorous Gas Production Data Analysis

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Automated data gathering, increased computing power, fit for purpose software and specialized analysis i.e. Flowing Material Balance and Rate Transient Analysis (RTA) provides capabilities unheard of 20 years ago…

Although these significantly enhance the capabilities of engineers to grasp the underlying physics of reservoir behavior, the two key deliverables: gas in place (GIIP) estimation and production forecasting remain unchanged.

Production Data Analysis may appear simplistic, but it provides an independent assessment of the drive mechanism and connected GIIP (the reservoir physics). If it does not support more sophisticated modelling then STOP and understand why.

You can force the wrong model to fit the data (square peg into a round hole) but the solution and uncertainty range will be wrong.

Thinking outside the box by considering alternate geological realizations that honor pressure and production data is time better spent than attempting to finesse simulation models.

A Word to the Wise

Don't pay the heavy price of getting it wrong…

- Observations:
  - Computing power enables multiple realisations to be evaluated with automatic history matching. Such detail may give the impressions of accuracy.
  - Analytical methods based on production data, that identify the key reservoir drive mechanisms and architecture, may produce GIIP estimates outside the range obtained from automatic history matching.
  - An anchored (biased) multi-realisation P50 model may unrealistically limit the range of GIIP uncertainty.

- Conclusions:
  - Analytical methods based on gas production data have no pre-conceived reservoir interpretation:
    - They will unbiasedly identify the reservoir drive mechanism and key reservoir architecture.
  - Such methods can readily bracket the range of GIIP in gas fields and are an important quality control check at the early stages of multi-realisation:
    - Analytical methods should be used to constrain simulation rather than verify results.
    - If the GIIP ranges are not congruent then STOP! Something is not right…

www.riscadvisory.com

Perth

Level 2
1138 Hay Street
WEST PERTH WA 6005
P. +61 8 9420 6660
F. +61 8 9420 6690
E. admin@riscadvisory.com

Brisbane

Level 10
239 George Street
BRISBANE QLD 4000
P. +61 7 3025 3397
F. +61 7 3188 5777
E. admin@riscadvisory.com

London

4th floor Rex House
10 Regent Street
LONDON UK SW1Y 4PE
P. +44 203 356 2960
F. +44 203 356 2701
E. admin@riscadvisory.com

Dubai

Suite 503, Shangri La Offices
Sheikh Zayed Road
DUBAI UAE
P. +971 4 401 9875
F. +61 8 9420 6690
E. admin@riscadvisory.com

South East Asia

Jakarta
Indonesia
P. +61 8 9420 6660
F. +61 8 9420 6690
E. admin@riscadvisory.com