Invitation to join a Research Consortium on:

PRACTICAL WELL TEST ANALYSIS OF COMPLEX RESERVOIR-FLUID-WELL SYSTEMS

from

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EXECUTIVE SUMMARY

Complexities in reservoirs exit at three main levels: (1) geology, due to different depositional and tectonic processes, with reservoirs formed via deposition in fluvial environments being the most complex; (2) fluid, notably in gas condensate reservoirs below the dew point pressure and in volatile oil reservoirs below the bubble point pressure; and (3) wells, particularly multilateral horizontal wells.

The combination of complex reservoirs, complex fluids, and complex wells create well test pressure behaviours that can be very difficult to interpret. Simplifying assumptions allow the derivation of analytical solutions, and these are routinely used for describing reservoir dynamic behaviours during well tests. Simplified interpretation models, however, restrict the amount of information that can be obtained from well test analysis in complex systems by not accounting for complexity. They also yield results that are often difficult to relate to reality.

The Centre of Petroleum Studies at Imperial College London has been involved in research in these areas since 1997, sponsored mainly by consortia of oil companies. Results from this work have already greatly improved the understanding of well test behaviours in gas condensate and volatile oil reservoirs; in reservoirs with commonly found geological features (such as semi-infinite channels with non-parallel boundaries; T-shaped channels; meandering channel with different well locations, channel branch widths and meander angles; and pinch-out boundaries); and in multilateral wells. They have also greatly improved the ability to interpret well tests in such reservoirs.

The objective of this proposal is to expand the work performed to-date in these three area in order to develop a better understanding of well test behaviours in complex systems, and to use this understanding to develop new, practical analysis methods for calculating well and reservoir parameters, for estimating reserves, and for predicting and improving well productivity in such reservoir-fluid-well systems. Limitations and uncertainties in the analyses as a function of the data available will also be a focus of the research.

The work will be performed by staff, MSc and PhD students from the Centre for Petroleum Studies at Imperial College, with input and guidance from industry partners.

BENEFITS

- Access to the results of Phases 1 to 3 (2000-2008) of the research programme on “Well Test Analysis in Gas-Condensate and Volatile Oil Reservoirs” and to the research work on well test analysis in multilateral wells and on the influence of geological features
- New understanding of near-wellbore pressure behaviour in complex systems, with various well, fluid and reservoir characteristics and comprehensive and systematic interpretation of typical well test data from different complex systems from industry partners and corresponding well test analysis reports.
- Annual forum at Imperial College to review progress and provide input into research directions.

RESEARCH AREA

The objective of the well test analysis research at Imperial is to explain complex well test data, to provide practical methods for interpreting them, and to assess uncertainties and limitations of the corresponding analysis results as a function of the information available. The starting point is well data provided by our sponsors, which ensures that the research addresses actual problems. This approach has led to many advances in well test analysis[1].

The focus of the research over the past ten years has been the improvement of existing techniques[2-11] and the development of new well test solutions for reservoir characterisation[12-15] and environmental protection[16-17]. The work performed under the current proposal will expand on the studies performed to-date in three areas:

(1) Complex fluids, notably in gas condensate reservoirs below the dew point pressure and in volatile oil reservoirs below the bubble point pressure
(2) Complex geologies, particularly multilayered reservoirs
(3) Complex wells, such as multilateral horizontal wells.

(1) COMPLEX FLUIDS

The Centre for Petroleum Studies at Imperial College London started a research project on well test analysis in gas condensate and volatile oil reservoirs in 1997, with the objective of understanding the conditions of the existence of the different mobility zones due to condensate drop-out below the dew point pressure and gas coming out of solution below the bubble point pressure; and of investigating methods for preventing or reversing the corresponding loss of well productivity, for different reservoir, well and fluid characteristics.

This research was performed in three phases: it first concentrated on the Britannia lean gas condensate field, and was sponsored by Britannia Oil Limited (BOL). It was then extended in 2002 to include a number of other fields worldwide, in a JIP that included Anadarko, Burlington, BHP Billinton, Britannia Operator Ltd, ConocoPhillips, Gaz de France, Total and the UK Department of Trade and Industry (DTI). A third phase took place from 2005 to 2008, sponsored by the BG group, Burlington, ConocoPhillips, ENI, Petro SA, Petrom and Total. The total number of different fields studied exceeds thirty.

A total of forty-eight MSc theses have been produced between 1998 and 2009 (see Appendix). In addition, eleven PhD projects have been initiated, with four still in progress. Results have also been presented in SPE papers (seventeen to-date)[2-18] and in a SPE Distinguished Lecture[19].

Phases I and II concentrated on lean condensate gas in sandstone reservoirs. Research results to October 2006 were summarised in paper SPE 100993: "Well Test Analysis in Lean Gas Condensate Reservoirs: Theory and Practice" [10]. The main conclusions were:

1. Condensate deposition around the well when the bottomhole pressure drops below the dew point pressure during production creates an impediment to flow which is reduced by capillary number effects.
2. Condensate deposit and capillary number effects yield a three-region composite well test behaviour when single phase pseudo-pressures are used for analysis. After some time of production, the three-region composite well test behaviour reduces to a two-region composite behaviour when the capillary number effects no longer impact the derivative curve.
3. The derivative stabilization corresponding to the mobility of the condensate bank varies with the condensate saturation and therefore with the rate. At constant rate, its level increases with time until a maximum level is reached.

4. The final radial flow derivative stabilization corresponding to the reservoir effective permeability in the composite behaviour is usually not reached in production tests. The stabilization seen on the derivative is likely to represent the condensate bank mobility.
5. The reservoir effective permeability is consistent with core permeability in sandstone reservoirs. The core permeability can be used to distinguish between condensate bank and reservoir mobility if only a single stabilization is seen on the derivative
6. No composite behaviour is obtained if two-phase pseudo pressure is used for analysis. The radial flow derivative stabilization in that case corresponds to the reservoir absolute permeability.
7. The condensate saturation distribution during a build up is approximately constant and the same as that at the end of the preceding drawdown.
8. The condensate bank decreases in size and saturation only when the production rate decreases.
9. A procedure was developed to calculate the bank total compressibility, which is required to estimate the bank outer radius. The bank total compressibility is greater than the gas compressibility above the dew point pressure by a factor 2 to 4.
10. Behaviour often changes with time as the condensate bank grows and reaches the boundaries. Successive drawdowns and build up's must be analyzed together to understand these changes (time-lapse well test analysis).
11. It is often difficult to distinguish condensate bank effects from layering, boundary or derivative calculation effects. A series of tools must be used for identification and verification, including conventional well test analysis, deconvolution, forward modelling with analytical and numerical models, and compositional simulation.
12. Wellbore phase redistribution may dominate the entire test, which often becomes un-analysable.
13. Pseudo-relative permeabilities, absolute permeability can be estimated using single-phase and two-phase pseudo-pressures together, whereas the base capillary number can be estimated using single-phase pseudo-pressures.
14. The gas relative permeability at near-wellbore saturation and at the initial liquid saturation, and the absolute permeability are the most important parameters for predicting well productivity.
15. Fracturing vertical wells and drilling horizontal wells is equally effective for improving productivity in gas-condensate reservoirs below the dew point. Fracturing a well after the bank has developed makes the bank to disappear, but it eventually reappears along the fracture.
16. Capillary numbers often compensate for inertia effects. As a result, the wellbore skin may increase, decrease or remain constant as the gas rate increases (this last point, however, has been invalidated by further studies in Phase III).

Phase III expanded the work initiated during Phase II into:

- Rich gas condensate reservoirs
- Hydraulically fractured gas condensate wells
- Naturally fractured gas condensate reservoirs
- Multilayered gas condensate reservoirs
- Very tight gas condensate reservoirs
- Volatile oil reservoirs
- Use of two-phase pseudo-pressures to predict dry gas effective permeability from production tests
- Further assessment of capillary number effects and non-Darcy flow effects relationship.
- Experimental and theoretical work to predict (and therefore avoid) wellbore phase redistribution
- Application of deconvolution to the analysis of gas condensate and volatile oil well test data

The main conclusions of Phase III were:

Volatile oil

1. A high gas saturation zone is created around the wellbore when the bottomhole pressure falls below the bubble point pressure during a drawdown.
2. This creates an impairment to flow and a mobility contrast in well test analysis.
3. During a build up, the gas created around the wellbore during the preceding drawdown condenses into the oil and the saturation in the near-wellbore region returns to the initial gas saturation.
4. The log-log pressure-derivative behaviours below the bubble point therefore correspond to a two-zone radial composite model, with decreasing mobility during drawdowns and increasing mobilities during build ups. The log-log pressure derivative plot of the build up reflects the oil mobility distribution in the reservoir at the end of the preceding drawdown.
5. High volatility oils have higher mobilities than less volatile oils above the bubble point pressure. Below the bubble point pressure, however, higher gas saturation causes relatively larger mobility reductions for the more volatile oils.
6. Highly volatile oil reservoirs have higher productivity indexes than low volatility oil reservoirs when producing above the fluid bubble point pressure. Below the bubble point pressure, on the other hand, high near-wellbore gas saturation causes a relatively larger reduction in productivity index in highly volatile oil reservoirs than in less volatile oil reservoirs.
7. End point relative permeability of oil phase and fluid composition are the most important factors affecting well productivity of volatile oil reservoirs producing below bubble point pressure.
8. Vertical hydraulic fractures and horizontal wells can be used to improve well productivity in volatile oil reservoirs even when reservoir is already producing below the bubble point pressure.
9. Vertical hydraulic fractures and horizontal wells should be implemented early in the wells life to delay the time when the flowing bottomhole pressure drops below the bubble point pressure, which consequently leads to improved recovery.
10. The optimum choice between hydraulically fractured vertical wells and horizontal well can only be made from economic analysis.

Rich gas condensate

1. A liquid region (condensate bank) develops around the producing well below the dew point pressure in a rich gas condensate reservoir. This yields a composite behaviour in well tests when single-phase pseudo pressure is used for analysis.
2. The near-wellbore liquid saturation grows to a maximum and the radial extent of the condensate bank continues to grow as the reservoir pressure declines. Eventually, the condensate bank can extend across the entire reservoir when the pressure at the boundaries drops below the dew point pressure. This process leads to a loss of well productivity and reduction in hydrocarbon recovery.
3. Productivity loss below the dew point is primarily due to reduced effective gas permeability. The loss in well productivity can be overestimated if the capillary number effect is not incorporated.
4. Unlike behaviours seen in lean gas condensate reservoirs, the near-wellbore capillary effect region is not prominent on well test data and the corresponding three-region composite behaviour is only observed at very high rates.
5. Contrary to what happens in lean gas condensate reservoirs, the near-wellbore fluid saturation below the dew point pressure in a build-up is different from that at the end of the preceding drawdown, because of the significant differences in fluid properties and saturations. In rich condensate fluids, the oil and gas properties in the two-phase region are strongly dependent on pressure and the separated phases have similar properties. As

pressure increases during the build-up, re-vaporisation takes place and just above the dew point, the fluids can recombine to form a single-phase rich gas.

6. As a result, log-log pressure derivative plot of the build-up has a reverse profile to the log-log pressure derivative profile of the preceding drawdown, with decreasing mobility during drawdowns and increasing mobilities during build ups. A similar behaviour is observed in volatile oils where the liberated gas in the two-phase region re-dissolves in the oil during a build-up.
7. A practical method to evaluate the condensate bank storativity, which is used to calculate the bank radius has been developed and verified. The calculated bank radius approximates the extent of the two-phase region at the end of preceding drawdown.
8. When a reservoir is re-pressurised as a result of gas injection, the effects of fluid displacement, changing late-time behaviour and re-vaporisation can be captured and characterised from well test analysis.
9. In lean gas reservoirs, the wellbore skin vs. rate relationship below the dew point pressure with single-phase pseudo-pressures is not linear and not monotonic, and depends on the rate history. Hence a skin vs. rate plot cannot be used for calculating the turbulence factor D. The relationship with two-phase pseudo-pressures is linear and gives a D below the dew point pressure which is about 30% smaller than D above the dew point pressure.
10. In rich gas reservoirs, the wellbore skin vs. rate relationship with single-phase pseudo-pressures is linear and monotonic, but gives a D below the dew point pressure which is about 25% smaller than D above the dew point pressure. The relationship with two-phase pseudo-pressures is linear and gives the same D as the D above the dew point pressure.
11. In volatile oil reservoirs below the bubble point pressure, the wellbore skin vs. rate relationship with pressures is linear and monotonic, and gives a D which is about 17% smaller than D with two-phase pseudo-pressures.

Although a large body of knowledge has been acquired through our research in the last seven years, significant challenges remain in the analysis of well tests in gas condensate reservoirs below the dew point pressure, and of well tests in volatile oil reservoirs below the bubble point pressure.

The proposed research aims at expanding the work initiated during Phases I to III, particularly studying gas condensate reservoirs of different condensate richness, from very lean to near-critical, and different volatile oils, in different permeability environments, from very tight to highly permeable.

One of the objectives will be to determine when the well test behaviours change from those observed in lean gas reservoirs to those typical of volatile oils, and how the use of single-phase and two-phase pseudo-pressures affects the analysis results. Another important focus will be on developing methods for predicting and improving well productivity and evaluating the effectiveness of different remediation solutions. Finally, the experimental and theoretical work on phase redistribution will continue, with the aim of producing software that can be used to predict wellbore phase redistribution, and therefore to design test that avoid it.

(2) COMPLEX GEOLOGY AND COMPLEX WELLS

Accounting for geological and well complexities requires complex interpretation models often not available in the literature. Investigations at Imperial have shown that complex geometries could be revealed on well test pressure derivatives by non-standard transitions between the main radial flow derivative stabilizations and the late time boundary behaviours. These transitions may be analyzed as combinations of simpler, known behaviours to give access to quantitative information related to the complex geometry that is usually ignored in routine well test interpretation.

For instance[13,15]:

- A semi-infinite channel with non-parallel sides behaves as two sequential wedges. The corresponding analyses yield the angles between the various lateral boundaries and the distances from the well to the boundaries.
- A T-shaped channel behaves as two successive channels. When the well is located in the main branch, well test analysis yields the width of each branch and the distance from the well to the lateral boundaries of the main branch, and to the intersection of the two branches.
- A meandering channel behaves as a wedge followed by a channel, or as two consecutive wedges and a channel. Analysis yields the meander angle, the arithmetic average of the widths of the channel on each side of the meander, and the distance to the well closest lateral boundary.
- A pinch-out boundary behaves as a single sealing fault, but with a longer transition between radial flow and the fault derivative stabilization. If the pinch-out angle is small, it can be obtained from well test analysis, along with the distance form the well to the pinch-out.

On the other hand, using simple models that do not account for geological or well complexities yields results that are difficulty to relate to reality. For instance, what is the meaning of a boundary distance in a commingled multilayer reservoir with seismic boundaries at different distances in the various layers, when analysis is performed with a single layer model (because no PLT is available)? Similarly, what is the meaning of analysis results in a multilateral well when all branches are tested together and the analysis is performed with a single horizontal branch model?

The objective of this research is to investigate (1) the capability of well tests to identify and quantify geologically complex reservoirs and complex wells; and (2) the meaning of well test analysis results obtained with simple interpretation models that do not account for these complexities.

The work will be performed by staff, PhD and MSc students from the Centre for Petroleum Studies at Imperial College London over a period of 3 years, with input and guidance from industry partners.

The exact amount of work that will be performed in the context of this proposal will depend on the number of companies joining the project. It is expected that the participants will be able to also contribute well test data to the project.

BRIEF RESUME OF PRINCIPAL RESEARCHERS

Prof. Alain C. Gringarten - Professor of Petroleum Engineering

Prof. Gringarten will be the principal investigator for this project. He holds the Chair of Petroleum Engineering at Imperial College in London and is also director of the Centre for Petroleum Studies, Department of Earth Science and Engineering, which covers all petroleum activities at Imperial. Before joining Imperial College in March 1997, Dr. Gringarten spent 25 years with service companies, first with Schlumberger where he was Director of Engineering and created their well test interpretation service; then with Scientific Software-Intercomp, where he held several senior technical, marketing and management positions including Executive Vice President for E&P Consulting and Products. Prof. Gringarten is a recognised expert in well test analysis and has published numerous articles on that subject. He received the Society of Petroleum Engineers (SPE) Formation Evaluation award for 2001, the 2003 SPE John Franklin Carll award, and was a SPE Distinguished Lecturer for 2003-2004. He has been elected a SPE Distinguished Member in 2002 and a SPE Honorary Member in 2009. Prof. Gringarten holds an engineering degree from Ecole Centrale, Paris, France, and obtained an MSc and a Ph.D. in Petroleum Engineering from Stanford University.

Professor Martin J. Blunt – Professor of Petroleum Engineering

Professor Martin J. Blunt is professor of Petroleum Engineering in the Centre for Petroleum Studies at Imperial since June 1999. He was previously an Associate Professor of Petroleum Engineering in the Department of Petroleum Engineering at Stanford University and worked for four years at BP's research centre in Sunbury-on-Thames. Professor Blunt's research interests are in multiphase flow in porous media with applications to oil and gas recovery, and contaminant transport and clean-up in polluted aquifers. He performs experimental, theoretical and numerical research into many aspects of flow and transport in porous systems, including pore-scale modelling of displacement processes, and large-scale simulation using streamline-based methods. He is on the editorial board of SPE Journal and Advances in Water Resources. He has over 70 scientific publications. He holds B.A., M.A. and Ph.D. degrees in Physics from Cambridge University.

Prof. G. F. Hewitt - Professor of Chemical Engineering

Prof. Hewitt and his team are involved in the study of a wide variety of multiphase flow systems, including both two-phase (liquid-liquid) and three-phase (liquid-liquid-gas) flows in horizontal, inclined and vertical tubes. In recent years, there have been great improvements in the understanding of the development of flow patterns in vertical pipes (as will be relevant to the present project) and Prof. Hewitt and his team have published widely in this area.

Centre for Petroleum Studies (CPS) at Imperial College

The Centre for Petroleum Studies is a focus for research, postgraduate teaching and professional development within the framework of Petroleum Sciences and Engineering at Imperial College. Its main objectives are to facilitate multi-disciplinary research between geologists, geophysicists, petroleum engineers and members of other key disciplines in order to advance the state of the art in exploration, appraisal/development and reservoir management, and to plan and implement related postgraduate teaching programmes which reflect current best practice within the petroleum industry. The Centre has one of the largest concentrations of petroleum scientists and engineers in a UK academic institution, with almost 50 members of staff providing research expertise across the complete Exploration-Production spectrum.

REFERENCES

1. Gringarten A. C.:" From Straight lines to Deconvolution: the Evolution of the State of the art in Well Test Analysis," paper SPE 102079, presented at the 2006 SPE Annual Technical Conference and Exhibition, San Antonio, Texas, U.S.A., 24–27 September 2006; SPEREE (Feb. 2008) 11-1 pp. 41-62.
2. Daungkaew, S., Hollaender, F. and Gringarten, A. C. :"Frequently Asked Questions in Well Test Analysis", in *Proc. 2000 SPE Ann. Tech. Conf. Exh.*, Soc. Pet. Eng., Dallas, paper SPE 63077, (2000).
3. von Schroeter, T., Hoellander, F. and Gringarten, A. C.:"Deconvolution of Well test Data as a Non-linear Total Least Square Problem", in *Proc. 2001 SPE Ann. Tech. Conf. Exh.*, Soc. Pet. Eng., Dallas, paper SPE 71574, (2001).
4. von Schroeter, T., Hoellander, F. and Gringarten, A. C: "Analysis of Well Test Data From Permanent Downhole Gauges by Deconvolution" in *Proc. 2002 SPE Ann. Tech. Conf. Exh.*, Soc. Pet. Eng., San Antonio, paper SPE 77688, (2002).
5. Hoellander, F., P. Hammond and Gringarten, A. C: "Harmonic Testing for Continuous Well and Reservoir Monitoring" in *Proc. 2002 SPE Ann. Tech. Conf. Exh.*, Soc. Pet. Eng., San Antonio, paper SPE 77692, (2002).
6. Gringarten, A. C.:" Well Test Analysis in Low Permeability Multilateral Wells," paper IPTC-10686, presented at the International Petroleum Technology Conference, Doha, Qatar, 21-23 November 2005.
7. T. von Schroeter and A. C. Gringarten: "Superposition Principle and Reciprocity for Pressure Transient Analysis of Data from Interfering Wells," paper SPE 110465 presented at the 2007 SPE Annual Technical Conference and Exhibition, Anaheim, California, 11-14 November 2007.
8. Azi, A. C., Gbo, A., Whittle, T and Gringarten, A.C.:" Evaluation of confidence intervals in well test interpretation results," paper SPE 113888 presented at the 2008 SPE Europec/EAGE Annual Conference and Exhibition, Italy, 9–12 June 2008.
9. Whittle, T. and Gringarten A. C.:" The Determination of Minimum Tested Volume from the Deconvolution of Well Test Pressure Transients," paper SPE 116239, presented at the 2008 SPE Annual Technical Conference and Exhibition, Denver, Co., U.S.A., 21–24 September 2008.
10. Whittle, T., Jiang, H., Young, S. and Gringarten A. C.:"Well Production Forecasting by Extrapolation of the Deconvolution of the Well Test Pressure Transients," paper SPE 122299 presented at the 2009 SPE EUROPEC/EAGE Annual Conference and Exhibition held in Amsterdam, The Netherlands, 8–11 June 2009.
11. Madahar, A., Stewart G. and Gringarten, A.C.:" Effect of Material Balance on Well Test Analysis", paper SPE 124524 presented at the 2009 SPE Annual Technical Conference and Exhibition held in New Orleans, Louisiana, USA, 4–7 October 2009.
12. Gringarten, A. C.:"Evolution of Reservoir Management Techniques: From Independent Methods to an Integrated Methodology. Impact on Petroleum Engineering Curriculum, Graduate Teaching and Competitive Advantage of Oil Companies" SPE 39713, proceedings of the 1998 SPE Asia Pacific Conference on Integrated Modelling for Asset Management held in Kuala Lumpur, Malaysia, 23-24 March (1998).
13. Zambrano, J., Zimmerman, R. W. and Gringarten, A. C.:"Influence of Geological Features on Well Test Behavior" SPE 59398, proceedings of the 2000 SPE Asia Pacific Conference on Integrated Modelling for Asset Management held in Yokohama, Japan, 25-26 April (2000).
14. Alain C. Gringarten:" Analysis of an Extended Well Test to Identify Connectivity Between Adjacent Compartments in a North Sea Reservoir," paper SPE 93988 presented at the 14th Europec Biennial Conference, Madrid, Spain, 13-16 June 2005.
15. Mijinyawa, A., and Gringarten, A.C.:" Influence of Geological Features on Well Test Behavior," paper SPE 113877 presented at the 2008 SPE Europec/EAGE Annual Conference and Exhibition, Rome, Italy, 9–12 June 2008.

16. Florian Hollaender, Jim G. Filas, Curtis O. Bennett and Alain C. Gringarten: ”Use of Downhole Production/Reinjection for Zero-Emission Well Testing: Challenges and Rewards” in *Proc. 2002 SPE Ann. Tech. Conf. Exh.*, Soc. Pet. Eng., San Antonio, paper SPE 77620, (2002).
17. T. M. Whittle, J. Lee and A.C. Gringarten: "Will Wireline Formation Tests Replace Well Tests?" in *Proc. 2003 SPE Ann. Tech. Conf. Exh.*, Soc. Pet. Eng., Denver, paper SPE 84086 (2003).
18. A. C. Gringarten, A. Al-Lamki, S. Daungkaew, R. Mott, and T. M. Whittle: “Well Test Analysis in Gas-Condensate Reservoirs” paper SPE 62920 presented at the 2000 SPE Annual Conference and Exhibition, Dallas, Texas, 1–4 October 2000.
19. Daungkaew S., Ross F, and Gringarten A.C.: "Well Test Analysis of Condensate Drop-Out Behaviour in a North Sea Lean Gas Condensate Reservoir", Paper SPE 77548, presented at the 2002 SPE Annual Conference and Exhibition, San Antonio, Texas, 29 Sept. -2 October (not in proceedings).
20. M.Bozorgzadeh and A.C. Gringarten: "New Estimate for the Radius of a Condensate Bank from Well Test Data Using the Dry Gas Pseudopressure" paper SPE 89904 presented at the 2004 SPE Annual Conference and Exhibition, Houston, Texas, 26–29 September 2004.
21. A. Hashemi and A.C. Gringarten: "Well Test Analysis of Horizontal wells in Gas-Condensate Reservoirs" paper SPE 89905 presented at the 2004 SPE Annual Conference and Exhibition, Houston, Texas, 26–29 September 2004
22. T. von Schroeter and A.C. Gringarten: "Estimates For The Radius Of A Condensate Zone From A Simple Compositional Model" in Proc. 2004 SPE Ann. Tech. Conf. Exh., Soc. Pet. Eng., Houston, paper SPE 89911 (2004).
23. Ali, A. M, Falcone, G., Bozorgzadeh, M., Gringarten, A. C. and Hewitt, G. F: "Experimental Investigation of Wellbore Phase Redistribution Effects on Pressure-Transient Data" SPE-96587 presented at the 2005 SPE Annual Technical Conference and Exhibition, Dallas, Tx, 9-12 Oct-2005.
24. Tarik Baig, Uwe Droegemueller and Alain C. Gringarten:”Productivity Assessment of Fractured and Non-Fractured Wells in a Lean/Intermediate Low Permeability Gas Condensate Reservoir”, Paper SPE 93136 presentated at the 14th Europec Biennial Conference, Madrid, Spain, 13-16 June 2005.
25. Manijeh Bozorgzadeh and Alain C. Gringarten:”Application of Build-Up Transient Pressure Analysis to Well Deliverability Forecasting in Gas Condensate Reservoirs Using Single-Phase and Two-Phase Pseudo-Pressures”, paper SPE/IADC 94018 presentated at the 14th Europec Biennial Conference, Madrid, Spain, 13-16 June 2005.
26. Abdolnabi Hashemi and Alain C. Gringarten:”Comparison of Well Productivity between Vertical, Horizontal and Hydraulically Fractured Wells in Gas-Condensate Reservoirs” paper SPE 94178 presented at the 14th Europec Biennial Conference, Madrid, Spain, 13-16 June 2005.
27. Gringarten A. C., Daungkaew S., Hashemi S. and Bozorgzadeh, M: "Well Test Analysis in Gas Condensate Reservoirs: Theory and Practice," paper SPE 100993, presented at the 2006 SPE Russian Oil and Gas Technical Conference and Exhibition, Moscow, Russia, 3–6 October 2006.
28. Amudo C., Turner, J., Frewin J.; Kgogo, T., and Gringarten A. C.:”Integration of Well Test Deconvolution Analysis and Detailed Reservoir Modelling in 3D Seismic Data Interpretation: A Case Study,” paper SPE 100250 presented at the SPE Europec/EAGE Annual Conference and Exhibition, Vienna, Austria, 12–15 June 2006
29. Sanni, M. and Gringarten A. C.:” Application of Well Testing for Well Deliverability Forecasting in Volatile Oil Reservoirs,” paper SPE 118377, presented at the 2008 Abu Dhabi International Petroleum Exhibition and Conference, Abu Dhabi, UAE, 3–6 November 2008.
30. Sanni, M. and Gringarten A. C.:” Well Test Analysis in Volatile Oil Reservoirs,” paper SPE 116239, presented at the 2008 SPE Annual Technical Conference and Exhibition, Denver, Co., U.S.A., 21–24 September 2008.

31. Krukrubo G. J., and Gringarten, A.C.:" Predicting the onset of condensate accumulation near the wellbore in a gas condensate reservoir," paper SPE 121326 presented at the 2009 SPE EUROPEC/EAGE Annual Conference and Exhibition held in Amsterdam, The Netherlands, 8–11 June 2009.
32. Aluko, O.A. and Gringarten, A.C.:" Well Test Dynamics in Rich Gas Condensate Reservoirs under Gas Injection," paper SPE 121848 presented at the 2009 SPE EUROPEC/EAGE Annual Conference and Exhibition held in Amsterdam, The Netherlands, 8–11 June 2009.
33. Mavromoustaki A., Lim B., Ng B., Mirza S.M., Hale C.P., Manolis I., Gringarten A.C., Hewitt G.F. and Matar O.K.:"An experimental study of wellbore phase redistribution effects in gas condensate reservoirs", presented at the 4th International Conference on Multiphase Production Technology, Cannes, France, 17-19 June 2009.
34. Gringarten, A. C.:"Making sense of well tests in gas condensate reservoirs," SPE Distinguished Lecture, 2003-2004.

Appendix: Imperial College reports on Gas Condensates and Volatile oil Well test Analysis

1	Saifon DAUNGKAEW	Well-Test Analysis using a Triple Radial Composite Model and its Application to Gas Condensate Reservoirs	MSc 1997/98
2	William BEVERIDGE	Britannia Gas Condensate Well Deliverability Predictions	
3	Edward CHAMBERS	An Investigation and Simulation to Determine Development Sensitivities of a North Sea Gas-Condensate Field	
4	Nicolas FETTA	Flow to a Well in a Gas Condensate Reservoir	
5	Djamel OUZZANE	Experimental Study of Wettability Alteration to Gas-Wetness in Porous Media	
6	Lamia GOUAL	Modelling of Wax Precipitation in Gas Condensate Systems	

7	Ali AL-LAMKI	The effects of rate-dependent relative permeabilities on the interpretation of gas condensate well tests.	MSc 1998/99

8	Gregor COLVILLE	Effect of condensate dropout on productivity and recovery from a lean gas condensate field.	MSc1999/00
9	Hashem MONFARED	Well test analysis in multi-layer gas condensate reservoir: effect of individual layer skins.	

10	Jirades TANAPATCHAIPONG	Well test analysis in a gas condensate reservoir in the Gulf of Thailand	MSc 2000/01
11	Binayak AGARWAL	Wireline formation test interpretation in a gas condensate reservoir	
12	George MYKONIATIS	Composite behaviour in multilayer reservoirs	
13	Akepeki AKEMU	Wellbore Dynamics in Gas Condensate Wells	
14	Daniel MAROKANE	The Applicability Of Timely Gas Injection In Gas Condensate Fields To Improve Well Productivity	
15	Manijeh BOZORGZADEH	Evaluation of the potential of well 30/7A-P1 in the Judy field	
16	Abdolnabi HASHEMI	High Pressure High Temperature Well Test Interpretation: Jade Field, UKCNS	

17	Abdimurat AYAPBERGENOV	Prediction of the Production Performance of Highly Volatile Oil Reservoirs Below the Bubble Point Pressure	MSc 2001/02
18	Clare HOWAT	A Feasibility Study of Horizontal Wells in the Development of a Carbonate Reservoir Oil Rim – Comparative Sensitivities Using a Sector Model	

19	Alekan ALUKO	Well Test Analysis on a Condensate Gas Field in the North Sea	MSc 2002/03
20	Mirza Tariq BAIG	Productivity enhancement of gas condensate wells by fracturing	
21	Thierry LAUPRETRE	Determine the level of grid refinement required around Jade wells to ensure the most correct prediction of wellbore productivity below the dew point.	
22	Arsyad SIREGAR	Well test analysis in a volatile oil reservoir in Algeria	
23	Piyatad TABMANEE	Well test analysis in the Hassi R'Mel field, Algeria	

24	Bandar AL-MALKI	Well Test Analysis In Condensate Gas Reservoirs In Carbonate Formations In Saudi Arabia	MSc 2003/04
25	Ahmed ALI	Experimental investigation of phase redistribution effect on pressure transient data	
26	Moshood SANNI	Simulation of well tests in volatile oil reservoirs	

27	Aisha Alfa-Wali	Volatile Oil Well Testing 'Best Practice' and Productivity Enhancement in the MLNW Field, Algeria	MSc 2004/05
28	Babalola Abiose Daramola	Pentland Re-development Plan: Predicting the Effects of Condensate Banking in a North Sea HPHT Gas-Condensate Reservoir	
29	Nicolas Guézé	Composite well test interpretation model for horizontal wells	
30	Thabo Clifford Kgogo	Deconvolution Analysis of a Horizontal Gas Condensate Well	
31	Sabina Rattan	Evaluation Of Reservoir Heterogeneities For Modelling Gas Injection In A Retrograde Gas Condensate Reservoir	
32	Bernard P. Sinambela	Comparison Of Different Methods For Estimating Gas Condensate Well Deliverability	

33	Jean-Baptiste Berchoteau	Use of Deconvolution to Improve the Reservoir Behaviour Understanding of Some Gas Condensate Reservoirs in Britannia	MSc 2005/06
34	Perapon Fakcharoenphol	Well Test Behaviour in Multi-Layer Gas-Condensate Reservoirs	
35	Olivier Pippi	Well Test & Deconvolution Analyses of Gas Condensate Reservoirs	

36	Ali Cherif Azi	Evaluation of Confidence Intervals in Well test Interpretation Results	MSc 2006/07
37	George Krukrubo	Predicting the Onset of the Effect of Condensate Accumulation in the Build-Up Pressure Derivative Plot	
38	Amit Madahar	Effects of Material Balance on Well Test Analysis	
39	Hammed A. Shittu	Well Tests In Naturally Fractured Gas-Condensate Reservoirs	
40	Luther Sullivan	Prediction of the production performance of a Gas Condensate Well in the North Sea: A Simulation Study	
41	Nur Suut	Modeling of Near Wellbore Flow Effects in Gas Condensate Reservoirs	

42	Ahmed Albaqawi	Well Test Analysis In Naturally Fractured Gas Condensate Reservoirs Below Dew Point Pressure	MSc 2007/08
43	Ulan Burkitov	Simulation Of Possible Gas Condensate Banking in the Karachaganak field	
44	Sola Makinde	Estimating Storativity Ratio In Wells Producing Volatile Oil	
45	Adnan Merchant	Use of Black Oil Models for Complex Reservoir Fluids	
46	Sohaib M. Mirza	Experimental Study of Wellbore Dynamics in Gas Condensates	

47	Gadilbek Uxukbayev	Evaluating the Wellbore Skin vs. Rate Relationship in Gas Condensate and Volatile Oil Reservoirs	MSc 2008/09
48	Morounranti Vigo	Experimental Study Of Wellbore Dynamics In Gas Condensates	

1	Saifon DAUNGKAEW	Well test analysis in gas condensate wells	PhD	2001
2	Djamel OUZZANE	Phase behaviour in gas condensate reservoirs	PhD	2004
3	Manijeh BOZORGZADEH	Well Test Analysis in Gas Condensate and Volatile Oil Reservoirs	PhD	2005
4	Abdolnabi HASHEMI	Horizontal Well Test Analysis in Gas Condensate Oil Reservoirs	PhD	2006
5	Gioia FALCONE	Modelling of flows in vertical pipes and its application to multiphase flow metering at high gas content and to the prediction of well performance	Part-time PhD	2006
6	Moshood Olajide Sanni	Well Test Analysis in Volatile Oil Reservoirs	PhD	2008
7	Alekan ALUKO	Well Test Dynamics of Rich Gas Condensate Reservoirs	Part-time PhD	2009