


## Emeraude Models

# KAPPA

## INTERPRETATION THEORY MODELS

Module #11

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## Emeraude Models

**Use of the 2-phase flow models for 3-phase interpretation**

**2-phase model extended to 3-phase assuming there is no slippage between two of the three phases. (Version 2.00)**

**The mixed phase is either... oil and water,... or oil and gas.**

**Introduction of additional parameters in order to split the superficial velocity of this mixed phase into the two components.. “fo” & “fg”**

**3-Phase flow model introduced with Version 2.10 incorporating 2 slippage velocities, and 2 correlations.**

- Liquid - Gas
- Liquid - Liquid

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## 3 Phases

- In 3 phase flow, the problem is extended with one more holdup and one more phase velocity
- We now have 3 phase velocities so there will be 2 slippage velocities to be considered
- 3-Phase flow is treated as the combination of two 2-phase situations.
- With a bulk rate measurement and the use of slippage models, the interpretation is made from 2 independent holdup measurements (e.g. density + water holdup, water holdup + gas holdup, etc).

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## Three Phases

Mixed phase is oil+water: ( flowing with gas )    Liquid-Gas

Introduce  $f_o$ , oil fraction in the liquid phase

$$\begin{aligned} Q_{\text{GAS}} &= Q_L \\ Q_{\text{OIL}} &= f_o \cdot Q_H \\ Q_{\text{WATER}} &= (1-f_o) \cdot Q_H \end{aligned}$$

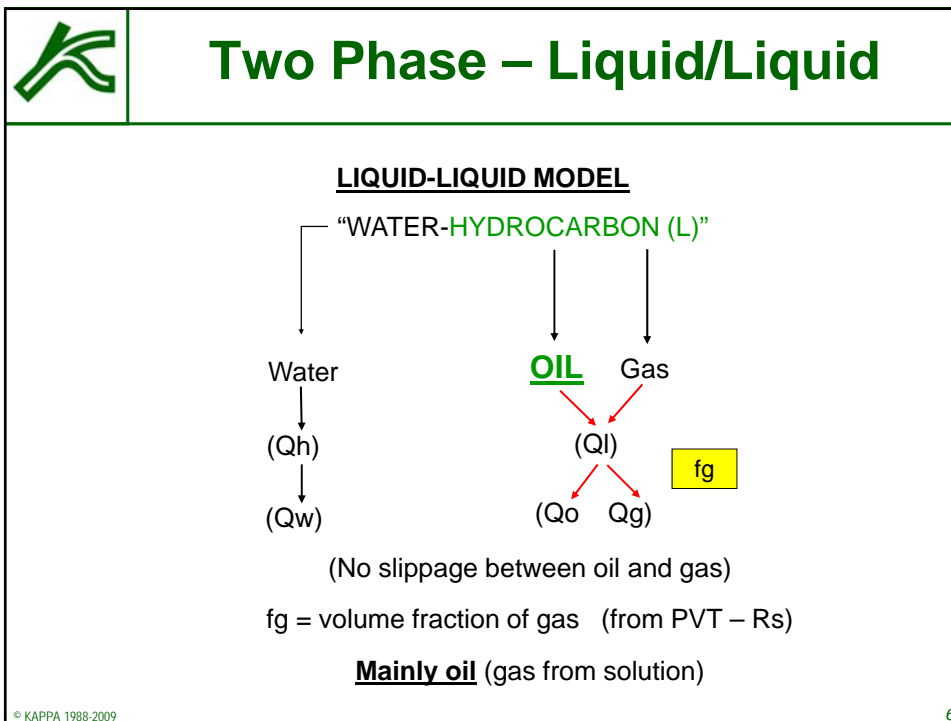
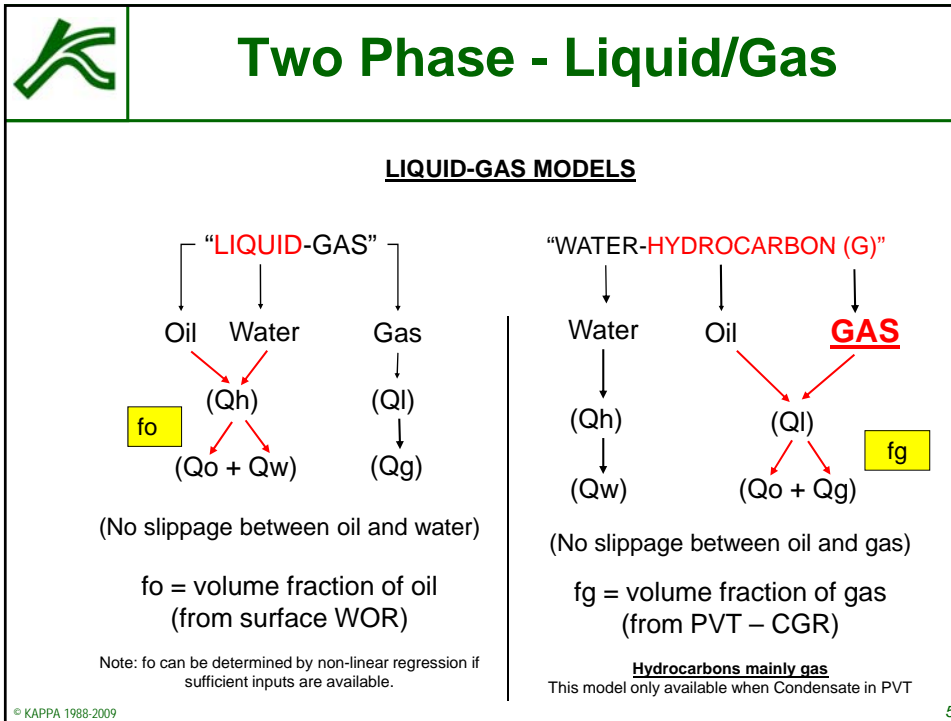
Mixed phase is oil+gas: ( gas flowing with water )    Liquid-Gas  
(oil flowing with water)    Liquid-Liquid

Introduce  $f_g$ , gas fraction in the hydrocarbon phase

$$\begin{aligned} Q_{\text{WATER}} &= Q_H \\ Q_{\text{OIL}} &= (1-f_g) \cdot Q_L \\ Q_{\text{GAS}} &= f_g \cdot Q_L \end{aligned}$$

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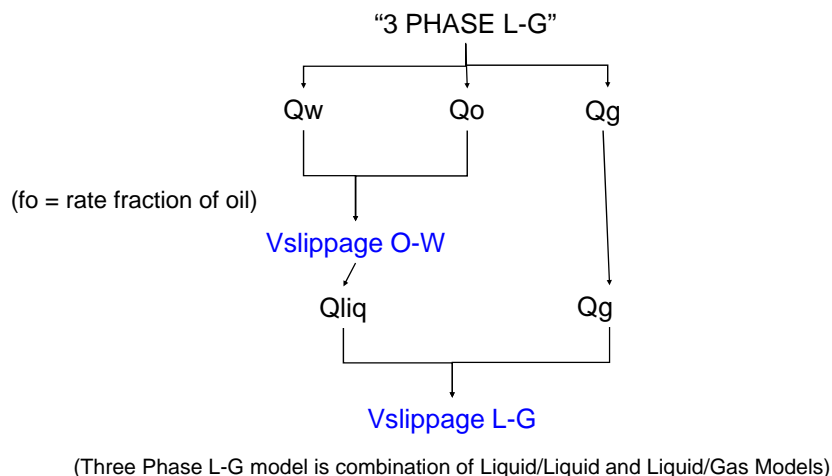
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## Three Phase - Water/Oil/Gas

### LIQUID-LIQUID-GAS MODEL



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## Models in Emeraude

### **Liquid-Gas**

The liquid phase can comprise oil, water, or a mixture of both. There is no slippage between oil and water. In 3-phase, the fraction of oil in the Liquid phase, fo is introduced. The initial fo value is based on the entered surface WOR. If the necessary measurements are available fo is a variable of the non-linear regression. In this case a green light will appear in front of the fo button in the Zone Rate dialog.

### **Water-Hydrocarbons (G)**

Liquid-Gas situation where the heavy phase is water and the light phase is mainly gas possibly with some oil (or condensate). There is no slippage between the oil and gas phases. If this model is used in 3-phase, the ratio of gas in the hydrocarbon phase, fg, is introduced. This value is fixed from the PVT CGR ratio.

### **Water-Hydrocarbons (L)**

Liquid-Liquid situation where the heavy phase is water and the light phase is oil possibly with evolved gas. There is no slippage between the oil and gas phases. If this model is used in 3-phase, the ratio of gas in the hydrocarbon phase, fg, is introduced. This value is fixed from the PVT Rs ratio.

### **3-Phase L-G**

This is the combination of a Liquid-Gas and Water-Oil models. There is slippage between the oil and water phases within the Liquid phase. There is also slippage between the gas and the mixed liquid. The oil fraction fo represents the ratio of the oil rate to the liquid rate. This model is only offered when there are enough measurements for fo to be a variable.

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# E03-15 Technical Reference

PVT	Flow model	Variable	Required Measurements
Single phase	Single phase	Vm	1 velocity (or temperature)
Oil-Gas	Single phase	Vm	1 velocity (or temperature)
	Liquid-Gas	Vsh, Vsl	2 including 1 velocity (or temperature)
Water-Gas	Liquid-Gas	Vsh, Vsl	2 including 1 velocity (or temperature)
Gas - Condensate	Single phase	Vm	1 velocity (or temperature)
	Liquid-Gas	Vsh, Vsl	2 including 1 velocity (or temperature)
Water-Oil-Gas	Liquid-Gas	Vsh, Vsl (fo fixed)	2 including 1 velocity (or temperature)
		Vsh, Vsl, fo	3 including 1 velocity (or temperature)
	Water-Hydrocarbons (L)	Vsh, Vsl	2 including 1 velocity (or temperature)
	3-Phase L-G	Vsh, Vsl, fo	3 including 1 velocity (or temperature)
Water-Gas-Condensate	Water-Hydrocarbons (G)	Vsh, Vsl	2 including 1 velocity (or temperature)

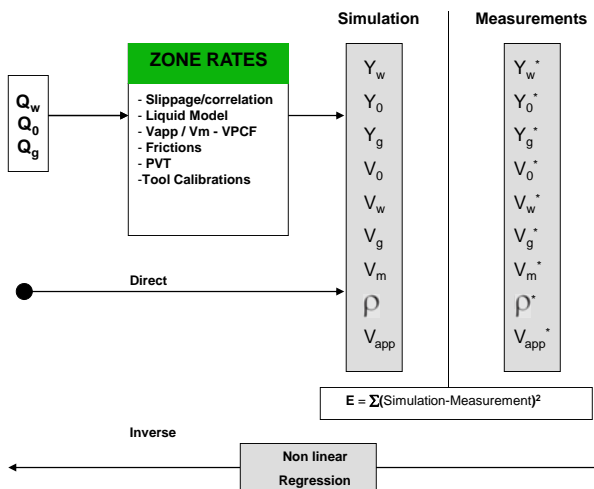
Page E03-15 Technical Reference

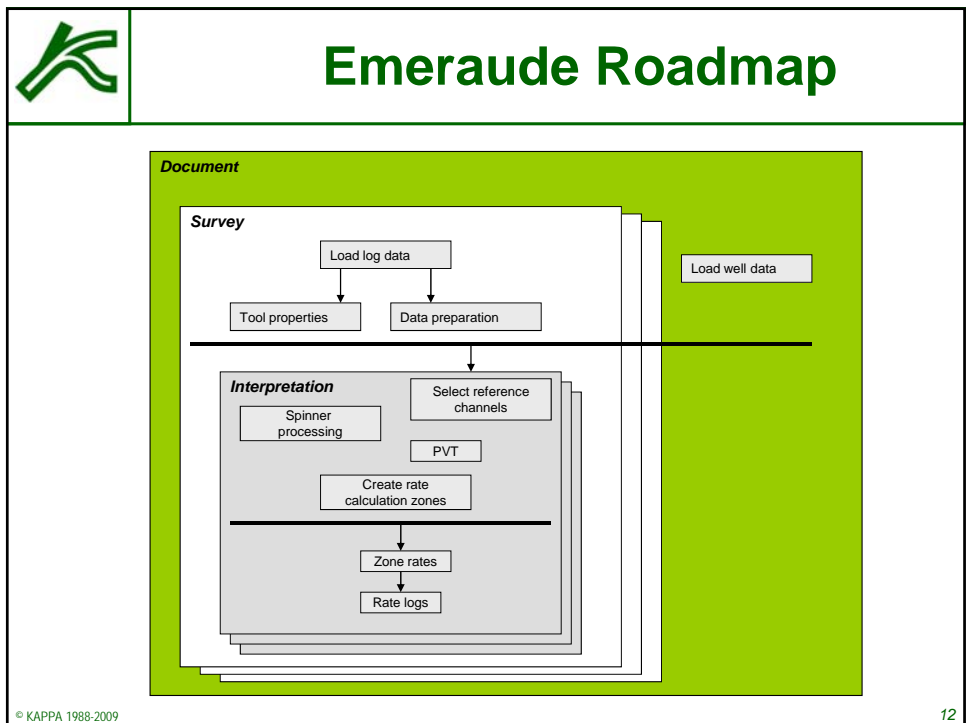
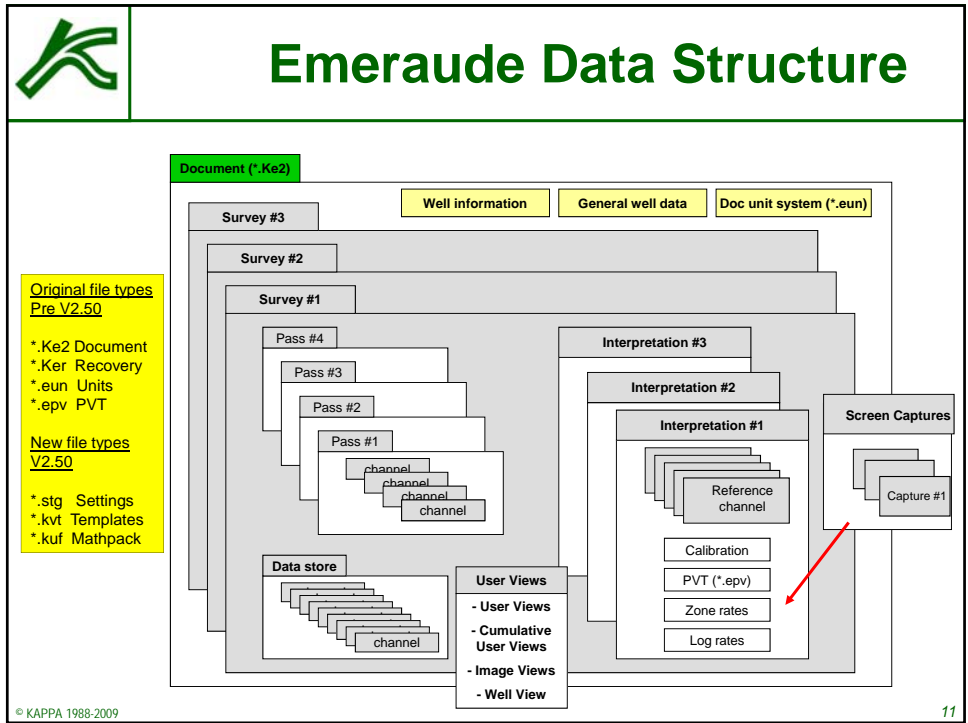


# Emeraude Process

**SURFACE RATES**  
• e.g. Test separator

Simulated  
Matched  
Computed  
Derived  
Synthetic  
Calculated  
Predicted







## Technical Reading

### SPE MONOGRAPH SERIES

#### Production Logging – Theoretical and Interpretive Elements, Vol.14 (A.D.Hill)

Cased Hole and Production Log Evaluation by James Smolen

Pennwell ISBN: 087814465X

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## SPE papers 1

Date	SPE No.	Title	Subject	Company	Authors
Apr-66	1245	Practical use of recent research in multiphase vertical and horizontal flow	Hagedorn & Brown		Hagedorn & Brown
Oct-69	2553	A comparison of existing multiphase flow methods for the calculation of pressure drop in vertical wells			Espanol & Holmes & Brown
Oct-72	4923	Measurements of multiphase fluid flow	Nicolas	Schlumberger	Nicolas & Witterbock
Nov-05	10186	Evaluation of Wireline Tractor Performance in Various Well Completions in Saudi Arabia			
Nov-05	10208	Production Logging Tool Behavior in Two-Phase Inclined Flow		Aramco	Hashem & Zaybek
Oct-82	10248	Solutions To Challenges in Production Logging of Horizontal Wells Using New Tool		Baker Atlas	Mill, A.D
Nov-05	10248	Solutions To Challenges in Production Logging of Horizontal Wells Using New Tool			T. Chandran
Nov-05	10248	Solutions To Challenges in Production Logging of Horizontal Wells Using New Tool			
Nov-05	10430	Identification of Water Entry with New Integrated Production Logging Tool in Challenging Horizontal Wells	MCFM Polaris	Baker Atlas	T.M. Al Bealji
Nov-05	10430	Identification of Water Entry with New Integrated Production Logging Tool in Challenging Horizontal Wells		Saudi Aramco	
	10430	Identification of Water Entry with New Integrated Production Logging Tool in Challenging Horizontal Wells			
	10492	An Integrated Approach For Evaluating and Characterizing Horizontal Well Inflow and Productivity in Heterogeneous Carbonate Reservoirs			
	11171	Production Logging Low Flow Rate Wells with High Water Cut			
	11265	Production Logging in Difficult Well Configurations			
	11433	Reduced Risk Alternatives for Water Entry Detection in High Water Producing Horizontal Wells			
	11567	Pushing The limits Of Tractor-Deployed Wireline Operations On Al Khafji Field In Qatar.			
Sep-85	14431	Research on Simultaneous Production Logging Instruments in Multiphase Flow Loops	Basic PL Tools	Dresser Atlas	Davarzani & Roesner
Aug-88	14463	New Production Logging Technique for Horizontal Wells			Joly, E.L.
Oct-88	18216	A new model for two-phase oil/water flow: Production log interpretation and tubular calculations			Yasan & Kabir
May-94	20630	A comprehensive mechanistic model for upward two-phase flow in wellbores			Ansari & Sylvestre
Sep-92	20632	A unified Model for predicting flowing temperature distribution in wellbores and pipelines	Ramey Enthalpy		Alves & Alhanati
Dec-93	20980	Production Logging as an Integral Part of Horizontal Well Transient Pressure Test		Schlumberger	Almed
Oct-90	21094	Production logging in horizontal wells: Applications and experience to date	Horizontal conventional PL	Schlumberger	Chauvel
Apr-92	24089	Acquiring Production Logging Data With Pulsed Neutron Logs from Highly Deviated or Non-Conventional Production Wells With Multiphase Flow in Prudhoe Bay, Alaska		Atlas	Barnette

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## SPE Papers 2

1992	25083	Stimulation and Production Logging of Horizontal Wells AGIP (NAME) Bouni Field, Offshore Libya				Hweg
May-03	26090	Planning a Coiled-Tubing-Conveyed Production Logging Job in a Horizontal Well		Atlas		Copoulos
Sep-03	26682	An evaluation of recent mechanistic models of multiphase flow for predicting pressure drops in oil and gas wells		BP		Pucknell & Mason
Aug-04	27559	Advances in two-phase flow modelling				Talbot
Nov-04	28757	Horizontal Well Production Logging in Australia		Schlumberger		Yves Chauvel
Mar-05	29815	New Fullbore Production Logging Sensor Improves the Evaluation of Production in Deviated and Horizontal Wells		Halliburton		Kessler
May-06	35669	Horizontal Well Production Optimization Using Production Logs Run on Coiled Tubing in the 26R Sand Reservoir, Stevens Zone, Elk Hills Field, California		Bechtel Petroleum		Walker
Oct-06	36560	Stratified flow model and interpretation in horizontal wells	Stratflo	Schlumberger		Theron & Urwin
Oct-06	36564	Production Logging Tool Developments for Horizontal Wells and Hostile Environments		Maritime		Gardner
Oct-06	36565	The Application of a New Radial Borehole Fluid Imaging Tool in Production Logging Highly Deviated Wells		Schlumberger		Vittachi
Oct-06	36625	Improved Production Log Interpretation in Horizontal Wells Using Pulsed Neutron Logs		ARCO Alaska		Brady
Nov-06	37127	Characterizing Horizontal Well Performance in a Tight Gas Sand Using Pressure Transient, Production Logging and Geological Data		PanCanadian Petroleum		Churcher
Nov-06	37147	Three phase hold up determination in horizontal wells using a pulsed neutron source	RST 3phase holdup	Schlumberger		Roscoe
Nov-06	37153	Oil and water velocity logging in horizontal wells using chemical markers	PVL	Schlumberger		Roscoe
Jun-07	38295	Diagnosing Horizontal Well Production in the Belridge Field with Downhole Video and Production Logs		Whittaker		Whittaker
Oct-07	38810	Characterisation of oil-water flow patterns in vertical and deviated wells				Flores & Brill
Nov-08	48851	Improved Production Log Interpretation in Horizontal Wells Using a Combination of Pulsed Neutron Logs, Quantitative Temperature Log Analysis, Time Lapse LWD resistivity Logs and Borehole Gravity				Brady
Sep-08	49089	Horizontal well performance evaluation and fluid entry mechanisms	PVL, DEFT, RST Horizontal	Schlumberger		Lenn
Oct-08	49994	Wireline Tractor Production Logging Experience in Australian Horizontal Wells		ORAD-Ltd		Local
Oct-08	50178	Application of New Generation Technology to Horizontal Well Production Logging - Examples from the North West Shelf of Australia		Schlumberger		Carnegie
Nov-08	50395	Interpretation of Horizontal-Well Production Logs: Influence of logging tools				E. Ozkan

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## SPE Papers 3

Oct-08	51612	Wireline tractor production logging experience in Australian horizontal wells	Tractor	Sondex		Local & Searight
Apr-09	54326	Advanced horizontal well production logging - an Australian offshore example - Carnegie A	Flagship Horizontal	Schlumberger		
	54652	Evaluating High-Angle Wells With Advanced Production-Logging Technology, North Slope Alaska				
	56650	Production Logging Problem Description in October Field, Gulf of Suez				
Aug-09	57415	Production Logging in Horizontal Wells by Use of Ultrasonics		KU Petroleum Research		Fridtjof Nyhavn
Oct-09	57890	Evaluating high angle wells with advanced production logging technology	DEFT	Schlumberger		Hupp & Scroer
Oct-00	63141	Applications of a new multiple sensor production logging system for horizontal and highly deviated multiphase producers	MCFM Polaris	Baker Atlas		Chace, Wang, Trycka
Oct-00	63188	Intermittent spinner response in multiphase bubble flow	Spinner	Baker Atlas		Chace & George
Oct-00	63262	A mechanistic model based approach to evaluate oil/water slip at horizontal or highly deviated wells	Horizontal slip	Chevron		Duyang
	64405	Critical Wellbore Considerations for Successful Carbon-Oxygen Log Applications: Benefits of a Teamwork Approach				
Nov-00	65528	The Challenges of Detecting Gas Entries in Horizontal Well by Using Integrated Production Logging Tool, Case Study		Saudi Aramco		Hussein Ali
Mar-01	68468	Use of flow pattern based models for interpreting oil-water flow in production		Chevron		Kabir & Hoadley
	71727	Flow Diagnosis and Production Evaluation in High Flowrate Oil-Water Producers Using Optical-Fiber Holdup Sensors				
	71729	A New Statistical Method for Interpreting Production Logs				
Oct-01	72114	Reservoir monitoring methodology for a giant gas field	BP	Total		Potapchik & De Witt
	72150	Evaluations of Sub Horizontal Well Performance with Optical and Electrical Probes				
	76749	Production Logging Advances in the Fractured Monterey				
May-02	77295	Interpretation of Horizontal-Well Production Logs: Influence of Logging Tool				Ozkan
Oct-02	77501	Mechanistic and simplified models for oil water counter-current flow in deviated and multilateral wells	Apparent downflow	Chevron		Duyang
Oct-02	77521	A case history on the use of downhole sensors in a field producing from long horizontal/multilateral wells	DTS			
Oct-02	77710	Installation of in-well fibre optic monitoring systems	DTS		Weatherford	Pruett
Oct-02	77782	Interpreting wellbore flow images with a conventional production log interpretation method	CAT	Halliburton		Frisch
Oct-02	77839	Advanced production logging technology for more accurate flow profiling - Case studies from the Gulf of Suez	RST/DEFT	Schlumberger		
Apr-03	81118	Horizontal production logging using tractor technology - a first for Trinidad	Schlum tools & tractor	BP		Allabar

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		SPE Papers 4			
	81534	Multiphase Flowmeter and Production Logs Diagnose Well Response in an Onshore ADCO Field, Abu Dhabi			
	83969	Gas Holdup Imaging Identifies Complex Gas-Liquid Flow Regimes and Introduces a New Velocity Measurement in a Long, Cased Hole, Horizontal, Production Well			
Oct-03	84207	Production Logging in Horizontal Gravel-Packed Highly Viscous Oil Producers in The North Sea		Baker Atlas	Steve Riley
	84208	Better Flow Profiling Against Producing Zones Using a New Production Log Interpretation Technique			
Oct-03	84324	Brunei Field trial of a fibre optic distributed temperature sensor DTS system in a 1000m open hole horizontal oil producer	DTS	Sensa	Luier & Brown
Oct-03	84379	Monitoring horizontal producers and injectors during cleanup and production using fibre optic distributed temperature measurements	DTS	Sensa	
Oct-03	84399	Production and injection profiling: a novel application of permanent downhole pressure gauges	Pressure gauges	Chevron	Duyang
	84873	In-Situ Diagnosis of Inflow Behavior in Horizontal Wells			
	85667	Using Production Logging Technology for Reservoir Management in the Persian Gulf			
Oct-04	86705	Observations and Lessons Learned from a Set of Production Logging Data in Horizontal Barefoot Completions		Schlumberger	Mohamed Al Hamawi
Sep-04	89848	A Novel Approach To Production Logging in Multiphase Horizontal Wells		Schlumberger	D. Vu-Hoang
	90541				
Mar-05	93526	Expanding advanced production logging operations to short radius horizontal wells		Baker Atlas	D. Kelder
Oct-05	96980	Advances in Integrated Horizontal Production Logging in Openhole Completions		Saudi Aramco	M.S. Al-Hamili
	101721	Characterization of Multilayer Reservoir Properties Using Production Logs			
Sep-06	102196	The Role of Enhanced Production Logging Measurements in Challenging Openhole Horizontal Completions		Schlumberger	Mukerj
	102256	Integration of Borehole Imaging, Open Hole Logs, Nuclear Magnetic Resonance, Modular Dynamic Tester, and Advanced Production Logging as a Guide for Perforation Interval Selection in Thin-Bedded Sands and Shales			
	102588	Characterization of Commingled Reservoir Properties With Production Logs			
	102894	Permeability From Production Logs - Method and Application			
	103069	Real-Time Fiber-Optic Distributed Temperature Sensing (DTS)-New Applications in the Oilfield			
	103097	Successful Flow Profiling of Gas Wells Using Distributed Temperature Sensing Data			

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		SPE Papers 5			
Oct-06	103589	Pushing the Envelope for Production Logging in Extended Reach Horizontal Wells in Chayvo Field, Sakhalin, Russia - New Conveyance and Flow Profiling Approach		ExxonMobil	D.E. Fitz
	103589	Production Logging in Extended Reach (ERD) Horizontal Wells in Chayvo Field, Sakhalin, Russia - New Conveyance and Flow Profiling Approach			
	104013	Evaluation of Commingled Reservoir Properties Using Production Logs			
	104018	Characterization of Reservoir Properties Using Production Logs			
	105327	Horizontal Well Production Logging Experience in Heavy Oil Environment with Sand Screens: A Case Study From Kuwait			
	105700	Reservoir Characterization: Integrating Advanced Production Logging and Near Wellbore Modeling in a Maximum Reservoir Contact (MRC) Well			
	107070	Downhole Leak Determination Using Fiber-Optic Distributed-Temperature Surveys at Prudhoe Bay, Alaska			
Apr-07	106094	Production and Video Logging in Horizontal Low Permeability Gas Wells			D. Sask
	110412	Using Production Log to Calibrate Horizontal Wells in Reservoir Simulation			
	110693	Workover Successes in Deviated Wells Using Multispinner Production Log Data			
	111347	An Innovative Tractor Design for Logging Openhole Soft Formation Horizontal Wells			
	112863	First Production Log Run in a Heavy-Oil Long-Horizontal Well Through a Y-Tool and Premium Screens			
	114165	Tight Gas Surveillance and Characterization: Impact of Production Logging			
	1	Pressure Drop in wells producing oil and gas	Aziz & Govier		Aziz & Govier
May-73	2	A study of two phase flow in inclined pipes	Beggs & Brill		Beggs & Brill
Sep-88	3	Models for multiphase flow in oil wells	Artef		Ferschneider & Ozon
May-80	4	Modelling flow pattern transition for steady upward gas-liquid flow in vertical tubes	Dukler		Dukler & Taitel

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