NEXT GENERATION INTELLIGENT COMPLETIONS FOR MULTI-STACKED BROWNFIELD IN MALAYSIA

NUR FAIZAH BINTI P MOSAR

A project report submitted in partial fulfillment of the requirements for the award of the Degree of Master of Engineering (Petroleum)

School of Chemical and Energy Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JANUARY 2019

To my beloved husband, dearest son,

dear parents, and family members,

especially my supervisor,

thank you for all your support, encouragement and guidance.

ACKNOWLEDGEMENT

Firstly, thank you to Almighty God who gave the idea, knowledge, hope and courage enabling me to complete this project.

Furthermore, I would like to thank my mother-in-law who looked after my son with open arm when I was working on this project, beloved husband, dearest son, supportive parents, and family members, without your understanding, support and unconditional love, I don’t think all this would be possible.

I would also like to thank my supervisor, Assoc. Prof. Issham bin Ismail who has supported me with full commitment, patience and confidence along the process of completing this project. His ideas, guidance, encouragement and understanding really inspired me to do my best in this project.

Finally, I would also like to thank my classmates for their continuous support throughout the process. I am extremely grateful to have all of you in my life.

ABSTRACT

Multi-stacked brownfield in Malaysia is known to have zonal contrast reservoir pressure and water cut. Commingled production without any flow control such as conventional on-off sliding sleeve will induce cross flow of production from a high pressure reservoir to lower pressure reservoir which disables optimum oil production. Having high zonal water cut contrast will cause early or excessive water production translates to deferred oil production. To pro-actively prevent these occurrences, adaptation of intelligent completion components such as Permanent Downhole Gauge (PDG) and surface-controlled Flow Control Valve (FCV) can be used. Downhole FCV choke is designed to cater for the dynamic changes of reservoir properties predicted over well life. In order to standardize the FCV choke sizing by well or by campaign, the choke sizing will be averaged to fit for all layers which is not the ultimate optimized design for maximum oil production. Latest in market today, electrical driven infinite position FCV is the solution to conventional hydraulic actuated FCV. Having infinite position enables optimized choke sizing for all reservoir layers and flexible to tackle uncertainties and dynamic changes of reservoir properties over time which enables the ultimate optimum oil production and water cut reduction. Besides choke sizing, deployment method and operating method also contribute to installation and operating efficiency. Conventional multi-position FCVs in market today are either fully hydraulic operated or electro-hydraulic operated which require hydraulic pump units at surface to enable pressuring up hydraulic control lines to change the position of FCV. It is also time consuming during deployment due to the requirement of electrical splicing, hydraulic splicing and FCV actuation sequence. Infinite position FCV is electrically operated using single downhole cable that can be multi-dropped to more than 25 FCV which reduces deployment time. With WellWatcher Advisor software that provides real time optimization features, operating efficiency is improved significantly with infinite position FCV as compared to conventional multi-position FCV and on-off sliding sleeve.

ABSTRAK

Medan matang yang berlapis di Malaysia mempunyai kontras tekanan reservoir dan potong air yang tinggi antara lapisan. Pengeluaran minyak secara bercampur tanpa alat kawalan aliran misalnya sarung gelongsor akan menyebabkan berlakunya aliran silang dari reservoir bertekanan tinggi ke reservoir bertekanan rendah, lalu menghalang pengeluaran secara optimum. Kontras potong air yang ketara mengakibatkan penghasilan air yang lebih awal lalu mengurangkan pengeluaran minyak. Untuk mencegah kejadian ini, komponen pelengkapan pintar seperti Tolok Kekal Bawah Lubang (PDG) dan Injap Kawalan Aliran (FCV) yang dikawal dari permukaan boleh diguna. FCV bawah lubang direka bentuk supaya sesuai dengan perubahan dinamik yang dialami reservoir. Saiz purata pencekik diguna pakai untuk semua lapisan bagi memaksimumkan pengeluaran minyak. Terkini di pasaran, FCV berposisi infiniti memberikan penyelesaian yang terbaik dengan pencekik bersaiz optimum boleh diguna pakai untuk semua lapisan reservoir demi mengoptimumkan pengeluaran minyak dan mengurangkan potong air. Selain saiz pembukaan, alat itu turut menyumbang kepada kecekapan pemasangan dan operasi. FCV kenvensional pelbagai posisi beroperasi secara hidraulik atau elektro-hidraulik memerlukan pam hidraulik di permukaan. Alat itu memakan masa pemasangan berikutan kerja penyambungan tiub elektrik dan hidraulik serta aturan penggubahan posisi. FCV berposisi infiniti dikendalikan sepenuhnya secara elektrik menggunakan satu kabel elektrik dan boleh digunakan untuk lebih daripada 25 FCV yang sudah pasti mengurangkan masa pemasangan. Penggunaan perisian WellWatcher Advisor yang berciri pengoptimuman masa nyata berjaya meningkatkan kecekapan operasi FCV berposisi infiniti berbanding FCV konvensional pelbagai posisi dan sarung gelongsor.

TABLE OF CONTENTS

DECLARATION		**ii**
DEDICATION		**iii**
ACKNOWLEDGEMENT		**iv**
ABSTRACT		**v**
ABSTRAK		**vi**
LIST OF TABLES		**x**
LIST OF FIGURES		**xi**
CHAPTER 1	**INTRODUCTION**	**1**
1.1.	**Background**	**1**
1.2.	**Problem Statement**	**5**
1.3.	**Objectives**	**8**
1.4.	**Hypothesis**	**9**
1.5.	**Research Scope**	**10**
1.6.	**Significance of Study**	**11**
1.7.	**Chapter Summary**	**11**
CHAPTER 2	**LITERATURE REVIEW**	**13**
2.1	**Mature Field in Malaysia**	**13**
2.2	**Types of Completions**	**14**

2.3 Multi-zone Intelligent Completions 15

2.4 Permanent Downhole Monitoring 16

2.5 Sliding Sleeve 19

2.6 Flow Control Valve 21

2.7 Chapter Summary 24

CHAPTER 3 METHODOLOGY 27

3.1 Introduction 27

3.2 Multi-zone Flow Simulation of Oil Producer with Sliding Sleeve and Infinite Position FCV 27

3.1.1 Data Gathering 28

3.1.2 Simulation 28

3.3 Downhole Installation Efficiency Comparison 31

3.4 Flow Control Operating Efficiency for Sliding Sleeve, Multi-Position FCV and Infinite Position FCV 31

3.5 Chapter Summary 32

CHAPTER 4 RESULTS AND DISCUSSIONS 33

4.1 Data Gathering 33

4.1.1 Samarang Field 33

4.1.2 Baram Delta Operations 35

4.2 Simulation Input 38

4.2.1 Oil Incremental Comparison 40

4.2.2 Water Production Comparison 43

4.3 Downhole Installation Efficiency Comparison Between Sliding Sleeve, Multi-Position FCV and Infinite Position FCV **45**

4.3.1 Downhole installation 45

4.3.2 Surface installation 52

4.4 FCV Operating Efficiency Comparison between Sliding Sleeve, Multi-Position FCV and Infinite Position FCV **54**

4.5 Chapter Summary **54**

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS **59**

5.1 Conclusions **59**

5.2 Recommendations **61**

REFERENCES **63**

APPENDIX A **71**

APPENDIX B **73**

APPENDIX B **75**

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Metrology of PDG (Schlumberger, 2018b)	16
2.2	Actual installed FCV and number of position (Schlumberger, 2018b)	24
4.1	Baram Delta Operations field properties	37
4.2	Constant reservoir parameter	39
4.3	Manipulated parameter	40
4.4	Accessories required to complete multi-zone sliding sleeve, multi-position FCV and infinite position FCV at reservoir section	46
4.5	Main parameter and rate for each activity for downhole deployment	50
4.6	Surface equipment required for multi-zone completions with sliding sleeve, multi-position FCV and infinite position FCV	53
4.7	Main parameter and rate for each activity for valve actuation during production	54

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	(a) Multi-zone with sliding sleeve, (b) Multi-zone with ICD, (c) Multi-zone with FCV and PDG	3
2.1	Single permanent downhole gauge (Schlumberger, 2018b)	17
2.2	PDG installation for above packer application (Samuel *et al*., 2014)	18
2.3	Sliding sleeve (Schlumberger, 2008)	20
2.4	Multi-zone completion wellbore (Konopczynski and Ajayi, 2004)	23
3.1	PIPESIM and WellWatcher Advisor simulation flowchart	30
4.1	One of Samarang well schematic completed with hydraulic actuated FCV with four positions	34
4.2	Water cut prediction between reservoir layers in a Samarang well that was completed with hydraulic actuated FCV	35
4.3	Fields in Baram Delta Operations (Abu Bakar et al., 2011)	36
4.4	Five zones created in PIPESIM software	39
4.5	Oil production comparison between on-off sliding sleeve and infinite position FCV	41
4.6	Incremental oil production comparing infinite position FCV and on-off sliding sleeve	42

4.7	Water production rate comparison between on-off sliding sleeve and infinite position FCV	44
4.8	Deployment time comparison between multi-zone completions with sliding sleeve, multi-position FCV and infinite position FCV	49
4.9	Operating efficiency comparison between multi-zone completions with sliding sleeve, multi-position FCV and infinite position FCV	55

LIST OF SYMBOLS

PDG	-	Permanent Downhole Gauge
ICD	-	Inflow Control Device
FCV	-	Flow Control Valve
SGM	-	Solid Gauge Mandrel
SAU	-	Surface Acquisition Unit
HPU	-	Hydraulic Power Unit
SCADA	-	Supervisory Control and Data Acquisition
PDC	-	Permanent Downhole Cable
SSD	-	Sliding Sleeve

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Simulation Output for 100 psi Zonal Incremental Pressure at Different Water Cut Incremental Rate	71
B	Simulation Output for 300 psi Zonal Incremental Pressure at Different Water Cut Incremental Rate	73
C	Simulation Output for 500 psi Zonal Incremental Pressure at Different Water Cut Incremental Rate	75

CHAPTER 1

INTRODUCTION

1.1 Background

Post drilling, a well must be completed safely and efficiently prior to initiating production. Completions system must be designed to withstand suspected loads throughout its life (PETRONAS, 2013). Numerous technologies today enable safe and efficient completions installation (Dyson *et al.*, 1999).

A well can be completed for a single reservoir or multi-stacked reservoir. As the associated cost for drilling a well in offshore environment is significantly high as compared to onshore, completing a well with multi-zone reservoirs can be a cost-effective solution for oil operators (Masoudi *et al.*, 2015). It also will enable operators to produce oil by commingling the production or selective sequential production from different layers.

One of the fundamental methodologies to enhance oil production in multi-zone completions is to incorporate reservoir monitoring and control technologies as part of completions accessories (Schlumberger, 2015a; Pogoson and Cardona, 2013). Reservoir monitoring can be achieved by installing Permanent Downhole Gauge (PDG) that reads pressure and temperature data near reservoir and transmit the data real time to end user (Samuel *et al.*, 2014; Shestov *et al.*, 2015). Active reservoir control can be achieved by having surface controlled downhole flow control device near reservoir. This will enable proactive measure to optimize production throughout well life by delaying water and gas breakthrough and ultimately increasing oil production (Schlumberger, 2018a; Al-Amri *et al.*, 2013). Multi-zone completions can be completed in few configurations as shown in Figure 1.1.

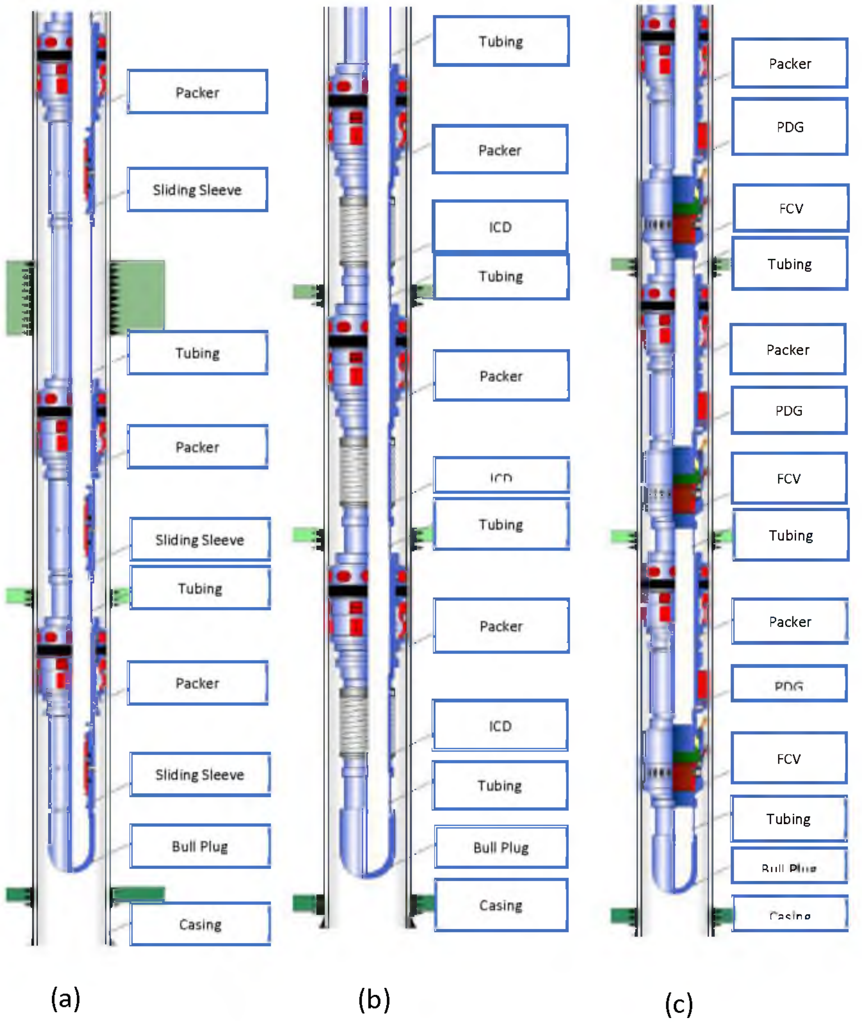

Figure 1.1 (a) Multi-zone with sliding sleeve, (b) Multi-zone with ICD, (c) Multi-zone with FCV and PDG

(1) Multi-zone with sliding sleeve – It requires slickline intervention to open and close the sliding sleeve.

(2) Multi-zone with passive Inflow Control Device (ICD) – Multiple ICD with pre-designed choke size usually installed along the reservoir section.

(3) Multi-zone with active Flow Control Valve (FCV) – Surface controlled flow control valves usually integrated with PDG (Rodriguez *et al.*, 2014; Mohammed Tawfik *et al.*, 2013).

Most FCVs in current market are available in two (Innes *et al.*, 2007), four (Rodriguez *et al.*, 2014; Mohammed Tawfik *et al.*, 2013), six, and eight (Masoudi *et al.*, 2015; Shestov *et al.*, 2015) positions. The FCV is operated with various means such as:

(1) Hydraulic operated FCV (Jannise *et al.*, 2017) – Hydraulic operated FCV usually utilizes N+1 concept. N is referencing to number of FCV. One common line is shared between all FCVs. As example, if three FCVs are used for three zones, four hydraulic control lines are required to operate the FCV.

(2) Electro-hydraulic operated FCV – Electro-hydraulic FCV utilizes one electrical cable and two hydraulic control lines to operate the FCV (Schlumberger, 2017b; Halliburton, 2015).

(3) Electrical operated FCV – Electrical operated FCV utilizes one electrical cable to operate the FCV (Basak and Gurses, 2015).

Prior to deciding choke size for FCV, a reservoir simulation study would be done to achieve the most optimized design. Prior to commissioning at site, a detailed completion design and planning is required to optimize rig time for complex installation of multi-zone FCV without jeopardizing safety nor quality.

1.2 Problem Statement

Multi-stacked reservoir in Malaysian brownfield is known to have great difference of reservoir pressure between the layers (Ceccarelli *et al.*, 2014). Commingled production without any choking capability such as sliding sleeve will induce cross flow between the zones (Hamid *et al.*, 2017).

Often, especially during oil crisis, completion design chosen is driven by cost. Multi-zone with sliding sleeve would be the cheapest option with regards to capital expenditure as compared to multi-zone with ICD or FCV. However, the setback of multi-zone with sliding sleeve would be higher operational expenditure as slickline intervention is required to open or close the sliding sleeve. In addition, as only open and close position is available with sliding sleeve, once the independent zone is not economical with excessive produced water or gas, there will be no capability to choke back water or gas production to produce remaining reserve. Hence, the sliding sleeve will be shut using slickline intervention.

Multi-zone completions with FCV require proper planning and tedious installation process. Control line termination at FCV, PDG cable termination at Solid Gauge Mandrel (SGM) and control lines splice at packer require longer installation time as compared to multi-zone completions with sliding sleeve. This translates to higher capital expenditure for multi-zone with FCV. However, on the other hand, the operational expenditure would be lower compared to multi-zone with sliding sleeve as FCV has multiple positions enable choking the production for the high water cut zone without intervention. This will permit the high water cut zone to still produce oil which directly translate in oil production incremental (Schlumberger, 2017a).

Hydraulic actuated FCV is operated using hydraulic pump while PDG is powered up by Surface Acquisition Unit (SAU) from surface which require space, instrument gas or air supply, and power allocation on the platform.

Conventional FCV is also limited by the number of positions. To design the choke size for these positions, a detailed study on the reservoir condition and production is required and simulation accuracy is extremely important. Sometime, the data available during design stage is limited which reduces the accuracy of the simulation. In addition, if the reservoir condition after drilling was found to be different as compared to simulated production, the actual production could be smaller than target.

Conventional FCV installation is normally integrated with Pressure and Temperature PDG across each zone. The real-time data transmission every second can be configured to be sent to town for reservoir monitoring capability. Proactive measure to diligently monitor the real-time data and also the performance of the production is crucial. If changing to different choke size is required, production surveillance will need to be present at the platform physically to monitor the valve cycling operation with Hydraulic Power Unit (HPU) to ensure operations are completed successfully. Physical monitoring is required as valve cycling requires pressuring up control lines to actuate the FCV. Fluid return can be monitored to confirm downhole choke position.

Latest electrical operated FCV technology in market that has infinite position and embedded with sensors enable real time monitoring such as zonal pressure, temperature, flow rate and water cut will enhance fast loop decision making to optimize production over well life (Basak and Gurses, 2015; Almadi, 2014). The fact that more than 10 zones can be multi-dropped with one cable to actuate FCV will simplify offshore installation and surface commissioning significantly as compared to conventional FCV and PDG installation (Schlumberger, 2015b). The infinite position FCV will greatly increase the flexibility to tackle uncertainties and dynamic changes over time of multi-stacked reservoir properties to enable maximum oil production.

1.3 Objectives

The objectives of this study are as follow:

(1) To evaluate infinite position FCV in improving oil production and reducing water cut as compared to on/off sliding sleeve in high zonal contrast of water cut and pressure.

(2) To compare and prove adaption of infinite position FCV will improve installation time comparing to conventional multi-position FCV.

(3) To compare and prove improved operating efficiency of infinite position FCV as compared to on-off sliding sleeve and conventional multi-position FCV.

1.4 Hypothesis

The hypothesis of this study are as follow:

(1) By having an infinite FCV that is flexible to cater dynamic changes of reservoir over well life, the oil production will significantly increase and water production will decrease as compared to on-off sliding sleeve application.

(2) One cable connected from downhole to surface to operate infinite FCV will simplify and reduce risk for downhole installation, surface installation and save significant amount of rig time as compared to conventional FCV.

(3) Having real time optimizer WellWatcher Advisor software fed with real time data such as pressure, temperature, flow rate and water cut will facilitate a proactive measure to ensure full well potential achieved for oil production.

(4) By simplifying method of operating infinite FCV by sending command from software, faster response time is achievable as compared to conventional FCV and sliding sleeve application in multi-zone commingled oil production.

1.5 Research Scope

The scope of research are as follow:

(1) The study used common brownfield multi-stacked reservoir condition in Malaysia as an input into the flow simulations. The main idea was to understand the impact of reservoir properties contrast of multi-stacked brownfield reservoir such as the pressure and water cut difference between the reservoir layers towards oil and water production. Using these data, multiphase flow simulation was done using PIPESIM and WellWatcher Advisor software to compare oil and water production for multi-zone completions with sliding sleeve and infinite position FCV.

(2) The installation and post installation operating efficiency was compared between sliding sleeve, conventional multi-position FCV and infinite FCV in multi-zone commingled production.

1.6 Significance of Study

High zonal reservoir properties contrast in multi-stacked brownfield oil reservoir is common in Malaysia. In addition, almost all wells in Malaysia are drilled from offshore platforms which incur high capital and operating cost as compared to onshore wells development. This study has proven significant incremental in oil production and reduction in water cut by having infinite position downhole flow control to cater for dynamic changes of reservoir properties over time. This study has provided lots of information for future consideration of adapting multi-zone Intelligent Completions with infinite position FCV.

1.7 Chapter Summary

Completing wells in multi-stacked brownfield reservoir is common in Malaysia to reduce overall cost by drilling fewer wells. It is known to have high contrast reservoir properties between reservoir layers such as pressure and water cut. Without the capability of controlling zonal production, commingled multi-zone oil production optimization is impossible due to cross flow from high pressure zone to low pressure zone and due to water production. Besides, with FCV, water and gas breakthrough can be delayed for maximizing oil production. By adapting downhole monitoring and controlling device, commingled production enables maximum well potential for oil production. However, it is essential for downhole flow control to be flexible to cater for the dynamic change and uncertainty of reservoir properties over well life (Ghosh, *et al*., 2013). Simplifying operating method for valve actuation using WellWatcher Advisor software aided with real time data such as zonal pressure, temperature, flow rate and water cut enables faster response time for valve optimization without the need of well intervention (Abuahmad *et al*., 2016; Saeed *et al*., 2015).

REFERENCES

Abu Bakar, M., Yeap, Y. C., Nasir, E., Din, A., Chai, C. F., Adamson, G. R., Valdez, R. (2011, January 1). *EOR Evaluation for Baram Delta Operations Fields, Malaysia.* Society of Petroleum Engineers. doi:10.2118/144533-MS.

Abuahmad, Y., Saleh, R., Bouldin, B., Turner, R., Al-Sheikh Ali, S. A., (2016) *Drilling for Next Generation of Multilateral Completion Systems.* Offshore Technology Conference, Houston, Texas, USA

Adan, I. (2013, September 30). *Radio Frequency Identification (RFID) Leads the Way in the Quest for Intervention Free Upper Completion Installation.* Society of Petroleum Engineers. doi:10.2118/166182-MS

Al-Amri, N., Al-Yateem, K., El-Fattah, M. A., Gottumukkala, V., (2013), *Offshore Field Completion Evolution Overcomes Field Challenges and Optimizes Multilateral Wells Production.* SPE Annual Technical Symposium and Exhibition, Khobar, Saudi Arabia

Ali, A. B., Hashim, A. H., Hashim, F., Said, R., Nair, D., Chan, K. S., & Samuel, M. M. (2005, January 1). *Successful Stimulation of Sandstones in the Dulang Field, Malaysia, Using Surfactant-Based Diverter: A Novel Solution for Mature Fields.* Society of Petroleum Engineers. doi:10.2118/96309-MS

Almadi, S., (2014). *Intelligent Field Infrastructure: Distributed Intelligence and Retention Based System.* SPE Intelligent Energy Conference and Exhibition, Utrecht, The Netherlands

Atkinson, W. R., Ceccarelli, T. U., Zabala, J. J., Khalis, A., Razak, F., Yildiz, R., … Raw, I. (2014, October 14). *Achieving Operation Efficiency and Enhancing Production in a Brownfield with Multi-zone Gravel-Packed Intelligent Completions: Two Case Studies from Malaysia.* Society of Petroleum Engineers. doi:10.2118/171477-MS

Babadagli, T. (2005, January 1). *Mature Field Development - A Review.* Society of Petroleum Engineers. doi:10.2118/93884-MS

Basak, D., Gurses, S., (2015), *Advanced Intelligent Completion Solution for Extended Reach Wells.* SPE Middle East Intelligent Oil & Gas Conference & Exhibition, Abu Dhabi, UAE

Bui, T., Bandal, M. S., Hutamin, N., & Gajraj, A. (2006, January 1). *Material Balance Analysis in Complex Mature Reservoirs - Experience in Samarang Field, Malaysia.* Society of Petroleum Engineers. doi:10.2118/101138-MS

Carpenter, C. (2018). *Intelligent Completion in Laterals Becomes a Reality.* Society of Petroleum Engineers. doi:10.2118/0518-0058-JPT

Ceccarelli, T. U., Atkinson, W. R., Zabala, J. J., Khalis, A., Razak, F., Yildiz, R., Gil, J., (2014). *Innovative Intelligent Multi-*

zone Gravel-Pack Completion Revives Production in Malaysian Brownfield. IADC/SPE Asia Pacific Drilling Technology Conference

Chan, K. S., Masoudi, R., Karkooti, H., Shaedin, R., & Othman, M. B. (2014). *Production Integrated Smart Completion Benchmark for Field Re-Development. International Petroleum Technology Conference.* doi:10.2523/IPTC-17220-MS

Cuauro, A. J., Ali, M. I., Jadid, M., & Kasap, E. (2006, January 1). *An Approach for Production Enhancement Opportunities in a Brownfield Redevelopment Plan.* Society of Petroleum Engineers. doi:10.2118/101491-MS

Dyson, W. Q., Coludrovich, E., Creech, R., Weldy, J. C., Fruge, M., & Guidry, M. (1999, January 1). *Best Completion Practices.* Society of Petroleum Engineers. doi:10.2118/52810-MS

Ghosh, B., King, P., (2013), *Optimization of Smart Well Completion Design in the Presence of Uncertainty.* SPE Reservoir Characterization and Simulation Conference and Exhibition, Abu Dhabi, UAE

Halliburton. (2015). *SmartPlex Downhole Control System.* Retrieved from Halliburton website:http://www.halliburton.com/public/wd/contents/Data_Sheets/web/h07558

Hamid, S., Jannise, R., Garrison, G., Coffin, Maxime., (2017), *New Technology Provide Zonal Pressure Maintenance in Single*

Trip Multi-zone Completions. SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA

Innes, G., Lacy, R., Neumann, J., Guinot, F., (2007), *Combining Expandable and Intelligent Completions to Deliver a Selective Multi-zone Sandface Completion, Subsea Nigeria.* SPE Offshore Europe, Aberdeen, Scotland, UK

Jannise, R., Joubran, J., Gavin, B., Coffin, M., Techentien, B., Geoffroy, B., Craik, S., Perez, E., (2017), *The Qualification Methodology Behhind and Integrated Multi-zone Frac Pack and Intelligent Completion for Lower Tertiary.* Offshore Technology Conference, Houuston, Texas, USA

Konopczynski, M., & Ajayi, A. (2004, January 1). *Design of Intelligent Well Downhole Valves for Adjustable Flow Control.* Society of Petroleum Engineers. doi:10.2118/90664-MS

Kumaran, P. N., Charbernaud, T., Ibrahim, R., Kadir, Z., Kamat, D., Yaakob, M. T., Cavallini, A. (2018, October 19). *Delivering the First Horizontal Well Under the Harsh Economic Conditions in an Offshore Brownfield in Malaysia.* Society of Petroleum Engineers. doi:10.2118/192061-MS

Masoudi, R., Chan, K. S., Karkooti, H., Soni, S., Jalan, S., Shahreyar, N., Kalyani, T., Finley, D., (2015), *Workflow Application for Advanced Well Completions to Meet IOR/EOR Challenges in Malaysia.* SPE Enhance Oil Recovery Conference, Kuala Lumpur, Malaysia

Masoudi, R., Chan, K. S., Karkooti, H., Soni, S., Jalan, S., Shahreyar, N., Kalyani, T., Finley, D., (2015), *Workflow Application for Advanced Well Completions to Meet IOR/EOR Challenges in Malaysia.* SPE Enhance Oil Recovery Conference, Kuala Lumpur, Malaysia

Mohammed Tawfik, M. E., Mohd, S., Ogbonna, C., Ahmad, A., Raw, I., Goh, G., Kaka Singh, P. K., (2013), *Innovative Solution to Produce Intelligently a Multi-zone Gravel Packed Completion with a Multi Drop Hydraulic Module – First in Offshore Malaysia.* SPE Middle East Intelligent Energy Conference and Exhibition, Dubai, UAE

PETRONAS. (2013). *Drilling and Well Operations Volume 8*, PETRONAS Procedures and Guidelines for Upstream Activities

Petrowiki. (2015). *AFE: projected drilling time;* Retrieved from Petrowiki website: https://petrowiki.org/AFE:_projected_drilling_time

Pogoson, O., Cardona, A., (2013), *Flow Analysis: A Critical Step in Completion Design and Optimization. A Case Study of Multi-zone Completion Designs.* SPE Annual Technical Conference and Exhebition, New Orleans, Louisiana, USA

Rodriguez, J. C., Dutan, J., Serrano, G., Sandoval, L. M., Arevalo, J. C., Suter, A., (2014). *Compact Intelligent Completion: A Game Change for Shushufindi Field.* SPE Latin American and Caribbean, Maracaibo, Venezuela

Saeed, Abubaker., Noui-Mehidi, M. N., Black, M. J., Abbad, M., Wallwork, C., Shafiq, M., (2015), *A Full Scale Two-Phase Flow Loop Test of Downhole Permanent Multiphase Flow Meter*. SPE Middle East Oil & Gas Show and Conference, Manama, Bahrain

Samuel, O. B., Khalid, M. Z., Raw, I., Kaka Singh, P. K., (2014), *Highest Reliability Provides World Class Benchmark for Permanent Downhole Monitoring Installation and Data Delivery in Malaysia.* IADC/SPE Asia Pacific Drilling Technology Conference. doi:10.4043/25153-MS

Schlumberger. (2008). *CS-1-Seried Sliding Sleeve*. Retrieved from Schlumberger website: https://www.slb.com/completions

Schlumberger. (2014), *Intellitite Downhole Dual-Seal Dry-Mate Connector*. Retrieved from Schlumberger website : https://www.slb.com/~/media/Files/completions /product_sheets/wellwatcher/intellitite_edmc_ps.pdf

Schlumberger. (2015a). *First Deployment of Multizonal Intelligent Completion More Than Doubles Production from Shushufindi Well.*Retrieved from Schlumberger website:https://www.slb.com/intellizone

Schlumberger. (2015b). *Manara: Production and Reservoir Management System.*Retrieved from Schlumberger website:https://www.slb.com/manara

Schlumberger. (2016). *WellWatcher: Permanent Monitoring Systems.*Retrieved from Schlumberger website:https://www.slb.com/WellWatcher

Schlumberger. (2017a). *Intelligent Completion System Boosts Oil Production by 41% in High-GOR Field.* Retrieved from Schlumberger website: https://www.slb.com/fcv

Schlumberger. (2017b). *Proteus System Simplifies Flow Control for Five-Zone Multilateral Well in the Middle East.* Retrieved from Schlumberger website: https://www.slb.com/intelligent

Schlumberger. (2018a). *Intelligent Completions.* Retrieved from Schlumberger website: https://www.slb.com/services/completions/intelligent.aspx

Schlumberger. (2018b). *WellWatcher eQuartz, ESP-immune high-temperature, high-resolution PT gauge.* Retrieved from Schlumberger website: https://www.slb.com/wellwatcher

Schorn, P. (2008, April 1). *Intelligently Using Intelligent Completions.* Society of Petroleum Engineers. doi:10.2118/0408-0040-JPT

Shestov, S., Golenkin, M., Senkov, A., Nizhnevolzhskneft, L., Blekhman, V., Gottumukkala, V., Bulygin, I., (2015), *Real-Time Production Optimization of and Intelligent Well Offshore, Caspian Sea.* SPE Russian Petroleum Technology Conference, Moscow, Russia